City of Aspen
Detention Analysis

Prepared for:
City of Aspen

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EXECUTIVE SUMMARY

This report provides an overview of updated analysis of rainfall and runoff in the City of Aspen (City). The City of Aspen undertook this study with two end goals in mind: (1) to determine if the City could and should assign a standard detention volume and release rate specific to the basins of the City and (2) to determine if water quality treatment requirements are lessening the demand on the City's stormwater system, and therefore, providing more allowable capacity in the system than was calculated in the existing Surface Drainage Master Plan (WRC 2001). The City's ultimate goal is to have a stormwater system that can carry the 10-year storm (ten-percent chance of occurring in any given year) through the piping network without flooding streets or properties.

The 2001 Master Plan was developed to identify major surface drainage systems in the City that convey runoff from the mountain and urbanized portions of the City via storm drains, pipes, and streets to the Roaring Fork River. It also analyzed the stormwater system to determine its condition and the portions of the system that would be overwhelmed during certain storm events. Finally, it listed a number of alternative solutions out of which the City choose Alternative #3 which included increased pipe sizes for Ute and Spring in System #1 and Gilbert, Snark, Garmisch and Francis in System #2.

Wright Water Engineers (WWE) addressed the City's goals for this study through updates to the 2001 Master Plan storm drainage models and by applying these models to determine present and future capacity problem areas and current detention and water quality requirements in the urban core of Aspen. Modeling scenarios developed as a part of this project include: (1) Calibration, (2) Existing Conditions, (3) Predevelopment Conditions, (4) Required Storage, (5) Water Quality Capture Volume (WQCV) Implementation and (6) Alternatives Analysis.

Through this process the City also made decisions regarding the use of updated rainfall data from National Oceanic and Atmospheric Agency (NOAA)'s recently published Atlas 14. The updated data were reviewed and compared to current rainfall data in Aspen's Urban Runoff Management Plan (URMP—based generally on older NOAA Atlas 2 mapping), and modeled flows were compared between the current and new rainfall data. The previous data available for the Aspen area was based on NOAA Atlas 2 which included a period of record from 1948-1973 (roughly 25 years). The new NOAA Atlas 14 provides data for this area through 2010 – nearly 40 years of additional rainfall data. WWE confirmed with a number of experts the accuracy and appropriateness of using the new data. The updated data reduce rainfall values by up to one third thus reducing the modeled flows through the City's storm system by up to one half. <u>The City decided to use the updated NOAA Atlas 14 mean rainfall values and these updated values were used to conduct the remainder of analyses in this study.</u>

Analysis of the City's current system was conducted using information from the 2001 Master Plan in an updated "existing conditions" model. Modeling was performed using EPA SWMM and Urban Drainage Flood Control District's Colorado Urban Hydrograph Procedure (CUHP). <u>Generally flooding appeared to be the worst in System #1 (along Spring Street) and System #3 (along Garmisch Street), primarily only for the 100-year storm.</u>

Aspen's URMP requires that development and redevelopment projects be designed so that detention meets historic runoff rates (predevelopment hydrology). This study models existing and historic runoff rates for all sub-basins in the Aspen Mountain Drainage Basin and then applies detention of stormwater to that historic rate for every development within a sub-basin to determine the effects this might have on the pipe network downstream of the basin. Through this modeling WWE determined that the upland portion of the watershed, which includes a large portion of Aspen Mountain, produces much higher peak flows than those from the urban areas of the City (with or without detention). <u>This means that detention in the urban areas was found to provide marginal capacity benefit to the system for larger storm events because the flows from the mountain dominate the system. This report suggests that continued use of the detention requirement might be re-examined and potentially substituted with a requirement for low impact development (LID) or greener alternatives that would provide both a water quality and aesthetic benefit to the City.</u>

Finally, this report analyzed the effects of implementing the URMP-required WQCV in each basin at different levels of implementation – 25%, 50%, 75%, and 100%. WQCV is acheived by installing various forms of LID and other best management practices that promote infiltration of stormwater into the soil. <u>The various levels of implementation of the WQCV were found to provide some benefit to the majority of urban sub-basins for the 2- through 10-year storms (when the mountain</u>

runoff contributes less runoff due to the effects of pervious area and local urban drainage is the larger issue), but as expected implementation was not helpful for larger storms, where mountain runoff dominates the peak flows in Aspen’s stormwater system.

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1.0 INTRODUCTION AND SCOPE OF WORK

Wright Water Engineers, Inc. (WWE) conducted an analysis of the City of Aspen's storm drainage system and potential future conditions related to required water quality volume capture (WQVC) and detention for flood control. The purpose of this study is to update the City's storm drainage models, apply models to determine present and future capacity problem areas, and evaluate detention requirements in the urban core of Aspen. Various scenarios were developed as a part of this project including: (1) Calibration, (2) Existing Conditions, (3) Predevelopment Conditions, (4) Required Storage, (5) WQCV Implementation and (6) Alternatives Analysis.

Through this process the City also made decisions regarding the use of updated rainfall data from National Oceanic and Atmospheric Agency (NOAA)'s recently published Atlas 14. Modeling was performed with the newly released rainfall to inform the City on which dataset would best characterize the City's rainfall and address the City's drainage planning needs.

2.0 PREVIOUS STUDIES

2.1 2001- Surface Drainage Master Plan for the City of Aspen

A drainage master plan, hereinafter 2001 Master Plan, was developed for the City by WRC Engineering, Inc. in 2001. This study developed flows for 25 subbasins for various storms in the City's portion of the Roaring Fork watershed. The subbasins were delineated using storm sewer information, field data, and topographic mapping. The storm drainage system was divided into three main systems (Systems 1, 2, and 3) based on outfalls from the urbanized area of the City as depicted in the 2001 Master Plan with three additional outfalls to the Roaring Fork River outside of the urban core. Hydrology for this master plan was generated using Urban Drainage Flood Control District's (UDFCD) Colorado Urban Hydrograph Procedure (CUHP). Hydraulic analysis for the study was performed in Urban Drainage Stormwater Model (UDSWM). The 2001 Master Plan additionally evaluated alternatives to upgrade or construct new drainage facilities to reduce or alleviate flooding problems and then selected a "best" alternative. Rainfall used in this study was taken from published NOAA one-hour precipitation values at the time of the study (late

1990's/early 2000's). These are slightly different than the values currently used in the City's Urban Runoff Management Plan (URMP) which was based on rainfall analysis by Dr. James Guo who used NOAA Atlas 2 to refine rainfall data. In addition, the 2001 Master Plan evaluated potential mud and debris flows in the City, which was not a component of this study. An updated mud and debris flow analysis is recommended using the revised hydrology from this report.

3.0 RAINFALL

A major component of this study involved assisting the City in making an informed decision on the appropriate regulatory rainfall data to use. The current URMP rainfall is based on the 1973 NOAA Atlas 2 rainfall amounts. In 2013 NOAA published updated rainfall depths in the Atlas 14 document. This updated document increased the period of record in Aspen from 25 to 62 years and added confidence limits around the mean precipitation values. In reviewing the updated rainfall data Aspen considered three main options for regulatory use and application in this study: (1) keep the current URMP rainfall values, (2) revise the values to the Atlas 14 90th percent confidence values which are similar to the current URMP values, or (3) revise to the new Atlas 14 mean values.

In the case of Aspen, the NOAA Atlas 2 data (and consequently the URMP data) were actually based on a fairly short (approximately 25 year) period of record, especially when compared to what is now available, and to our knowledge, there is only one long-term gage available in the immediate vicinity of Aspen. In Table 1, values from the new NOAA Atlas 14 are compared with values from the URMP. Based on this analysis, the URMP values (on the right) fall above the 90 percent upper confidence interval for the updated NOAA Atlas 14 data, with the updated NOAA mean values being as much as 30 percent lower than the URMP values. Note that the 90 percent upper confidence limits are more similar to the current URMP values, being only slightly lower for many of the storm events.

Table 1. URMP and NOAA Atlas 14 1-Hour Rainfall Depth Comparisons

Design Storm Event	NOAA Atlas 14 Lower 90% Confidence Interval	NOAA Atlas 14 Mean	NOAA Atlas 14 Upper 90% Confidence Interval	Aspen Urban Runoff Management Plan (Rev 2/2010)
Frequency, Duration	Depth (in)	Depth (in)	Depth (in)	Depth (in)
2-yr, 1-hr	0.401	0.47	0.563	0.64
5-yr, 1-hr	0.541	0.64	0.766	1
10-yr, 1-hr	0.651	0.77	0.935	1.2
25-yr, 1-hr	0.76	0.95	1.21	1.4
50-yr, 1-hr	0.843	1.09	1.41	1.6
100-yr, 1-hr	0.902	1.23	1.64	1.69

While the reductions in the 1-hour *precipitation depths* in NOAA Atlas 14 were on the order of approximately 30 percent, this translates into even larger differences in the *peak flow rates* that are produced by the model. To evaluate the implications of the different sets of rainfall data, WWE ran model simulations using the mean values for NOAA Atlas 14, the upper 90% confidence interval depths from NOAA Atlas 14, and the values that are currently in the URMP. Using the mean values from the new NOAA Atlas 14 results in significant reductions in peak flow estimates, cutting values almost in half in many places.

WWE spoke with a NOAA representative and other hydrology experts including Ben Urbonas, P.E., former Chief of Master Planning at UDFCD and Doctor Jim Guo, professor at University of Colorado Denver and longtime UDFCD advisor, regarding the updated data and the lower values and confirmed that there is not a known reason to question the reduced depths for Aspen, and that the revised data should be the most accurate data published to date. The City ultimately decided to select the mean NOAA Atlas 14 data to update its regulatory criteria and these updated rainfalls are used throughout the remainder of the analyses in this study.

4.0 HYDROLOGY AND HYDRAULICS

Methods used to generate hydrology and hydraulics for this study primarily follow the methods used in the 2001 Master Plan. Hydrology was determined with UDFCD's 2005 CUHP using information for the subbasins taken from 2001 Master Plan. Information included the area, impervious percentage, slope, pervious and impervious detention and infiltration parameters. Table 2 summarizes model input parameters from the 2001 Master Plan that were used in conjunction with the new NOAA Atlas 14 to analyze runoff. WWE made some minor refinements to input parameters based on mapping, street cross sections and other information provided by the City. Values used for parameters including Maximum Depression Storage and Horton's Infiltration Parameters are published UDFCD accepted limits as detailed in the *UDFCD CUHP 2005 User Manual*.

The storm sewer system was configured based on figures and tables from the 2001 Master Plan. System components include: junctions/dividers, outfalls and conduits. Figure 1 shows a schematic for the existing conditions modeled system. Table 3 lists the various nodes of the existing condition model and corresponding locations in the City.

Conduits in the model are the pipes and channels that convey storm water in the system. The sizes, lengths, and roughness of pipes and channels were taken from the 2001 Master Plan. Conduits are additionally used in the model to simulate surcharge from the storm sewer system flow onto and through curb and gutter on streets.

Junctions represent where multiple pipes meet in the system, many times at the intersection of streets. Junctions were modeled to provide data on when and how much they overtopped during storms. Invert elevations for junctions were pulled from GIS data on manholes and spot elevations provided by City staff and then depth to invert values from the Storm Sewer Inventory table in the 2001 Master Plan were subtracted. Junctions in the urban areas of the City were designed in the model as weirs that divert flow above their capacity into the street.

Table 2. CUHP Parameters (based on 2001 Master Plan)

Subcatchment Name	EPA SWMM Target Node	Area (mi^2)	Length to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Maximum Depression Storage (Watershed Inches)		Horton's Infiltration Parameters			Cp Calibration[1]
							Pervious	Impervious	Initial Rate (in/hr)	Decay Coefficient (1/seconds)	Final Rate (in/hr)	
1	1Out	0.100	0.15	0.44	0.0447	6.10	0.35	0.1	4.50	0.0018	0.6	
2	102div	0.058	0.11	0.42	0.0157	25.50	0.35	0.1	4.50	0.0018	0.6	0.30
3	103div	0.087	0.23	0.63	0.0119	70.00	0.35	0.1	4.50	0.0018	0.6	0.60
4	4Out	0.083	0.19	0.36	0.0449	30.00	0.35	0.1	4.50	0.0018	0.6	
5	105div	0.049	0.28	0.61	0.0402	19.80	0.35	0.1	3.00	0.0018	0.5	0.50
6	106div	0.069	0.16	0.38	0.058	10.00	0.35	0.1	3.00	0.0018	0.5	0.50
7	107div	0.040	0.11	0.34	0.0131	40.00	0.35	0.1	4.50	0.0018	0.6	0.20
8	108Out	0.084	0.11	0.39	0.0144	20.00	0.35	0.1	4.50	0.0018	0.6	0.35
9	109div	0.066	0.28	0.54	0.057	15.00	0.35	0.1	3.00	0.0018	0.5	0.60
10	110Out	0.015	0.07	0.12	0.0403	10.00	0.35	0.1	4.50	0.0018	0.6	
11	111div	0.077	0.39	0.76	0.0326	65.00	0.35	0.1	4.50	0.0018	0.6	
12	112div	0.074	0.23	0.68	0.0244	40.00	0.35	0.1	4.50	0.0018	0.6	
13	113div	0.064	0.36	0.60	0.054	10.00	0.35	0.1	4.50	0.0018	0.6	0.60
14	114div	0.186	0.57	1.00	0.056	10.00	0.35	0.1	4.50	0.0018	0.6	
15	115div	0.012	0.07	0.28	0.054	10.00	0.35	0.1	4.50	0.0018	0.6	
16	116div	0.167	0.48	0.99	0.056	25.00	0.35	0.1	4.50	0.0018	0.6	0.40
17	117div	0.045	0.16	0.45	0.0266	70.00	0.35	0.1	4.50	0.0018	0.6	
18	118Out	0.049	0.15	0.40	0.0299	60.00	0.35	0.1	4.50	0.0018	0.6	0.40
19	119div	0.080	0.25	0.68	0.0282	70.00	0.35	0.1	4.50	0.0018	0.6	0.40
20	120div	0.080	0.28	0.60	0.058	10.00	0.35	0.1	3.00	0.0018	0.5	0.50

[1] **Cp is an accepted, standard calibration procedure used when updating hydrology studies for UDFCD in the Denver metro area.**

21	121	0.125	0.38	0.72	0.058	10.00	0.35	0.1	4.50	0.0018	0.6	0.65
22	122	0.184	0.45	0.94	0.055	10.00	0.35	0.1	3.00	0.0018	0.5	
23	123	0.387	0.31	0.99	0.054	10.00	0.35	0.1	3.00	0.0018	0.5	
24	122	0.149	0.29	0.75	0.057	10.00	0.35	0.1	3.00	0.0018	0.5	0.30
25	125Out	0.020	0.09	0.21	0.0335	40.00	0.35	0.1	4.50	0.0018	0.6	

Table 3. Nodes and Corresponding City Locations

Design Point	Type	Associated Location in Aspen
123	NODE	Upland
122	NODE	Upland
121	NODE	Upland
110Out	OUTFALL	Outfall from Mill
118Out	OUTFALL	Outfall from Garmisch Overland
108Out	OUTFALL	Outfall from Gillespie Through Pond
125Out	OUTFALL	Outfall south of the City Near Waters Ave.
4Out	OUTFALL	Outfall at Castle Creek and Roaring Fork
1Out	OUTFALL	Outfall North of Gillespie
113div	JUNCTION	Ute
114div	JUNCTION	Ute
115div	JUNCTION	Ute and Original
112div	JUNCTION	Main and Original
111div	JUNCTION	Near Rio Grande and Spring
116div	JUNCTION	Durant and Galena
117div	JUNCTION	Rio Grande and Mill
120div	JUNCTION	Snark and Monarch
109div	JUNCTION	Garmisch and Durant
106div	JUNCTION	Second and Hyman
107div	JUNCTION	Garmisch and Main
119div	JUNCTION	Garmisch and Hallam
103div	JUNCTION	Garmisch and Francis
102div	JUNCTION	Gillespie Near Third
105div	JUNCTION	Third and Main
212	CONDUIT	Main and Spring
213	CONDUIT	Ute
214	CONDUIT	Ute
215	CONDUIT	Original from Ute to Main
222	CONDUIT	Upland
223	CONDUIT	Upland
216	CONDUIT	Mill
211	CONDUIT	Spring over to Mill
217	CONDUIT	Mill from Rio Grande to Roaring Fork
221	CONDUIT	Upland
220	CONDUIT	Monarch and Durant
209	CONDUIT	Garmisch from Durant to Main
206	CONDUIT	Second to Garmisch
205	CONDUIT	Main from Third to Garmisch

207	CONDUIT	Garmisch from Main to Hallam
219	CONDUIT	Garmisch from Hallam to Francis
203	CONDUIT	Overland from Francis to Roaring Fork
202	CONDUIT	Gillespie Through pond to Roaring Fork
213over	OVERFLOW	Ute
214over	OVERFLOW	Ute
215over	OVERFLOW	Original from Ute to Main
212over	OVERFLOW	Main and Spring
211over	OVERFLOW	Spring over to Mill
216over	OVERFLOW	Mill
217over	OVERFLOW	Mill from Rio Grande to Roaring Fork
220over	OVERFLOW	Monarch and Durant
209over	OVERFLOW	Garmisch from Durant to Main
206over	OVERFLOW	Second to Garmisch
207over	OVERFLOW	Garmisch from Main to Hallam
219over	OVERFLOW	Garmisch from Hallam to Francis
203over	OVERFLOW	Overland from Francis to Roaring Fork
202over	OVERFLOW	Gillespie Through pond to Roaring Fork
205over	OVERFLOW	Main from Third to Garmisch

4.1 Agreement with Previous Studies

The existing conditions model was calibrated using flows from the 2001 Master Plan. Due to the use of UDSWM and an older version of CUHP in the 2001 Master Plan, flows from this WWE study were not expected to match exactly. Initially a slope correction was made per UDFCD CUHP criteria in Appendix B of the user manual. Corrected slopes are shown in the "Slope" column of Table 2. Primary calibration of the model consisted of altering the Cp factor which relates imperviousness and area to peak flow. Cp values were applied to subbasin areas in CUHP and final SWMM flows were compared to the stated routing element flows in the 2001 Master Plan. A goal of less than 10 percent difference in flows was set. Flow results calibrated to within 10 percent of the 2001 Master Plan flows for the 100-year storm are shown in Table 4. Based on numerous master plans and hydrology studies that WWE has conducted for UDFCD, calibration within 10 percent of values from previous studies is a reasonable standard given that the uncertainty in peak runoff flow estimates are easily on the order of 10 percent due to the assumptions used in rainfall-runoff modeling.

