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1.0 INTRODUCTION

This introduction provides basic information including purpose and scope, mapping sources, and data collection. The remainder of this report represents the hydrologic analysis conducted on subbasins which are tributary to North St. Vrain Creek, South St. Vrain Creek, and St. Vrain Creek near the Town of Lyons, Colorado (Town).

1.1 Purpose and Scope

The intent of this report is to document the hydrologic analysis conducted by Wright Water Engineers, Inc. (WWE) to provide updated peak discharges for the 2-, 5-, 10-, 50-, and 100-year storm events for subbasins which are tributary to North St. Vrain Creek, South St. Vrain Creek, and St. Vrain Creek as they flow through the Town. This hydrologic analysis focused on the existing and future drainage conditions of the watershed that can be used to develop alternative drainageway planning concepts and prepare a preliminary design of improvements.

1.2 Mapping

Mapping used in the hydrologic analysis was based on 2011 LIDAR topography with 1-ft contour intervals provided by ICON Engineering, Inc. As a result of the September 2013 flood, there were significant changes in channels due to avulsion, scour, and deposition. However, these changes primarily affected channel and floodplain areas rather than upland areas that comprise the vast majority of subbasin drainage areas. The 2011 LIDAR data was found to be suitable for subbasin delineation and parameterization. Aerial mapping from Google Earth dated October 2015 was used to determine existing land use conditions and calculate subbasin imperviousness.

1.3 Data Collection

The following summarizes the information that was used as a reference for this hydrologic analysis:

- Town of Lyons, Boulder County, Colorado, Drainage Master Plan Final report, BRW, Inc., April 1998.

- Zoning District Map of the Town of Lyons, Colorado, King Surveyors, Inc., Readopted January 2009.

- 2010 Lyons Planning Area Map, Civil Resources, 2010.

- Urban Drainage and Flood Control District (UDFCD) Urban Storm Drainage Criteria Manual.

2.0 HYDROLOGIC ANALYSIS

This section of the report provides an overview of the hydrologic characteristics, calculations, and modeling used to develop the hydrology for the project area, as well as detailed descriptions of the design rainfall, subbasin characteristics, model input, model results, results, and comparisons with previous studies.

2.1 Project Area Description

The project area includes the subbasins tributary to the North Saint Vrain Creek, South Saint Vrain Creek, Red Hill Gulch, and Stone Canyon within the Town. The total drainage area studied is approximately 8.6 square miles.

Existing drainage in the area consists of mostly open channels with some storm sewers in urbanized areas in Town. Most of the Town's existing drainage infrastructure is undersized due to the increase in development within the Town during the 1990s. The existing conveyance system has the capacity to convey the nuisance flows, but it does not have the capacity to convey even the minor (5-year) storm events.

2.2 Previous Studies

Hydrology of watersheds running through the Town was previously studied by BRW, Inc. for the *Town of Lyons Drainage Master Plan Final Report* dated April 1998. This drainage master plan utilized the Colorado Urban Hydrograph Procedure (CUHP) and the Urban Drainage Storm Water Management Model (SWMM) to simulate developed stormwater runoff rates and volumes to identify problem areas. Additionally, the drainage master plan formulated a strategy to cost effectively upgrade the Town's flood control facilities and provided feasibility-level cost analyses to enable subsequent capital budgeting.

The hydrologic analysis conducted for the Town as a part of this effort was not "calibrated" to the hydrology defined in the BRW, Inc. drainage master plan. Comparisons were made to the unit rates of runoff from the BRW, Inc. drainage master plan, but the hydrologic analysis described in this report was conducted independently using the CUHP version 2.0. Both hydrologic studies utilized CUHP so differences between the BRW and WWE model results can be explained by physical factors (i.e. differences in subbasin imperviousness and the use of updated NOAA Atlas 14 precipitation data).

2.3 Hydrologic Model

To evaluate the latest version of CUHP (and other methods) and to determine the appropriate model inputs, WWE conducted a peak flow sensitivity analysis for a typical undeveloped subbasin near the Town using various hydrologic methods. This sensitivity analysis was conducted to determine which hydrologic method should be utilized for the Lyons stormwater master plan since Lyons is located outside of the UDFCD boundary and the hydrologic method to be used to estimate peak discharges is not limited to CUHP. The following lists the hydrologic methods that were utilized in this sensitivity analysis:

- United States Geologic Survey (USGS) Regional Regression Equations.
- Rational Method.
- CUHP 2005 Version 1.4.4 -- This is the current model used by UDFCD and has been used for over 40 years to estimate peak flows in the Denver metropolitan area.
- CUHP Version 2.0 -- Recently the UDFCD has determined that peak flows developed in recent hydrologic studies using CUHP 2005 version 1.4.4 deviated from statistical stream gage analysis across the District and created uncertainty with CUHP model results for some studies. Additionally, CUHP 2005 version 1.4.4 has not been calibrated with gage data since its inception in the 1970s with adjustments made in the 1980s. Therefore, UDFCD has recalibrated CUHP with updated rainfall and runoff with results tested against stream gage frequency analysis. However, it should be noted that during the recalibration of CUHP, there were no watersheds with an imperviousness less than 20 percent. Therefore, for subbasins with imperviousness below 20 percent, the peak flows are estimated using similar methodology used in CUHP 2005 version 1.4.4.

