C I T Y O F B O U L D E R
WATER RESOURCES ADVISORY BOARD
AGENDA ITEM

MEETING DATE: APRIL 27, 2015

AGENDA TITLE: Public Hearing and consideration of a recommendation to City Council regarding the Gregory Canyon Creek Flood Mitigation Plan

PRESENTER/S:
Jeff Arthur, Director of Public Works for Utilities
Annie Noble, Acting Principal Engineer for Flood and Greenways
Katie Knapp, Engineering Project Manager
Kristin Dean, Utilities Planner

EXECUTIVE SUMMARY

The purpose of this memorandum is to present the Gregory Canyon Creek *Draft* Flood Mitigation Plan (**Attachment A)** for the WRAB's consideration, input and recommendation to Council.

The city has retained CH2MHill to evaluate potential alternatives to help alleviate future flooding along Gregory Canyon Creek. CH2MHill's Alternative Analysis Memorandum ("Analysis") is included as Appendix A of the *Draft* Flood Mitigation Plan (**Attachment A)**. This Analysis contains a detailed description of the data and models used to determine the improvements which would help flood conveyance along Gregory Canyon Creek. The intent of the Analysis was to identify various types of improvements which could be constructed along the creek corridor, assess the costs and benefits associated with each improvement, and include an engineer's recommendation.

Staff reviewed the Analysis and developed a staff recommended plan based on the engineering recommendation, input from the public and observations from the 2013 flood event. The staff recommended plan is illustrated graphically in Section 6 of the *Draft* Flood Mitigation Plan (**Attachment A)** which also includes additional information about the Gregory Canyon Creek watershed, the planning process and the alternatives considered. Please note that not all sections of the document have been completed. Pending consideration and input from WRAB, conceptual drawings will be developed and the mitigation plan will be finalized and presented to City Council for acceptance.

STAFF RECOMMENDATION:

Staff requests Water Resources Advisory Board consideration of this matter and action in the form of the following motion:

Motion to recommend the Gregory Canyon Creek Flood Mitigation Plan be finalized based on the Staff Recommended Plan and presented to City Council for acceptance.

BOARD AND COMMISSION FEEDBACK

The Gregory Canyon Creek flood mitigation study was presented to WRAB as an information item on October 20, 2014. In general, the WRAB was supportive of the approach being taken and the alternatives under consideration. Much of the WRAB discussion focused on outreach and education and has been shared with the city's watershed sustainability and outreach group. The feedback from WRAB is summarized in the minutes from that meeting as **Attachment B**.

PUBLIC FEEDBACK

There have been many opportunities for public involvement and feedback throughout this mitigation study. Open Houses were held on October 13, 2013 (post flood-67 people attended), June 12, 2014 (17 people attended), October 20, 2014 (22 people attended) and March 30, 2015 (20-25 people attended). Eight people provided public comments at the October 20, 2015 WRAB meeting and their comments are also included in the attached minutes. Staff conducted neighborhood site walks with residents in the area on Feb. 9 and Feb. 10, 2015 (a total of approximately 25 residents participated). Staff has also met individually with several property owners and was available to meet with small focus groups. The project website provided opportunities for comments to be submitted electronically and so far, 13 comments have been submitted through this option.

Public notification post cards about the WRAB meetings, the preceding Open Houses, and the neighborhood site walks were sent to all property owners in the study area and a project web site has been developed to provide information: (https://bouldercolorado.gov/flood/gregory-canyon-creek-flood-mitigation-study).

Additionally, posters notifying the neighborhood of the meetings and open house were posted at various visible locations along the creek corridor. Emails have been sent to all interested parties whom have signed up for email notifications and to all parents of children attending Flatirons Elementary School. The most recent school newsletter included a flyer about the March 30, 2015 open house.

BACKGROUND

A detailed description of the scope of the mitigation study and the preliminary alternatives were presented to WRAB at their Oct. 20, 2014 meeting. The memo and attachments can be accessed here: https://documents.bouldercolorado.gov/weblink8/0/doc/126654/Electronic.aspx. This memo also included detailed background information and a discussion about the applicable master plan policies from the Boulder Valley Comprehensive Plan, the Comprehensive Flood and Stormwater Utility Master Plan, the Greenways Master Plan and the Urban Drainage and Flood Control District Drainage Criteria Manual.

Considering the limited opportunities for mitigating a 100-year storm along Gregory Canyon Creek, a mitigation study was not a part of the Utilities work program until the September 2013 flood occurred. Because of the flood, there was increased public support for infrastructure improvements in the area. Following the storm, the trash racks at the culverts on Willowbrook St. and on 7th St. across from Flatirons Elementary School were removed, redesigned and replaced with ones that meet current design standards. Also, the wire fencing on the downstream side of the culvert at 6th St. and Aurora Ave. was

removed because it trapped considerable debris. This mitigation study looks at other opportunities along the creek to improve flood conveyance, enhance the creek corridor and facilitate routine maintenance.

Since obtaining feedback from WRAB and the public, staff and the engineering consultants have worked towards refining the alternatives and also formulating the benefit cost analysis for each improvement. Site walks were conducted with additional maintenance and engineering staff including stormwater management, drainage maintenance, flood control and transportation maintenance to obtain their feedback about the potential alternatives.