Table 4. Model Calibration Results

Element	2001 Master Plan 100yr Flows (cfs)	WWE 100-yr Flows (cfs)	Percent Difference
123	224	218	2.7%
122	389	387	0.6%
121	110	104	6.0%
110Out	713	737	-3.3%
118Out	556	499	10.8%
108Out	116	119	-2.5%
125Out	22	22	0.0%
4Out	78	73	6.7%
1Out	56	52	8.0%
113div	47	48	-2.4%
114div	477	484	-1.4%
115div	485	489	-0.7%
112div	528	534	-1.2%
111div	587	593	-0.9%

116div	111	121	-8.4%
117div	160	169	-5.3%
120div	173	169	2.1%
109div	204	204	-0.2%
106div	80	75	7.1%
107div	323	318	1.5%
119div	410	386	6.1%
103div	509	463	9.5%
102div	49	47	3.2%
105div	43	43	-0.7%

4.2 Updated Rainfall

As stated in Section 3.0 the City selected the NOAA Atlas 14 mean rainfall data as its updated regulatory rainfall values. Rainfall depths taken from Atlas 14 for the 2, 5, 10, 25, 50, and 100 year storms were used throughout the remainder of analyses in this report and are shown in Table 5, below.

Table 5. City of Aspen Updated Regulatory Rainfall Depths (in inches)

Storm Duration	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
One Hour	0.47	0.64	0.77	0.95	1.09	1.23

This study was conducted focusing specifically on rainfall events and not snowmelt or rainfall on snow since the greater intensities of summer thunderstorms are more valuable for capacity analysis in the City.

4.3 Existing Conditions

The existing conditions model was used to determine current capacity issues in the City's system and is the baseline model used for all other modeling. The system in the existing model was updated from the calibrated model by altering the manning's n value to be more consistent with actual estimated roughness on the roadways for the overflow-street nodes. Additionally, surveyed cross sections for three City streets provided by the City were incorporated into the geometry of the overflow-street conduits. The model configuration was also altered slightly in a few areas to better represent the current system layout. Note that changes to the system are only reflected along the trunk lines in the model. Changes to collector lines are not captured. Finally, the timing for wet weather runoff routing was shortened from 5 minutes to 1 minute in SWMM to decrease continuity error. Modeling results from the existing conditions are provided in Appendix A.

Three modifications to the system were captured in the existing conditions model: (1) replacement of street conveyance with pipes on Ute, (2) pipe size changes on Mill from Rio Grande to the Roaring Fork and (3) pipe changes from Francis to the Roaring Fork. Results from these updates to the system are reflected in Tables 6 and 8.

4.4 Identification of Problem Areas

Problem areas were identified in the City's storm sewer system by modeling the depth of stormwater in the overflow-street conduits in the urban areas of the City. Depths of stormwater in the overflow-streets of the model are shown visually in Figures 2, 3, and 4 for the URMP 100-year storm, and the NOAA Atlas 14 Mean 10- and 100-year storms. Table 6, below, is a list of problem areas (pipes and streets) and the associated severity of modeled flooding. From Figure 3, the westernmost line (along Garmisch) is the most problematic and the easternmost line (along Spring) is also a problem in large events due to street overflow.

Table 6. Existing Conditions Problem Areas

Node	Street	Street Depth (in)	
		10 yr	100 yr
213over	Ute	0	0
214over	Ute	0	23
215over	Original from Ute to Main	0	14
212over	Main and Spring	0	13

211over	Spring over to Mill	0	11
216over	Mill	0	0
217over	Mill from Rio Grande to Puppy Smith	0	0
217over _2	Mill from Puppy Smith to Roaring Fork	0	0
220over	Monarch and Durant	0	4
209over	Garmisch from Durant to Main	0	7
206over	Second to Garmisch	0	4
207over	Garmisch from Main to Hallam	0	12
219over	Garmisch from Hallam to Francis	0	12
203over	Francis to Roaring Fork – East/West Pipe	0	10
203over_2	Francis to Roaring Fork – North/South Pipe 1	0	0
203over_3	Francis to Roaring Fork – North/South Pipe 2	0	0
202over	Gillespie Through pond to Roaring Fork	0	0
205over	Main from Third to Garmisch	0	1

4.5 Alternatives Analysis Model

The purpose of the 2001 Master Plan was to identify system upgrades. In the 2001 Master Plan, WRC presented several options and the City selected Alternative #3. Alternative #3 was modeled as part of this study to evaluate how capital improvements implemented since the 2001 Master Plan perform given the revised hydrology (are new pipe sizes adequate, oversized, undersized, etc.). Because the scope of WWE's modeling was limited to trunk lines (as modeled by WRC in the 2001 Master Plan), improvements to collection systems within sub-basins that feed into trunk lines were not evaluated.

Alternative #3 is a plan to carry the 10-year storm event (minor storm) in stormwater pipes or swales without overtopping or flooding streets and carry the 100-year storm event (major storm) within the street without overtopping curbs. This plan included increased pipe sizes for Ute and Spring in System #1 and Gilbert, Snark, Garmisch and Francis in System #2. The alternatives analysis model developed includes upgrades at Garmisch and Ute and the system flowing to the pond at the junction of Garmisch and Francis. WWE did not; however, model collector lines within subbasins if they were not included in the 2001 Master Plan model. Flow results associated with this alternatives analysis are located in Appendix B.

4.5 Pre-Development Baseline

To examine natural pre-development hydrology, pre-development baseline flows were modeled for the City using the existing conditions model with modified hydrology from CUHP. Detention to pre-development peak flow rates is a common detention requirement, and establishing the pre-development conditions provides the goal/allowable release rates for detention to keep peak flow rates at pre-development levels. CUHP parameters altered for each subbasin include: Percent Imperviousness (changed to 2 percent) and Maximum Depression Storage (changed to 0.4 for pervious and 0.1 for impervious). Appendix C shows flow results for the pre-development hydrology.

4.6 Mud Flood/Mudflow Considerations

The 2001 Master Plan discusses and analyzes the potential and magnitude of mud floods and mudflows in the City. For the purposes of this study these scenarios were not analyzed, but it should be understood that clear flow flooding behaves differently than mudflows or mud floods. Mudflow and mud flood events are a reality in Aspen, and peak flows from mudflow/mud floods would be higher than clear water flows.

5.0 EVALUATION OF DETENTION REQUIREMENTS

Another major objective of this study was the analysis of effects of detention requirements on the City's storm system capacity in the urban areas. WWE analyzed the required detention for urban areas of the City using the UDFCD spreadsheet and an iterative process in SWMM. Table 7 shows the parameters used in these calculations.

5.1 Detention to Pre-Development Peak Flow Rates

As required in the URMP, new development and redevelopment must detain stormwater runoff onsite to the historic level (i.e. stormwater cannot runoff the site at a higher rate than the rate of runoff before the town was developed). Detention was modeled using pre-development hydrology as the required detention outflow. Initial storage was estimated using UDFCD detention basin volume spreadsheet. These volumes were incorporated into storage nodes in

SWMM and then iteratively adjusted to achieve the desired pre-development outflow. Flow results from the existing conditions model were used as inflow into the storage systems. Storage was sized with a maximum depth of 4 feet[2]. Results from detention modeling are shown in Appendix D.

5.2 Detention to Pre-Development Conditions

From Table 7, detention volumes needed to return to predevelopment hydrology would generally range from around 0.8 to 1.1 inches per acre of impervious area or around 0.02 to 0.03 inches per 1,000 square feet of impervious area. This is a reasonable amount of detention to achieve pre-development hydrology and is consistent with the findings of the Full Spectrum Detention work that Ben Urbonas, P.E. has been developing for simplified water quality and flood control detention in Colorado. An analysis of street and system capacity based on storage is shown in Table 8 and Figure 5. Table 8 shows pipe flows, additional capacity for flows in pipes, and depth of overflows onto streets for both existing (current) conditions and the scenario where detention is implemented in each urban subbasin for pipes and channels for the 10- and 100-year storms. Flow results for all nodes for the 10- and 100-year storms are located in Appendix D. Improvements in capacity can be seen visually by comparing Figures 3 and 5 to see which conduits are no longer overflowing to the street. The minimal effects of detention on system capacity appear to be due to the large subbasins upland from the urban area which are not being detained and contribute a large portion of the flow to the system.

[2] Four feet was selected as a representative depth for a water quality vault and/or pond. This depth would be fairly typical of a detention vault, which is common in very dense urban areas. In a specific case, the depth in any given detention facility could be lesser or greater; however, the SWMM model is not sensitive to the depth parameter selected (volume is more important), and model results using a depth that is several feet lower or higher would not show a meaningful difference in results.

Table 7. Detention and Sizing Parameters and Calculations

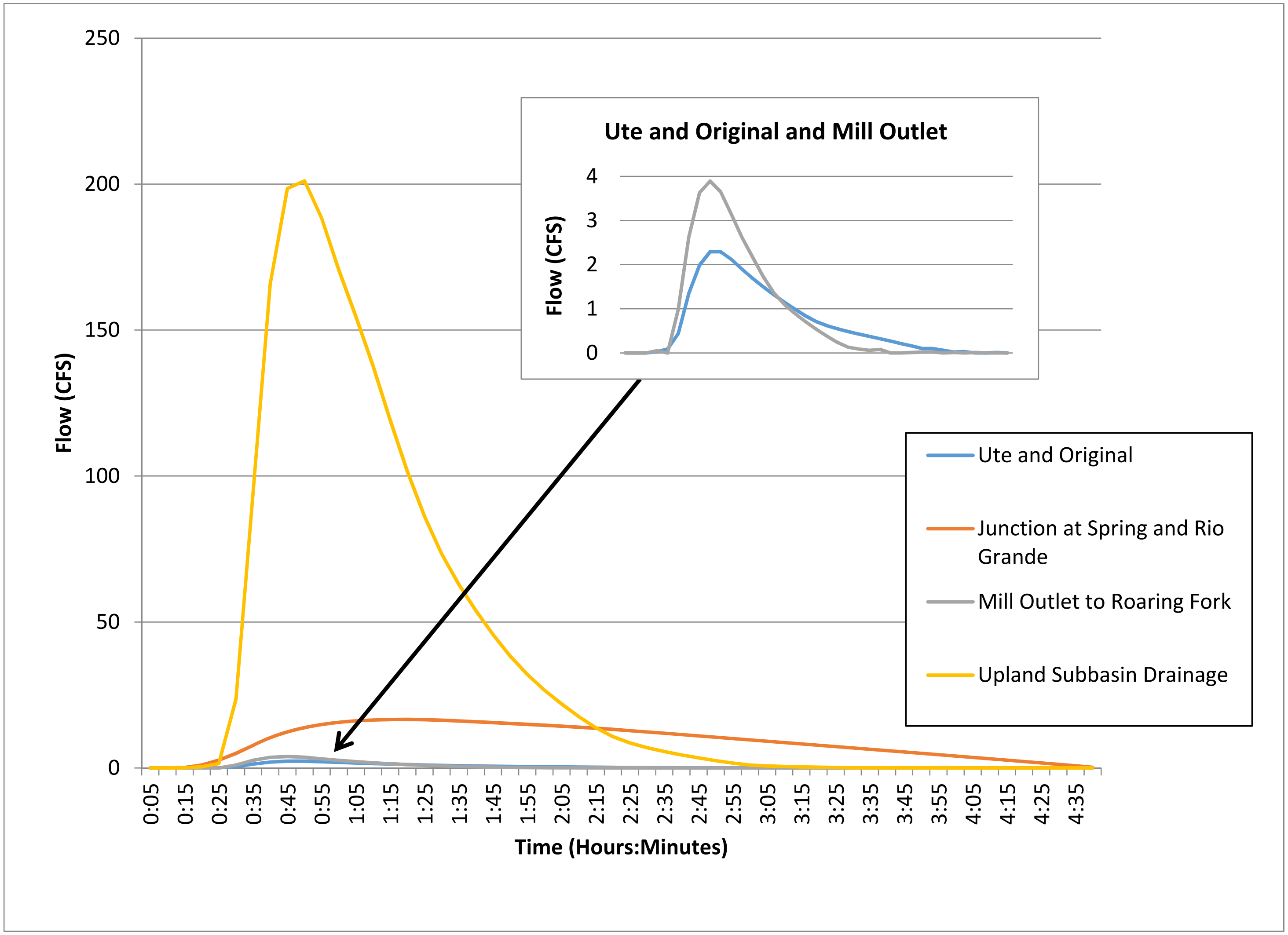
Node	Type	Maximum Lateral Inflows (CFS)	Maximum Lateral Outflow (based on predevelopment hydrology) (CFS)	Area (ac)	Impervious Area (%)	Impervious Area (Ac)	cfs/ac	UDFCD Spreadsheet Storage Volume Estimate (ft^3)	Depth Area (ft^2)	SWMM Storage Volume (ft^3)	Storage Requirement (ft^3 per Impv. Ac)	Storage Requirement (in/Impv. Ac)	Storage Requirement (in/1000 Sq Ft Impv.)
110Out	OUTFALL	4	2	9.6	10	1.0	0.23	7100	1775	3019	3145	0.87	0.02
118Out	OUTFALL	45	8	31.4	60	18.8	0.26	53500	13375	59073	3140	0.86	0.02
108Out	OUTFALL	39	14	53.8	20	10.8	0.27	47800	11950	35366	3289	0.91	0.02
113div	DIVIDER	22	11	41.0	10	4.1	0.27	27500	6875	15035	3671	1.01	0.02
114div	DIVIDER	28	15	119.0	10	11.9	0.13	120800	30200	45250	3801	1.05	0.02
115div	DIVIDER	2	1	7.7	10	0.8	0.17	6900	1725	2232	2906	0.80	0.02
112div	DIVIDER	37	6	47.4	40	18.9	0.13	82300	20575	72661	3836	1.06	0.02
111div	DIVIDER	64	5	49.3	65	32.0	0.11	130300	32575	125336	3913	1.08	0.02
116div	DIVIDER	65	20	106.9	25	26.7	0.19	125900	31475	97395	3645	1.00	0.02
117div	DIVIDER	48	4	28.8	70	20.2	0.15	75000	18750	73228	3632	1.00	0.02
120div	DIVIDER	36	23	51.2	10	5.1	0.46	20500	5125	20500	4004	1.10	0.03
109div	DIVIDER	37	22	42.2	15	6.3	0.51	17000	4250	20856	3292	0.91	0.02
106div	DIVIDER	41	26	44.2	10	4.4	0.59	11300	2825	16963	3841	1.06	0.02
107div	DIVIDER	18	4	25.6	40	10.2	0.15	41500	10375	36988	3612	1.00	0.02
119div	DIVIDER	71	11	51.2	70	35.8	0.21	114000	28500	32820	916	0.25	0.01
103div	DIVIDER	91	14	55.7	70	39.0	0.25	113800	28450	127666	3276	0.90	0.02
102div	DIVIDER	26	8	37.1	26	9.5	0.22	40700	10175	31395	3317	0.91	0.02
105div	DIVIDER	25	12	31.4	20	6.2	0.40	20500	5125	19988	3219	0.89	0.02

Table 8. System Capacity with Detention

			10-yr						100-yr					
			Pipe Flow (cfs)		Remaining Pipe Capacity (in)		Depth of Flow on Street (in)		Pipe Flow (cfs)		Remaining Pipe Capacity (ft)		Depth of Flow on Street (in)	
Node	Location	Pipe Size (in) **Channel Size (in)	Existing Condition	Detention	Existing Condition	Detention	Existing Condition	Detention	Existing Condition	Detention	Existing Condition	Detention	Existing Condition	Detention
212	Main and Spring	36	30	25	23	24	0	0	114	113	0	0	13	12
213	Ute	12**	2		7		0		6		0		0	
214	Ute	30**	22		21		0		121		0		23	
215	Original from Ute to Main	36	22	22	21	21	0	0	59	59	0	0	14	13
216	Mill	36	16	7	23	27	0	0	61	18	2	22	0	0
211	Spring over to Mill	36	46	28	20	24	0	0	123	123	0	0	11	10
217	Mill from Rio Grande to Puppy Smith	52	34		35		0		96		5		0	
217_2	Mill from Puppy Smith to Roaring Fork	60 x 38	34		27		0		96		21		0	
220	Monarch and Durant	6**	8	8	2	2	0	0	22	22	0	0	4	2
209	Garmisch from Durant to Main	24	12	13	12	12	0	0	28	28	0	0	7	6
206	Second to Garmisch	24	4	4	14	14	0	0	11	11	0	0	4	2
205	Main from Third to Garmisch	22	5	4	14	15	0	0	18	12	0	8	1	0
207	Garmisch from Main to Hallam	36	25	21	12	15	0	0	35	35	0	0	12	10
219	Garmisch from Hallam to Francis	48	52	27	19	29	0	0	83	83	0	0	12	7
203	Francis to Roaring Fork - East/West Pipe	36	96		3		0		97		0		10	
203_2	Francis to Roaring Fork - North/South Pipe 1	54	95		38		0		301		24		0	
203_3	Francis to Roaring Fork - North/South Pipe 2	60 x 38	95		24		0		301		13		0	
202	Gillespie Through pond to Roaring Fork	24	7	3	18	19.9	0	0	25	8	13	18	0	0

Additionally, the overflow depth on streets is not drastically improved by detaining to the pre-development level in the urban areas. Figure 6 shows hydrographs from the 100-year storm for three of the detention junctions (show the outflow from detention) and one of the upland junctions. It is obvious that the upland flow is much greater than the subbasin flows detained and then discharged from detention. Additionally, the reduction but increased time period of flow release could reduce capacity because of the delayed entry into the system of those flows.

Figure 6. Example Hydrographs from Upland Junction and Urban Detention Junctions for 100-year Storm



Detention was also examined in subbasins directly adjacent to the Roaring Fork. Two separate scenarios were modeled for detention in the lower portion of the City: detention was included in Subbasins 8, 10, and 18 in one model and detention was omitted from these basins in the other. Flow and capacity results from these subbasins and subbasins directly up-system from them show that detention does not provide a significant benefit and flows were even the same for one subbasin as shown in Table 9, below.

Table 9. Detention Versus Existing Conditions Flow and Depth Capacity

		Flow (CFS)			
		10-year		100-year	
Node	Corresponding Location	Detention Adjacent	No detention adjacent	Detention Adjacent	No detention adjacent
110Outlet	Outfall from Mill	37	37	243	243
118Outlet	Outfall from Garmisch Overland	40	43	152	159
108Outlet	Outfall from Gillespie Through Pond	8	11	22	43

5.3 Effects of Water Quality Capture Volume Implementation

The final analysis conducted for this report pertains to the benefit to the City's system capacity from implementation of the Water Quality Capture Volume (WQCV). From the URMP, the City's WQCV requirement is 0.26 inches/watershed acre. For purposes of this study 100%, 75%, 50% and 25% implementation of the WQCV was modeled for the urbanized subbasins in the City. This was simulated by adding the capture volume to the existing impervious storage depth in CUHP to generate reduced flows/hydrology that was input into SWMM. Appendix E shows results from the four levels of implementation over the 2, 5, 10 and 50-year events. Table 10 compares the different levels of implementation to the current existing capacity for the 10-year storm. Noticeable benefit is provided by WQCV implementation at a number of nodes, but this tapers off and is not observed at the 50-year storm. Since the WQCV is small it would not be expected to effectively attenuate larger storms. Areas of the system and City that most benefit from the WQCV included: Rio Grande and Spring, Garmisch and Hallam, and Garmisch and Francis as well as the majority of outfall nodes. All of these areas are at the bottom of the watershed and benefit from a cumulative effect of implementation throughout the urbanized area.