- HEC-HMS Model -- using Curve Number method.

- UDFCD Allowable Release Rates -- The UDFCD *Urban Storm Drainage Criteria Manual, Volume 2, Storage* chapter provides pre-development peak unit discharge rates for watersheds of various slopes and Hydrologic Soil Groups (HSGs) that are utilized to determine the maximum allowable 100-year release rates for a full spectrum detention facility.

Based on the results of the undeveloped subbasin peak flow sensitivity analysis, WWE recommended using CUHP version 2.0 for the hydrologic modeling for the Lyons stomwater master plan. The unit rates of runoff from CUHP version 2.0 were in the same range as those generated using the Rational Method and the UDFCD allowable release rates. The unit rates of runoff generated using CUHP 2005 version 1.4.4 were higher than any of the other hydrologic methods which may overestimate the peak flows for the Town. The regional regression equations significantly underestimate the unit rates of runoff when compared to the other hydrologic model methods.

2.4 Subbasin Delineation

Subbasins were delineated using the 2011 LIDAR and associated 1-ft contours. There is a total of 44 subbasins within the project area. The undeveloped subbasins located higher up in the watersheds are larger in size than the subbains within the urbanized Town. Subbasin sizes range from 17 acres to 335 acres. Figure 1 provides an overview of the subbasins.