The alternatives analysis includes an Engineer's Recommended Plan. Staff has thoroughly evaluated this recommended plan and has used it as the basis for the Staff Recommended Plan, which includes some additional enhancements, mitigation opportunities and maintenance considerations. Input from the public and WRAB has also been considered and incorporated into the Staff Recommended Plan.

ANALYSIS

The city has retained CH2MHill to evaluate potential alternatives to help mitigate future flooding along Gregory Canyon Creek. CH2MHill's Alternative Analysis Memorandum ("Analysis") is included in Appendix A of the *Draft* Flood Mitigation Plan (**Attachment A**). This Analysis contains a detailed description of the data and models used to determine the improvements which would help flood conveyance along Gregory Canyon Creek. The intent of the Analysis was to identify various types of improvements which could be constructed along the creek corridor, assess the costs and benefits associated with each improvement, and include an engineer's recommendation.

Currently, the Gregory Canyon Creek channel does not have adequate capacity to contain a 10-year event. Flood mitigation plans are typically developed with the intent to adequately convey a 100-year storm event. Due to the existing residential development, channel mitigation to convey a 100–year event would not be feasible unless many of the existing homes along the creek corridor were removed. Under the Analysis, it was determined that improvements along the creek could be constructed which would facilitate flows from a 10-year event.

Since the topographical and development constraints along Gregory Canyon Creek prevent modification which would convey flows that are greater than a 10-year event, it was recognized that the streets in the neighborhoods could be modified to better convey floodwaters in larger events. During the September 2013 event, floodwaters were observed in various roadways, with primary conveyance paths being 6th Street, 7th Street and 8th Street. Thus, street improvements have been considered which would direct and retain additional water within the streets.

Areas for detention and sediment traps were also evaluated, as well as opportunities for the acquisition of properties within the designated High Hazard Zone.

Channel and Culvert Improvements

These improvements include channel maintenance, brush and debris clearing, replacements and improvements to culvert crossings and creek channel modifications. The proposed culvert improvements are predominantly within city ROW, but most would

also require creek channel work on private property in order to accommodate the larger culvert sizes. Three private culverts were also included in this analysis. Each culvert was evaluated for existing conditions, the size required to convey a 10-year event, and the maximum size that could feasibly be constructed without impacting existing buildings.

Improvements Outside of the Channel

The Analysis includes street conveyance improvements proposed along 6th Street, 7th Street and 8th Street as well as on Willowbrook Rd. at the more southerly area of the stream reach (i.e. in close proximity to Flagstaff Road). Segments of these streets already convey 50-year flows. Thus, the improvements considered are to segments which do not adequately convey a 50-year flow under current conditions.

Detention

An evaluation of detention along Gregory Canyon Creek was performed to identify possible areas where detention facilities could help improve flows by attenuation or other means. The following areas were reviewed for potential detention:

- Immediately upstream of Flagstaff Rd.
- Smith Park
- Flatirons Elementary School

More detail about these proposed detention areas is included in the Analysis. Detention is not a recommendation due to the limited benefit.

Acquisition of High Hazard Properties

The city's property acquisition program, in conjunction with flood mitigation improvements has been very successful over the years and has resulted in 134 of 279 identified high hazard structures being removed from the high hazard floodplain. As a part of mitigation along Gregory Canyon Creek, the city should consider purchasing certain properties in the high hazard zone. Removing structures in the high hazard zone would allow for additional channel improvements in selected areas. Opportunity-based property acquisition is a key element of the floodplain management program given the city's interest in working with a willing seller.

In 2012, 810 Marine St., which is located along Gregory Canyon Creek, was purchased by the city and the structure was removed. Along this creek, there are 32 structures located in the high hazard zone. Through this flood mitigation planning effort, the city has identified several properties in the high hazard zone along Gregory Canyon Creek which should be prioritized for purchase. There properties are along the downstream section of Gregory Canyon Creek, in close proximity to each other and to the recently purchased 810 Marine St. property, and therefore could facilitate a more consolidated and comprehensive flood mitigation planning effort.

Other Improvements

Additionally, areas for sediment traps and habitat improvements were evaluated as well as opportunities to implement other improvements based on public input and observations from the 2013 Flood, such as a sanitary sewer main relocation and additional drainage inlets and possible grates.

BENEFIT COST ANALYSIS

The Analysis includes a detailed description of the methodologies used to determine the benefit cost ratio associated with the improvements. CH2M Hill, the consultants for this mitigation study, followed FEMA requirements for developing the benefit cost analysis (BCA). The following table summarizes the results of the BCA, which is explained in further detail in Appendix A of the *Draft* Flood Mitigation Plan (**Attachment A)**:

Benefit Cost Analysis Summary

Alternative	Benefit Cost Ratio
10-year culvert improvements	2.67
10-year culvert improvements with street conveyance improvements	1.52
Maximum size culvert improvements	1.78
Maximum size culvert improvements with street conveyance improvements	1.28

ENGINEER'S RECOMMENDED PLAN

The Engineer's Recommended Plan (ERP) to minimize the identified flooding issues along Gregory Canyon Creek is the 10-year alternative without roadway improvements. This recommendation is based on feedback from public meetings, project stakeholders, staff input and preliminary discussions with WRAB. The ERP focuses on alleviating flooding along Gregory Canyon Creek, without affecting adjacent structures and minimizing the amount of right-of-way used while providing the greatest level of service throughout the corridor in the most cost effective way possible. The recommended improvements will provide additional protection from more frequent flooding events, but will not eliminate the 100-year flood hazards. The Engineer's Recommended Plan does not include any street improvements, because they were not determined to be a cost effective option.