Table 10. WQCV Implementation Flows for 10-Year Storm

10 yr Storm Flows (CFS)						
Node	Type	Existing Conditions (No modeled WQCV)	WQCV Implementation 25	50	75	100
123	JUNCTION	11.30	11.30	11.30	11.30	11.30
122	JUNCTION	19.85	19.85	19.85	19.85	19.85
121	JUNCTION	5.02	4.02	2.53	1.10	0.84
110Out	OUTFALL	77.01	66.88	61.90	51.48	46.06
118Out	OUTFALL	114.79	95.93	81.74	65.42	50.25
108Out	OUTFALL	14.94	12.69	10.10	6.89	4.24
125Out	OUTFALL	4.65	3.99	3.37	2.62	2.05
4Out	OUTFALL	11.89	11.89	11.89	11.89	11.89
1Out	OUTFALL	1.57	1.57	1.57	1.57	1.57
113div	DIVIDER	2.29	1.80	1.13	0.50	0.38
114div	DIVIDER	21.54	20.79	19.86	18.88	18.58
115div	DIVIDER	21.71	20.92	19.96	18.93	18.62
112div	DIVIDER	29.79	28.12	26.41	24.72	23.79
111div	DIVIDER	46.18	43.04	39.94	36.72	34.59
116div	DIVIDER	17.01	14.07	11.35	8.18	5.28
117div	DIVIDER	34.07	29.08	24.06	18.49	13.80
120div	DIVIDER	8.00	6.35	4.37	2.47	1.65
109div	DIVIDER	12.22	9.87	7.37	4.81	3.25
106div	DIVIDER	4.15	3.60	2.81	1.69	0.96
107div	DIVIDER	25.49	21.01	16.65	12.12	8.63
119div	DIVIDER	52.32	44.40	36.89	29.14	22.09
103div	DIVIDER	93.72	80.73	68.05	54.10	41.48
102div	DIVIDER	6.65	5.70	4.59	3.21	2.08
105div	DIVIDER	4.92	4.11	3.46	2.62	1.83
212	CONDUIT	29.78	28.11	26.40	24.71	23.78
213	CONDUIT	2.28	1.78	1.12	0.50	0.37
214	CONDUIT	21.53	20.78	19.86	18.87	18.58
215	CONDUIT	21.61	20.77	19.82	18.82	18.51
222	CONDUIT	17.68	17.68	17.68	17.68	17.68

223	CONDUIT	11.15	11.15	11.15	11.15	11.15
216	CONDUIT	16.40	13.83	10.96	7.90	5.19
211	CONDUIT	46.14	42.93	39.89	36.64	34.54
217	CONDUIT	20.66	20.70	20.69	18.38	13.79
221	CONDUIT	4.75	3.64	2.29	1.02	0.73
220	CONDUIT	7.89	6.23	4.31	2.43	1.62
209	CONDUIT	12.12	9.80	7.30	4.76	3.21
206	CONDUIT	3.70	3.02	2.28	1.50	0.87
205	CONDUIT	4.79	4.11	3.40	2.55	1.79
207	CONDUIT	25.40	20.96	16.58	12.09	8.61
219	CONDUIT	52.29	44.38	36.88	29.12	22.08
203	CONDUIT	97.77	80.47	67.86	53.91	41.43
202	CONDUIT	6.65	5.66	4.52	3.17	2.06
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	14.59	9.42	4.07	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.83	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

6.0 CONCLUSIONS AND RECOMMENDATIONS

From the analyses conducted through this study, problem areas in Aspen's system were identified and correlated well with results from the 2001 Master Plan. The addition of detention in each subbasin was also analyzed for system capacity and was found to provide marginal capacity benefit to the system for all storm events due largely to the amount of runoff from upland areas. Continued use of this requirement might be re-examined and potentially substituted with a requirement for low impact development (LID) or greener alternatives that would provide both a water quality and aesthetic benefit to the City. The various levels of implementation of the WQCV were found to provide some benefit to the majority of urban subbasins for the 2- through 10-year storms (when much of the mountain runoff does not make it down to the City and local urban drainage is the larger issue), but as expected were not helpful for larger storms (where again mountain runoff dominates). Flooding appeared to be the worst in System #1 and System #3 and primarily only for the 100-year storm. Future capital project efforts might focus on system upgrades in these areas.

7.0 REFERENCES

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WRC Engineering, Inc. *Surface Drainage Master Plan for the City of Aspen*. November 2001.

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WWE

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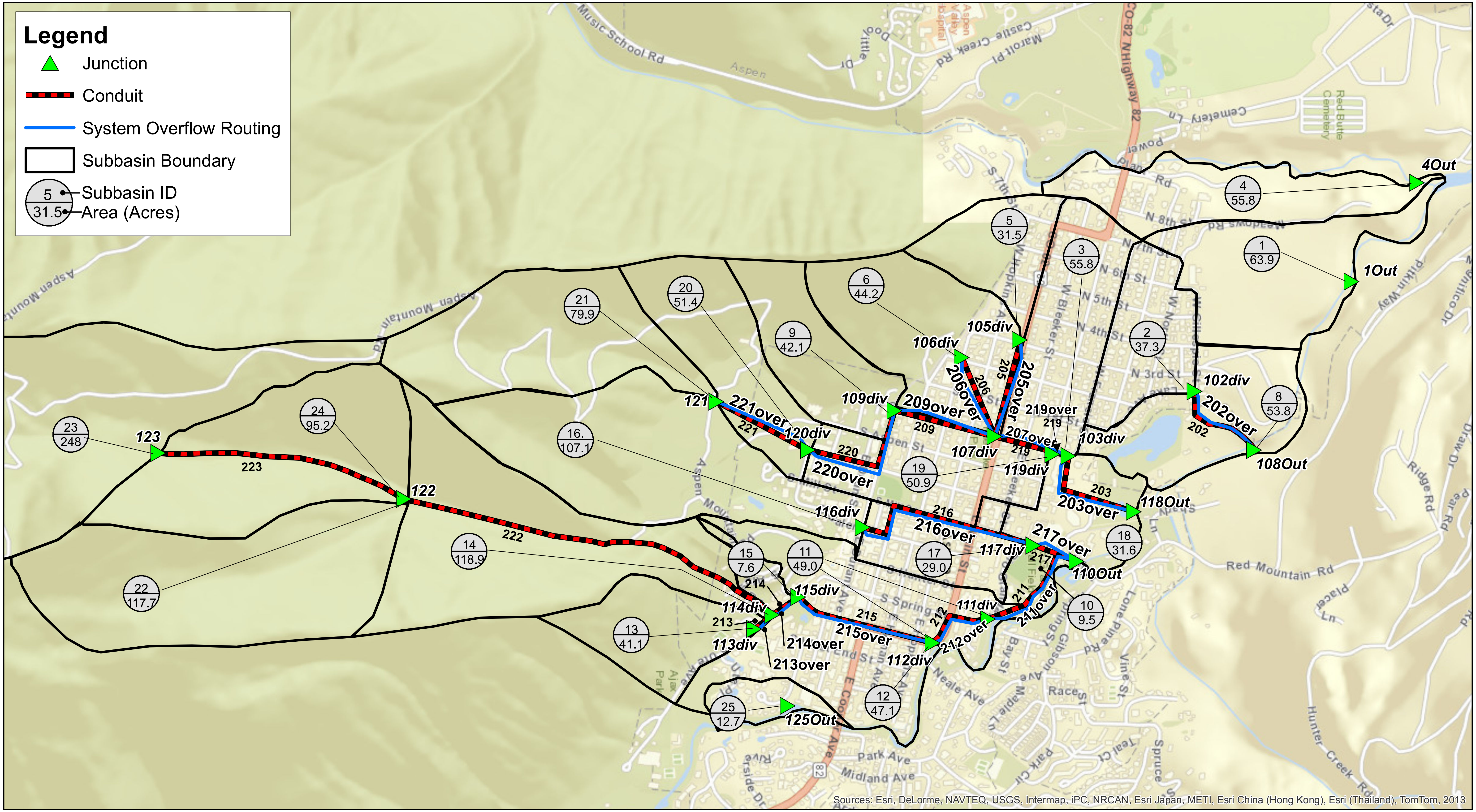

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ASPEN, COLORADO

ASPEN DETENTION ANALYSIS

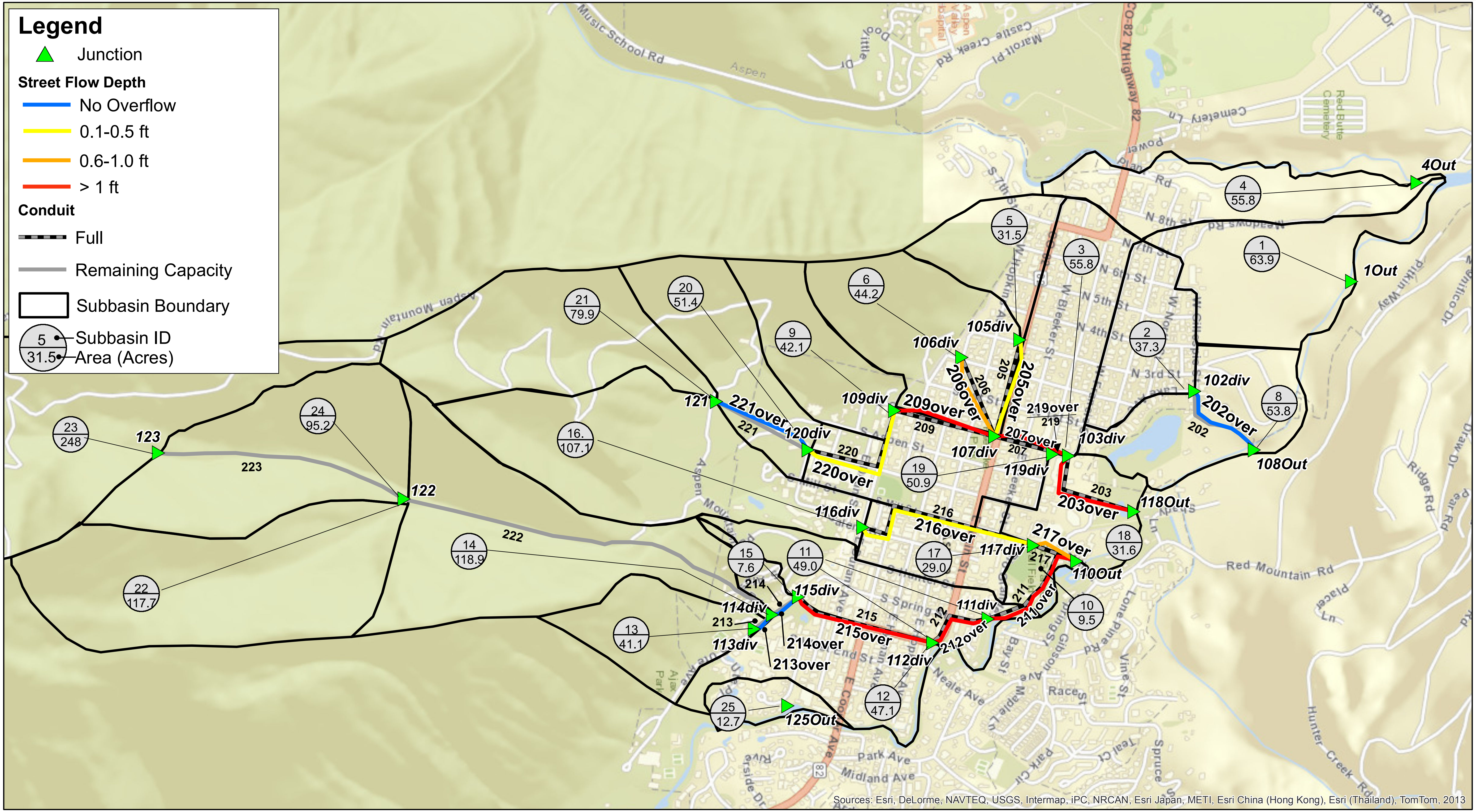
SWMM ROUTING ELEMENTS

1 inch = 1,300 feet

0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
1



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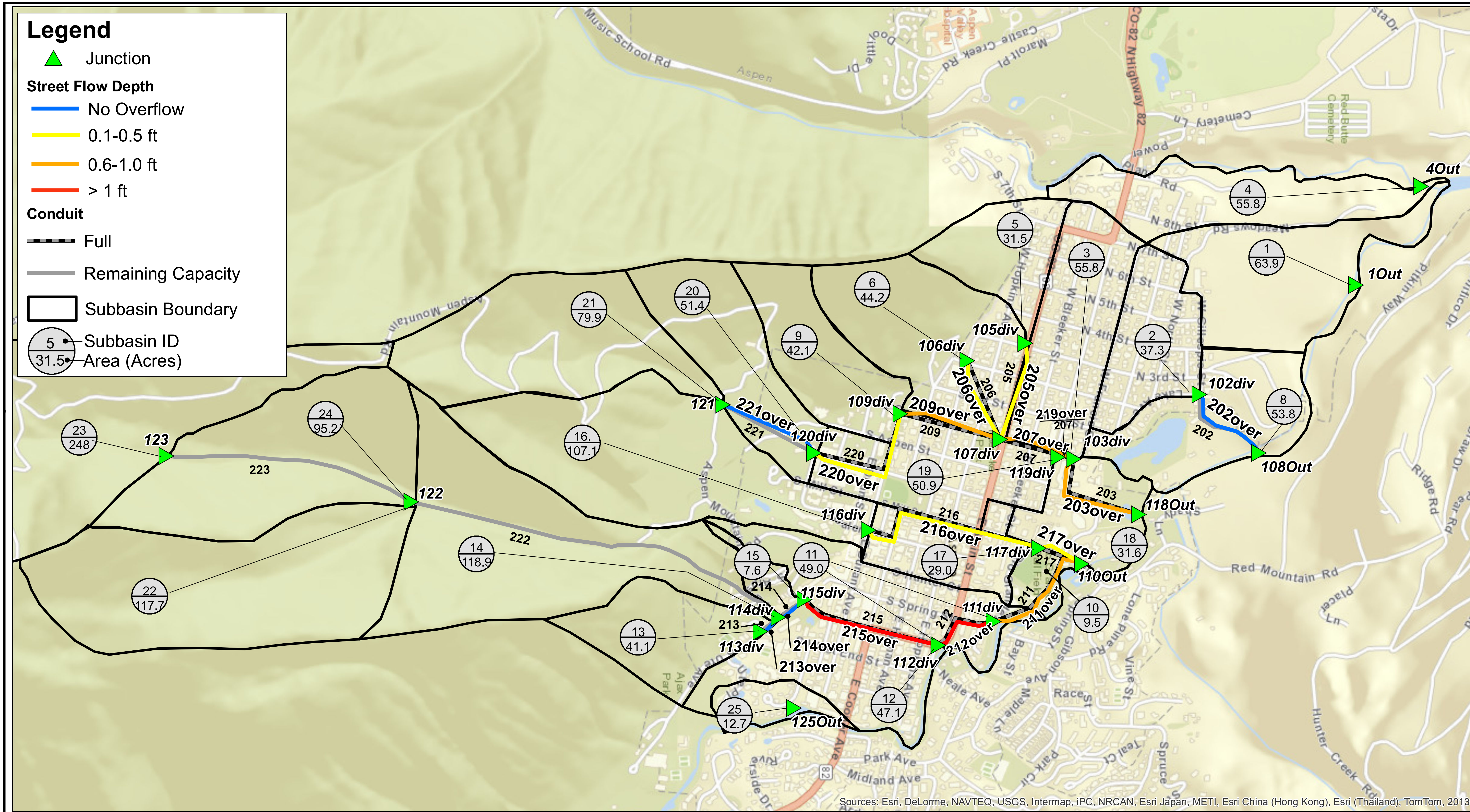
ASPEN DETENTION ANALYSIS
EXISTING CONDITIONS WITH URMP RAINFALL-100 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
2



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ASPEN DETENTION ANALYSIS
EXISTING CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-100 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
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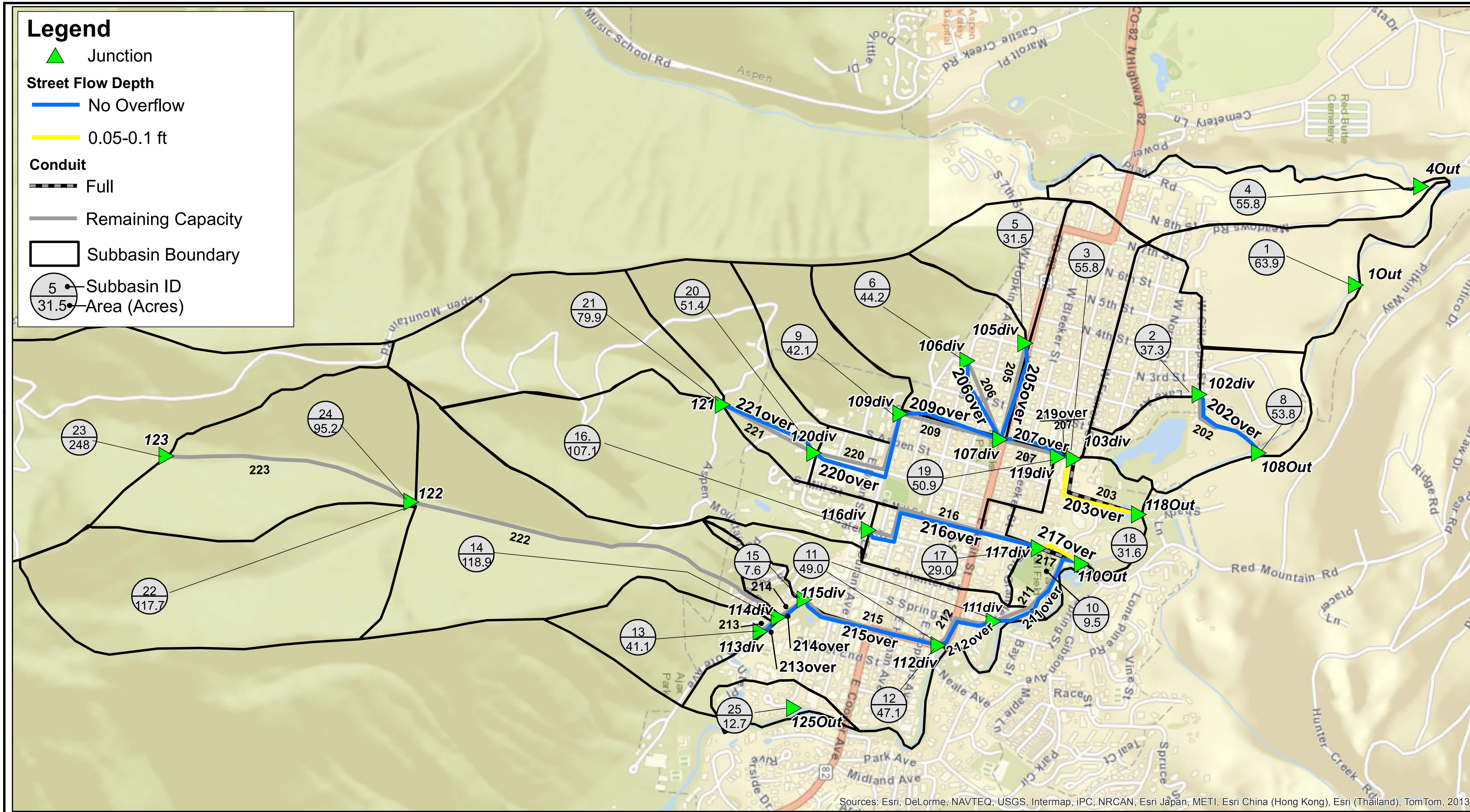
FIGURE
3