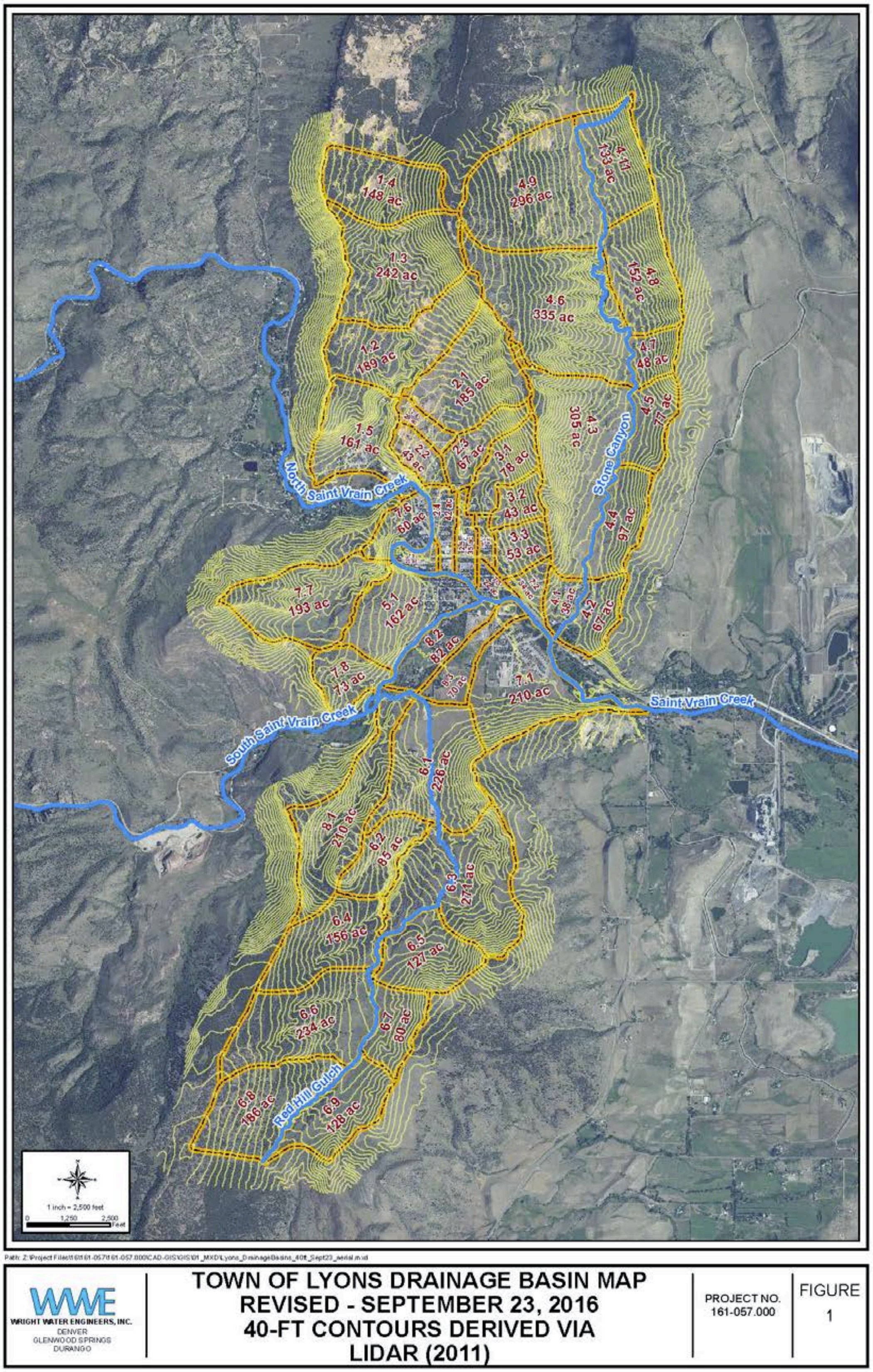

Figure 1. Subbasin Overview Map

2.5 Design Rainfall

The design rainfall for the project was derived using the one-hour precipitation depths from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14. One-hour point precipitation depths were based on the centroid of the entire project area and were recorded for the 2-, 5-, 10-, 50-, and 100-year recurrence intervals. Point precipitation depths for varying elevation within the project area were identified, but point precipitation depth adjustments due to elevation were not necessary since the difference in the one-hour precipitation depths by elevation was less than 0.1 inches. Using the one-hour precipitation depth, CUHP calculates the incremental depth for each time increment from 5 to 120 minutes. Due to the smaller sizes of subbasins, precipitation depth-area reduction factors were not utilized. Table 1 summarizes the design rainfall depths for various recurrence intervals.

Table 1. Design Rainfall Depths (inches) for Recurrence Intervals

Storm Duration	2-Year	5-Year	10-Year	50-Year	100-Year
One-Hour	0.77	1.05	1.33	2.23	2.71

2.6 CUHP Input Parameters

The following summarizes the input parameters utilized in CUHP version 2.0. Using GIS, subbasin characteristics were calculated and input into CUHP. The summary of CUHP input parameters for existing conditions and future conditions for the 2-, 5-, 10-, 50-, and 100-year recurrence intervals is provided in Appendix A.

2.6.1 Length to Centroid

The length to centroid is calculated as the distance from the design point of the subbasin along the main drainageway path to the subbasin's centroid. Figure 2 provides an overview of the longest flow paths. The subbasin centroids are identified on the figure with the red and white dots. The length to the centroid was measured from the downstream design point of the subbasin to the centroid along the flow path.