The ERP has a benefit-cost ratio of 2.67. This means that the city's investment in infrastructure to address flooding generates a favorable return by reducing the average annual flood damages by a factor of 2.67 over the investment cost. The improvements recommended under the ERP will have impacts on private property and in most areas, will require easements. Thus, moving forward with any of the culvert or channel improvements will necessitate obtaining easements from these property owners. Roadway improvements were not included in the ERP because they did not have as favorable of a benefit to cost ratio.

STAFF'S RECOMMENDED PLAN

Based on the Engineer's Recommended Plan, public input, input from WRAB, and a thorough analysis of the improvements proposed, Staff has developed a Staff Recommended Plan which is depicted in Section 6 of the *Draft* Flood Mitigation Plan (**Attachment A**).

The Staff Recommended Plan includes the 10-year culvert improvements included in the ERP, but modifies some of the recommendations for channel improvements, eliminating

some of the improvements between Euclid and College and including continuous channel improvements between University and Arapahoe. The Staff Recommended plan also includes roadway improvements, recommending that they be incorporated with future roadway construction projects in order to be more cost effective. In addition, a pedestrian bridge is recommended at Pennsylvania Ave. instead of a box culvert and a vehicular bridge is recommended at the entrance to the Highland School property. The Staff Recommended Plan also includes sediment traps, habitat improvements, piping a section of the Anderson Ditch, a sanitary sewer relocation, new drainage inlets, possible grates installed over culverts, a prioritization for property acquisition and non-structural methods such as emergency warning systems, flood education and private property flood protection. The Staff Recommended Plan is summarized in the following table:

Recommendation	Cost
1. Culvert Replacement: Replace culverts where needed to convey the 10-year storm. Provide a pedestrian bridge at Pennsylvania Ave. and a vehicular bridge at the Highland School entrance.	$4,692,167
2. Channel Improvements: Increase channel capacity in select locations to convey the 10-year storm and as needed to accommodate new culverts and bridges. Investigate modifications to the channel alignment in select locations to reduce the flood damage risk.	$353,502
3. Road Improvements: Implement flood conveyance modifications in conjunction with other roadway construction.	$2,082,217
4. Provide sediment traps at the following locations:	
a. Upstream of Culvert C1 (Willowbrook Rd.)	$46,527
b. Upstream of Culvert C6 (7th St. across from Flatirons School)	$80,677
c. Smith Park	$63,766
5. Assess stream and riparian areas and identify habitat improvements	TBD
6. Pipe the Anderson Ditch to the east of 7th St.	$23,450
7. Relocate the sanitary sewer manhole and pipes currently located within the "Gregory Gulch".	$164,597
8. Add new storm drainage inlets on Willowbrook Rd. to help capture floodwaters that overtop the culvert	$147,550
9. Investigate installing grates above culverts	TBD
10. Property Acquisition: Continue acquiring high hazard zone properties, focusing on the properties identified as priority structures.	$6,354,700
11. Non-Structural Methods: Continue to implement non-structural measures and encourage property owners to prepare for floods and protect their properties and themselves.	N/A
Total:	**$14,009,153**

Note: Items marked TBD (To Be Determined) have variable scope or costs and therefore will need to be evaluated as the opportunities to incorporate the improvements are identified.

The *Draft* Flood Mitigation Plan (**Attachment A**) was prepared based on the Analysis and recommendations noted above. Section 5 of the *Draft* Flood Mitigation Plan includes a discussion about each culvert, including the existing size and conveyance

capacity, along with the size needed to convey the 10-year storm, the maximum sized culvert which could be installed, required channel grading associated with the culvert replacement options, estimated construction costs and a recommendation for replacement.

The Final Mitigation Plan will include conceptual design drawings and a prioritization for the proposed improvements.

NEXT STEPS

Following input from WRAB and a recommendation for the mitigation plan, conceptual drawings will be developed and the mitigation plan will be finalized. The Final Mitigation Plan will be presented to City Council for acceptance. Projects will then be selected and programmed into the CIP for implementation.

ATTACHMENTS

Attachment A: *Draft* Flood Mitigation Plan
Attachment B: WRAB Meeting Minutes 10/20/2014

Gregory Canyon Creek

Draft Flood Mitigation Plan

April 20, 2015

Project Sponsors

Executive Summary 1
Purpose and Objective 1
Project Area Description 1
Alternative Analysis 1
Recommended Plan 2
Section 1–Introduction 2
Planning Process 2
Mapping and Surveys 3
Data Collection 3
Acknowledgements 3
Section 2–Study Area Description 4
Project Area 4
Soils 5
Land Use 6
Flood History 8
Environmental Assessment 9
Previous Studies and Master Plans 9
Section 3-Hydrologic Analysis 12
Previous Studies 12
Summary of Peak Discharges 12
Section 4-Hydraulic Analysis 13
Evaluation of Existing Facilities 13
Flood Hazards 14
Section 5-Alternative Analysis 15
Alternative Development Process 15
Alternative Categories 15
Alternative Costs 29
Alternative Plans 29
Qualitative Evaluation Procedure 33
Section 6-Recommended Plan 34
Plan Description 34
Section 7-Conceptual Design 39
Section 8-References 39
Appendices 39
Appendix A-Alternative Analysis Memorandum 39
Appendix B-Public Comments 39
Appendix C-Wetland and Habitat Evaluations 39
Appendix D-Conceptual Design Drawings 39

Executive Summary

Purpose and Objective

The purpose of this study is to analyze the existing drainage conditions within the Gregory Canyon Creek floodplain, develop alternative drainageway planning concepts to mitigate flood damages, and prepare a preliminary design of the recommended flood mitigation plan selected by the Project Sponsors.

