City of Boulder

2016 Wastewater Collection System Master Plan

City of Boulder, Colorado

July 14, 2016

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Glossary of Terms

Annual average dry weather flow (ADWF)	The yearly average daily wastewater flow comprised of population, employment and SIU contributions associated with non-rainfall periods. For this study, ADWF includes base infiltration associated with irrigation ditches and other groundwater influences. Generally used to represent the sanitary sewer system response to an average dry day of flow.
Base Infiltration (BI)	Groundwater that seeps into a collection system through defective pipes, pipe joints, and manhole structures. The rate of infiltration depends on the depth of groundwater above the defects, the size of the defects, and the percentage of the collection system that is submerged. Variation in groundwater levels and the associated infiltration is both seasonal and weather dependent.
Base Sanitary Flow (BSF)	Sanitary loading mostly from homes and businesses. Daily fluctuations in ADWF are mostly attributed to variations in BSF, such as domestic, industrial, and commercial wastewater contributions and how these contributions vary throughout a day.
Collector Sewer	A sewer that collects flows from the local and local collector sewers and conveys that flow to the interceptor sewers. Typical collector sewer diameters range from 12- to 24-inch.
Diurnal Pattern	A repeating pattern of factors which represents hourly changes over a day. In the context of a hydraulic model, the diurnal pattern represents hourly changes in flow contribution due to normal residential, commercial, and industrial behaviors.
Dry Weather Flow	The portion of the wastewater flow that is comprised of population, employment and SIU contributions with base infiltration from irrigation ditches and streams. The flow does not include rainfall dependent infiltration and inflow.
Groundwater Infiltration (GWI)	Measured during average dry weather flow period. The average of the low nighttime flows (midnight to 6 am) per day for the same time period, minus significant industrial or commercial nighttime flows
Force Main	A sewer that conveys pumped flow from a wet-well and pump station over a hydraulic obstacle where the flow cannot be conveyed by gravity such as a hill.
Hydraulic Model	A hydraulic network which attempts to best represent the actual collection system to evaluate and locate problems areas and to provide improvement recommendations for these areas. Hydraulic models mimic the actual operation of the system but do not match it exactly due to the many variables present between the system and model.
Hydrograph	A graph showing stage (the height of a water surface above an established datum plane), flow, velocity, or other property of water with respect to time.
Infiltration	Water that enters the collection system through cracks in the manholes and pipes and leaking pipe joints in aging pipes. The source of the infiltration can come from a number of sources including groundwater, irrigation ditches, streams, and rainfall seeping through the ground.
Inflow	Water that enters the collection system mainly through manhole lids and other surface entrances. The primary source of the inflow is from rainfall drainage that flows over the manhole lids but can also come from fire hydrant flushes and other liquid spills.
Interceptor Sewer	A sewer that collects flows from the local, local collector and collector sewers and conveys that flow to the wastewater treatment plant. Typical interceptor sewer diameters are greater than 24-inch.

Local Collector Sewer	A sewer that collects flows from the local sewers and conveys that flow to the collector and interceptor sewers. Since this system has steeper slopes and therefore longer reaches of smaller diameter of pipe, this definition of local collectors has been used to represent these collection pipes that link the local sewers to the collector sewers. Typical local collector sewer diameters can range from 8- to 12-inch.
Local Sewer	A sewer that collects flows from homes and business service connections and conveys that flow to the local collector, collector and interceptor sewers. Typical local sewer diameters are less than 10-inch.
Model Calibration	Calibration is a process of changing model variables in the attempt to more closely match the model results to actual system operation. Due to the many variables present, exact calibration between the two is very difficult; instead an understanding of the level of model calibration obtainable is important while analyzing the system using the model.
Peak Hour Wet Weather Flow (PHWWF)	The highest one hour flow during a significant rain event.
Peaking Factor	The ratio of peak hourly flow to average daily flow.
Rainfall Dependent Inflow and Infiltration (RDII)	The fraction of rainfall that enters the sanitary sewer system due to precipitation. Generally used to represent the sanitary sewer system response to rainfall.
Return Frequency	The reciprocal of the annual probability of exceedance of a specific flow value (also known as recurrence interval). For example, a return frequency of 10-year indicates that in any given year, there is a 1-in-10 (10 percent) chance of that flow or precipitation value occurring.
Sanitary Flow	The portion of the wastewater flow that is comprised solely of population, employment and SIU contributions with no infiltration and inflow.
Sanitary Sewer	A sewer that conveys liquid and waterborne wastes from residences, commercial and industrial buildings, and institutions together with minor quantities of groundwater and stormwater that are not admitted intentionally into the system.
Sanitary Sewer Overflow (SSO)	An event when wastewater flow spills out from a manhole due to a backed up sewer. Causes can range from blocked pipes to an overloaded system due to heavy rainfall. Sanitary sewer overflows are considered disadvantageous and even hazardous since the wastewater flow that escapes can contaminate.
Service Line	A pipe that conveys wastewater flow from a customer to a point where it joins the public sewer system.
Sewer Basin	An area of the collection system where the majority of flow in the area drains into a single interceptor pipe which conveys the flow downstream into another sewer basin or to the wastewater treatment plant.
Sewershed	An area defined using boundaries such as streets, property lines, streams, and topography as well as engineering judgment which creates a collection of manholes of which loading can be assigned.
Significant Industrial User (SIU)	An industrial user which contributes a large quantity and/or poor quality of wastewater where pretreatment and monitoring of flow are required. Significant industrial users contribute non-domestic flow that is accounted for separately during system loading.
Siphon	A designed pipeline segment that flows under pressure to go under a hydraulic obstacle such as a stream.

Thiessen Polygon	In the context of sewer collection systems, a polygon shape which bisects areas between manholes of which the contributing flow from that polygon can be assigned to a particular manhole.
Traffic Analysis Zones (TAZ)	Publicly available spatially-oriented data that provides population and employment projections for estimating growth and increased sanitary flow contributions.
Unit Flow Factors	Sanitary flow factors that are based on contribution from a single unit such as a person. Typically, unit flow factors are expressed in gallons per day per person or employee.
Wastewater Flow	The total wastewater stream comprised of all sanitary flow and infiltration and inflow.
Wet Weather Flow	The wastewater flow stream that is comprised of population, employment and SIU contributions with base infiltration from irrigation ditches and streams as well as rainfall dependent infiltration and inflow.
Wastewater Treatment Facility (WWTF)	The facility where all wastewater flow is conveyed to by the collection system and treated to all applicable permits and regulations. In this study, the WWTF refers to City of Boulder's 75th Street Wastewater Treatment Facility.

Acronyms and Abbreviations

2009 WWCSMP	2009 Wastewater Collection System Master Plan
2016 WWCSMP	2015 Wastewater Collection System Master Plan Update
ADWF	Annual average dry weather flow
BI	Base Infiltration
BSF	Base Sanitary Flow
BVCP	Boulder Valley Comprehensive Plan
CMOM	Capacity, Management, Operations, and Maintenance
CC	Centrifugally Cast
CCTV	Closed Circuit Television
CDPHE	Colorado Department of Public Health and Environment
CI	Cast Iron
CIP	Capital Improvement Project
city	City of Boulder
CMMS	Computerized Maintenance Management System
d/D	Modeled depth divided by the full flow depth
DRCOG	Denver Region Council of Government
DCS	Design and Construction Standards
DI	Ductile Iron
EPA	U.S. Environmental Protection Agency
FOG	Fats, Oils, and Grease
FSE	Food Service Establishments
gpd	Gallons per day
gpm	Gallons per minute
GRE	Grease Removal Equipment
GWI	Groundwater Infiltration
MWRD	Metropolitan Water Reclamation District
mgd	Million gallons per day
NASSCO	National Association of Sewer Service Companies
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
O&M	Operations and Maintenance
PHWWF	Peak Hour Wet Weather Flow
PF	Peaking Factor
PACP	Pipeline Assessment Certification Program
PVC	Polyvinyl Chloride
QC	Quality Control
RDII	Rainfall Dependent Inflow and Infiltration
RC	Reinforced Concrete
RPM	Reinforced Plastic Mortar
SSMP	Sewer System Management Plans
SIU	Significant Industrial User
SSO	Sanitary Sewer Overflow
TAZ	Traffic Analysis Zones
UMMS	Utility Maintenance Management System
VC	Vitrified Clay
WDR	Waste Discharge Requirements
WWCSMP	Wastewater Collection System Master Plan
WWTF	Wastewater Treatment Facility
WUSA	Wastewater Utility Service Area

Executive Summary

Existing Service Area and Collection System

The City of Boulder's (city) wastewater collection system and the 75th Street Wastewater Treatment Facility (WWTF) serve residences and businesses within the Wastewater Utility Service Area (WUSA). The WUSA is comprised of the Boulder Valley Comprehensive Plan (BVCP) Area I (within Boulder city limits) and Area II (areas adjacent to the city limits that may be subject to annexation in the future). Areas outside the WUSA boundary are served by other utility districts or septic systems. The resulting WUSA contains approximately 17,200 acres (27 sq. miles) and is shown on The wastewater collection system includes gravity sewers, diversion manholes, one inverted siphon and two lift station/force main systems that convey wastewater flow from the five sewer basins to the WWTF. Major features and gravity sewers by pipe size that compose the existing system are depicted in Figure ES-1 and summarized in Table ES-2.

Table ES-2. Existing Sewer System Summary – Modeled Elements

Collection System Feature / Sewer Basin	Modeled Gravity Sewer (miles)	Modeled Flow Split Manholes	Modeled Lift Stations	Modeled Force Mains	Modeled Inverted Siphons
Boulder Creek	120.5	14	0	0	0
Fourmile	48.0	1	0	0	0
Goose Creek	132.4	13	0	0	0
Gunbarrel	46.0	4	1 (City-owned)	1 (City-owned)	1
South Boulder Creek	31.0	8	1 (Private)	1 (Private)	0
Total	**377.9**	**40**	**2**	**2**	**1**

Source: City of Boulder GIS data.

Figure ES-1.

There are five sewer basins that contribute wastewater flow to the primary collector and interceptor system and ultimately to the WWTF (The wastewater collection system includes gravity sewers, diversion manholes, one inverted siphon and two lift station/force main systems that convey wastewater flow from the five sewer basins to the WWTF. Major features and gravity sewers by pipe size that compose the existing system are depicted in Figure ES-1 and summarized in Table ES-2.

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Source: City of Boulder GIS data.

Figure ES-1).

Table ES-1. Sewer Basins

Sewer Basin	Area (acres)
Gunbarrel	3,000
Fourmile	2,220
Goose Creek	5,020
Boulder Creek	5,430
South Boulder Creek	1,530
Total	**17,200**

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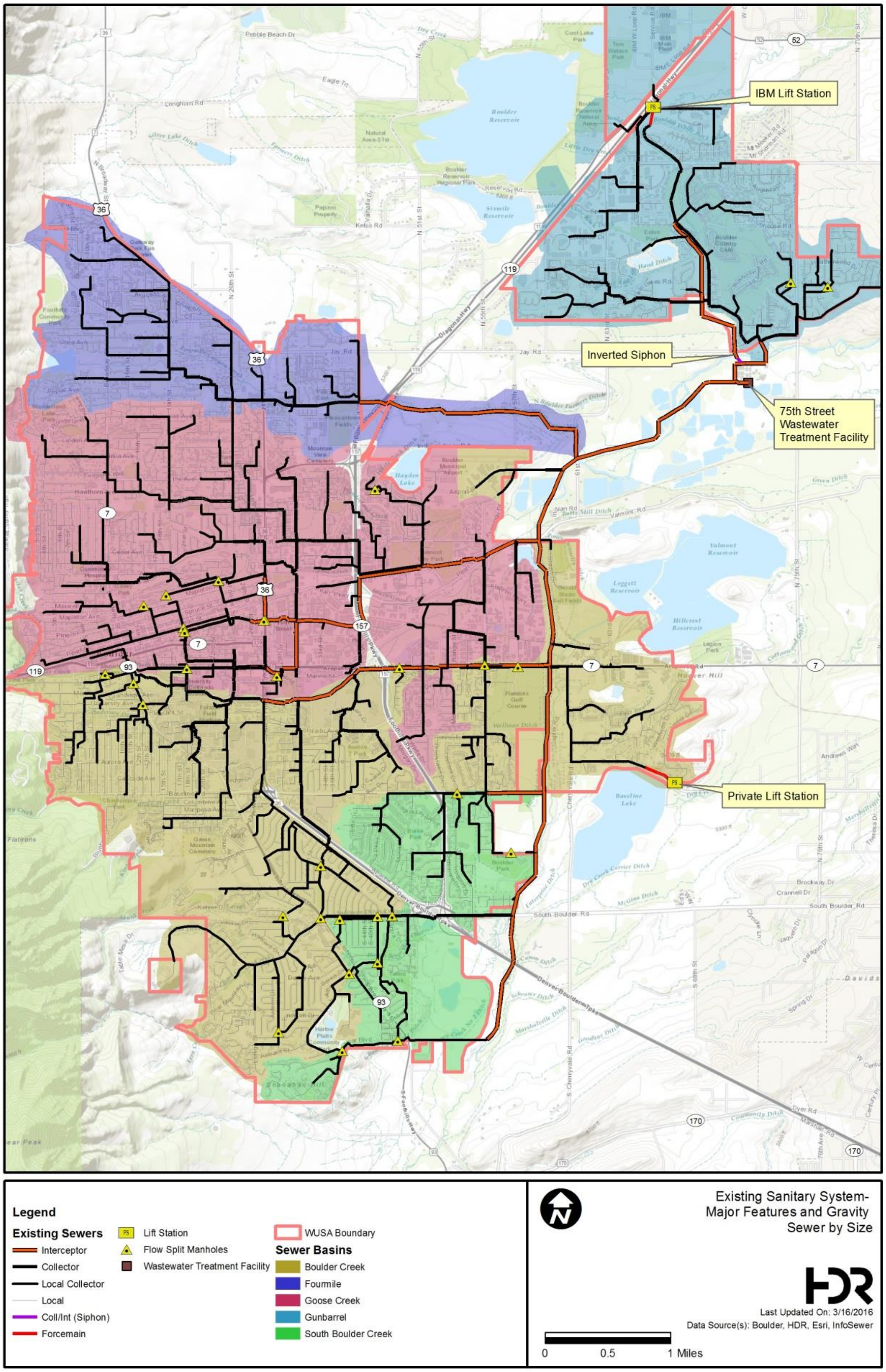
Source: City of Boulder GIS data.

Figure ES-1. Existing Sanitary System- Major Features and Gravity Sewer by Size



Flow Projections

The city provided existing (2014), 2035, and buildout data for city population and employment. This data, along with 2010 Census Data, was used to update city population and employment summaries for this 2016 Wastewater Collection System Master Plan (2016 WWCSMP). Growth projections are made to 2035 based on zoning capacity and growth rate assumptions. The 2010 BVCP has a planning timeframe of 15 years, but calls for growth projections to extend 20 years beyond the last update of the plan. The BVCP 20-year projections are based upon zoning capacity information supplemented by growth assumptions and input from DRCOG, the State Demographer's Office, and local and state economists. The WUSA is made up of the BVCP planning Areas I and II within these projections. Table ES-3 presents these city projections for the WUSA. The population projections summarized as part of the 2009 Wastewater Collection System Master Plan (2009 WWCSMP) were greater for the 2030 population (128,162) compared to this 2035 population projection (125,468), however, for employment the previous buildout projection (155,864) was less compared this projection (165,230).

Table ES-3. Population and Employment Projections for WUSA

Year	2010	2014	2035	Buildout
Population	109,200	114,200	125,468	125,468[1]
Employment	99,750	105,450	119,180	165,230

Source: City of Boulder Department of Planning, Housing and Sustainability, 1/20/2012; and 2014 Community Profile, 04/2014.

[1] Population was not separated between 2035 and buildout in the provided projections.

In the 2009 WWCSMP DRCOG TAZ polygons, with population and employment projections, were used to establish existing and future sanitary base flows. The TAZ polygons, however, have not been updated in several years, and the BVCP update process is just being initiated and will not be available to use for the 2016 WWCSMP. Therefore, 2014 use data from potable water meters and their GIS locations were used exclusively to spatially allocate the base sanitary loads to the hydraulic model.

The city's 2011 Wastewater Utility Master Plan (WUMP) water distribution model contains a detailed allocation of future water use and, therefore, represents the corresponding future sanitary load generation and how it is anticipated to be distributed across the city. By incorporating the city's 2011 WUMP future water use, future conditions modeling in the 2015 WWSMP Update is consistent with the water plan. The future water use allocation in the 2011 WUMP model, reduced by an appropriate winter (indoor) use factor of 0.65, is applied as future Base Sanitary Flow (BSF) loading for the 2016 WWCSMP. This future sanitary load allocation process aligns the future water use and sanitary sewer loads. Based on this process, it is estimated that Boulder's winter water demand will increase 2,395 gpm (3.45 mgd) by 2035. Of the 2,395 gpm (3.45 mgd) increase in 2035 winter water demand, 92 percent, or 2,208 additional gpm (3.18 mgd), is estimated to enter the WUSA.

Existing Dry Weather Flow

Existing potable water meter data from winter periods and Significant Industrial User (SIU) information were used to allocate BSF.

Monthly metered water use volumes from December 2013 through February 2014 were converted and averaged to a monthly rate of consumption. These averages were converted to a BSF of 8.9 million gallons per day [mgd] (6,158 gpm). This flow rate includes SIUs, which are owners who contribute high sanitary loadings.

The city provided updated average annual 2014 daily flows for the current SIUs. These flows were compared to the water meter data for those SIUs and the larger of the two values were used. In addition, a 70 percent reduction (30 percent flow through) was applied for the University of Colorado at Boulder's main campus based on the University's master plan. This process yields a total modeled SIU sanitary contribution of 816 gpm (1.17 mgd) or 13 percent of the total 8.9 mgd BSF to the WWTF for 2014.

BSF flows were allocated to the model by developing Thiessen polygons for the model manholes within each sewershed and spatially joining these sewersheds to the GIS water meter locations. The location of SIUs with respect to the Thiessen polygons was then reevaluated and, if necessary, flow allocations were adjusted so that they were loaded to the closest manhole to that SIU's outlet location, as provided by the city.

The total BSF for 2035 conditions is estimated be 8,366 gpm (12.0 mgd) by applying the additional 2035 flows estimated from the 2011 WUMP water distribution model. Future SIU flow is estimated to be approximately 10 percent of this 2035 BSF.

Base infiltration (BI) was developed from the city's permanent flow monitor data from August 26, 2015 by subtracting the contributing BSF from the average flow at the corresponding permanent flow monitor. BI was allocated to the model based on pipe diameter and pipe length and the BI loadings were calibrated to be within +10 percent of the annual average dry weather flow (ADWF) peak and daily volume for the permanent flow monitors.

Table ES-4 summarizes the modeled BSF, BI, and resulting ADWF for this 2016 WWCSMP.

Table ES-4. Existing and Buildout Dry Weather Flows

Model Flow Scenario	Existing (2015) (mgd)	Buildout (2035) (mgd)
Base Sanitary Flow (BSF)	8.9	12.1
Base Infiltration (BI)	6.0	6.0
Annual Average Dry Weather Flow (ADWF)	14.9	18.1

Wet Weather Flow

Wet weather flows are comprised of rainfall dependent inflow and infiltration (RDII) in addition to the ADWF. Wet weather infiltration is the additional infiltration that occurs due to rainfall-induced higher groundwater conditions and is typically seen in the hours or days following rain events. Inflow is rainfall related water that enters a collection system from sources such as private laterals, downspouts, manhole defects, foundation piping, and cross-connections with storm drains. RDII is directly influenced by the intensity and duration of a storm event as well as antecedent soil moisture conditions and is therefore variable from storm to storm.

The RDII flow response for the 2016 WWCSMP is based on the sanitary sewer system's response to the wet weather event that occurred on May 9, 2015 as seen at the permanent flow monitors and WWTF influent monitor. The model was calibrated to this event with the goal of having a slightly positive percent error and for modeled flows to be within +5% of the measured peak hour wet weather flow (PHWWF).

The collection system's level of service is defined by the level of wet weather event that the system can sustain without causing sanitary sewer overflows or backups into buildings. The collection system's level of service is therefore directly related to the excess capacity in the collection system which is available to convey RDII flows. The level of service can therefore be represented by the rainfall recurrence interval that results in the maximum conveyable RDII. For this project, the 15-, 20-, and 25-year levels of service are examined, with the city's ultimate objective being that the collection system can serve the 25-year level of service under buildout conditions.

15-, 20-, and 25-year levels of service were calculated based on rainfall/RDII relationship developed from WWTF influent flows in conjunction with available rainfall data. The calibrated wet weather flows were scaled to these 15-, 20-, and 25-year levels of service flows for collection system analysis. Table ES-5 summarizes these level of service flows used for the 2016 WWCSMP.

Table ES-5. PHWWF at the WWTF Influent for Existing and Buildout Condition Scenario Modeling

Model Condition	ADWF (mgd)	PHWWF 15-Year Level of Service (mgd)	PHWWF 20-Year Level of Service (mgd)	PHWWF 25-Year Level of Service (mgd)
Calibrated and Refined Existing Conditions	14.9	50.0	60.0	69.3
Buildout Conditions	18.1	53.2	63.2	72.5

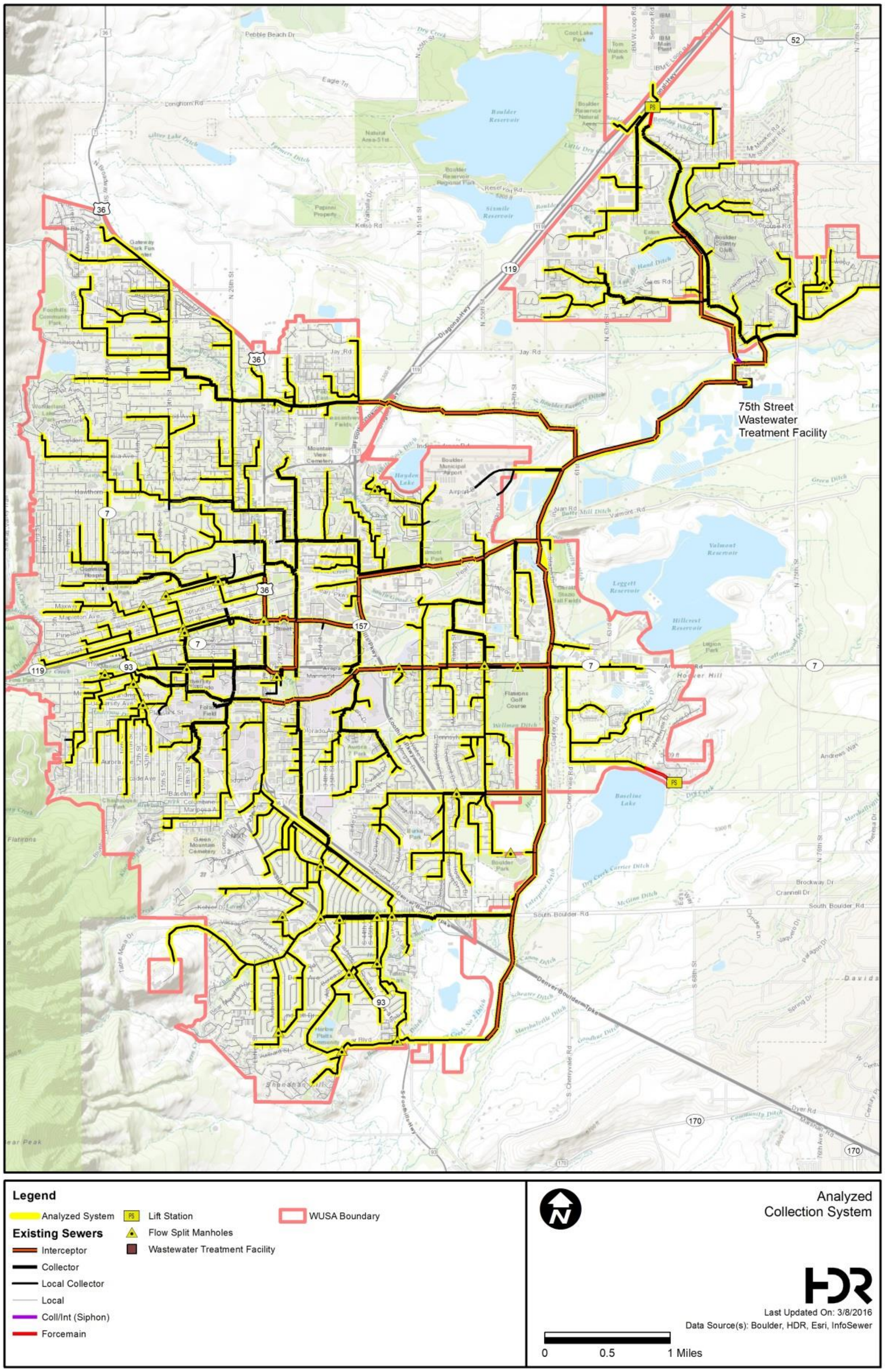
Collection System Analysis

The primary source of data that was used for the collection system model development and analysis was the city's sanitary sewer GIS layers for manholes and sewer pipes. This database was provided to HDR in August 2014 and formed the basis of all subsequent work. Combined, the two GIS layers represent 9,952 manholes and 10,038 sewer main pipe segments, ranging in size from 4 inch to 60 inch in diameter.

Gravity sewers are typically classified as local, collector and interceptor sewers. Local sewers have diameters that are typically less than 10 inches and convey wastewater from relatively small service areas (20 acres +/- and less). Local sewers have numerous service line connections collecting wastewater from individual customers. Collector sewers have diameters that typically range between 12 and 24 inches. Collector sewers convey flow from multiple local sewers and also include individual service line connections, although not as many as local sewers. Interceptor sewers typically have very few, if any, individual service line connections and convey wastewater from connections with collector sewers to the WWTF.

Many of Boulder's local sewers provide service to relatively large areas with some local sewers serving areas up to 100 acres in size and/or highly developed areas. These small diameter local sewers are an integral part of the gravity sewer system. As a result, the local sewers that serve large areas have been termed "local collectors" for purposes of this study. The scope of this study was to analyze the hydraulic capacity of interceptor, collector and local collector sewers. Additional collection system features included in the model and analysis are lift stations, force mains, diversion manholes, and inverted siphons. The modeled collection system is shown on Figure ES-2.

Figure ES-2. Analyzed Collection System



Type A problems account for 50 percent of the problem pipes or a total of 247 pipes with a cumulative length of approximately 12.8 miles (Figure ES-3). Type B problems account for 25 percent of the problem pipes or a total of 125 pipes with a cumulative length of approximately 3.9 miles (Figure ES-3). Type C problems account for the remaining 25 percent of problem pipes or a total of 128 pipes with a cumulative length of approximately 6.3 miles (Figure ES-4).

Recommended Collection System Improvements

The recommended system improvements that resolve the existing and future capacity issues are shown on Figure ES-5. This figure includes improvements that address both Type A and Type B problem categories. Type A problems consist of a series of problem pipes that are hydraulically connected to one another. Type B problems are isolated hydraulic restrictions that are not hydraulically connected to other problem locations or series of problem pipes.

The recommended improvements were grouped into three tiers to establish implementation priority:

- Tier 1 projects address Type A problems and have the highest priority.
- Tier 2 projects also address Type A problems but have lower priority compared to Tier 1.
- Tier 3 projects address Type B problems which have the lowest priority.

The improvement priorities were assigned based on a number of qualitative factors including discussions with the city, the flow conditions in which they occur (15-, 20-, or 25-year level of service), extent of the problem, potential for sanitary sewer overflows (SSOs) and service lateral backups, and relative benefit over other improvement projects. The relative benefit takes into account the amount of pipe replaced compared to the extent of the problem remedied. These factors are summarized in the problem characterization tables in Section 6 of this report. The resulting implementation priorities as developed in Section 7 and associated estimates of capital construction cost are shown in Table ES-6. Itemized capital cost estimate worksheets are included in Appendix A of this report.

Figure ES-3. Type A and Type B Problem Locations: Buildout Peak Hour Wet Weather Flows for 15, 20, and 25-Year Levels of Service

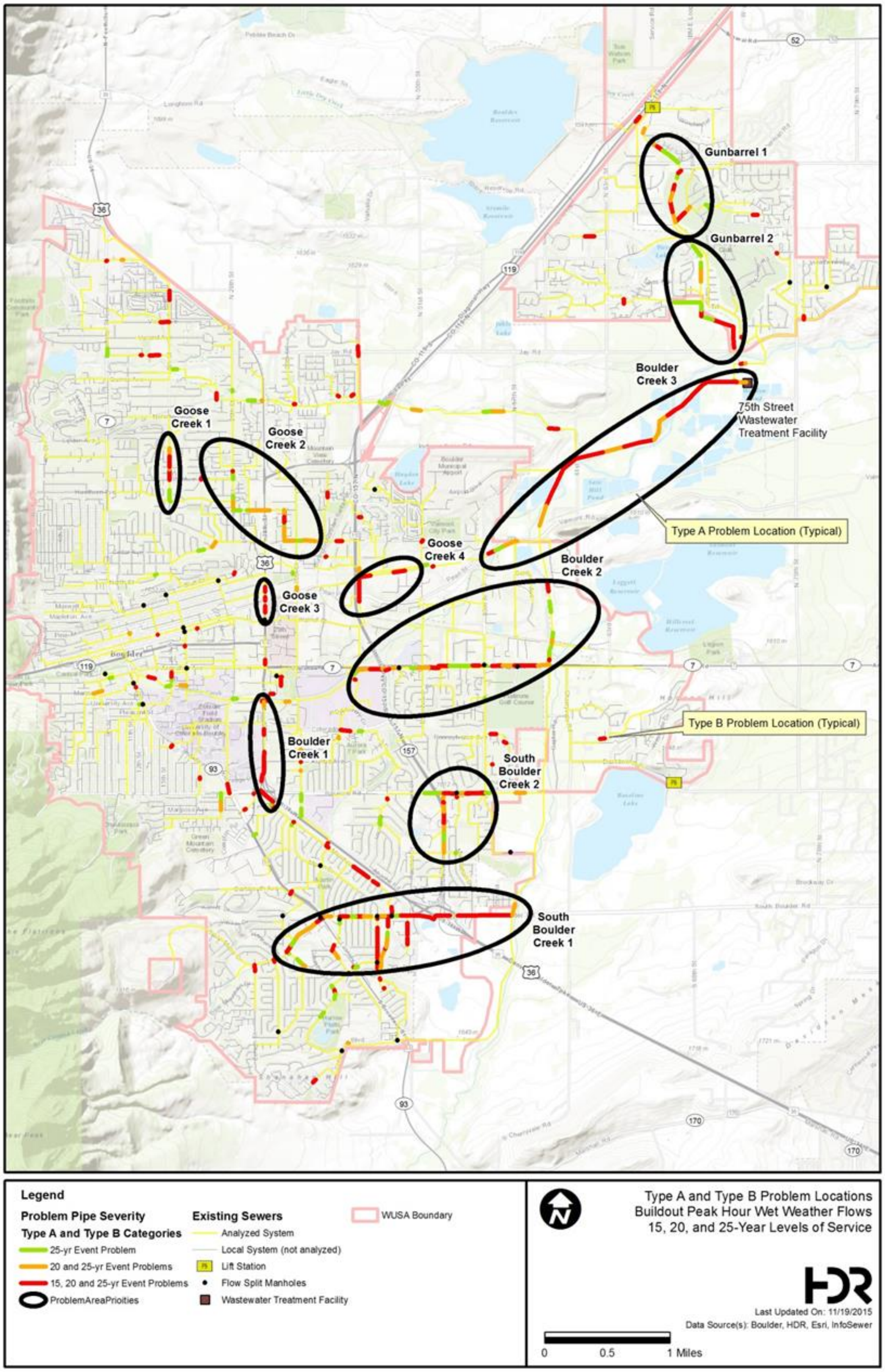


Figure ES-4. Type C Problem Locations: Buildout Peak Hour Wet Weather Flows for 15, 20, and 25-Year Levels of Service

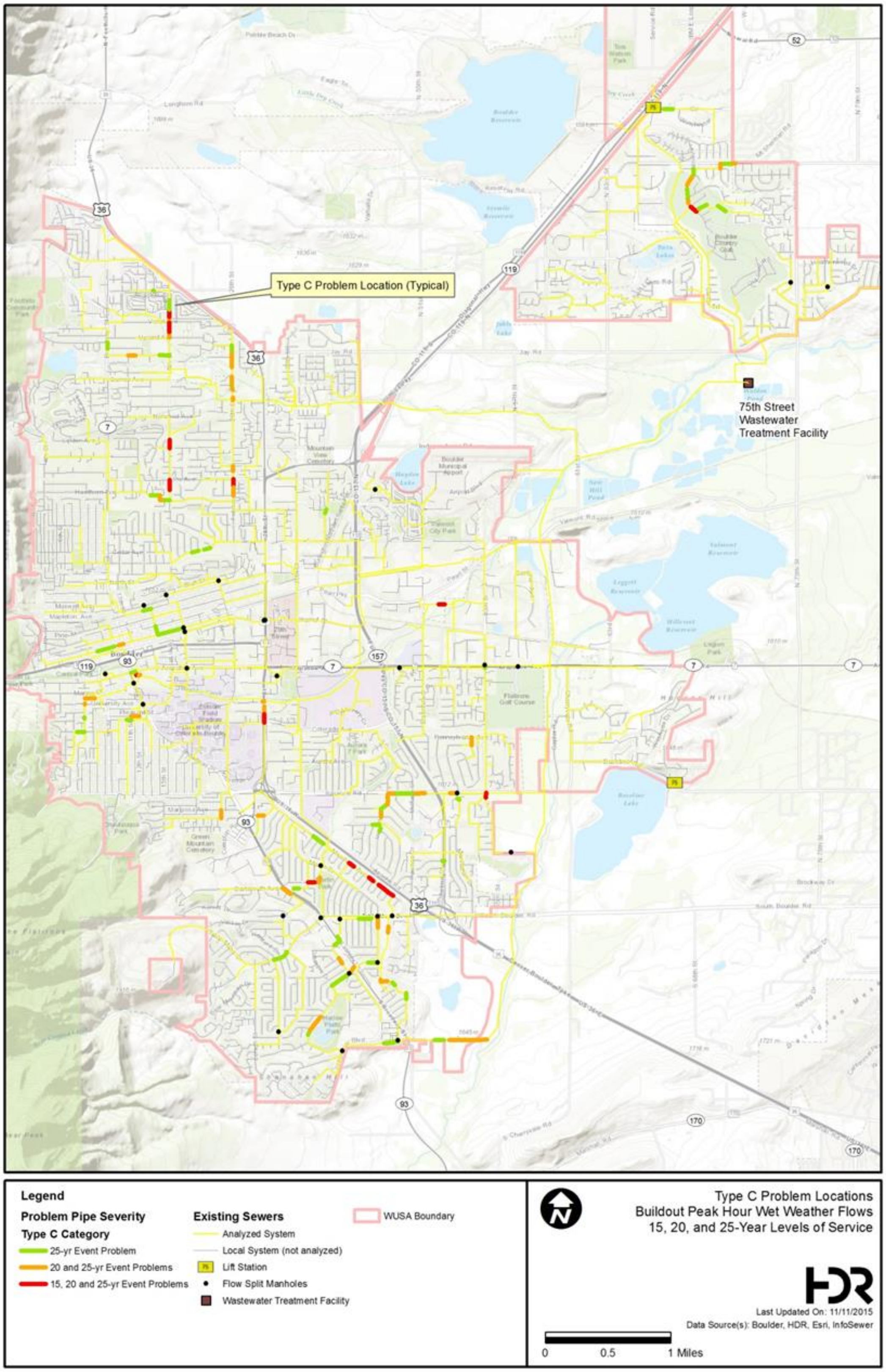
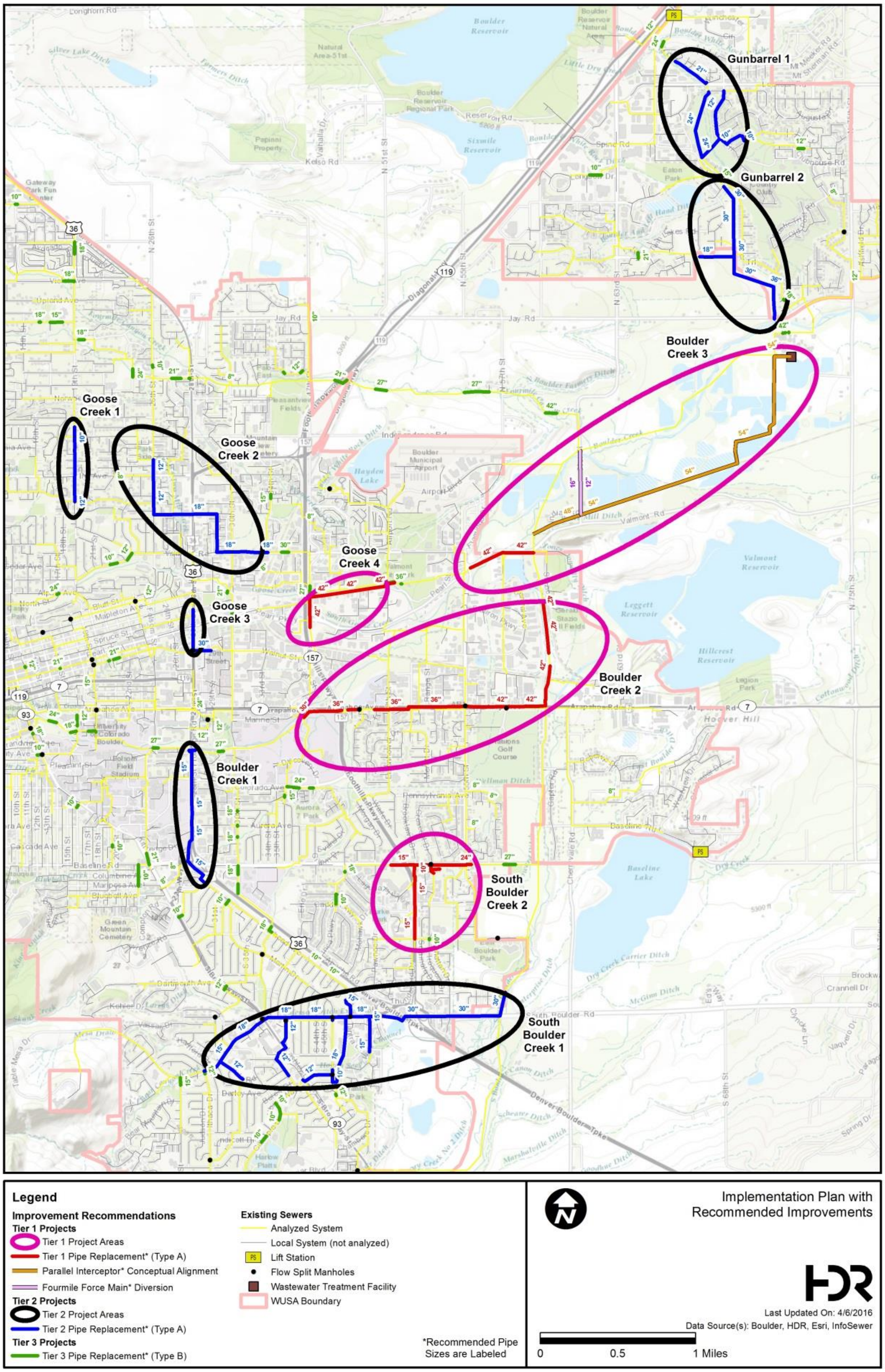


Table ES-6. Existing Sewer System Summary – Modeled Elements

Problem Priority	Improvement ID	Improvement Location	Improvement Size (inches)	Total Improvement Length (feet)	Capital Cost
Tier 1	Boulder Creek 3	Valmont Rd and 61st St to WWTP	12,16,42, 48, 54	19,174	$26,040,000
Tier 1	South Boulder Creek 2	Foothills Pkwy, Baseline Rd	10, 12, 15, 18, 21, 24, 30	5,880	$3,497,000
Tier 1	Boulder Creek 2	Arapahoe Ave and Foothills Pkwy to Old Tale Rd; South Boulder Creek corridor	30, 36, 42	10,810	$12,605,000
Tier 1	Goose Creek 4	Foothills Pkwy and Pearl St	42	4,016	$8,320,000
				TIER 1 TOTAL	**$50,462,000**
Tier 2	Goose Creek 1	19th Street from Kalmia Ave to Grape Ave	10, 12	2,539	$1,292,000
Tier 2	South Boulder Creek 1	Table Mesa Dr, South Boulder Rd, S 46th St	10, 12, 15, 18, 21, 24, 30	21,478	$17,370,000
Tier 2	Boulder Creek 1	Colorado Ave and 28th St	12, 15, 24	5,118	$4,298,000
Tier 2	Goose Creek 3	28th Street from Pine St to Walnut St	24, 30	1,945	$1,250,000
Tier 2	Goose Creek 2	Folsom St/Glenwood Dr/Valmont Rd	12, 18	7,063	$4,004,000
Tier 2	Gunbarrel 1	Boulder and Left Hand Ditch; Idylwild Tr/Boulder Country Club	8, 10, 12, 15, 21, 24	7,395	$4,388,000
Tier 2	Gunbarrel 2	Boulder Supply Canal north of Jay Rd	18, 30, 36,	6,786	$5,467,000
				TIER 2 TOTAL	**$38,069,000**
				TIER 3 TOTAL[1]	**$18,299,000**
				TOTAL ALL PROJECTS TOTAL	**$106,830,000**

[1]Tier 3 cost reflect Type B improvements

Figure ES-5. Implementation Plan with Recommended Improvements



O&M Review and Recommendations

The review and recommendations for the collection system operations and maintenance (O&M) procedures from the 2009 WWCSMP were not revised for this 2016 WWCSMP. This section therefore remains as previously published.

The 2009 WWCSMP project team reviewed the collection system operations and maintenance (O&M) procedures. The purpose of this O&M procedure was to review the current state of collection system O&M practices and evaluate potential increases in service levels due to trends in the regulatory environment in the western United States. In addition, the 2008 QualServe peer review program and self assessment survey evaluated the Utility's overall performance, efficiency and customer service as well as maintaining industry best management practices.

Both the QualServ program and the WWCSMP O&M review found that the Gravity System's Maintenance group operates and maintains the collection system such that it continues to provide a high level of service to its existing customers.

Boulder developed a methodology for determining the mileage and cost of the 20-year CIP for rehabilitating wastewater pipes and manholes. This methodology was based on spreadsheet model that characterized pipe failure as a function of time to assist in forecasting long-term budgetary needs for rehabilitation of sanitary sewer pipe. This analysis resulted in a recommendation for an annual manhole and sewer pipe rehabilitation budget of $850,000. This methodology was given an independent review which recommended that an annual sewer rehabilitation budget of $500,000 would be adequate for the 20-year planning period.

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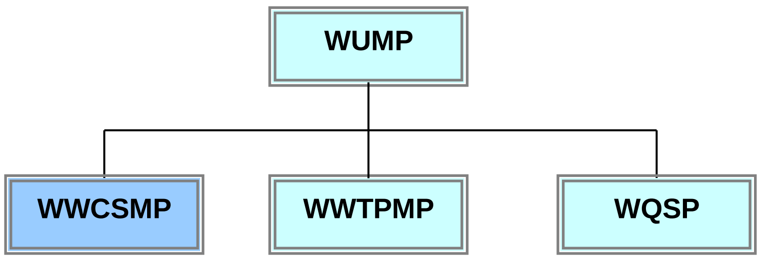
1 Introduction

The Wastewater Utility Master Plan (WUMP) is the overarching planning document that is intended to present key issues, projects and budgets for the collection system, wastewater treatment plan and, water quality programs. The WUMP is supported by the Wastewater Treatment Plant Master Plan (WWTPMP), the Water Quality Strategic Plan (WQSP), and this Wastewater Collection System Master Plan (WWCSMP). This document is the WWCSMP and it addresses the wastewater collection system through development of a master plan that addresses issues associated with the capacity of the collection system capacity issues and collection system operations and maintenance programs.



The primary goals of the WWCSMP are to identify capacity problems within the collection system and develop a prioritized list of recommended capital projects to resolve the capacity limitations. These goals were met through the following tasks:

- Develop a computer model of the sewer collection system based on the city's GIS data.
- Analyze the existing collection system under existing and future land use conditions.
- Identify capacity problems within the collection system under future conditions.
- Develop improvement alternatives and identify recommended improvement projects.
- Prioritize the recommended improvements and develop planning level estimates of capital construction cost.

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2 Data Review and Assessment

This section inventories the data collected and reviewed for the City of Boulder (city) 2016 WWCSMP. The purpose of the data review and assessment is to compare the dataset used for the 2009 WWCSMP with the recently available dataset for the 2016 WWCSMP. The recently collected data from Boulder forms the basis for the hydraulic model and plan update. This data set contains more complete information than available for the 2009 WWCSMP. Updates include the latest collection system GIS data with details for modeling Boulder's flow split manholes. Existing and future flow allocation is improved with flow monitoring and water use data from 2014 and water use projections from the 2011 Water Utility Master Plan (2011 WUMP). In addition, this section provides an assessment and summary of the data related to the 2013 post-flood sewer conditions and the *2014 Flow Monitoring Program* report (Stantec, 2014).

2.1 Data Collection and Review

The following sections list and describe the data collected and reviewed to date related to the 2016 WWCSMP.

2.1.1 Data Inventory

Table 2-1 presents an inventory of the data provided by Boulder for this project (October 2014 through January, 2015).

Table 2-1. Data Inventory

Item[1]	Description	Type
2014 Flow Monitoring Program	Flow monitoring study by Stantec	pdf
2014 Flow Monitoring Program Rainfall Data	Appendix IV of the 2014 Flow Monitoring Report by Stantec	txt
2014 Flow Monitoring RDII Calculations	Appendix V I-I of the 2014 Flow Monitoring Report	xlsx
2009-2015 WWTF Influent Flow Data	Influent flow data from Boulder's WWTF from June 2009 through May 2015	xlsx
2013 Hot Spot Maps	Maps showing the ongoing Hot Spot Cleaning program focusing on problem areas of the sewer system	pdfs
2013-14 Winter Water Meter Data	Table and points containing winter water demand records	gdb
2011 Water Utility Master Plan	Planning document containing information relating the water system and future demand projections	pdf
Recent Sewer Replacement Data	Layer indicating recent sewer main repairs (included in Sanitary Sewer gdb)	Feature class
2009 Boulder Wastewater System Master Plan	Planning document containing information relating to the wastewater collection system	pdf

Table 2-1. Data Inventory

Item[1]	Description	Type
Groundwater shapefiles	Contains groundwater elevation data for the project area	shapefiles
Basemap.gdb	Background Boulder layers	gdb
Boulder_2013FloodData.gdb	Table and spatial containing results of survey done following the 2013 flood event	gdb
FEMA DFIRM.gdb	DFIRM geodatabase	gdb
FloodManagement.gdb	Boulder of Boulder flood management layers	gdb
Planning.gdb	Landuse, zoning, planning layers	gdb
SanitarySewer.gdb	Most recently updated GIS information	gdb
StormDrainage.gdb	Stormwater collection system	gdb
Transportation.gdb	Transportation layers	gdb
WaterDistribution.gdb	Water distribution system	gdb
TAZ Update shapefiles	Traffic analysis zone layers	shapefiles
Telecom shapefiles	Communications-related line layers	shapefiles
I&I Study shapefiles	Flow monitor and rain gauge locations	shapefiles

[1] gdb is the file type for geodatabase which contains multiple GIS feature classes (layers).

2.1.2 Recent Sanitary Sewer GIS

The most up-to-date GIS files of Boulder's wastewater collection system were provided in geodatabase format and included the four feature classes shown in **Table 2-2**.

Table 2-2. GIS Feature Classes Provided

Feature Class	Geometry Type	Description	Date Received
ssCasing	Polyline	Pipe Casing	8/14/2014
ssMain	Polyline	Wastewater Collection System Mains	1/7/2014
ssManhole	Point	Manholes	1/7/2014
ssService	Polyline	Service Laterals	8/14/2014

The ssMain and ssManhole feature classes, the only two layers included in the model, were compared to the 2009 WWCSMP InfoSewer model. Based on a match of unique identification fields in the GIS files and the model, it was determined that the model could be updated using the Table 2-2 GIS files. Based on the recent GIS files, an estimated 324 manholes need to be updated in the model (approximately three percent of the system's manholes) and an estimated 520 pipes equaling approximately 89,700 feet (ft) in length need to be updated in the model (approximately four percent of the system's pipes by length). Figure 2-1 shows manholes and sewer mains that need to be updated in the model.

In addition, the GIS attributes for the ssMain and ssManhole feature classes were reviewed for completeness. Invert values are missing from 1,773 of 10,133 pipes in the GIS. In the collector and interceptor systems (12 inches and greater), the inverts will be filled in using interpolation from upstream and downstream known values. Ninety percent of pipes missing inverts are less than or equal to 8 inches in diameter are missing invert elevations. For the purposes of this 2016 WWCSMP, missing elevations will be interpolated only for pipes that are larger than 8 inches in diameter. Pipes less than 8 inches in diameter without inverts will not be analyzed for capacity.

Diameter values are missing from 95 of 10,133 pipes in the GIS. These missing diameters will be filled in using upstream and downstream known values. These data gaps should be field collected and populated in the GIS prior to the next model update to enable a complete system analysis. The REHABTYPE and REHABDATE fields in the ssMain feature class will be used to identify pipes that were recently rehabilitated with cured-in-place pipe (CIPP) liners or other methods of rehabilitation.

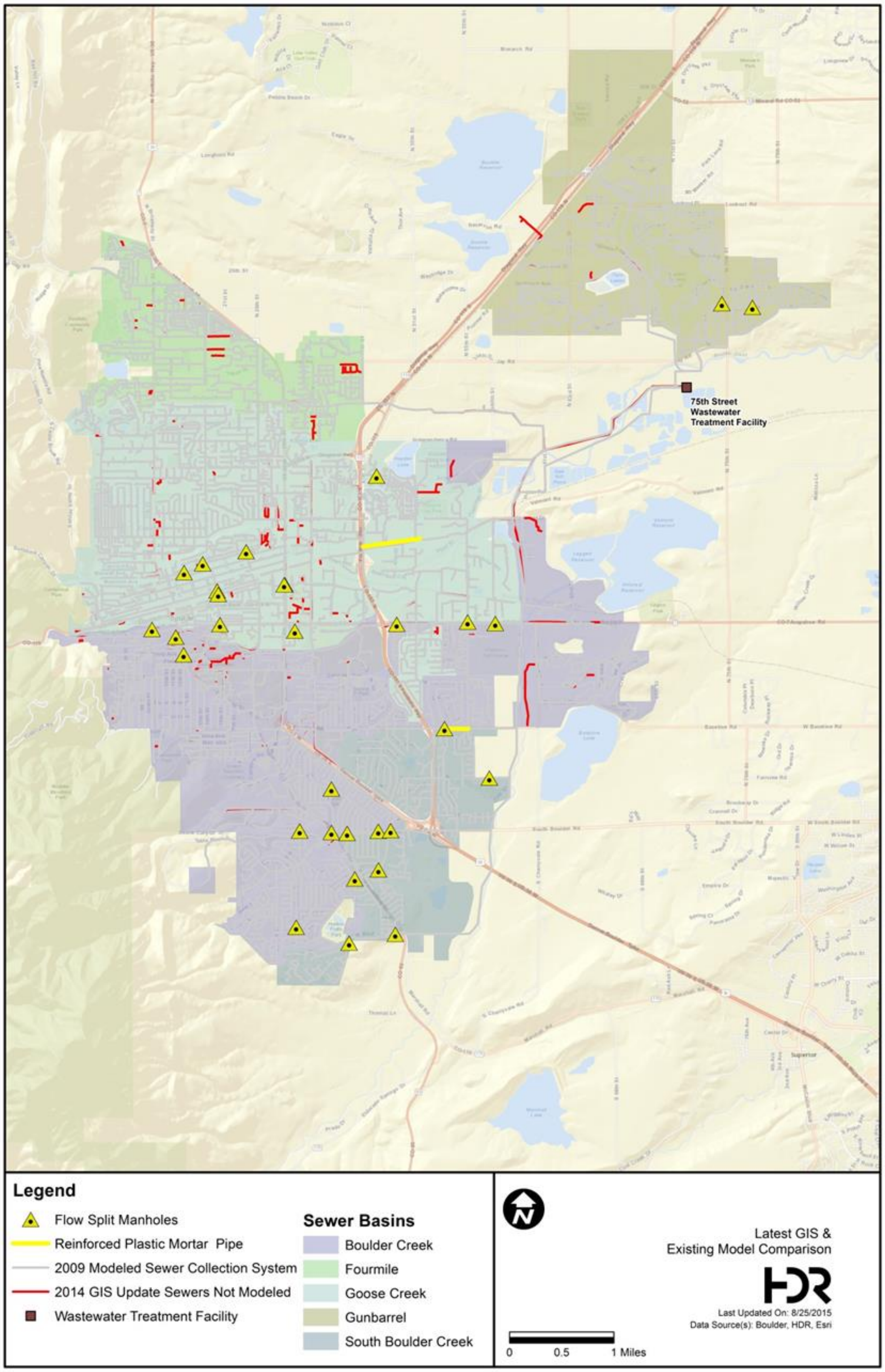
A review of the GIS data indicates that some pipes within the system are reinforced plastic mortar (RPM) pipe. The product name of RPM is Flextran and the material is a thin-walled fiberglass-based pipe that was installed in the early to mid 1970s. Flextran RPM pipes have been known to experience deterioration and/or be susceptible to structural failure over time in collection systems around the country. Boulder knows that these pipes need to be lined with a structural liner or replaced. According to the GIS data, 13 pipes within the system, for a total length of 4,117 feet, are comprised of RPM pipe. Existing RPM pipes within Boulder's collection system are highlighted in Figure 2-1.

2.1.3 2013 Post-flood Survey Data

The 2013 post-flood survey data provided by Boulder includes the Flood Survey layer and the Flood Call Log. The Flood Survey layer was the outcome of a survey conducted by Boulder and is the key data set. The flood survey's goal was to capture data on the origin of residential damages during the flood. This data can be used to determine if damages were caused by surface water flooding, sanitary sewer surcharges, or creek flows. The Flood Call Log is a compilation of 911 and Public Works call center calls. The notes in this dataset are based on the caller's interpretation of events. This data was used to initiate the Hot Spot Cleaning program in early 2014.