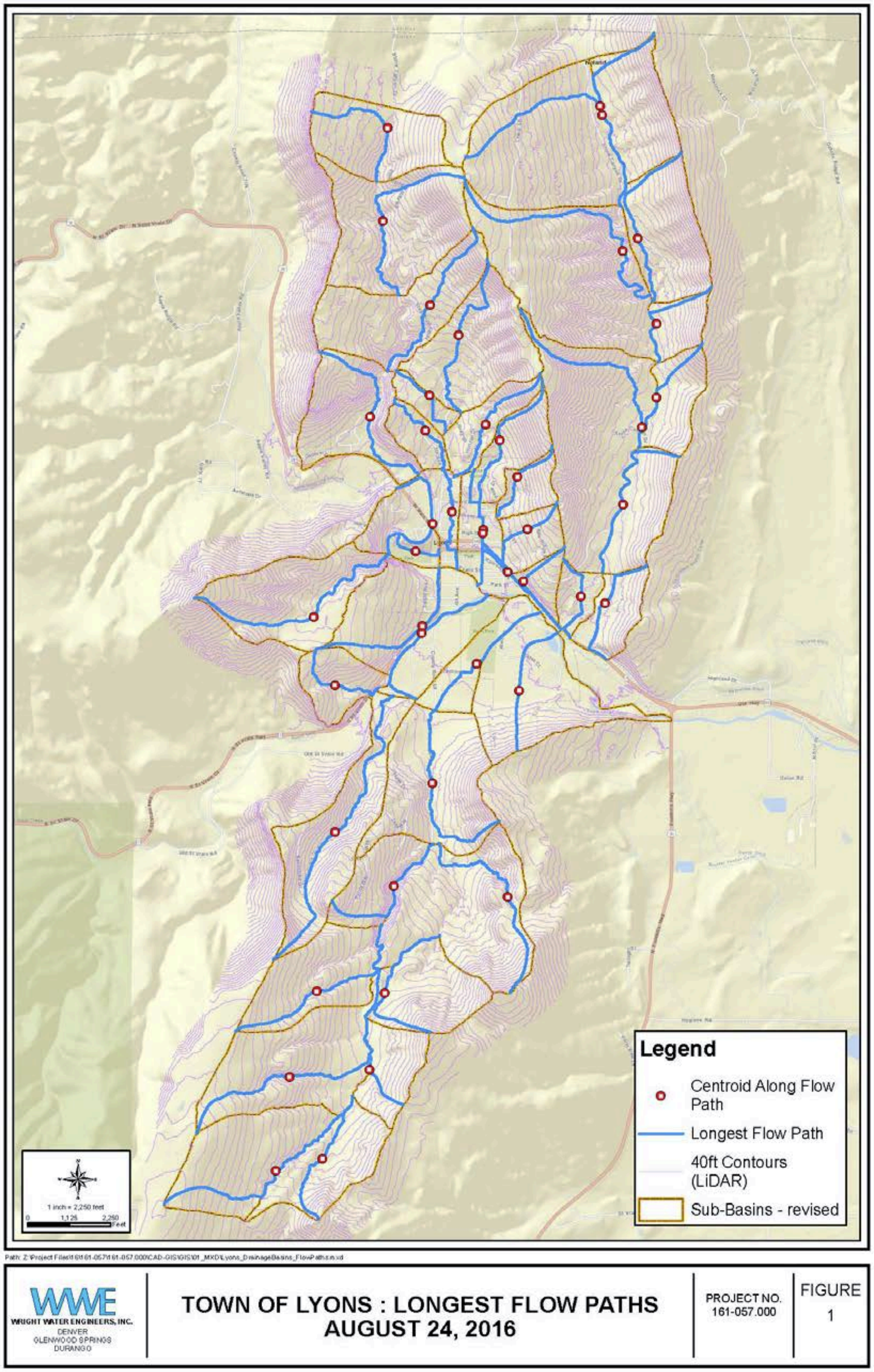

Figure 2. Subbasin Longest Flow Paths

2.6.2 Length

The length is the distance from the downstream design point of the subbasin along the main drainageway path to the furthest point on the subbasin boundary. The length was calculated based on the longest flow path (blue line) shown in Figure 2.

2.6.3 Slope

The slope is the length-weighted, corrected average slope of the subbasin in feet per foot. Per the UDFCD *Urban Storm Drainage Criteria Manual, Volume 1, Chapter 6 Runoff*, there are natural processes at work that limit the time to peak of a unit hydrograph as a natural stream or vegetated channel becomes steeper. To account for this phenomenon, it is recommended that the slope used in CUHP for stream and vegetated channels be adjusted. Table 2 provides a summary of the measured subbasin slopes compared to the adjusted slope for use in CUHP per Figure 6-4 of the UDFCD *Urban Storm Drainage Criteria Manual*.

Table 2. CUHP Subbasin Slope Adjustment

Subbasin	Measured Slope (ft/ft)	Adjusted Slope for use in CUHP (ft/ft)
1.2	0.19	0.06
1.3	0.15	0.06
1.4	0.12	0.06
1.5	0.11	0.06
2.1	0.20	0.06
2.2	0.10	0.06
2.3	0.20	0.06
2.4	0.03	0.03
2.5	0.04	0.04
3.1	0.19	0.06
3.2	0.22	0.06
3.3	0.18	0.06
3.4	0.04	0.04
4.1	0.10	0.06
4.11	0.10	0.06
4.2	0.09	0.06
4.3	0.10	0.06
4.4	0.09	0.06
4.5	0.15	0.06
4.6	0.11	0.06
4.7	0.16	0.06
4.8	0.16	0.06
4.9	0.12	0.06
5.1	0.10	0.06
6.1	0.11	0.06
6.2	0.17	0.06
6.3	0.15	0.06
6.4	0.14	0.06
6.5	0.16	0.06
6.6	0.10	0.06
6.7	0.10	0.06
6.8	0.12	0.06
6.9	0.13	0.06
7.1	0.13	0.06
7.2	0.10	0.06
7.3	0.02	0.02
7.4	0.09	0.06
7.5	0.003	0.003
7.6	0.02	0.02
7.7	0.17	0.06
7.8	0.14	0.06
8.1	0.11	0.06
8.2	0.01	0.01
8.3	0.02	0.01

2.6.4 Percent Imperviousness

The percent imperviousness model input was determined based on land use and soil types found in each subbasin. Land use was determined by compiling information from the 2009 Zoning

District Map, 2010 Lyons Planning Area Map, and by ground-truthing the land cover based on an October 2015 aerial image from Google Earth. Each land use category was assigned a percent imperviousness with guidance from Chapter 6 – Runoff of the UDFCD *Urban Storm Drainage Criteria Manual*. Table 3 outlines the land use categories and the corresponding percent imperviousness. In addition to the land use categories found in Table 3, Boulder County Open Space land use category represented a large amount of many subbasins. Soil types mapped using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey were assigned a percent imperviousness based on drainage and runoff class and area weighted within each subbasin. (See Appendix B for detailed soil descriptions). Table 4 displays the soil types used to calculate imperviousness for the Boulder County Open Space land use category.