The information in this plan will support the City of Boulder and others in the prioritization and implementation of improvements to reduce potential damages due to flooding. It will also be beneficial in completing grant applications and securing funding for future projects.

Project Area Description

The study area, shown on the Vicinity Map, extends from the confluence of Gregory Canyon Creek and Boulder Creek to the upstream city limits just south of Flagstaff Road. The study is located in part of Section 36, Township 1 North, Range 71 West, and a small part of Section 1 Township 1 South, Range 71 West.

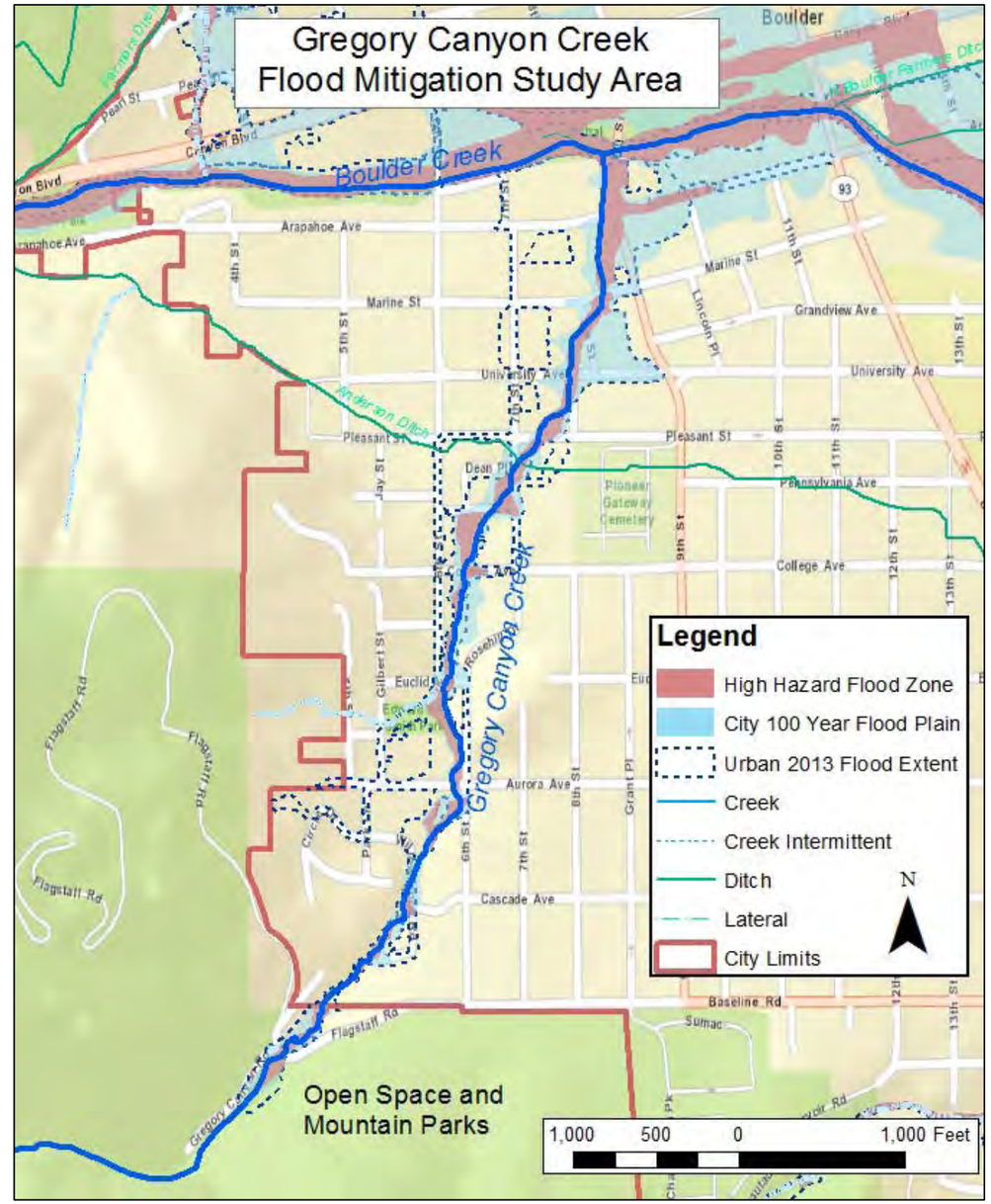
Alternative Analysis

The city retained CH2MHill to evaluate potential alternatives to help alleviate future flooding along Gregory Canyon Creek. CH2MHill's Alternative Analysis Memorandum is included as **Appendix A**. This analysis contains a detailed description of the data and models used to determine the improvements which would help flood conveyance along Gregory Canyon Creek. The intent of the analysis was to identify various types of improvements which could be constructed along the creek corridor, assess the costs and benefits associated with each improvement, and include an engineer's recommendation.