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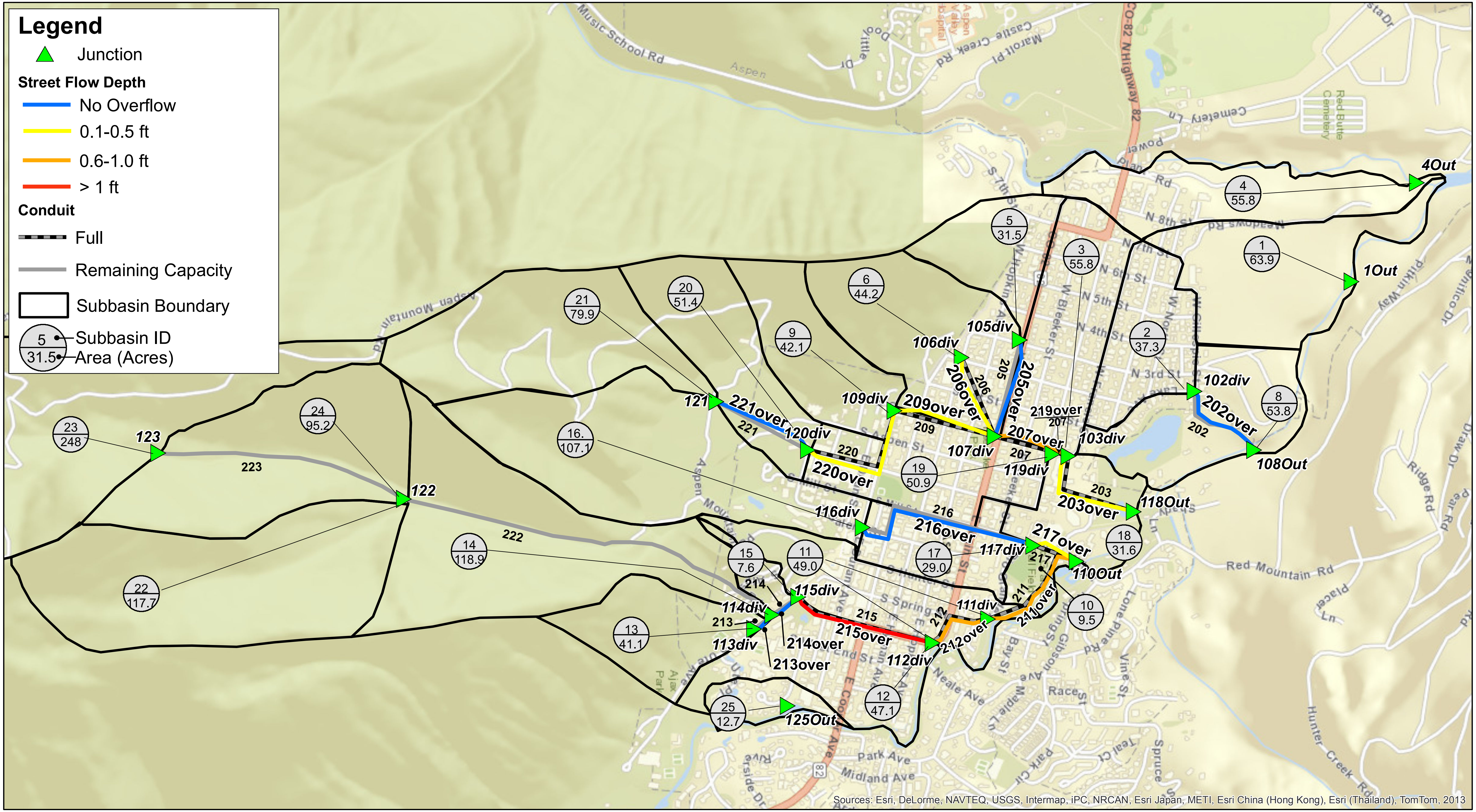
ASPEN DETENTION ANALYSIS
EXISTING CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-10 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
4



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ASPEN, COLORADO

ASPEN DETENTION ANALYSIS
DETENTION CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-100 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
5

APPENDIX A: Flows from Existing Condition Model

Design Point	Associated Location	Flow (CFS)					
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
123	Upland	1.81	6.46	11.30	29.19	68.41	113.86
122	Upland	3.09	11.08	19.85	52.29	120.93	202.03
121	Upland	1.02	2.06	5.02	11.27	22.20	48.2
110Out	Outfall from Mill	40.85	60.15	78.18	138.45	214.69	384.89
118Out	Outfall from Garmisch Overland	60.59	88.11	111.03	165.23	214.92	329.97
108Out	Outfall from Gillespie Through Pond	4.99	10.29	14.94	26.06	38.23	63.34
125Out	Outfall south of the City Near Waters	2.55	3.63	4.65	7.06	8.89	12.68
4Out	Outfall at Castle Creek and Roaring Fork	5.11	8.32	11.89	19.64	27.04	40.85
1Out	Outfall North of Gillespie	0.20	0.62	1.57	3.72	9.34	22.31
113div	Ute	0.44	0.94	2.29	5.16	9.93	21.61
114div	Ute	3.25	10.97	21.50	59.85	138.28	243.48
115div	Ute and Original	3.28	11.05	21.69	60.32	138.64	245.42
112div	Main and Original	7.42	17.04	29.84	75.66	154.66	272.49
111div	Near Rio Grande and Spring	24.23	34.86	46.64	97.12	180.62	313.76
116div	Durant and Galena	6.29	11.58	17.01	29.22	41.06	65.43
117div	Rio Grande and Mill	16.76	25.47	34.07	54.09	69.49	95.56
120div	Snark and Monarch	1.34	3.76	8.00	20.01	42.67	81.65
109div	Garmisch and Durant	2.13	6.66	12.22	30.33	62.93	114.29
106div	Second and Hyman	0.64	2.50	4.15	9.01	24.42	40.7
107div	Garmisch and Main	6.77	16.05	25.49	54.75	107.71	185.87
119div	Garmisch and Hallam	24.75	38.05	52.32	90.98	147.01	238.9
103div	Garmisch and Francis	50.18	72.88	93.72	140.95	192.42	301.51
102div	Gillespie Near Third	2.51	4.67	6.65	11.29	16.24	25.62
105div	Third and Main	1.33	3.36	4.92	8.91	16.35	24.57
117_2div	Rio Grande and Mill	16.73	25.44	34.03	53.90	69.43	95.53
103_2div	Francis to Roaring Fork	50.10	72.76	96.58	140.45	192.34	301.33
103_3div	Francis to Roaring Fork	50.08	72.70	94.83	140.47	192.35	301.36
212	Main and Spring	7.39	17.03	29.81	74.56	112.86	113.99

213	Ute	0.44	0.94	2.28	5.14	5.46	5.58
214	Ute	3.25	10.97	21.50	59.85	120.67	120.83
215	Original from Ute to Main	3.27	10.96	21.52	59.46	59.41	59.42
222	Upland	2.53	9.36	17.68	49.96	116.60	197.33
223	Upland	1.73	6.24	11.15	29.18	67.63	112.87
216	Mill	5.96	11.26	16.40	28.43	40.73	60.51
211	Spring over to Mill	24.05	34.55	46.64	97.01	123.35	123.46
217	Mill from Rio Grande to Roaring Fork	16.73	25.44	34.03	53.90	69.43	95.53
221	Upland	0.87	1.90	4.75	11.08	21.55	46.68
220	Monarch and Durant	1.31	3.69	7.89	19.85	21.69	21.69
209	Garmisch from Durant to Main	2.10	6.59	12.12	27.54	27.49	27.48
206	Second to Garmisch	0.50	2.00	3.70	8.97	10.97	10.95
205	Main from Third to Garmisch	1.28	3.32	4.79	8.88	16.09	17.97
207	Garmisch from Main to Hallam	6.74	15.98	25.40	35.04	34.95	34.99
219	Garmisch from Hallam to Francis	24.66	37.98	52.29	83.48	83.03	83.27
203	Francis to Roaring Fork	50.10	72.76	95.56	97.02	97.33	97.04
202	Gillespie Through pond to Roaring Fork	2.48	4.64	6.65	11.32	16.10	25.33
213over	Ute	0.00	0.00	0.00	0.00	4.73	16.32
214over	Ute	0.00	0.00	0.00	0.00	24.21	129.83
215over	Original from Ute to Main	0.00	0.00	0.00	5.25	82.49	189.86
212over	Main and Spring	0.00	0.00	0.00	0.00	48.08	166.21
211over	Spring over to Mill	0.00	0.00	0.00	0.00	63.45	194.28
216over	Mill	0.00	0.00	0.00	0.00	0.00	8.52
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0
220over	Monarch and Durant	0.00	0.00	0.00	0.00	20.52	59.53
209over	Garmisch from Durant to Main	0.00	0.00	0.00	4.81	35.37	87.24
206over	Second to Garmisch	0.00	0.00	0.00	0.00	10.97	25.79
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	21.96	74.93	153.15
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	12.96	69.12	161.02
203over	Francis to Roaring Fork	0.00	0.00	1.02	48.14	100.03	209.02
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0

205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	6.47
217_2	Mill from Rio Grande to Roaring Fork	16.72	25.43	34.02	53.88	69.42	95.51
217_2over	Mill from Rio Grande to Roaring Fork	0	0	0	0	0	0
203_2	Francis to Roaring Fork	50.08	72.7	94.83	140.47	192.35	301.36
203_2over	Francis to Roaring Fork	0	0	0	0	0	0
203_3	Francis to Roaring Fork	50.09	72.72	94.79	140.31	193.87	301.28
203_3over	Francis to Roaring Fork	0	0	0	0	0	0

APPENDIX B: Alternatives Analysis Flow Results

Node	Type	Flow (CFS)	
		10-Year	100-Year
123	JUNCTION	11.30	113.86
122	JUNCTION	19.85	202.03
121	JUNCTION	5.02	48.20
110Out	OUTFALL	77.48	387.34
118Out	OUTFALL	110.61	333.74
108Out	OUTFALL	14.94	63.34
125Out	OUTFALL	4.65	12.68
4Out	OUTFALL	11.89	40.85
1Out	OUTFALL	1.57	22.31
113div	DIVIDER	2.29	21.61
114div	DIVIDER	21.54	243.39
115div	DIVIDER	21.72	245.33
112div	DIVIDER	29.87	272.41
111div	DIVIDER	46.71	313.69
116div	DIVIDER	17.01	65.43
117div	DIVIDER	34.07	95.56
120div	DIVIDER	8.00	81.65
109div	DIVIDER	12.22	114.29
106div	DIVIDER	4.15	40.70
107div	DIVIDER	25.54	186.11
119div	DIVIDER	52.49	238.48
103div	DIVIDER	93.93	299.60
102div	DIVIDER	6.65	25.62
105div	DIVIDER	4.92	24.57
109div_alt	DIVIDER	12.15	113.37
212	CONDUIT	29.82	114.02
213	CONDUIT	2.28	21.57
214	CONDUIT	21.54	120.93
215	CONDUIT	21.57	59.40
222	CONDUIT	17.68	197.33
223	CONDUIT	11.15	112.87
216	CONDUIT	16.40	60.51
211	CONDUIT	46.67	123.45
217	CONDUIT	20.66	20.67
221	CONDUIT	4.75	46.68
220	CONDUIT	7.89	21.69
209	CONDUIT	12.15	28.76
206	CONDUIT	3.70	10.95

205	CONDUIT	4.79	17.97
207	CONDUIT	25.46	75.51
219	CONDUIT	52.46	113.59
203	CONDUIT	93.38	288.28
202	CONDUIT	6.65	25.33
213over	CHANNEL	0.00	0.00
214over	CHANNEL	0.00	129.74
215over	CHANNEL	0.00	189.78
212over	CHANNEL	0.00	166.13
211over	CONDUIT	0.00	194.23
216over	CHANNEL	0.00	8.52
217over	CHANNEL	14.59	76.22
220over	CHANNEL	0.00	59.53
209over	CHANNEL	0.00	86.66
206over	CHANNEL	0.00	25.79
207over	CHANNEL	0.00	115.90
219over	CHANNEL	0.00	131.86
203over	CHANNEL	0.00	23.74
202over	CHANNEL	0.00	0.00
205over	CHANNEL	0.00	6.47
209alt	CHANNEL	12.14	77.94
209over_alt	CHANNEL	0.00	39.95

APPENDIX C: Predevelopment Hydrology Flows

Design Point	Associated Location	Flow (CFS)					
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
123	Upland	0.07	0.80	1.84	4.40	33.58	81.01
122	Upland	0.07	1.24	3.03	7.52	57.78	140.24
121	Upland	0.04	0.11	0.72	1.92	2.64	24.35
110Out	Outfall from Mill	0.08	1.02	3.33	10.43	61.43	189.72
118Out	Outfall from Garmisch Overland	0.08	0.80	2.58	7.74	41.11	127.66
108Out	Outfall from Gillespie Through Pond	0.03	0.09	0.57	1.70	2.35	21.89
125Out	Outfall south of the City Near Waters	0.00	0.01	0.06	0.19	0.26	2.40
4Out	Outfall at Castle Creek and Roaring Fork	0.02	0.05	0.29	0.85	1.18	10.83
1Out	Outfall North of Gillespie	0.02	0.07	0.39	1.11	1.54	14.05
113div	Ute	0.02	0.05	0.30	0.87	1.22	11.02
114div	Ute	0.04	0.93	2.72	8.05	56.98	160.21
115div	Ute and Original	0.04	0.93	2.74	8.12	57.07	161.31
112div	Main and Original	0.04	0.94	2.82	8.46	59.88	166.25
111div	Near Rio Grande and Spring	0.05	0.95	2.93	8.83	59.58	171.03
116div	Durant and Galena	0.03	0.09	0.55	1.62	2.22	20.23
117div	Rio Grande and Mill	0.03	0.09	0.57	1.79	2.55	24.15
120div	Snark and Monarch	0.02	0.25	0.96	2.86	12.46	45.83
109div	Garmisch and Durant	0.03	0.42	1.26	3.75	21.11	65.24
106div	Second and Hyman	0.02	0.29	0.67	1.45	11.66	26.17
107div	Garmisch and Main	0.06	0.73	1.98	5.70	37.08	101.62
119div	Garmisch and Hallam	0.06	0.75	2.14	6.39	40.58	111.14
103div	Garmisch and Francis	0.08	0.79	2.39	7.32	41.15	124.36
102div	Gillespie Near Third	0.01	0.04	0.22	0.63	0.88	8.09
105div	Third and Main	0.01	0.13	0.28	0.67	5.09	12.45
212	Main and Spring	0.04	0.94	2.82	8.45	59.03	112.86
213	Ute	0.02	0.05	0.30	0.87	1.21	10.99
214	Ute	0.04	0.92	2.72	8.05	56.96	160.18
215	Original from Ute to Main	0.03	0.92	2.72	8.06	59.29	59.32

222	Upland	0.00	0.87	2.35	6.49	54.57	135.34
223	Upland	0.02	0.72	1.73	4.27	33.01	80.27
216	Mill	0.02	0.07	0.48	1.48	2.11	20.08
211	Spring over to Mill	0.05	0.95	2.96	8.82	59.10	123.32
217	Mill from Rio Grande to Roaring Fork	0.03	0.08	0.56	1.76	2.54	20.69
221	Upland	0.00	0.07	0.56	1.76	2.45	23.61
220	Monarch and Durant	0.02	0.23	0.94	2.83	12.19	21.69
209	Garmisch from Durant to Main	0.03	0.40	1.24	3.72	20.87	27.35
206	Second to Garmisch	0.01	0.21	0.48	1.25	10.53	10.96
205	Main from Third to Garmisch	0.01	0.12	0.27	0.65	5.06	12.26
207	Garmisch from Main to Hallam	0.05	0.71	1.95	5.68	35.04	35.00
219	Garmisch from Hallam to Francis	0.06	0.74	2.14	6.38	39.98	83.30
203	Overland from Francis to Roaring Fork	0.07	0.78	2.46	7.31	40.59	99.90
202	Gillespie Through pond to Roaring Fork	0.01	0.03	0.21	0.63	0.87	8.07
213over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
214over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
215over	Original from Ute to Main	0.00	0.00	0.00	0.00	0.44	105.44
212over	Main and Spring	0.00	0.00	0.00	0.00	0.00	59.75
211over	Spring over to Mill	0.00	0.00	0.00	0.00	0.00	51.25
216over	Mill	0.00	0.00	0.00	0.00	0.00	0.00
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	4.37
220over	Monarch and Durant	0.00	0.00	0.00	0.00	0.00	23.79
209over	Garmisch from Durant to Main	0.00	0.00	0.00	0.00	0.00	38.19
206over	Second to Garmisch	0.00	0.00	0.00	0.00	0.91	13.84
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	0.00	4.63	68.90
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	0.00	0.00	33.20
203over	Overland from Francis to Roaring Fork	0.00	0.00	0.00	0.00	0.00	29.98
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0.00
205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX D: Detention to Predevelopment for All Urban Watersheds Not Directly Adjacent to the Roaring Fork