Table 3. Land Use Categories and Corresponding Percent Imperviousness

Land Use Category	UDFCD Vol. 1 Table 6-3 Equivalent	Lyons Percentage Imperviousness
Agriculture	Undeveloped - Greenbelts, agricultural	0.20
Business	Business - Downtown areas	0.95
Park	Parks, cemeteries	0.10
Municipal Facilities	Business - Suburban areas	0.75
Estate Residential[1]	Residential - Single Family: 2.5 acres or larger	0.35
Low Density Residential[1]	Residential - Single Family: 0.25-0.75 acres	0.75
Medium Density Residential[1]	Residential - Single Family: 0.75-2.5 acres	0.85
Commercial	Business - Downtown areas	0.95
Employment Area	Business - Downtown areas	0.95
Commercial Entertainment	Business - Downtown areas	0.95
Light Industrial	Industrial - Light areas	0.80
General Industrial	Industrial - Heavy areas	0.90

[1] Land use category corresponds to the 2010 Lyons Planning Area Map, although the description and corresponding lot size is not representative of what is observed in aerial imagery. WWE revised the percent imperviousness to be more representative of what is observed through imagery and on the ground.

Table 4. Soil Types Found in Boulder County Open Space Land Use Category

Soil Unit	HSG	Soil Type	Drainage Class	Runoff Class	Percent Rock Outcrop	Percent Imperviousness
MdB	A	sandy loam	well	very low		2
Nh	B	loam	poorly	very low		2
Cu	A	gravelly sandy loam	excessively	low		5
NnB	C	sandy clay loam	well	medium		8
SmF	C	stony loam	well	high	10	10
BaF	D	very stony sandy loam	well	very high	10	10
PrF	D	very stony loamy fine sand	well	very high	35	35
Ro	D	unweathered bedrock	N/A	very high	100	100

Future imperviousness was determined by comparing the land use in the 2010 Lyons Planning Area Map to a 2015 Google Earth image and noting which areas of the Town reflected current zoning and which areas may be further developed based on the planning map. The directly connected impervious area was set at level zero to represent “standard practice,” meaning impervious surfaces are not designed to drain over grass buffer strips or other pervious surfaces before reaching a stormwater conveyance system.

2.6.5 Maximum Depression Storage

The maximum pervious depression storage was set to the recommended value of 0.4 inches for wooded areas and open fields. The maximum impervious depression storage was set to the recommended value of 0.1 inches. No adjustments were made to these recommended values.

2.6.6 Horton’s Infiltration Parameters

Soils data was obtained from USDA NRCS Soil Survey Geographic Database for the project area which classified the soils into HSGs. Figure 3 shows an overview of the HSGs for each of the subbasins. Additional soils mapping was obtained from the USDA NRCS Web Soil Survey which is provided in Appendix B.

The HSG A soils are colluvial land type soil. According to the colluvial land soil description, the depth to restrictive feature is 2 to 60 inches to lithic bedrock. Because of the underlying bedrock, it was assumed that the HSG A soils would have the drainage characteristics of HSG B soils.

The initial rate, final rate, and decay coefficient for the Horton's infiltration parameters were based on the recommended values in CUHP. The Horton's infiltration parameters were weighted based on the percentage of each soil type within each subbasin. Table 5 summarizes the Horton's infiltration parameters utilized in the analysis.

Table 5. Horton's Infiltration Parameters

Hydrologic Soil Group	**Infiltration (inches per hour)**		**Decay Coefficient**
	Initial - f_i	**Final – f_o**	
A/B	4.5	0.6	0.0018
C	3.0	0.5	0.0018
D	3.0	0.5	0.0018