The alternatives analysis also includes a benefit cost analysis (BCA) along with a detailed description of the methodologies used to determine the benefit cost ratios associated with the improvements. The following table summarizes the results of the BCA:

Benefit Cost Analysis Summary

Alternative	*Benefit Cost Ratio*
10-year culvert improvements	2.67
10-year culvert improvements with street conveyance improvements	1.52
Maximum size culvert improvements	1.78
Maximum size culvert improvements with street conveyance improvements	1.28



Vicinity Map

Recommended Plan

The Recommended Plan is depicted in **Section 6** and includes the following elements:

Recommendation	Cost
1. Culvert Replacement: Replace culverts where needed to convey the 10-year storm. Provide a pedestrian bridge at Pennsylvania Ave. and a vehicular bridge at the Highland School entrance.	$4,692,167
2. Channel Improvements: Increase channel capacity in select locations to convey the 10-year storm and as needed to accommodate new culverts and bridges. Investigate modifications to the channel alignment in select locations to reduce the flood damage risk.	$353,502
3. Road Improvements: Implement flood conveyance modifications in conjunction with other roadway construction.	$2,082,217
4. Provide sediment traps at the following locations:	
a. Upstream of Culvert C1 (Willowbrook Rd.)	$46,527
b. Upstream of Culvert C6 (7th St. across from Flatirons School)	$80,677
c. Smith Park	$63,766
5. Assess stream and riparian areas and identify habitat improvements	TBD
6. Pipe the Anderson Ditch to the east of 7th St.	$23,450
7. Relocate the sanitary sewer manhole and pipes currently located within the "Gregory Gulch".	$164,597
8. Add new storm drainage inlets on Willowbrook Rd. to help capture floodwaters that overtop the culvert	$147,550
9. Investigate installing grates above culverts	TBD
10. Property Acquisition: Continue acquiring high hazard zone properties, focusing on the properties identified as priority structures.	$6,354,700
11. Non-Structural Methods: Continue to implement non-structural measures and encourage property owners to prepare for floods and protect their properties and themselves.	N/A
Total:	**$14,009,153**

Section 1–Introduction

Planning Process

Following the September 2013 Flood, an open house was held on October 14, 2013. Public comments about the extent of the floodwaters and the damages sustained were received at this meeting. The community expressed a strong desire for flood mitigation improvements along Gregory Canyon Creek, so this mitigation plan was initiated by the City of Boulder and the Urban Drainage and Flood Control District.

The engineering consultant team, CH2M Hill, was selected to help with the development of the flood mitigation alternatives and mitigation plan. An open house to officially "kick-off" the flood mitigation planning process was held on June 12, 2014. The purpose of this public open house was to identify problem areas and collect ideas for future flood mitigation projects.

After reviewing previous studies, master plans and policies, flood mitigation alternatives were developed and assessed. Due to the existing development along the creek, it was determined that improvements to accommodate a 100-year flood event would not be feasible, but improvements along the creek could be constructed which would facilitate flows from a 10-year event. Improvements to culverts that could convey events greater than a 10-year event were also assessed. Each culvert was evaluated for existing conditions, the size required to convey a 10-year event, and the maximum size that could feasibly be constructed without impacting existing buildings. The primary categories of alternatives initially evaluated included:

- Improvements along the creek channel
- Improvements outside of the creek channel (roadway conveyance)
- Property acquisition
- Detention facilities

On October 20, 2014, a third public open house was held to present the potential alternatives, or categories of improvements, that had been developed. On that same day, the first public meeting with the Water Resources Advisory Board (WRAB) was held. Comments received at the open house and the WRAB meeting were assimilated and the mitigation plan was further refined based on these comments, where feasible and practical. The WRAB recommended that city staff facilitate the organization of smaller neighborhood groups to help identify and discuss mitigation options for more localized areas of the creek.

In February of 2015, staff conducted three site walks along the Gregory Creek Drainage. The first of these walks included city staff from the Stormwater, Road Maintenance and Drainageway Maintenance departments. Two walks with residents in the area were then conducted in order to obtain their feedback and suggestions related to the proposed alternatives. The comments received from city staff and residents were assimilated and reviewed and then submitted to the consultants to incorporate suggestions, where feasible.

A benefit cost analysis was performed to analyze the alternatives. The following four primary alternatives were analyzed:

- 10-year culvert improvements
- 10-year culvert improvements with street conveyance improvements
- Maximum size culvert improvements
- Maximum size culvert improvements with street conveyance improvements

An Engineer's Recommended Plan was developed by CH2M HILL based on the benefit cost analysis, feedback from public meetings, project stakeholders, staff input and preliminary discussions with WRAB. The Engineer's Recommended Plan to minimize the identified flooding issues along Gregory Canyon Creek includes improvements that would accommodate a 10-year storm event. The complete Alternative Analysis Memorandum with the Engineer's Recommended Plan is included in **Appendix A**.