Design Point	Associated Location	Flow (CFS)					
		2-Year	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**
123	Upland	1.81	6.46	11.30	29.19	68.41	113.86
122	Upland	3.09	11.08	19.85	52.29	120.93	202.03
121	Upland	1.02	2.06	5.02	11.27	22.20	48.20
110Out	Outfall from Mill	19.87	33.54	47.94	97.60	167.56	266.56
118Out	Outfall from Garmisch Overland	25.73	39.87	52.29	83.63	120.17	177.89
108Out	Outfall from Gillespie Through Pond	4.50	8.81	12.41	20.59	29.63	47.51
125Out	Outfall south of the City Near Waters	2.55	3.63	4.65	7.06	8.89	12.68
4Out	Outfall at Castle Creek and Roaring Fork	5.11	8.32	11.89	19.64	27.04	40.85
1Out	Outfall North of Gillespie	0.20	0.62	1.57	3.72	9.34	22.31
113divider	Ute	0.45	0.92	2.08	4.38	7.55	13.11
114divider	Ute	3.27	11.01	21.38	58.18	129.88	218.27
115divider	Ute and Original	3.34	11.14	21.55	58.62	130.81	220.37
112divider	Main and Original	7.67	17.07	28.56	72.73	141.42	233.72
111divider	Near Rio Grande and Spring	14.62	25.85	38.38	84.36	154.91	249.02
116divider	Durant and Galena	3.82	5.77	7.38	10.79	13.43	17.59
117divider	Rio Grande and Mill	5.22	7.84	9.97	14.10	17.09	21.72
120divided	Snark and Monarch	1.35	3.87	8.12	18.04	35.17	64.86
109divider	Garmisch and Durant	2.18	7.01	12.78	27.16	50.54	85.71
106divider	Second and Hyman	0.65	2.35	3.85	8.23	16.73	24.50
107divider	Garmisch and Main	4.36	12.75	21.31	46.24	79.45	126.70
119divider	Garmisch and Hallam	12.10	22.20	31.95	59.14	95.14	143.96
103divider	Garmisch and Francis	20.83	32.89	43.97	74.61	112.42	163.15
102divider	Gillespie Near Third	2.26	3.75	5.02	7.74	10.04	13.75
105divider	Third and Main	1.30	3.17	4.34	7.50	11.75	16.16
107div	Main and Spring	3.43	4.87	6.25	9.91	12.94	17.74
117div	Ute	13.84	19.85	24.24	33.21	39.67	47.79
105div	Ute	1.33	3.36	4.92	8.91	16.35	24.57

106div	Original from Ute to Main	0.64	2.50	4.15	9.01	24.42	40.70
109div	Upland	1.26	3.99	6.05	11.33	23.52	37.20
120div	Upland	0.59	2.10	3.72	9.09	22.36	36.46
119div	Mill	19.61	28.60	35.16	49.00	58.64	70.55
103div	Spring over to Mill	25.72	37.63	46.31	64.10	76.63	90.87
116div	Mill from Rio Grande to Roaring Fork	6.29	11.58	17.01	29.22	41.06	65.43
113div	Upland	0.44	0.94	2.29	5.16	9.93	21.61
114div	Monarch and Durant	0.61	1.22	2.80	6.88	13.42	27.87
115div	Garmisch from Durant to Main	0.05	0.10	0.24	0.56	1.12	2.33
112div	Second to Garmisch	7.05	10.00	12.83	20.37	26.58	36.89
111div	Main from Third to Garmisch	17.12	24.23	29.47	42.25	51.14	64.01
102div	Garmisch from Main to Hallam	2.51	4.67	6.65	11.29	16.24	25.62
212	Garmisch from Hallam to Francis	7.66	17.06	28.56	71.65	114.00	113.30
213	Overland from Francis to Roaring Fork	0.45	0.92	2.08	4.38	7.54	13.11
214	Gillespie Through pond to Roaring Fork	3.27	11.01	21.38	58.16	129.85	218.25
215	Ute	3.32	11.04	21.41	59.56	59.27	59.53
222	Ute	2.53	9.36	17.68	49.96	116.60	197.33
223	Original from Ute to Main	1.73	6.24	11.15	29.18	67.63	112.87
216	Main and Spring	3.80	5.76	7.37	10.79	13.43	17.58
211	Spring over to Mill	14.61	25.83	38.36	83.75	123.40	123.17
217	Mill	5.22	7.84	9.97	14.10	17.08	20.69
221	Mill from Rio Grande to Roaring Fork	0.87	1.90	4.75	11.08	21.55	46.68
220	Monarch and Durant	1.32	3.79	8.00	17.93	21.69	21.69
209	Garmisch from Durant to Main	2.15	6.92	12.65	27.55	27.45	27.52
206	Second to Garmisch	0.49	2.04	3.57	8.07	10.95	10.96
205	Garmisch from Main to Hallam	1.27	3.14	4.32	7.49	11.74	16.13
207	Garmisch from Hallam to Francis	4.35	12.67	21.20	35.05	34.97	35.02
219	Overland from Francis to Roaring Fork	12.10	22.17	31.93	59.10	83.26	83.39
203	Gillespie Through pond to Roaring Fork	20.82	32.85	43.94	74.53	99.82	99.84
202	Main from Third to Garmisch	2.25	3.75	5.01	7.74	10.04	13.74

213over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
214over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
215over	Original from Ute to Main	0.00	0.00	0.00	3.15	74.74	164.83
212over	Main and Spring	0.00	0.00	0.00	0.00	34.71	127.42
211over	Spring over to Mill	0.00	0.00	0.00	0.00	36.32	131.05
216over	Mill	0.00	0.00	0.00	0.00	0.00	0.00
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	2.56
220over	Monarch and Durant	0.00	0.00	0.00	0.00	13.22	42.89
209over	Garmisch from Durant to Main	0.00	0.00	0.00	1.50	23.82	59.26
206over	Second to Garmisch	0.00	0.00	0.00	0.00	6.16	13.76
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	12.59	46.85	94.13
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	0.00	17.26	66.11
203over	Overland from Francis to Roaring Fork	0.00	0.00	0.00	0.00	19.21	70.15
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0.00
205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	0.00
107_Out	Storage	1.01	1.47	1.86	2.76	3.13	3.73
117_Out	Storage	1.56	2.24	2.78	3.32	3.67	4.14
105_Out	Storage	1.30	3.17	4.34	7.50	11.75	16.16
106_Out	Storage	0.65	2.35	3.85	8.23	16.73	24.50
109_Out	Storage	1.24	3.54	5.07	9.24	15.65	21.88
120_out	Storage	0.58	2.02	3.38	7.50	14.43	21.07
119_out	Storage	7.95	10.04	11.43	14.54	16.28	18.58
103_out	Storage	8.76	10.92	12.35	15.64	17.47	19.89
116_out	Storage	3.82	5.77	7.38	10.79	13.43	17.59
113_out	Storage	0.45	0.92	2.08	4.38	7.55	13.11
114_out	Storage	0.59	1.12	2.24	4.63	7.43	12.24
115_out	Storage	0.10	0.20	0.25	0.56	1.12	2.33
112_out	Storage	4.64	6.04	7.18	10.05	12.00	14.92
111_out	Storage	6.98	8.82	10.04	12.85	14.46	16.62
102_out	Storage	2.26	3.75	5.02	7.74	10.04	13.75

APPENDIX E: WQCV Flows for 2, 10 and 50-year Storms

2-Year Storm (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	1.81	1.81	1.81	1.81	1.81
122	JUNCTION	3.09	3.09	3.09	3.09	3.09
121	JUNCTION	1.02	0.78	0.57	0.35	0.25
110Out	OUTFALL	40.74	31.63	22.49	15.63	13.28
118Out	OUTFALL	60.51	47.98	33.37	21.26	14.88
108Out	OUTFALL	4.99	3.93	2.79	1.79	1.31
125Out	OUTFALL	2.55	1.98	1.38	0.89	0.62
4Out	OUTFALL	5.11	5.11	5.11	5.11	5.11
1Out	OUTFALL	0.20	0.20	0.20	0.20	0.20
113div	DIVIDER	0.44	0.36	0.25	0.16	0.12
114div	DIVIDER	3.25	3.16	3.06	2.95	2.83
115div	DIVIDER	3.29	3.19	3.08	2.97	2.85
112div	DIVIDER	7.30	6.41	5.86	5.33	4.75
111div	DIVIDER	24.22	18.75	13.43	10.35	8.96
116div	DIVIDER	6.29	4.89	3.54	2.31	1.77
117div	DIVIDER	16.76	13.04	9.15	5.92	4.36
120div	DIVIDER	1.34	1.04	0.75	0.49	0.36
109div	DIVIDER	2.13	1.64	1.17	0.82	0.59
106div	DIVIDER	0.64	0.50	0.36	0.22	0.14
107div	DIVIDER	6.77	5.26	3.80	2.76	2.02
119div	DIVIDER	24.75	19.12	13.67	8.83	6.63
103div	DIVIDER	50.18	39.65	27.42	17.65	12.34
102div	DIVIDER	2.51	1.98	1.40	0.91	0.68
105div	DIVIDER	1.33	1.03	0.75	0.47	0.35
212	CONDUIT	7.26	6.40	5.86	5.33	4.75
213	CONDUIT	0.44	0.36	0.25	0.16	0.12
214	CONDUIT	3.25	3.16	3.06	2.95	2.83
215	CONDUIT	3.27	3.18	3.07	2.96	2.84
222	CONDUIT	2.53	2.53	2.53	2.53	2.53
223	CONDUIT	1.73	1.73	1.73	1.73	1.73
216	CONDUIT	5.96	4.63	3.37	2.29	1.73
211	CONDUIT	23.94	18.62	13.32	10.35	8.94
217	CONDUIT	16.72	12.94	9.13	5.90	4.35
221	CONDUIT	0.87	0.67	0.48	0.30	0.23
220	CONDUIT	1.31	1.01	0.73	0.48	0.36
209	CONDUIT	2.10	1.61	1.16	0.81	0.59
206	CONDUIT	0.50	0.38	0.26	0.18	0.13
205	CONDUIT	1.28	1.00	0.72	0.47	0.35

207	CONDUIT	6.74	5.23	3.79	2.75	2.02
219	CONDUIT	24.66	19.11	13.61	8.83	6.63
203	CONDUIT	50.08	39.38	27.39	17.52	12.34
202	CONDUIT	2.48	1.95	1.39	0.90	0.67
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	0.00	0.00	0.00	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.00	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

5-Year Storm (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	6.46	6.46	6.46	6.46	6.46
122	JUNCTION	11.08	11.08	11.08	11.08	11.08
121	JUNCTION	2.06	1.25	0.98	0.77	0.55
110Out	OUTFALL	58.59	50.05	40.10	32.95	29.94
118Out	OUTFALL	87.79	75.04	60.95	45.86	33.34
108Out	OUTFALL	10.29	7.36	4.97	3.78	2.79
125Out	OUTFALL	3.63	3.14	2.50	1.86	1.35
4Out	OUTFALL	8.32	8.32	8.32	8.32	8.32
1Out	OUTFALL	0.62	0.62	0.62	0.62	0.62
113div	DIVIDER	0.94	0.55	0.45	0.34	0.25
114div	DIVIDER	10.98	10.42	10.29	10.15	10.01
115div	DIVIDER	11.06	10.47	10.33	10.19	10.04
112div	DIVIDER	16.88	15.78	15.13	14.50	13.80
111div	DIVIDER	34.68	29.60	25.16	23.42	21.68
116div	DIVIDER	11.58	8.51	6.14	4.80	3.60
117div	DIVIDER	25.47	21.11	16.61	12.48	9.31
120div	DIVIDER	3.76	2.28	1.36	1.03	0.79
109div	DIVIDER	6.66	4.50	2.73	1.67	1.31
106div	DIVIDER	2.50	1.44	0.63	0.49	0.34
107div	DIVIDER	16.05	11.88	7.88	5.39	4.29
119div	DIVIDER	38.05	31.35	24.52	18.59	14.09
103div	DIVIDER	72.88	62.48	50.30	37.51	27.35
102div	DIVIDER	4.67	3.45	2.50	1.91	1.40
105div	DIVIDER	3.36	2.66	1.78	1.01	0.75
212	CONDUIT	16.85	15.76	15.11	14.50	13.80
213	CONDUIT	0.94	0.55	0.45	0.34	0.25
214	CONDUIT	10.98	10.42	10.29	10.15	10.00
215	CONDUIT	10.90	10.38	10.23	10.11	9.94
222	CONDUIT	9.36	9.36	9.36	9.36	9.36
223	CONDUIT	6.24	6.24	6.24	6.24	6.24
216	CONDUIT	11.26	8.33	5.93	4.60	3.57
211	CONDUIT	34.29	29.33	25.12	23.38	21.67
217	CONDUIT	20.66	20.63	16.53	12.43	9.31
221	CONDUIT	1.90	1.08	0.86	0.65	0.51
220	CONDUIT	3.69	2.24	1.33	1.01	0.78
209	CONDUIT	6.59	4.44	2.68	1.66	1.30
206	CONDUIT	2.00	1.23	0.49	0.38	0.28
205	CONDUIT	3.32	2.60	1.73	0.98	0.74

207	CONDUIT	15.98	11.81	7.87	5.39	4.28
219	CONDUIT	37.98	31.33	24.51	18.55	14.08
203	CONDUIT	72.78	62.18	50.08	37.39	27.32
202	CONDUIT	4.64	3.42	2.46	1.87	1.40
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	5.76	1.90	0.00	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.00	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

10 yr Storm Flows (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	11.30	11.30	11.30	11.30	11.30
122	JUNCTION	19.85	19.85	19.85	19.85	19.85
121	JUNCTION	5.02	4.02	2.53	1.10	0.84
110Out	OUTFALL	77.01	66.88	61.90	51.48	46.06
118Out	OUTFALL	114.79	95.93	81.74	65.42	50.25
108Out	OUTFALL	14.94	12.69	10.10	6.89	4.24
125Out	OUTFALL	4.65	3.99	3.37	2.62	2.05
4Out	OUTFALL	11.89	11.89	11.89	11.89	11.89
1Out	OUTFALL	1.57	1.57	1.57	1.57	1.57
113div	DIVIDER	2.29	1.80	1.13	0.50	0.38
114div	DIVIDER	21.54	20.79	19.86	18.88	18.58
115div	DIVIDER	21.71	20.92	19.96	18.93	18.62
112div	DIVIDER	29.79	28.12	26.41	24.72	23.79
111div	DIVIDER	46.18	43.04	39.94	36.72	34.59
116div	DIVIDER	17.01	14.07	11.35	8.18	5.28
117div	DIVIDER	34.07	29.08	24.06	18.49	13.80
120div	DIVIDER	8.00	6.35	4.37	2.47	1.65
109div	DIVIDER	12.22	9.87	7.37	4.81	3.25
106div	DIVIDER	4.15	3.60	2.81	1.69	0.96
107div	DIVIDER	25.49	21.01	16.65	12.12	8.63
119div	DIVIDER	52.32	44.40	36.89	29.14	22.09
103div	DIVIDER	93.72	80.73	68.05	54.10	41.48
102div	DIVIDER	6.65	5.70	4.59	3.21	2.08
105div	DIVIDER	4.92	4.11	3.46	2.62	1.83
212	CONDUIT	29.78	28.11	26.40	24.71	23.78
213	CONDUIT	2.28	1.78	1.12	0.50	0.37
214	CONDUIT	21.53	20.78	19.86	18.87	18.58
215	CONDUIT	21.61	20.77	19.82	18.82	18.51
222	CONDUIT	17.68	17.68	17.68	17.68	17.68
223	CONDUIT	11.15	11.15	11.15	11.15	11.15
216	CONDUIT	16.40	13.83	10.96	7.90	5.19
211	CONDUIT	46.14	42.93	39.89	36.64	34.54
217	CONDUIT	20.66	20.70	20.69	18.38	13.79
221	CONDUIT	4.75	3.64	2.29	1.02	0.73
220	CONDUIT	7.89	6.23	4.31	2.43	1.62
209	CONDUIT	12.12	9.80	7.30	4.76	3.21
206	CONDUIT	3.70	3.02	2.28	1.50	0.87
205	CONDUIT	4.79	4.11	3.40	2.55	1.79

207	CONDUIT	25.40	20.96	16.58	12.09	8.61
219	CONDUIT	52.29	44.38	36.88	29.12	22.08
203	CONDUIT	97.77	80.47	67.86	53.91	41.43
202	CONDUIT	6.65	5.66	4.52	3.17	2.06
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	14.59	9.42	4.07	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.83	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

50-Year Storm						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	68.41	68.41	68.41	68.41	68.41
122	JUNCTION	120.93	120.93	120.93	120.93	120.93
121	JUNCTION	22.20	21.37	20.63	19.65	18.67
110Out	OUTFALL	219.42	215.73	211.90	207.51	203.23
118Out	OUTFALL	211.60	203.52	194.21	184.23	174.61
108Out	OUTFALL	38.23	36.35	34.45	32.21	30.02
125Out	OUTFALL	8.89	8.39	8.03	7.56	7.10
4Out	OUTFALL	27.04	27.04	27.04	27.04	27.04
1Out	OUTFALL	9.34	9.34	9.34	9.34	9.34
113div	DIVIDER	9.93	9.63	9.36	9.01	8.66
114div	DIVIDER	138.05	137.26	136.57	135.68	134.79
115div	DIVIDER	139.01	138.19	137.46	136.54	135.61
112div	DIVIDER	156.06	154.58	153.16	151.44	149.71
111div	DIVIDER	183.96	181.65	179.25	176.33	173.43
116div	DIVIDER	41.06	39.06	37.05	34.68	32.31
117div	DIVIDER	69.49	65.90	62.05	57.52	53.54
120div	DIVIDER	42.67	41.25	39.90	38.29	36.72
109div	DIVIDER	62.93	60.80	58.62	56.09	53.58
106div	DIVIDER	24.42	23.91	23.32	22.71	22.11
107div	DIVIDER	107.71	103.85	99.73	95.22	90.85
119div	DIVIDER	147.01	141.47	135.52	128.91	122.34
103div	DIVIDER	192.42	184.95	176.66	167.98	159.38
102div	DIVIDER	16.24	15.41	14.57	13.58	12.58
105div	DIVIDER	16.35	15.88	15.27	14.63	13.99
212	CONDUIT	113.10	112.59	113.11	112.65	112.72
213	CONDUIT	9.93	9.62	9.34	8.97	8.62
214	CONDUIT	138.02	137.24	136.54	135.66	134.77
215	CONDUIT	59.28	59.33	59.41	59.45	59.34
222	CONDUIT	116.60	116.60	116.60	116.60	116.60
223	CONDUIT	67.63	67.63	67.63	67.63	67.63
216	CONDUIT	40.73	38.51	36.39	33.85	31.44
211	CONDUIT	123.17	123.21	123.32	123.17	123.34
217	CONDUIT	20.61	20.62	20.63	20.47	20.70
221	CONDUIT	21.55	20.74	20.12	19.32	18.54
220	CONDUIT	21.69	21.69	21.69	21.69	21.69
209	CONDUIT	27.49	27.26	27.44	27.38	27.45
206	CONDUIT	10.97	10.95	10.93	10.95	10.95
205	CONDUIT	16.09	15.64	15.00	14.36	13.71