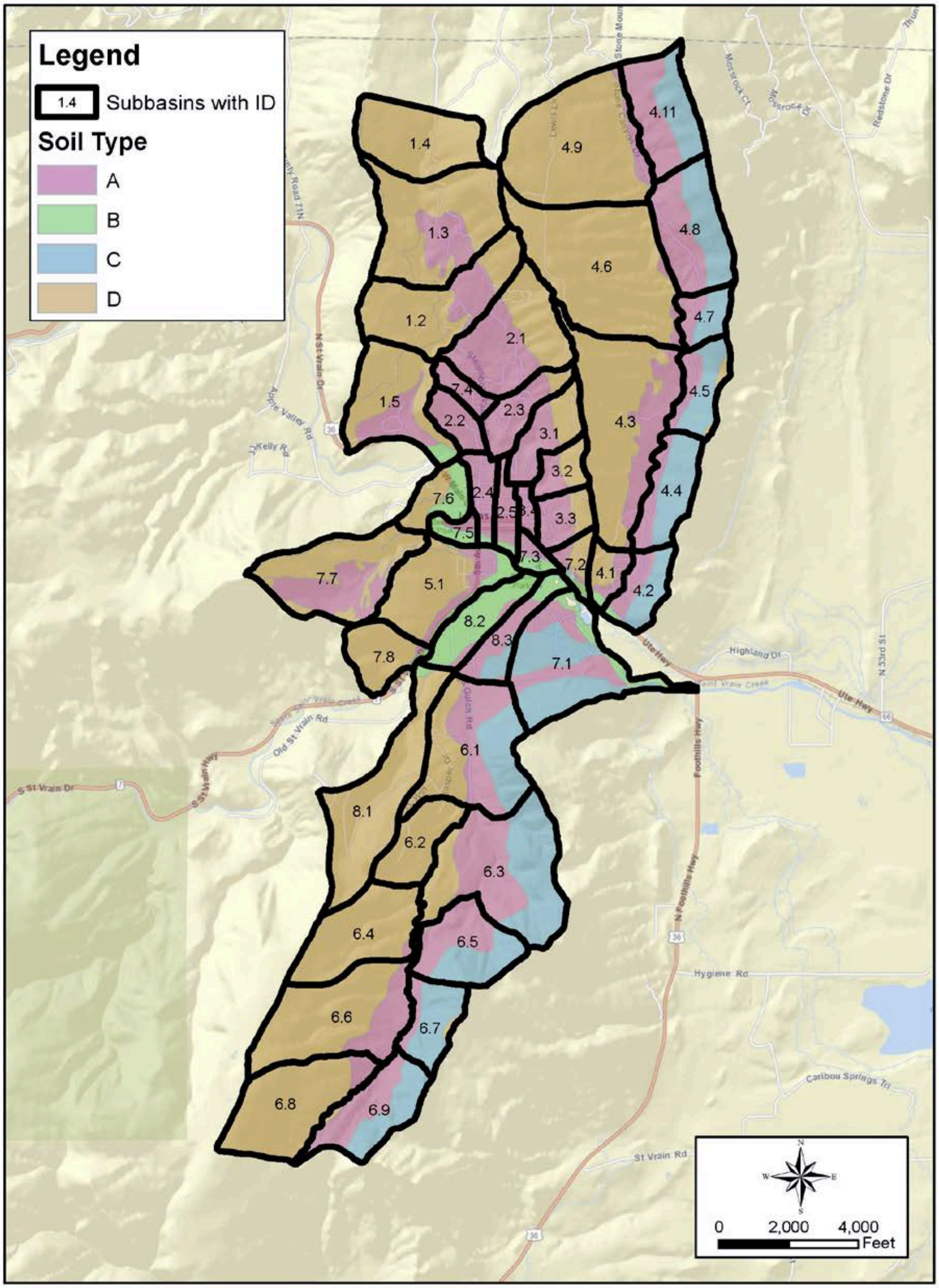

Figure 3. Soils Data

2.7 CUHP Output

The hydrologic analysis was conducted for both existing conditions and future conditions. The 100-year peak discharges from CUHP version 2.0 for both conditions are presented in Table 6. CUHP output for other recurrence intervals is provided in Appendix A.

Although this hydrologic analysis did not calibrate peak flows to the previous Town of Lyons Drainage Master Plan Final Report prepared by BRW, the CUHP unit rates of runoff were compared with the previous study unit rates of runoff for subbasins that were similarly delineated. In some cases, the unit rates of runoff are similar, but there are cases where the unit rates of runoff differ. These differences are primarily due to physical differences in input assumptions (imperviousness, HSGs, etc.).

Table 6. CUHP Output, 100-Year

Subbasin	Existing Conditions 100-Year Peak Discharge (cfs)	Existing Conditions Unit Rate of Runoff (cfs/ac)	Future Conditions 100-Year Peak Discharge (cfs)	Future Conditions Unit Rate of Runoff (cfs/ac)
1.2	408	2.16	408	2.16
1.3	534	2.21	534	2.21
1.4	403	2.72	403	2.72
1.5	449	2.79	401	2.49
2.1	306	1.65	306	1.65
2.2	97	2.27	97	2.27
2.3	130	1.95	130	1.95
2.4	109	2.57	109	2.57
2.5	102	2.89	102	2.89
3.1	142	1.83	167	2.15
3.2	111	2.55	111	2.55
3.3	114	2.16	114	2.16
3.4	51	3.04	51	3.04
4.1	102	2.66	128	3.33
4.11	183	1.38	183	1.38
4.2	113	1.68	114	1.70
4.3	387	1.27	387	1.27
4.4	128	1.33	128	1.33
4.5	117	1.52	117	1.52
4.6	526	1.57	526	1.57
4.7	70	1.47	70	1.47
4.8	227	1.49	227	1.49
4.9	575	1.94	575	1.94
5.1	375	2.32	386	2.39
6.1	367	1.62	373	1.65
6.2	187	2.18	187	2.19
6.3	370	1.37	370	1.37
6.4	186	1.19	186	1.19
6.5	213	1.68	213	1.68
6.6	233	1.00	233	1.00
6.7	176	2.21	176	2.21
6.8	252	1.35	252	1.35
6.9	216	1.69	216	1.69
7.1	531	2.52	599	2.84
7.2	65	1.92	65	1.92
7.3	73	3.35	73	3.35
7.4	68	2.37	68	2.37
7.5	33	1.43	33	1.43
7.6	134	2.25	134	2.25
7.7	360	1.87	360	1.87
7.8	143	1.96	145	1.98
8.1	313	1.49	313	1.49
8.2	93	1.13	93	1.13
8.3	75	1.07	75	1.07