Sewer overflows and basement backups during the 2013 flood event were found to be largely the result of severe levels of inflow and infiltration in both the City owned and private sewer systems. In some areas of the system the main source of sewer backups was found to be excessive flow from floor drains which overwhelmed the local sewer system as basements flooded from groundwater seepage and surface flooding.

Figure 2-1. Latest GIS & Existing Model Comparison



The location of these backups and surcharges will be used in the 2016 WWCSMP to analyze potential capacity issues using the hydraulic model and to make improvement recommendations in specific areas that experienced substantial localized issues during the 2013 flood event.

2.1.4 Sanitary Sewer Cleaning and Hot Spots

Following the 2013 flooding event, Boulder began conducting sewer cleaning and field inspections of reported backups. These priority inspections have been completed and no blockages were found. Boulder provided maps showing priority areas of the system and scheduled cleaning. The entire collection system is planned to be inspected with closed-circuit television (CCTV) within the next 2 years. Infiltration and inflow (I&I) has been observed at pipe joints in local sewers. I&I at service connections is a known issue that will be addressed over time. Inflow into manholes is also being looked into by Boulder.

2.1.5 Population and Employment Data

Boulder provided existing (2014) and buildout (2035) data for Boulder population and employment. This information along with 2010 Census Data will be used to update Boulder-wide population and employment summaries in their corresponding WWCSMP sections. In the 2009 WWCSMP, TAZ from the DRCOG with population and employment projections were used for establishing existing and future sanitary base flows. However, the TAZ polygons haven't been updated in several years. In addition, the BVCP update process is just being initiated and will not be available in time to use during this project. Therefore, 2014 use data from water meters and their GIS locations will be used to spatially allocate the base sanitary loads to the hydraulic model.

2.1.6 Wastewater Treatment Facility Influent Flow

Recent influent flow data for the city's 75th Street WWTF were received and analyzed to determine average, maximum, and minimum flows as summarized in Table 2-3. According to the data, the maximum average daily influent to the WWTF occurred on September 13, 2013 at 51.7 million gallons per day (mgd) during the 2013 flood event. Minimum average daily influent flow occurred on December 19, 2012 at 7.3 mgd. Average influent flow for the entire study period was 13.4 mgd.

Table 2-3. 75th Street Wastewater Treatment Facility Influent Flow (mgd)

		2009[1]	2010	2011	2012	2013	2014[2]	Entire Period [3]
Hourly	Average	13.36	13.93	12.63	11.89	15.07	14.16	13.43
	Max	20.48	39.03	31.52	50.00	53.63	57.70	57.70
	Min	5.91	0.56	-	0.78	0.00	6.68	-
Daily	Max	15.94	24.39	23.60	16.12	51.69	16.96	51.69
	Min	9.42	7.88	8.77	7.25	8.56	11.20	7.25
	Max Day	7/30/2009	4/23/2010	5/19/2011	7/9/2012	9/13/2013	4/15/2014	9/13/2013
	Min Day	12/25/2009	12/25/2010	1/1/2011	12/19/2012	1/1/2013	1/1/2014	12/19/2012

[1] Data from June 25, 2009
[2] Data through April 29, 2014
[3] Data from June 25, 2009 through April 29, 2014

2.1.7 *2014 Flow Monitoring Program* Report

Stantec performed flow monitoring throughout the wastewater collection system at 60 manholes between April and July, 2014. The *2014 Flow Monitoring Program* report (Stantec, 2014) presents an I&I analysis based on the data collected during this period. Stantec provided flow monitoring data and I&I analysis results to Boulder that can be viewed using their software. The data from this report will be used in the model update including base infiltration allocation for dry-weather conditions and rainfall dependent infiltration and inflow (RDII) allocation for wet-weather conditions. In addition, the data will be used for dry- and wet-weather model calibration.

2.1.8 Water Demands

Existing water use data and water demand projections will be used to allocate base sanitary loads. Water use data from meters provides an enhanced spatial preciseness of load allocation in the model based on having actual, instead of estimated, use data. Using detailed water use data is improved over the approach used in the 2009 WWCSMP which was based on TAZ-based population and employment projections and applied equal unit flows across Boulder. Water meter data better represents the local base sanitary flow generation because of its generally accepted increased data accuracy and reliability. This will improve the ability to calibrate the model at a more local level than in the 2009 WWCSMP.

2.1.8.1 Existing Meters

Water meter use data for winter, 2013 through spring, 2014 were provided by Boulder, including GIS points of the account locations. This data will be used to calculate base sanitary loads for existing conditions. These loads will then be allocated to the model as the basis for the existing scenario flows along with the 2014 I&I data from the 2014 Flow Monitoring Program.

2.1.8.1 Future Demand Projections from Water Utility Master Plan

The 2011 WUMP provides future demand projections for Boulder's water distribution system in five year increments from 2010 through buildout (2035). These water demands will serve as the basis for buildout base sanitary loads in the 2015 WWCSMP model along with the 2014 I&I data. These demand projections will be applied to the WWCSMP model update directly from the final 2011 WUMP model provided to Boulder for the winter month 2035 scenario.

2.1.9 Significant Industrial Users

A spreadsheet listing fifteen SIUs was provided by Boulder. The spreadsheet includes 2013 average discharge flows for each of these SIU. This spreadsheet will be used to update the model with average dry-weather flow contributions from these users.

2.1.10 Flow Split Manholes

Boulder completed the process of collecting data on flow split manholes throughout the collection system. There are 40 structures with flow split-related information in GIS including:

- 4 with weir overflows.
- 1 shared manhole.
- 8 splits that are plugged.
- 7 that are invert overflows.
- 2 with abandoned gate structures.
- 15 percentage flow splits.
- 3 apex manholes.

These flow split manholes will be incorporated accordingly in the hydraulic model. Analysis will be completed during the 2016 WWCSMP using the updated model to determine whether some of these flow split manholes can be plugged to allow for more straightforward system operations.

2.1.11 Recent Sewer Replacement

Boulder provided a GIS feature class of Sewer Main Repairs in the sanitary sewer collection system indicating approximately 4.8 miles of sewer main was repaired between 2002 and 2013. Additionally, Boulder is embarking on an R&R/lining program that will address the vast majority of the system in the next 20 years.

2.1.12 Lift Station Changes

No lift station changes have occurred since the 2009 WWCSMP; however improvements to the IBM Lift Station are planned in the near future. Boulder is in the process of designing improvements to both the overall pumping capacity and wet-well volume to reduce the risk of overflows due to limited on-site storage and better manage flow through the lift station and downstream force main. One additional pump of similar capacity to the existing three will be added to increase total and firm lift station capacities by approximately 33 percent and 50 percent, respectively. Additional wet-well volume for handling overflows during wet-weather events is being designed for the lift station.

2.2 2013 Post-Flood Survey Data

Boulder's post-flood survey asked residents that reported damage to FEMA to identify the source of the flooding that caused the damage as originating from surface flooding, groundwater seepage through foundations, sewer lateral backups, floor drain backups or a combination of the above.

Although the survey distinguished between sewer lateral backups and floor drain backups, Boulder's building codes require floor drains to be plumbed to the sanitary sewer meaning that floor drain backups should also be considered a sewer lateral backup. The difference between these two survey responses could therefore be interpreted as the severity of the surcharge which caused the backup. A low-level surcharge may cause a backup from floor drains but may not be severe enough to reach the level of higher plumbing fixtures such as toilets or sinks which would cause a resident to clearly identify it as a sewer backup. Residents that do not have bathrooms in their basements would also only experience sanitary sewer backups though the basement floor drains.

The post-flood survey data was reviewed to identify any clusters of sewer-related flooding or backups or any other trends in the data that should be considered in the 2016 WWCSMP. The review showed that groundwater seepage contributed to the most cases of flooding with 732 total reported instances. Floor drains and sewer laterals contributed to 290 and 243 instances of flooding, respectively. Table 2-4 shows the reported sources of flooding by sewer collection system basin.

Table 2-4. Flood Survey Results by Sewer Basin: Instances of Flooding by Reported Source

Sewer Basin	Groundwater Seepage	Sewer Lateral Backup	Floor Drain Backup
Boulder Creek	219	55	78
Fourmile	64	11	27
Goose Creek	226	85	99
Gunbarrel	2	1	2
South Boulder Creek	221	91	84
Total	**732**	**243**	**290**

Some survey respondents indicated that there was more than one source of flooding so the data was further analyzed to evaluate if there were any trends between different combinations of sources. The results of this exercise, shown in Table 2-5, indicate that the individual source of groundwater seepage still constituted the majority of flooding instances, and that the combination of groundwater seepage and floor drain backups was the second largest contributor. It makes sense that groundwater seepage would be found frequently in combination with sewer backups through floor drains since areas with high rates of groundwater seepage likely also had overwhelmed local sanitary sewers due to the groundwater seepage discharging to the sanitary sewers via floor drains.

Table 2-5. 75th Street Wastewater Treatment Facility Influent Flow (mgd)

Basin	Ground-water Seepage Only	Sewer Lateral Backup	Floor Drain Backup Only	Ground-water and Sewer Lateral	Ground-water and Floor Drain	Sewer Lateral and Floor Drain	All Three	Total Instances
Boulder Creek	160	20	19	10	34	10	15	268
Fourmile	44	2	8	3	13	2	4	76
Goose Creek	160	43	37	15	35	11	16	317
Gunbarrel	1	1	1	0	1	0	0	4
South Boulder Creek	145	42	16	20	39	12	17	291
Total	**510**	**108**	**81**	**48**	**122**	**35**	**52**	**956**

There were 290 instances of floor drain backups, 261 of which were in the Goose Creek, South Boulder Creek, and Boulder Creek basins. Thirty-five of these instances coincided with sewer laterals backups in the same residence. One hundred twenty-two (42 percent) of residences experiencing floor drain backups also reported flooding from groundwater seepage.

The survey data was further analyzed to investigate the flooding causes in each flow monitoring sub-basin. The flow monitoring sub-basins were established during the *2014 Flow Monitoring Program*. Table 2-6 and

Table 2-7. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

present the data by the sources of flooding within the basins.

Table 2-6. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Basin	Flow Monitoring	Basin	Flow Monitoring
Boulder Creek	S-51	99	34
Fourmile	S-31	64	11
South Boulder Creek	S-34	44	32
South Boulder Creek	S-52	36	31
Goose Creek	S-49	40	19
Goose Creek	S-24	48	1
Goose Creek	S-28	34	31
Boulder Creek	S-25	34	10
Goose Creek	S-54	27	15
South Boulder Creek	S-05	64	12
Goose Creek	S-47	25	17
South Boulder Creek	S-01	23	0
Boulder Creek	S-58	14	0
Boulder Creek	S-27	43	8
Goose Creek	S-29	29	0
Goose Creek	S-22	12	2
South Boulder Creek	S-14	12	6
South Boulder Creek	S-36	20	1
Gunbarrel	S-45	1	0
South Boulder Creek	S-03	7	0
Boulder Creek	S-10	6	0
Boulder Creek	S-11	6	1
South Boulder Creek	S-13	0	1
South Boulder Creek	S-15	8	7
South Boulder Creek	S-16	2	0
Boulder Creek	S-19	6	1
Boulder Creek	S-26	7	1
Goose Creek	S-48	4	0
South Boulder Creek	S-12	2	0
Boulder Creek	S-18	1	0

Table 2-6. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Basin	Flow Monitoring	Basin	Flow Monitoring
Goose Creek	S-32	7	0
South Boulder Creek	S-35	3	1
Gunbarrel	S-37	0	1
Boulder Creek	S-44	3	0
Gunbarrel	S-46	1	0
Total		**732**	**243**

Table 2-7. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Basin	Flow Monitoring Sub-Basin	Ground-water Seepage Only	Sewer Lateral Backup Only	Floor Drain Backup Only	Ground-water and Sewer Lateral	Ground-water and Floor Drain	Sewer Lateral and Floor Drain	All Three	Total
Boulder Creek	S-51	62	9	12	8	17	5	12	125
Fourmile	S-31	44	2	8	3	13	2	4	76
South Boulder Creek	S-05	53	4	2	1	5	2	5	72
South Boulder Creek	S-34	20	12	7	9	7	3	8	66
Goose Creek	S-28	21	20	9	7	3	1	3	64
South Boulder Creek	S-52	17	18	4	5	11	5	3	63
Goose Creek	S-24	38	1	10	0	10	0	0	59
Goose Creek	S-49	25	2	5	4	4	6	7	53
Boulder Creek	S-27	40	6	1	0	3	2	0	52
Goose Creek	S-54	18	10	5	1	6	2	2	44
Boulder Creek	S-25	22	4	2	1	8	2	3	42
Goose Creek	S-47	15	10	5	3	5	2	2	42
Goose Creek	S-29	25	0	2	0	4	0	0	31
South Boulder Creek	S-01	15	0	3	0	8	0	0	26
South Boulder Creek	S-36	16	0	0	1	3	0	0	20
Boulder Creek	S-58	9	0	2	0	5	0	0	16
South Boulder Creek	S-14	6	3	0	2	3	0	1	15
South Boulder Creek	S-15	6	4	0	2	0	1	0	13
Goose Creek	S-22	8	0	1	0	2	0	2	13
Boulder Creek	S-11	6	1	1	0	0	0	0	8
Boulder Creek	S-26	7	0	0	0	0	1	0	8
South Boulder Creek	S-03	6	0	0	0	1	0	0	7
Boulder Creek	S-10	6	0	1	0	0	0	0	7
Goose Creek	S-32	7	0	0	0	0	0	0	7
Boulder Creek	S-19	4	0	0	1	1	0	0	6
South Boulder Creek	S-35	3	1	0	0	0	0	0	4

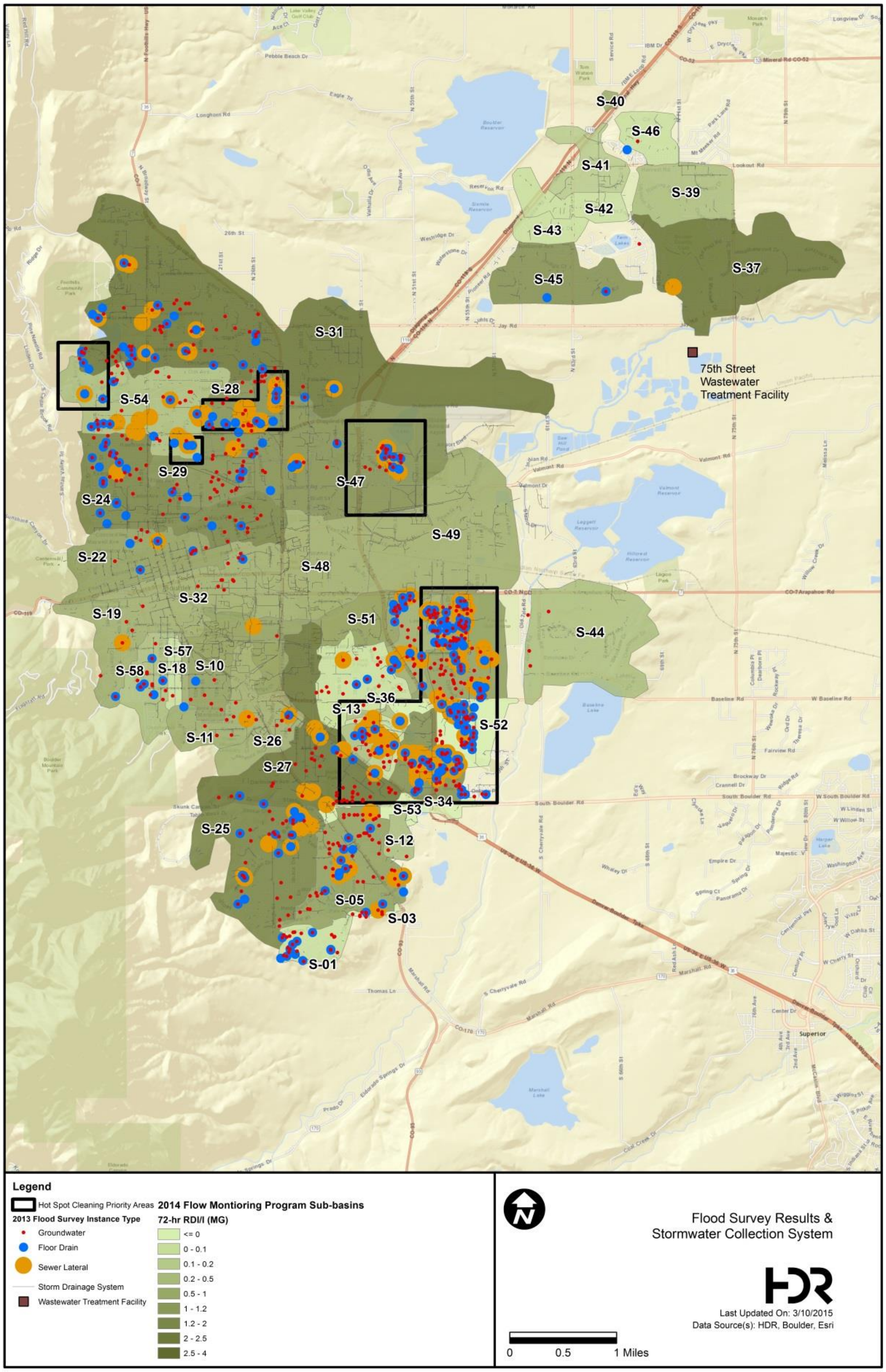
Table 2-7. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Basin	Flow Monitoring Sub-Basin	Ground-water Seepage Only	Sewer Lateral Backup Only	Floor Drain Backup Only	Ground-water and Sewer Lateral	Ground-water and Floor Drain	Sewer Lateral and Floor Drain	All Three	Total
Goose Creek	S-48	3	0	0	0	1	0	0	4
Boulder Creek	S-44	3	0	0	0	0	0	0	3
South Boulder Creek	S-12	2	0	0	0	0	0	0	2
South Boulder Creek	S-16	1	0	0	0	1	0	0	2
Gunbarrel	S-45	0	0	1	0	1	0	0	2
South Boulder Creek	S-13	0	0	0	0	0	1	0	1
Boulder Creek	S-18	1	0	0	0	0	0	0	1
Gunbarrel	S-37	0	1	0	0	0	0	0	1
Gunbarrel	S-46	1	0	0	0	0	0	0	1
Total		**510**	**108**	**81**	**48**	**122**	**35**	**52**	**956**

A map of the post-flood survey data is provided as Figure 2-2. This figure shows the location of the reported instances of groundwater seepage, floor drain backups, and sewer lateral backups. The figure also includes the sewer collection system flow monitoring sub-basins and their RDII results from the *2014 Flow Monitoring Program* report (Stantec, 2014) for reference.

The Flood Survey Results by Flow Monitoring Sub-basin table values along with Figure 2-2 show the areas of the system with higher density of reported instances of groundwater seepage, floor drain backups, and sewer lateral backups. The reported instances generally appear within sub-basins with higher RDII rates. The data from the 2013 post-flood survey will be used to help prioritize capital improvement projects in this WWCSMP Update.

Figure 2-2. 2013 Flood Survey Results & Stormwater Collection System



2.3 2014 Flow Monitoring Program

The *2014 Flow Monitoring Program* report (Stantec, 2014) was reviewed and assessed for use during the 2016 WWCSMP including the model update. This section does not include any additional analysis but only summarizes the findings of the *2014 Flow Monitoring Program* report (Stantec, 2014). Table 2-8 shows the temporary meters correlated to model sub-basins including upstream, downstream, crossing, and internal meters. Figure 2-3 shows the schematic of the temporary flow monitoring locations and basins while Figure 2-4 shows the actual locations of the temporary flow monitors and basins within Boulder. When using this data in the 2015 WWCSMP the data quality presented in the *2014 Flow Monitoring Program* report (Stantec, 2014) will be used to determine the confidence in the data to be used for flow allocation and calibration.

Table 2-8. Temporary Flow Monitoring Locations and Corresponding Flow Monitoring Sub-basins

Sewer Basin	Flow Monitoring Sub-basin	Assigned Rain Gauge	Downstream Meters	Upstream Meters	Crossing Meters	Internal Meters
South Boulder Creek	S-01	RG-5	FM-01, 02			
South Boulder Creek	S-03	RG-5	FM-03	FM-01	FM-04	
South Boulder Creek	S-05	RG-5	FM-05, 06, 08	FM-02, 07	FM-04	
Boulder Creek	S-10	RG-1	FM-10			
Boulder Creek	S-11	RG-1	FM-11			
South Boulder Creek	S-12	RG-5	FM-12			
South Boulder Creek	S-13	RG-5	FM-13	FM-35		
South Boulder Creek	S-14	RG-5	FM-14			
South Boulder Creek	S-15	RG-5	FM-15			
South Boulder Creek	S-16	RG-5	FM-16			
Boulder Creek	S-18	RG-1	FM-18			
Boulder Creek	S-19	RG-1	FM-19	FM-18, 57, 58	FM-17	
Goose Creek	S-22	RG-4	FM-21, 22, 23			
Goose Creek	S-24	RG-4	FM-24			
Boulder Creek	S-25	RG-5	FM-25		FM-09	
Boulder Creek	S-26	RG-1	FM-26		FM-55, 56	
Boulder Creek	S-27	RG-1	FM-27		FM-09, 55, 56	
Goose Creek	S-28	RG-4	FM-28	FM-54		
Goose Creek	S-29	RG-4	FM-29	FM-30		
Fourmile	S-31	RG-2	FM-31			
Goose Creek	S-32	RG-1	FM-20, 32	FM-21	FM-17	

Table 2-8. Temporary Flow Monitoring Locations and Corresponding Flow Monitoring Sub-basins

Sewer Basin	Flow Monitoring Sub-basin	Assigned Rain Gauge	Downstream Meters	Upstream Meters	Crossing Meters	Internal Meters
South Boulder Creek	S-34	RG-5	FM-34			
South Boulder Creek	S-35	RG-5	FM-35	FM-14, 15, 16		
South Boulder Creek	S-36	RG-1	FM-36			
Gunbarrel	S-37	RG-3	FM-37		FM-38	
Gunbarrel	S-39	RG-3	FM-39			
Gunbarrel	S-40	RG-3	FM-40			
Gunbarrel	S-41	RG-3	FM-41	FM-42		
Gunbarrel	S-42	RG-3	FM-42	FM-43		
Gunbarrel	S-43	RG-3	FM-43			
Boulder Creek	S-44	RG-2	FM-44			
Gunbarrel	S-45	RG-3	FM-45			
Gunbarrel	S-46	RG-3	FM-46			
Goose Creek	S-47	RG-2	FM-47	FM-28		
Goose Creek	S-48	RG-2	FM-48	FM-22, 23, 24, 32, 29		
Goose Creek	S-49	RG-2	FM-49	FM-47, 48	FM-50	
Boulder Creek	S-51	RG-2	FM-51	FM-10, 11, 19, 20, 26, 27, 36	FM-50	
South Boulder Creek	S-52	RG-5	FM-52	FM-13, 34		FM-33
South Boulder Creek	S-53	RG-5	FM-53, 07	FM-05, 06, 08, 12, 25		
Goose Creek	S-54	RG-4	FM-30, 54			
Boulder Creek	S-57	RG-1	FM-57			
Boulder Creek	S-58	RG-1	FM-58			

Figure 2-3. Temporary 2014 Flow Monitoring Schematic (Stantec, *2014 Flow Monitoring Program* Report – Figure 1.2)

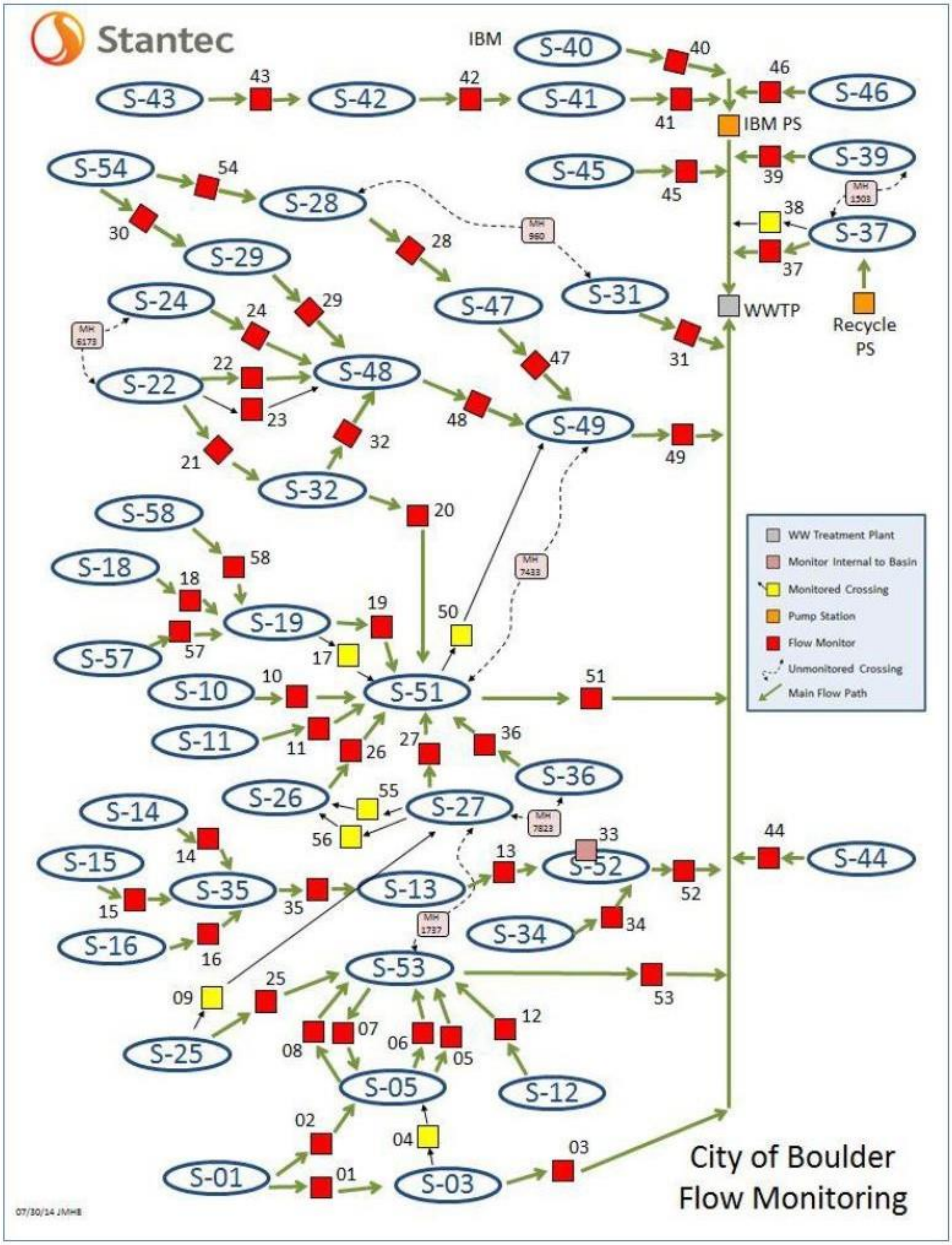
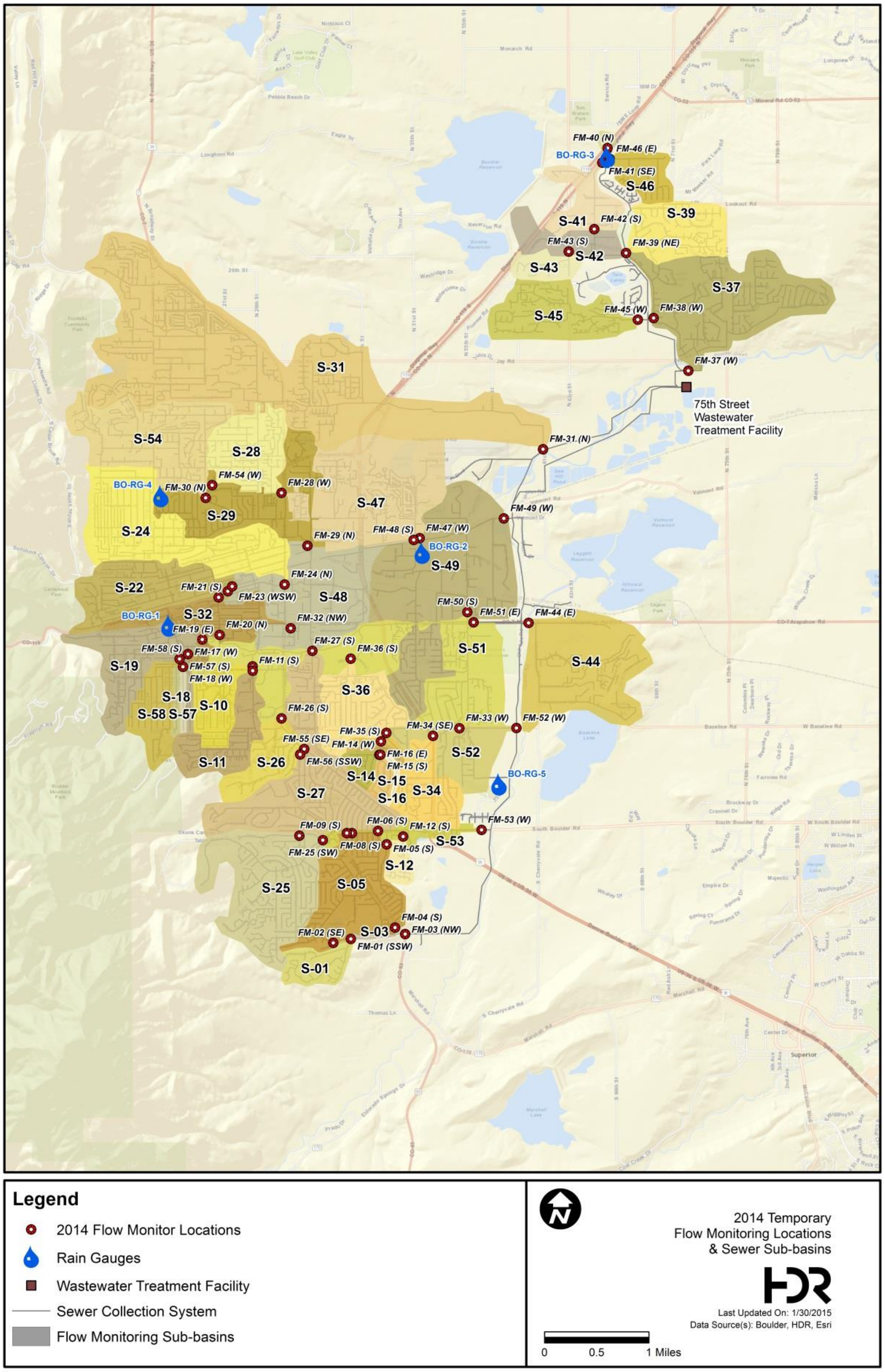


Figure 2-4. 2014 Temporary Flow Monitoring Locations & Sewer Sub-basins



Precipitation records for the five rain gauges were used in the *2014 Flow Monitoring Program* (Stantec, 2014) to calculate I&I volumes. These records contain rainfall data for three storm events used for the RDII analysis including May 11th, May 30th, and June 8th, 2014. Other storms that occurred during the flow monitoring period were not consistent enough across the City to use in the RDII analysis. Table 2-9 summarizes these three observed rainfall events for in the analysis.

Table 2-9. *2014 Flow Monitoring Program* Rainfall Event Summary

Storm Event Date	Total Rainfall Depth (inches)[2]	Total Duration (hours)[2]	Estimated Reoccurrence Interval (years)
May 11th, 2014[1]	1.78-2.01	38	2
May 30th, 2014	0.23-0.33	1-2	Less than 1
June 8th, 2014	0.47-0.5	7-8	Less than 1

[1] The May 11th event was rainfall on top of snow and could result in skewed flow monitoring results as rain melts the snow which results in additional I&I volumes at a different rate than only rainfall would.

[2] Rainfall depth and durations are the range of values for all five rain gauges.

Figure 2-5 shows a comparison of rainfall intensity between rain gauges for the period of the 2015 Flow Monitoring Program. These records will be used with corresponding monitor results at peak flow periods in re-assessing system I&I and capacity responses to rainfall. When using the May 11th storm data, it should used with the understanding that the event was a rain on snow event. Although the rainfall volume was lesser, the May 30th storm had no snowfall and included intense periods of rainfall that are spatially consistent across the City. Therefore, this storm event will be used as the existing wet-weather model calibration scenario.

None of the storms during the flow monitoring program used for analysis were large enough to be used as a capacity evaluation event so the calibrated model scenario’s I&I factors for each flow monitoring sub-basin will be increased using the precipitation event versus peak wet weather flow equation developed in the 2009 WWCSMP report (HDR, 2009 WWCSMP, Figure 3-3). The desired evaluation event for Boulder’s collection system is the 25-year reoccurrence interval storm.

Figure 2-5. Comparison of Rainfall Data between the Five Rain Gauges (inches) (Stantec, *2014 Flow Monitoring Program* Report - Appendix IV)

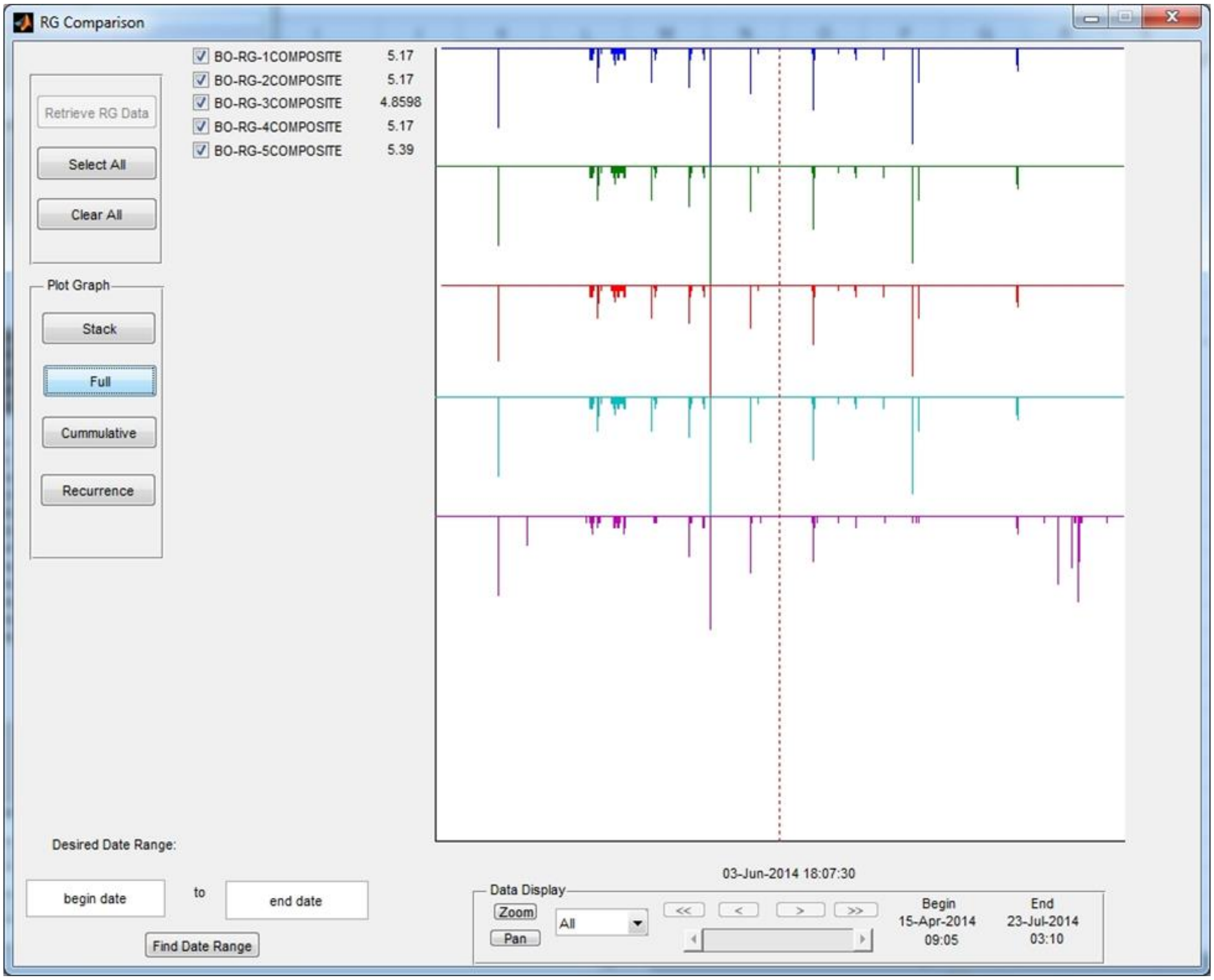


Table 2-10 shows values of average day sanitary flow rate (ADSF) and spring seasonal low groundwater infiltration rate (GWI) in gpm. Boulder commented that although the IBM Campus was reported as a critical infiltration area in the *2014 Flow Monitoring Program* report (Stantec, 2014), there was a reported significant industrial discharge that could have skewed the results in the Gunbarrel sewer basin (S-40).

Table 2-10. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Sewer Basin	Flow Monitoring Sub-basin	ADSF (gpm)[1]	Seasonal Low GWI (gpm)[1]
South Boulder Creek	S-01	47	15
South Boulder Creek	S-03	(7)	(15)
South Boulder Creek	S-05	152	83
Boulder Creek	S-10	171	97
Boulder Creek	S-11	85	81
South Boulder Creek	S-12	39	21
South Boulder Creek	S-13	14	43
South Boulder Creek	S-14	14	9
South Boulder Creek	S-15	9	6
South Boulder Creek	S-16	5	1
Boulder Creek	S-18	19	2
Boulder Creek	S-19	161	120
Goose Creek	S-22	298	131
Goose Creek	S-24	472	196
Boulder Creek	S-25	323	40
Boulder Creek	S-26	74	80
Boulder Creek	S-27	607	192
Goose Creek	S-28	238	197
Goose Creek	S-29	302	151
Fourmile	S-31	696	353
Goose Creek	S-32	388	83
South Boulder Creek	S-34	156	84
South Boulder Creek	S-35	15	1
South Boulder Creek	S-36	147	53
Gunbarrel	S-37	297	506
Gunbarrel	S-39	87	13
Gunbarrel	S-40	97	68
Gunbarrel	S-41	73	55
Gunbarrel	S-42	19	14
Gunbarrel	S-43	12	9
Boulder Creek	S-44	89	17
Gunbarrel	S-45	215	240
Gunbarrel	S-46	54	1

Table 2-10. Flood Survey Results by Flow Monitoring Sub-Basin: Instances of Flooding by Reported Source

Sewer Basin	Flow Monitoring Sub-basin	ADSF (gpm)[1]	Seasonal Low GWI (gpm)[1]
Goose Creek	S-47	362	117
Goose Creek	S-48	462	627
Goose Creek	S-49	997	(159)
Boulder Creek	S-51	220	(114)
South Boulder Creek	S-52	(156)	(75)
South Boulder Creek	S-53	(62)	5
Goose Creek	S-54	106	23
Boulder Creek	S-57	13	1
Boulder Creek	S-58	108	18

[1] ADSF and Seasonal Low GWI values with parenthesis indicate negative values which with flow monitoring basins are flow subtraction issues between upstream and downstream meters whose flows do not add up. These meters and their data should not be relied on for hydraulic modeling.

Table 2-11 shows the RDII for each monitored sub-basin in the system. Inflow values were based on the maximum values for the three storm events that occurred during the flow monitoring period. Infiltration values were based on the May 11th storm except for S-11 which was based on the June 6th storm. Based on these calculations, the maximum total RDII for the system is approximately 32 million gallons over the storm event. Boulder commented that Southeast Boulder is known as an area of the collection system with high I&I contributions which can be seen on Figure 2-2 and in the data below in the Boulder Creek and South Boulder Creek sewer basins.

Table 2-11. Rainfall Derived Inflow and Infiltration per Sub-basin

Sewer Basin	Flow Monitoring Sub-basin	Rainfall Derived Infiltration – (Total 72-hr Infiltration per length of Pipe, Gal/ft)	Rainfall Derived Inflow (4-hr RDII per length of Pipe, Gal/ft)	Rainfall Derived Infiltration (Million Gallons)	Rainfall Derived Inflow (Million Gallons)	Total RDII (Million Gallons)
Fourmile	S-31	15.2	0.5	3.75	0.11	3.86
Gunbarrel	S-37	33.9	0.7	2.85	0.06	2.91
Boulder Creek	S-27	26.6	0.8	2.65	0.08	2.73
Goose Creek	S-24	18	1.8	2.11	0.21	2.32
Boulder Creek	S-25	21.5	0.9	1.95	0.08	2.03
Gunbarrel	S-45	36.8	0.9	1.56	0.04	1.60
Goose Creek	S-28	26.9	0.9	1.49	0.05	1.54
Goose Creek	S-29	20.5	0.7	1.42	0.05	1.46
Goose Creek	S-47	14.8	0.5	1.35	0.05	1.40
South Boulder Creek	S-34	41.3	1.9	1.28	0.06	1.34
South Boulder Creek	S-05	16.3	0.7	1.11	0.05	1.16
Boulder Creek	S-51	11.3	0.7	1.06	0.07	1.13
Goose Creek	S-22	15.4	1.4	0.99	0.09	1.08
Boulder Creek	S-10	33.3	2.5	0.99	0.08	1.06
Goose Creek	S-49	10.2	0.8	0.90	0.07	0.96
Goose Creek	S-48	10.2	0.8	0.72	0.05	0.77
Boulder Creek	S-19	13	0.7	0.72	0.04	0.76
Boulder Creek	S-26	28.4	2.1	0.67	0.05	0.72
Goose Creek	S-32	13.5	0.7	0.61	0.03	0.64
Gunbarrel	S-40	85.2	3.8	0.54	0.02	0.57
Boulder Creek	S-11	16.8	0.2	0.52	0.01	0.52
Gunbarrel	S-39	10.7	0.9	0.43	0.04	0.47
South Boulder Creek	S-12	56.4	2.8	0.42	0.02	0.44
South Boulder Creek	S-13	140.7	4.3	0.42	0.01	0.44
Boulder Creek	S-58	11.4	1.1	0.30	0.03	0.33
Boulder Creek	S-44	5.8	0.3	0.31	0.02	0.33
South Boulder Creek	S-14	44.8	2.3	0.27	0.01	0.29
Goose Creek	S-54	2.8	0.2	0.23	0.02	0.25
South Boulder Creek	S-15	21	1.1	0.13	0.01	0.14
Gunbarrel	S-41	7.1	1	0.11	0.02	0.13
Gunbarrel	S-46	6.4	0.6	0.09	0.01	0.09

Table 2-11. Rainfall Derived Inflow and Infiltration per Sub-basin

Sewer Basin	Flow Monitoring Sub-basin	Rainfall Derived Infiltration – (Total 72-hr Infiltration per length of Pipe, Gal/ft)	Rainfall Derived Inflow (4-hr RDII per length of Pipe, Gal/ft)	Rainfall Derived Infiltration (Million Gallons)	Rainfall Derived Inflow (Million Gallons)	Total RDII (Million Gallons)
Boulder Creek	S-18	20.5	2.9	0.08	0.01	0.09
South Boulder Creek	S-16	23.6	1.8	0.08	0.01	0.08
South Boulder Creek	S-01	2.8	1.4	0.05	0.02	0.07
South Boulder Creek	S-35	23.2	0.5	0.07	0.00	0.07
Gunbarrel	S-42	6.1	0.5	0.06	0.00	0.07
Boulder Creek	S-57	17.6	2	0.06	0.01	0.06
Gunbarrel	S-43	3.7	0.3	0.02	0.00	0.03
South Boulder Creek	S-36	-	0.2			
South Boulder Creek	S-53	-38.5	-1.2	-0.57	-0.02	-0.59
South Boulder Creek	S-52	-58.3	-0.6	-1.62	-0.02	-1.64
South Boulder Creek	S-03	-	-	-	-	-
Total		-	-	**30.19**	**1.56**	**31.75**

Table 2-12 shows the RDII for each monitored basin in the system. Overall, the Goose Creek and Boulder Creek sewer basins have more RDII than the other basins.

Table 2-12. Rainfall Derived Inflow and Infiltration per Basin

Basin	Rainfall Derived Infiltration (Million Gallons)	Rainfall Derived Inflow (Million Gallons)	Total RDII (Million Gallons)
Goose Creek	9.83	0.62	10.45
Boulder Creek	9.30	0.47	9.77
Gunbarrel	5.67	0.19	5.86
Fourmile	3.75	0.11	3.86
South Boulder Creek	1.64	0.17	1.81
Total	**30.19**	**1.56**	**31.75**

2.3.1 Permanent Flow Monitoring Locations

Boulder would like to install permanent flow monitors at select locations within the collection system to capture dry- and wet-weather flows for future capacity analysis and model calibration. The chance of monitoring peak flows during significant storm events increase with permanent flow monitoring. Having permanent flow monitoring locations spread out across the system allows for continual system performance allowance as system-wide rehabilitation and other improvements that reduce I&I and expand capacity continue. Figure 2-6 shows the recommended permanent flow monitoring locations within the collection system. These nine recommended sites break up the overall system into reasonable basins for future flow monitoring purposes. Along with the permanent flow monitoring locations, permanent rain gauges should be considered to provide good coverage for rainfall monitoring across the system. At least three permanent rain gauges are recommended but with the variability of rainfall in this area, up to five would be appropriate.

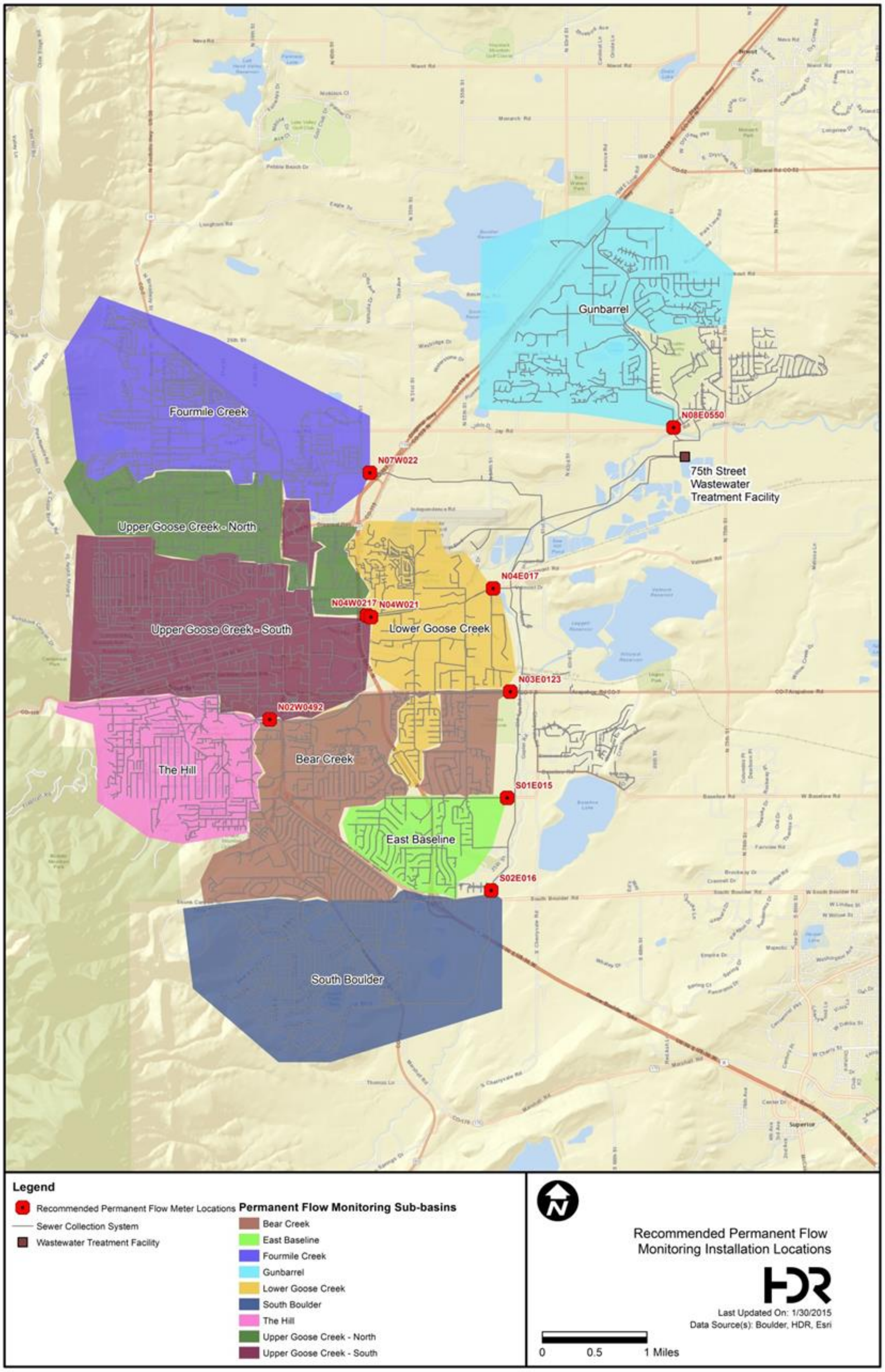
2.4 Summary

Based on the review and assessment of the data, there is sufficient detail in the data to provide an enhanced update to the collection system hydraulic model and WWCSMP analyses. The 2013 post-flood survey data related to the collection system including sewer lateral backups, floor drain backups, and groundwater seepage can be used to help prioritize capital improvement projects in the 2016 WWCSMP. The 2009 WWSCMP model can be efficiently updated using the latest GIS data and flow split manhole information.

Using the 2014 water use data, water meter locations, 2011 WUMP model demand projections, and updated SIU flows, a more accurate allocation of base sanitary flow in the model is possible for existing and buildout (2035) conditions. Applying the data and results of the *2014 Flow Monitoring Program* (Stantec, 2014), GWI and RDII flow allocation can be accounted for in the WWCSMP model at a more detailed level by flow monitoring basin. The May 30th, 2014 storm event captured by the *2014 Flow Monitoring Program* will be used as the existing wet-weather model calibration scenario. Overall, the increased detail and apparent accuracy of data available will improve the level of model calibration and related analysis.

In addition, this updated WWCSMP will be coordinated at a higher level than before with the parallel Stormwater Master Plan Update project. Areas that do not have existing stormwater infrastructure will be evaluated based on their existing and future wastewater capacity limitations. Capital improvement extents and prioritization will be coordinated to schedule construction for reduced public disturbances and increased cost savings by working at the same time in the same area of Boulder.

Figure 2-6. Recommended Permanent Flow Monitoring Installation Locations



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3 Dry Weather Model Update and Calibration

This section documents the process and results of the dry weather model update and calibration for the City of Boulder (city) 2016 WWCSMP. It documents updates to the model network, BSF, and BI allowances for existing conditions dry weather model development and calibration. It also documents development of buildout dry weather BSF projections.

This section discusses the following:

- System infrastructure summary and model update based on the current (2014) GIS information.
- Existing BSF loadings from 2014 water use data.
- BI allocations from 2015 permanent flow monitoring data.
- Dry weather model calibration process and results.
- Water use projections from the 2011 WUMP for future BSF loading.

Solid model development and calibration are important for the confidence level associated with its results.

3.1 Wastewater Utility Service Area

The WUSA contains approximately 16,610 acres (25.9 square miles) that are served by 386 miles of sanitary sewers located within 5 major sewer basins. The sewer collection system includes gravity sewers, diversion manholes, one inverted siphon, and two lift station/force main systems that convey wastewater flow to the 75th Street WWTF. Major features and gravity sewer, by pipe size, that make up the existing system are depicted in Figure 3-1. Table 3-1 summarizes, by sewer basin, the major features found in the sanitary sewer collection system contained in the WUSA that were included in the model update.

Figure 3-1. Existing Sanitary System - Major Features and Gravity Sewer by Size

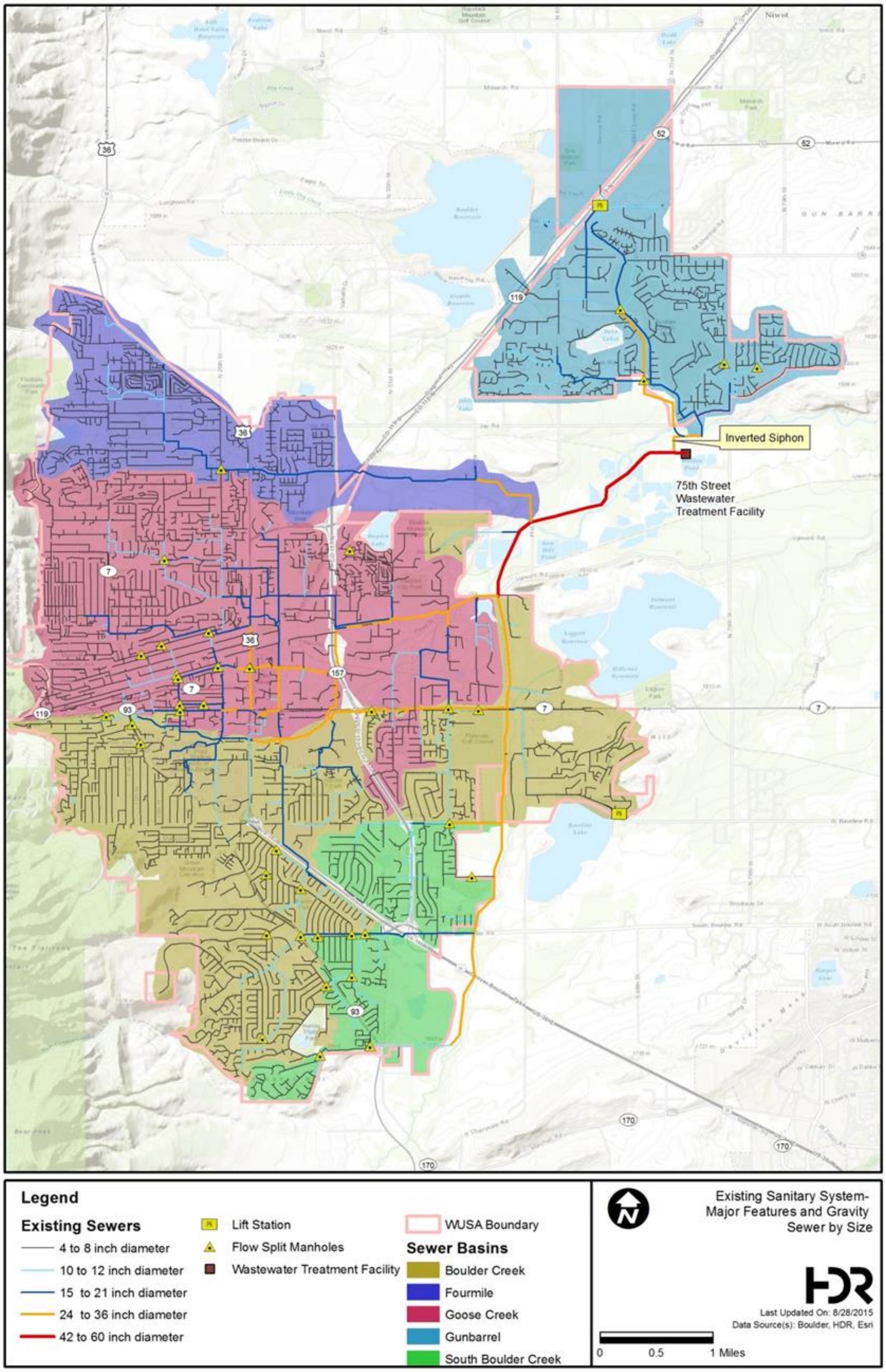


Table 3-1. Existing Sewer System Summary – Modeled Elements

Collection System Feature / Sewer Basin	Modeled Gravity Sewer (miles)	Modeled Flow Split Manholes	Modeled Lift Stations	Modeled Force Mains	Modeled Inverted Siphons
Boulder Creek	120.5	14	0	0	0
Fourmile	48.0	1	0	0	0
Goose Creek	132.4	13	0	0	0
Gunbarrel	46.0	4	1 (City-owned)	1 (City-owned)	1
South Boulder Creek	31.0	8	1 (Private)	1 (Private)	0
Total	**377.9**	**40**	**2**	**2**	**1**

Source: City of Boulder GIS data.