207	CONDUIT	34.95	35.00	34.94	35.02	34.96
219	CONDUIT	83.03	83.42	83.01	83.44	83.56
203	CONDUIT	99.90	99.68	98.88	99.66	98.75
202	CONDUIT	16.10	15.24	14.40	13.41	12.43
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	82.83	82.00	81.27	80.34	79.39
212over	CHANNEL	49.41	47.93	46.49	44.74	42.99
211over	CONDUIT	64.24	61.91	59.50	56.70	53.91
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	50.08	46.48	42.64	38.22	34.26
220over	CHANNEL	20.52	19.07	17.71	16.09	14.59
209over	CHANNEL	35.37	33.25	31.16	28.81	26.47
206over	CHANNEL	10.97	10.45	9.89	9.35	8.85
207over	CHANNEL	74.93	71.07	67.00	62.54	58.22
219over	CHANNEL	69.12	63.59	57.64	51.04	44.45
203over	CONDUIT	99.39	92.09	84.15	75.30	66.61
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

APPENDIX A: Flows from Existing Condition Model

Design Point	Associated Location	Flow (CFS)					
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
123	Upland	1.81	6.46	11.30	29.19	68.41	113.86
122	Upland	3.09	11.08	19.85	52.29	120.93	202.03
121	Upland	1.02	2.06	5.02	11.27	22.20	48.2
110Out	Outfall from Mill	40.85	60.15	78.18	138.45	214.69	384.89
118Out	Outfall from Garmisch Overland	60.59	88.11	111.03	165.23	214.92	329.97
108Out	Outfall from Gillespie Through Pond	4.99	10.29	14.94	26.06	38.23	63.34
125Out	Outfall south of the City Near Waters	2.55	3.63	4.65	7.06	8.89	12.68
4Out	Outfall at Castle Creek and Roaring Fork	5.11	8.32	11.89	19.64	27.04	40.85
1Out	Outfall North of Gillespie	0.20	0.62	1.57	3.72	9.34	22.31
113div	Ute	0.44	0.94	2.29	5.16	9.93	21.61
114div	Ute	3.25	10.97	21.50	59.85	138.28	243.48
115div	Ute and Original	3.28	11.05	21.69	60.32	138.64	245.42
112div	Main and Original	7.42	17.04	29.84	75.66	154.66	272.49
111div	Near Rio Grande and Spring	24.23	34.86	46.64	97.12	180.62	313.76
116div	Durant and Galena	6.29	11.58	17.01	29.22	41.06	65.43
117div	Rio Grande and Mill	16.76	25.47	34.07	54.09	69.49	95.56
120div	Snark and Monarch	1.34	3.76	8.00	20.01	42.67	81.65
109div	Garmisch and Durant	2.13	6.66	12.22	30.33	62.93	114.29
106div	Second and Hyman	0.64	2.50	4.15	9.01	24.42	40.7
107div	Garmisch and Main	6.77	16.05	25.49	54.75	107.71	185.87
119div	Garmisch and Hallam	24.75	38.05	52.32	90.98	147.01	238.9
103div	Garmisch and Francis	50.18	72.88	93.72	140.95	192.42	301.51
102div	Gillespie Near Third	2.51	4.67	6.65	11.29	16.24	25.62
105div	Third and Main	1.33	3.36	4.92	8.91	16.35	24.57
117_2div	Rio Grande and Mill	16.73	25.44	34.03	53.90	69.43	95.53
103_2div	Francis to Roaring Fork	50.10	72.76	96.58	140.45	192.34	301.33
103_3div	Francis to Roaring Fork	50.08	72.70	94.83	140.47	192.35	301.36
212	Main and Spring	7.39	17.03	29.81	74.56	112.86	113.99

213	Ute	0.44	0.94	2.28	5.14	5.46	5.58
214	Ute	3.25	10.97	21.50	59.85	120.67	120.83
215	Original from Ute to Main	3.27	10.96	21.52	59.46	59.41	59.42
222	Upland	2.53	9.36	17.68	49.96	116.60	197.33
223	Upland	1.73	6.24	11.15	29.18	67.63	112.87
216	Mill	5.96	11.26	16.40	28.43	40.73	60.51
211	Spring over to Mill	24.05	34.55	46.64	97.01	123.35	123.46
217	Mill from Rio Grande to Roaring Fork	16.73	25.44	34.03	53.90	69.43	95.53
221	Upland	0.87	1.90	4.75	11.08	21.55	46.68
220	Monarch and Durant	1.31	3.69	7.89	19.85	21.69	21.69
209	Garmisch from Durant to Main	2.10	6.59	12.12	27.54	27.49	27.48
206	Second to Garmisch	0.50	2.00	3.70	8.97	10.97	10.95
205	Main from Third to Garmisch	1.28	3.32	4.79	8.88	16.09	17.97
207	Garmisch from Main to Hallam	6.74	15.98	25.40	35.04	34.95	34.99
219	Garmisch from Hallam to Francis	24.66	37.98	52.29	83.48	83.03	83.27
203	Francis to Roaring Fork	50.10	72.76	95.56	97.02	97.33	97.04
202	Gillespie Through pond to Roaring Fork	2.48	4.64	6.65	11.32	16.10	25.33
213over	Ute	0.00	0.00	0.00	0.00	4.73	16.32
214over	Ute	0.00	0.00	0.00	0.00	24.21	129.83
215over	Original from Ute to Main	0.00	0.00	0.00	5.25	82.49	189.86
212over	Main and Spring	0.00	0.00	0.00	0.00	48.08	166.21
211over	Spring over to Mill	0.00	0.00	0.00	0.00	63.45	194.28
216over	Mill	0.00	0.00	0.00	0.00	0.00	8.52
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0
220over	Monarch and Durant	0.00	0.00	0.00	0.00	20.52	59.53
209over	Garmisch from Durant to Main	0.00	0.00	0.00	4.81	35.37	87.24
206over	Second to Garmisch	0.00	0.00	0.00	0.00	10.97	25.79
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	21.96	74.93	153.15
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	12.96	69.12	161.02
203over	Francis to Roaring Fork	0.00	0.00	1.02	48.14	100.03	209.02
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0

205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	6.47
217_2	Mill from Rio Grande to Roaring Fork	16.72	25.43	34.02	53.88	69.42	95.51
217_2over	Mill from Rio Grande to Roaring Fork	0	0	0	0	0	0
203_2	Francis to Roaring Fork	50.08	72.7	94.83	140.47	192.35	301.36
203_2over	Francis to Roaring Fork	0	0	0	0	0	0
203_3	Francis to Roaring Fork	50.09	72.72	94.79	140.31	193.87	301.28
203_3over	Francis to Roaring Fork	0	0	0	0	0	0

APPENDIX B: Alternatives Analysis Flow Results

Node	Type	Flow (CFS)	
		10-Year	100-Year
123	JUNCTION	11.30	113.86
122	JUNCTION	19.85	202.03
121	JUNCTION	5.02	48.20
110Out	OUTFALL	77.48	387.34
118Out	OUTFALL	110.61	333.74
108Out	OUTFALL	14.94	63.34
125Out	OUTFALL	4.65	12.68
4Out	OUTFALL	11.89	40.85
1Out	OUTFALL	1.57	22.31
113div	DIVIDER	2.29	21.61
114div	DIVIDER	21.54	243.39
115div	DIVIDER	21.72	245.33
112div	DIVIDER	29.87	272.41
111div	DIVIDER	46.71	313.69
116div	DIVIDER	17.01	65.43
117div	DIVIDER	34.07	95.56
120div	DIVIDER	8.00	81.65
109div	DIVIDER	12.22	114.29
106div	DIVIDER	4.15	40.70
107div	DIVIDER	25.54	186.11
119div	DIVIDER	52.49	238.48
103div	DIVIDER	93.93	299.60
102div	DIVIDER	6.65	25.62
105div	DIVIDER	4.92	24.57
109div_alt	DIVIDER	12.15	113.37
212	CONDUIT	29.82	114.02
213	CONDUIT	2.28	21.57
214	CONDUIT	21.54	120.93
215	CONDUIT	21.57	59.40
222	CONDUIT	17.68	197.33
223	CONDUIT	11.15	112.87
216	CONDUIT	16.40	60.51
211	CONDUIT	46.67	123.45
217	CONDUIT	20.66	20.67
221	CONDUIT	4.75	46.68
220	CONDUIT	7.89	21.69
209	CONDUIT	12.15	28.76
206	CONDUIT	3.70	10.95

205	CONDUIT	4.79	17.97
207	CONDUIT	25.46	75.51
219	CONDUIT	52.46	113.59
203	CONDUIT	93.38	288.28
202	CONDUIT	6.65	25.33
213over	CHANNEL	0.00	0.00
214over	CHANNEL	0.00	129.74
215over	CHANNEL	0.00	189.78
212over	CHANNEL	0.00	166.13
211over	CONDUIT	0.00	194.23
216over	CHANNEL	0.00	8.52
217over	CHANNEL	14.59	76.22
220over	CHANNEL	0.00	59.53
209over	CHANNEL	0.00	86.66
206over	CHANNEL	0.00	25.79
207over	CHANNEL	0.00	115.90
219over	CHANNEL	0.00	131.86
203over	CHANNEL	0.00	23.74
202over	CHANNEL	0.00	0.00
205over	CHANNEL	0.00	6.47
209alt	CHANNEL	12.14	77.94
209over_alt	CHANNEL	0.00	39.95

APPENDIX C: Predevelopment Hydrology Flows

Design Point	Associated Location	Flow (CFS)					
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
123	Upland	0.07	0.80	1.84	4.40	33.58	81.01
122	Upland	0.07	1.24	3.03	7.52	57.78	140.24
121	Upland	0.04	0.11	0.72	1.92	2.64	24.35
110Out	Outfall from Mill	0.08	1.02	3.33	10.43	61.43	189.72
118Out	Outfall from Garmisch Overland	0.08	0.80	2.58	7.74	41.11	127.66
108Out	Outfall from Gillespie Through Pond	0.03	0.09	0.57	1.70	2.35	21.89
125Out	Outfall south of the City Near Waters	0.00	0.01	0.06	0.19	0.26	2.40
4Out	Outfall at Castle Creek and Roaring Fork	0.02	0.05	0.29	0.85	1.18	10.83
1Out	Outfall North of Gillespie	0.02	0.07	0.39	1.11	1.54	14.05
113div	Ute	0.02	0.05	0.30	0.87	1.22	11.02
114div	Ute	0.04	0.93	2.72	8.05	56.98	160.21
115div	Ute and Original	0.04	0.93	2.74	8.12	57.07	161.31
112div	Main and Original	0.04	0.94	2.82	8.46	59.88	166.25
111div	Near Rio Grande and Spring	0.05	0.95	2.93	8.83	59.58	171.03
116div	Durant and Galena	0.03	0.09	0.55	1.62	2.22	20.23
117div	Rio Grande and Mill	0.03	0.09	0.57	1.79	2.55	24.15
120div	Snark and Monarch	0.02	0.25	0.96	2.86	12.46	45.83
109div	Garmisch and Durant	0.03	0.42	1.26	3.75	21.11	65.24
106div	Second and Hyman	0.02	0.29	0.67	1.45	11.66	26.17
107div	Garmisch and Main	0.06	0.73	1.98	5.70	37.08	101.62
119div	Garmisch and Hallam	0.06	0.75	2.14	6.39	40.58	111.14
103div	Garmisch and Francis	0.08	0.79	2.39	7.32	41.15	124.36
102div	Gillespie Near Third	0.01	0.04	0.22	0.63	0.88	8.09
105div	Third and Main	0.01	0.13	0.28	0.67	5.09	12.45
212	Main and Spring	0.04	0.94	2.82	8.45	59.03	112.86
213	Ute	0.02	0.05	0.30	0.87	1.21	10.99
214	Ute	0.04	0.92	2.72	8.05	56.96	160.18
215	Original from Ute to Main	0.03	0.92	2.72	8.06	59.29	59.32

222	Upland	0.00	0.87	2.35	6.49	54.57	135.34
223	Upland	0.02	0.72	1.73	4.27	33.01	80.27
216	Mill	0.02	0.07	0.48	1.48	2.11	20.08
211	Spring over to Mill	0.05	0.95	2.96	8.82	59.10	123.32
217	Mill from Rio Grande to Roaring Fork	0.03	0.08	0.56	1.76	2.54	20.69
221	Upland	0.00	0.07	0.56	1.76	2.45	23.61
220	Monarch and Durant	0.02	0.23	0.94	2.83	12.19	21.69
209	Garmisch from Durant to Main	0.03	0.40	1.24	3.72	20.87	27.35
206	Second to Garmisch	0.01	0.21	0.48	1.25	10.53	10.96
205	Main from Third to Garmisch	0.01	0.12	0.27	0.65	5.06	12.26
207	Garmisch from Main to Hallam	0.05	0.71	1.95	5.68	35.04	35.00
219	Garmisch from Hallam to Francis	0.06	0.74	2.14	6.38	39.98	83.30
203	Overland from Francis to Roaring Fork	0.07	0.78	2.46	7.31	40.59	99.90
202	Gillespie Through pond to Roaring Fork	0.01	0.03	0.21	0.63	0.87	8.07
213over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
214over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
215over	Original from Ute to Main	0.00	0.00	0.00	0.00	0.44	105.44
212over	Main and Spring	0.00	0.00	0.00	0.00	0.00	59.75
211over	Spring over to Mill	0.00	0.00	0.00	0.00	0.00	51.25
216over	Mill	0.00	0.00	0.00	0.00	0.00	0.00
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	4.37
220over	Monarch and Durant	0.00	0.00	0.00	0.00	0.00	23.79
209over	Garmisch from Durant to Main	0.00	0.00	0.00	0.00	0.00	38.19
206over	Second to Garmisch	0.00	0.00	0.00	0.00	0.91	13.84
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	0.00	4.63	68.90
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	0.00	0.00	33.20
203over	Overland from Francis to Roaring Fork	0.00	0.00	0.00	0.00	0.00	29.98
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0.00
205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX D: Detention to Predevelopment for All Urban Watersheds Not Directly Adjacent to the Roaring Fork

Design Point	Associated Location	Flow (CFS)					
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
123	Upland	1.81	6.46	11.30	29.19	68.41	113.86
122	Upland	3.09	11.08	19.85	52.29	120.93	202.03
121	Upland	1.02	2.06	5.02	11.27	22.20	48.20
110Out	Outfall from Mill	19.87	33.54	47.94	97.60	167.56	266.56
118Out	Outfall from Garmisch Overland	25.73	39.87	52.29	83.63	120.17	177.89
108Out	Outfall from Gillespie Through Pond	4.50	8.81	12.41	20.59	29.63	47.51
125Out	Outfall south of the City Near Waters	2.55	3.63	4.65	7.06	8.89	12.68
4Out	Outfall at Castle Creek and Roaring Fork	5.11	8.32	11.89	19.64	27.04	40.85
1Out	Outfall North of Gillespie	0.20	0.62	1.57	3.72	9.34	22.31
113divider	Ute	0.45	0.92	2.08	4.38	7.55	13.11
114divider	Ute	3.27	11.01	21.38	58.18	129.88	218.27
115divider	Ute and Original	3.34	11.14	21.55	58.62	130.81	220.37
112divider	Main and Original	7.67	17.07	28.56	72.73	141.42	233.72
111divider	Near Rio Grande and Spring	14.62	25.85	38.38	84.36	154.91	249.02
116divider	Durant and Galena	3.82	5.77	7.38	10.79	13.43	17.59
117divider	Rio Grande and Mill	5.22	7.84	9.97	14.10	17.09	21.72
120divided	Snark and Monarch	1.35	3.87	8.12	18.04	35.17	64.86
109divider	Garmisch and Durant	2.18	7.01	12.78	27.16	50.54	85.71
106divider	Second and Hyman	0.65	2.35	3.85	8.23	16.73	24.50
107divider	Garmisch and Main	4.36	12.75	21.31	46.24	79.45	126.70
119divider	Garmisch and Hallam	12.10	22.20	31.95	59.14	95.14	143.96
103divider	Garmisch and Francis	20.83	32.89	43.97	74.61	112.42	163.15
102divider	Gillespie Near Third	2.26	3.75	5.02	7.74	10.04	13.75
105divider	Third and Main	1.30	3.17	4.34	7.50	11.75	16.16
107div	Main and Spring	3.43	4.87	6.25	9.91	12.94	17.74
117div	Ute	13.84	19.85	24.24	33.21	39.67	47.79
105div	Ute	1.33	3.36	4.92	8.91	16.35	24.57

106div	Original from Ute to Main	0.64	2.50	4.15	9.01	24.42	40.70
109div	Upland	1.26	3.99	6.05	11.33	23.52	37.20
120div	Upland	0.59	2.10	3.72	9.09	22.36	36.46
119div	Mill	19.61	28.60	35.16	49.00	58.64	70.55
103div	Spring over to Mill	25.72	37.63	46.31	64.10	76.63	90.87
116div	Mill from Rio Grande to Roaring Fork	6.29	11.58	17.01	29.22	41.06	65.43
113div	Upland	0.44	0.94	2.29	5.16	9.93	21.61
114div	Monarch and Durant	0.61	1.22	2.80	6.88	13.42	27.87
115div	Garmisch from Durant to Main	0.05	0.10	0.24	0.56	1.12	2.33
112div	Second to Garmisch	7.05	10.00	12.83	20.37	26.58	36.89
111div	Main from Third to Garmisch	17.12	24.23	29.47	42.25	51.14	64.01
102div	Garmisch from Main to Hallam	2.51	4.67	6.65	11.29	16.24	25.62
212	Garmisch from Hallam to Francis	7.66	17.06	28.56	71.65	114.00	113.30
213	Overland from Francis to Roaring Fork	0.45	0.92	2.08	4.38	7.54	13.11
214	Gillespie Through pond to Roaring Fork	3.27	11.01	21.38	58.16	129.85	218.25
215	Ute	3.32	11.04	21.41	59.56	59.27	59.53
222	Ute	2.53	9.36	17.68	49.96	116.60	197.33
223	Original from Ute to Main	1.73	6.24	11.15	29.18	67.63	112.87
216	Main and Spring	3.80	5.76	7.37	10.79	13.43	17.58
211	Spring over to Mill	14.61	25.83	38.36	83.75	123.40	123.17
217	Mill	5.22	7.84	9.97	14.10	17.08	20.69
221	Mill from Rio Grande to Roaring Fork	0.87	1.90	4.75	11.08	21.55	46.68
220	Monarch and Durant	1.32	3.79	8.00	17.93	21.69	21.69
209	Garmisch from Durant to Main	2.15	6.92	12.65	27.55	27.45	27.52
206	Second to Garmisch	0.49	2.04	3.57	8.07	10.95	10.96
205	Garmisch from Main to Hallam	1.27	3.14	4.32	7.49	11.74	16.13
207	Garmisch from Hallam to Francis	4.35	12.67	21.20	35.05	34.97	35.02
219	Overland from Francis to Roaring Fork	12.10	22.17	31.93	59.10	83.26	83.39
203	Gillespie Through pond to Roaring Fork	20.82	32.85	43.94	74.53	99.82	99.84
202	Main from Third to Garmisch	2.25	3.75	5.01	7.74	10.04	13.74