2.8 Hydrograph Routing

WWE developed the hydrograph routing network based on field reconnaissance, survey of the existing storm sewer network within Town, and the BRW, Inc. drainage master plan using EPA SWMM. The routing network in EPA SWMM includes: nodes (junctions and dividers), conduits (including overflow or diverted links), storage units, storage outlets, and outfalls. The model input parameters for nodes include: node identifier, invert elevation, maximum node depth, and overflow or diverted link identifier. Input parameters for conduits include: conduit identifier, upstream and downstream node identifiers, shape (e.g. trapezoidal, circular, rectangular, etc.), length, bottom width, side slopes, roughness coefficient, number of barrels, and inlet/outlet offset depths. Input parameters for storage units include: storage unit identifier, invert elevation, maximum depth, and a stage-area relationship. Input parameters for storage outlets include: outlet identifier, upstream and downstream node identifiers, and a stage-discharge relationship. Input parameters for outfalls include the outfall identifier and invert elevation. Input parameters for the SWMM model are provided in Appendix C.

2.8.1 SWMM Node Input Parameters

Node identifiers in SWMM are synonymous with the subbasin IDs. Invert elevations were determined using the 2011 LIDAR data. In some instances, a divider was used to allow the flow to be routed through the existing storm sewer system but when the capacity of the storm sewer is exceeded, the water overflows into the street (along 2nd Avenue south of E. Main Street and near the intersection of Main Street and E. Main Street).

2.8.2 SWMM Conduit Input Parameters

For the drainage basins located outside of Town, transects of the drainage channels were generated using the 2011 LIDAR and a representative channel cross-section was input into the SWMM model. The manning's roughness coefficient for these undeveloped drainage basins was estimated to be 0.035 to represent channels with some weeds and stones.

Within the developed areas, characteristics of the drainage facilities were based on survey of the existing storm sewer system, field reconnaissance, and sizing the channels so that the flow could adequately be conveyed to the outfall. Between 5th Avenue and 4th Avenue, there is an existing drainage ditch that varies in width and depth but is enclosed downstream to accommodate development over the ditch. For the purposes of the SWMM model, it was assumed to have a uniform width and depth. There is a small roadside swale with intermittent driveway and roadway culverts along the west side of 3rd Avenue. However, the swale and culverts have such limited capacity and during large storm events, the water would flow down 3rd Avenue. At 3rd Avenue and Main Street there is a 30" reinforced concrete pipe that diverts flow from 3rd Avenue to the southeast along E. Main Street. During large storm events, the flow continues down within E. Main Street, which was modeled as an open channel, until it discharges into the St. Vrain Creek. South of E. Main Street along 2nd Avenue there is a storm sewer system consisting of 18-inch, 12-inch, and 15-inch corrugated metal pipe which discharges into the St. Vrain Creek. This storm sewer system was modeled as a 12-inch pipe in the SWMM model.

There are many subbasins which are direct flow areas into the North St. Vrain Creek, South St. Vrain Creek, or St. Vrain Creek. Therefore, the conduits for these subbasins were modeled as "dummy" conduits.

2.8.3 SWMM Storage Input Parameters

There is an existing detention pond located within Subbasin 1.5. The stage-area relationship was taken from the BRW, Inc. drainage master plan, as well as the stage-discharge relationship for the outlet. Although there may be inadvertent storage and/or privately owned detention elsewhere within the project area, no additional detention ponds were modeled for the existing conditions.

2.8.4 SWMM Output

The SWMM routing was conducted for both existing conditions and future conditions. The 100-year peak discharges at all of the outfalls from SWMM for both conditions are presented in Table 7. SWMM output for other recurrence intervals is provided in Appendix C.

Table 7. SWMM Output, 100-Year

SWMM Outfall Name	Routed Subbasins	Receiving Water	Existing Conditions 100-Year Peak Discharge (cfs)	Future Conditions 100-Year Peak Discharge (cfs)
StoneCanyonSt.VrainOUT	4.9, 4.11, 4.6, 4.8, 4.7, 4.3, 4.5, 4.4, 4.1, 4.2	St. Vrain Creek	2,357	2,361
EagleCanyonN.St.VrainOUT	1.4, 1.3, 1.2, 1.5	North St. Vrain Creek	1,362	1,362
RedHillGulchS.St.VrainOUT	6.8, 6.9, 6.6, 6.7, 6.4, 6.5, 6.2, 6.3, 6.1	South St. Vrain Creek	2,357	2,361
Sub2.4N.St.VrainOUT	2.1, 2.2, 7.4, 2.3, 2.4	North St. Vrain Creek	695	695
Sub7.2St.VrainOUT	3.1, 3.2, 2.5, 3.4, 3.3, 7.2	St. Vrain Creek	577	610
Sub7.3St.VrainOUT	7.3	St. Vrain Creek	73	73
Sub7.7N.St.VrainOUT	7.7	North St. Vrain Creek	360	360
Sub7.8S.St.VrainOUT	7.8	South St.Vrain Creek	143	145
Sub5.1N.St.VrainOUT	5.1	North St. Vrain Creek	375	386
Sub7.5N.St.VrainOUT	7.5	North St. Vrain Creek	33	33
Sub8.2St.VrainOUT	8.2	St. Vrain Creek	93	93
Sub8.3St.VrainOUT	8.3	St. Vrain Creek	75	75
Sub7.1St.VrainOUT	7.1	St. Vrain Creek	531	599
Sub7.6N.St.VrainOUT	7.6	North St. Vrain Creek	134	134