City of Boulder staff assessed the Engineer's Recommended Plan and developed a Staff Recommended Plan, incorporating input from the public, maintenance considerations and observations from the 2013 flood event. The Staff Recommended Plan includes the 10-year culvert improvements included in the Engineer's Recommended Plan, but modifies some of the recommendations for channel improvements, eliminating some of the improvements between Euclid and College and including continuous channel improvements between University and Arapahoe. The Staff Recommended plan also includes roadway improvements, recommending that they be incorporated with future roadway construction projects in order to be more cost effective. In addition, a pedestrian bridge is recommended at Pennsylvania Ave. instead of a box culvert and a vehicular bridge is recommended at the entrance to the Highland School property. The Staff Recommended Plan also includes sediment traps, habitat improvements, piping a section of the Anderson Ditch, a sanitary sewer relocation, new drainage inlets, possible grates installed over culverts, a prioritization for property acquisition and non-structural methods such as emergency warning systems, flood education and private property flood protection. The Staff Recommended Plan is included in **Section 6**.

An open house was held on March 30, 2015 to present the alternatives, the Engineer's Recommended Plan and a draft of Staff's Recommended Plan. Feedback from the open house was used to refine the staff recommendations. A compilation of public comments is included in **Appendix B**.

The Staff Recommended Plan is being presented to the WRAB on April 27, 2015.

Mapping and Surveys

Elevation data for the Study Area was provided by the City of Boulder. The topographic mapping included 2013 Light Detection and Ranging (LiDAR) data that was sponsored by FEMA and collected after the September 2013 flood event. In addition, survey collected as part of previous hydraulic studies or as-built construction drawings was also incorporated in the analysis. No new mapping or survey was performed as part of this analysis.

Data Collection

In addition to GIS data and other City resources, recent studies were analyzed during the process of developing this mitigation plan. The following is a list of these studies:

- *Major Drainageway Planning Study - Boulder and Adjacent County Drainageways "Phase A",* Greenhorne and O'Mara, 1984.
- *Major Drainageway Planning Study - Boulder and Adjacent County Drainageways "Phase B"*, Greenhorne and O'Mara, 1987.
- *Flood Hazard Area Delineation Boulder and Adjacent County Drainageways* Greenhorne and O'Mara, 1987
- *Hydraulic Mitigation Analysis - Gregory Canyon Creek High Hazard Zone Reanalysis – Mini - Master Plan,* Belt Collins West, 2009.
- *LOMR Determination - Gregory Canyon Creek LOMR Determination Data Reconciliation (Approved by FEMA, 2010)*, Belt Collins West, 2010.
- *Hydraulic Mitigation Analysis - Gregory Canyon Creek Mitigation Analysis,* WH Pacific, 2012.
- *Alternative Analysis - Pennsylvania Avenue Flood Repair / Improvement Alternative Analysis,* City of Boulder, 2014.

Acknowledgements

This report was completed with the support and input from various individuals at the City of Boulder, the Urban Drainage and Flood Control District (UDFCD) and CH2M HILL. The key participants in the development of this memorandum are shown in the following table:

Project Contributors

Project Team Members	Affiliation	Role
Katie Knapp	City of Boulder	Project Manager
Annie Noble	City of Boulder	Flood and Greenways Engineering Coordinator
Kristin Dean	City of Boulder	Utilities Planner
Christin Shephard	City of Boulder	Civil Engineer I / GIS Analyst
Shea Thomas	UDFCD	Sr. Project Engineer
Alan Turner	CH2M HILL	Project Manager
Morgan Lynch	CH2M HILL	Project Engineer
Frans Lambrechtsen	CH2M HILL	Staff Engineer

Section 2–Study Area Description

Project Area

Gregory Canyon Creek originates in City of Boulder Open Space. From the city limits at Flagstaff Road to its confluence with Boulder Creek, Gregory Canyon Creek is approximately 1.8 miles in length and ranges in elevation from approximately 5727 feet to 5360 feet USGS. The watershed associated with this creek is approximately 1.9 square miles.

The upper part of the watershed is south of the city limits. Upslope areas are covered with a variety of rock outcroppings, thick residual soils on bedrock, and thicker debris, alluvium, and slope wash deposits that are vegetated with grasses, trees, and shrubs. Deeper soils and wetland vegetation are found on alluvial deposits adjacent to streams. A well-defined channel is visible upstream of Flagstaff Road. The Gregory Canyon trail is located along this section of the creek.

Gregory Canyon Creek Upstream of City Limits

Within the city limits, the creek generally flows to the northeast through developed neighborhoods, crossing both public and private land. Throughout this area, the creek is mostly confined in narrow channels, due to fairly dense residential development, and conveyed under streets through culverts.

Gregory Canyon Creek North of University Ave.

Residential development along Gregory Canyon Creek began as early as 1890 in areas closer to the center of the city and peaked between the 1950's and 1960's as development moved closer to Baseline Rd. Development has altered historic channels, stormwater flow paths, runoff characteristics, and surface water quality. Most of the development within the Gregory Canyon Creek floodplain occurred prior to the city's adoption of floodplain regulations and drainage system requirements, and therefore does not conform to current development standards. There are currently only a few drainage and flood control easements across the private properties located along this creek.