3.2 System Infrastructure Model Update

The first step in the process was to update the 2009 WWCSMP InfoSewer model with the city's current GIS sewer network data from August 2014. InfoSewer Version 7.6 Service Pack 1 Update 2 by Innovyze was used to update the model.

3.2.1 GIS Pipe and Manhole Data

With the city's 2014 GIS data, existing pipe and manhole diameters, materials, elevations, and inverts were updated. New developments and infrastructure improvements that have occurred since the 2009 WWCSMP and are reflected in the city's GIS were added to the model. The updated model elements were snapped to the GIS data, creating a near 1:1 relationship between the two datasets (as of August 2014).

The modeled system for the 2016 WWCSMP is made up of pipes greater than 8 inches. Linear interpolation was used to estimate missing pipe inverts or to correct negative slopes within the analyzed system. Pipe connectivity and direction issues in the GIS data were resolved in the model prior to completing flow loading and scenario modeling.

3.2.2 Flow Split and Diversion Manholes

Since the 2009 WWCSMP, the city has obtained better information on their diversion manholes. City staff has visited all of the known diversion manholes contained in the GIS and documented the relative flow split between downstream pipes. This effort also revealed that some of the flow splits contained in the GIS were no longer active due to one or more of the downstream pipes having been abandoned using concrete plugs. There are 40 manholes with information related to flow splits in city's GIS, including:

- 15 flow split manholes where effluent sewers share similar invert elevations and flow is split at all times.
- 4 manholes with weir walls that split flows during high-flow events.
- 7 manholes that have elevated secondary effluent sewers that activate during surcharges.

- 1 manhole shared by two parallel sewers.
- 8 splits that have been plugged.
- 2 with abandoned (closed) gate structures.
- 3 apex manholes at topographic high points that serve as common access points between two lines flowing to different sewersheds.

The flow splits at these manholes are now reflected in the current model. When flow splits are not specifically defined as a percentage split, the modeling software automatically splits the flow based on the downstream invert elevations and hydraulic grade lines. Incorporating the flow splits in the model results in a better downstream representation of the modeled flow and capacity analysis. An analysis will be completed during a later phase of the 2016 WWCSMP to determine whether some of these flow splits can be plugged to facilitate more straightforward system operations.

3.2.3 Network Validation

Additional steps were taken to validate the city's collection system network and, as necessary, changes were made to the model. Network validation included:

- Pipe slopes that were negative or excessively positive (greater than 15 percent) were identified and the pipe inverts were adjusted to correct the slope, if they were found to be erroneous.
- Manhole rim elevations were checked for irregularities, such as elevations causing excessively deep or negative pipe cover at manholes, and fixed as necessary.
- Pipe cover was checked for shallow pipes with less than 3 feet of cover at manholes and adjusted as necessary.
- Interceptor profiles within the model environment were checked for irregularities, such as negative slopes, and corrected as necessary.

3.2.4 Steady-State Modeling

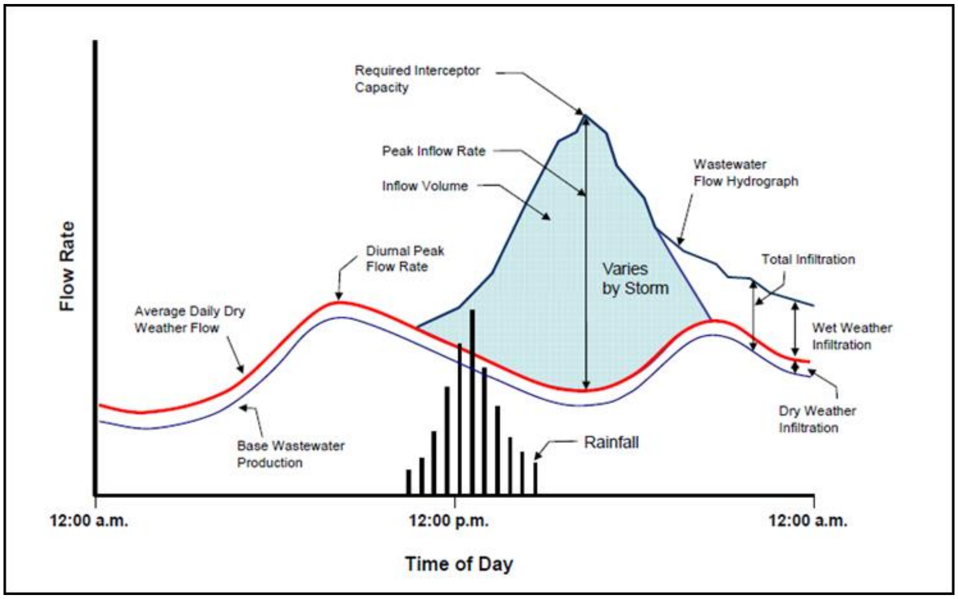
Steady-state modeling was selected for the 2016 WWCSMP. This method is common in drier climate areas of the United States without frequent sanitary sewer overflows for master planning-level models to determine system capacity deficiencies and develop capacity improvements. The modeled average day and peak hour flows for this 2005 WWCSMP Update represent a snapshot in time. Peak hour flows drive the capacity analysis.

Unsteady-state scenarios, also known as extended period simulation (EPS) modeling, can more accurately account for detention and flow attenuation. However, the city does not have a lot of collection system storage, other than at two lift station wet wells and one siphon which are a small volume as compared to the system volume. Also, flow diversions are also relatively straightforward and pipe slopes are relatively steep compared to most collection systems. Therefore, there is little opportunity for detention and flow attenuation in the system that would make unsteady-state modeling beneficial. Finally, since InfoSewer (the software used to update the model) is based only on Manning's equation and does not use the dynamic Saint Venant equation to calculate flow attenuation through the system, there is little hydraulic calculation advantage to using EPS (unsteady) scenarios.

3.3 Dry Weather Analysis

Dry weather flow represents the flow in the sanitary sewer system outside of the influence of individual rainfall events. ADWF is the flow that it is in a sanitary sewer system on a normal dry day and represents the average daily loading to the WWTF. ADWF is comprised of BSF and BI. Figure 3-2 shows the typical flow components for dry and wet weather conditions over the course of a day.

Figure 3-2. Typical Collection System Flow Components



BSF is the sanitary loading mostly from homes and businesses and BI is mostly groundwater that seeps into a collection system through defective pipes, pipe joints, and manhole structures. The rate of infiltration depends on the depth of groundwater above the defects, the size of the defects, and the percentage of the collection system that is submerged. Variation in groundwater levels and the associated infiltration is both seasonal and weather dependent.

ADWF is the expected wastewater flow on a day with no precipitation events and no residual influence of previous precipitation events. ADWF can vary seasonally as groundwater levels change and cause fluctuations in the base infiltration. Daily fluctuations in ADWF are mostly attributed to variations in BSF, such as domestic, industrial, and commercial wastewater contributions and how these contributions vary throughout a day. These daily fluctuations in wastewater flows over the course of the day are represented by diurnal patterns.

The 2009 WWCSMP used the best available data at the time, including potable water meter data, to develop BSFs. The Denver Regional Council of Governments (DRCOG) transportation analysis zones (TAZ) and the associated population and employment projections were used to establish future sanitary base flows.

In April 2015, the city installed ten permanent flow monitors throughout the WUSA. Data from these permanent flow monitors are used to update and calibrate the model for dry weather infiltration and wet weather inflow.

The following sections describe the estimation and development of dry weather flows for the updated model.

3.3.1 Population and Employment

The city provided existing (2014), 2035, and buildout data for city population and employment. This data, along with 2010 Census Data, was used to update city population and employment summaries for the 2016 WWCSMP. Growth projections are made to 2035 based on zoning capacity and growth rate assumptions. The 2010 BVCP has a planning timeframe of 15 years, but calls for growth projections to extend 20 years beyond the last update of the plan.

In 2002, as part of the Jobs to Population project, the city developed new projection methods. Previous growth projections were done by identifying vacant land, opportunity sites, and areas of anticipated growth. A review of this method determined that it was not very accurate. One of the defined roles of the Jobs to Population Task Force was to examine the growth projections, methods, and assumptions, and to offer advice on how to improve the accuracy and quality of the projections. The task force provided guidance on developing a new method of projections that uses a combination of a land use model and an economic model. It requested examination of the total non-residential development that could occur under existing zoning. This zoning capacity (or buildout) number is useful to determine whether building under current zoning regulations results in the amount and mix of development that is desired for the future and has no associated time frame. The BVCP 20-year projections are based upon this zoning capacity information supplemented by growth assumptions and input from DRCOG, the State Demographer's Office, and local and state economists. The WUSA is made up of the BVCP planning Areas I and II within these projections. Table 3-2 presents these city projections for the WUSA. The population projections summarized as part of the 2009 WWCSMP were greater for the 2030 population (128,162) compared to this 2035 population projection (125,468), however, for employment the previous buildout projection (155,864) was less compared this projection (165,230).

Table 3-2. Population and Employment Projections for WUSA

Year	2010	2014	2035	Buildout
Population	109,200	114,200	125,468	125,468[1]
Employment	99,750	105,450	119,180	165,230

Source: City of Boulder Department of Planning, Housing and Sustainability, 1/20/2012; and 2014 Community Profile, 04/2014.

[1] Population was not separated between 2035 and buildout in the provided projections.

In the 2009 WWCSMP DRCOG TAZ polygons, with population and employment projections, were used to establish existing and future sanitary base flows. The TAZ polygons, however, have not been updated in several years, and the BVCP update process is just being initiated and will not be available to use for the 2016 WWCSMP. Therefore, 2014 use data from potable water meters and their GIS locations were used exclusively to spatially allocate the base sanitary loads to the hydraulic model.

3.3.2 Sanitary Flows

Existing potable water meter data from winter periods, SIU information, and buildout (2035) water demand projections (from the water model 2035 demands) were used to allocate BSF. Using winter potable water meter data for BSF generation is generally accepted within the industry for its increased data accuracy, detail, and reliability over other methods, such as TAZ polygons.

3.3.2.1 Winter Water Meter Data (Existing)

The city provided monthly potable water meter data from November 2013 through March 2014, as well as the spatial location of these meters. This water meter data was filtered to remove duplicate values and further filtered to December 2013 through February 2014, with the assumption that outdoor water use is minimal during this time and therefore the majority of water is discharged to the sanitary sewer system. Winter water meter data is also characteristically equal to dry weather wastewater flows because at this time of year there is limited infiltration caused by increased groundwater levels due to irrigation ditches and high stream flows. Because of this, the potable water use records from this time period are considered the most accurate spatial representation of existing BSF contributions to use for the 2016 WWCSMP.

Monthly metered water use volumes were converted to a monthly rate of consumption. The monthly flow rates, converted to gallons per minute (gpm), were averaged over the three months for each meter. Some meters used in the analysis did not have records for each of the three months, and this was accounted for by including only the months with data in the average. These averages converted to a BSF of 8.9 million gallons per day [mgd] (6,158 gpm). This flow rate includes SIUs, which are described in the next section.

3.3.2.1 Significant Industrial Users

SIUs are owners who contribute high sanitary loadings and need to be accounted for in the sanitary flow projections. Since the 2009 WWCSMP, several SIUs have gone out of business and one is no longer permitted to discharge. New SIUs include Advanced Probing Systems, Agilent Technologies Inc., Avery Brewing Company, Corden Pharma Colorado Inc., KBI Biopharma, Merck Boulder, and the National Institute of Standards & Technology (NIST).

The city provided the updated average annual 2014 daily flows for the current SIUs, shown in Table 3-3. Figure 3-3 shows the locations of the SIUs in the WUSA. Since water meter data is being used for this 2016 WWCSMP, these average annual flows were compared against the winter water meter data from December 2013 through February 2014 to estimate an average flow for each SIU. The winter water meter flow (provided in Table 3-3) was either:

- Kept the same if it compared well to city provided SIU flow.
- Modified to the city provided SIU flow as an additional load to the system if winter water use was underestimating that SIU's average flows.

The last column in Table 3-3 provides the final flow rates for each respective SIU used in the 2015 model update.

Note that based on the University of Colorado at Boulder's Master Plan, only 30 percent of the potable water used in the main campus area reaches the sanitary collection system due to use, loss, and recycle in its steam heating and chilled water cooling system. Therefore, only 30 percent of winter water use for the University of Colorado at Boulder's main campus is used for its SIU contribution.

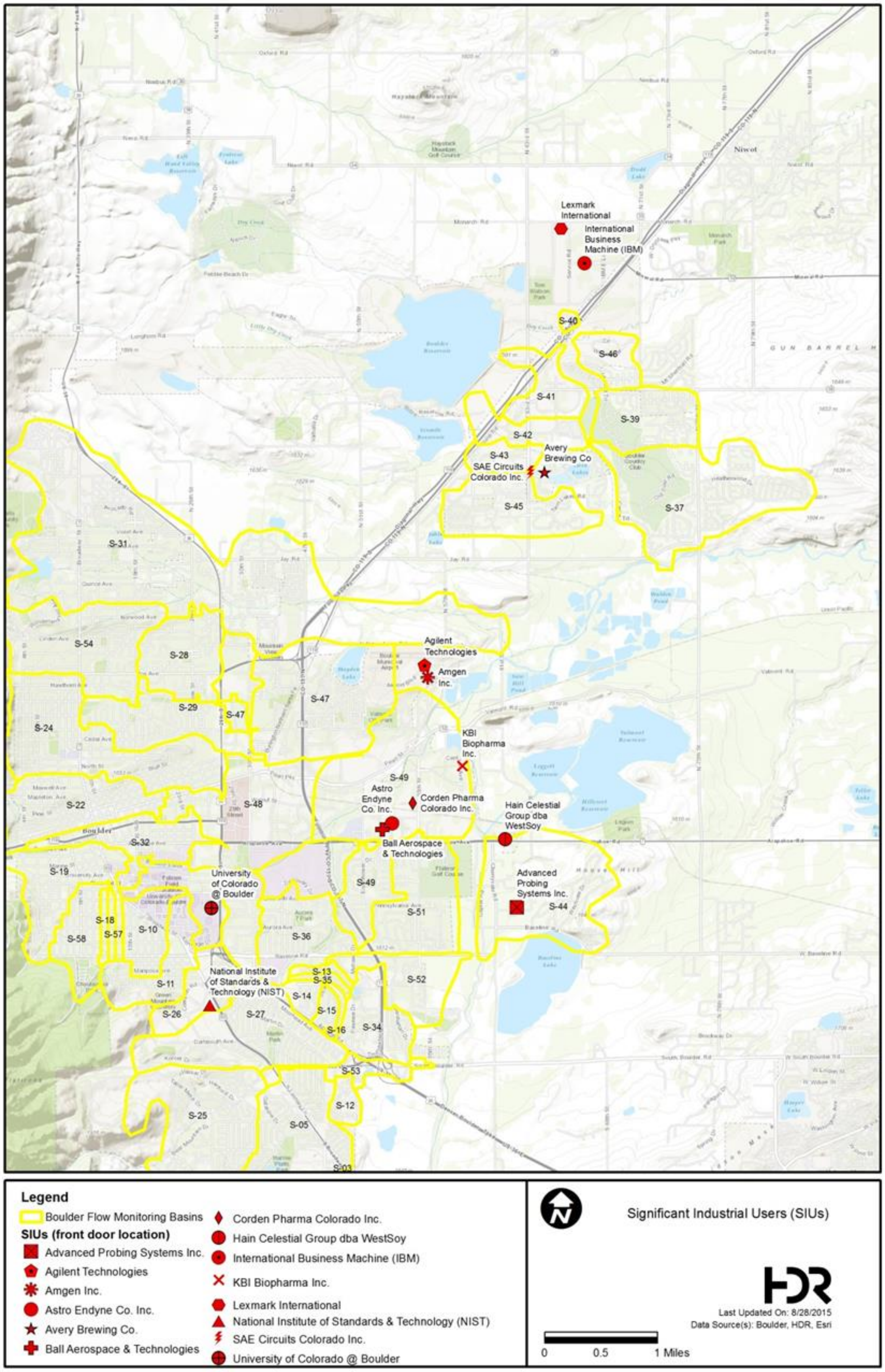
The water use for all SIUs is estimated to be approximately 924 gpm (1.33 mgd) from the annual averages and 819 gpm (1.18 mgd) from the winter water meter data. Extracting the larger of the two values for each SIU and applying a 70 percent reduction (30 percent flow through) for the University of Colorado at Boulder's main campus yields a total modeled SIU sanitary contribution of 816 gpm

(1.17 mgd), or 13 percent of the total 8.9 mgd BSF to the WWTF for 2014. Unlike the 2009 WWCSMP, future SIUs are not planned for or modeled in this 2016 WWCSMP.

Table 3-3. 2014 SIU Data from the City of Boulder

Significant Industrial User (SIU)	Service Address of SIU	New SIU since 2009 WWCSMP	Discharge for Previous 12 months (gpd)	Avg. Sewer Flow from Jan. to Dec. 2013 (gpd)	Avg. Water Meter Flow from Dec. 2013 to Feb. 2014 (gpd)	Flow Allocated to the Model (gpd)
Advanced Probing Systems, Inc.	PO Box 17548	Yes	<100	44	0	**44**
Agilent Technologies	5555 Airport Blvd.	Yes	101-10,000	1,738	6,966	**6,966**
Amgen, Inc.	4000 Nelson Road	No	> 25,000	35,911	37,207	**37,207**
Astro Endyne, Co., Inc.	1770 Range St	No	< 100	75	146	**146**
Avery Brewing Co	4910 Nautilus Court	Yes	10,001-25,000		-	**-**
Ball Aerospace & Technologies	1600 Commerce St, MS FT-3S	No	> 25,000	30,040	33,351	**33,351**
Corden Pharma Colorado, Inc.	2075 N 55th St	Yes	> 25,000	26,507	74,827	**74,827**
Hain Celestial Group	6123 Arapahoe Rd	No	>25,000	40,710	23,054	**40,710**
International Business Machine (IBM)	PO Box 1900; 001B	No	> 25,000	194,000	276,252	**276,252**
KBI Biopharma, Inc.	2590 Central Avenue	Yes			11,722	**11,722**
Lexmark International	6555 Monarch Rd	No	> 25,000	30,846	Part of IBM Loading	
National Institute of Standards & Technology (NIST)	325 Broadway, MC 173.02	Yes	> 25,000	423,580	125,717	**423,580**
SAE Circuits Colorado, Inc.	4820 N 63rd St	No	> 25,000	41,261	39,127	**39,127**
University of Colorado @ Boulder	EH&S, 413 UCB, Univ of CO	No	> 25,000	505,959		
	Main Campus (assume 30% pass through contribution):				457,591	**137,277**
	East Campus:				94,376	**94,376**
Total SIU Flow (gpd)				**1,330,671**	**1,180,336**	**1,175,585**

Figure 3-3. Significant Industrial Users (SIUs)



3.3.2.1 BSF Allocation

The following section describes the process of how BSF wastewater loads were allocated spatially to the model.

Stantec Consulting Services Inc. (Stantec) was contracted to perform a flow monitoring analysis across the city with the analysis summarized in the *2014 Flow Monitoring Program* (Stantec, 2014). This analysis performed flow monitoring throughout the wastewater collection system at 60 manholes between April and July, 2014 and refined contributing sewersheds for each flow monitor were developed as part of this analysis. Therefore, sanitary sewersheds from the 2009 WWCSMP were updated based on the further refined flow monitoring basins from the *2014 Flow Monitoring Program*. The resulting sewersheds, along with the 2014 flow monitoring basins, are presented in Figure 3-4.

The water meter data was joined to the GIS water meter spatial locations. Of the 26,961 water meters, only 12 meters did not have a GIS equivalent and amounted to only 1 gpm of flow. Thiessen polygons for the model manholes were generated within each of the adjusted sewersheds and joined spatially to the GIS meter locations. The water meter data flow rates, described in Section 3.3.2.1, were summed within each Thiessen polygon for each model manhole (the majority of Thiessen polygons contain multiple water meters) and assigned as BSF to that respective model manhole (Load 1 column). If a Thiessen polygon for a model node did not contain a water meter, then that model node was not assigned a BSF load. Figure 3-5 illustrates an example of this BSF load allocation using Thiessen polygons within each sewershed.

The location of SIUs with respect to the Thiessen polygons was then reevaluated and, if necessary, flow allocations were adjusted so that they were loaded to the closest manhole to that SIU's outlet location, as provided by the city. For instances when the winter water meter data underrepresented the total SIU load, or when the winter water meter data had to be distributed among numerous outfalls, the additional SIU load was accounted for as an additional model load rather than an increase in the winter water meter load (Load 2 column).

These winter water meter loads and additional SIU flows result in the total 8.9 mgd BSF allocated to the model (Load 1 plus Load 2 columns) and are the basis for the existing scenario flows. The total existing conditions BSF allocated to the model is 6,158 gpm (8.87 mgd), including the SIUs.

Figure 3-4. Sewershed and Flow Monitoring Basins

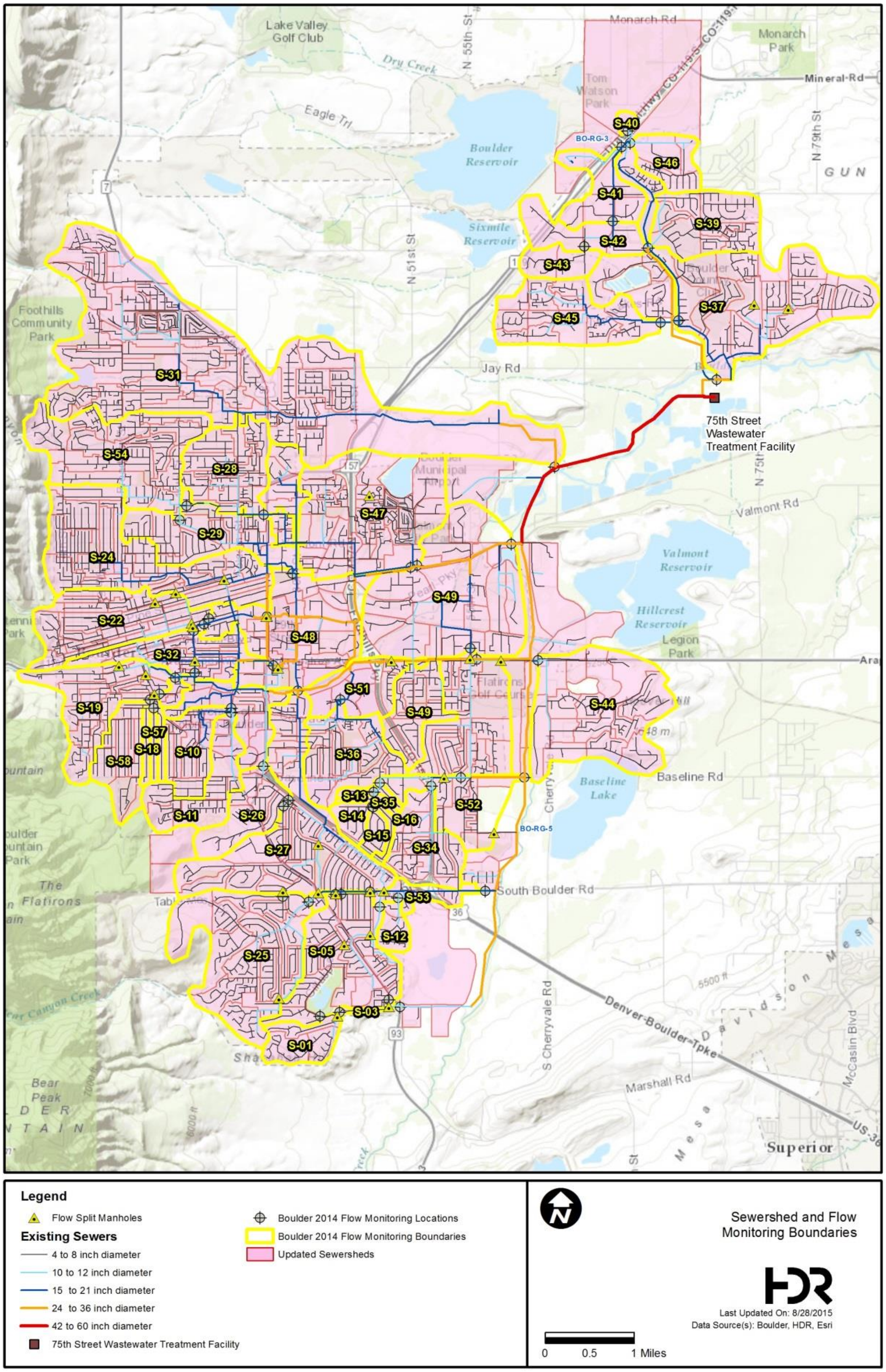
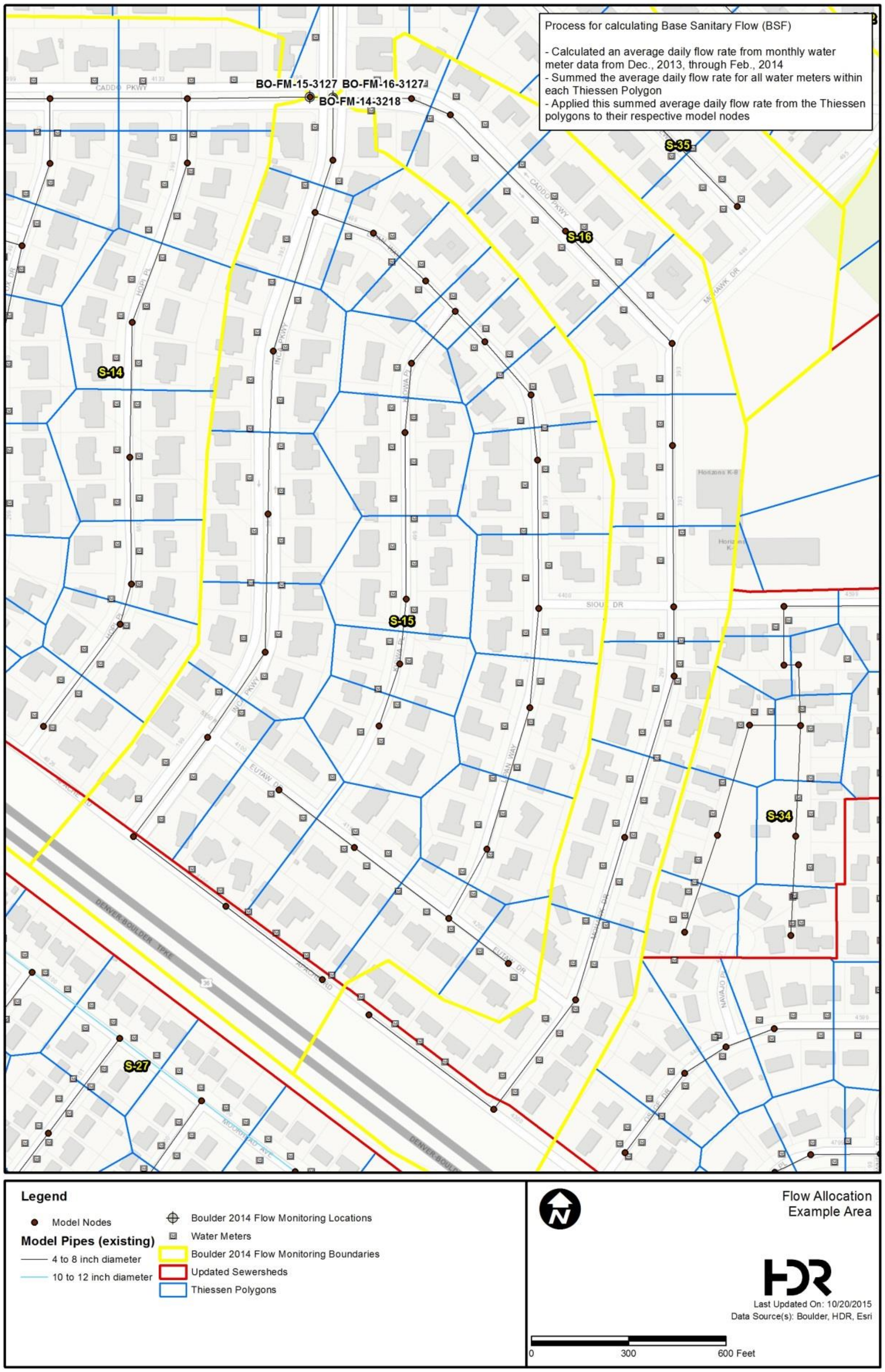


Figure 3-5. Flow Allocation Example Area



3.3.2.1 Water Utility Master Plan Demands (Buildout)

The city's 2011 WUMP water distribution model contains a detailed allocation of future water use and, therefore, represents the corresponding future sanitary load generation and how it is anticipated to be distributed across Boulder. By incorporating the city's 2011 WUMP future water use, future conditions modeling in the 2015 WWSMP Update is consistent with the water plan. The future water use allocation in the 2011 WUMP model, reduced by an appropriate winter (indoor) use factor, is applied as future BSF loading for the 2016 WWCSMP. This future sanitary load allocation process aligns the future water use and sanitary sewer loads.

The buildout sanitary base loading is based on the 2011 WUMP water use projections and the associated water distribution model. The existing condition (2011) flows were subtracted from the future condition (2035) demands in the water distribution model to estimate the projected increase in water use.

Assuming that outdoor water use is minimal during the winter months, an estimate of the winter water demand was calculated using a winter water use fraction. This winter water use fraction was derived by dividing the average water use for a year (December 2013 through November 2014) by the average water use in the winter (December 2013 through February 2014). This results in a winter use fraction of 0.65, which was applied to the projected increase in water use. Based on this process, it is estimated that Boulder's winter water demand will increase 2,395 gpm (3.45 mgd) by 2035.

Because of the uncertainty of industrial process contribution, the SIU loads will be held constant for existing and future flow scenarios. BI allocations are also considered unchanged from existing to future conditions.

The 2011 WUMP water distribution model used Thiessen polygons to allocate water loads to their respective water junctions. This spatial allocation of water demand was compared to the sewer manhole Thiessen polygons to determine projected increases which fall outside of the WUSA and should not be included in the wastewater system model.

Based on this comparison process, of the 2,395 gpm (3.45 mgd) increase in 2035 winter water demand, 92 percent, or 2,208 additional gpm (3.18 mgd), will enter the WUSA.

The total BSF for 2035 conditions is therefore estimated be 8,366 gpm (12.0 mgd). Future SIU flow is estimated to be approximately 10 percent of this 2035 BSF.

3.3.3 Dry Weather Infiltration Flows

Dry weather infiltration, or BI, occurs even during dry weather due to groundwater and can be influenced by stream flows and irrigation ditches. BI is an important consideration when analyzing system capacity because this flow component of ADWF can increase sanitary flows substantially. To illustrate, the BSF was estimated to be 8.87 mgd (6,158 gpm) based on the potable water meter data, however, the average daily WWTF influent flow for the same time period was measured to be 13.2 mgd. BI can therefore be inferred to account for the 4.3 mgd (33 percent) difference since there were no other major sources of wastewater contributions such as wet weather events. In the summer, flows in irrigation ditches and high stream flows further elevate the groundwater table and cause even greater BI. Since summer BI is higher than winter BI, the summer BI is used for this model update.

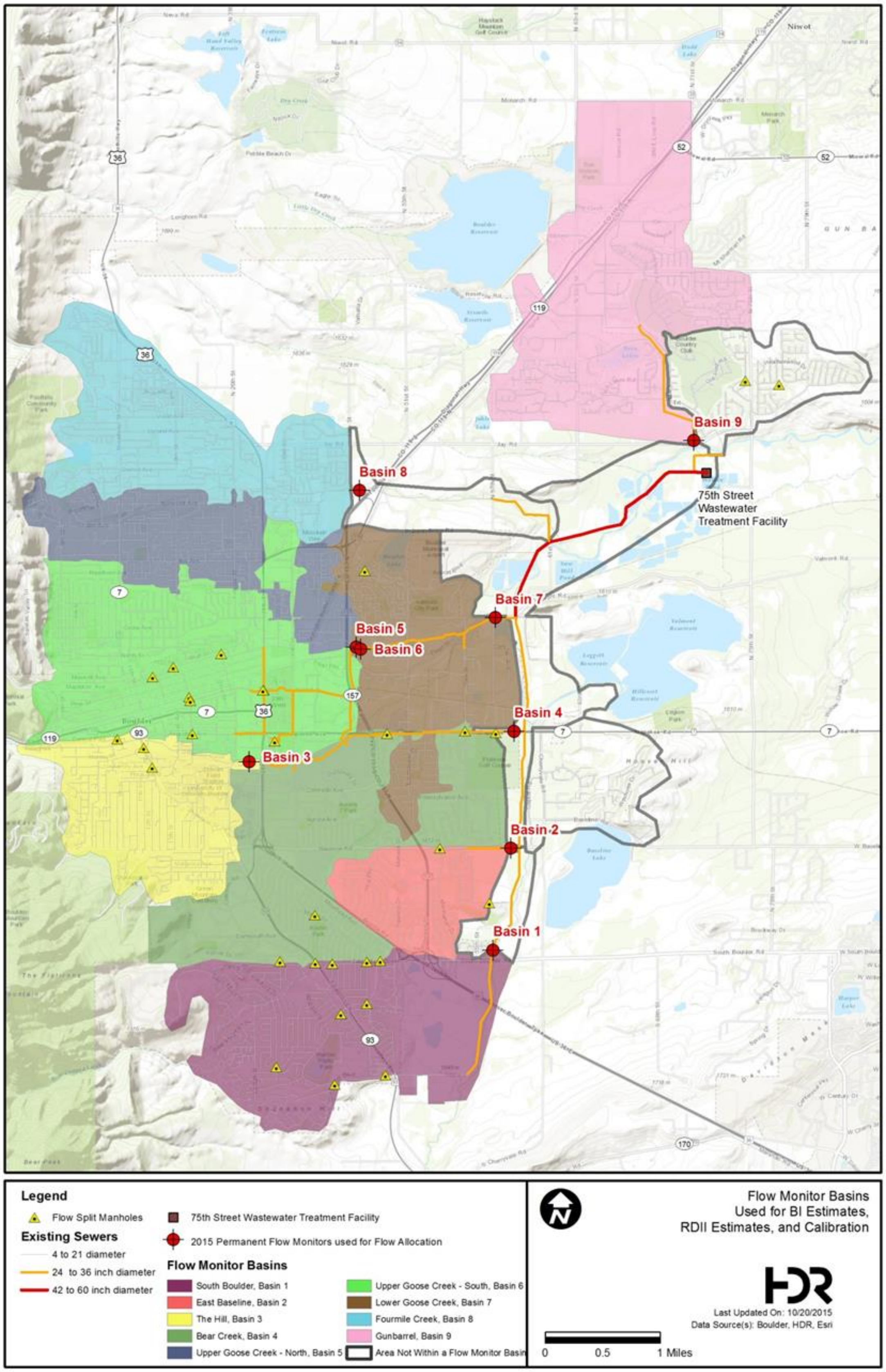
Stantec conducted a comprehensive I&I analysis as part of the *2014 Flow Monitoring Program*. The analysis produced spring and summer groundwater infiltration values for each flow monitoring basin. The results of the study were not used for the current modeling effort because:

- Some basins were calculated to have negative groundwater infiltration which is not reasonable.
- Some of the model network was not represented in the 2014 Flow Monitoring Program.
- Groundwater infiltration values in the 2014 Flow Monitoring Program were estimated based on calculated ADWF at the flow monitors rather than from BSF. This may be the reason some of the calculated groundwater infiltration values were negative.
- There is suspect data at some of the flow monitors due to negative groundwater infiltration or some data was noted as being suspect in the report. Flow monitors assigned with "Some Limitations" or "Poor" quality in the report were used in the I&I calculations, which can create uneven flow balancing and skew modeling results.
- A significant rainfall event (both in total rainfall depth and distribution across Boulder) did not occur during the 2014 Flow Monitoring Program.

In April 2015, the city installed ten permanent flow monitors into major trunk sewers throughout its sanitary sewer system. Most of the permanent flow monitors have recorded flows that are influenced by the mix of land uses within the system. There were a number of significant rainfall events in May 2015 that caused the WWTF influent monitor to reach its capacity of approximately 50 mgd. Rainfall data observations also indicate that these May rainfall events had a relatively even distribution across Boulder, which is good for balanced hydraulic modeling across the collection system. Due to these factors, the permanent flow monitors were used instead of the *2014 Flow Monitoring Program* data for developing and calibrating the summer BI.

Contributing areas were developed for the permanent flow monitors based on the sewersheds described in Section 3.3.2. These contributing areas are referred to as flow monitor basins and are illustrated in Figure 3-6. The flow monitor basins were used for BI and RDII estimates and calibration.

Figure 3-6. Flow Monitor Basins Used for BI Estimates, RDII Estimates, and Calibration

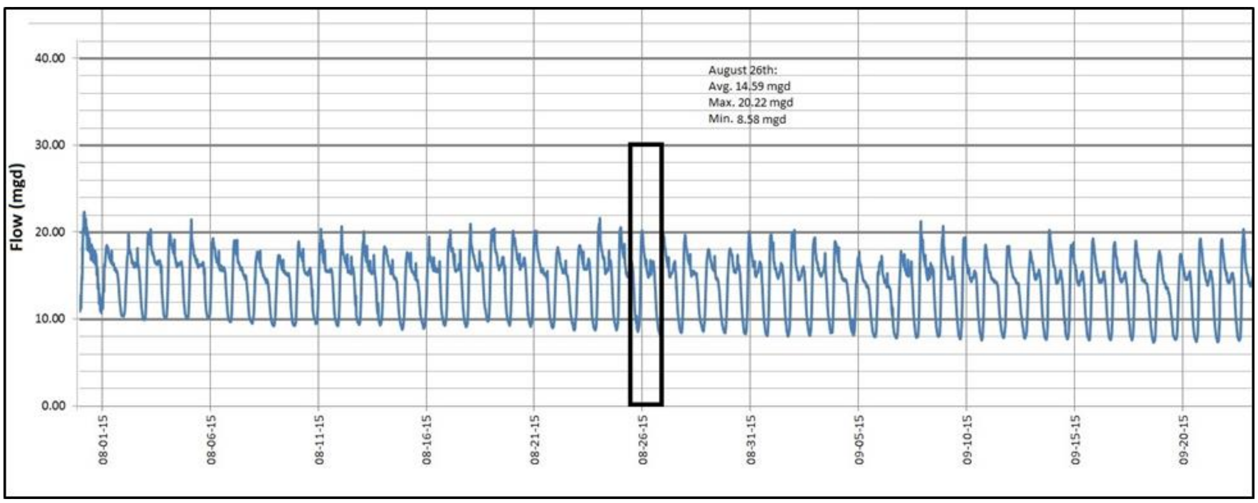


After a review of WWTF influent flow monitor data and rainfall data, August 26, 2015, was chosen as the date of BI development and dry weather model calibration based on the following:

- It is at a time of year when irrigation ditches and creeks were flowing so the groundwater-induced BI is likely present at a higher level in the flow meter data.
- Classes for the University of Colorado at Boulder started on August 24, and August 26 is a date that reflects when students are on campus. It was observed that the start of classes has an appreciable influence on sanitary flow within Basins 3 and 4 when meter data was compared for off-class/summer periods. BSF estimates were also developed for the winter period when students are on campus and this date reflects the higher flows in these basins when school is in session.
- There was about 0.2 - 0.3 inch of rainfall on the August 19, but no rainfall between August 20 and 26. Any remaining effect from the rainfall is not apparent in the flow monitors or at the WWTF on August 26.
- The average daily flow at the WWTF on August 26 was 14.59 mgd. This flow rate is similar to other summer dry days recorded at the WWTF in 2015.

Figure 3-7presents the WWTF influent flow for August 2015 with August 26 highlighted, indicating its appropriateness for BI generation and dry weather model calibration.

Figure 3-7. WWTF Influent Flow for August 2015 with the Day of BI Development Highlighted



The process for developing BI was as follows:

- Every pipe and manhole was assigned to its corresponding 2015 flow monitor basin that was developed from the sewersheds described in Section 3.3.2.1.
- Flow meter data for the dry day of August 26, 2015, was extracted from the 2015 flow monitoring data.
- Potable water meter data was summarized for each flow monitor basin to determine the estimated BSF contribution to the respective permanent flow monitors.

- Average daily flow for August 26 was determined for each permanent flow monitor. If there was a flow monitor basin upstream of another flow monitor basin, this upstream flow was removed to isolate flow contributions specific to each flow monitor basin.
- BI was calculated for each flow monitor basin by subtracting the contributing BSF from the average flow at the corresponding permanent flow monitor.
- Each sewer pipe was multiplied by its corresponding diameter (inches) and length (miles) and assigned to its upstream manhole.
- The total pipe diameter (in)-length (feet) was summed in each flow monitor basin.
- The calculated BI was then allocated to the pipes based on their individual diameter (in)-length (feet) in proportion to the total diameter (in)-length (feet) in each flow monitor basin.
- BI was summed to each of the model manholes based on the BI fraction assigned to their downstream effluent pipes and assigned as BI to that manhole (Load 3 column).
- For pipes and manholes not within a flow monitor basin, the remaining winter water meter BSF was calculated and compared against the WWTF ADWF minus the ADWF of the upstream flow monitors. The remaining BI was then allocated to these manholes based on the diameter (in)-length (feet) of the downstream effluent pipes.

This process resulted in non-negative BI values and a good correlation to existing dry weather flows.

3.3.4 Dry Weather Calibration

Modeled dry weather flows were calibrated against the flow monitoring data from the ten permanent flow monitors and the overall WWTF influent flow. The results of the dry weather calibration and verification are described below.

3.3.4.1 Dry Weather Calibration – Permanent Flow Monitoring Data

Following the completion of the Section 3.3.3 processes, the updated existing conditions uncalibrated model was run for the base dry weather scenario. Initial results were compared to the permanent flow monitor data for August 26, 2015 to calibrate BI allowances, assuming that BSF was well-represented by the water meter and SIU data. The target for the model calibration was to be within +10 percent of the ADWF peak and daily volume for the permanent flow monitors.

BI allowances were refined for the model pipes within each flow monitor basin based on the following process:

- The initial, uncalibrated model results for ADWF (total daily dry weather volume) were compared to the August 26, 2015, monitored flows for each permanent flow monitor.
- BI allowances were adjusted to reflect the measured average daily flow (or total volume).
- This modeled BI adjustment was repeated iteratively until the calibration goal was met within each flow allocation basin (within +10 percent of the ADWF peak and daily volume for the permanent flow monitors).

This process created a good correlation between the model and the observed flows at the permanent flow monitors and at the WWTF. The calibrated BIs for each permanent flow monitor basin are presented in Table 3-4. Table 3-5 provides the calibration results for the steady-state, dry weather model based on the methods described above.

Table 3-4. Calibrated Infiltration Parameters per Permanent Flow Monitor Basin

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	ADWF at Permanent Flow Monitor for August 26th, 2015	ADWF for Flow Monitor Basin (minus upstream monitors)	Base Sanitary Flow (BSF) (gpm)	Calibrated Base Infiltration (BI) (gpm)	Calibrated Base Infiltration (BI) (%)	Calibrated ADWF for Flow Monitor Basin (minus upstream monitors)
South Boulder	Basin 1	976	976	455	652	59%	1,106
East Baseline	Basin 2	563	563	256	337	57%	593
The Hill	Basin 3	642	642	602	56	8%	658
Bear Creek1	Basin 4	2,096	1,454[1]	1,106	348	24%	1,454
Upper Goose Creek - North	Basin 5	883	883	439	466	52%	905
Upper Goose Creek - South	Basin 6	1,644	1,644	1,463	181	11%	1,644
Lower Goose Creek2	Basin 7	3,367	839[2]	411	449	52%	861
Fourmile Creek	Basin 8	1,146	1,146	461	684	60%	1,146
Gunbarrel	Basin 9	1,286	1,286	642	644	50%	1,286
N/A[3]	WWTF	10,132	699[3]	323	376	54%	699
Total				**6,158**	**4,194**		**10,351**

[1] The Hill (Basin 3) permanent flow monitor is upstream of the Bear Creek (Basin 4) permanent flow monitor and needed to be subtracted from the ADWF for BI allocation.

[2] The Upper Goose Creek North and South (Basins 5 and 6) permanent flow monitors are upstream of the Lower Goose Creek (Basin 7) permanent flow monitor and needed to be subtracted from the ADWF for BI allocation.

[3] The WWTF ADWF used for BI allocation results from the ADWF influent flow minus the ADWFs from the directly contributing permanent flow monitors.

Table 3-5. Dry Weather Calibration Steady-State Results Based on Flow Data for August 26, 2015

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	Monitored ADWF (gpm)	Modeled ADWF (gpm)	Model vs. Monitor ADWF (Difference)
South Boulder	Basin 1	976	999	23
East Baseline	Basin 2	563	580	17
The Hill	Basin 3	642	645	3
Bear Creek	Basin 4	2,096	2,230	134
Upper Goose Creek - North	Basin 5	883	898	15
Upper Goose Creek - South	Basin 6	1,644	1,643	-1
Lower Goose Creek	Basin 7	3,367	3,399	32
Fourmile Creek	Basin 8	1,146	1,146	0
Gunbarrel	Basin 9	1,286	1,289	3
N/A	WWTF	10,132	10,351	219

3.3.4.1 ADWF vs. Base Sanitary Flow Relationship

The modeled ADWF at the treatment plant for August 26, 2015, is 14.9 mgd (10,351 gpm), as shown in Table 3-5. The average daily BSF, assuming the water meter and SIUs are the sole BSF contributions, is estimated to be 8.87 mgd (6,158 gpm). These results imply that the BI accounts for 6.04 mgd (4,194 gpm) or 41 percent of flow, which is higher than the 33 percent winter season BI calculated in Section 3.3.3. The BI may be influenced by higher stream flows and actively flowing irrigation ditches and is considered a significant contributor of wastewater flows this time of year.

3.3.4.1 Dry Weather Model Comparison to 2009 WWCSMP

The results from the 2009 WWCSMP indicated a modeled existing condition ADWF of 16.9 mgd at the WWTF and a projected 2015 ADWF of 19.2 mgd. The 2015 model results are lower than the previous ADWF flow at 14.9 mgd. However, the average WWTF flow for the meteorological summer months (June, July, and August) from 2009 to 2014 is around 15.1 mgd, which is similar to the results of the current analysis (14.9 mgd).

The reasons for this difference in ADWF can be attributed to slower than predicted population and employment growth, water conservation (including installation of water efficient fixtures), better monitoring data with the newly installed permanent flow meters, and more refined monitoring data at the WWTF.

3.3.5 Buildout (2035) Flows

The additional buildout flows in the WUSA totaling 2,208 gpm (3.18 mgd), as described in Section 3.3.2.1, were applied as a separate model load (Load 5 column). This generated a total BSF of

8,366 gpm (12.0 mgd). Keeping BI consistent with existing conditions, these future loads increased model ADWF flows at the WWTF from 14.9 mgd to 18.1 mgd.

3.3.6 Summary

The following summarizes the dry weather steady-state flow analysis for values at the WWTF influent:

- The calculated 2015 BSF for this analysis is 8.87 mgd (6,158 gpm).
- The modeled 2015 ADWF for this analysis is 14.91 mgd (10,351 gpm).
- The calculated 2035 BSF for this analysis is 12.05 mgd (8,367 gpm).
- The modeled 2035 ADWF for this analysis is 18.08 mgd (12,559 gpm).

Table 3-6 summarizes the existing and buildout (2035) BSFs based on the calibrated model for each permanent flow monitor basin. Table 3-7 summarizes the BI values.

Table 3-6. Existing and Buildout Base Sanitary Loads at the Flow Allocation Basins

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	Existing (2015) Sanitary Loads (gpm)	Additional Buildout (2035) Sanitary Loads (gpm)	Total Buildout (2035) Sanitary Loads (gpm)
South Boulder	Basin 1	455	98	553
East Baseline	Basin 2	256	87	343
The Hill	Basin 3	602	182	784
Bear Creek	Basin 4	1,106	267	1,373
Upper Goose Creek - North	Basin 5	439	193	632
Upper Goose Creek - South	Basin 6	1,463	728	2,191
Lower Goose Creek	Basin 7	411	164	576
Fourmile Creek	Basin 8	461	205	666
Gunbarrel	Basin 9	642	189	831
N/A	WWTF	323	95	418
TOTAL		**6,158**	**2,209**	**8,367**

Table 3-7. Existing and Buildout Base Infiltration Loads at the Flow Allocation Basins

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	2015 Summer BI (gpm)	2035 Summer
South Boulder	Basin 1	652	652
East Baseline	Basin 2	337	337
The Hill	Basin 3	56	56
Bear Creek	Basin 4	348	348
Upper Goose Creek - North	Basin 5	466	466
Upper Goose Creek - South	Basin 6	181	181
Lower Goose Creek	Basin 7	449	449
Fourmile Creek	Basin 8	684	684
Gunbarrel	Basin 9	644	644
N/A	WWTF	376	376
TOTAL		**4,193**	**4,193**

3.3.6.1 Unit Flow Factors

Unit flow factors were updated based on the city's population and employment projections to compare to unit flow factors used in the 2003 and 2009 WWCSMPs. They are calculated using ADWF flows and the existing and projected population and employment numbers. Per capita wastewater flow production values of 102 gallons per day (gpd) per capita and 50 gpd per employee were developed in the 2003 WWCSMP, used in the 2007 WWTP Master Plan, and were adopted for the 2009 WWCSMP and the 2010 WUMP. These values are based on historical flow data at the WWTF versus population and employment numbers from 1996 to 2001.

Using updated available data, new unit flow factors for the population, assuming the employment factor is kept at 50 gpd per employee, were developed for comparison and are presented in Table 3-8. Without more information, recalculating both population and employment unit factors is difficult. It is likely the employment factor has decreased, making the population unit flow factor increase in the calculations presented in Table 3-8. Overall, it appears that the unit flow factors have decreased some due to water conservation, water efficient fixtures in new construction and renovations, and actions to reduce infiltration and inflow such as sewer lining activities. For future conditions, the calculated new population unit flow factor is a little higher than the value used in previous planning efforts. This means that the future modeling conducted for this 2016 WWCSMP is likely conservative and appropriate for master planning.

Table 3-8. Unit Flow Factor Comparison

Condition	Population (number of capita)	Population Unit Flow Factor (gpd per capita)	Employment (number of employees)	Employment Unit Flow Factor (gpd per employee)
2003 WWCSMP	-	102	-	50
2014 BSF Conditions	102,420	95	102,500	50
2035 BSF Conditions	114,025	105	116,230	50

Since this 2016 WWCSMP uses the permanent flow monitors for existing flows and the 2011 WUMP water demand projections for 2035 flows, the flow factors are presented in this section only for comparison purposes.

3.4 Summary

The dry weather steady-state modeling results presented in this Section are satisfactory for developing wet weather flows and capacity analyses going forward.

The next steps in model development are as follows:

- Develop the level of service RDII versus rainfall recurrence interval relationship using influent flow monitor data from 2009 to 2015.
- Identify level of service for 50 and 60 mgd flow scenarios and identify estimated flow rate associated with 25-year level of service.
- Compare resulting peaking factors with other regional agencies/municipalities (Metropolitan Water Reclamation District, DRCOG, Westminster, etc.).
- Develop and calibrate wet weather flows based on the permanent flow meter data.

4 RDII Response and Level of Service Assessment

This section documents the process and results of updating rainfall-derived inflow and infiltration (RDII) allowances and wet weather flow projections used for current model development in association with the City of Boulder (city) 2016 WWCSMP. This section also discusses the estimated levels of service associated with these RDII allowances.

This section discusses the following:

- Updates to the level of service equation using the city's 75th Street WWTF influent flow meter and available rain gauge data from 2009 to 2015
- Identifies the level of service for 50 and 60 mgd flow scenarios as well as the estimated flow rate associated with 25-yr level of service
- Compares resulting peaking factors with other regional agencies/municipalities' peaking equations or actual peaking factor values (MWRD, DRCOG, Westminster, etc.)

4.1 Wet Weather Analysis

Wet weather flows are comprised of RDII. Wet weather infiltration is the additional infiltration that occurs due to rainfall-induced higher groundwater conditions and is typically seen in the hours or days following significant rain events. Inflow is rainfall related water that enters a collection system from sources such as private laterals, downspouts, manhole defects, foundation piping, and cross-connections with storm drains. RDII is directly influenced by the intensity and duration of a storm event as well as antecedent soil moisture conditions and is therefore a variable quantity.

RDII, coupled with BI, is an important aspect when analyzing system capacity because wet weather flow in the city can be significantly greater than the BSF. During storm events, and for a period afterwards, flows within the collection system rise in response to the rainfall. The peak RDII flow component is combined with ADWFs to define the total peak wastewater flow that must be conveyed by the wastewater collection system and treated at the WWTF.