3.0 WILDFIRE ANALYSIS

Post-wildfire flooding was evaluated for the subbasins tributary to the North St. Vrain Creek, South St. Vrain Creek, and St. Vrain Creek near the Town based on forest coverage determined from aerial imagery inspection. Beetle kill mapping from an aerial detection survey performed by the U.S. Forest Service was reviewed; however, the trees in this area do not exhibit signs of beetle kill. The purpose of this modeling exercise was to illustrate how peak discharges could potentially temporarily increase following a wildfire. This analysis is intended to provide the Town of Lyons with an order of magnitude approximation of potential wildfire effects on hydrology. Post-wildfire hydrology is typically analyzed using the Curve Number (CN) method (USDA, 2016). For this post-wildfire flood scenario, the watershed was assumed to experience moderate burn severity since the forest coverage in these watersheds is not extremely dense. The CN WWE assigned to a moderate burn severity was an 89, which is consistent with the CN developed by WWE in other post-wildfire hydrology assessments, including the Boulder County Fourmile wildfire in 2010, and the newly released Hydrology Technical Note No. 4, Hydrologic Analyses of Post-Wildfire Conditions, issued by the NRCS in August 2016.

Three representative subbasins, each with different watershed slopes, were modeled in HEC-HMS using existing condition (pre-wildfire) curve numbers as well as post-wildfire curve numbers. These modeling scenarios provide a relative increase in the unit rate of runoff for post-wildfire conditions. Table 8 provides the average factors of increase of the unit rates of runoff for existing, pre-wildfire conditions to post-wildfire conditions.

Table 8. Average Factor of Increase in Unit Rate of Runoff from Existing, Pre-Wildfire Conditions to Post-Wildfire Conditions

Recurrence Interval	Average Factor of Increase
2-yr	11
5-yr	5
10-yr	3
50-yr	2
100-yr	2

Each subbasin was evaluated for forest cover and assigned an approximate percent coverage found in Table 2. Subbasins that are not displayed in Table 9 were either in town, and therefore have minimal potential to experience wildfire, or do not have notable forest coverage. The peak discharge resulting from a wildfire burned subbasin is dependent on the forest coverage in each basin. In other words, the 2-year event may only increase the peak discharge in a subbasin with 20 percent forest coverage by approximately a 2.2 factor of increase (or about two times the existing condition peak discharge).

Table 9. Approximate Percent Coverage of Forest for Forested Subbasins

Subbasin with Forest Coverage	Percent Cover
1.2	20
1.3	30
1.4	80
4.3	10
4.6	20
4.9	50
6.1	20
6.2	70
6.3	20
6.4	90
6.6	80
6.8	70
6.9	10
8.1	50

The results in this evaluation provide useful information on the potential magnitude of hydrologic effects of burn areas in this watershed. The unit rate of runoff average factors of increase can be applied to the existing, pre-wildfire unit rates of runoff generated from the CUHP modeling to determine the potential increase in runoff after a wildfire. Changes in hydrology due to wildfires are temporary in nature and decrease back to pre-burn levels over periods of time ranging from 5 to 10 years or more; however, changes in runoff and volumes in the years immediately following a wildfire can be extreme.

Mud and debris flows can be triggered by as little as 0.25 inches of rain in 30 minutes on steep, burned slopes (WWE, 2011). Mud and debris flows are most common in smaller tributaries, but some “bulking” would be expected even on the main stems due to ash, sediment, and debris. In addition, debris damming and subsequent breaching (which are not accounted for in the modeling) can significantly increase peak discharges in post-wildfire floods. WWE did not account for sediment bulking in this hydrologic analysis, and additional analysis would be needed to determine approximate bulking factors for different reaches. Debris damming and breaching also was not evaluated as a part of this study. If there are high risk locations that could be affected by this phenomenon in Town, additional analysis using dam break routines could be used to estimate potential peak discharges.

This post-wildfire flooding analysis is just a representative scenario. Additional studies could be performed to evaluate different burn area scenarios based on factors including locations of key infrastructure in the watershed, applying USGS debris flow regression equations to specific subbasins, varying burn area size and severity, and other considerations discussed above.

4.0 CONCLUSIONS

This effort to develop updated hydrology for subbasins tributary to the North Saint Vrain Creek, South Saint Vrain Creek, Red Hill Gulch, and Stone Canyon within the Town utilizes an updated hydrologic model than the model that was utilized in the previous hydrologic study. Results of this hydrologic analysis provide reasonable estimates of peak discharges that can be used to develop alternative drainageway planning concepts and prepare a preliminary design of improvements.

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