Soils

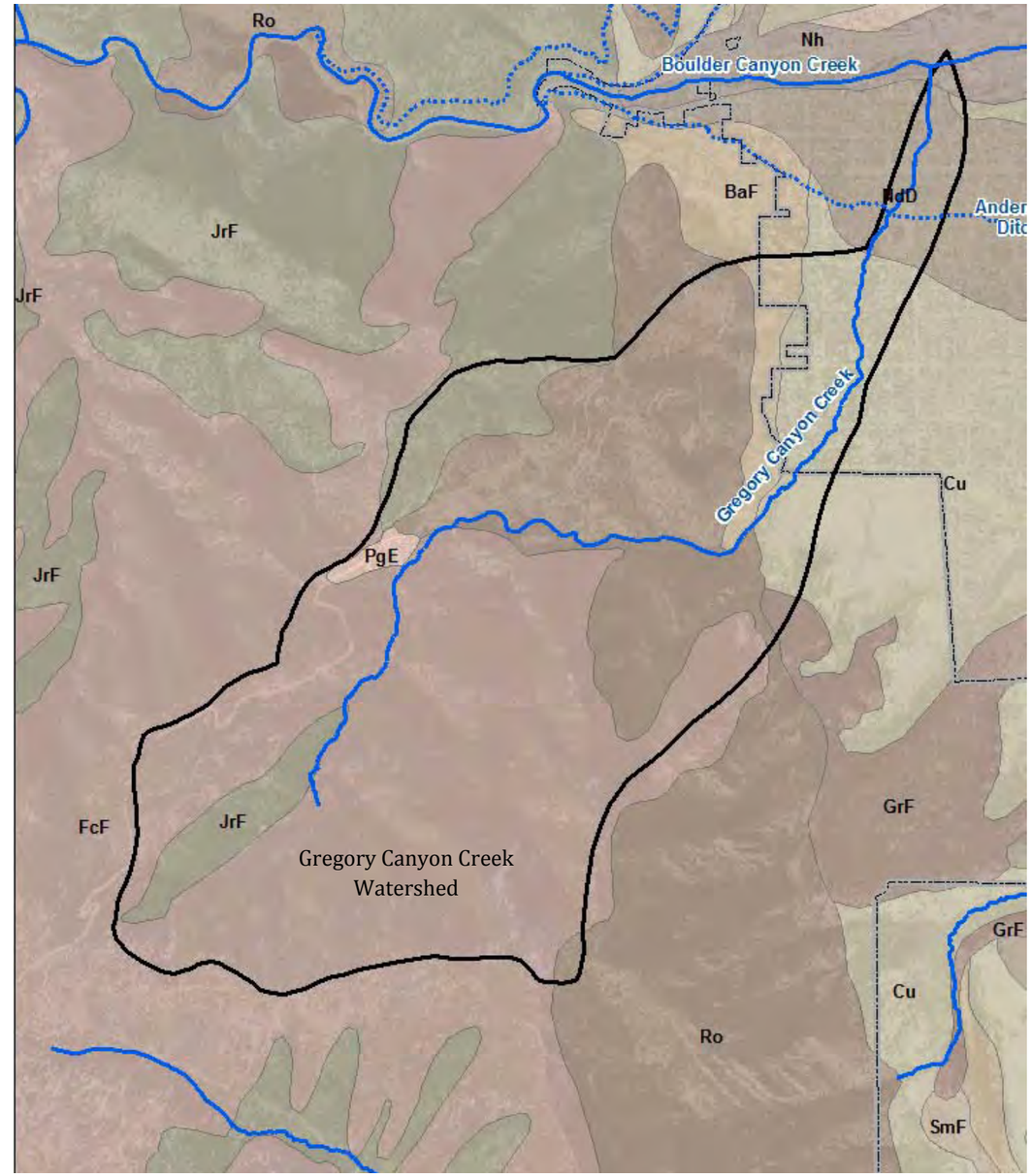
According to the Soil Survey of Boulder County Area, Colorado (United States Department of Agriculture Soil Conservation Service in cooperation with Colorado Agriculture Experiment Station (1975)), the land within the Gregory Canyon Creek watershed is comprised of the following soil classifications: Fern Cliff-Allens Park-Rock Outcrop Complex (FcF), Juget-Rock Outcrop Complex (JrF), Rock Outcrop (Ro), Payton-Juget (PgE), Godvale Rock Outcrop Complex (Gfr), Colluvial Land (Cu), Baller Stony Sandy Loam (BaF), Nederland Series (NdD), and the Niwot Series (Nh).

The upper portion of the watershed is predominantly Fern Cliff-Allens Park-Rock Outcrop Complex (FcF) and Juget-Rock outcrop complex(Jrf). These soils, consist of stony sandy loam, gravely sandy loam and rock outcrops on mountain side slopes. The runoff potential is medium to rapid and the erosion potential is high.

The central part of the watershed contains Rock Outcrop (Ro), Payton-Juget (PgE), and Godvale Rock Outcrop Complex (Gfr). Steep rock outcrops with exposed bedrock dominate. Pockets of gravely, loamy sand allow roots to penetrate to depths of 40 to 60 inches or more. These areas provide prime habitat for wildlife.