This peak wet weather flow condition is a worst-case scenario in evaluating a collection system, especially when locating capacity restrictions and potentials for sanitary sewer overflows (SSOs). However, due to unavailable instantaneous flow data at flow monitors and the WWTF influent meter, PHWWF is often used during planning and modeling efforts like this one. Instantaneous flow is also highly variable and makes it very difficult to model. Local storage in manholes and pipes helps address short-term instantaneous flows in a collection system; however wet-weather responses in a system over a longer duration from one hour to one day can be indicative of a better system-wide response and systemic capacity deficiencies. Steady state PHWWF modeling was used to represent the average flow over the peak hour and associated response in the system to RDII.

4.1.1 Wastewater Treatment Facility Capacity

The existing peak capacity at the WWTF is 50 mgd due to hydraulic limitations at the headworks and pumping capacity from the primary to secondary treatment processes. The secondary and downstream treatment processes can treat up to 60 mgd. The modeling effort investigated three peak wet weather flow scenarios; with the 50 mgd treatment capacity being used for the minimum wet weather flow scenario because the sewer system will need to deliver at least that quantity to take advantage of the WWTF's existing peak capacity. The difference between the existing condition dry weather calibrated model flow (14.9 mgd) and the 50 mgd wastewater flow target was made up with a system-wide RDII increase distributed across the flow meter basins. The resulting 35.1 mgd RDII allowance translates to a wet weather peaking factor of 3.4. The secondary treatment process hydraulic capacity of 60 mgd was used as another peak wet weather flow scenario. The resulting 45.1 mgd RDII allowance translates to a wet weather peaking factor of 4.0. The third wet weather flows scenario was not based on any existing WWTF capacities but rather the peak flows resulting from a 25-year storm.

4.1.2 Level of Service

The collection system's level of service is defined by the level of wet weather event that the system can sustain without causing sanitary sewer overflows or backups into buildings. The collection system's level of service is therefore directly related to the excess capacity in the collection system which is available to convey RDII flows. The level of service can therefore be represented by the rainfall recurrence interval that results in the maximum conveyable RDII.

A rainfall recurrence interval is the likelihood of a given rainfall event occurring based on both the event's depth and duration. Rainfall recurrence intervals are used for risk analysis and are defined as the inverse of the probability that a certain magnitude of rainfall event (defined by both depth and duration) will be exceeded in any one year. For example, a 25-year rainfall event has a 0.04 (1/25) or 4 percent chance of being exceeded in any one year while a 100-year rainfall event has a 0.01 (1/100) or 1% chance of being exceeded in any one year.

4.1.2.1 RDII Response to Rainfall Events and Associated Level of Service

Flows in the city's wastewater collection system increase as a result of significant precipitation events (i.e., 2-year storms and greater). Similar rainfall events may not result in similar responses in the collection system though due to a number of factors including:

- Antecedent soil moisture conditions prior to the rainfall event (saturated versus dry).
- Sanitary loadings at the time of the event.
- Rainfall intensity and how long the intensity is sustained.
- Height of groundwater table above or below collection system prior to rainfall event.

For the 2009 Master Plan, HDR evaluated 20 years of precipitation data to identify storm events that had a measurable RDII impact on collection system flows. Large rainfall events were identified and a corresponding rainfall recurrence interval was estimated using the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service's (NWS) rainfall Atlas 2 (1973). Given data limitations, RDII was estimated for a rainfall event by taking the peak total daily flow for the month in which the rainfall event occurred and subtracting the lowest total daily flow for the month. The estimated recurrence intervals of several rainfall events were then plotted against the associated RDII and a linear relationship was developed.

Since the 2009 Master Plan, more detailed WWTF influent flow and rainfall data has become available. In addition, NOAA released Atlas 14 Volume 8 (2013) which supersedes NOAA rainfall Atlas 2 (1973) used in the previous analysis.

Recorded precipitation data from several rainfall gauges within the city were compared with RDII flow increases at the WWTF influent flow meter to develop a new correlation between precipitation and the total peak wet weather flow. For this effort, RDII was determined by taking the approximate ADWF prior to the start of increased WWTF influent flows and subtracting it from the 15-minute maximum WWTF influent flow. The total rainfall duration and associated depth were extracted from all the available gauges. Atlas 14 was then used to estimate the corresponding rainfall recurrence interval for the extracted rainfall depths and durations. Rainfall recurrence intervals for each event were determined via the following:

- For rainfall durations that fall between those reported in Atlas 14, linear interpolation was used estimate rainfall depths between the reported durations.
- Exponential relationships between rainfall recurrence intervals and rainfall depths were developed for each rainfall duration.
- To determine the rainfall recurrence for an event, the exponential rainfall recurrence/rainfall depth relationship associated with rainfall duration was used.
- The calculated rainfall recurrence interval was back checked against the Atlas 14 source data for validation.

According to city staff, longer duration rainfall events for storm periods in excess of 24-hours were identified to have the most influence on RDII. Therefore, only events longer than 12 hours and greater than a 1-year calculated recurrence interval were retained in the analysis. Due to the different analysis approach and better data sources, only the data from 2010 until present (2015) was applied to this RDII response and level of service evaluation. For dates in which there was rainfall data from more than one gauge, the gauge that produced the greatest rainfall recurrence interval versus RDII correlation was retained. Table 4-1 presents the results of this analysis, with the shortest duration rainfall event being 24 hours and longest being 550 hours (23-day). The lowest rainfall recurrence interval being used is a 1-year event and the highest is a 15.9-year event. Note that the September 2013 event was not used for analysis due to unreliable flow data.

Table 4-1. WWTF Peak Flow Response to Various Rainfall Events

Date	Estimated Rainfall Data			Estimated WWTF Response		
	Total Rainfall Depth (in)	*Total Rainfall Duration (hr)*	*Estimated Rainfall Recurrence Interval*	*Approx. ADWF at First Date of WWTF Response (mgd)*	*WWTF Peak Flow (mgd)*	*Calculated RDII (mgd)*
May 9, 2015	6.64	550	15.9	15.00	51.24	36.24
April 17, 2015	2.32	24	3.1	15.00	35.61	20.61
July 30, 2014	2.68	29	4.9	16.00	35.31	19.31
May 11, 2014	1.88	35	1.4	17.00	26.92	9.92
September 15, 2013[1]	15-16	140	500 to 1,000	14.00	>51.69[1]	>37.69
April 1, 2013	1.5	24	1.0	16.50	24.14	7.64
June 7, 2012	2.2	45	1.8	13.4	20.87	7.47
July 9, 2011	1.84	54	1.4	16.00	24.52	8.52
May 18, 2011	3.28	194	2.6	12.80	31.52	18.72
June 13, 2010	2.3	53	2.0	17.00	29.41	12.41
April 21, 2010	3.2	53	5.6	16.00	35.01	19.01

[1]The WWTF influent flow meter reached capacity above 50 mgd. Most likely the WWTF influent flow was greater than indicated in the table. As a result, this date was not used for the rainfall recurrence versus RDII correlation.

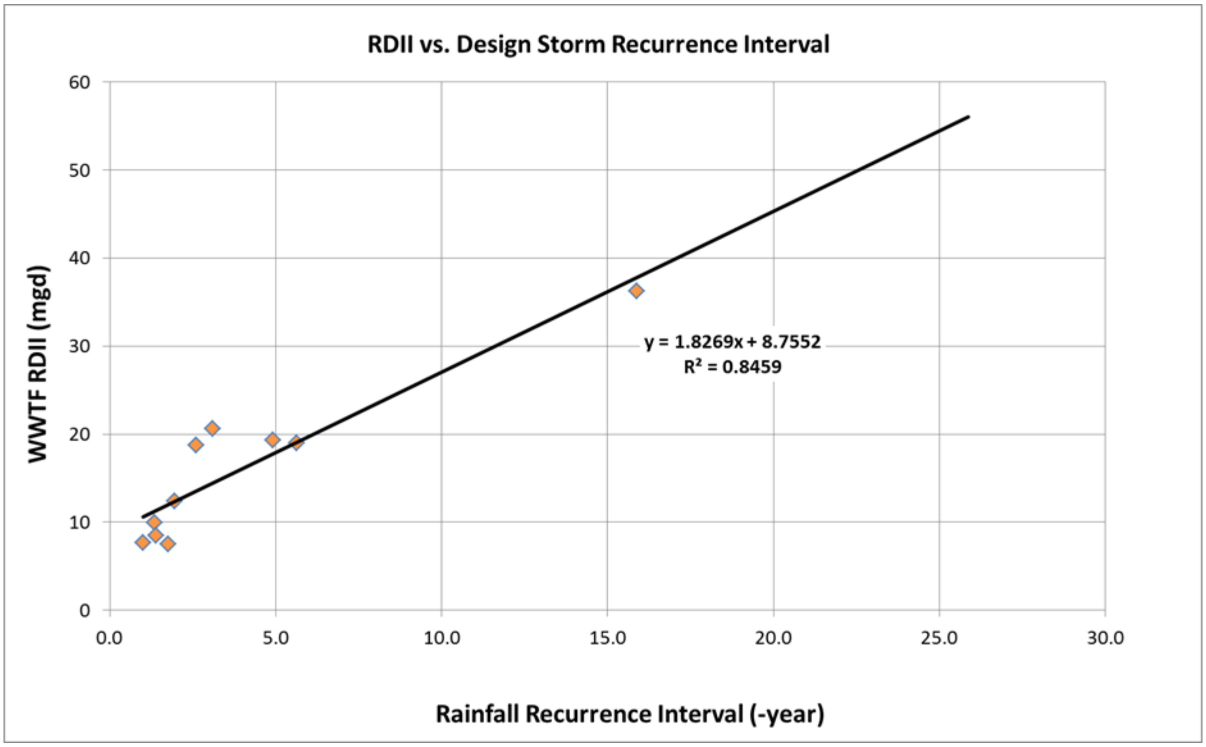
The estimated rainfall recurrence interval versus the calculated RDII of Table 4-1 is plotted in Figure 4-1. The linear relationship between rainfall recurrence interval and the corresponding RDII at the WWTF is defined by Equation 1.

Equation 1

$$y = 1.8269x + 8.7552$$

Where x equals the probability of the event expressed as recurrence interval in years and y equals the estimated wet weather flow increase (RDII allowance in mgd) at the WWTF. The coefficient of determination (R^2) of Equation 1 is 0.85 and indicates that it is well suited for the 2016 WWCSMP.

Figure 4-1. Rainfall Recurrence Interval versus Peak RDII for the WWTF



This relationship analysis is limited based on the 50 mgd capacity of the WWTF influent flow meter. The extreme reoccurrence interval events such as the September, 2013, event had to be removed from this analysis as the actual influent flow in the collection system was likely quite higher than the 52 mgd measured at the WWTF. To better estimate the rainfall reoccurrence interval related to a certain RDII, a permanent flow monitor or flume should be installed at the WWTF influent that has a capacity up to 80 mgd. If possible, two meters separated with a wet-weather flow weir is a favorable arrangement to accurately measure lower flows as well as capture larger RDII flows during significant storm events.

4.1.2.1 Uncertainties

There are several uncertainties related to the development of the RDII versus rainfall recurrence interval. They are acknowledged and discussed below.

1. **Confidence level of Atlas 14 data.** The rainfall depths for the various durations and rainfall recurrence intervals, as presented in Atlas 14, come with their own uncertainties. To assess these uncertainties, each rainfall depth is accompanied by 90 percent confidence intervals. As recurrence intervals or rainfall durations increase, the range between the confidence intervals also increases due to the events being less frequent and therefore not having as many data points from which to generate the statistics. As an example, the 25-year recurrence interval has a range between the 90 percent confidence intervals of over an inch of precipitation. The present analysis extracted the average precipitation estimates at the 50 percent confidence interval.
2. **Reliability of rain gauge data.** Rain gauges provide information on rainfall depths in a specific location and do not reflect rainfall across the entire city for a particular event. Rain gauges can also be influenced by wind as well as turbulence and eddy currents near the

gauge. Rain gauge maintenance and rain gauge location in relation to a specific storm event can also be an issue. Radar data validated to ground rain gauge data is likely the most accurate representation of rainfall but is intensive to process and provides limited implementation into steady state modeling.

3. **Nature of the rainfall event.** Rainfall events can have periods of varying intensity at different locations or have several different peaks, depending upon the duration of the storm. How rain falls on a watershed can greatly influence the runoff and groundwater response of that watershed and have a subsequent influence on the RDII response.
4. **Rainfall events being independent of other events.** A recurrence interval associated with a rainfall event needs to be related only to that rainfall event. Subsequent events are not represented in a rainfall recurrence interval.
5. **Antecedent soil moisture conditions and base infiltration.** Similar to having a specific rainfall event independent of other rainfalls event, the antecedent soil moisture conditions such as ground saturation, groundwater levels, and time of year can influence basin infiltration and residual RDII on the sanitary collection system's response to a rainfall event.
6. **Reliability of the WWTF influent meter.** Although considered reliable, there is inherent error associated with flow measurements, especially open channel flow meters. The WWTF influent flow meter also has a maximum capacity of around 50 mgd which limits the ability to capture flow from storm events above a 14 to 15-year reoccurrence.

These uncertainties were minimized by using the following methods:

1. **Using more than one rain gauge.** As stated above, rainfall data was extracted from all available rain gauges and compared in the analysis.
2. **Consistent extraction of data.** By extracting rainfall and WWTF flow data based on the time of first influence at the WWTF, influence of antecedent soil moisture conditions was accounted for in reasonable fashion. RDII is based on the ADWF specific to the time period prior to the rainfall event and not over a monthly average or low flow. What constitutes the duration of a rainfall event was also made consistent by having it dependent upon WWTF flow. Many rainfall events used in the analysis occurred over several days and could contain several hours of no rainfall. This created many multi-day rainfall events that correspond with RDII response at the WWTF.
3. **Extracting all data with the same method.** Only recent data was used for analysis to ensure consistency of extraction and interpretation.
4. **Removing the influence of short duration storms or limited rainfall.** Since the WWTF response is greatest during long duration storms, all storms less than a 24-hour duration or a 1-year calculated recurrence interval were removed from the analysis. As a result, the shortest duration storm used for analysis is a 24-hour duration and 1-year recurrence interval type event.

4.1.3 50 MGD and 60 MGD Capacity Levels of Service

With the modeled ADWF of 14.9 mgd and a collection system capacity of 50 mgd, the associated system wide RDII that should be handled in the system is 35.1 mgd. This flow scenario equates to the collection system being able to convey flows associated with approximately a 15-year (14.4-year calculated) design storm event.

For the 60 mgd flow scenario the RDII increases to 45.1 mgd, which equates approximately to a 20-year (19.9 calculated) design storm event.

4.1.4 25-yr Rainfall Event Capacity

Using the RDII / rainfall recurrence equation (Equation 1), the RDII at the WWTF for a 25-year event was calculated to be 54.4 mgd. Adding the modeled ADWF of 14.9 mgd, the total 25-year level of service peak hour wet weather flow at the WWTF is therefore 69.3 mgd.

4.1.5 Peaking Factor Comparison

Based on an ADWF of 14.9 mgd, the peaking factor (ratio of peak hour wet-weather flow to average daily flow) for the 25-year event was calculated to be 4.7. For the 2035 buildout scenarios, a buildout peaking factor of 4.0 was calculated based on the higher ADWF of 18.1.

For reference and general validation, these peaking factors were compared with other methods and standards for calculating peaking factors.

Colorado Department of Public Health and Environment (CDPHE) Policy 96-1, Design Criteria Considered in the Review of Wastewater Treatment Facilities recommends a peaking factor not be less than 4 for laterals and sub-main sewers and not less than 2.5 for main, trunk, and outfall sewers. Neither the existing nor buildout peaking factor for the outfall sewer at Boulder's WWTF are less than 2.5.

The Metcalf & Eddy book "Wastewater Engineering: Treatment and Reuse", page 151, provides an hourly peaking factor curve based on an average flow rate. The City of Boulder's existing peaking factor based on this curve would be approximately 2.5. The buildout peaking based on this curve would be approximately 2.4.

Based on Metro Wastewater Reclamation District's (MWRD)'s equation, the calculated existing and buildout peaking factors would be 2.60 and 2.54, respectively. Based on DRCOG's equation, the calculated existing and buildout peaking factors would be 2.32 and 2.25, respectively.

Table 4-2 compares the city's calculated peaking factors against various industry and regional peaking factor determination methods. Based on this comparison, a peaking factor of 4.65 for existing conditions and 4.01 for the buildout scenarios are greater than the range of other peaking factor determination methods.

It should be noted that the 25 year level of service is a goal which the current collection system cannot yet achieve and therefore should not be compared directly to minimum design requirements which would be expected to be lower than this goal. The city is striving to provide a higher level of service for the local, collector and interceptor system based on the impacts resulting from the historic 2013 flood and the 25-year level of service reflects this.

Table 4-2. WUSA Peaking Factor Comparison

Model Flow Scenario	City Model (50 mgd)	City Model (60 mgd)	City Model (25-year[1])	CDPHE	Metcalf & Eddy	MWRD	DRCOG
Existing ADWF Peaking Factor	3.36	4.03	4.65	> 2.5	2.5	2.60	2.32
Buildout ADWF Peaking Factor	2.94	3.49	4.01	> 2.5	2.4	2.54	2.25

[1] The 25-year level of service equates to 69.4 mgd and 72.5 mgd at the WWTF influent, respectively.

Peaking factor comparisons were also made to other neighboring Colorado utilities including Westminster, Evans, and Northglenn. The source of the peaking factors was from their latest collection system master plans. In contrast to the city, these peaking factors are not tied to levels of services but were based on observed peak flows at the respective WWTFs from previous years. Table 4-3 summarizes the peaking factor comparison between the city and other similar-sized utilities in the same vicinity. The city's peaking factor is somewhat greater than for these other utilities. This difference can be attributable to Boulder's older sewer system which contains a significant portion of clay sewers and Boulder's hydrology which may include more creeks, irrigation ditches, and swamps that cause elevated groundwater tables.

Table 4-3. Neighboring Communities Basin and Design Peaking Factor Comparison

Model Flow Scenario	City Model (50 mgd)	City Model (60 mgd)	City Model (25-year)[1]	Westminster	Evans[2]	Northglenn
Existing WWTF Peaking Factor	3.36	4.03	4.65	3.11	2.67	2.80
Buildout WWTF Peaking Factor	2.94	3.49	4.01	2.93	2.85[2]	3.00[2]
Peaking Factor Based on Design Equations for 1 mgd	3.50[3]	3.50[3]	3.50[3]	3.60	4.00[4]	3.00[5]

[1] The 25-year level of service equates to 69.4 mgd and 72.5 mgd at the WWTF influent, respectively.

[2] The main Evans Wastewater Treatment Plant was used in the comparison. Their Hill-n-Park Wastewater Treatment Plant has too low of average day flows to make a proper comparison.

[3] The Evans and Northglenn buildout peaking factors were based on increasing the existing peaking factor since they were lower than desired for the purposes of master planning based on historically available basin flow data.

[4] The City design peaking factor is based on pipe size categories. 1 mgd would be in the 12 to 15 inch category which has a design peaking factor of 3.50.

[5] The Evans design peaking factor is a constant 4.00 independent of pipe size or ADWF flow.

[6] The Northglenn design peaking factor is based on the highest observed peaking factor in their system based on their current Wastewater Treatment Facility Master Plan and the Northglenn Collection System Modeling Report.

4.2 Summary

The RDII versus rainfall recurrence interval analysis and the associated levels of service presented in this section will be used as the basis for developing wet weather flows and capacity analyses going forward. Table 4-4 summarizes the calculated levels of service associated with Equation 1 as well as the calculated RDII flows at the WWTF. Some of the numbers in Table 4-4 may be adjusted slightly in subsequent modeling efforts based on the results of wet-weather modeling and calibration. The 50 mgd scenario was determined to equate to a 15-year level of service. For the 60 mgd scenario, the level of service increases to a 20-year level of service. For a 25-year level of service, the collections system would have to be able to convey 69.3 mgd.

Table 4-4. WWTF Peak Flow Response to Various Rainfall Events

Model Flow Scenario	Existing RDII (mgd)	Existing Flow (Base plus RDII) (mgd)	Existing Level of Service	Buildout RDII (mgd)	Buildout Flow (Base plus RDII) (mgd)	Buildout Level of Service
ADWF	-	14.9	-	-	18.1	-
50 mgd WWTF Capacity	35.1	50	15	35.1	53.2	15
60 mgd WWTF Capacity	45.1	60	20	45.1	63.2	20
25-Year Event	54.4	69.3	25	54.4	72.5	25

The next steps in model development and documentation in the next section are as follows:

- Develop and calibrate wet weather flows based on the permanent flow meter data.
- Perform a system wide capacity analysis based on the 25-year level of service.

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5 Wet Weather Flow Generation and Model Calibration

This section documents the process and results of the wet weather model update and calibration for the City of Boulder (city) 2016 WWCSMP. Section 3 discussed the process and results of the dry weather model update, calibration, and ADWF development and section 4 discussed the process and results of updating RDII allowances and wet weather flow projections as well as the estimated levels of service associated with those RDII allowances. This section documents updates to the RDII allocations for existing conditions wet weather model development and calibration. It also documents development of buildout wet weather projections and summarizes the modeling approach and existing and buildout flow projections used during the 2016 WWCSMP.

This section discusses the following:

- RDII allowances developed from the 2015 permanent flow monitoring data.
- Wet weather model calibration and results.
- Existing condition wet weather model results for the 15-year, 20-year, and 25-year levels of service for the collection system.
- Buildout condition wet weather model results for the 15-year, 20-year, and 25-year levels of service for the collection system.
- Spatial distribution of modeled existing and future condition ADWF and 25-year wet weather level of service.
- Summary of the modeling approach and existing and buildout flow projections.

5.1 Wet Weather Analysis

Wet weather flows are comprised of RDII in addition to the ADWF. Wet weather infiltration is the additional infiltration that occurs due to rainfall-induced higher groundwater conditions and is typically seen in the hours or days following rain events. Inflow is rainfall related water that enters a collection system from sources such as private laterals, downspouts, manhole defects, foundation piping, and cross-connections with storm drains. RDII is directly influenced by the intensity and duration of a storm event as well as antecedent soil moisture conditions and is therefore variable from storm to storm.

RDII, coupled with BI, is an important aspect when analyzing system capacity because wet weather flow in the city can be significantly greater than the BSF. During storm events, and for a period afterwards, flows within the collection system rise in response to the rainfall. The peak RDII flow component is combined with the ADWF to define the total peak wastewater flow that must be conveyed by the wastewater collection system and treated at the WWTF.

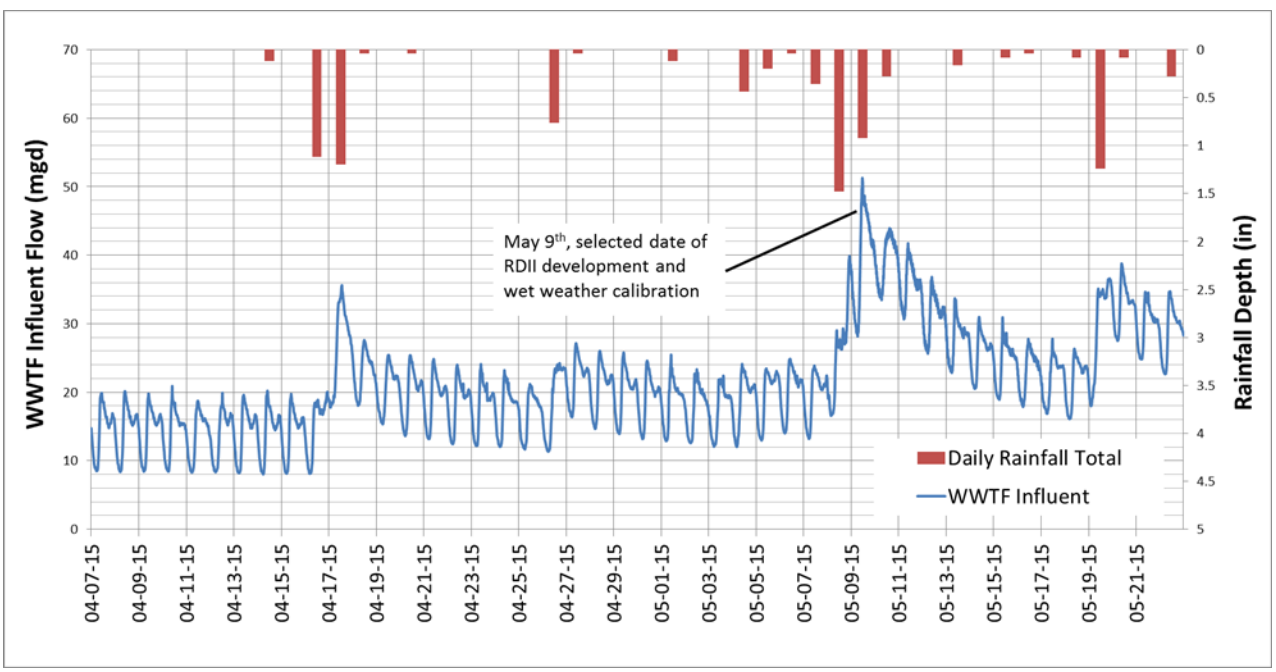
This peak wet weather flow condition is a worst-case scenario in evaluating a collection system, especially when identifying capacity restrictions and potential hot-spots for SSOs. PHWWF is often used during planning and modeling efforts like this one because instantaneous flow is highly variable and is therefore very difficult to monitor for and model. The wet-weather response of the collection system over a longer duration from one hour to one day can be indicative of an extended system-wide response and systemic capacity deficiencies. This modeling approach allows for evaluation of longer reaches of the collection system. Using longer time periods and use of PHWWF is therefore more applicable to long-term capital planning. Because of this, steady state PHWWF modeling was used to represent the average flow over the peak hour and associated response in the collection system to RDII.

5.1.1 RDII Allowances

Estimates for total RDII flow response across the system during a wet weather event were made based on a steady-state load allocation at the model manholes. As with the development of BI and ADWF estimates, the permanent flow monitors installed in April 2015 and the WWTF influent flow monitor data were used to develop the RDII allowances.

The RDII flow response is based on the sanitary sewer system's response to the wet weather event that occurred on May 9, 2015. The May 9, 2015 event caused a measured 15-minute average peak flow of 51.24 mgd at the WWTF and had a PHWWF of 50.63 mgd. The WWTF started experiencing increasing levels of RDII on April 16, 2015, 23 days before the May 9th event. It rained during 12 of the 23 days leading up to this flow event, with substantial rainfall events on April 16th (1.12 inches), 17th (1.2 inches), and 26th (0.76 inch); and May 4th (0.44 inch), 5th (0.2 inch), 7th (0.36 inch), 8th (1.48 inches), and 9th (0.92 inch). Flow at the WWTF did not return to typical ADWF conditions during this period, with the greatest flows occurring on April 16 and 17 and on May 8 and 9. The corresponding rainfall over these 23 days was measured at 6.64 inches, corresponding roughly to a 16-year rainfall recurrence interval. Radar data was used to graphically examine if the spatial extent of the rainfall events were relatively evenly distributed across the city. By modeling a storm event that covered most the city in an even fashion, a better representation of system-wide wet-weather response is provided for capacity planning purposes. Figure 5-1 provides the WWTF influent flows for the days surrounding May 9th along with the total daily rainfall depths.

Figure 5-1. WWTF Influent Flow and Daily Precipitation Depth Time Period Surrounding the May 9, 2015 Date used for RDII Development



Wet weather flows were allocated to the manholes based on the wet weather response and PHWWF for May 9, 2015, using the following method:

- Peak hour flows for the permanent flow monitors were calculated for the May 9, 2015 event by averaging the 15 minute interval meter data.
- The difference between the calibrated ADWF discussed in section 3 and the May 9 peak hour flow was determined for each permanent flow monitor to determine the RDII flow contribution from each flow monitoring basin. If there was a flow monitor basin upstream of another flow monitor basin, this upstream flow was removed to isolate flow contributions specific to each flow monitor basin.
- The sanitary system was experiencing SSOs during the May 9 event and created surcharge conditions at the Basin 7 flow monitor and overflows at the manhole immediately downstream of the meter. This resulted in unreliable measurements during the surcharge and overflow period for this meter. The interceptor leading to WWTF was also experiencing SSOs, meaning that WWTF influent flows would have been greater than what was measured. Estimated peak hour flow rates for both Basin 7 and at the WWTF were provided by the city to account for these surcharges and SSOs. The city determined these flow rates based on a flow balance from the remaining meters and trending of flow rates for the period before and after the overflow events.
- Each sewer pipe was multiplied by its corresponding diameter (inch) and length (feet) and assigned to its upstream manhole.
- The total pipe diameter (inch)-length (feet) was summed in each flow monitor basin.
- The resulting May 9, 2015 RDII was allocated to the pipes based on their individual diameter (inch)-length (feet) in proportion to the total diameter (inch)-length (feet) in each flow monitor basin.
- RDII was summed to each of the model manholes based on the RDII fraction assigned to their downstream pipes and assigned as RDII to that manhole (Load 4 column).
- For pipes and manholes not within a flow monitor basin, the remaining RDII was calculated and compared against the WWTF PHWWF minus the PHWWF of the upstream flow monitors. The remaining RDII was then allocated to these manholes based on the diameter (inch)-length (feet) of their downstream pipes.
- The model was then executed using the above RDII loadings for wet weather modeling.

The RDII allocation process described above created an evenly distributed wet-weather system response across the city for capacity planning purposes.

5.1.2 Wet Weather Calibration

Wet weather-calibration is completed to validate the RDII allowances for each flow monitoring basin. The purpose of the wet weather calibration for this project is to validate the rainfall vs. RDII relationship established in section 4 and correlate the modeled PHWWF to the observed PHWWF at both the flow monitors serving the flow monitoring basins and at the WWTF influent flow monitor.

As with the development of the wet weather RDII allocation, the May 9, 2015 event was used for the wet weather calibration. The goal of the calibration was to have a slight positive percent error and for modeled flows to be within +5% of the measured PHWWF. The wet weather events for this project were run with a steady state analysis in InfoSewer. Table 5-1 provides the resulting adjusted RDII contribution for wet-weather conditions. Table 5-2 provides the modeled PHWWF alongside the monitored PHWWF as well as the percent error.

Table 5-1. Wet Weather Calibration Steady-State Results Based on Flow Data for May 9, 2015

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	Calibrated ADWF (gpm)	Calibrated RDII (gpm)	Calibrated RDII (% of total flow)
South Boulder	Basin 1	1,106	5,850	84%
East Baseline	Basin 2	593	2,358	80%
The Hill	Basin 3	658	2,372	78%
Bear Creek	Basin 4	1,454	3,577	71%
Upper Goose Creek - North	Basin 5	905	1,945	68%
Upper Goose Creek - South	Basin 6	1,644	4,664	74%
Lower Goose Creek	Basin 7	861	313	27%
Fourmile Creek	Basin 8	1,146	2,193	66%
Gunbarrel	Basin 9	1,286	3,111	71%
N/A	WWTF Influent Meter	699	914	57%
TOTAL		**10,351**	**27,297**	**73%**

Table 5-2. Wet Weather Calibration Results for the May 9, 2015 Event

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	Monitored PHWWF (gpm)	Modeled PHWWF (gpm)[1]	Percent Error Peak Hour Flow
South Boulder	Basin 1	6,530	6,554	0.4%
East Baseline	Basin 2	2,839	2,844	0.2%
The Hill	Basin 3	2,983	2,999	0.5%
Bear Creek	Basin 4	8,203	8,460	3.1%
Upper Goose Creek - North	Basin 5	2,794	2,827	1.2%
Upper Goose Creek - South	Basin 6	6,262	6,311	0.8%
Lower Goose Creek	Basin 7	10,000[2]	10,311	3.1%
Fourmile Creek	Basin 8	3,339	3,342	0.1%
Gunbarrel	Basin 9	4,249	4,365	2.7%
N/A	WWTF Influent Meter	37,000[3]	37,645	1.7%

[1] These flows are not additive. Basin 3 is upstream of Basin 4 and Basins 5 and 6 are upstream of Basin 7. All basins are upstream of the WWTF influent flow monitor.

[2] Flow monitor was surcharging at the time of calibration and a SSO was occurring in nearby manholes. The city provided this peak flow estimate obtained from projecting the pre and post surcharge hydrograph slopes to a point of convergence.

[3] Flow was lost via SSOs before reaching the WWTF influent monitor. The city provided this peak flow estimate based WWTF monitor data and on flow from permanent flow monitors 1, 2, 4, 9, and a corrected monitor 7 as well as 5,218 gpm of flow from the unmetered areas (with the assumption that this 5,218 gpm flow remains constant during the surcharge period)

The rainfall event used for wet weather calibration for the current modeling effort was 6.64 inches of rain in 23 days and is roughly equivalent to a 16-year rainfall recurrence interval based on NOAA Atlas 14. Based on flows at the WWTF influent monitor, the calculated RDII for this event is 39.3 mgd (27,297 gpm), which was calculated by subtracting the ADWF of 14.9 mgd from the modeled peak flow of 54.2 mgd (37,645 gpm, Table 5-2). Using Equation 1 from section 4, which relates RDII flow rates to rainfall recurrence intervals, the 39.3 mgd RDII was estimated to have been caused by a 17-year storm (16.7 calculated). This correlation between actual recurrence interval and the calculated interval validates the rainfall vs. RDII relationship established by Equation 1.

5.1.3 50 mgd and 60 mgd Capacity Assessment Scenarios

With the modeled ADWF of 14.9 mgd and the WWTF influent hydraulic limitation of approximately 50 mgd, the resulting maximum system wide RDII the influent processes at the WWTF can handle is 35.1 mgd. This 50 mgd existing conditions PHWWF scenario is comparable to the existing collection system conveying flows associated with approximately a 15-year (14.4-year calculated) storm event when this 35.1 mgd of RDII is applied to Equation 1. For the purposes of this 2016 WWCSMP, the 50 mgd model scenario is also referred to by its 15-year level of service. This 15-year level of service model was executed by scaling down the calibrated wet weather flow of 54.2 mgd (based on the May 9, 2015 event) to reach 50 mgd at the WWTF.

When a 60 mgd WWTF hydraulic limitation is considered (based on post-primary treatment process limitations), the RDII increases to 45.1 mgd (60 mgd minus 14.9 mgd). The resulting existing condition PHWWF conveyed by the collection system were calculated to be the result of a 20-year (19.9 calculated) design storm wet weather event using Equation 1. For the purposes of this document the 60 mgd model scenario is also referred to by its 20-year level of service. The 20-year level of service scenario was developed and executed by scaling up the calibrated wet weather flow of 54.2 mgd to reach 60 mgd at the WWTF.

5.1.4 25-year Rainfall Event Capacity Assessment Scenario

Using Equation 1, the RDII for a 25-year event was estimated to be 54.4 mgd. Adding this RDII to the ADWF results in an existing condition PHWWF of 69.3 mgd. The 25-year model was developed and executed by scaling up the calibrated wet weather flow of 54.2 mgd to reach 69.3 mgd at the WWTF.

5.1.5 Buildout Conditions Modeling

Buildout conditions modeling is performed by allocating an additional future BSF load to the model as described in section 3. BI and RDII are kept consistent with the existing conditions model scenarios, meaning that future flow increases are based solely on BSF increases and the potential reduction in RDII due to current and planned sewer rehabilitation efforts is not included at this time. This was done since the potential reduction has been shown to vary greatly between utilities and it is therefore difficult to quantify the reductions. Any reductions which are realized will therefore serve to further increase the level of service of the collections system beyond what this modeling effort and master plan are planning for. The buildout condition flow increases at the WWTF are summarized in Table 5-3.

Table 5-3. PHWWF at the WWTF Influent for Existing and Buildout Condition Scenario Modeling

Model Condition	ADWF (mgd)	PHWWF 15-Year Level of Service (mgd)	PHWWF 20-Year Level of Service (mgd)	PHWWF 25-Year Level of Service (mgd)
Calibrated and Refined Existing Conditions	14.9	50.0	60.0	69.3
Buildout Conditions	18.1	53.2	63.2	72.5

5.1.6 Comparison to 2009 Wastewater Collection System Master Plan

This section compares the updated wet weather model results to those presented in the 2009 WWCSMP. Both the model results and corresponding level of service are compared.

5.1.6.1 Wet Weather Model Comparison to 2009 Master Plan

The 2009 WWCSMP included a 50 mgd WWTF capacity limiting scenario as the basis for wet weather modeling. Hence, to compare current results to the 2009 WWCSMP, the existing conditions PHWWF from the 15-year level of service scenario is used. Table 5-4 summarizes the results of this comparison. The existing and future ADWFs at the WWTF have decreased by about 5.8 mgd and

7.7 mgd, respectively, since the 2009 WWCSMP. Some of the reasons for this difference in ADWF can be attributed to slower than predicted population and employment growth, water conservation (including installation of water efficient fixtures), better monitoring data with the newly installed permanent flow meters, and more refined flow monitoring data at the WWTF. The existing PHWWF is the same due to the 50 mgd at the WWTF influent being held constant and the buildout PHWWF has decreased by about 2.1 mgd since the 2009 WWCSMP due to the reduction in ADWF and a refined future BSF projection based on the 2011 Water Utility Master Plan (2011 updated buildout base sanitary flow projections from the WUMP).

Table 5-4. Model Flow comparisons at the WWTF between the 2009 WWCSMP and the 2016 WWCSMP

Model	Existing ADWF(mgd)	Existing PHWWF (mgd)[1]	Buildout ADWF(mgd)	Buildout PHWWF (mgd)[1]
2009 WWCSMP	20.7	50.0	25.8	55.3
2016 WWCSMP	14.9	50.0	18.1	53.2

[1] For the 50 mgd at the WWTF/15-year level of service scenario

5.1.6.1 Level of Service

The 2009 WWCSMP estimated that the 50 mgd scenario was equivalent to a 12-year level of service. For the current 50 mgd scenario, this level of service is estimated at a 15-year level of service due to the decreased ADWF as well as the updated rainfall recurrence interval/RDII relationship (Equation 1) that is based on more current flow and rainfall data.

5.2 Spatial Distribution of Planning Projections

This section compares the model results for ADWF and 25-year PHWWF for existing and 2035 buildout conditions within each flow monitor basin.

5.2.1 Dry Weather

Table 5-5 and Table 5-6 summarize BSF and BI for existing and buildout conditions within each flow monitor basin. The existing and buildout BI values in Table 5-6 are the same and assumed to be consistent between all model scenarios. Figure 5-2 provides the existing conditions ADWF contributions for each flow monitor basin. Similarly, Figure 5-3 provides the buildout conditions ADWF contributions for each flow monitor basin. A comparison of these two figures illustrates that the greatest increases in the WUMP winter water use and therefore the sanitary loadings occur in Basins 6 (44 percent increase), 3 (28 percent increase), and 5 (21 percent increase) which are located in the Goose Creek and Boulder Creek sewer basins. These locations correspond to the Central Boulder, Colorado University and Cross-Roads sub-communities of Boulder and are projected to have the greatest future demands within the WUMP water distribution model. These increases in future water demand as reflected in the WUMP water distribution model are mapped on a sub-community basis in Figure 5-4 with flows presented as gpm increase per square mile.

Table 5-7 provides the corresponding model results for total BSF, BI and ADWF using the flows provided in Table 5-5 and Table 5-6. The ADWF increases 3.2 mgd from existing to buildout conditions.

Table 5-5. Existing and Buildout Sanitary Loads

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	Existing (2015) Sanitary Loads (gpm)	Additional Buildout (2035) Sanitary Loads (gpm)	Total Buildout (2035) Sanitary Loads (gpm)
South Boulder	Basin 1	455	98	553
East Baseline	Basin 2	256	87	343
The Hill	Basin 3	602	182	784
Bear Creek	Basin 4	1,106	267	1,373
Upper Goose Creek - North	Basin 5	439	193	632
Upper Goose Creek - South	Basin 6	1,463	728	2,191
Lower Goose Creek	Basin 7	411	164	576
Fourmile Creek	Basin 8	461	205	666
Gunbarrel	Basin 9	642	189	831
N/A	WWTF Influent Meter	323	95	418
TOTAL		**6,158**	**2,209**	**8,367**

Table 5-6. Existing and Buildout Base Infiltration Loads at the Flow Allocation Basins

Permanent Flow Monitor Basin	Alternate Permanent Flow Monitor Basin Name	2015 Summer BI (gpm)	2035 Summer BI (gpm)
South Boulder	Basin 1	652	652
East Baseline	Basin 2	337	337
The Hill	Basin 3	56	56
Bear Creek	Basin 4	348	348
Upper Goose Creek - North	Basin 5	466	466
Upper Goose Creek - South	Basin 6	181	181
Lower Goose Creek	Basin 7	449	449
Fourmile Creek	Basin 8	684	684
Gunbarrel	Basin 9	644	644
N/A	WWTF Influent Meter	376	376
TOTAL		**4,194**	**4,194**

Figure 5-2. Existing Conditions ADWF Contributions for Each Flow Monitor Basin

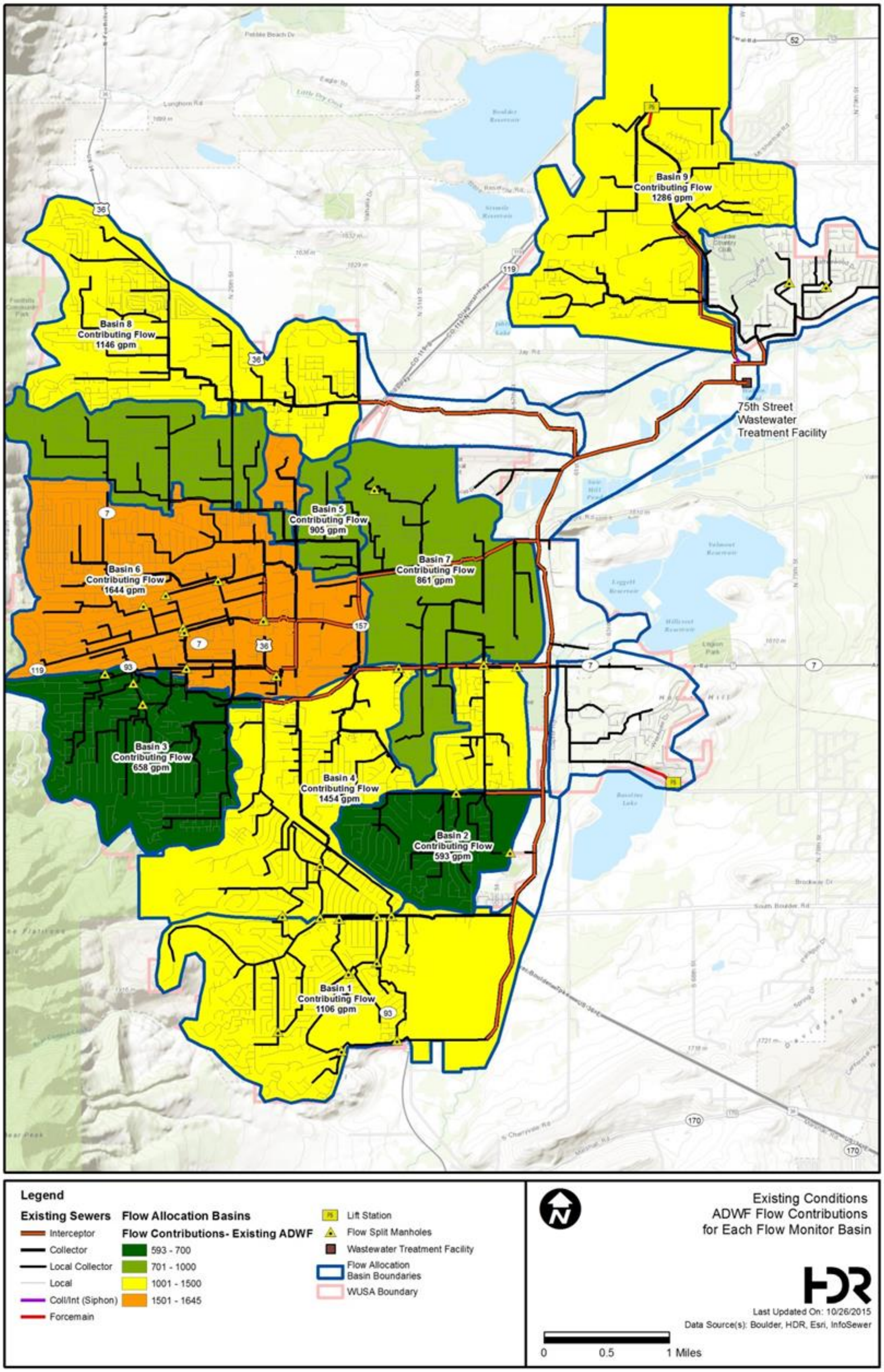


Figure 5-3. Buildout (2035) Conditions ADWF Contributions for Each Flow Monitor Basin

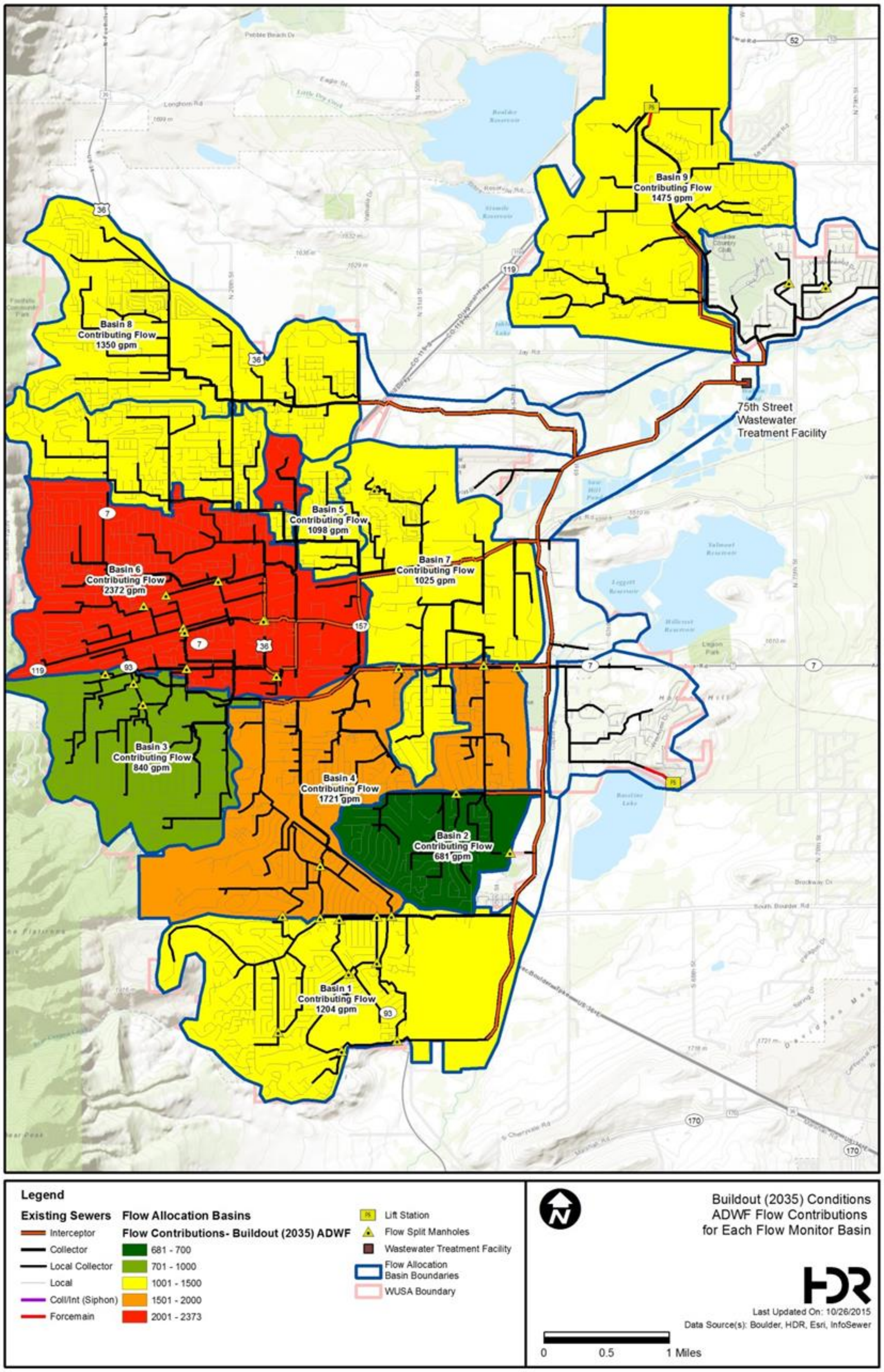


Figure 5-4. Buildout (2035) Winter Water Demand Increases in Each City of Boulder Sub-Community (Increase in GPM per Square Mile)

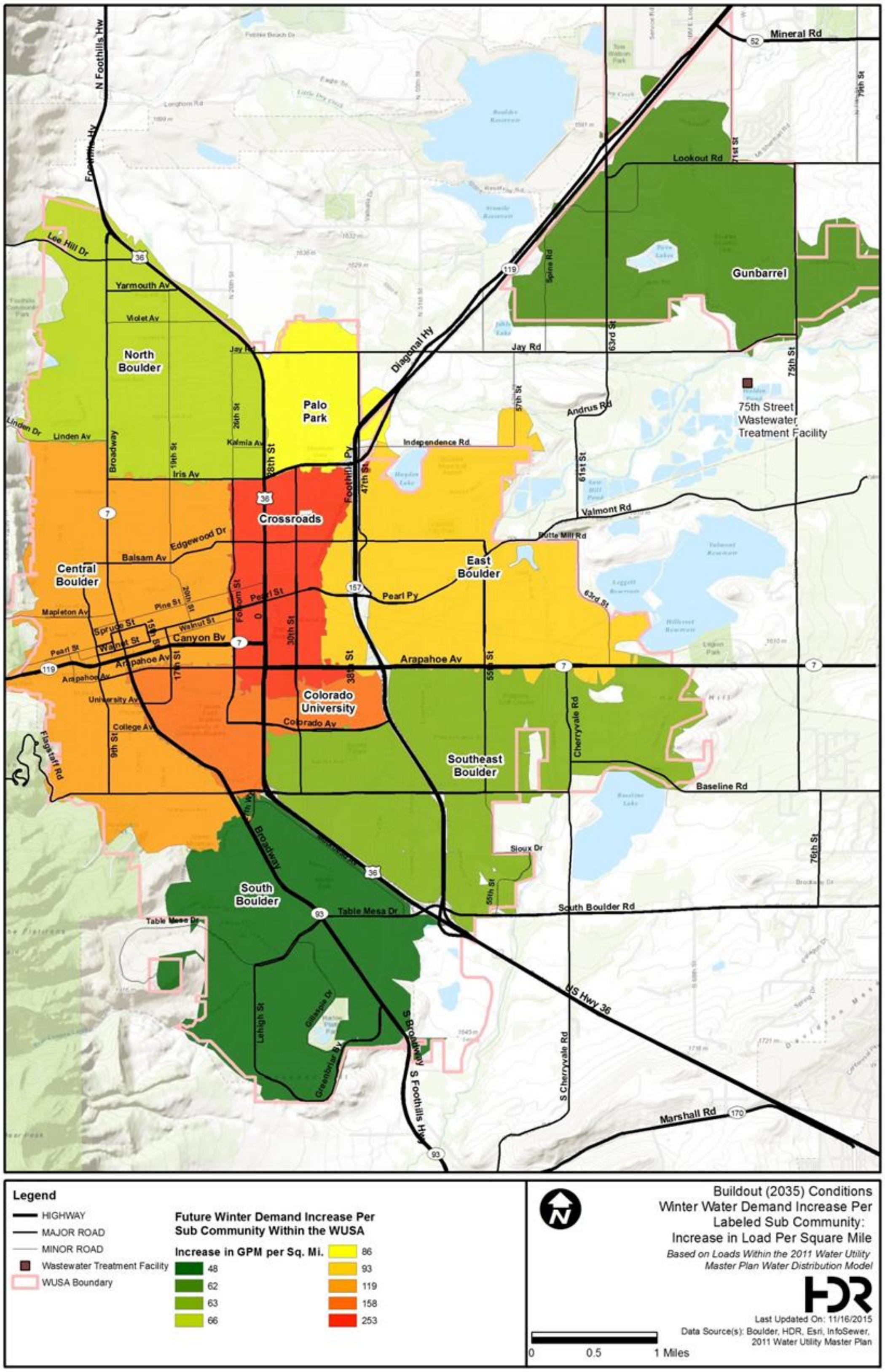


Table 5-7. Existing and Buildout Dry Weather Flows

Model Flow Scenario	Existing (2015) Flow (mgd)	Buildout (2035)
Base Sanitary Flow (BSF)	8.9	12.1
Base Infiltration (BI)	6.0	6.0
Annual Average Dry Weather Flow (ADWF)	14.9	18.1

5.2.2 Wet Weather

Figure 5-5 provides the existing conditions 25-year PHWWF contributions for each flow monitor basin. Similarly, Figure 5-6 provides the buildout conditions 25-year wet weather flow contributions for each flow monitor basin. Since the RDII values remain the same between the two, the general patterns of PHWWF are consistent between existing and buildout conditions.

Table 5-8 summarizes the RDII and PHWWF for existing and buildout conditions.