213over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
214over	Ute	0.00	0.00	0.00	0.00	0.00	0.00
215over	Original from Ute to Main	0.00	0.00	0.00	3.15	74.74	164.83
212over	Main and Spring	0.00	0.00	0.00	0.00	34.71	127.42
211over	Spring over to Mill	0.00	0.00	0.00	0.00	36.32	131.05
216over	Mill	0.00	0.00	0.00	0.00	0.00	0.00
217over	Mill from Rio Grande to Roaring Fork	0.00	0.00	0.00	0.00	0.00	2.56
220over	Monarch and Durant	0.00	0.00	0.00	0.00	13.22	42.89
209over	Garmisch from Durant to Main	0.00	0.00	0.00	1.50	23.82	59.26
206over	Second to Garmisch	0.00	0.00	0.00	0.00	6.16	13.76
207over	Garmisch from Main to Hallam	0.00	0.00	0.00	12.59	46.85	94.13
219over	Garmisch from Hallam to Francis	0.00	0.00	0.00	0.00	17.26	66.11
203over	Overland from Francis to Roaring Fork	0.00	0.00	0.00	0.00	19.21	70.15
202over	Gillespie Through pond to Roaring Fork	0.00	0.00	0.00	0.00	0.00	0.00
205over	Main from Third to Garmisch	0.00	0.00	0.00	0.00	0.00	0.00
107_Out	Storage	1.01	1.47	1.86	2.76	3.13	3.73
117_Out	Storage	1.56	2.24	2.78	3.32	3.67	4.14
105_Out	Storage	1.30	3.17	4.34	7.50	11.75	16.16
106_Out	Storage	0.65	2.35	3.85	8.23	16.73	24.50
109_Out	Storage	1.24	3.54	5.07	9.24	15.65	21.88
120_out	Storage	0.58	2.02	3.38	7.50	14.43	21.07
119_out	Storage	7.95	10.04	11.43	14.54	16.28	18.58
103_out	Storage	8.76	10.92	12.35	15.64	17.47	19.89
116_out	Storage	3.82	5.77	7.38	10.79	13.43	17.59
113_out	Storage	0.45	0.92	2.08	4.38	7.55	13.11
114_out	Storage	0.59	1.12	2.24	4.63	7.43	12.24
115_out	Storage	0.10	0.20	0.25	0.56	1.12	2.33
112_out	Storage	4.64	6.04	7.18	10.05	12.00	14.92
111_out	Storage	6.98	8.82	10.04	12.85	14.46	16.62
102_out	Storage	2.26	3.75	5.02	7.74	10.04	13.75

APPENDIX E: WQCV Flows for 2, 10 and 50-year Storms

2-Year Storm (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	1.81	1.81	1.81	1.81	1.81
122	JUNCTION	3.09	3.09	3.09	3.09	3.09
121	JUNCTION	1.02	0.78	0.57	0.35	0.25
110Out	OUTFALL	40.74	31.63	22.49	15.63	13.28
118Out	OUTFALL	60.51	47.98	33.37	21.26	14.88
108Out	OUTFALL	4.99	3.93	2.79	1.79	1.31
125Out	OUTFALL	2.55	1.98	1.38	0.89	0.62
4Out	OUTFALL	5.11	5.11	5.11	5.11	5.11
1Out	OUTFALL	0.20	0.20	0.20	0.20	0.20
113div	DIVIDER	0.44	0.36	0.25	0.16	0.12
114div	DIVIDER	3.25	3.16	3.06	2.95	2.83
115div	DIVIDER	3.29	3.19	3.08	2.97	2.85
112div	DIVIDER	7.30	6.41	5.86	5.33	4.75
111div	DIVIDER	24.22	18.75	13.43	10.35	8.96
116div	DIVIDER	6.29	4.89	3.54	2.31	1.77
117div	DIVIDER	16.76	13.04	9.15	5.92	4.36
120div	DIVIDER	1.34	1.04	0.75	0.49	0.36
109div	DIVIDER	2.13	1.64	1.17	0.82	0.59
106div	DIVIDER	0.64	0.50	0.36	0.22	0.14
107div	DIVIDER	6.77	5.26	3.80	2.76	2.02
119div	DIVIDER	24.75	19.12	13.67	8.83	6.63
103div	DIVIDER	50.18	39.65	27.42	17.65	12.34
102div	DIVIDER	2.51	1.98	1.40	0.91	0.68
105div	DIVIDER	1.33	1.03	0.75	0.47	0.35
212	CONDUIT	7.26	6.40	5.86	5.33	4.75
213	CONDUIT	0.44	0.36	0.25	0.16	0.12
214	CONDUIT	3.25	3.16	3.06	2.95	2.83
215	CONDUIT	3.27	3.18	3.07	2.96	2.84
222	CONDUIT	2.53	2.53	2.53	2.53	2.53
223	CONDUIT	1.73	1.73	1.73	1.73	1.73
216	CONDUIT	5.96	4.63	3.37	2.29	1.73
211	CONDUIT	23.94	18.62	13.32	10.35	8.94
217	CONDUIT	16.72	12.94	9.13	5.90	4.35
221	CONDUIT	0.87	0.67	0.48	0.30	0.23
220	CONDUIT	1.31	1.01	0.73	0.48	0.36
209	CONDUIT	2.10	1.61	1.16	0.81	0.59
206	CONDUIT	0.50	0.38	0.26	0.18	0.13
205	CONDUIT	1.28	1.00	0.72	0.47	0.35

207	CONDUIT	6.74	5.23	3.79	2.75	2.02
219	CONDUIT	24.66	19.11	13.61	8.83	6.63
203	CONDUIT	50.08	39.38	27.39	17.52	12.34
202	CONDUIT	2.48	1.95	1.39	0.90	0.67
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	0.00	0.00	0.00	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.00	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

5-Year Storm (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	6.46	6.46	6.46	6.46	6.46
122	JUNCTION	11.08	11.08	11.08	11.08	11.08
121	JUNCTION	2.06	1.25	0.98	0.77	0.55
110Out	OUTFALL	58.59	50.05	40.10	32.95	29.94
118Out	OUTFALL	87.79	75.04	60.95	45.86	33.34
108Out	OUTFALL	10.29	7.36	4.97	3.78	2.79
125Out	OUTFALL	3.63	3.14	2.50	1.86	1.35
4Out	OUTFALL	8.32	8.32	8.32	8.32	8.32
1Out	OUTFALL	0.62	0.62	0.62	0.62	0.62
113div	DIVIDER	0.94	0.55	0.45	0.34	0.25
114div	DIVIDER	10.98	10.42	10.29	10.15	10.01
115div	DIVIDER	11.06	10.47	10.33	10.19	10.04
112div	DIVIDER	16.88	15.78	15.13	14.50	13.80
111div	DIVIDER	34.68	29.60	25.16	23.42	21.68
116div	DIVIDER	11.58	8.51	6.14	4.80	3.60
117div	DIVIDER	25.47	21.11	16.61	12.48	9.31
120div	DIVIDER	3.76	2.28	1.36	1.03	0.79
109div	DIVIDER	6.66	4.50	2.73	1.67	1.31
106div	DIVIDER	2.50	1.44	0.63	0.49	0.34
107div	DIVIDER	16.05	11.88	7.88	5.39	4.29
119div	DIVIDER	38.05	31.35	24.52	18.59	14.09
103div	DIVIDER	72.88	62.48	50.30	37.51	27.35
102div	DIVIDER	4.67	3.45	2.50	1.91	1.40
105div	DIVIDER	3.36	2.66	1.78	1.01	0.75
212	CONDUIT	16.85	15.76	15.11	14.50	13.80
213	CONDUIT	0.94	0.55	0.45	0.34	0.25
214	CONDUIT	10.98	10.42	10.29	10.15	10.00
215	CONDUIT	10.90	10.38	10.23	10.11	9.94
222	CONDUIT	9.36	9.36	9.36	9.36	9.36
223	CONDUIT	6.24	6.24	6.24	6.24	6.24
216	CONDUIT	11.26	8.33	5.93	4.60	3.57
211	CONDUIT	34.29	29.33	25.12	23.38	21.67
217	CONDUIT	20.66	20.63	16.53	12.43	9.31
221	CONDUIT	1.90	1.08	0.86	0.65	0.51
220	CONDUIT	3.69	2.24	1.33	1.01	0.78
209	CONDUIT	6.59	4.44	2.68	1.66	1.30
206	CONDUIT	2.00	1.23	0.49	0.38	0.28
205	CONDUIT	3.32	2.60	1.73	0.98	0.74

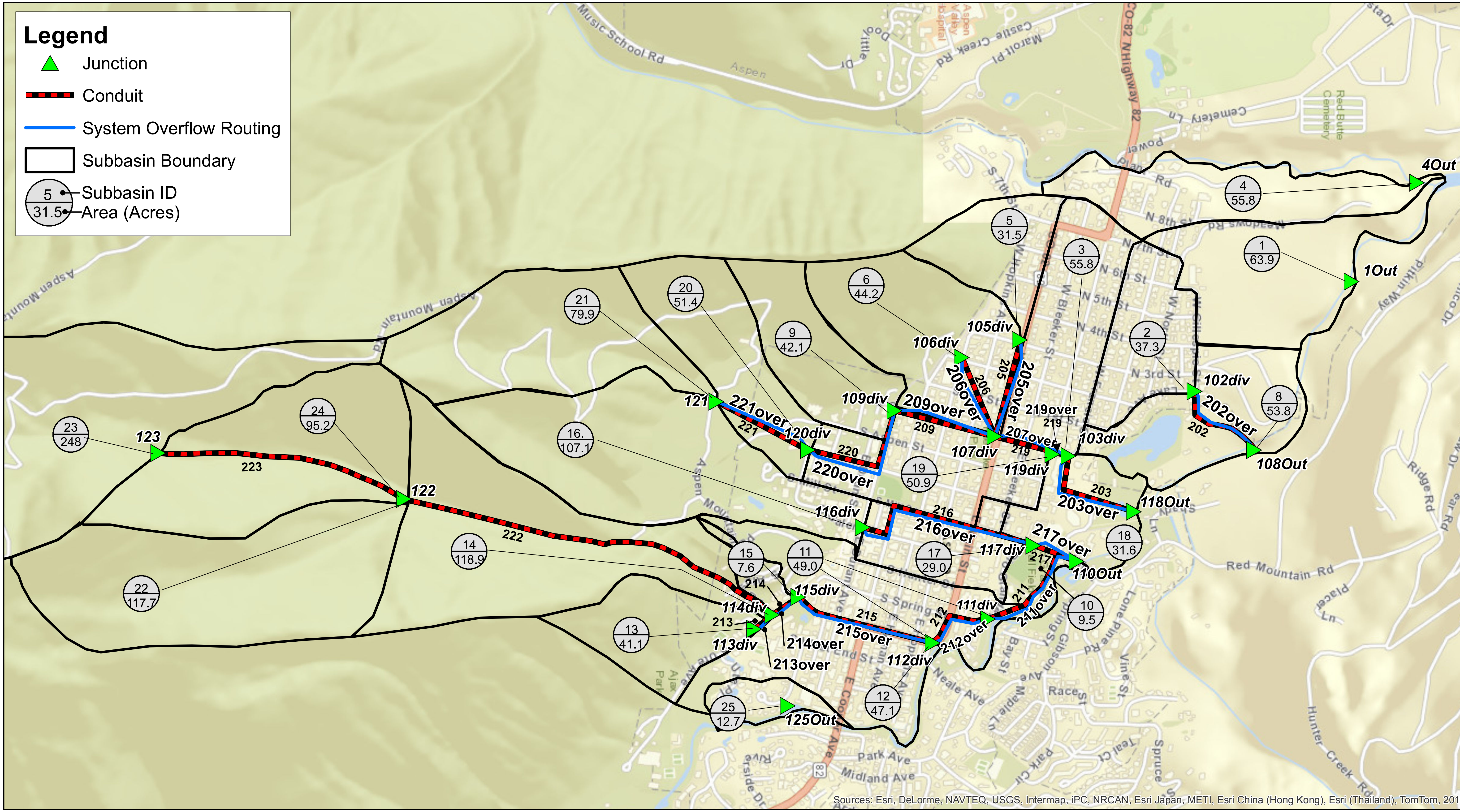
207	CONDUIT	15.98	11.81	7.87	5.39	4.28
219	CONDUIT	37.98	31.33	24.51	18.55	14.08
203	CONDUIT	72.78	62.18	50.08	37.39	27.32
202	CONDUIT	4.64	3.42	2.46	1.87	1.40
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	5.76	1.90	0.00	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.00	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

10 yr Storm Flows (CFS)						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	11.30	11.30	11.30	11.30	11.30
122	JUNCTION	19.85	19.85	19.85	19.85	19.85
121	JUNCTION	5.02	4.02	2.53	1.10	0.84
110Out	OUTFALL	77.01	66.88	61.90	51.48	46.06
118Out	OUTFALL	114.79	95.93	81.74	65.42	50.25
108Out	OUTFALL	14.94	12.69	10.10	6.89	4.24
125Out	OUTFALL	4.65	3.99	3.37	2.62	2.05
4Out	OUTFALL	11.89	11.89	11.89	11.89	11.89
1Out	OUTFALL	1.57	1.57	1.57	1.57	1.57
113div	DIVIDER	2.29	1.80	1.13	0.50	0.38
114div	DIVIDER	21.54	20.79	19.86	18.88	18.58
115div	DIVIDER	21.71	20.92	19.96	18.93	18.62
112div	DIVIDER	29.79	28.12	26.41	24.72	23.79
111div	DIVIDER	46.18	43.04	39.94	36.72	34.59
116div	DIVIDER	17.01	14.07	11.35	8.18	5.28
117div	DIVIDER	34.07	29.08	24.06	18.49	13.80
120div	DIVIDER	8.00	6.35	4.37	2.47	1.65
109div	DIVIDER	12.22	9.87	7.37	4.81	3.25
106div	DIVIDER	4.15	3.60	2.81	1.69	0.96
107div	DIVIDER	25.49	21.01	16.65	12.12	8.63
119div	DIVIDER	52.32	44.40	36.89	29.14	22.09
103div	DIVIDER	93.72	80.73	68.05	54.10	41.48
102div	DIVIDER	6.65	5.70	4.59	3.21	2.08
105div	DIVIDER	4.92	4.11	3.46	2.62	1.83
212	CONDUIT	29.78	28.11	26.40	24.71	23.78
213	CONDUIT	2.28	1.78	1.12	0.50	0.37
214	CONDUIT	21.53	20.78	19.86	18.87	18.58
215	CONDUIT	21.61	20.77	19.82	18.82	18.51
222	CONDUIT	17.68	17.68	17.68	17.68	17.68
223	CONDUIT	11.15	11.15	11.15	11.15	11.15
216	CONDUIT	16.40	13.83	10.96	7.90	5.19
211	CONDUIT	46.14	42.93	39.89	36.64	34.54
217	CONDUIT	20.66	20.70	20.69	18.38	13.79
221	CONDUIT	4.75	3.64	2.29	1.02	0.73
220	CONDUIT	7.89	6.23	4.31	2.43	1.62
209	CONDUIT	12.12	9.80	7.30	4.76	3.21
206	CONDUIT	3.70	3.02	2.28	1.50	0.87
205	CONDUIT	4.79	4.11	3.40	2.55	1.79

207	CONDUIT	25.40	20.96	16.58	12.09	8.61
219	CONDUIT	52.29	44.38	36.88	29.12	22.08
203	CONDUIT	97.77	80.47	67.86	53.91	41.43
202	CONDUIT	6.65	5.66	4.52	3.17	2.06
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	0.00	0.00	0.00	0.00	0.00
212over	CHANNEL	0.00	0.00	0.00	0.00	0.00
211over	CONDUIT	0.00	0.00	0.00	0.00	0.00
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	14.59	9.42	4.07	0.00	0.00
220over	CHANNEL	0.00	0.00	0.00	0.00	0.00
209over	CHANNEL	0.00	0.00	0.00	0.00	0.00
206over	CHANNEL	0.00	0.00	0.00	0.00	0.00
207over	CHANNEL	0.00	0.00	0.00	0.00	0.00
219over	CHANNEL	0.00	0.00	0.00	0.00	0.00
203over	CONDUIT	0.83	0.00	0.00	0.00	0.00
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00

50-Year Storm						
			WQCV Implementation			
Node	Type	Existing	25	50	75	100
123	JUNCTION	68.41	68.41	68.41	68.41	68.41
122	JUNCTION	120.93	120.93	120.93	120.93	120.93
121	JUNCTION	22.20	21.37	20.63	19.65	18.67
110Out	OUTFALL	219.42	215.73	211.90	207.51	203.23
118Out	OUTFALL	211.60	203.52	194.21	184.23	174.61
108Out	OUTFALL	38.23	36.35	34.45	32.21	30.02
125Out	OUTFALL	8.89	8.39	8.03	7.56	7.10
4Out	OUTFALL	27.04	27.04	27.04	27.04	27.04
1Out	OUTFALL	9.34	9.34	9.34	9.34	9.34
113div	DIVIDER	9.93	9.63	9.36	9.01	8.66
114div	DIVIDER	138.05	137.26	136.57	135.68	134.79
115div	DIVIDER	139.01	138.19	137.46	136.54	135.61
112div	DIVIDER	156.06	154.58	153.16	151.44	149.71
111div	DIVIDER	183.96	181.65	179.25	176.33	173.43
116div	DIVIDER	41.06	39.06	37.05	34.68	32.31
117div	DIVIDER	69.49	65.90	62.05	57.52	53.54
120div	DIVIDER	42.67	41.25	39.90	38.29	36.72
109div	DIVIDER	62.93	60.80	58.62	56.09	53.58
106div	DIVIDER	24.42	23.91	23.32	22.71	22.11
107div	DIVIDER	107.71	103.85	99.73	95.22	90.85
119div	DIVIDER	147.01	141.47	135.52	128.91	122.34
103div	DIVIDER	192.42	184.95	176.66	167.98	159.38
102div	DIVIDER	16.24	15.41	14.57	13.58	12.58
105div	DIVIDER	16.35	15.88	15.27	14.63	13.99
212	CONDUIT	113.10	112.59	113.11	112.65	112.72
213	CONDUIT	9.93	9.62	9.34	8.97	8.62
214	CONDUIT	138.02	137.24	136.54	135.66	134.77
215	CONDUIT	59.28	59.33	59.41	59.45	59.34
222	CONDUIT	116.60	116.60	116.60	116.60	116.60
223	CONDUIT	67.63	67.63	67.63	67.63	67.63
216	CONDUIT	40.73	38.51	36.39	33.85	31.44
211	CONDUIT	123.17	123.21	123.32	123.17	123.34
217	CONDUIT	20.61	20.62	20.63	20.47	20.70
221	CONDUIT	21.55	20.74	20.12	19.32	18.54
220	CONDUIT	21.69	21.69	21.69	21.69	21.69
209	CONDUIT	27.49	27.26	27.44	27.38	27.45
206	CONDUIT	10.97	10.95	10.93	10.95	10.95
205	CONDUIT	16.09	15.64	15.00	14.36	13.71