Table 5-8. Existing and Buildout Wet-Weather Flows

Model Flow Scenario	Existing (2015) RDII (mgd)	Existing (2015) Total Wet Weather Flow (mgd)	Buildout (2035) RDII (mgd)	Buildout (2035) Total Wet Weather Flow (mgd)
Annual Average Dry Weather Flow (ADWF)	-	14.9	-	18.1
15-Year Level of Service	35.1	50.0	35.1	53.1
20-Year Level of Service	45.1	60.0	45.1	63.2
25-Year Level of Service	54.4	69.3	54.4	72.5

Figure 5-5. Existing Conditions 25-Year PHWWF Contributions for Each Flow Allocation Basin

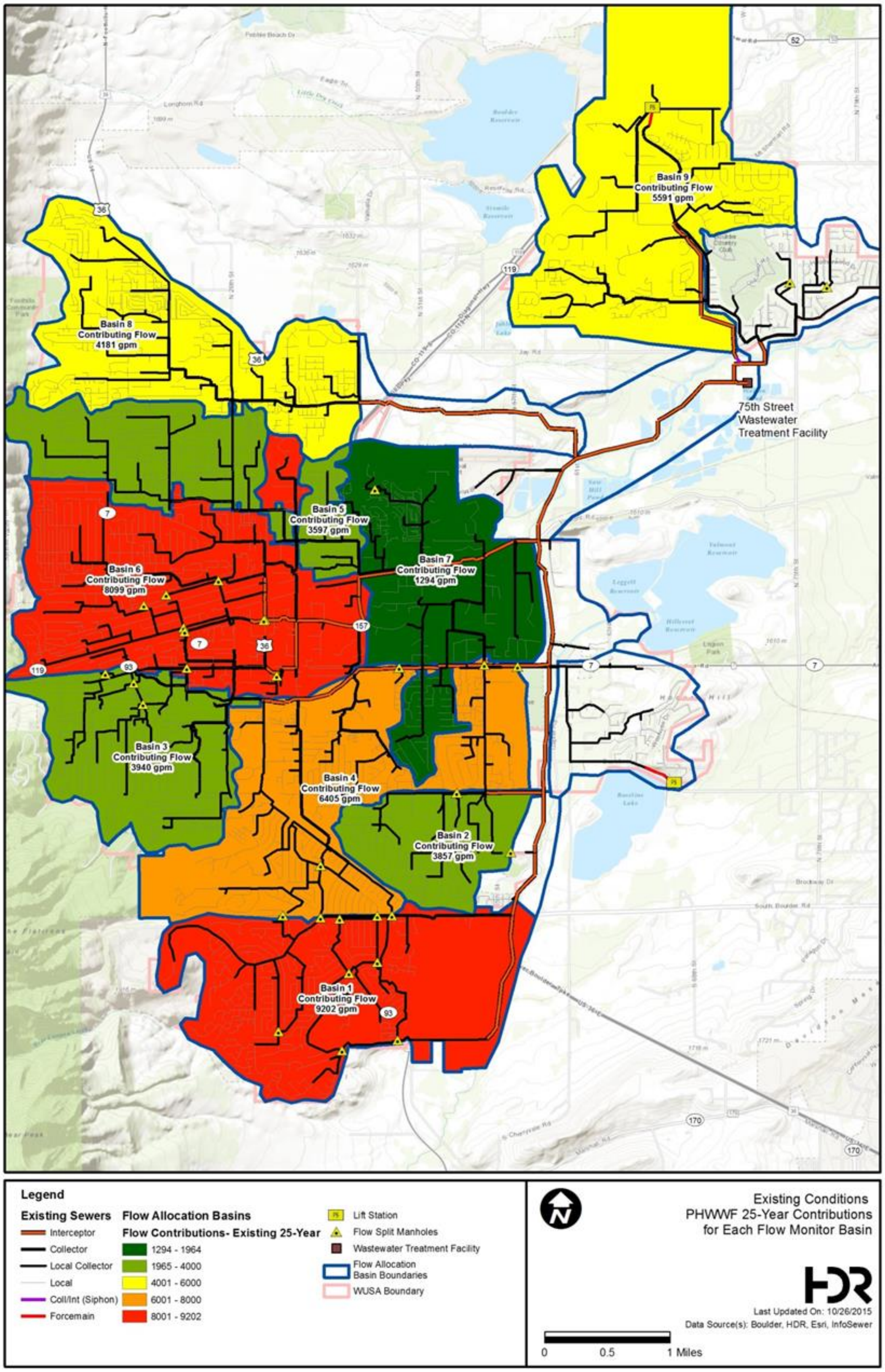
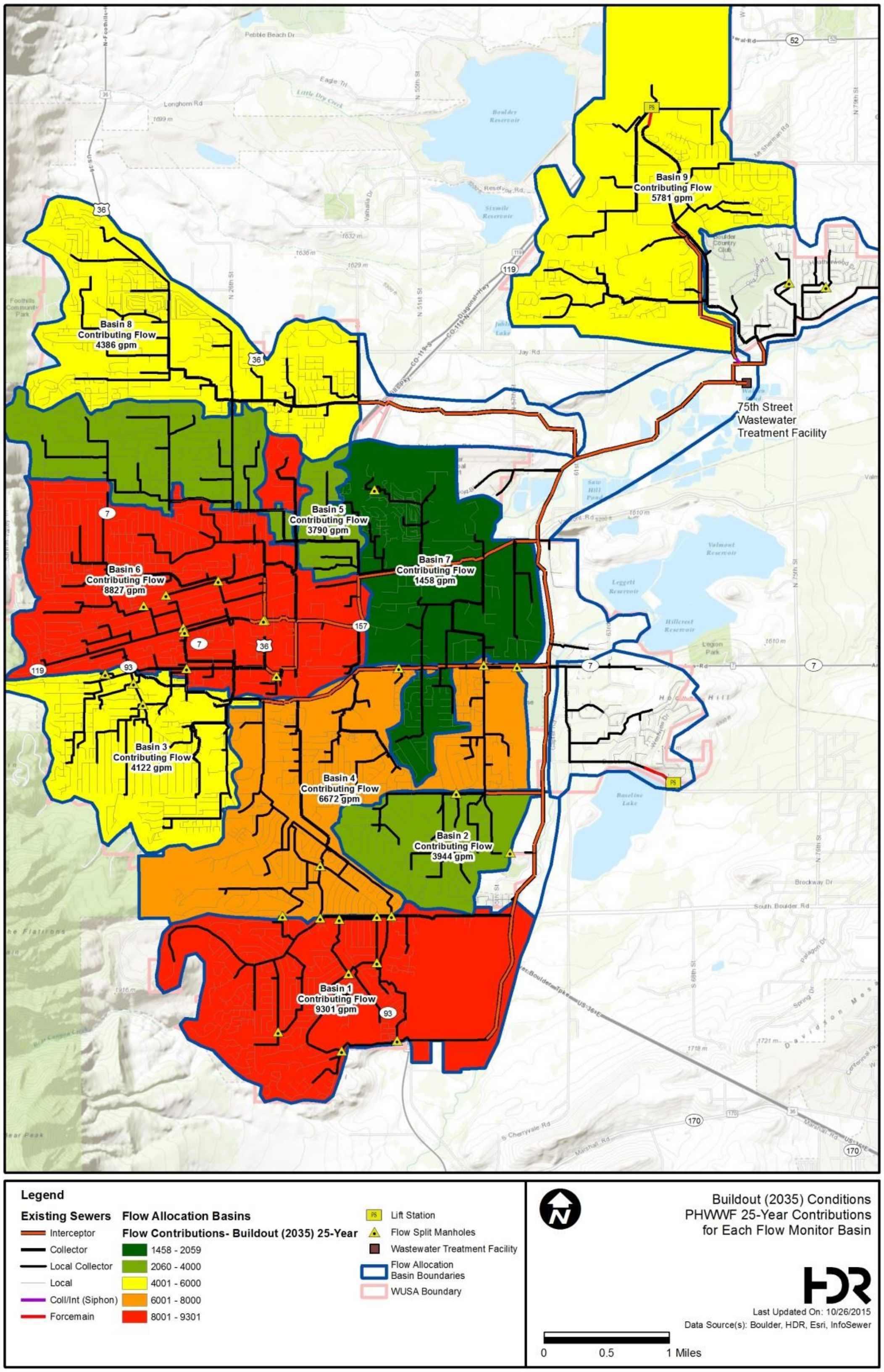


Figure 5-6. Buildout (2035) Conditions 25-Year PHWWF Contributions for Each Flow Allocation Basin



5.3 Summary

Since the 2009 WWCSMP, there is several more years' worth of available data to assess wet weather flows and update the hydraulic model. Two key new data sets used in this analysis include data from the city's new permanent flow monitoring program and more detailed data related to flow split manholes. As a result, several changes were made to the modeling approach to incorporate this data and provide more confidence in the model results and subsequent capacity analysis.

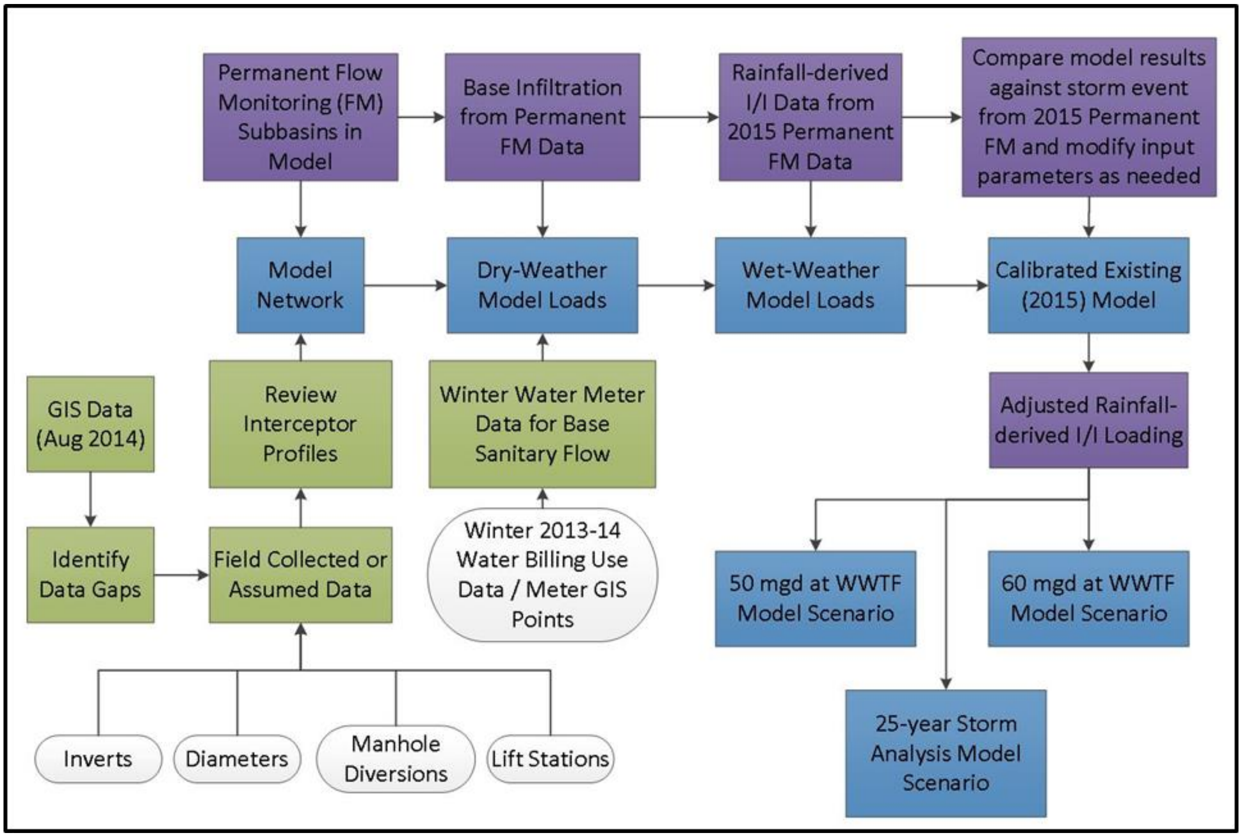
5.3.1 Modeling Approach

The following list summarizes the modeling approach used for this effort:

- The model network was updated using recent collection system GIS data and additional information on flow split manholes.
- Sewersheds were altered based on the flow monitoring basins in the 2014 Flow Monitoring Program. Model nodes and pipes were assigned a corresponding flow monitoring basin from the permanent flow monitors.
- BSF was generated both from water meter and SIU data. BSF was calculated from monthly water meter data from December, 2013 through February, 2014 and allocated to the model nodes using Thiessen polygons aligned to the sewersheds and flow monitoring basins.
- BI rates were calculated for each flow monitor basin based on the dry day of August 26, 2015. BI was calculated by subtracting the BSF estimated from the water meter data from the average day flow for the corresponding permanent flow monitors. BI was then assigned to the manholes based on the diameter and length of the downstream pipe.
- ADWF was calibrated in a steady state analysis based on the August 26, 2015 average daily flow to the 2015 permanent flow monitors and the WWTF influent monitor.
- Wet weather flows were generated for each flow monitor basin from the 2015 permanent flow monitors and WWTF influent monitor based on the May 9, 2015 rainfall event. RDII was calculated by subtracting the calibrated ADWF from the measured PHWWF for the permanent flow monitors. RDII was assigned to the manholes based on their corresponding flow monitoring basin and on the diameter and length of the downstream pipe.
- The PHWWFs were calibrated in a steady state analysis to the May 9, 2015 event to reflect the peak flows in the steady-state analysis to the 2015 permanent flow monitors and the WWTF influent monitor.
- The rainfall data/WWTF influent flows since the previous master plan were incorporated into the RDII equations to determine a new RDII/rainfall reoccurrence interval relationship (Equation 1). The calibrated flows were determined to correspond to a rainfall recurrence interval of 17-years based on this equation, which correlates well to the actual 16-year rainfall recurrence interval determined strictly from the precipitation data using NOAA Atlas 14.
- The 15-year, 20-year, and 25-year level of service scenarios were then developed based on Equation 1 and the calibrated wet weather model.

The existing conditions model update and calibration approach used during this project can be summarized by the schematic presented as Figure 5-7.

Figure 5-7. Existing Conditions (2015) Modeling Approach Schematic

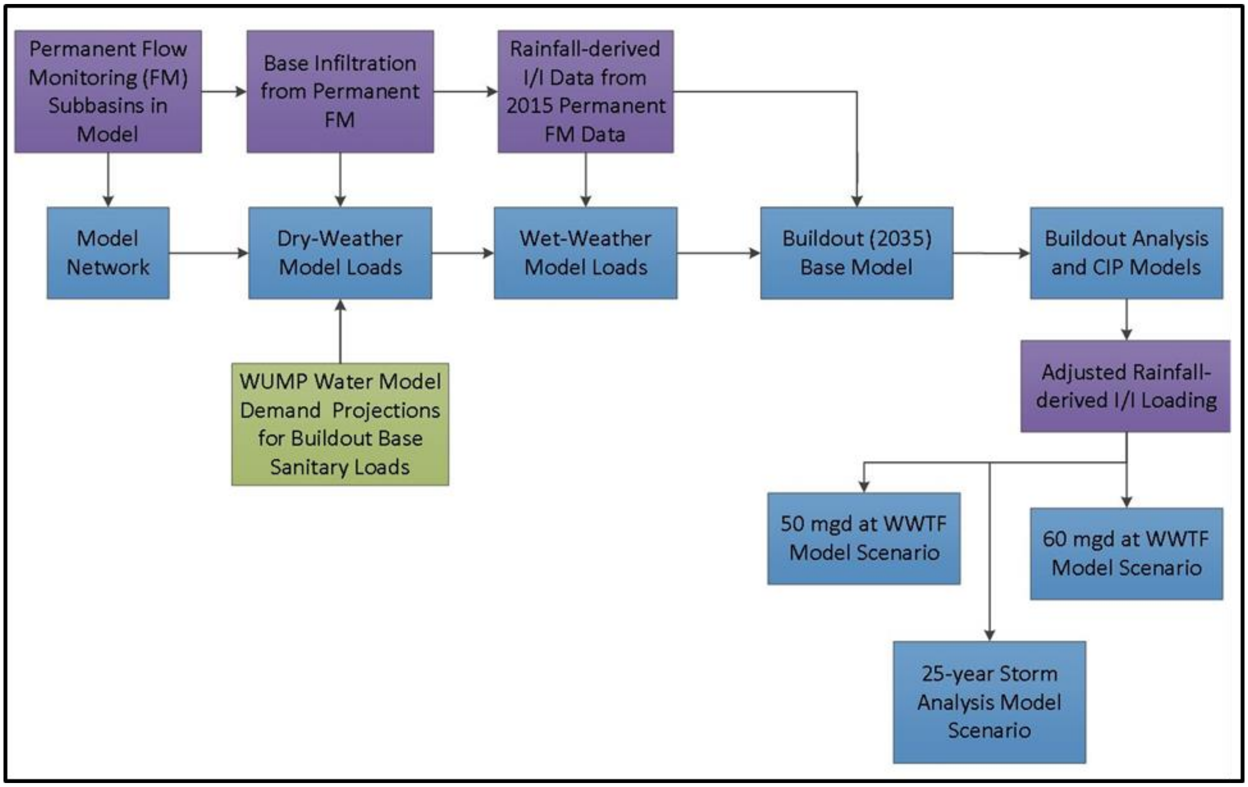


Future buildout (2035) flows were also estimated with a different approach since the previous master plan. The following list summarizes the 2035 conditions modeling approach used for this effort:

- 2035 BSF was developed based on the 2011 WUMP water use projections from the associated water distribution model and modified to reflect winter water use. The resulting BSF was applied to the sanitary sewer model manholes by using the 2011 WUMP water model Thiessen polygons in conjunction with the sewer Thiessen polygons developed in this effort.
- The same BI and RDII flow from the existing conditions modeling was applied to the future conditions modeling for the buildout 50 mgd, 60 mgd, and 25-year event model scenarios.

The buildout (2035) conditions model update and calibration approach used during this project can be summarized by the schematic presented as Figure 5-8.

Figure 5-8. Future Buildout (2035) Conditions Modeling Approach Schematic



5.3.2 Existing Flow Summary

Table 5-9 summarizes the existing (2015) condition model results for collection system capacity analysis.

Table 5-9. Modeled (Steady-State) Flows for Existing (2015) Conditions

Existing Model Flow Scenario	Flow (gpm)	Flow (mgd)	Peaking Factor[1]	Level of Service
Base Sanitary Flow (BSF)	6,158	8.9	-	-
Base Infiltration (BI)	4,193	6.0	-	-
Average Dry-Weather Sanitary Flow (ADWF)	10,352	14.9	-	-
15-Year Level of Service Peak Hour Wet Weather Flow (PHWWF)	34,725	50.0	3.4	15-year
20-Year Level of Service PHWWF	41,685	60.0	4.0	20-year
25-Year Level of Service PHWWF	48,126	69.3	4.6	25-year

[1] Peaking factor calculated based on ADWF

For comparison, recent influent flow data for the city's 75th Street WWTF was analyzed to determine maximum influent flows over the last five years. According to the data, the maximum average daily influent to the WWTF occurred on September 13, 2013 at 51.7 mgd during the 2013 flood event; however, the peak flows within the collection system were much higher than what could be recorded at the WWTF influent meter. To model what the flows in the collection system may have been for such high-flow events, the 20- and 25-year level of service PHWWF scenarios push the entire interceptor system to convey higher flows that can be analyzed during planning efforts.

5.3.3 Buildout Flow Projections

Table 5-10 summarizes the buildout (2035) condition model results for collection system capacity analysis.

Table 5-10. Modeled (Steady-State) Flows for Buildout (2035) Conditions

Buildout Model Flow Scenario	Flow (gpm)	Flow (mgd)	Peaking Factor[1]
Additional Buildout BSF	2,209	3.2	-
Total BSF	8,367	12.1	-
Base Infiltration (BI)	4,193	9.8	-
Average Dry-Weather Sanitary Flow (ADWF)	12,560	18.1	-
15-Year Level of Service PHWWF Scenario (50 mgd at the WWTF)	36,933	53.2	2.9
20-Year Level of Service PHWWF Scenario (60 mgd at the WWTF)	43,897	63.2	3.5
25-Year Level of Service PHWWF Scenario	50,335	72.5	4.0

[1] Peaking factor calculated based on ADWF

5.3.4 Summary

The wet-weather model update, calibration, verification, and refinement described in this section yield a hydraulic model that fulfills the requirement of the 2016 WWCSMP and provides a higher degree of confidence for capacity evaluation of they city's collectors and interceptors than the 2009 WWCSMP. This model can therefore be used for system capacity analysis and sanitary sewer capital improvement planning purposes.

6 Collection System Capacity Analysis and Capacity Limitations Identification

This section documents the collection system capacity analysis in association with the City of Boulder (city) 2016 WWCSMP. The analysis is developed from the updated planning level model described section 5. The basis of this analysis are the buildout conditions flow projections for BSF, the calibrated BI allowances, and the RDII allowances associated with the 15-, 20-, and 25-year levels of service.

6.1 Collection System Capacity Analysis

The purposes of the conveyance system analysis are to:

1. Document the analysis of the existing collection system with existing wet weather flows compared to the 2013 flood survey results.
2. Document the analysis of the existing collection system with buildout wet weather flows with RDII associated with the 15-, 20-, and 25-year levels of service.
3. Identify and characterize hydraulic capacity issues based on buildout wet weather flows with RDII associated with the 15-, 20-, and 25-year levels of service.

Capacity-limited areas were identified by analyzing the existing collection system under buildout flow conditions against the established system analysis criteria. Characterizing the capacity- limited areas assists in developing and prioritizing improvement alternatives and recommendations. For the capacity analysis, there are three model scenarios, all of which are under buildout conditions, which will be used to evaluate the capacity of the system.

1. Buildout conditions wet-weather with RDII associated with the 15-year level of service
2. Buildout conditions wet-weather with RDII associated with the 20-year level of service.
3. Buildout conditions wet-weather with RDII associated with the 25-year level of service.

6.1.1 System Analysis Criteria

The calibrated collection system model was used for the hydraulic analysis to locate capacity- limited areas during wet weather scenarios under existing and buildout conditions. The modeling approach for the WUSA uses data from all the pipes and manholes that exist in the city's collection system to develop an "all pipes" model. The benefits of an all-pipes model include increased accuracy in allocating wastewater flows to the sewer system, improved flow routing and attenuation from upper reaches of system, and simplifying the task of adding to and updating the model in the future from GIS.

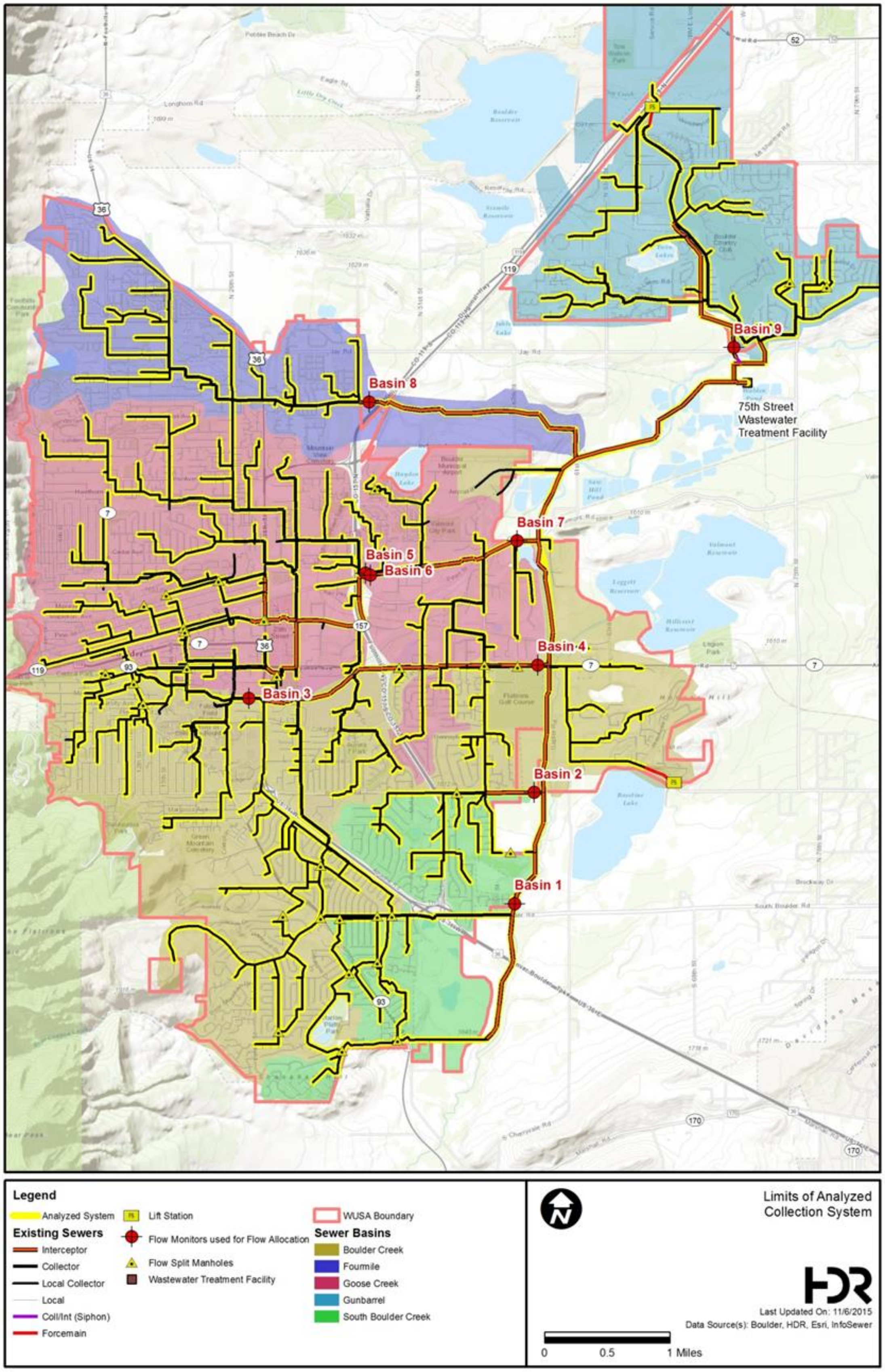
Although the entire system is modeled, some of the system will not be analyzed as part of the 2016 WWCSMP. Due to the trend of less accurate or missing invert and diameter data for the local 8-inch pipes, this portion of the collection system will not be analyzed in the evaluation phase of the project. The missing information for these smaller, local pipes could cause inaccurate or misleading results and therefore misidentify capacity- limited areas. As redevelopment occurs within the local system, missing data can be collected and the accuracy of the local system model can be increased. The scope of this project was to analyze the local collector, collector and interceptor systems for hydraulic capacity. The limits of the analyzed system are shown on Figure 6-1.

To accomplish the analysis, project capacity criteria were developed based on discussions with city staff and the city's Design and Construction Standards (DCS). Capacity limitation identification criteria are based on the percentage of full-flow within pipes and surcharge conditions at manholes.

The criteria remain the same for existing and future buildout scenarios but differ between peak dry weather and peak wet weather flow scenarios and pipe class. The capacity limitation identification criteria is based on the pipe class (interceptor/collector, local collector/local), the modeled depth divided by the full flow depth (d/D), and sanitary sewer overflows (SSOs). The capacity limitation identification criteria established for the 2016 WWCSMP consist of the following:

1. Local Collector / Local System (8-inch – 24-inch)
   a. Sanitary sewer overflows (SSO) prohibited.
   b. Peak-hour ADWF - flow equal to a depth of one-half of the full pipe (50 percent d/D).
   c. Peak-hour wet weather - flow equal to a depth of 60 percent of the full pipe (60 percent d/D).
2. Interceptor / Collector System (> 24-inch) System
   a. Sanitary sewer overflows (SSO) prohibited.
   b. Peak-hour dry weather - flow equal to a depth of 70 percent of the full pipe (70 percent d/D).
   c. Peak-hour wet weather - flow equal to a depth of 80 percent of the full pipe (80 percent d/D).

Figure 6-1. Limits of Analyzed Collection System



The interceptor system has a greater peak-hour dry weather criterion since flow depths within the corresponding larger pipes are not as impacted by equal flow increases compared to the smaller pipes in the collector system.

Compared to local and local collector system pipes, interceptors typically have less variable flow depth versus pipe diameter (d/D) values during normal dry weather and smaller wet weather conditions. For sewer mains (not interceptors), the design criteria set forth in the DCS, Section 6 - Wastewater Design, Paragraph 6.06 (A) (2) are the same as presented above for peak-hour flow, although the DCS does not differentiate between dry and wet weather conditions.

6.1.2 Model Results

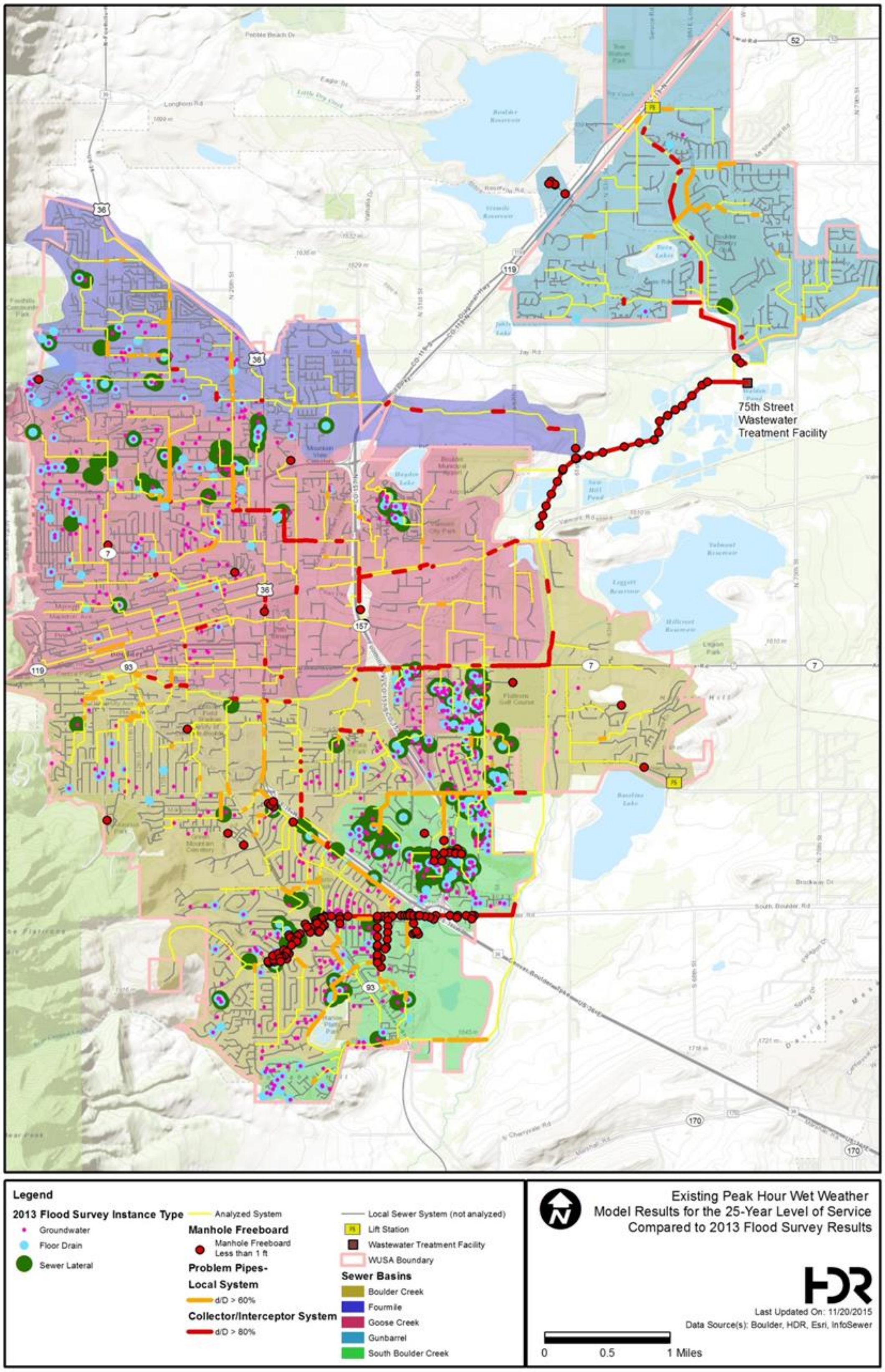
Model results were compared against the analysis criteria to locate potential hydraulic limitations within the system. The model results were recorded for PHWWF for each individual analyzed pipe to capture the worst-case loading scenario throughout the system. These model results represent the greatest stress placed on the collection pipes for each scenario. Manhole freeboard depth was taken from the model results to locate possible SSO risk.

6.1.2.1 Comparison to 2013 Flood Capacity Problems

Existing condition 25-year model results were overlaid with the 2013 flood capacity problems. This overlay is provided in Figure 6-2, which shows the locations of the reported instances of groundwater seepage, floor drain backups, and sewer lateral backups in comparison to the capacity issues indicated by the existing condition 25-year level of service model. The city's post-flood survey asked residents that reported damage to FEMA to identify whether the source of the flooding originated from surface flooding, groundwater seepage through foundations, sewer lateral backups, floor drain backups, or a combination of the above. It should be noted that although the survey distinguished between sewer lateral backups and floor drain backups, the city's building codes require floor drains to be plumbed to the sanitary sewer. This means that floor drain backups should also be considered a sewer lateral backup and the difference between these two survey responses can be interpreted as the severity of the surcharge which caused the backup. A low-level surcharge may cause a backup from floor drains but may not be severe enough to reach the level of higher plumbing fixtures such as toilets or sinks which would cause a resident to clearly identify it as a sewer backup. Residents that do not have bathrooms in their basements would only experience sanitary sewer backups through the basement floor drains.

Figure 6-2 indicates that there are similar locations where the reported flood instances appear in areas with collection system capacity issues. The data from the 2013 post-flood survey will be used to help prioritize capital improvement projects in the 2016 WWCSMP.

Figure 6-2. 25-Year Existing Peak Hour Wet Weather Results for the 25-Year Level of Service Compared to 2013 Flood Survey Results



6.1.3 Buildout Condition Model Results

A summary of peak-hour flows at the 75th Street WWTF are shown in Table 6-1 for each of the four buildout scenarios.

Table 6-1. Modeled WWTF Influent Flows for Buildout Conditions

Buildout Model Flow Scenario	Flow (gpm)	Flow (mgd)	Peaking Factor[1]
Average Dry-Weather Sanitary Flow (ADWF)	12,560	18.1	-
15-Year Level of Service PHWWF Scenario	36,933	53.2	2.9
20-Year Level of Service PHWWF Scenario	43,897	63.2	3.5
25-Year Level of Service PHWWF Scenario	50,335	72.5	4.0

[1] Peaking factor calculated based on ADWF

The model results for buildout wet weather scenarios are depicted in Figure 6-3, Figure 6-4, Figure 6-5, and Figure 6-6 for flow associated with the ADWF and the 15-, 20-, and 25-year levels of service, respectively. Potential capacity-limited pipes were based on the established criteria and manholes with freeboard of less than 1 foot have also been highlighted. Manholes with freeboard of less than 1 foot are considered at-risk for SSOs.

RDII loading for the 25-year level of service was thematically mapped for each of the permanent flow monitoring basins to illustrate the RDII contributions from different areas within the collection system (Figure 6-7). The relative distribution of RDII loading is the same for all wet weather scenarios, with only the magnitude and flow percentages increasing. Only RDII for the 25-year level of service was mapped because this model scenario represents the highest wet weather flows that were analyzed. The location of greatest SSO occurrence is in Basin 1 and corresponds to the location of greatest RDII loading.

Figure 6-3. Buildout (2035) Model Results for Average Dry Weather Flow

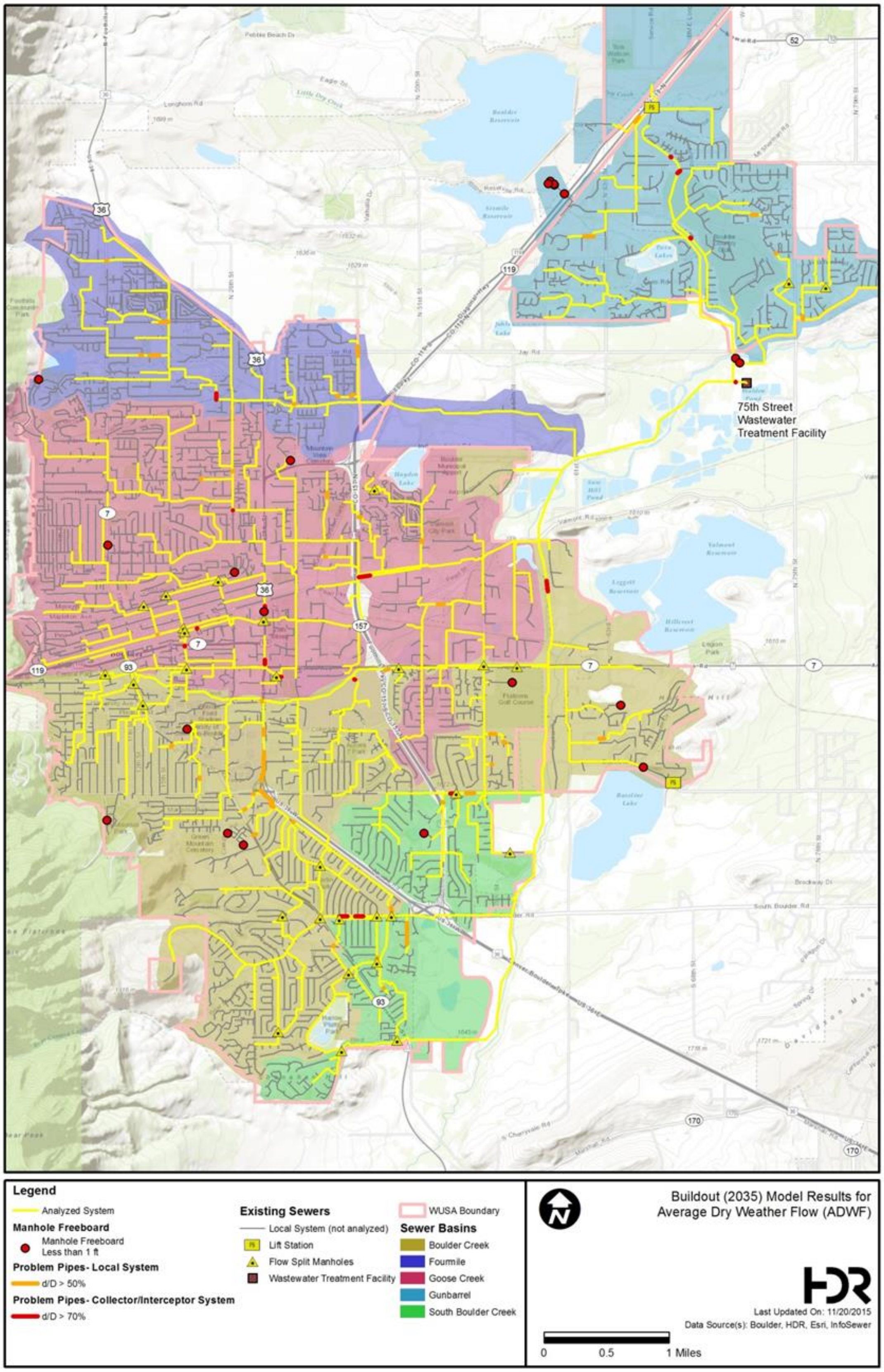


Figure 6-4. Buildout (2035) Peak Hour Wet Weather Model Results for the 15-Year Level of Service

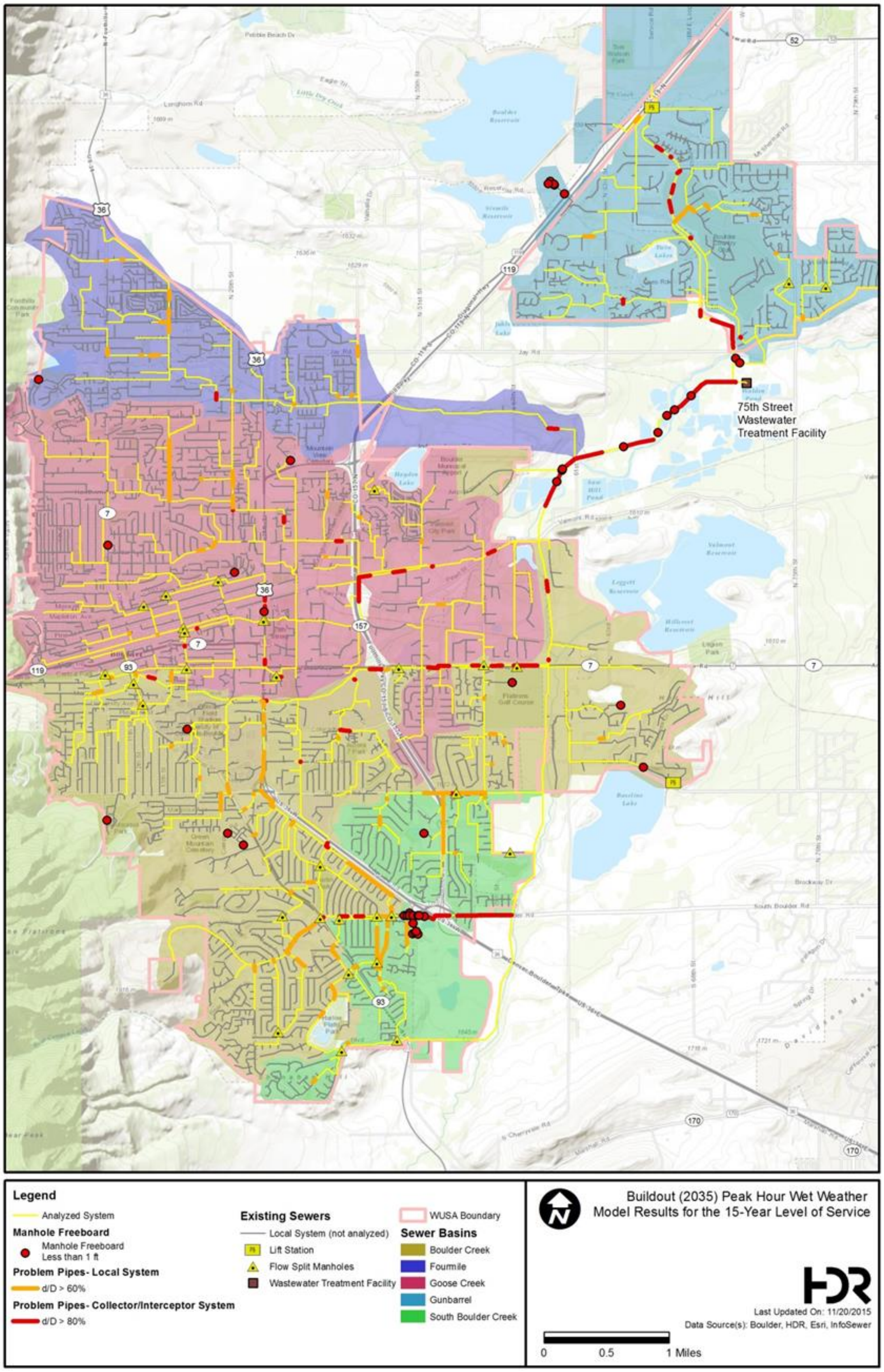


Figure 6-5. Buildout (2035) Peak Hour Wet Weather Model Results for the 20-Year Level of Service

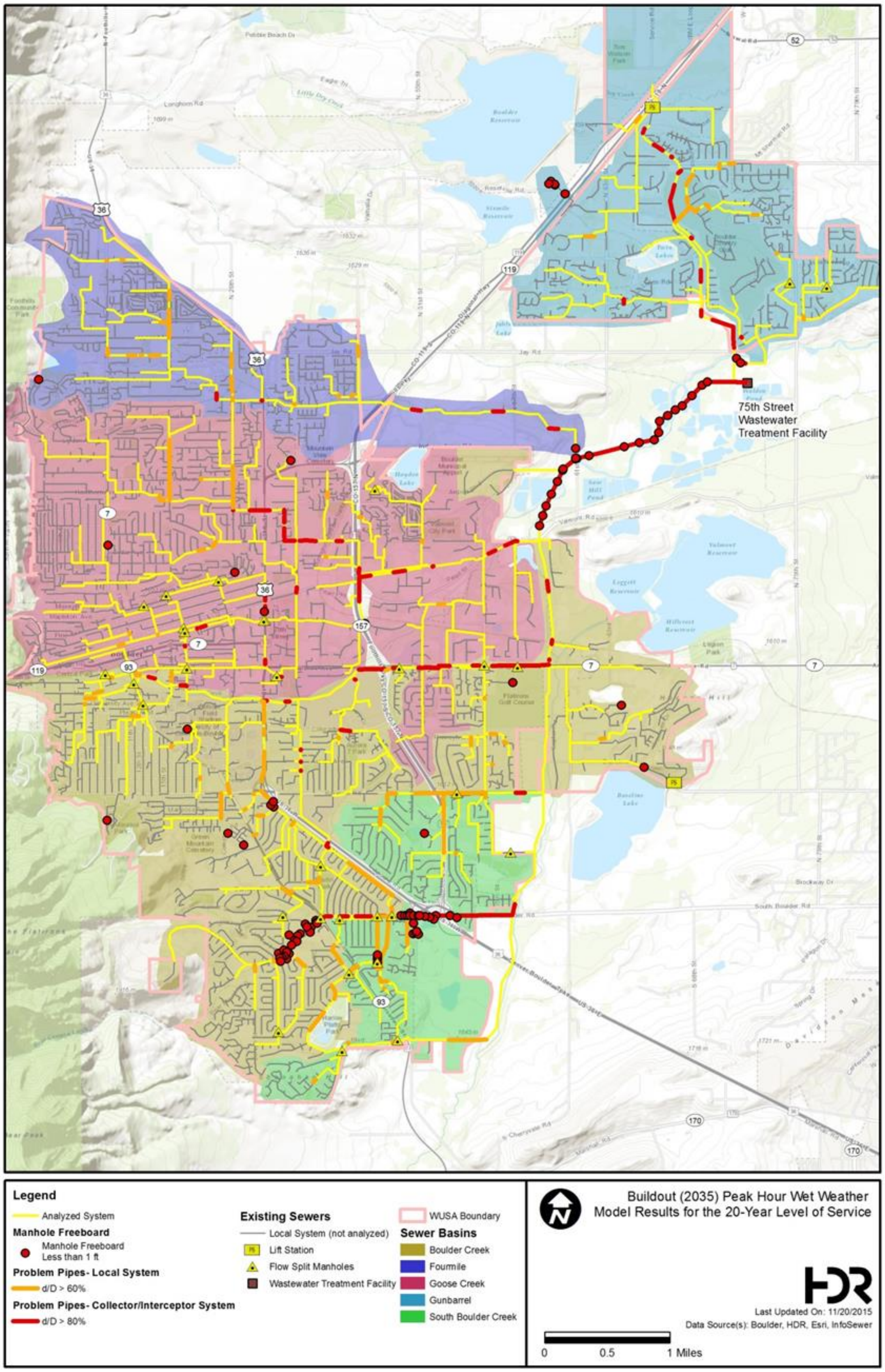


Figure 6-6. Buildout (2035) Peak Hour Wet Weather Model Results for the 25-Year Level of Service

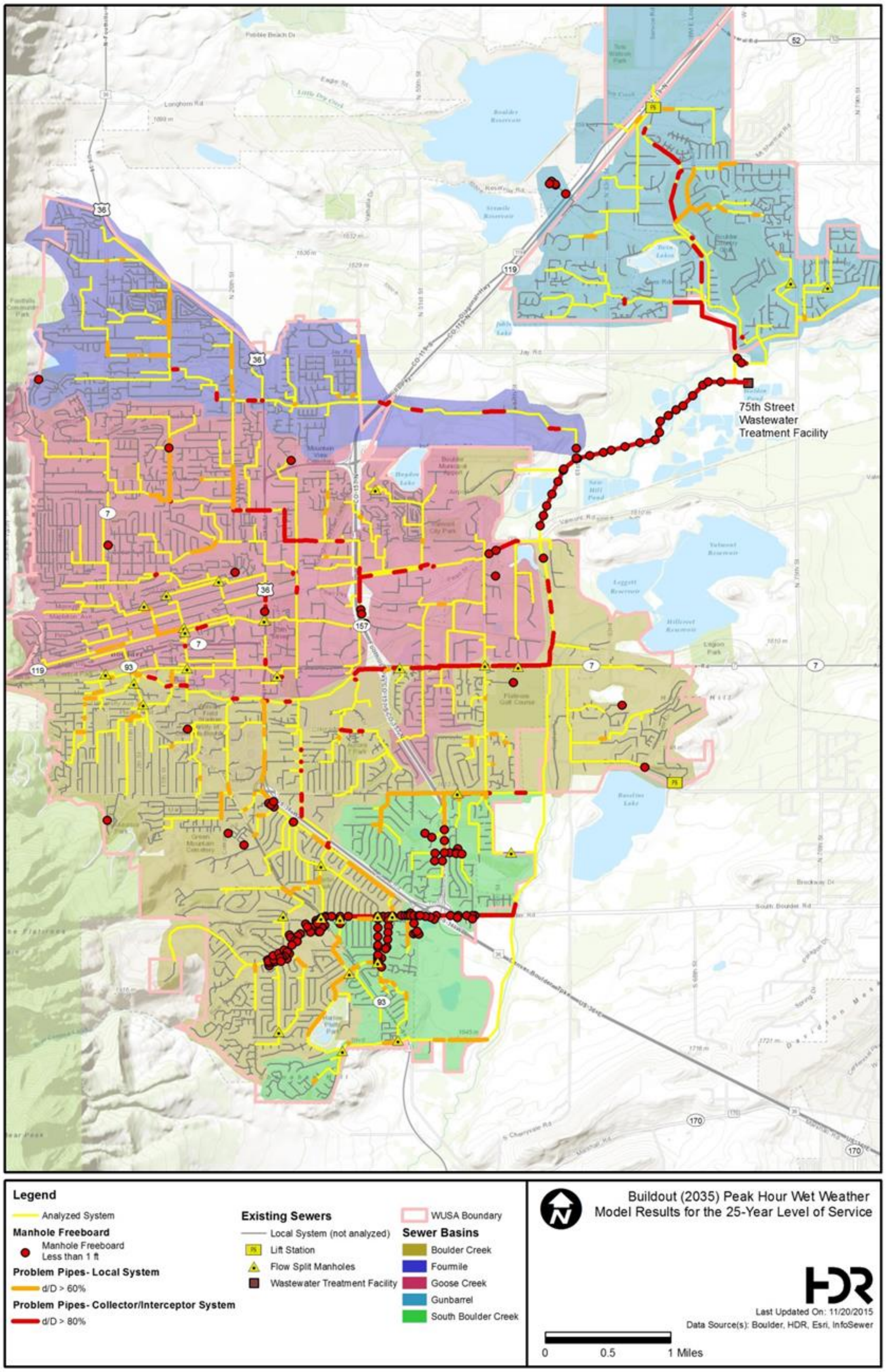
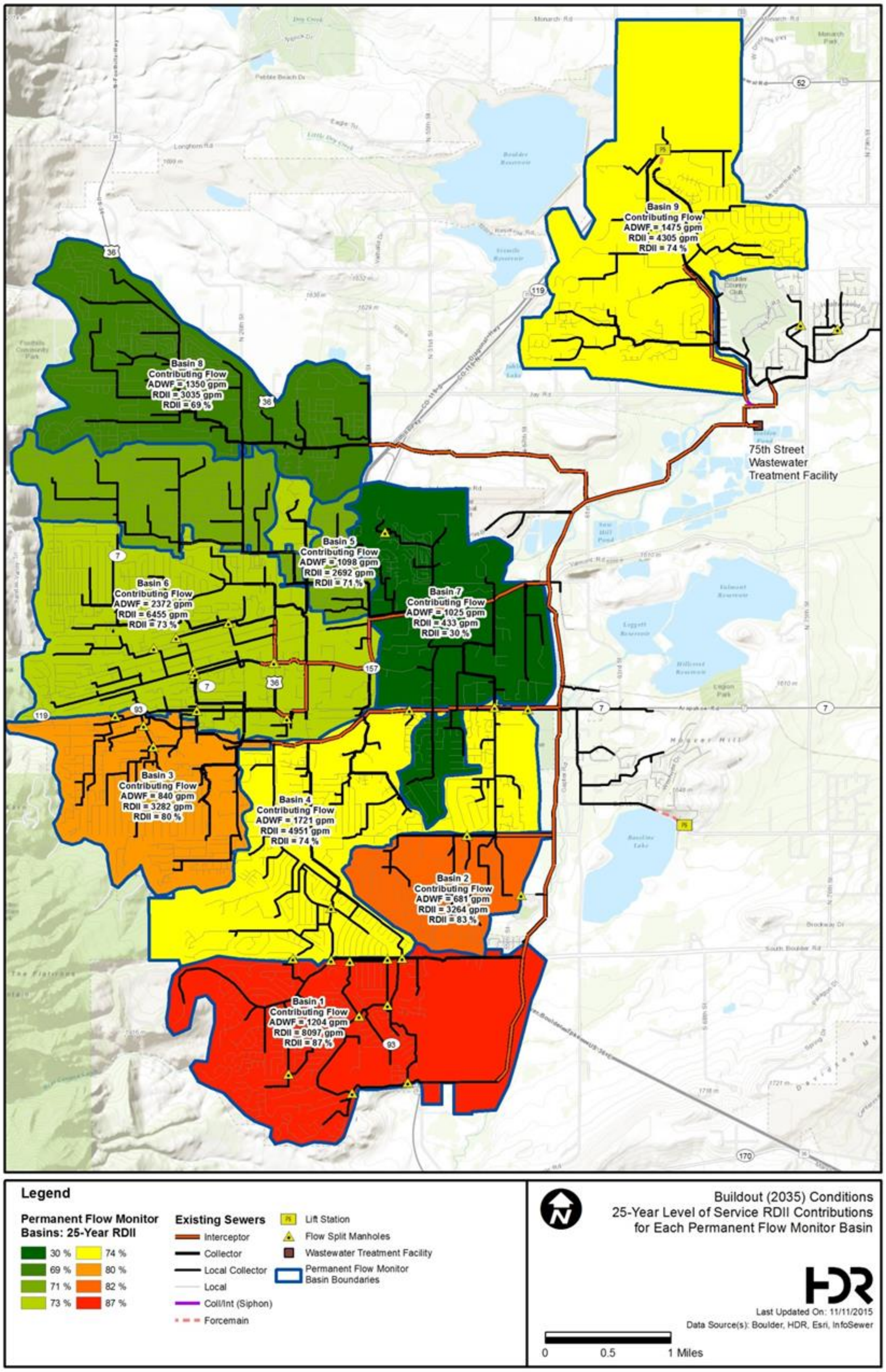


Figure 6-7. Buildout (2035) RDII Loadings Per Permanent Flow Monitoring Basin for the 25-Year Level of Service



6.2 Capacity-Limited Identification and Characterization

The collection system pipes with identified capacity limitations, established from the model results, were examined to identify likely hydraulic issues under the various flow scenarios. Table 6-2 summarizes pipes in the analyzed collection system with identified hydraulic limitations. A capacity-limited identification and characterization process was completed to better understand the nature and extent of these issues. This process is described in the following sections.

Table 6-2. Summary of Pipes with Modeled Hydraulic Limitations under Buildout Flow Projections in the Analyzed Collection System

Buildout Model Flow Scenario	Number of Pipes with Hydraulic Limitations	Total Length of Pipe with Hydraulic Limitations (miles)	Total Length of Pipe with Hydraulic Limitations (as a Percent of Total Analyzed System Length)	Number of Surcharged Manholes (Less than 1 foot of Freeboard)
15-Year Level of Service PHWWF	288	12.6	10%	41
20-Year Level of Service PHWWF	391	17.9	14%	99
25-Year Level of Service PHWWF	500	23.1	18%	176

6.2.1 Problem Identification

The hydraulic problems were separated into three categories for characterization and prioritization: Type A, Type B, and Type C. These three categories are defined as follows:

- **Type A:** A series of under capacity pipes that are hydraulically connected to one another. For Type A hydraulic problems, the system wide criteria is a modeled peak wet weather flow level exceeding 80 percent d/D and includes the interceptor, collector, local collector, and local systems.
- **Type B:** Isolated under capacity pipes that are not hydraulically connected to other problem locations. For Type B hydraulic problems, the system wide criteria is a modeled peak wet weather flow level exceeding 80 percent d/D and includes the interceptor, collector, local collector, and local systems.
- **Type C:** Under capacity pipes that are part of the local collector and local systems that can be either isolated or hydraulically connected to other problem pipes. For Type C hydraulic problems, the modeled peak wet weather flow level criteria is between 60 and 80 percent d/D and includes only the local collector and local systems.

Type C problems were placed in a separate category because they apply to local collector and local system pipes that are just above their hydraulic capacity criteria and, while modeling indicates they are hydraulically restricted, they do not have the same level of priority or risk as the Type A and Type B categories. In addition, the accuracy of the data that are used to identify these potential capacity restrictions may outweigh the precision provided by the hydraulic model. These Type C restrictions will likely require further assessment with flow monitoring and pipe invert validation.

Type A problems account for 50 percent of the problem pipes or a total of 247 pipes with a cumulative length of approximately 12.8 miles. Type B problems account for 25 percent of the problem pipes or a total of 125 pipes with a cumulative length of approximately 3.9 miles. Type C problems account for the remaining 25 percent of problem pipes or a total of 128 pipes with a cumulative length of approximately 6.3 miles.

Type A and Type B problem areas will have system improvement recommendations developed and estimates of capital cost prepared. Type A capacity limitations will be identified as recommendations for capital improvements. Type B capacity limitations should be further validated through additional localized flow monitoring and invert survey to verify capacity constraints and, if still valid, further capital project recommendations may be necessary. Type C capacity limitations reflect a series of pipes that should be monitored via CCTV or localized flow monitoring and, if necessary based on actual upstream growth, considered for isolated upsizing at a later time. Many of the Type C problems are expected to be addressed through decreased RDII contribution as the local systems are rehabilitated.

Figure 6-8 shows the Type A and Type B problem areas and Figure 6-9 shows the Type C problem areas. A total of 12 Type A capacity-limited areas, or groups, were identified based on the relative proximity of the problem pipes and hydraulic connectivity. The most extensive Type A capacity-limited areas are in permanent flow monitor basins 1, 2, 3, and 4 and correspond to the basins receiving the greatest RDII loadings (Figure 6-7). Each Type A capacity-limited group is identified by the sewer basin it is located in followed by an identification number. These capacity-limited groups are discussed in the following sections.

Figure 6-8. Type A and Type B Problem Locations: Buildout Peak Hour Wet Weather Flows for 15, 20, and 25-Year Levels of Service

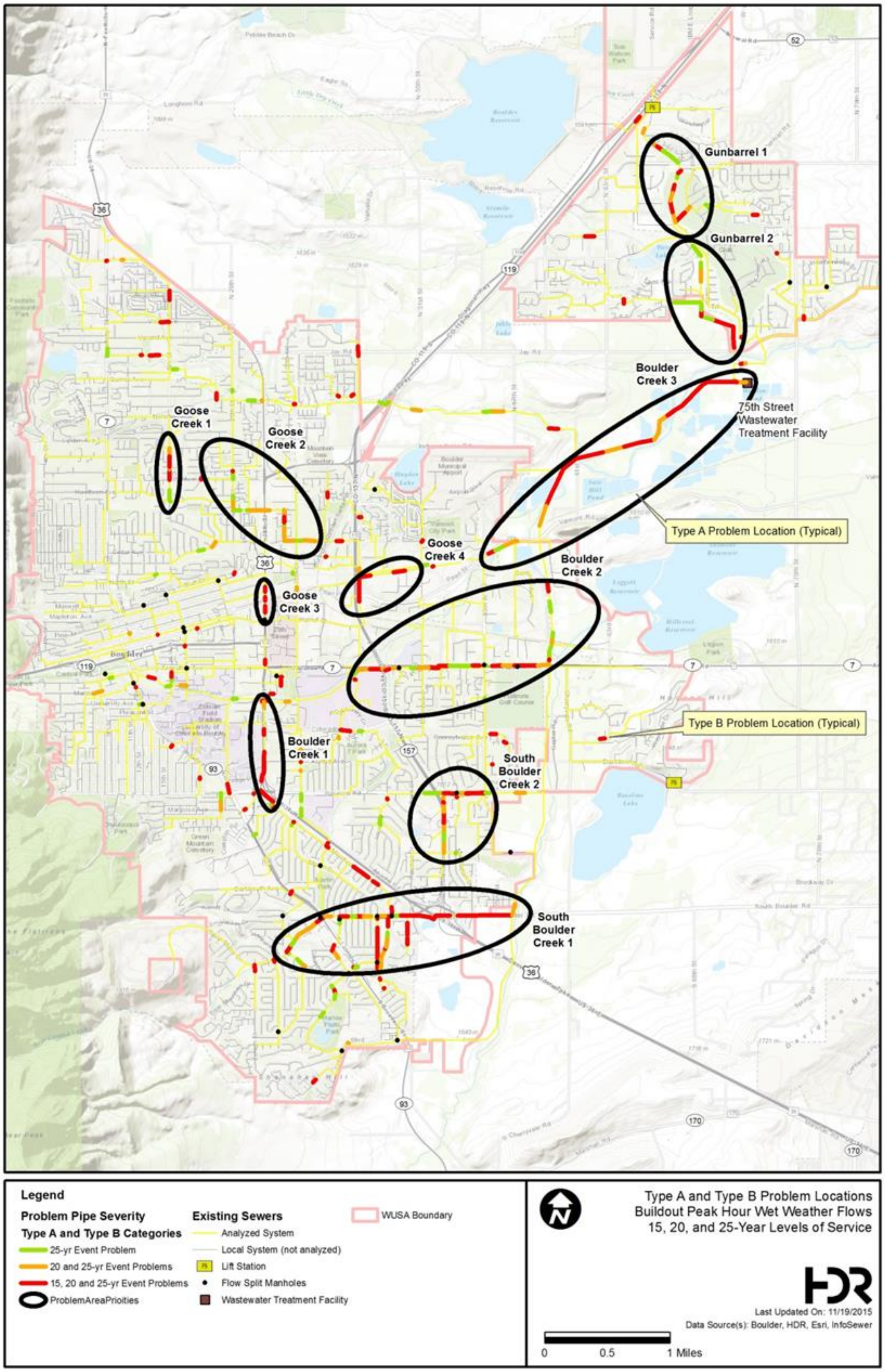
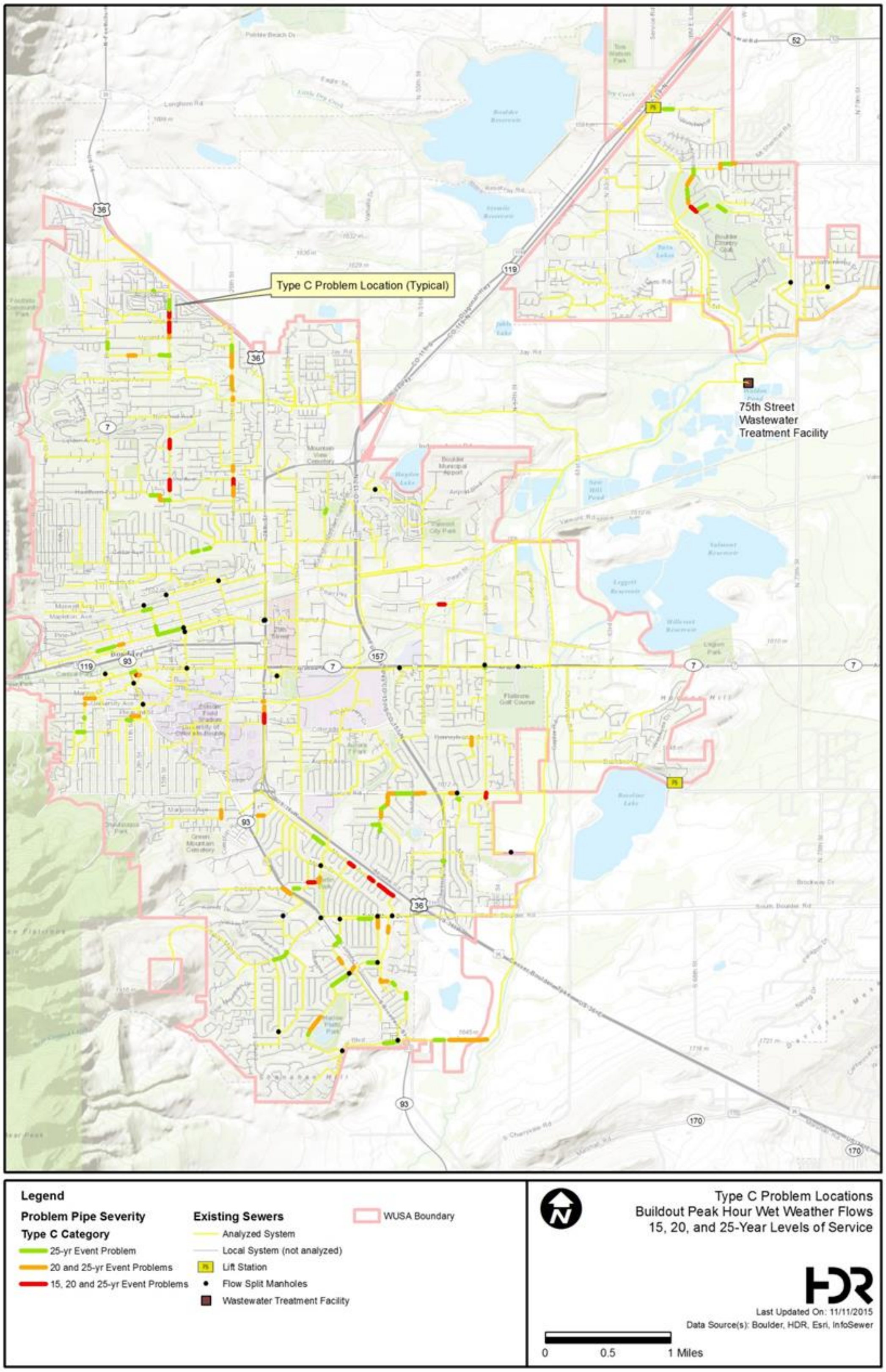


Figure 6-9. Type C Problem Locations: Buildout Peak Hour Wet Weather Flows for 15, 20, and 25-Year Levels of Service



6.2.2 Problem Characterization – Type A Problem Locations

As previously defined, the criteria for a Type A hydraulic limitation is based on sewers with a peak wet weather flow level exceeding 80 percent d/D. Type A locations were characterized using a set of descriptive categories to better understand the nature, extent, and hydraulics of the issues for the eventual development of improvements. Table 6-3 identifies the descriptive categories and what they entail in helping to define the capacity-limited groups. Table 6-4 through Table 6-14 characterize each of the problem groups using the descriptive categories. Figure 6-8 references these locations.

Table 6-3. Capacity Limitation Characterization Categories and Definitions

Location:	Identifies the sewer basin, major street intersection(s) or adjacent feature(s).
Pipe Classification:	Identifies if the pipes are categorized as local, local collector, collector or interceptors. If the system is an interceptor or collector that is located along a creek corridor, the manhole lid condition (sealed or un-sealed) will be noted.
Diameter Range:	Summarizes the range in pipe diameters.
Material Types:	Summarizes the pipe material types.
Install/Rehab Date:	Identifies the average or predominant installation date of the pipes and also notes if segments have been recently rehabilitated through the O&M program. This information is extracted from the city's GIS.
Problem Extent (Buildout with 15-Year Level of Service):	Summarizes the total length of Type A problem pipe under buildout wet weather 15-year level of service flow scenario.
Problem Extent (Buildout with 20-Year Level of Service):	Summarizes the total length of Type A problem pipe under buildout wet weather 20-year level of service flow scenario.
Problem Extent (Buildout with 25-Year Level of Service):	Summarizes the total length of Type A problem pipe under buildout wet weather 25-year level of service flow scenario.
Manhole SSO Risk (Buildout, 25-Year Level of Service):	Summarizes the number of manholes that have less than 1 foot of freeboard under the buildout wet weather 25-year level of service flow scenario.
Estimated Number of Services:	Identifies the number of sewer services connected to the problem pipes.
Calibration Confidence:	Identifies the calibration confidence in the vicinity of the problem area based on the results from the dry weather calibration. A qualitative ranking from low to medium to high is assigned to each problem area depending on accuracy of model versus meter flow. Capacity-limited areas not in the vicinity of a calibration flow meter are assigned a medium calibration confidence ranking. The calibration confidence ranking represents model confidence during the dry weather scenarios only since the permanent flow meter calibration was based on dry weather. Because of this, only the dry weather portion of the total flow and associated flow difference between permanent flow meter and model is represented during wet weather flow which establishes the greatest potential for capacity problems.
Data Confidence:	Summarizes the number of manhole inverts that did not have survey or as-built data and were therefore interpolated for modeling purposes. Data confidence of 100% indicates that all manhole invert data was obtained from as-built or survey data and was not adjusted as part of the network validation process.
Accessibility:	Identifies if the problem pipes are generally located in roadways, creek/stream corridors or other alignment conditions.
Comments:	Provides a brief problem assessment considering the characterization findings for each category.

Table 6-4. Capacity Limitation Characterization: Boulder Creek 1

BOULDER CREEK 1	
Location:	Boulder Creek Sewer Basin - Colorado Ave and 28th St
Pipe Classification:	Local Collector, Interceptor
Diameter Range:	8-21 inch diameter
Material Types:	VC
Install/Rehab Date:	Install: varies (Unknown – 1976) / Rehab: varies (none, 2005, 2006, 2012, 2013)
Problem Extent (Buildout ADWF):	1,906 feet
Problem Extent (Buildout with 15-Year Level of Service):	2,629 feet
Problem Extent (Buildout with 20-Year Level of Service):	2,851 feet
Problem Extent (Buildout with 25-Year Level of Service):	3,020 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	4
Estimated Number of Services:	1
Data Confidence:	80 percent (3 of 15 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Accessibility:	Highway, Major Arterial Road
Comments:	Most of the problem pipes in this group run north to south on 28th St and have relatively shallow slopes which are causing deep pipe flow. There is a fairly high total length of problem pipe. Existing dry weather flows are causing problems in potentially older pipe constructed of vitrified clay.

Table 6-5. Capacity Limitation Characterization: Boulder Creek 2

BOULDER CREEK 2	
Location:	Boulder Creek Sewer Basin - Arapahoe Ave and Foothills Pkwy to Old Tale Rd; South Boulder Creek corridor
Pipe Classification:	Local Collector, Collector/Interceptor, Interceptor
Diameter Range:	12-36 inch diameter
Material Types:	VC, PVC, RC
Install/Rehab Date:	Install: varies (Unknown – 1957, 1991, 2007) / Rehab: none
Problem Extent (Buildout ADWF):	635 feet
Problem Extent (Buildout with 15-Year Level of Service):	3,787 feet
Problem Extent (Buildout with 20-Year Level of Service):	6,137 feet
Problem Extent (Buildout with 25-Year Level of Service):	9,268 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	0
Estimated Number of Services:	8
Data Confidence:	80 percent (6 of 30 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Highway, Major Arterial Road
Comments:	The problem pipes run west to east along Arapahoe Ave west of Foothills Pkwy to Old Tale Rd. There is a high total length of problem pipe and areas of relatively shallow slopes. Construction will have major traffic impacts as the roadway is a heavily traveled commuter route.

Table 6-6. Capacity Limitation Characterization: Boulder Creek 3

BOULDER CREEK 3	
Location:	Boulder Creek Sewer Basin - Valmont Rd and 61st St to WWTF
Pipe Classification:	Interceptor along Boulder Creek Corridor (manholes sealed)
Diameter Range:	30-60 inch diameter
Material Types:	VC, RC, DI
Install/Rehab Date:	Install: varies (unknown – 1966) / Rehab: varies (none, 2003)
Problem Extent (Buildout ADWF):	0 feet
Problem Extent (Buildout with 15-Year Level of Service):	8,605 feet
Problem Extent (Buildout with 20-Year Level of Service):	12,677 feet
Problem Extent (Buildout with 25-Year Level of Service):	13,265 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	2, plus surcharging in several sealed manholes
Estimated Number of Services:	0
Data Confidence:	100 percent (0 of 32 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Accessibility:	Major Road, Creek Corridor
Comments:	The influent sewer to the WWTF is expected to flow full during significant wet weather events. Construction access would be very difficult in this area. However, this project is highlighted as a top priority due to the constant occurrence of SSOs during even marginal rainfall events. Addressing this section of interceptor is one of the main environmental compliance goals of the city.

Table 6-7. Capacity Limitation Characterization: Goose Creek 1

GOOSE CREEK 1	
Location:	Goose Creek Sewer Basin – 19th Street from Kalmia Ave to Grape Ave
Pipe Classification:	Local Collector, Collector/Interceptor
Diameter Range:	8-15 inch diameter
Material Types:	VC
Install/Rehab Date:	Install: varies (unknown – 1959) / Rehab: varies (none, 2005, 2011)
Problem Extent (Buildout ADWF):	0 feet
Problem Extent (Buildout with 15-Year Level of Service):	886 feet
Problem Extent (Buildout with 20-Year Level of Service):	1,339 feet
Problem Extent (Buildout with 25-Year Level of Service):	1,832 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	1
Estimated Number of Services:	5
Data Confidence:	80 percent (2 of 10 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Accessibility:	Minor Road
Comments:	The problem pipes in this group run north to south along 19th Street. The problem pipe sections appear to be at or over capacity for their size.

Table 6-8. Capacity Limitation Characterization: Goose Creek 2

GOOSE CREEK 2	
Location:	Goose Creek Sewer Basin – Folsom St/Glenwood Dr/Valmont Rd
Pipe Classification:	Local Collector, Collector/Interceptor
Diameter Range:	10- 15 inch diameter
Material Types:	VC
Install/Rehab Date:	Install: varies (unknown – 1969; 1971, 1979, 1983) / Rehab: none
Problem Extent (Buildout ADWF):	30 feet
Problem Extent (Buildout with 15-Year Level of Service):	274 feet
Problem Extent (Buildout with 20-Year Level of Service):	3,097 feet
Problem Extent (Buildout with 25-Year Level of Service):	4,228 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	0
Estimated Number of Services:	14
Data Confidence:	71 percent (6 of 21 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Local and Major Roads
Comments:	The general direction of the in this problem run is from the northwest to the southeast, with problem pipes running north to south and west to east along Folsom St, Glenwood Dr, along the border of private properties, and Valmont Rd. Construction accessibility may be difficult along the major roads and private properties. These are older pipes constructed of vitrified clay. There is a high total length of problem pipe and modeling shows that pipe surcharging along this stretch may be significant.

Table 6-9. Capacity Limitation Characterization: Goose Creek 3

GOOSE CREEK 3	
Location:	Goose Creek Sewer Basin – 28th Street from Pine St to Walnut St
Pipe Classification:	Collector/Interceptor
Diameter Range:	24 inch diameter
Material Types:	RC
Install/Rehab Date:	Install: unknown / Rehab: 2008
Problem Extent (Buildout ADWF):	0 feet
Problem Extent (Buildout with 15-Year Level of Service):	622 feet
Problem Extent (Buildout with 20-Year Level of Service):	622 feet
Problem Extent (Buildout with 25-Year Level of Service):	622 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	1
Estimated Number of Services:	2
Data Confidence:	66 percent (1 of 3 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Accessibility:	Highway
Comments:	The problem pipes in this group run north to south along 28th Street. The problem pipe sections have a relatively shallow slope. Construction accessibility may be difficult.

Table 6-10. Capacity Limitation Characterization: Goose Creek 4

GOOSE CREEK 4	
Location:	Goose Creek Sewer Basin – Foothills Pkwy and Pearl St
Pipe Classification:	Interceptor
Diameter Range:	21-30 inch diameter
Material Types:	RC
Install/Rehab Date:	Install: varies (1956, 1967, 1972, 1980, 1987) / Rehab: none
Problem Extent (Buildout ADWF):	487 feet
Problem Extent (Buildout with 15-Year Level of Service):	1,999 feet
Problem Extent (Buildout with 20-Year Level of Service):	1,999 feet
Problem Extent (Buildout with 25-Year Level of Service):	2,067 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	2
Estimated Number of Services:	3
Data Confidence:	70 percent (3 of 10 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Local Road, Highway
Comments:	The problem pipes in this group run south to north and then east to west along Foothills Pkwy and Pearl St. There is a single segment 21" diameter pipe restriction along this predominantly 30" pipe run. The problem pipe sections have a relatively shallow slope. There are pipes north of Pearl Street that are constructed with RFM pipes that have a high structural failure potential. Construction accessibility may be difficult.

Table 6-11. Capacity Limitation Characterization: Gunbarrel 1

GUNBARREL 1	
Location:	Gunbarrel Sewer Basin – Boulder and Left Hand Ditch; Idylwild Tr/Boulder Country Club
Pipe Classification:	Local Collector, Collector/Interceptor
Diameter Range:	12-21 inch diameter
Material Types:	VC
Install/Rehab Date:	Install: varies (unknown, 1965) / Rehab: varies (none, 2003)
Problem Extent (Buildout ADWF):	207 feet
Problem Extent (Buildout with 15-Year Level of Service):	1,914 feet
Problem Extent (Buildout with 20-Year Level of Service):	3,188 feet
Problem Extent (Buildout with 25-Year Level of Service):	4,173 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	0
Estimated Number of Services:	5
Data Confidence:	80 percent (3 of 15 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Ditch Corridor, Open Space, Golf Course, Local Street
Comments:	The problem pipes in this area are showing stress due to increasing flows from growth in the northern part of the Gunbarrel sewer basin. There is a high total length of problem pipe in this area. The problem pipes run north to south along the ditches as well as along Idylwild Tr and across the Boulder Country Club golf course. The problem pipes along the collector/interceptor have a shallow slope. Construction accessibility would need to be coordinated with the Ditch Company and Boulder Country Club.

Table 6-12. Capacity Limitation Characterization: Gunbarrel 2

GUNBARREL 2	
Location:	Gunbarrel Sewer Basin - Boulder Supply Canal north of Jay Rd
Pipe Classification:	Collector/Interceptor, Interceptor along Canal
Diameter Range:	15-24 inch diameter
Material Types:	CC, VC
Install/Rehab Date:	Install: varies (1971 – 1976) / Rehab: none
Problem Extent (Buildout ADWF):	0 feet
Problem Extent (Buildout with 15-Year Level of Service):	2,065 feet
Problem Extent (Buildout with 20-Year Level of Service):	2,562 feet
Problem Extent (Buildout with 25-Year Level of Service):	5,241 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	0
Estimated Number of Services:	3
Data Confidence:	43 percent (8 of14 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Open Space, Canal Corridor
Comments:	The problem pipes in this area run along irrigation ditches upstream of the Gunbarrel siphon and are comprised of the north to south 24" interceptor and a west to east 15" collector/interceptor. There is a high total length of problem pipe with a relatively shallow slope.

Table 6-13. Capacity Limitation Characterization: South Boulder Creek 1

SOUTH BOULDER CREEK 1	
Location:	South Boulder Creek Sewer Basin – Table Mesa Dr, South Boulder Rd, S 46th St,
Pipe Classification:	Local Collector, Collector/Interceptor
Diameter Range:	8-30 inch diameter
Material Types:	VC, RC, CI, PVC
Install/Rehab Date:	Install: varies (unknown, 1961, 1971, 1984, 1988, 2013) / Rehab: varies (none, 2005, 2008, 2013)
Problem Extent (Buildout ADWF):	1,535 feet
Problem Extent (Buildout with 15-Year Level of Service):	10,293 feet
Problem Extent (Buildout with 20-Year Level of Service):	14,557 feet
Problem Extent (Buildout with 25-Year Level of Service):	16,600 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	65
Estimated Number of Services:	23
Data Confidence:	High (15 of 72 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Local and Major Roads, Highway
Comments:	The problem pipes in this area are the collector/interceptor system running west to east along Table Mesa Dr and South Boulder Rd as well as four local collectors discharging into it. There are capacity issues along the entire length of pipe. The SSO risk increases for the higher frequency scenarios where the pipe profile abruptly changes from a near 4% slope to a less than 1% slope near Table Mesa Dr and Moorhead Ave. There are several potential SSO locations indicated by the model for all model scenarios and the majority of the problem lines may experience SSOs for the 25-year level of service. There is a high total length of problem pipe and construction accessibility may be difficult.

Table 6-14. Capacity Limitation Characterization: South Boulder Creek 2

SOUTH BOULDER CREEK 2	
Location:	South Boulder Creek Sewer Basin – Foothills Pkwy, Baseline Rd
Pipe Classification:	Local Collector, Collector/Interceptor
Diameter Range:	8-24 inch diameter
Material Types:	VC, PVC, RPM
Install/Rehab Date:	Install: varies (unknown, 1957, 1973, 1978, 1987, 1989, 1990) / Rehab: none
Problem Extent (Buildout ADWF):	805 feet
Problem Extent (Buildout with 15-Year Level of Service):	2,783 feet
Problem Extent (Buildout with 20-Year Level of Service):	4,770 feet
Problem Extent (Buildout with 25-Year Level of Service):	6,563 feet
Manhole SSO Risk (Buildout, 25-Year Level of Service):	9
Estimated Number of Services:	5
Data Confidence:	85 percent (3 of 20 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Accessibility:	Local and Major Roads, Highway
Comments:	The problem pipes in this area are the local collector running south to north along Foothills Pkwy and the collector/interceptor running west to east along Baseline Rd. Capacity issues exist where the collector/interceptor flattens at the upstream of the intersection of Baseline Rd and Foothills Pkwy. There are capacity issues along the entire length of pipe. There are pipes along Baseline Rd that are constructed with RFM pipes that have a high structural failure potential. There is a high total length of problem pipe and construction accessibility may be difficult.

6.2.3 Problem Characterization – Type B Problem Locations

As previously defined, Type B problem locations have the same capacity criterion as Type A problems, however, Type B problems are relatively isolated and are not hydraulically connected to other problem locations. Type B problems often result from isolated flat pipe slopes limiting the capacity of single pipe segments. Figure 6-8 shows the Type B problem locations.

6.2.4 Problem Characterization – Type C Problem Locations

As previously defined, Type C problems are isolated stretches of sewer in the local collector and local systems where peak wet weather flow levels fall between 60 and 80 percent d/D. For the majority of these sewers this threshold is only marginally exceeded. Figure 6-9 shows these locations.

Type C sewers are under stress for the model scenarios, but are not significant enough to constitute their own capital improvement projects. Type C areas are locations where CCTV and localized flow monitoring and invert survey are recommended to validate the problem extent. Based on the results from the capacity validation activities and actual upstream growth, they could be considered for upsizing if necessary.

6.3 Remaining Capacity Analysis

An analysis was also performed to determine the remaining capacity in the existing sewers after buildout ADWF loadings and the 25-year level of service RDII is applied to the model. The results of this analysis, based on the problem identification hydraulic criteria on the analyzed system, are presented in Table 6-15 (total number of pipes) and Table 6-16 (total length of pipes) as well as in Figure 6-10. The results presented in these tables and the figure are based on the buildout modeled flow divided by the full flow capacity (q/Q), which generally correspond with the results based on the d/D ratio.

Assuming d/D and q/Q to be roughly equivalent, interceptor and collector pipes with a q/Q less than 80 percent (excess capacity greater than 20 percent) and local collector and local pipes with a q/Q less than 60 percent (excess capacity greater than 40 percent) were assumed to have a remaining flow capacity available to support future growth while still providing for conveyance of a 25 year storm level of RDII. For the collector/interceptor system, about 637 pipes in the analyzed system with a total pipe length of 28.2 miles have available remaining capacity. For the local collector systems, about 1,617 pipes in the analyzed system with a total pipe length of 67.6 miles have available remaining capacity.

For comparison, the remaining capacity in the analyzed system for existing conditions was also mapped (Figure 6-11). Comparing Figure 6-10 to Figure 6-11 illustrates where there is capacity today versus in the future as anticipated development occurs.

Table 6-15. Buildout Peak Hour Wet Weather 25-Year Level of Service Capacity Analysis - Remaining Capacity Summary by Number of Pipes for the Analyzed System

Sewer Classification	Remaining Capacity[1] (Number of Pipe Segments)						Number of Analyzed Pipes with Available Remaining Capacity (Sum of Bold/Italicized Values)
	Surcharged Pipe	***< 20 %***	***20 – 40 %***	***40 – 60 %***	***60 – 80 %***	***80 – 100%***	
Collector/ Interceptor	192	93	**108**	**140**	**166**	**223**	**637**
Local Collector	156	67	117	**227**	**450**	**940**	**1,617**
Total	348	160	225	367	616	1,163	**2,254**

[1] Remaining capacity is calculated as: 100 x (Full Flow Capacity – 25-year modeled peak flow)/Full Flow Capacity; Values that are bold and italicized are the number of pipes that have available capacity for the 25-year event in accordance with the problem identification hydraulic criteria.

Table 6-16. Buildout Peak Hour Wet Weather 25-Year Level of Service Capacity Analysis-Remaining Capacity Summary by Length of Pipe in Miles for the Analyzed System

Sewer Classification	Excess Capacity[1] (Length of Pipe In Miles)						Length of Analyzed Pipes with Available Remaining Capacity (Sum of Bold/Italicized Values)
	Surcharged Pipe	***< 20 %***	***20 – 40 %***	***40 – 60 %***	***60 – 80 %***	***80 – 100%***	
Collector/ Interceptor	10.0	4.7	**5.5**	**6.7**	**6.6**	**9.4**	**28.2**
Local Collector	5.7	3.4	5.2	**9.5**	**19.3**	**38.8**	**67.6**
Total	15.7	8.1	10.7	16.2	26.0	48.2	**95.8**

[1] Remaining capacity is calculated as: 100 x (Full Flow Capacity – 25-year modeled peak flow)/Full Flow Capacity; Values that are bold and italicized are the length of pipes that have available capacity for the 25-year event in accordance with the problem identification hydraulic criteria.

Figure 6-10. Buildout Peak Hour Wet Weather Capacity Analysis - Remaining Capacity to the 25-Year Level of Service

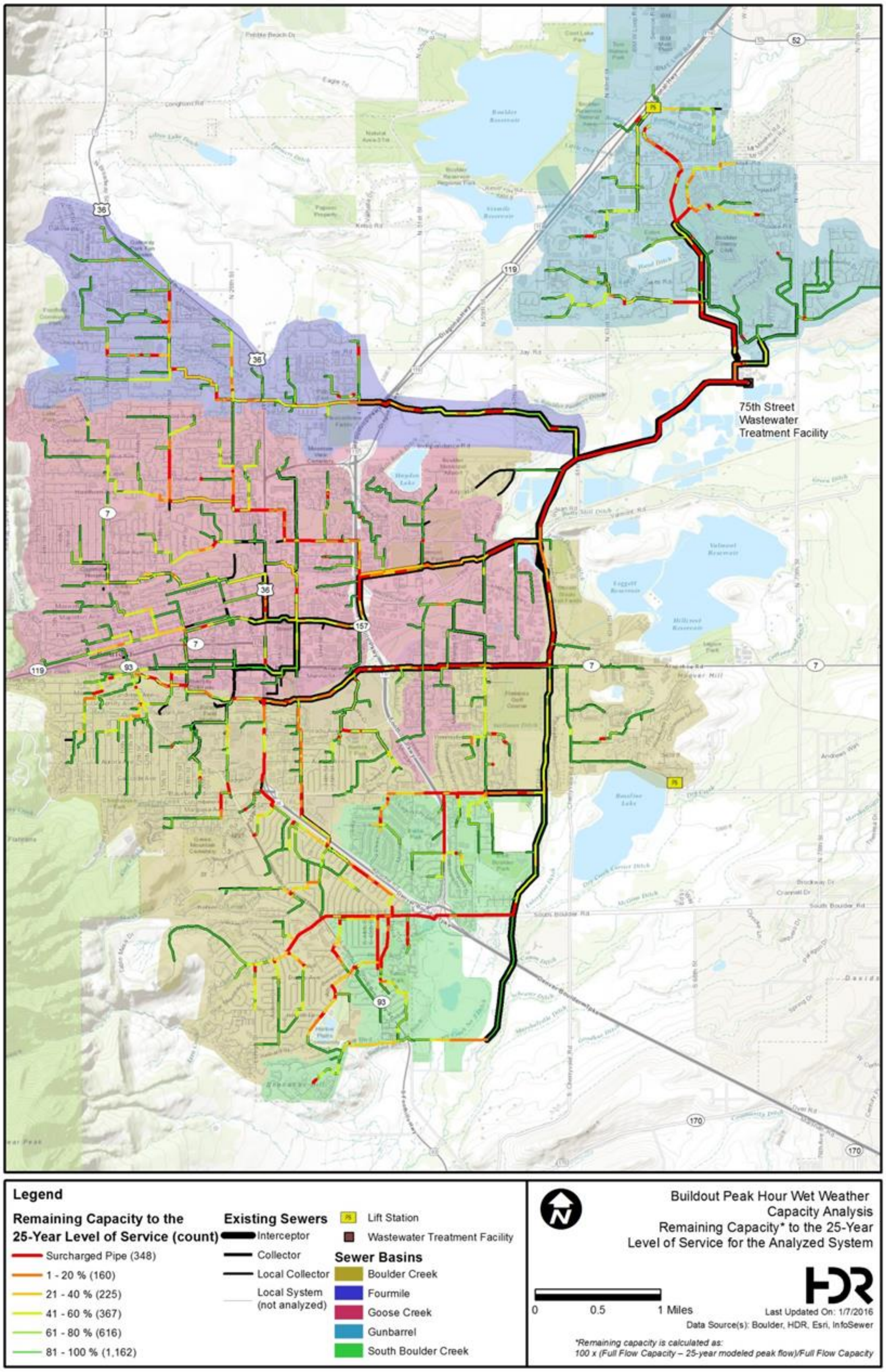
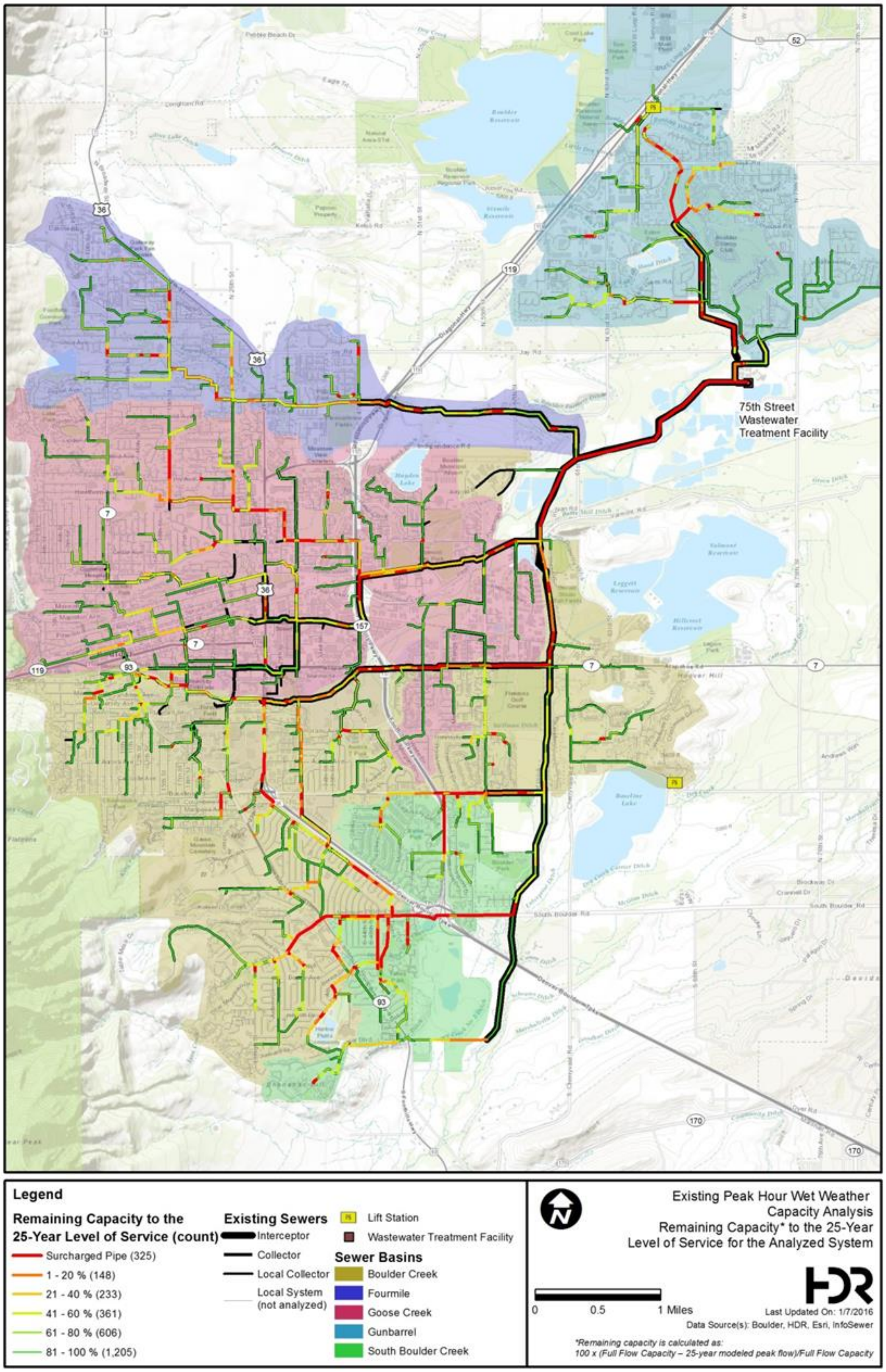


Figure 6-11. Existing Peak Hour Wet Weather Capacity Analysis - Remaining Capacity to the 25-Year Level of Service



7 Capital Project Recommendations

This section documents the capital project recommendations and planning-level opinion of probable construction costs in association with the city's 2016 WWCSMP. These recommendations are developed from the updated master plan model described in Section 3- Dry Weather Model Update and Calibration , Section 4- RDII Response and Level of Service Assessment, and Section 5-Wet Weather Flow Generation and Model Calibration, as well as the collection system capacity analysis described in Section 6- Collection System Capacity Analysis and Capacity Limitations Identification. The basis of these recommendations are the buildout conditions flow projections for BSF, the calibrated BI allowances, and the RDII allowances associated with the 15-, 20-, and 25-year levels of service.

7.1 Improvement Recommendations

In Section 6- Collection System Capacity Analysis and Capacity Limitations Identification, the hydraulic problems were separated into three categories; Type A, Type B, and Type C. Type A problems consist of a series of hydraulically connected problem pipes with modeled 25-year peak wet weather flow levels exceeding 80 percent d/D for the interceptor/collector, local collector, and local systems. Type B problems are isolated hydraulic restrictions that are not hydraulically connected to other problem locations with modeled 25-year peak wet weather flow levels exceeding 80 percent d/D for the interceptor/collector, local collector, and local systems. Type C problems are under capacity pipes with modeled 25-year peak wet weather flow levels between 60 and 80 percent d/D that are part of the local collector and local systems that can be either isolated or hydraulically connected to other problem pipes.

For this project, capacity issues for both Type A and Type B problem areas are resolved with increases in pipe diameter and have system improvement recommendations developed and estimates of capital cost prepared. Alternatives to pipe replacement and upsizing can be considered through the preliminary design phase of the recommended improvements. Modifications to upstream flow split manholes, if feasible, are recommended in the near-term to utilize the capacity of the existing system in areas which are experiencing existing hydraulic restrictions. The exception to pipe upsizing is the recommended Boulder Creek parallel interceptor at the downstream end of the system.

Type A capacity limitations are identified as recommendations for capital improvements. Type B capacity limitations should be further validated through additional localized flow monitoring and invert survey to verify capacity constraints and, if still valid, further capital improvements may be necessary. Type C capacity limitations reflect a series of pipes that should be inspected via CCTV or with localized flow monitoring and, if necessary based on actual upstream growth and additional flow, considered for necessary upsizing at a later time. In areas of the system with little upstream growth and future additional flow, some of the Type C problems may be addressed through decreased RDII contribution as the local and local collector systems are rehabilitated.

7.1.1 Recommended Improvement Priority

The recommended improvements were grouped into three tiers to establish implementation priority:

- Tier 1 projects address Type A problems and have the highest priority.

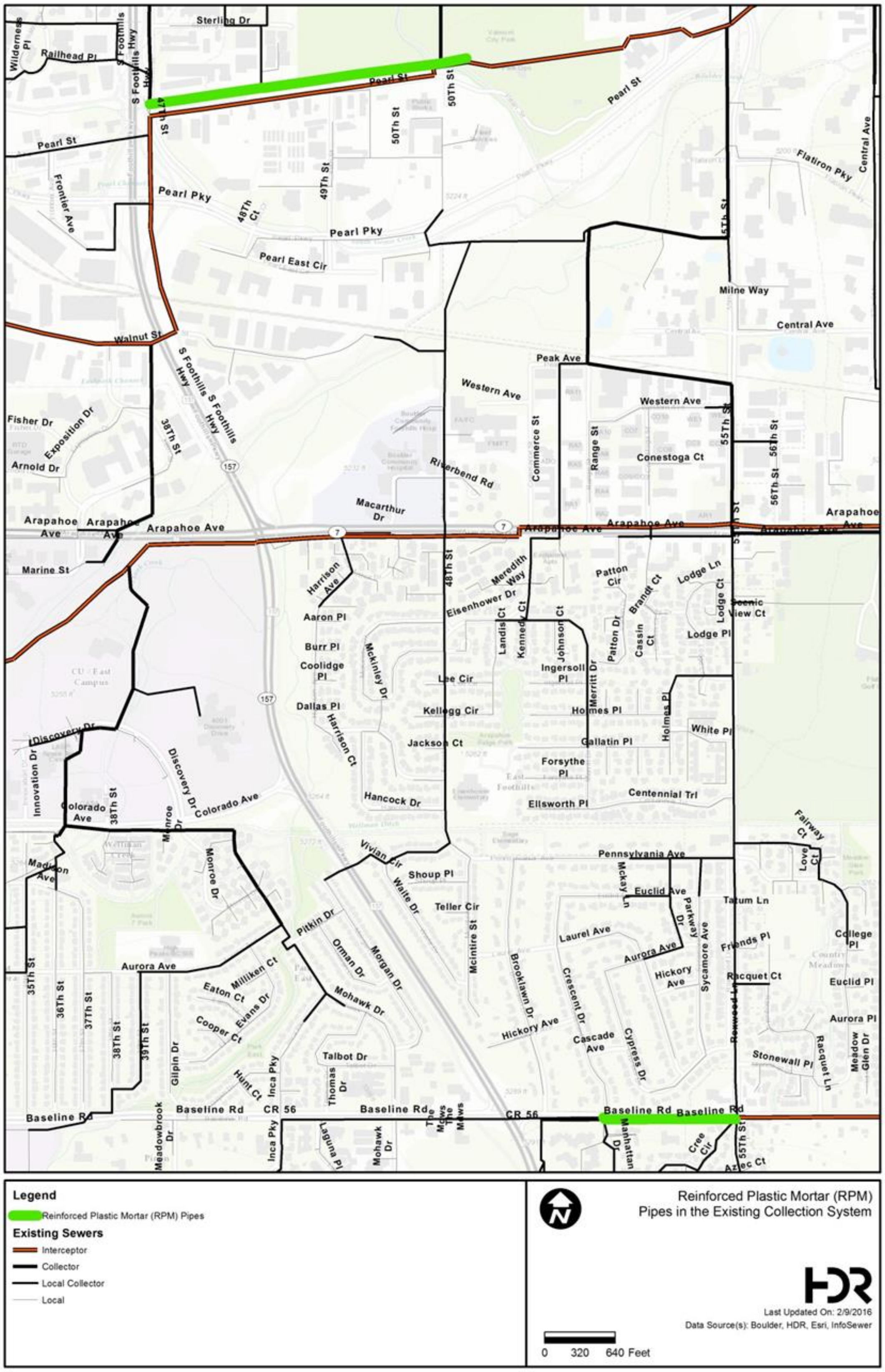
- Tier 2 projects also address Type A problems but have lower priority compared to Tier 1.
- Tier 3 projects address Type B problems which have the lowest priority.

The improvement priorities were assigned based on a number of qualitative factors including the observed performance of the system during high flow events, the level of service provided by the current system, extent of the problem, potential for SSOs and service lateral backups, and relative benefit over other improvement projects. The relative benefit takes into account the amount of pipe replaced compared to the extent of the problem remedied. These factors are summarized in the problem characterization tables in Section 6- Collection System Capacity Analysis and Capacity Limitations Identification.

7.1.2 Reinforced Plastic Mortar Pipes

A review of the GIS data indicates that some pipes within the system are reinforced plastic mortar (RPM) pipe. The product name of RPM is Flextran and the material is a thin-walled fiberglass-based pipe that was installed in the early to mid 1970s. Flextran RPM pipes have been known to experience deterioration and/or be susceptible to structural failure over time in collection systems around the country. The city knows that these pipes need to be lined with a structural liner or replaced. According to the GIS data 13 pipes within the system are constructed with RPM (Figure 7-1). These pipes should be lined with cured in place pipe, replaced or abandoned as soon as feasible due to the structural failure potential. These pipes are located in the Goose Creek 4 and South Boulder Creek 1 Type A problem areas.

Figure 7-1. Reinforced Plastic Mortar (RPM) pipes in the Existing Collection System



7.1.3 Type A Problem Improvements

Type A problem locations were characterized using a set of descriptive categories to better understand the nature, extent, and severity of the problems for the eventual development of improvements. Improvement recommendations for Type A problem locations are developed for each problem area to correct these hydraulic issues. Pipe improvement recommendations are developed to convey the flow conditions during the buildout 25-year wet weather scenario to allow for future system loading conditions in addition to alleviating existing hydraulic problems.

Using the model, improvements developed for the Type A alternatives were verified by checking that the hydraulic problems were remedied and the analysis criteria was met for each of the buildout flow scenarios. Improvements considered during this project were pipe replacements with the exception of the Boulder Creek Interceptor parallel. Figure 7-2 depicts and Table 7-1 summarizes the Type A improvements with the original and replacement pipe sizes.

Multiple factors were considered in developing each improvement recommendation. 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.
- Improvements were developed to address each problem area starting at the downstream end and working upstream. This process ensures that only hydraulically deficient pipes were addressed, as opposed to pipes that have adequate capacity but experience surcharging due to downstream bottlenecks.
- Capacity improvements were only extended far enough downstream so that the capacity criteria were met. This could result in a larger pipe discharging into a smaller pipe if that smaller pipe has sufficient capacity to carry the upstream flow due to increased pipe slope.

Table 7-1 lists each Type A problem area with a relative ranking (low, medium, high) for each of the priority factors based on a comparison between problem areas. In addition, discussions were held with the city regarding model results and areas where they have seen hydraulic capacity issues. Tier 1 or 2 is assigned in the last column depending on the overall outcome of the priority factor ranking, as well as observations made by the city, with the number of categories containing more high rankings reigning. Figure 7-2 depicts the Type A improvements by their Tier 1 or Tier 2 improvement priority.

Each Type A improvement project recommendations should be confirmed using localized flow monitoring and complete invert survey during preliminary design. The hydraulic model should be updated and improvement sizing and their extents confirmed prior to final design.

Figure 7-2. Type A Improvement with Original and Replacement Pipe Sizes

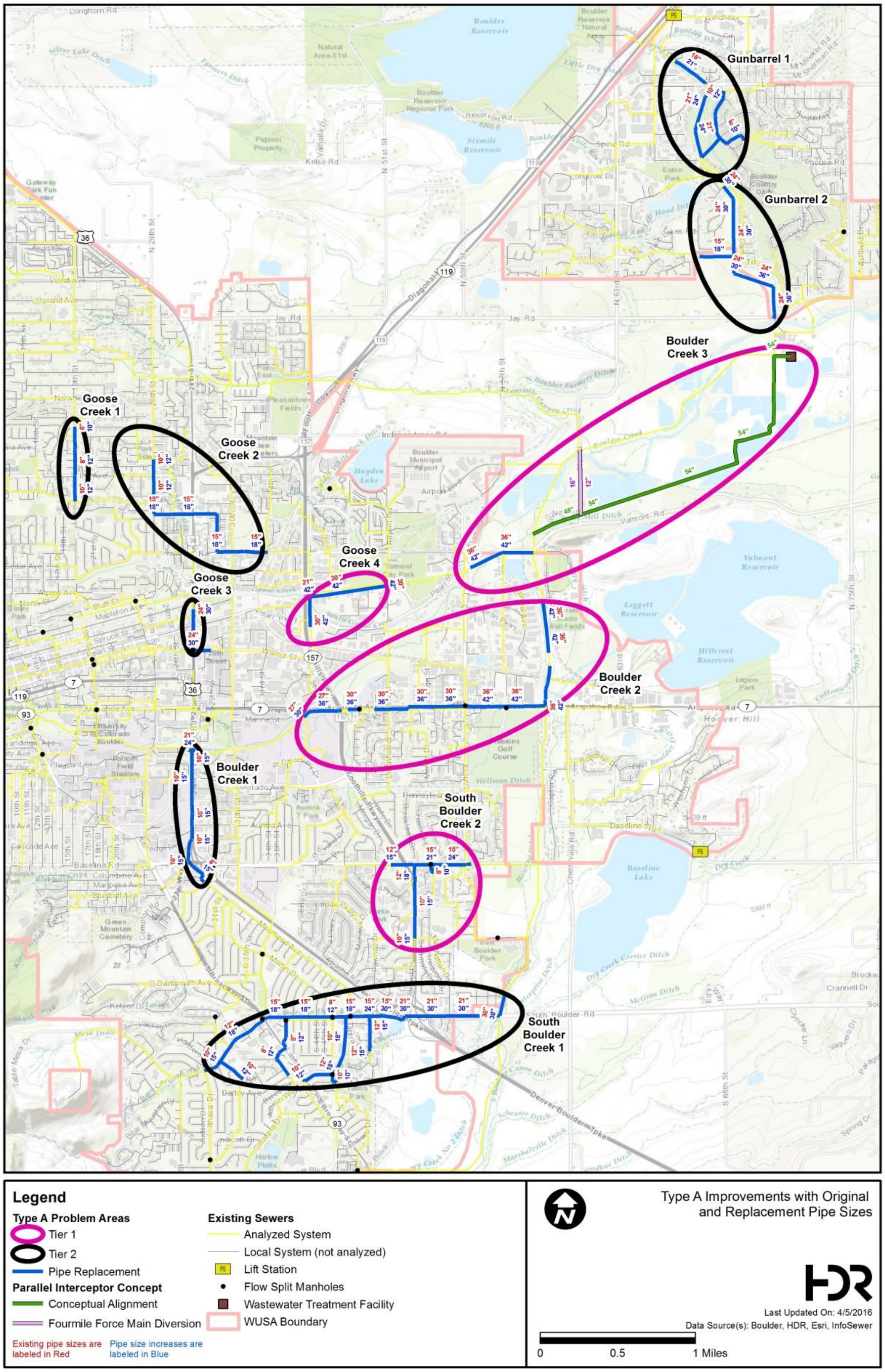


Table 7-1. Type A Improvement Summary with Original and Replacement Pipe Sizes

Problem Location	Existing Pipe Diameter(s)	Recommended Diameter(s)	Project Extents: Pipe Length per Diameter Size
Boulder Creek 1	8-, 10-, and 12-inch	12-inch	324 feet
		15-inch	4,586
		24-inch	208
Boulder Creek 2	27-, 30-, and 36-inch	30-inch	262 feet
		36-inch	4,687 feet
		42-inch	5,861 feet
Boulder Creek 3	36-inch	12-inch	2,210 feet
		16-inch	2,210 feet
		42-inch	2,216 feet
		48-inch	1,750 feet
		54-inch	10,788 feet
Goose Creek 1	8-, and 10-inch	10-inch	363 feet
		12-inch	2,176 feet
Goose Creek 2	10-, and 15-inch	12-inch	1,866 feet
		18-inch	5,197 feet
Goose Creek 3	24-inch	24-inch	272 feet
		30-inch	1,673 feet
Goose Creek 4	21-, and 30-inch	42-inch	4,016 feet
Gunbarrel 1	8-, 10-, 12-, 18-, and 21-inch	8-inch	37 feet
		10-inch	1,111 feet
		12-inch	1,278 feet
		15-inch	784 feet
		21-inch	1,877 feet
		24-inch	2,308 feet
Gunbarrel 2	15-, and 24-inch	18-inch	1,194 feet
		30-inch	3,585 feet
		36-inch	2,007 feet
South Boulder Creek 1	8-, 10-, 12-, 15-, 18-, 21-, and 30-inch	10-inch	109 feet
		12-inch	5,229 feet
		15-inch	3,017 feet
		18-inch	7,076 feet
		21-inch	377 feet
		24-inch	375 feet
		30-inch	5,295 feet
South Boulder Creek 2	8-,10-,12-,15-, and 24-inch	10-inch	619 feet
		12-inch	24 feet
		15-inch	2,891 feet
		18-inch	417 feet

Table 7-1. Type A Improvement Summary with Original and Replacement Pipe Sizes

Problem Location	Existing Pipe Diameter(s)	Recommended Diameter(s)	Project Extents: Pipe Length per Diameter Size
		21-inch	1,326 feet
		24-inch	447 feet
		30-inch	156 feet

Table 7-2. Type A Improvement Priority Ranking

Problem Location	Level of Service	Problem Extent	RPM Pipes	SSO Risk	Lateral Backup Risk	Construct-ability	Observed Problem	Relative Benefit	Priority Tier
Boulder Creek 1	15-, 20-, and 25-Year	High	N/A	Medium	Medium	High	Low	Low	Tier 2
Boulder Creek 2	15-, 20-, and 25-Year	High	N/A	Low	High	Low	Medium	High	Tier 1
Boulder Creek 3	15-, 20-, and 25-Year	High	N/A	High	Low	Low	High	High	Tier 1
Goose Creek 1	15-, 20-, and 25-Year	Medium	N/A	Medium	Medium	Medium	Low	Low	Tier 2
Goose Creek 2	15-, 20-, and 25-Year	High	N/A	Low	High	Low	High	Medium	Tier 2
Goose Creek 3	15-, 20-, and 25-Year	Low	N/A	Medium	Medium	Low	Low	Low	Tier 2
Goose Creek 4	15-, 20-, and 25-Year	Medium	High	Medium	Medium	Low	High	High	Tier 1
Gunbarrel 1	15-, 20-, and 25-Year	High	N/A	Low	Medium	High	Medium	Low	Tier 2
Gunbarrel 2	15-, 20-, and 25-Year	High	N/A	Low	Medium	High	Medium	Low	Tier 2
South Boulder Creek 1	15-, 20-, and 25-Year	High	N/A	High	High	Low	Medium	Medium	Tier 2
South Boulder Creek 2	15-, 20-, and 25-Year	High	High	High	Medium	Low	High	High	Tier 1

7.1.4 Type B Problem Improvements

Type B problems identified in TM 4.1 – Collection System Capacity Analysis and Capacity Limitations Identification were addressed with pipe replacements, upsizing, or, in cases where there is a reverse slope pipe, re-grading until the pipe met capacity criteria under 25-year buildout peak hour wet weather conditions. No alternatives to pipe replacement, upsizing, or regrading reversed slope pipes were developed. Figure 7-3 depicts Type B improvements recommendations with the original and replacement pipe sizes. Type B improvement costs are addressed as one lump sum in the cost estimate section. These pipe deficiencies and improvements should be verified before any design is begun. Type B capacity limitations should be further validated through additional localized flow monitoring and invert survey to verify capacity constraints and, if still valid, further capital improvements may be necessary.