207	CONDUIT	34.95	35.00	34.94	35.02	34.96
219	CONDUIT	83.03	83.42	83.01	83.44	83.56
203	CONDUIT	99.90	99.68	98.88	99.66	98.75
202	CONDUIT	16.10	15.24	14.40	13.41	12.43
213over	CHANNEL	0.00	0.00	0.00	0.00	0.00
214over	CHANNEL	0.00	0.00	0.00	0.00	0.00
215over	CHANNEL	82.83	82.00	81.27	80.34	79.39
212over	CHANNEL	49.41	47.93	46.49	44.74	42.99
211over	CONDUIT	64.24	61.91	59.50	56.70	53.91
216over	CHANNEL	0.00	0.00	0.00	0.00	0.00
217over	CHANNEL	50.08	46.48	42.64	38.22	34.26
220over	CHANNEL	20.52	19.07	17.71	16.09	14.59
209over	CHANNEL	35.37	33.25	31.16	28.81	26.47
206over	CHANNEL	10.97	10.45	9.89	9.35	8.85
207over	CHANNEL	74.93	71.07	67.00	62.54	58.22
219over	CHANNEL	69.12	63.59	57.64	51.04	44.45
203over	CONDUIT	99.39	92.09	84.15	75.30	66.61
202over	CONDUIT	0.00	0.00	0.00	0.00	0.00
205over	CHANNEL	0.00	0.00	0.00	0.00	0.00



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WRIGHT WATER ENGINEERS, INC.
2490 W 26TH AVE 100A
DENVER, CO. 80211
(303) 480-1700

ASPEN, COLORADO

ASPEN DETENTION ANALYSIS

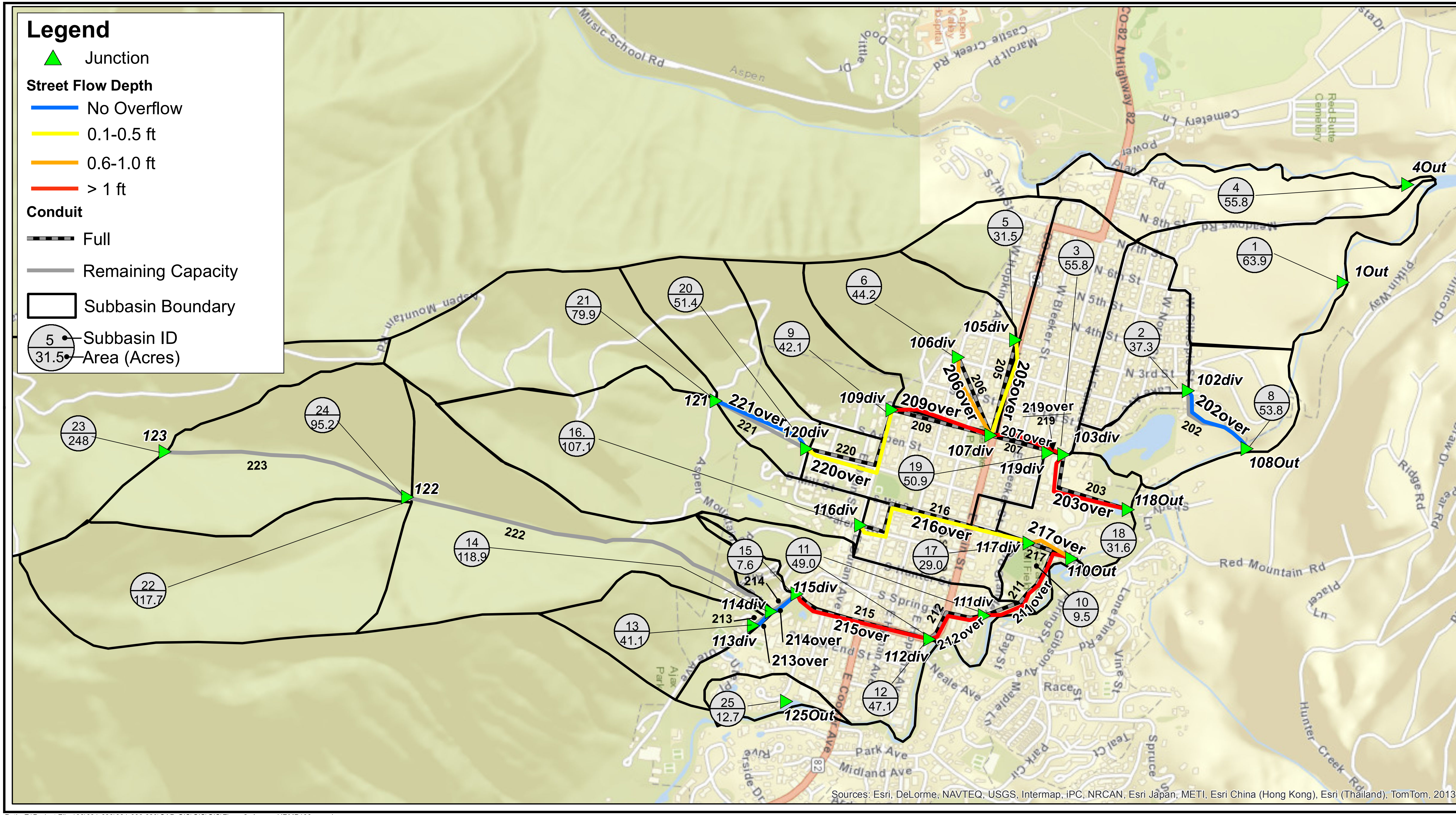
SWMM ROUTING ELEMENTS

1 inch = 1,300 feet

0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
1



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ASPEN, COLORADO

ASPEN DETENTION ANALYSIS
EXISTING CONDITIONS WITH URMP RAINFALL-100 YR

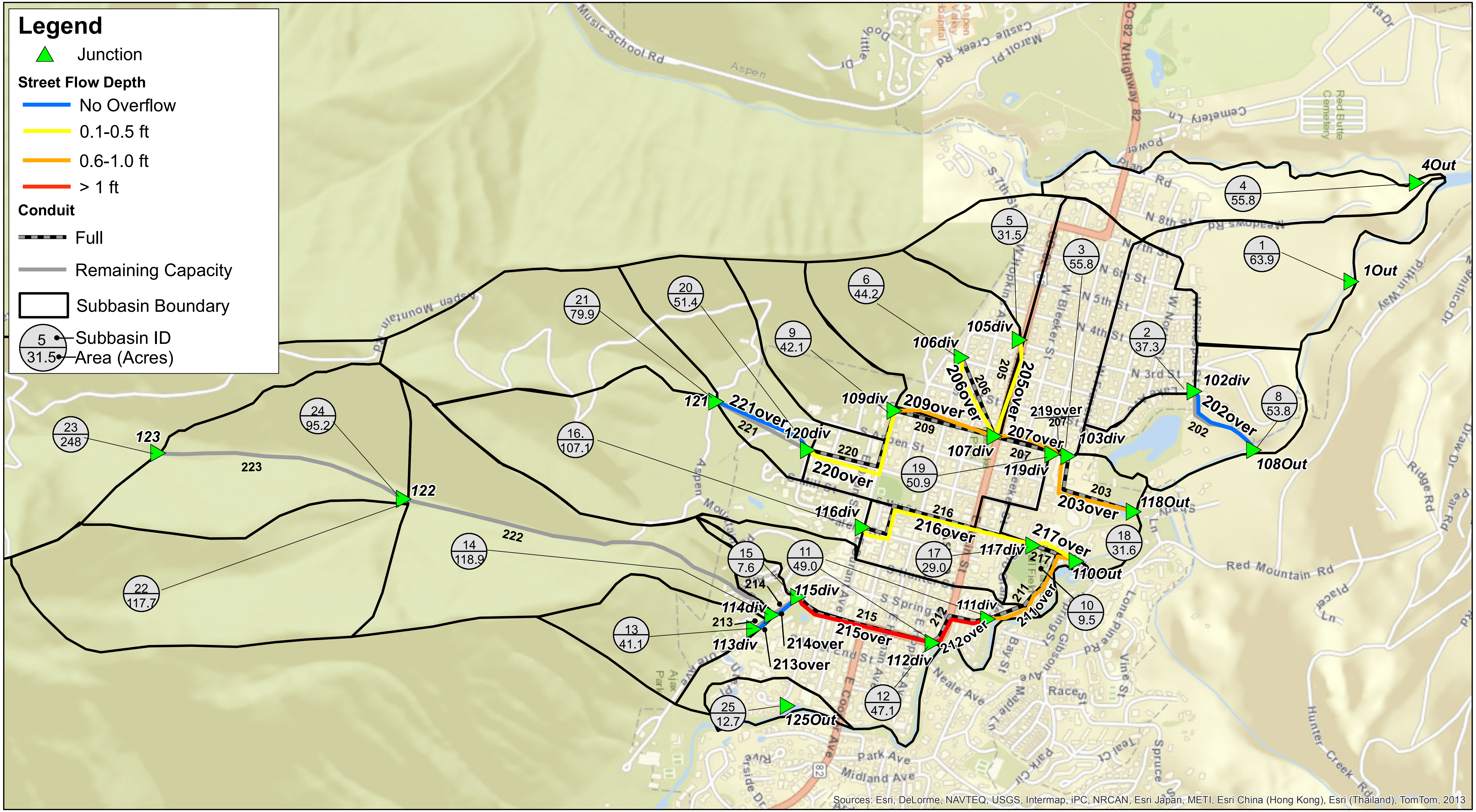
SYSTEM CAPACITY

1 inch = 1,300 feet

0 650 1,300 2,600 Feet

PROJECT NO. 081-099.020

FIGURE 2



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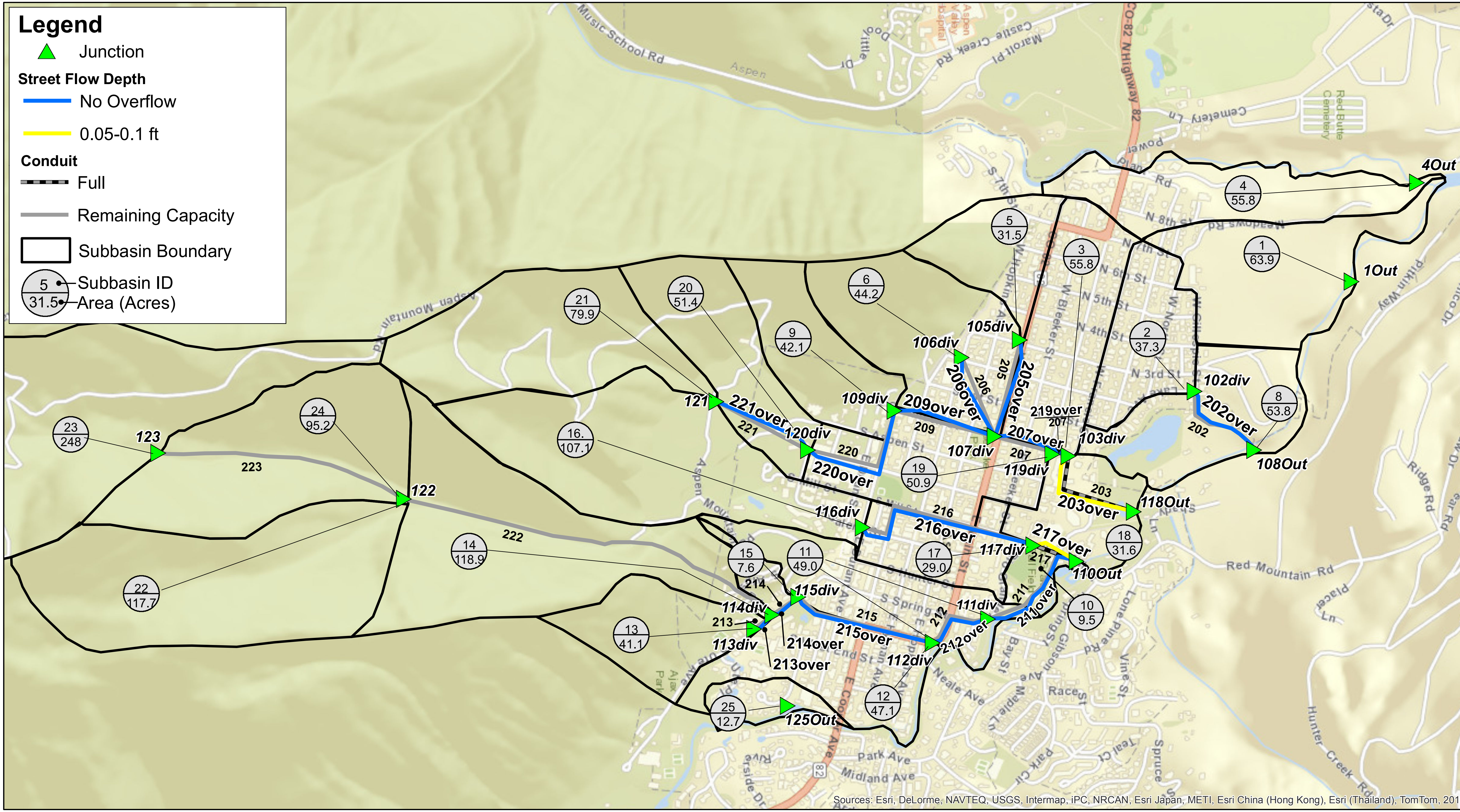
ASPEN, COLORADO

ASPEN DETENTION ANALYSIS
EXISTING CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-100 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
3



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ASPEN, COLORADO

ASPEN DETENTION ANALYSIS

EXISTING CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-10 YR

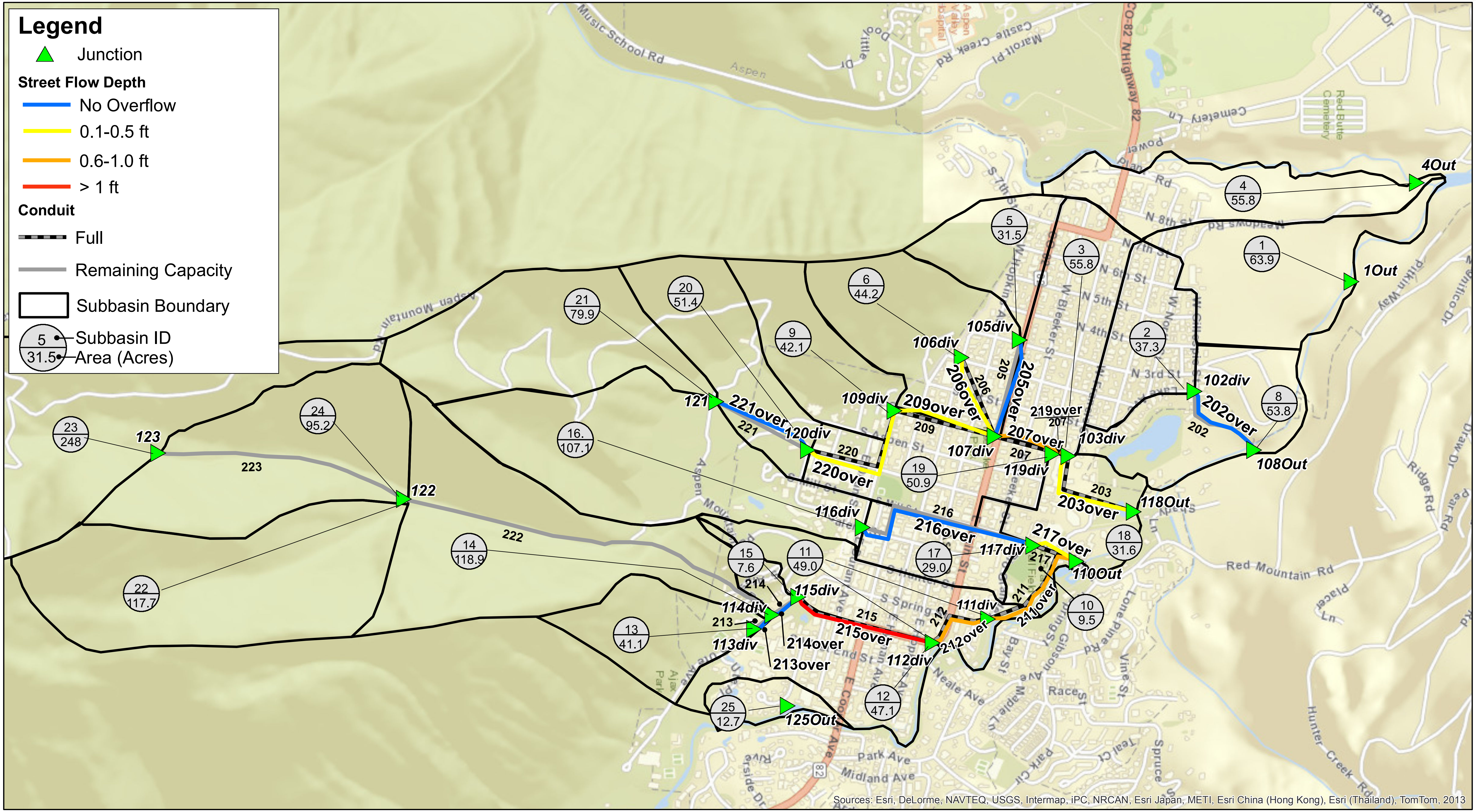
SYSTEM CAPACITY

1 inch = 1,300 feet

0 650 1,300 2,600 Feet

PROJECT NO. 081-099.020

FIGURE 4



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ASPEN, COLORADO

ASPEN DETENTION ANALYSIS
DETENTION CONDITIONS WITH NOAA ATLAS 14 MEAN RAINFALL-100 YR
SYSTEM CAPACITY

1 inch = 1,300 feet
0 650 1,300 2,600 Feet

PROJECT NO.
081-099.020

FIGURE
5