7.1.5 Type C Problem Improvements

Type C problems are isolated stretches of sewer in the local collector and local systems where peak wet weather flow levels fall between 60 and 80 percent d/D. For the majority of these sewers this threshold is only marginally exceeded. Figure 7-4 shows these locations.

Type C sewers are under stress for the model scenarios, but are not significant enough to constitute their own capital improvement projects. Type C areas are locations where CCTV and localized flow monitoring and invert survey are recommended to validate the problem extent. Based on the results from the capacity validation activities and actual upstream growth, they could be considered for upsizing if necessary. In areas of the system with little upstream growth and future additional flow, some of the Type C problems may be addressed through decreased RDII contribution as the local and local collector systems are rehabilitated. Neither pipe improvement alternatives nor costs were developed for Type C problems.

Figure 7-3. Type B Improvement with Original and Replacement Pipe Sizes

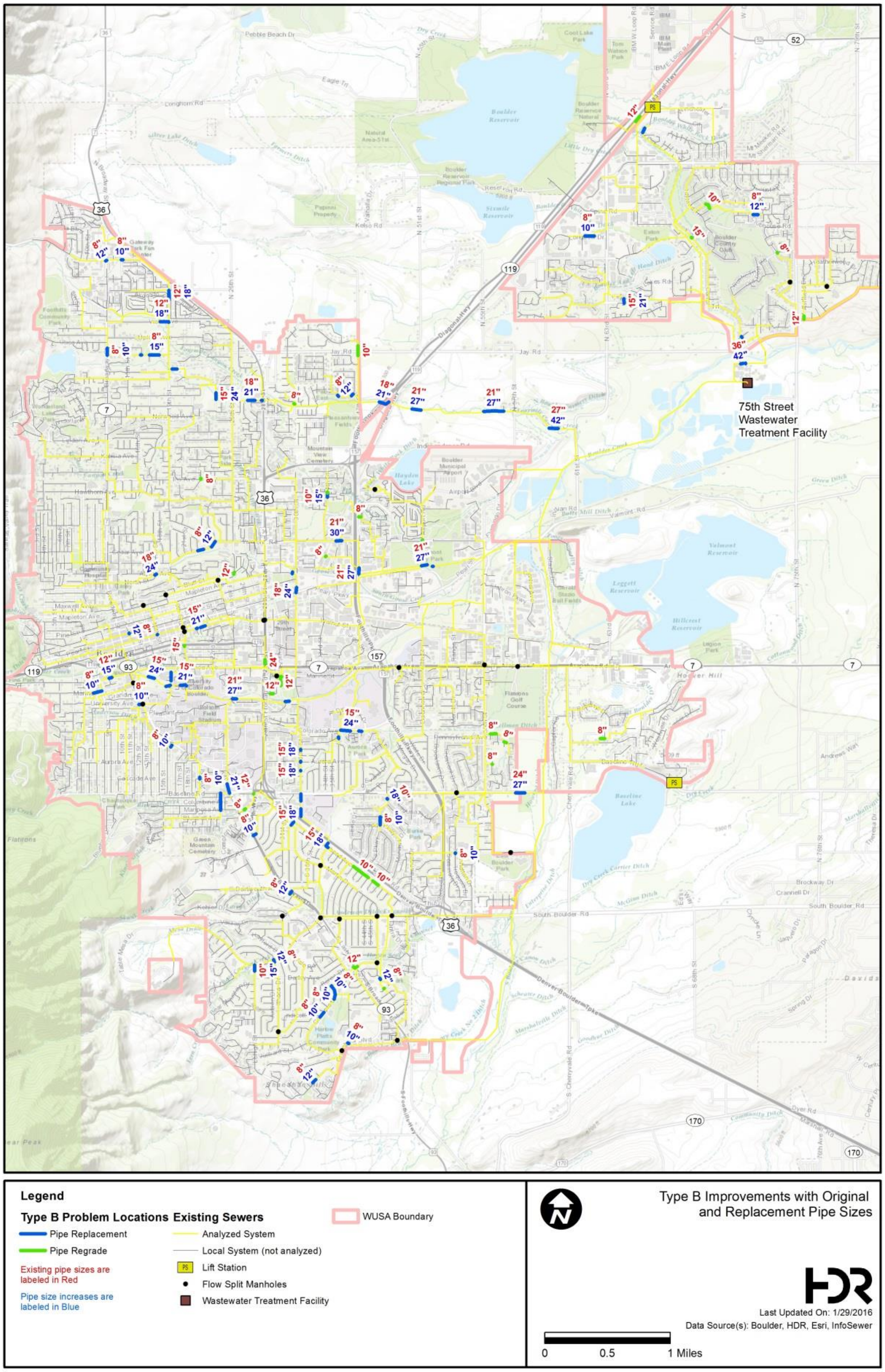
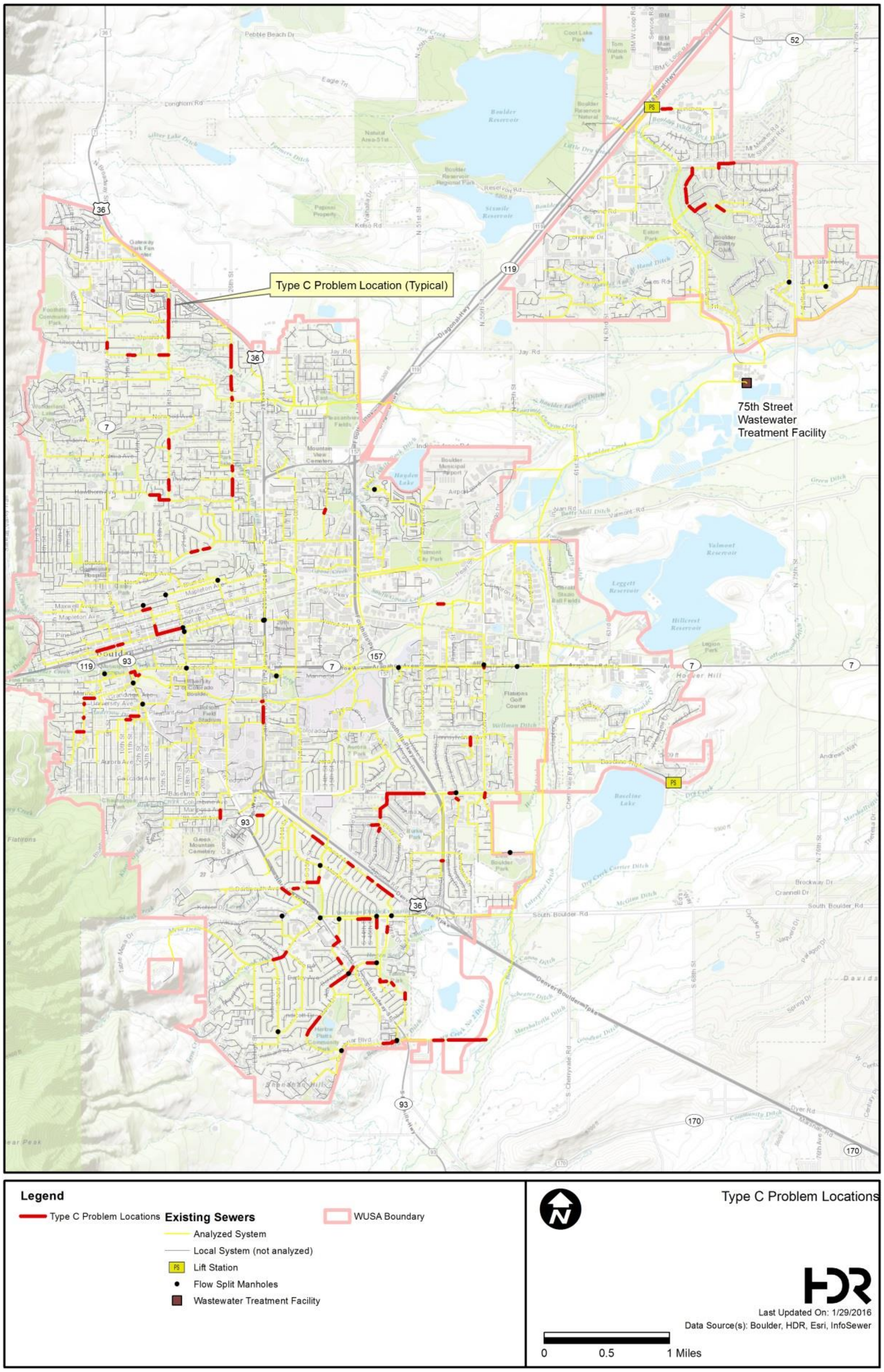


Figure 7-4. Type C Problem Locations



7.2 Boulder Creek Interceptor Capacity

The city has observed that the Boulder Creek Interceptor is reaching capacity during wet weather events and has experienced surcharging and SSOs during rainfall events less than a 15-year reoccurrence interval. Modeling confirms this observation in that the Boulder Creek Interceptor is under capacity for all modeled events, including portions of the interceptor under existing ADWF conditions. One of the main environmental compliance goals of the city is addressing this section of interceptor. Therefore, the Boulder Creek Interceptor parallel improvement project is recommended as a Type A Tier 1 improvement. Through modeling under the 25-year buildout peak hour wet-weather condition scenario, a 48-inch transitioning into a 54-inch parallel interceptor improvement is recommended to accommodate the 70 mgd flow from the Goose Creek, Boulder Creek, Fourmile Creek, and South Boulder Creek basins.

Of the 70 mgd total interceptor flow, 7 mgd is from the Fourmile Creek basin. The flow from the Fourmile Creek basin would need to be routed to the parallel interceptor via a diversion along 61st Street. Challenges of this diversion include:

- Passing under Boulder Creek
- Construction along 61st Street.
- The diversion sewer bucking grade going south away from Boulder Creek

These challenges would result in a likely siphon lift station and force main to pass the 7 mgd flows under Boulder Creek to minimize depth along 61st Street. The force main is recommended to be two parallel 12-inch and 16-inch diameter pipes to balance flows through the force mains between dry and wet weather conditions as well as handle the range of existing and future flows. Duel force mains also provide the advantage of operational redundancy during maintenance periods and maintaining scour velocity during dry-weather flow periods.

7.3 Construction Costs

Itemized opinion of probable construction cost (OPCC) estimates were developed for each recommended Type A improvement project with an anticipated level of accuracy of +50% to –30% (order-of-magnitude cost estimates). Type B improvement project costs are provided as a lump sum to be considered for use in monitoring and verifying capacity problems and improvement of confirmed issues. These cost estimates were prepared with the use of costing spreadsheets and model layouts typical of a master plan, with applying topography and system requirements to overall horizontal and vertical pipe layout. Cost estimates were not prepared to the detail of site specific information, constructability issues, or equipment details. The cost estimate worksheets are included in Appendix A for reference.

The estimates include capital construction costs and estimated land acquisition costs. Unit costs were obtained from Front Range bid tabs, RSMeans® Site Work and Landscape Cost Data, and equipment suppliers. Unit costs for pipeline and manhole construction include material, excavation, and backfill. Surface restoration was developed as a separate cost item. Minor utility relocations were accounted for as a percentage of the total construction cost. Quantities for pipes, manholes, and related improvements were obtained from the project GIS and hydraulic model based on the capacity analysis.

The wastewater utility modeling identified project areas (Type A) and pipes (Type B) that would have to be removed and replaced, augmented, or regraded. This information was broken down per problem type (Type A or Type B), problem area (Type A), pipe diameter, manhole diameter, and improvement bury depths. The costs were developed based on the factors these quantities along with the stated assumptions below. All estimates are escalated to 2015 dollars and equate to an Engineering News Record, Construction Cost Index of 10,092.

Each heading is discussed in the order presented in the Budget Cost estimate sheets.

Insurance and Bonding – 10 percent of Pipe Improvement Subtotal costs for contractor insurance and bonding.

Mobilization – 6 percent of Pipe Improvement Subtotal costs for contractor equipment mobilization and staging setup. Mobilization was reduced for Boulder Creek 3 due to economy of scale.

Traffic Control – 5 percent of Pipe Improvement Subtotal costs for required traffic control during improvement construction. Traffic control was reduced for Boulder Creek 3 due to alignment being in a non-urban location.

Utility Relocation – 5 percent of Pipe Improvement Subtotal costs for temporary relocation of utilities (water, gas, electric, communications, etc.) encountered during improvement construction. Utility relocation was reduced for Boulder Creek 3 due to alignment being in a non-urban location.

Dewatering – 6 percent of Pipe Improvement Subtotal costs for dewatering of open trenches due to pipe alignments elevations determined to be at or below the mapped 8 foot groundwater table or within the 100-year flood plain.

Bypass Pumping – 12 percent of Pipe Improvement Subtotal costs for temporary routing of wastewater flows for pipes removed in the active system. Where possible, parallel pipes should be temporarily established to keep the active system in service and reduce or avoid parallel pipes until the new pipe is put into service. Bypass pumping was assigned a lump sum for Boulder Creek 3 based on discussion with the city based on the 61st Street Interceptor project.

Removal and Disposal – Cost based on pipe diameter of existing pipe and manhole to be removed and disposed.

Connect to Existing System – Reflects the number and cost of connecting to existing main lines that remain to the proposed new/replacement manholes.

Pipe – Shows the cost per diameter and depth of each replacement pipe segment within the problem area. The pipes are shown as “diameter in inches.depth to invert in feet”, i.e. 12.10 is a 12 inch diameter pipe with an average invert depth of 10 feet. Pipe cost has been developed utilizing contractor budget pricing for pipe equal to and greater 18 inch in diameter based on Vylon PS46 and A2000 PVC pipe. The cost of pipe below 18 inch diameter is based on 2008 Boulder Asset Management unit cost data using SDR 35 PVC pipe escalated to 2015 costs. The pipe costs reflect differences in excavation, bedding, and backfill quantities per pipe diameter and depth. This cost includes controlled fill placement over pipe but does not include final surface treatment. Existing Type B pipe was calculated to have an average depth to pipe of 10.5 feet and therefore pipe costs are based on the specified pipe diameter with a pipe depth of 12 feet (costs are based on every 2 feet of depth).

Service Taps – Cost to connect existing wastewater service lines to new wastewater main lines. This cost is sensitive to depth and is based on the 4 inch pipe cost from the pipe cost section above. The service lines replacement was assumed to be an average length of 25 feet in order to extend it to the edge of the right-of-way. Type B service taps were based on the average pipe depth of 11 feet. The number of service lines/taps was obtained from the city's GIS data.

Stream/Road Crossing – Stream and road crossings are difficult to estimate based on unknown costs for permitting, stream flow rates, surrounding improvements and channel confinement among other factors. For this budget level cost estimate, sewers crossing streams were assumed to be cased with a casing pipe diameter 18" greater than the carrier pipe diameter. Unit costs are based on inch-diameter/100 lineal feet for the casing pipe.

Surface Restoration – Cost to restore surface to final condition, landscaped or hard paved. Assumes subgrade has been placed to appropriate elevation and density. The three surface restoration types assume a 12 foot surface restoration width regardless of the pipe diameter or depth. Asphalt depth was assumed to be 6 inches.

Manholes – Cost to replace manholes based on manhole type and diameter. Manhole depth was assumed to be a standard 10 feet.

Design Contingency – Type A Design Contingency is 30 percent, typical for budget planning efforts based on the detail of design data. Type B Design Contingency is 35% due to the averaging and combining of improvements. In addition, this allows for Type B projects to be extended some to address their confirmed project extents. Type B improvement project budget should be first used to confirm and then address any problems.

Engineering Design and Construction Administration – This cost is a standard 20 percent cost, typical for this level of budget planning.

7.4 Implementation Plan

Table 3 summarizes the implementation priorities as developed in Section 2 along with the opinions of probable construction costs. Itemized capital cost estimate worksheets are included in Appendix A. Based on discussion with the city, the Type A problems were prioritized accordingly. Table 3 presents these capital improvement costs in order of established priority.

Table 7-3. Existing Sewer System Summary – Modeled Elements

Problem Priority	Improvement ID	Improvement Location	Improvement Size (inches)	Total Improvement Length (feet)	Capital Cost
Tier 1	Boulder Creek 3	Valmont Rd and 61st St to WWTP	12 (FM),16 (FM),42, 48, 54, and 7 mgd Firm Lift Station	19,174	$19,673,000
Tier 1	South Boulder Creek 2	Foothills Pkwy, Baseline Rd	10, 12, 15, 18, 21, 24, 30	5,880	$3,497,000
Tier 1	Boulder Creek 2	Arapahoe Ave and Foothills Pkwy to Old Tale Rd; South Boulder Creek corridor	30, 36, 42	10,810	$12,605,000
Tier 1	Goose Creek 4	Foothills Pkwy and Pearl St	42	4,016	$2,584,000
				TIER 1 TOTAL	**$38,359,000**
Tier 2	Goose Creek 1	19th Street from Kalmia Ave to Grape Ave	10, 12	2,539	$1,292,000
Tier 2	South Boulder Creek 1	Table Mesa Dr, South Boulder Rd, S 46th St	10, 12, 15, 18, 21, 24, 30	21,478	$17,370,000
Tier 2	Boulder Creek 1	Colorado Ave and 28th St	12, 15, 24	5,118	$4,298,000
Tier 2	Goose Creek 3	28th Street from Pine St to Walnut St	24, 30	1,945	$1,250,000
Tier 2	Goose Creek 2	Folsom St/Glenwood Dr/Valmont Rd	12, 18	7,063	$4,004,000
Tier 2	Gunbarrel 1	Boulder and Left Hand Ditch; Idylwild Tr/Boulder Country Club	8, 10, 12, 15, 21, 24	7,395	$4,388,000
Tier 2	Gunbarrel 2	Boulder Supply Canal north of Jay Rd	18, 30, 36,	6,786	$5,467,000
				TIER 2 TOTAL	**$38,069,000**
				TIER 3 TOTAL1	**$18,299,000**
				TOTAL ALL PROJECTS TOTAL	**$94,727,000**

[1]Tier 3 cost reflect Type B improvements

7.5 Capital Project Tier I Fact Sheets

Fact sheets were developed to provide details regarding each of the Tier 1 improvement areas. These fact sheets provide the problem area ID, improvement location and alignment, technical data for initiating the design process, land ownership and acquisition needs, probable implementation issues, and an estimate of the capital construction costs. Flow triggers are included for the interceptor improvements to provide a flow rate when the capacity of the interceptor is reached according to the established capacity limitation criteria, and when improvements should be designed. The improvement plan map shown in the fact sheets identifies the recommended pipe size and lengths and general manhole locations.

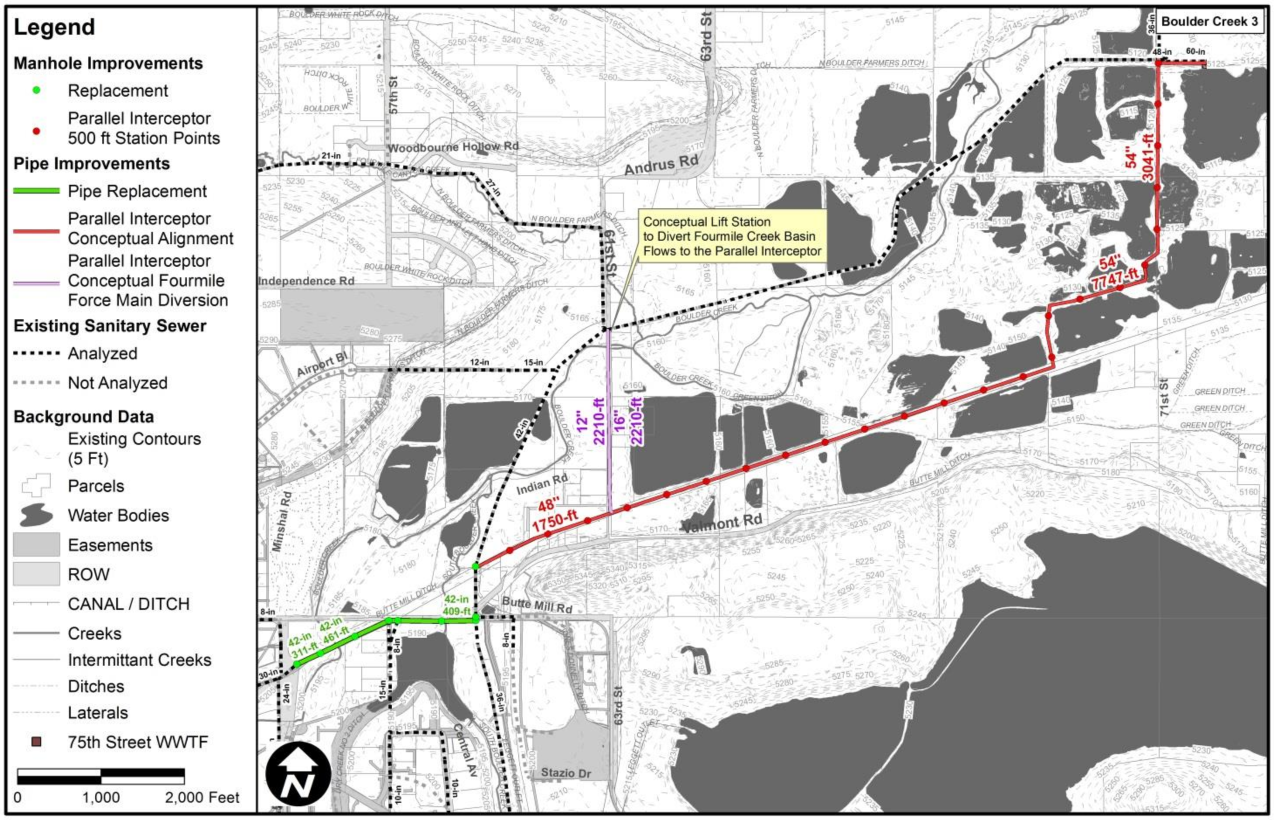
The Data Confidence category within the fact sheets refers to the percentage of interpolated invert elevations needed to complete the modeling effort; specific information regarding this category is included in the problem characterization tables in Section 6. Similarly, the Calibration Confidence refers to how well model results matched the permanent flow meter data. *It is recommended that projects with a Medium confidence level in the Calibration category and confidence levels below 70 percent in the Data category be refined through data surveys and/or temporary flow monitoring before they are included in the Utilities' 6-year CIP project list to validate the project elements.*

This section includes fact sheets that provide details for each of the Type A (Tier 1 and Tier 2) improvement areas. These fact sheets are organized by their established priority.

Table 7-4. Boulder Creek 3 Capital Project Tier I Fact Sheet

Improvement Location: **Valmont Rd and 61st St to WWTP**

Problem ID: **Boulder Creek 3 (Tier 1 Priority Level)**



Improvement Description

- Replace 2,216 feet of existing interceptor pipe from 36-inch diameter to 42-inch diameter.
- Construct 1,750 feet of 48-inch diameter and 10,788 feet of 54-inch diameter parallel interceptor pipe.
- Plug and abandon existing interceptor to the north of the new parallel interceptor.
- Construct new 7 mgd firm lift station to divert flows from the Fourmile Creek basin to the new parallel interceptor.
- Construct 2,210 feet of parallel 16-inch and 12-inch diameter force main along 61st Street

Technical Data: The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 13,849 gpm in the Valmont Road interceptor (from the Goose Creek basin) to 43,687 gpm in the parallel Boulder Creek interceptor (after receiving Boulder Creek flow).

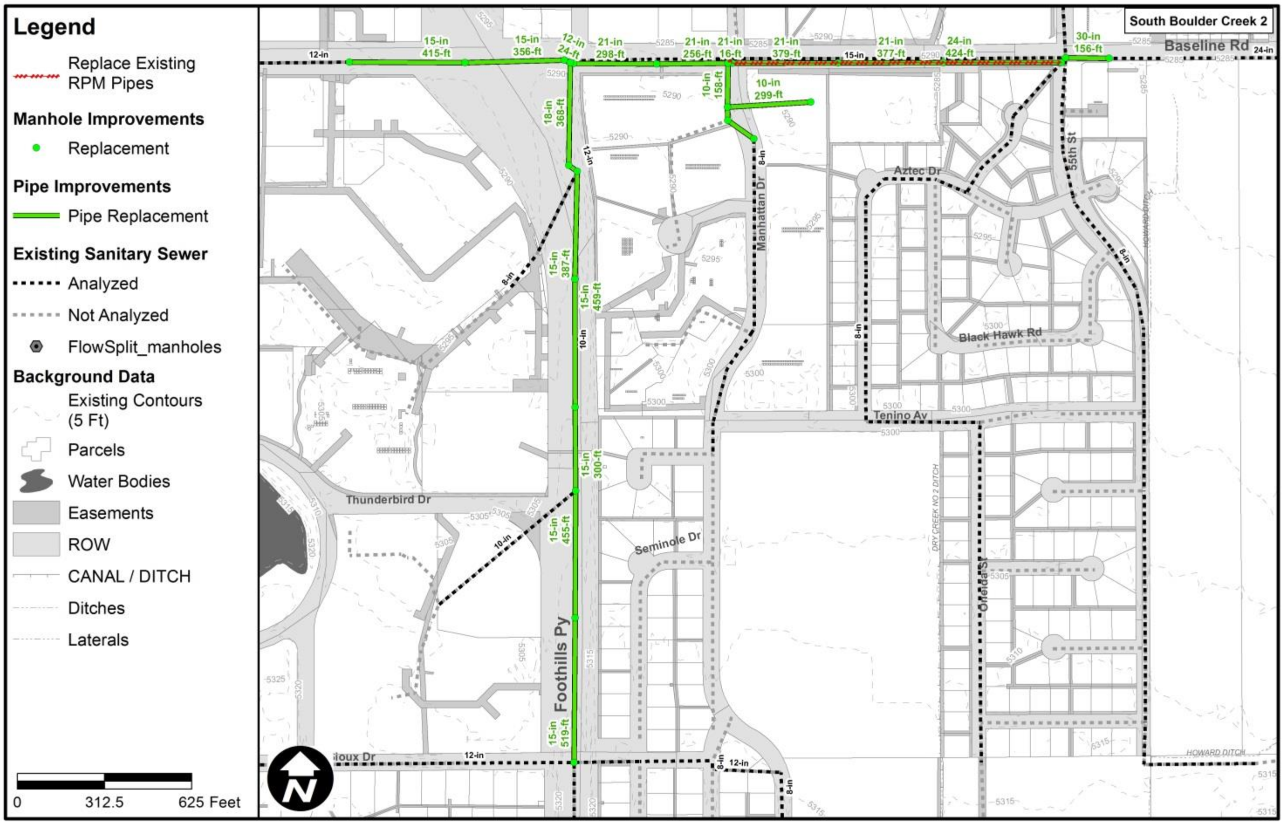
Data Confidence: 100% (0 of 32 pipes in the corresponding pipe run adjusted)

Calibration Confidence: High

Flow Trigger:	9,870 gpm on 30-inch line along Valmont Rd
Land Ownership:	ROW purchase will be necessary for the parallel interceptor as the alignment does not follow an established road or easement.
Implementation Issues:	• Dewatering will be required along the entire alignment. • Constructability issues due to alignment around existing gravel pits and potentially along a railroad ROW • Surface treatment of primarily open space with some asphalt pavement.
Estimated Capital Cost:	$19,673,000

Table 7-5. South Boulder Creek 2 Capital Project Tier I Fact Sheet

Improvement Location:	**Foothills Pkwy, Baseline Rd**
Problem ID:	**South Boulder Creek 2 (Tier 1 Priority Level)**

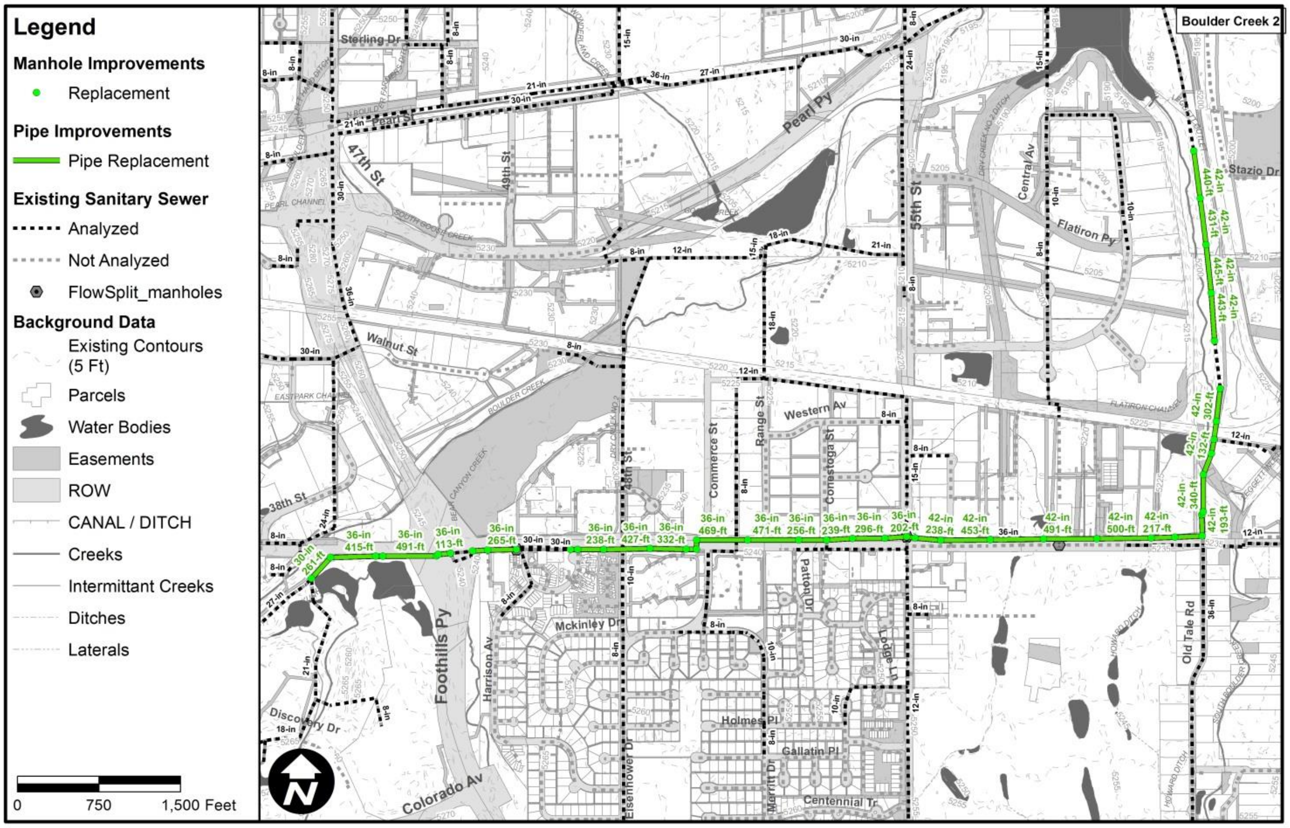


Improvement Description	• Replace 619 feet of existing local collector pipe from 8-inch diameter to 10-inch diameter. • Replace 2,120 feet of existing pipe from 10-inch diameter to 15-inch diameter. • Construct 24 feet of 12-inch diameter pipe connection so that only one sewer line needs to be upsized. • Replace 771 feet of existing local collector pipe from 12-inch diameter to 15-inch diameter. • Replace 405 feet of existing local collector pipe from 12-inch diameter to 18-inch diameter. • Replace 12 feet of existing collector/interceptor pipe from 15-inch diameter to 18-inch diameter. • Replace 1,326 feet of existing collector/interceptor pipe from 15-inch diameter to 21-inch diameter (7 feet of which is RPM pipe). • Replace 447 feet of existing collector/interceptor pipe from 15-inch diameter to 24-inch diameter (424 feet of which is RPM pipe). • Replace 156 feet of existing pipe from 24-inch diameter to 30-inch diameter.

Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 12 gpm in the local collector pipes to 3,583 gpm in the collector/interceptor pipes.
Data Confidence:	85% (3 of 20 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	750 gpm on 12-inch line along Baseline Rd; 600 gpm on 10-inch line along Foothills Pkwy
Land Ownership:	Construction is limited to Foothills Pkwy, Baseline Rd, and Manhattan Dr ROWs and land presently owned by the city. No land ownership issues should be present.
Implementation Issues:	• Constructability issues due to highway and major roads will slow rate of construction. • Requires a crossing of three canals: West Valley Split Flow, 55th Street Split Flow, and Dry Creek Ditch No. 2. • Surface treatment of asphalt pavement.
Estimated Capital Cost:	$3,497,000

Table 7-6. Boulder Creek 2 Capital Project Tier I Fact Sheet

Improvement Location:	**Arapahoe Ave and Foothills Pkwy to Old Tale Rd; South Boulder Creek Corridor**
Problem ID:	**Boulder Creek 2 (Tier 1 Priority Level)**

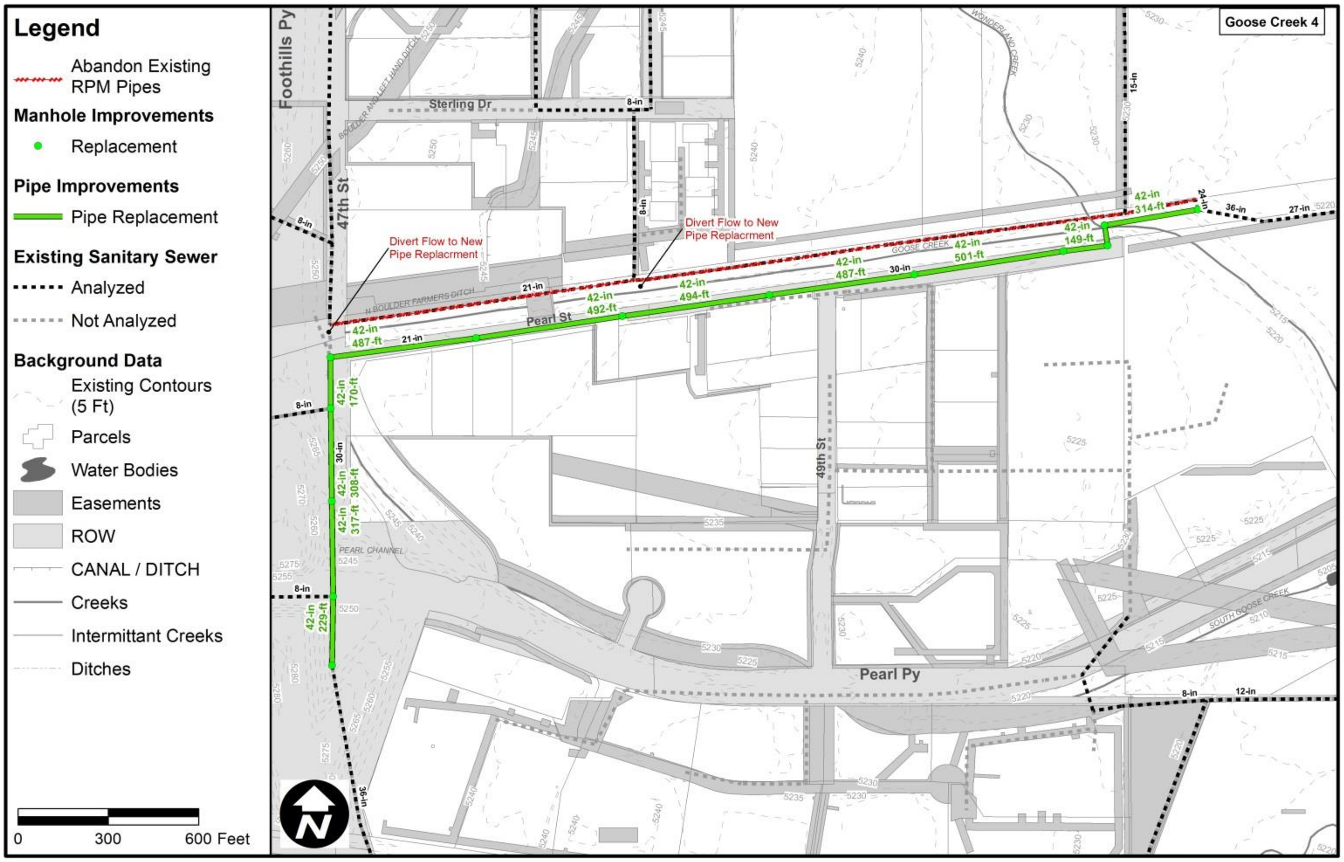


Improvement Description	• Replace 262 feet of existing collector/interceptor pipe from 27-inch diameter to 30-inch diameter. • Replace 973 feet of existing collector/interceptor pipe from 27-inch diameter to 36-inch diameter. • Replace 3,714 feet of existing collector/interceptor pipe from 30-inch diameter to 36-inch diameter. • Replace 5,861 feet of existing collector/interceptor pipe from 36-inch diameter to 42-inch diameter.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 2,017 gpm to 4,108 gpm in the collector/interceptor pipes.
Data Confidence:	80% (6 of 30 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	9,330 gpm on 27-inch line along Arapahoe Ave

Land Ownership:	Construction is limited to Arapahoe Ave. ROW, utility ROW, and land presently owned by the city. No land ownership issues should be present.
Implementation Issues:	• Constructability issues due to highway and major roads will slow rate of construction. • Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. • Requires crossing Arapahoe Ave. • Requires crossing Foothills Pkwy. • Bypass pumping of large volumes of sewage. • Surface treatment of primarily asphalt pavement with some open space.
Estimated Capital Cost:	$12,605,000

Table 7-7. Goose Creek 4 Capital Project Tier I Fact Sheet

Improvement Location:	**Foothills Pkwy and Pearl St**
Problem ID:	**Goose Creek 4 (Tier 1 Priority Level)**

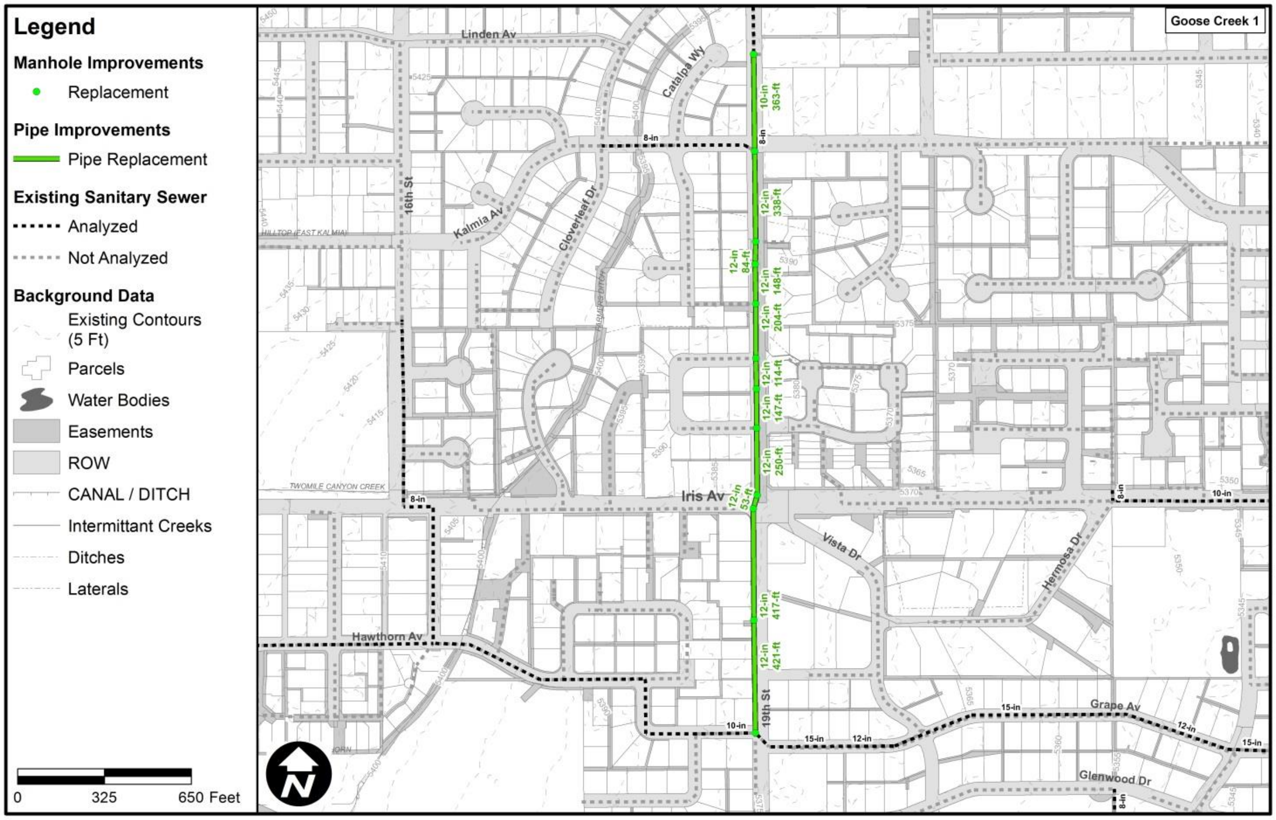


Improvement Description	• Replace 487 feet of existing collector/interceptor pipe from 21-inch diameter to 42-inch diameter. • Replace 3,529 feet of existing collector/interceptor pipe from 30-inch diameter to 42-inch diameter. • Abandon existing RPM pipes and divert flow south to new replacement pipe.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 8,650 gpm to 8,876 gpm in the collector/interceptor pipes.
Data Confidence:	70% (3 of 10 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	4,300 gpm on 30-inch line at the intersection of Pearl Pkwy and Foothills Pkwy
Land Ownership:	Construction is limited to Foothills Pkwy and Pearl St ROWs and land presently owned by the city. No land ownership issues should be present.

Implementation Issues:	• Dewatering will be required. • Constructability issues due to road construction. • Requires crossing Foothills Pkwy. • Requires crossing North Goose Creek • Bypass pumping of large volumes of sewage.
Estimated Capital Cost:	$2,584,000

Table 7-8. Goose Creek 1 Capital Project Tier I Fact Sheet

Improvement Location:	**19th Street from Kalmia Ave to Grape Ave**
Problem ID:	**Goose Creek 1 (Tier 2 Priority Level)**

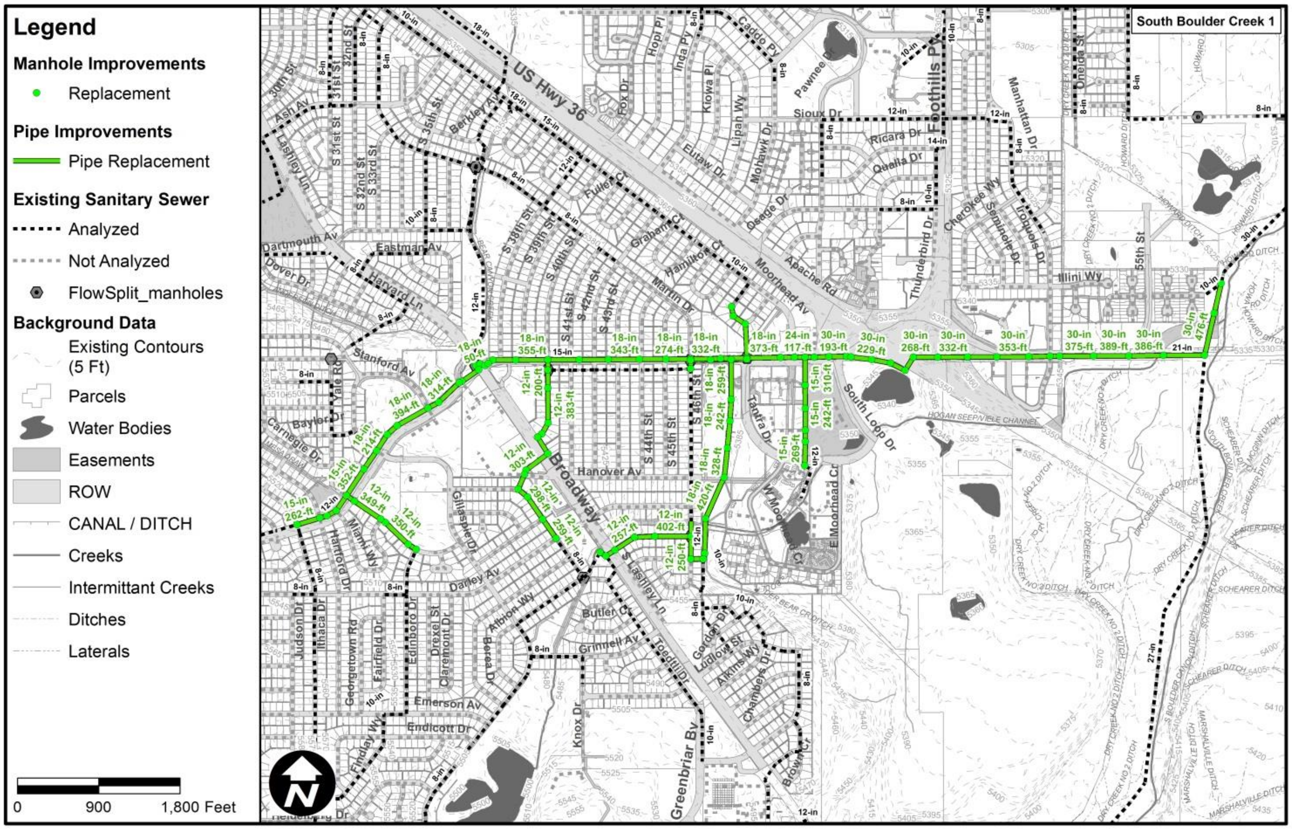


Improvement Description	• Replace 363 feet of existing local collector pipe from 8-inch diameter to 10-inch diameter. • Replace 1,338 feet of existing local collector pipe from 8-inch diameter to 12-inch diameter. • Upsize 838 feet of existing local collector pipe from 10-inch diameter to 12-inch diameter.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 319 gpm to 631 gpm in the local collector pipes.
Data Confidence:	80% (2 of 10 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Flow Trigger:	230 gpm on 8-inch line along 19th St
Land Ownership:	Construction is limited to 19th Street ROW along local streets

Implementation Issues:	• Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. • Constructability issues due to road construction. • Bypass pumping required.
Estimated Capital Cost:	$1,292,000

Table 7-9. South Boulder Creek 1 Capital Project Tier I Fact Sheet

Improvement Location:	**Table Mesa Dr, South Boulder Rd, S 46th St**
Problem ID:	**South Boulder Creek 1 (Tier 2 Priority Level)**



Improvement Description

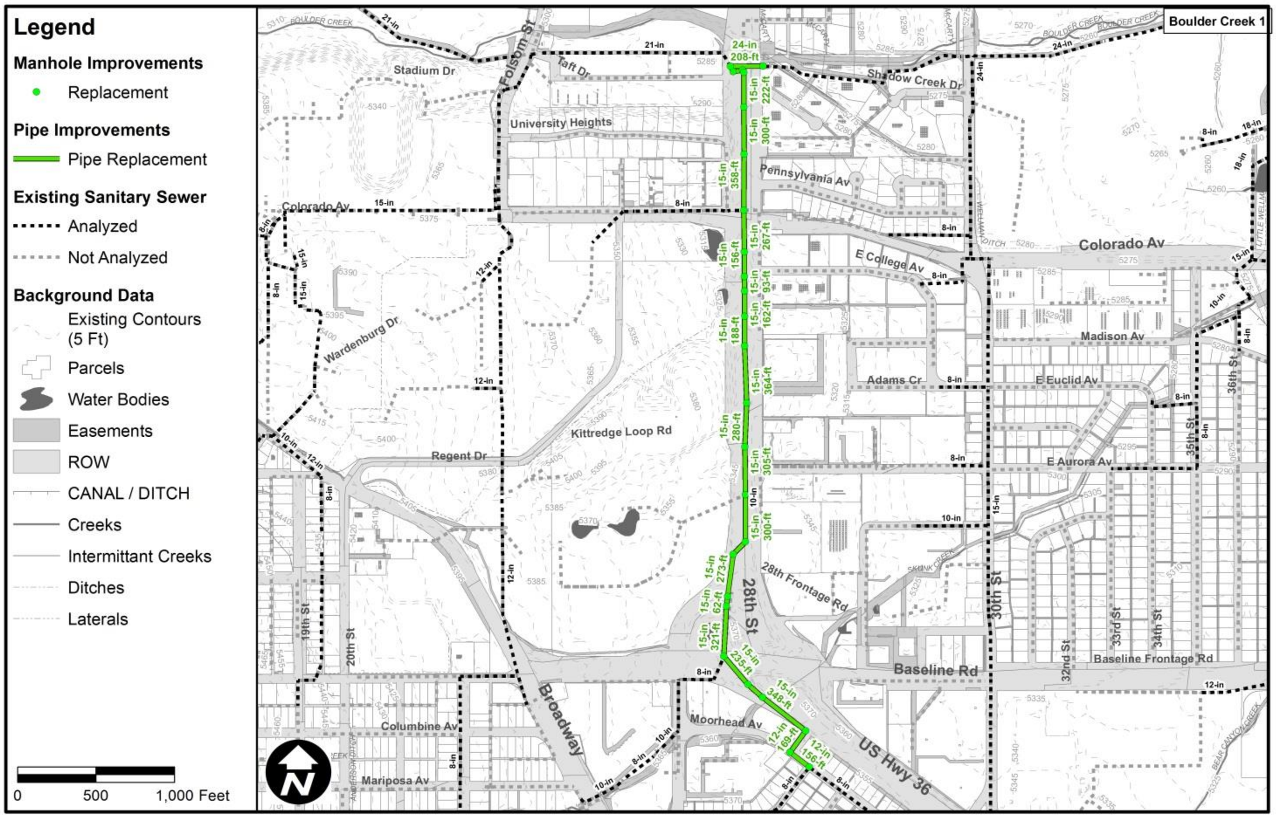
- Replace 109 feet of existing local collector pipe from 8-inch diameter to 10-inch diameter.
- Replace 2,863 feet of existing local collector pipe from 8-inch diameter to 12-inch diameter.
- Replace 2,366 feet of existing local collector pipe from 10-inch diameter to 12-inch diameter.
- Replace 616 feet of existing local collector pipe from 10-inch diameter to 15-inch diameter.
- Replace 2,401 feet of existing local collector pipe from 12-inch diameter to 15-inch diameter.
- Replace 1,500 feet of existing local collector pipe from 10-inch diameter to 18-inch diameter.
- Replace 2,469 feet of existing local collector pipe from 12-inch diameter to 18-inch diameter.
- Replace 3,107 feet of existing collector/interceptor pipe from 15-inch diameter to 18-inch diameter.

	• Replace 377 feet of existing local collector pipe from 10-inch diameter to 21-inch diameter. • Replace 375 feet of existing collector/interceptor pipe from 15-inch diameter to 24-inch diameter. • Replace 549 feet of existing collector/interceptor pipe from 15-inch diameter to 30-inch diameter. • Replace 354 feet of existing collector/interceptor pipe from 18-inch diameter to 30-inch diameter. • Replace 3,576 feet of existing collector/interceptor pipe from 21-inch diameter to 30-inch diameter. • Replace and re-grade 816 feet of 30-inch diameter collector/interceptor pipe (slope adjustment). • Plug 10 inch line at an existing flow diversion to only upsize on stretch of sewer main
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 5 gpm in the local collector pipes to 9,290 gpm in the collector/interceptor pipes.
Data Confidence:	79% (15 of 72 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	2,040 gpm on 12-inch line along Table Mesa Dr, 210 gpm on 8-inch line along Toedtli Dr; 270 gpm on 8-inch line at Broadway Ave at the Viele Lake Canal crossing
Land Ownership:	Construction is limited to Table Mesa Dr, US Hwy 36, Foothills Pkwy,Yale Rd, S 40th St, Toedtli Dr, Whitney Pl, 48th St, Brookfield Dr, Ingram Ct, and 46th St ROWs, utility easements, land presently owned by the city, and private parking lots.
Implementation Issues:	• Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. • Large area of construction impacting several roadways. • Constructability issues due to highway and major roads will slow rate of construction. • Requires crossing Bear Canyon Creek, Viele Lake Canal at three locations, and Anderson Extension Ditch at seven locations. • Requires crossing Broadway at three locations. • Requires crossing US Hwy 36. • Requires crossing Foothills Pkwy. • Bypass pumping of large volumes of sewage. • Requires crossing Tantra Dr.
Estimated Capital Cost:	$17,370,000

Table 7-10. Boulder Creek 1 Capital Project Tier I Fact Sheet

Improvement Location: **Colorado Ave and 28th St**

Problem ID: **Boulder Creek 1 (Tier 2 Priority Level)**



Improvement Description

- Replace 324 feet of existing local collector pipe from 8-inch diameter to 12-inch diameter.
- Replace 472 feet of existing local collector pipe from 8-inch diameter to 15-inch diameter.
- Replace 4,114 feet of existing local collector pipe from 10-inch diameter to 15-inch diameter.
- Replace 208 feet of existing pipe from 21-inch diameter to 24-inch diameter.

Technical Data: The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 639 gpm to 5,250 gpm in the local collector pipes.

Data Confidence: 80% (3 of 15 pipes in the corresponding pipe run adjusted)

Calibration Confidence: Medium

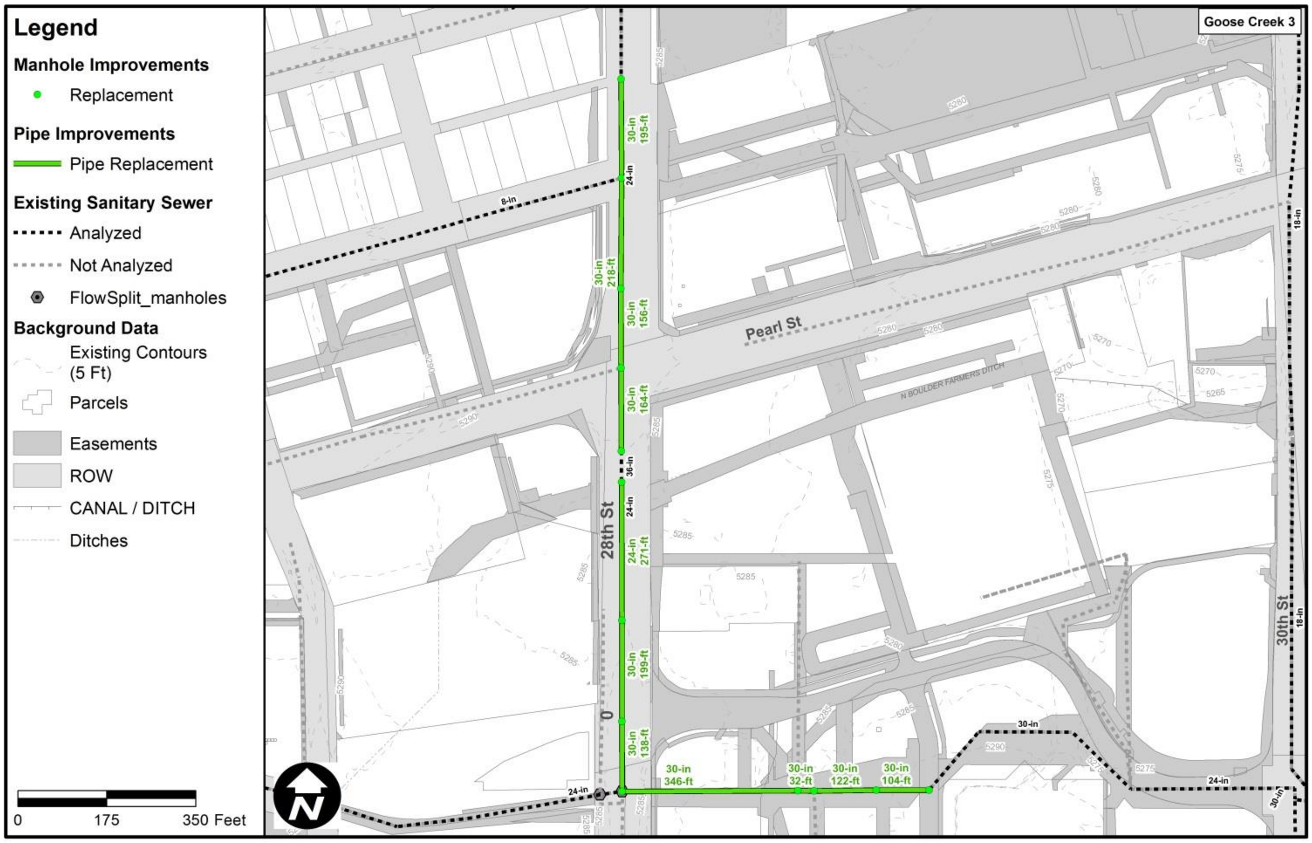
Flow Trigger: 230 gpm on 8-inch line along Moorhead Ave

Land Ownership: Construction is limited to Moorhead Ave, Moorhead Frontage Rd, US Highway 36, and 28th Frontage Rd ROWs. No land ownership issues should be present.

Implementation Issues:	• Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. • Constructability issues due to highway and major roads will slow rate of construction. • Requires construction under Colorado Avenue Creek and along US Highway 36. • Bypass pumping of large volumes of sewage. • Requires construction under Skunk Creek. • Surface treatment of concrete and asphalt pavement.
Estimated Capital Cost:	$4,298,000

Table 7-11. Goose Creek 3 Capital Project Tier I Fact Sheet

Improvement Location:	**28th Street from Pine St to Walnut St**
Problem ID:	**Goose Creek 3 (Tier 2 Priority Level)**

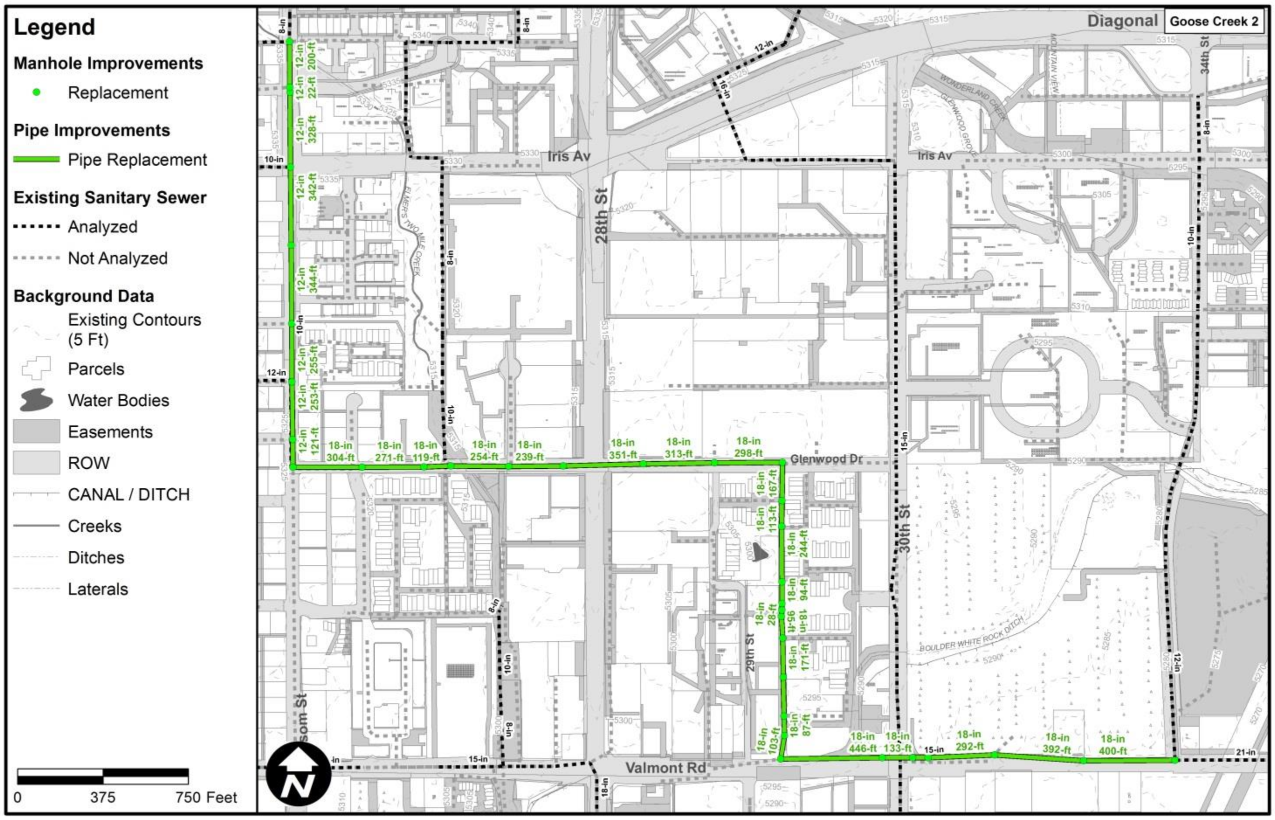


Improvement Description	• Replace and re-grade 272 feet of 24-inch diameter collector/interceptor pipe (slope adjustment). • Replace 1,673 feet of existing collector/interceptor pipe from 24-inch diameter to 30-inch diameter.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 2,106 gpm to 2,961 gpm in the collector/interceptor pipes.
Data Confidence:	66% (1 of 3 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	Medium
Flow Trigger:	3,150 gpm on 24-inch line along 28th St
Land Ownership:	Construction is limited to 28th Street ROW and utility easements across privately owned parking lots. Access to the utility easements across privately owned parking lots should be accessible but may require special permission from owners.

Implementation Issues:	• Constructability issues due to highway and major roads will slow rate of construction. • Bypass pumping required. • Surface treatment of concrete and asphalt pavement.
Estimated Capital Cost:	$1,250,000

Table 7-12. Goose Creek 2 Capital Project Tier I Fact Sheet

Improvement Location:	**Folsom St/Glenwood Dr/Valmont Rd**
Problem ID:	**Goose Creek 2 (Tier 2 Priority Level)**

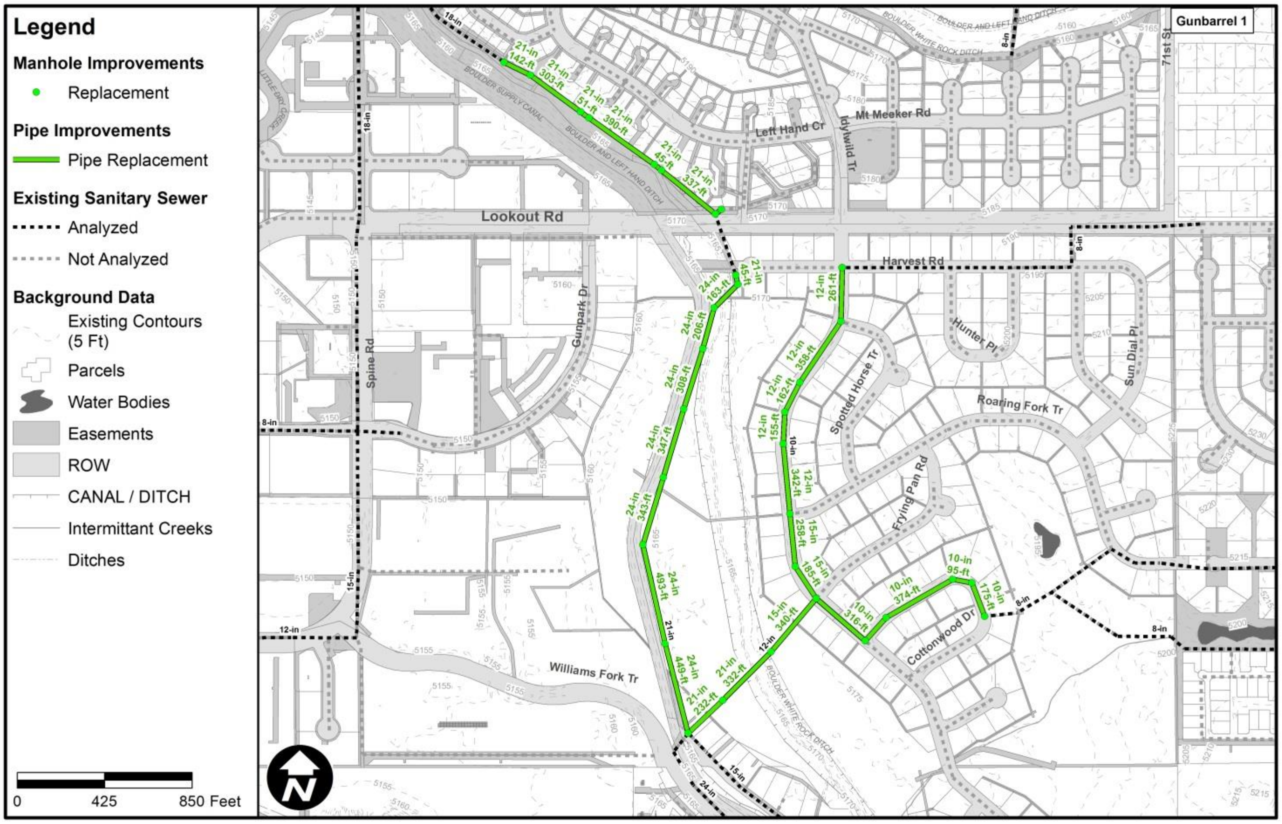


Improvement Description	• Replace 1,866 feet of existing local collector pipe from 10-inch diameter to 12-inch diameter. • Replace 5,197 feet of existing collector/interceptor pipe from 15-inch diameter to 18-inch diameter.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 443 gpm in the local collector pipes to 2,986 gpm in the collector/interceptor pipes.
Data Confidence:	71% (6 of 21 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	440 gpm on 10-inch line along Folsom St
Land Ownership:	Construction is limited Folsom St, Glenwood Dr, and Valmont Rd ROWs and utility easements across private property boundaries. Access to the utility easements across private property should be accessible but may require special permission from owners.

Implementation Issues:	• Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. • Constructability issues due to highway and major roads will slow rate of construction. • Requires crossing 28th St. • Requires crossing Elmer's Twomile Creek at two locations. • Requires crossing White Rock Ditch. • Bypass pumping required. • Surface treatment of open space, concrete and asphalt pavement.
Estimated Capital Cost:	$4,004,000

Table 7-13. Gunbarrel 1 Capital Project Tier I Fact Sheet

Improvement Location:	**Boulder and Left Hand Ditch; Idylwild Tr/Boulder Country Club**
Problem ID:	**Gunbarrel 1 (Tier 2 Priority Level)**

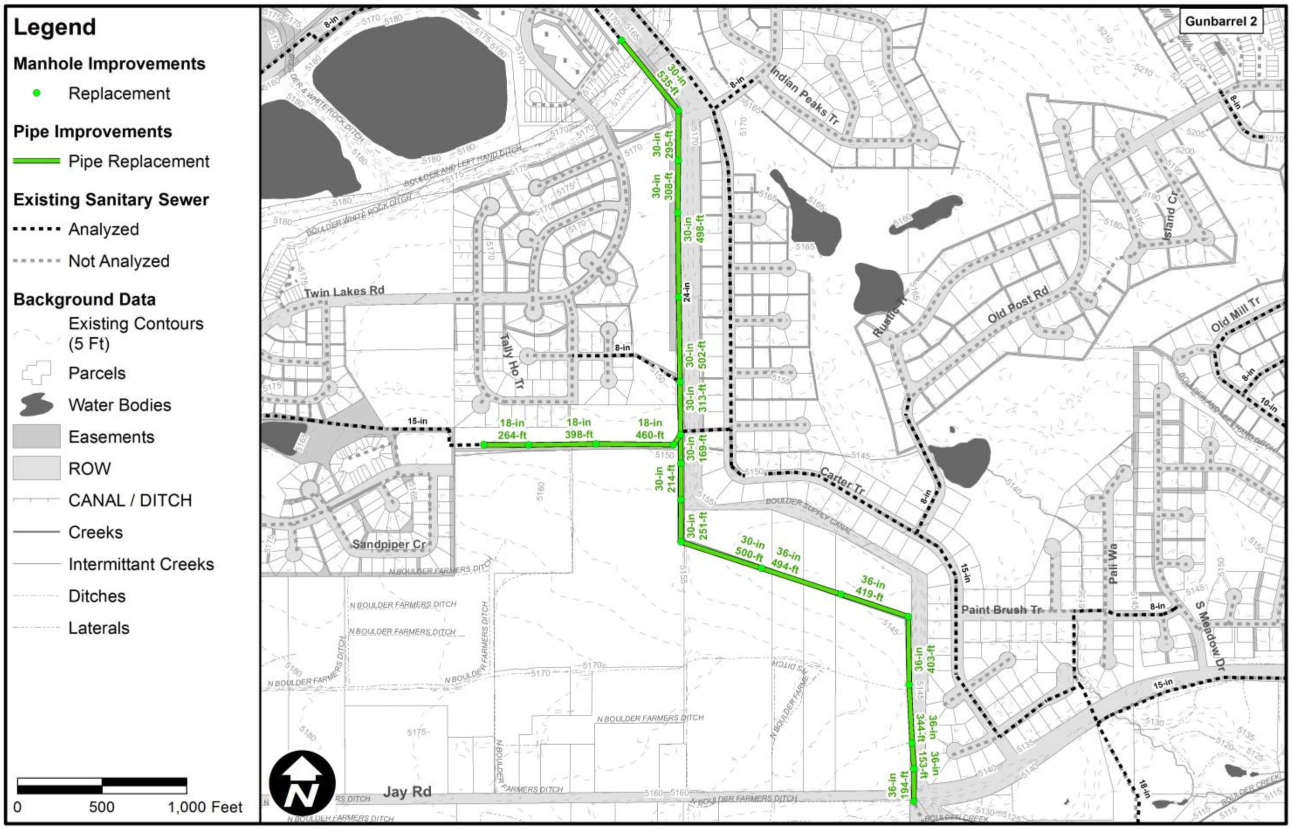


Improvement Description	• Replace and re-grade 37 feet of 8-inch diameter local collector pipe (slope adjustment). • Replace 1,111 feet of existing local collector pipe from 8-inch diameter to 10-inch diameter. • Replace 1,278 feet of existing local collector pipe from 10-inch diameter to 12-inch diameter. • Replace 784 feet of existing local collector pipe from 12-inch diameter to 15-inch diameter. • Replace 564 feet of existing local collector pipe from 12-inch diameter to 21-inch diameter. • Replace 1,268 feet of existing collector/interceptor pipe from 18-inch diameter to 21-inch diameter. • Replace and re-grade 45 feet of 21-inch diameter collector/interceptor pipe (slope adjustment). • Upsize 2,308 feet of existing pipe from 21-inch diameter to 24-inch diameter.

Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 61 gpm in the local collector pipes to 2,265 gpm in the collector/interceptor pipes.
Data Confidence:	80% (3 of 15 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	380 gpm on 10-inch line along Idylwild Tr; 1,160 gpm on 18-inch line along the ditch
Land Ownership:	Construction is along Idylwild Tr and Cottonwood Dr ROWs, along ditch corridors, through a golf course, and through residential properties. Special permission from landowner will be required and may involve purchase of ROW.
Implementation Issues:	• Constructability issues due to canal corridor. • Constructability issues due to private residential property. • Constructability issues due to golf course. • Requires crossing White Rock Ditch at two locations. • Requires crossing Lefthand Ditch at two locations. • Bypass pumping of large volumes of sewage. • Surface treatment of primarily open space and asphalt pavement. • Coordination issues and construction disturbance due to adjacent golf course.
Estimated Capital Cost:	$4,388,000

Table 7-14. Gunbarrel 2 Capital Project Tier I Fact Sheet

Improvement Location:	**Boulder Supply Canal north of Jay Rd**
Problem ID:	**Gunbarrel 2 (Tier 2 Priority Level)**



Improvement Description	• Replace 1,194 feet of existing collector/interceptor pipe from 15-inch diameter to 18-inch diameter. • Replace 3,585 feet of existing collector/interceptor pipe from 24-inch diameter to 30-inch diameter. • Replace 2,007 feet of existing collector/interceptor pipe from 24-inch diameter to 36-inch diameter.
Technical Data:	The entire system is required to convey buildout dry weather and 25-year level of service wet weather flows to the established analysis criteria. Expected buildout 25-year peak flow ranges from 1,357 gpm to 5,752 gpm in the collector/interceptor pipes.
Data Confidence:	43% (8 of14 pipes in the corresponding pipe run adjusted)
Calibration Confidence:	High
Flow Trigger:	3,590 gpm on 24-inch line along the ditch
Land Ownership:	Construction along a ditch corridor and across private property. If utility ROW exists in canal corridor, then no land ownership issues should be present along these segments. However, where the alignment crosses private property, sewer either may need to be realigned to follow the ditch corridor or ROW may need to be purchased.

Implementation Issues:	• Constructability issues due to ditch corridors. • Requires crossing Jay Rd. • Requires crossing Lefthand Ditch. • Requires crossing Boulder Farmers Ditch. • Requires crossing a perennial stream at two locations (name unknown). • Requires crossing a perennial stream (different from above, name unknown). • Bypass pumping of large volumes of sewage. • Surface treatment of primarily open space with some asphalt pavement.
Estimated Capital Cost:	$5,467,000

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8 Collection System Maintenance Review

The review and recommendations for the collection system operations and maintenance (O&M) procedures from the 2009 WWCSMP were not revised for this 2016 WWCSMP. This section therefore remains as published in the 2009 WWCSMP.

This section presents the findings of the Gravity Systems Maintenance Program Review and identifies the increases in service level that the city may need to implement to comply with trends currently evolving in the wastewater collection system industry. The purposes of this analysis were:

1. to examine the current state of Boulder's operations and maintenance (O&M) practices; and
2. to develop an estimation of increases in service level due to trends in the regulatory environment in the western region.

HDR's analysis is comprised of data collection and review, interviews, and telephone conversations with city staff. Data was collected during an on-site visit on December 18 and 19, 2007. The staff members who were interviewed are knowledgeable in Boulder's collection system O&M practices. This analysis assesses the current programs employed by the City of Boulder's Utility Maintenance group.

8.1 Background

The first sewer mains were installed in 1895 upon the creation of the utility in the city. Data stored in the GIS database indicate the oldest pipes where installed in the 1940s. It is not accurately known how many miles of sewers were installed between 1895 and 1940 or if any of these pipes are currently active. The utility does not have installation dates for all of its assets, but has made an assumption on installation date based on age of the developments where the assets are located. Based on these numbers, nearly 1/3 of the system is over 50 years old.

For purposes of this analysis, assumptions for probable changes in the regulatory environment in Colorado will be based on examples recently set in the west. The State of California has developed the Waste Discharge Requirements (WDR) regulation and Arizona has developed Rule C305. These regulations for sanitary sewer systems are similar in content to the Capacity, Management, Operations, and Maintenance (CMOM) regulation proposed but never implemented by the U.S. Environmental Protection Agency (EPA). Even though CMOM was never implemented, the EPA does support such state requirements and has enforced even stricter provisions to reduce or eliminate spills under the provisions of the Clean Water Act.

The WDR contains requirements for monitoring, reporting, developing and implementing Sewer System Management Plans (SSMPs). This regulation affects all municipal sewer agencies in the state with more than one mile of collection system and regulates the discharge of sanitary sewer overflows (SSOs).

The WDR defines an SSO as any overflow, spill, release, discharge, or diversion of untreated or partially treated wastewater from a sanitary sewer system, including:

- Overflows or releases of untreated or partially treated wastewater that reach waters of the United States;

- Overflows or releases of untreated or partially treated wastewater that do not reach waters of the United States; and
- Wastewater backups into buildings and on private property caused by blockages or flow conditions within the publicly owned portion of a sanitary sewer system.

8.2 Project Approach

HDR evaluated City of Boulder's Utility Maintenance performance based on industry knowledge of new regulations in the west. The city was evaluated as to whether they would be in regulatory compliance. Recommendations for improvement were made for areas where the city would not be in compliance, or where it was felt that business processes should be changed to meet standard industry practices. This analysis is a means of examining systemic factors that have contributed to or caused a gap between the current and future desired state of the system as outlined in the compliance requirements. The analysis process includes an in-depth analysis of the factors that have created the current state and lays the groundwork for improvement planning. This approach ensures that the system improvement process does not jump from identifying the problem areas to proposing and implementing solutions without first understanding the conditions that created the current state.

HDR conducted the analysis in accordance with the following guidelines:

- The research team gathered information and used it to develop desired system performance baselines (or levels of service) that are formed on the indicators mentioned in the analysis;
- The team identified the gaps between the current and future system performance level, and developed a problem statement that summarizes the underlying issues that must be addressed to progress towards full compliance;
- The team developed a root-cause analysis to determine the factors that are crucial for improvement; and
- These factors were then used to develop specific goals, and objectives for the improvement plan to satisfy the goals associated with any future state regulation.

8.3 Sewer System Management Plan

A critical requirement of California's WDR is to prepare a plan and a schedule to properly manage, operate, and maintain all parts of Boulder's sanitary sewer system in order to reduce, prevent, and mitigate SSOs. The WDR requires collection system managers to develop and implement the SSMP document and revise and update it every two years.

This section discusses the elements of the general WDR and HDR's opinion of Boulder's current performance status. Only the sections of the WDR relating to O&M of the system will be evaluated.

8.3.1 Operation and Maintenance Program - Organization and Staffing

Staff

The Utility Maintenance Group has three two-person cleaning crews, two rodding crews and one hydro flushing crew. There is also one three-person construction crew and two one-person CCTV vans and crews. Classifications and positions that support the operations and maintenance programs are as follows:

Wastewater Maintenance Supervisor (1) – Supervises all collection system activities

Maintenance Person IV (1) –This position is the construction crew lead and performs tasks related to the maintenance and repair of the sewer system. This position is the equipment operator for the construction crew.

Maintenance Person III (4) – One of the positions in this classification is on the construction crew and performs tasks related to sewer repairs. The other three positions are the operator's of the two-person maintenance crews. One operates a hydro flushing truck and the other two operate the mechanical rodding equipment.

Maintenance Person II (2) – One of these positions is a crew member on the construction crew and the other is a crew member on one of the rodding crews. These positions perform semi-skilled functions in the maintenance and repair of the sewer system.

Maintenance Person I (2) – These positions are entry-level helpers on maintenance crews. One is a helper on a rodding truck and the other on the hydro flush truck.

TV Operator I (2) – The TV operator positions are one-man crews that videotape and record the condition of 8" to 15" sewer pipes throughout the system.

Types of Crews

As mentioned above, there are three two-person cleaning crews, one three-person construction crew, and a one-person television crew. Crews work Monday through Friday, from 7am to 3:30pm.

The construction crew typically performs manhole maintenance, sewer repairs, and confined space entry. These repairs are based on referrals from the maintenance crews or from the television crew. These are typically issues that either need immediate attention or projects that are too small to warrant inclusion on a CIP.

There are two different types of maintenance crews. There are two mechanical rodding crews and one hydro flushing crew. The hydro flushing crew handles hot spots related to grease twice a year. The remainder of the year that crew cleans the rest of the system. Boulder's goal is to clean the entire system every 18 months. The two mechanical rodding crews handle root related maintenance issues. It is Boulder's goal to rod the entire system every three years.

There is one, one-person CCTV crew. Currently the CCTV crew televises the entire system of pipes, less than 16 inches in diameter every 7-9 years. Having a one-man crew may pose safety issues for crews working in the street. It may also be less efficient due to the time spent setting up traffic control and CCTV equipment.

Workday

The city's operations and maintenance personnel work five 8-hour days per week, Monday through Friday. The current work order and time management procedures and systems do not allow for a performance assessment.

Productivity

There are no performance measures in place to benchmark productivity of cleaning crews to industry averages for daily production averages per crew. There are no benchmarks established for daily production goals. There are goals established for how frequently the entire system is cleaned. Using the frequency of entire system cleanings and approximating the number of days crews are out cleaning, in general, flushing crews seem to be more productive than industry standards, while rodding appears below average.

8.3.2 Maintain an Up-to-Date Map of the Sanitary Sewer System

Assessment

The city currently has two sources for maps of the system. One is paper map books that crews use in the field for navigating to their work orders. The city also maintains all system assets in GIS and this is used for planning functions. There is missing data in the GIS database that the city is working to complete. Some examples of these are missing installation dates, diameters, materials, and invert and manhole rim elevations. As city crews visit these locations, they are attempting to capture the data to update their database.

The Computerized Maintenance Management System (CMMS) software for generating work orders and managing data is not tied to the GIS system. The CMMS will be addressed further in the following section.

Recommendations

Only one asset database should be maintained for the system and this should be the system that is used for all maintenance activities related to the sanitary sewer system. Maintaining two systems is time consuming and updates may not always be made to both depending on desired use of the group responsible for data maintenance.

Completion of the GIS database should be made a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to ensure that the existing GIS database is continually checked against reality.

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8.3.4 Routine and Preventive Maintenance

Assessment

Boulder's maintenance program includes cleaning their trouble areas or hot-spots locations every six months, as well as maintenance of the sanitary sewer system whenever an O&M related problem occurs. The city uses both hydro flushing and mechanical rodding equipment to clean and remove debris from the sewer system. Boulder's goal is to hydro flush the entire system every 18 months and to mechanically rod the entire system every three years. This means every pipe in the system is maintained an average of once per year. The city proactively maintains their buried sewer assets, thus helping to avoid any maintenance problems or SSOs that could result in a threat to the public health and/or a loss of human life. The following sections present findings and suggestions should be considered to refine the preventive maintenance program.

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM

The current system, Utility Maintenance Management System (UMMS), was built by a board member who still maintains and upgrades the system. UMMS houses asset and some maintenance information for water, stormwater, and sewer assets. Maintenance information collected by field crews and stored in the UMMS includes coded values that categorize manhole problems, the operator's assessment of a pipe's overall condition, and the specific location and type of problem in a pipe. This system is not currently integrated with GIS. CCTV data is collected and entered into the system, and the system has the ability to collect some simplistic findings. As CCTV operators televise sections of pipe events such as lateral tie-ins are recorded as well as significant structural defects are mentioned, but not rated. When events such as blockages or SSOs occur, the Utilities Program Planner maps them in GIS, which is a separate database from UMMS, though the UMMS spill data is frequently exported and joined to the GIS spill points. Also, only "serious" events, such as SSOs, are documented, not general maintenance findings.

Recommendations

UMMS should be updated and more closely integrated with the GIS system, or a new GIS-based CMMS system should be implemented specifically for the sanitary sewer system. This will be discussed further in the following section. UMMS has the ability to generate and track work orders, but since it was created to work with several different utilities, it lacks some of the planning tools that a CMMS geared just for the wastewater industry would include. At a minimum, it should be able to collect maintenance findings by asset and support geographical work scheduling.

UMMS should be updated to store condition data which would be collected on maintenance and inspection visits. Currently, maintenance crews are identifying the pipeline cleaned and recording the type of maintenance performed, but not recording condition findings. This should be corrected by capturing the findings in UMMS. Condition findings should be code-based and not text-based.

The city should have all data, such as trouble area cleaning records, root treatment, and others, entered into the UMMS. This database should be the one source for all maintenance-related issues and should be integrated with GIS software for data management and development of work orders. CMMS software should be integrated with GIS in producing map-based work orders so field activities can be planned and performed using the most up-to-date data. Also, planners could query and link data from UMMS to GIS for analysis and long-term planning.

A detailed service request or work order form should be created and provided to crews who maintain the sewer 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. This code-based data would be captured in UMMS and used for planning future maintenance activities and could also be used for analyzing trends in the system or identifying problem spots or grease dischargers.

The city should provide training to staff in the effective usage of GIS and CMMS software.

CLEANING PROGRAM

The existing collection system pipes are cleaned on a routine basis to minimize the risk of having an SSO, maintain capacity, and to minimize system deterioration and odor generation. An analysis of the last 5 years of SSOs shows the primary causes of SSOs in the city are grease buildup from commercial and residential sources, and root intrusion. Cleaning is performed on pipes that have documented grease problems at a frequency of every six months. Pipes with a documented root problem are placed on the chemical root program. Pipes without a documented maintenance-related condition get cleaned at a lower frequency as will be discussed in the following sections.

Hydro flushing is a cleaning method using high pressure water to remove grease, sand, sludge, and many other obstructions from sewer lines. Mechanical rodding is another cleaning method commonly used in the city to clean sewer lines. This form of cleaning is specifically targeted at the removal of roots from the system but is also used for the penetration of solid blockages. This equipment uses blades that spin on a heavy-duty cable or rod, used for cutting through roots from trees and bushes or other types of debris. The city also contracts with an outside service provider for the application of chemical root inhibitor. Annually between five and eight miles of pipelines are chemically treated for roots.

Each segment of the collection system is hydro flushed once every 18 months and mechanically rodded once every three years. Segments of the system known to have hydraulic problems, or “Hot Spots”, are cleaned more frequently. These areas are typically cleaned on 6 month cycles in May and November. “Hot Spots” are generally near the point where a restaurant discharges into the system. In 2007 the city cleaned approximately 22,000 feet of pipe on each of its "Hot Spot" cycles. Interviews with staff and planning personnel confirmed that once a pipe was placed on a "Hot Spot", there was next to no chance of it ever coming off.

Recommendations

The system is currently being cleaned, on average, once per year, and the City's cleaning program has resulted in a reduction of SSOs. By comparing this to industry best management practices, this frequency is considered over-cleaning, and it is possible to realize similar effectiveness while cleaning less. The city is currently cleaning the entire system on what is normally considered an accelerated cleaning schedule, which is a frequency of less than once every two years. This is considered a high level of service, but also means that crews are most likely cleaning clean pipe. Additionally, there are studies that show that cleaning practices such as hydro-flushing and mechanical rodding can actually cause structural damage to a pipe and reduce the service life of a pipe. Hydro flushing and mechanical cleaning should only be performed to remove roots, grease, or other debris when needed.

As mentioned in the CMMS section, the city should move to code-based collection of findings and collection of this data should be stored in an upgraded CMMS. Over the next few cleaning cycles, data could be collected and, most likely, more accurate cleaning frequencies could be developed for the individual line segments. This would allow the city to ease away from such an aggressive system-wide cleaning program. This same methodology can be used for collection of cleaning findings on the current "Hot Spot" schedule. Once the scheduled cleaning is run through several more times, the data collected will help identify the optimal cleaning frequencies which will most likely lessen the cleaning workload. This data collected would allow for a periodic reevaluation of the cleaning frequencies. The schedule can be level loaded throughout the year for all pipes in the system to provide steady work for crews throughout the year.

As the city implements the above two recommendations, they will likely modify their cleaning schedule to only clean pipes when they are in need of cleaning. This will result in a reduction of the net feet cleaned per year. Instead of downsizing, the utility should look at moving resources to the repair crew or creating a second repair crew. As will be discussed in the following section, the CCTV crew should be generating repair work that city crews could be repairing. Additionally, as the city does less cleaning they may want to consider transitioning from using mechanical rodding equipment to combination jet rodder units. This can be accomplished by replacing one of the mechanical rodders with a combination jet rodder during the next replacement cycle. The combination units are more versatile and more effective.

Large diameter sewer cleaning is an area where there is liability in the future from a regulatory perspective. The probability of a sewer overflow from a large diameter sewer is very small; however, the consequence can be very large. In California, the EPA has required cities such as San Diego and Los Angeles to have a program in place to either clean large diameter sewers periodically or inspect large diameter sewers to determine if cleaning is necessary. The city currently does not inspect pipes that are larger than 15" in diameter and rarely cleans pipes that are larger than 18" in diameter. It is recommended that the city develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues. Condition assessment of large diameter pipes will most likely require the purchase of new equipment capable of large diameter inspections or should be contracted out to a qualified company.

The majority of maintenance issues in large diameter sewers are the accumulation of debris. This condition is usually exacerbated by flat slopes. Due to the exorbitant cost of large diameter inspections, the city should perform an analysis of flow conditions in large diameter sewers to identify the most likely candidates for maintenance defects. This should be used in conjunction with Boulder's CIP prioritization methodology for identifying structural defects. Together, this priority list would be used to create a risk-based inspection program of only the large diameter sewers that either have a higher probability of maintenance or structural issues or have an elevated consequence of failure, such as near high profile public facilities. The program should then be expanded or contracted based on the findings from the initial inspections.

INSPECTION PROGRAM

Utility Maintenance staff performs inspections on all pipes and manholes on a routine basis. These inspections are either visual, to determine the integrity of manholes, or Closed Circuit Television (CCTV) inspections of the distributed assets. Inspection of the entire collection system using CCTV is currently able to be completed approximately every nine years. The CCTV crew inspects sewers less than 16" in diameter. The data collected from CCTV inspections is used to document the condition of the system and plan long-term CIP projects. Additionally, the data is used to identify areas requiring special or immediate maintenance attention, such as blockages or structural damage. When issues arise, maintenance activities are scheduled to repair the damaged segment or relieve the blockage. CCTV video data is stored in a database so that maintenance staff can review it if necessary.

Recommendations

The city does not currently have a defect coding system for their CCTV program. They currently have one CCTV crew that notes the defect and what it is but it isn't coded and there is no place to document the severity. It is recommended that the city move to an industry recognized defect coding system. This will enable the city to collect consistent records if there is turn-over on the CCTV crew as well as becoming a standard for contractors. Should there ever be a need for CCTV inspections to be done by outside contractors; the data collected would be in the same format as Boulder's data. Additionally, collection of code-based defects and severity data allow for the evaluation of the condition of the system as well as the development of long-term CIPs. These coding systems are typically built into the newer inspection software. The current CCTV van is 10 years old and the city is about to purchase a new inspection van and equipment. The city should identify the coding system that they intend to use prior to making the investment in the new equipment and including the coding system in their specifications.

One such coding system is the Pipeline Assessment Certification Program (PACP). This is a sewer condition coding system and certification program developed by National Association of Sewer Service Companies (NASSCO). The program was developed for the purposes of standardizing the way condition data is classified and how CCTV inspection results are managed. Regardless of whether the city chooses a certification program or another recognized classification program, training should be provided initially and periodically to the CCTV crews as well as to any other personnel who might need to use the software or operate the equipment.

Currently the CCTV data is used to identify CIP projects to be contracted out, or it identifies areas that need to be repaired immediately because they are near the point of catastrophic failure. Once a defect coding system is implemented, a full range of projects could be identified that could be repaired by city crews before they reach the catastrophic failure point.

CCTV crews should be used for quality control (QC) on maintenance and repair activities. Quality control on cleaning operations should consist of random evaluation of cleaning quality using CCTV inspection on a spot check basis within one week of sewer cleaning activities. This evaluation should be performed on at least 3 pipes per 100 pipes cleaned per cleaning crew. At current production levels, this would account for approximately 1.25% of the CCTV crew's workload. This can include tandem cleaning and CCTV activities where CCTV crews provide instant feedback to cleaning crews by monitoring cleaning effectiveness using CCTV during cleaning operations. This is a best management practice and can be considered to be both a quality assurance and quality control activity.

Additionally, as mentioned in the prior section, it is recommended that the city develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues.

8.3.5 Rehabilitation and Replacement Program

Assessment

When identifying projects to address failing assets, the city has primarily been focusing on replacing assets once they reach a critical stage and has a near-term impact on system reliability. The city does not have a structured process to analyze the condition of assets to optimize the timing of repair, rehabilitation and replacement projects with a focus on minimizing the long-term cost of asset ownership.

Rehabilitation and replacement projects are identified in two ways. The first is through inspection or maintenance activities identifying structurally unsound pipe and the second is through the hydraulic model in order to identify capacity related issues.

The city currently does not have a formal project prioritization or ranking process for all projects. When inspection or maintenance activities identify pipes that require a significant capital improvement, the maintenance staff that has identified the problem notifies the Public Works Utility Project Management Staff of the need for a capital improvement project (CIP) to alleviate the problem. Once Project Management Staff has been notified, they assume responsibility for planning, scheduling, and implementing the CIP. A procedure for this process exists but it has not been formally documented in writing. This is a highly reactive means for identifying CIP needs and is not the best way to manage a system with better than 50% of its assets in excess of 50 years old.

In 2003, the city retained services of Brown and Caldwell to revise their Wastewater Collection System Master Plan (WWCSMP). As part of this project, the Hydraulic Model was revised. As a result of the modeling performed for the revised WWCSMP, capacity-based capital improvement needs were identified. These CIP needs have been categorized into four separate classes based on how immanent the need was. It was also recommended that the CIP budget be increased by 50% annually to accommodate these additional CIP needs that were not currently in the 5-year CIP plan.

Recommendations

The city should develop a standardized methodology to determine repair, rehabilitation, and replacement needs. With approximately 20 sewer line segments per mile, the city's sewer CCTV program quickly produces large amounts of data that should be analyzed in an objective manner for several purposes including capital planning. To assure consistent decision-making in the city's sewer repair, rehabilitation and replacement project identification process, it is very important that the city processes future CCTV data based on a formal decision process. It is a best practice to have a formal, reproducible repair, rehabilitation and replacement decision process that is documented in a decision flow diagram. This decision process would have decision guidelines that lead the person following the process to a preliminary decision about the pipe segment based on the type, severity and quantity of defects in the line segment. This can be done manually based on the decision flow diagram, or can be an algorithm developed from the diagram.

The city should be able to integrate the condition findings with the GIS. The city has a relatively complete GIS system. If sewer and manhole inspection and condition assessment data is collected by sewer and manhole asset number, city staff can display the results on the GIS system. This expedites and optimizes the groupings for staff and contractor sewer and manhole repair, rehabilitation and replacement projects.

If a backlog of capital improvement projects develops, it is a best practice to develop a formal project prioritization process to assure the highest risk and/or consequence assets are addressed to assure stakeholders that available resources are focused on the highest priority projects. Criteria that are often considered in prioritization programs include workplace safety, public safety, reliability of service for customers, regulatory compliance, environmental impacts, and discretionary or aesthetic concerns. Weighting factors could be applied to the different criteria to align priorities with the Boulder's mission and goals.

The development of code-based maintenance findings and CCTV inspections that have been centralized in one location should be leveraged to assist in the planning process.

8.3.6 Training

Assessment

The city encourages its staff to attend training courses. Wastewater Maintenance staff members are encouraged to obtain the highest level of Collection System Operator Certification available through the Colorado Department of Public Health and Environment. All WWTP operators keep up-to-date certification and registrations for their various licenses and records are kept of training participation by all Utility Maintenance employees.

There is a formal safety training program and all staff members are required to participate. The safety program addresses the following topics; first aid/CPR, confined space entry, trenching and shoring, and defensive driving. Additional specialized trainings are available for field crews for topics such as specialized equipment operation training and asbestos cement pipe repair training.

The City also offers an in-house basic traffic control training annually, ensuring that all new employees are trained in this subject.

Recommendations

The city should develop a cleaning crew training program. The cleaning crew training program should have components that focus on improving both the cleaning work process and the cleaning information process. The training program should include the following:

- Conduct training on objectively assessing condition and defect severity of pipes based on maintenance activities. Use photos to train personnel on the difference between light, medium and heavy condition findings (or 1-5 code). Use other objective measures to assess the condition of a pipe.
- Conduct training to properly record the assessment on the work order form
- Conduct formal training in cleaning techniques for each type of equipment.
- Use CCTV while cleaning to provide feedback and training.
- The city may want to consider holding a “training academy” where a professional training service comes in and provides thorough equipment and cleaning training.
- Training should also be held for the CCTV coding system that the city chooses for their CCTV crews.

8.4 Design & Performance Provisions

Assessment

A key element in the efficient management of the collection system is the provision of well designed and installed sewers and pump stations. New facilities designed and installed with an emphasis on long-term sustainability can greatly reduce maintenance labor and expense. To facilitate this, the city has adopted a set of standards for all new facilities. Boulder’s standards are documented in the “Design and Construction Standards for Wastewater Collection Systems”. The “Design and Construction Standards for Wastewater Collection Systems” contain no provisions or information on planned or necessary acceptance inspections.

Recommendations

The city should amend the “Design and Construction Standards for Wastewater Collection Systems” to incorporate guidelines for the acceptance inspection of facilities. These inspections include:

Developer Work – This includes all new pipelines, manholes, and smaller pump stations.

Capital Projects – Larger pumping stations and sewer pipelines designed and contracted directly by the city.

The city should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate SOPs for the testing of all new facilities. These SOPs should include provisions for testing requirements and acceptance criteria.

8.5 Overflow Emergency Response Program

Assessment

Currently the city responds to emergencies by sending out maintenance crews to the incident location. After hours, the wastewater standby employee is contacted. The spill is quickly assessed and resources are secured to mitigate the spill occurrence. During the mitigation process, the maintenance crews use visual, and sometimes CCTV, inspections to determine the nature and cause of the spill event.

Following an SSO, the CCTV crews will inspect and the section of sanitary sewer main where the stoppage occurred. The Wastewater Maintenance Supervisor, CCTV inspector, and Repair Crew Lead review the tape and attempt to determine the cause of the stoppage, and access any immediate maintenance concerns with the pipeline.

Response to all SSOs is guided by the Sanitary Sewer Overflow Response Plan. This document was put into place by the city in August of 2003. This plan is necessary to meet the requirements of the City of Boulder's Wastewater Treatment Plant Permit. The plan includes sections outlining the assessment of a spill, resolution, follow-up, and reporting.

Recommendations

The city's Overflow Emergency Response Program meets most of the requirements of California's WDR. The one recommendation for improvement would be to modify existing procedures executed in response to a spill. Current procedures of placing the problem asset on a list for root control treatment or submitting it to engineering as a potential CIPP should be modified to include the possibilities of increasing the maintenance frequency of the problem pipe, or placing it on the "hot-spot" program. If the asset is currently on one of these programs, the city should evaluate developing a cleaning frequency that is less than six months. Also, to be in compliance with the CWA, the city needs to develop a formal SSO tracking system.

8.6 Fats, Oils, and Grease (FOG) Control Program

One of the major causes of maintenance problems, blockages, and sanitary sewer overflows in the city's collection system is grease. The city addresses grease in the collection system through two programs: the sewer cleaning program and in the Industrial Pretreatment Program. The sewer cleaning program is discussed in earlier sections.

The purpose of the city's Pretreatment program is to ensure that commercial and residential entities are not contributing pollutants to the system. One of the pollutants is grease or oil in levels that would impact the operation of the city's collection system. The pretreatment program does not have a formal FOG program.

8.6.1 Installation of Grease Removal Devices

Assessment

The city's FOG program is governed by municipal code regulation with specific section relating to fats, oils, and grease. This code establishes a threshold for dischargers of 100 mg/l, or requires a plumbing device for FOG for those who exceed the threshold. Currently the municipal code refers to the International Plumbing Code for the design criteria of grease removal equipment. The municipal code has minimal requirement for grease removal equipment cleaning, which is every 6 months or as needed.

FOG producing facilities are not currently required to obtain permitting from the city. FOG producers are identified by Development Services. When applying for permits, applicants fill out a Business Environmental Questionnaire. If the facility generates wastewater, they are required to fill out an industrial waste survey. Any applicant determined to exceed the above mentioned discharge threshold is required to install grease removal equipment (GRE). There is an existing plan check system for restaurants during the initiation phase. Design approval is performed by the Development Review group. During construction, inspection of the GRE is performed by the plumbing inspector.

Recommendations

The FOG municipal code should be modified to require all new grease-producing facilities to install and maintain grease removal equipment (GRE). Any new or remodel of existing facilities that will have a kitchen, cooking equipment, or a food producing facility should contact the city to determine the need and size of the grease controlling device. Modifications should be made to the municipal code to allow for the development of a FOG program that can perform inspections and assess violations accordingly. According to California's WDR section vii of the SSMP, the following suggestions shall be included in the FOG ordinance:

- An implementation plan and schedule for a public education outreach program either through the local public newspaper, radio, television advertisements, flyers or newsletters that will promote proper disposal of FOG;
- A list of acceptable disposal facilities and/or additional facilities needed to adequately dispose of FOG generated within its service area;
- A legal authority to prohibit discharges to the sewer collection system and identify measures to prevent SSOs and blockages caused by FOG;
- A requirement to install grease removal devices such as an interceptor or trap, using the most current regulations and design standards (e.g. CPC), maintenance requirements, BMP requirements, record keeping and reporting requirements; and Authority to inspect the grease producing facilities, enforcement authorities, and enforcing penalties to the businesses that violate FOG control measures.

8.6.2 Inspection & Maintenance Program

Assessment

Currently, there are approximately 400 GRE facilities in the city. After design approval and inspection during construction, it then becomes the owner's responsibility to regularly inspect and maintain the GRE. Currently, the city does not have any staff dedicated to the inspection of the performance and maintenance of an existing GRE. The pretreatment program has responded reactively with additional site inspections, notices of violation, and issuing requirements for plumbing device installation following SSO events. Due to the lack of an inspection and maintenance program, the property owners may have not been maintaining their GREs. It is possible that food service establishments (FSE) may bypass their grease trap/interceptor and discharge directly into the sewer line.

Recommendations

The city should perform a business case for investment in a FOG prevention program. Development of a formal inspection program should be considered to be included in their FOG ordinance. The business case would evaluate the cost of a formal FOG program against the cost of maintenance and potential SSOs or blockages.

The first step in developing the FOG program would be the identification of all of the FSEs that would require grease removal equipment. There is a database that currently keeps this data, but it is incomplete. The database could be used as a starting point and added to over time. The FOG program would work with the operations group to identify grease hot-spots in the system and evaluate the businesses in the area to identify any that should have GREs. The city should develop a policy on how to handle existing FSEs that do not have GREs. Additionally, the FOG program needs to work with Development Services to ensure that all new food establishments are entered into the database.

Once data collection of the existing and new facilities is under way, the city can focus on developing an inspection schedule for the restaurants as well as recommending maintenance schedules for the facilities GREs. A report or a log should be prepared after each inspection. Depending on the findings of the inspection reports or logs, the facility will be issued a schedule that enables it to achieve compliance with the current regulations. If the facility fails to follow the regulations and/or FOG ordinance, a system of progressive discipline should be defined that will ultimately result in Boulder's ability to shut off the water of non-compliant FSEs.

8.7 Monitoring, Measurement, and Program Modifications

Assessment

The city uses a computerized maintenance management system for tracking its maintenance, repairs, and inspections of the sewer system. Additionally, it maintains separate GIS data documenting the locations of SSOs as well as repair and replacement projects. CCTV data is collected to monitor the condition of the system. Maintenance and structural issues are documented and the appropriate crew is assigned to perform the repair or to maintain the pipeline.

The city has developed several performance indicators for the maintenance of its sewer system. Boulder has set goals and developed performance measures to document what they are doing to maintain the wastewater collection system and to gauge how well it is being done. Performance measures are calculated annually and documented in the Utility Maintenance Division's annual report. The annual report also documents how the utility is performing against like size agencies in the area.

Currently modifications to the maintenance frequency of pipes in the system are performed in a reactive way. When CCTV crews identify a problem, there is an SSO or blockage, or a customer complaint is received, the Utility Maintenance Division responds to alleviate the problem. This may either be a one-time maintenance event or it may be the inclusion of the facility in the hot-spot program.

Recommendations

The city should assign a person to review the SSMP periodically to check its effectiveness and timeliness. This person can prepare regular progress reports documenting the effectiveness, potential changes, and summary of the program activities. Currently the city collects a large amount of data about maintenance activities in UMMS. The data is used now as documentation a maintenance event occurred and used to measure progress towards performance goals. As recommended in prior sections of this report, additional information could be gathered during maintenance events about the condition of the pipes. This data could be analyzed and modifications to maintenance activities could be optimized.

8.8 Program Audits and Communication Program

Assessment

California's WDR requires that an agency perform an audit of all programs associated with the SSMP every two years. The audit should identify any deficiencies in the SSMP programs and include the corrective steps to resolve the issues. The audit will help ensure the effectiveness of the SSMP implementation program. The audit should be conducted by a person other than a member of the agency's staff. The auditor should conduct random interviews of the staff in reviewing the SSMP performance.

Recommendations

An effective communication program can keep the city from missing the critical SSMP deadlines. The city should involve the key stakeholders and the public during the process of developing an SSMP avoiding any controversial discussions on its various elements.

8.9 Conclusions and Recommendations

In general, the city has the framework in place that will bring it into general compliance with the terms of the emerging regulations of the Western United States in the near future. Many of the recommendations made here are for the improvement of the maintenance of the utility. These are recommendations that incorporate best management practices and industry standards for the operation of the utility. The challenge for the city will be to implement these recommendations to improve the condition of the system. Below is a summary of the recommendations:

1. Maintain an Up-to-Date Map of the Sanitary Sewer System
    a. Completion of the GIS database should be made a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to ensure that the existing GIS database is continually checked against reality.
2. Computerized Maintenance Management System
    a. UMMS should be updated and more closely integrated with the GIS system, or a new GIS-based CMMS system should be implemented specifically for the sanitary sewer system. It should be able to collect maintenance findings by asset and support geographical work scheduling.
    b. UMMS should be updated to store condition data which would be collected on maintenance and inspection visits. The city should have all data, such as trouble area cleaning records, root treatment, and others, entered into the UMMS.
    c. A detailed service request or work order form should be created and provided to crews who maintain the sewer 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.
    d. The city should provide training to staff in the effective usage of GIS and CMMS software.
3. Cleaning Program
    a. The system is currently being cleaned, on average, once per year, and the City's cleaning program has resulted in a reduction of SSOs. The city should move to code-based collection of findings and collection of this data should be stored in an upgraded CMMS. Over the next few cleaning cycles, data could be collected and, most likely, more accurate cleaning frequencies could be developed for the individual line segments.
    b. The utility should look at moving resources to the repair crew or creating a second repair crew. As will be discussed in the following section, the CCTV crew should be generating repair work that the city crews could be repairing. Additionally, as the city does less cleaning they may want to consider transitioning from using mechanical rodding equipment to combination jet rodder units.
    c. It is recommended that the city develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues.
4. Inspection Program
    a. It is recommended that the city move to an industry recognized defect coding system. This will enable the city to collect consistent records if there is turn-over on the CCTV crew as well as becoming a standard for contractors. Training should be provided initially and periodically to the CCTV crews as well as to any other personnel who might need to use the software or operate the equipment.
    b. CCTV crews should be used for quality control (QC) on maintenance and repair activities. This evaluation should be performed on at least 3 pipes per 100 pipes cleaned per cleaning crew.
5. Rehabilitation and Replacement Program

   a. The city should develop a standardized methodology to determine repair, rehabilitation, and replacement needs. To assure consistent decision-making in Boulder's sewer 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 can be an algorithm developed from the diagram.
   b. The city should be able to integrate the condition findings with the GIS.
   c. When a backlog of capital improvement projects develops, it is a best practice to develop a formal project prioritization process to assure the highest risk and/or consequence assets are addressed to assure stakeholders that available resources are focused on the highest priority projects.

6. Training
   a. The city should develop a cleaning crew training program. The cleaning crew training program should have 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 their CCTV crews.
7. Design & Performance Provisions
   a. The city should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate guidelines for the acceptance inspection of facilities. The city should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate SOPs for the testing of all new facilities.
8. Overflow Emergency Response Program
   a. The one recommendation for improvement would be to modify existing procedures executed in response to a spill. Current procedures of placing the problem asset on a list for root control treatment or submitting it to engineering as a potential CIPP should be modified to include the possibilities of increasing the maintenance frequency of the problem pipe, or placing it on the "hot-spot" program.
9. Installation of Grease Removal Devices
   a. The FOG municipal code should be modified to require all new grease-producing facilities to install and maintain grease removal equipment (GRE).
   b. Modifications should be made to the municipal code to allow for the development of a FOG program that can perform inspections and assess violations accordingly.
10. FOG Inspection & Maintenance Program
   a. The city should perform a business case for investment in a FOG prevention program. Development of a formal inspection program should be considered to be included in their FOG ordinance.
   b. The city should identify all of the FSEs that would require grease removal equipment. There is a database that currently keeps this data, but it is incomplete.
   c. The city should develop a policy on how to handle existing FSEs that do not have GREs. Additionally, the FOG program needs to work with Development Services to ensure that all new food establishments are entered into the database.

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9 References

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10 Appendices

Appendix A – Cost Estimate Worksheets

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