Further down in the watershed, where Gregory Canyon Creek crosses Flagstaff Road, Colluvial Land (Cu) is the predominant soil type until transitioning into the NdD soils at the Columbia Cemetery and Flatirons School. Cu soils vary widely in depth, texture, color, and stoniness due to the runoff from adjacent slopes that these lands receive. Most area of Colluvial land have stones and cobbles on the surface. The erosion hazard associated with Cu soils is high. The Nederland series (NdN) is made up of deep, well-drained soils that formed on old high terraces and alluvial fans. The soils developed on loamy alluvium that contains many cobblestones and other stones. These soils have moderate permeability and roots can penetrate to a depth of 60 inches or more. These areas have many stones and cobblestones on the surface. Runoff is slow to medium on this soil and the hazard is slight. A band of Baller Stony Sandy Loam (BaF) exists along the western city limits in the lower watershed. These soils are shallow and well drained with rapid permeability, high erosion hazard and rapid runoff potential

Niwot Series (Nh) soils are located at the confluence with Boulder Creek. The Niwot series is made up of deep, somewhat poorly drained soils that are shallow over gravelly sand. These soils formed on low terraces and bottom lands in loam alluvium. Niwot soils have moderate permeability. Roots can penetrate to a depth of 60 inches or more and the seasonal high water table is at a depth of between 6 and 18 inches. Niwot soils are typically found on stream terraces and bottoms. Runoff is slow on these soils and the erosion hazard is slight except for back cutting near channels. Because of their position in the landscape, these soils are frequently flooded and have seasonal high water table.



Soils Map

Land Use

Upstream of the city limits, the lands within the Gregory Canyon Creek watershed have been preserved as city Open Space. Within the city limits, the majority of the property within the watershed is comprised of low density, residential zoning districts (RE and RL-1). Density intensifies at approximately 6th St. and Marine where property is zoned RMX-1 (Residential-Mixed 1). The land areas zoned Public (P) contain the Columbia Cemetery and the East Senior Center.

Gregory Canyon Creek
Watershed

Zoning Map

Notable landmarks within the watershed include the Highlands School, Hannah Barker House, Columbia Cemetery, Anderson Ditch, Flatirons Elementary School, and Smith Park.

Highlands School

Built in 1891, the Highlands School (885 Arapahoe Ave.) was Boulder's fourth permanent school. Situated at the confluence of Gregory Canyon Creek and Boulder Creek, the school was constructed on an elevated area to protect it from flooding. During the 100-year flood of 1894, the school was unscathed while much of the town was substantially damaged. The school closed in the 1960's due to the opening of numerous other schools in the Boulder Valley School District. The school was placed on the National Register of Historic Places in December of 1978. That same year, the new owners set a course to restore and preserve the exterior while creating a luxurious interior space. The building is now home to high-end offices and the Highland City Club.

Highlands School

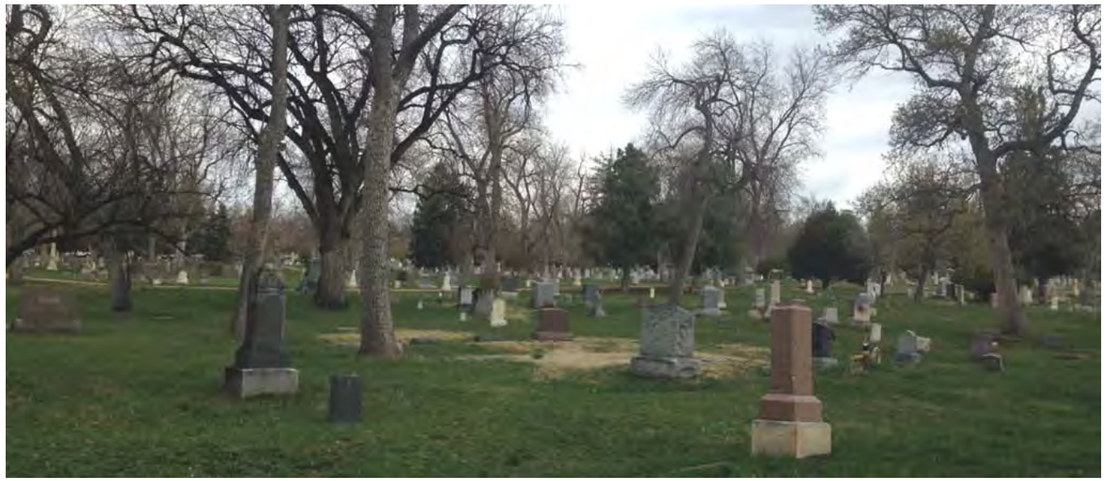
Hannah Barker House

One of the oldest buildings in Boulder, the Hannah Barker House, is located across the street from the historic Highlands School at 800 Arapahoe Ave. The house was originally built in 1875 by Caleb and Carrie Stowell, and is historically significant because of its association with Hannah Connell Barker, a prominent pioneer woman, civic leader, philanthropist and business woman. She was also one of the first female teachers in Boulder. The house is currently being restored by Historic Boulder, Inc., who purchased the property in 2010.

Hannah Barker House

Columbia Cemetery

Columbia Cemetery is located west of 9th St. between Pleasant St. and College Ave. The ten-acre tract of land was bought in 1870 by the Columbia Lodge #14 A.F. & A.M. ("Ancient Free and Accepted Masons") from Marinus G. Smith and his wife, Anna. Marinus Smith was also instrumental in constructing the Anderson Ditch which flows through the northerly portion of the cemetery. After many years of financial difficulty and various owners, the cemetery became the responsibility of the City of Boulder Parks and Recreation Department in 1966. The cemetery was placed on the National Register of Historic Places in 1997. Today, approximately 6,500 people are interred in the cemetery.



Columbia Cemetery

The Anderson Ditch

In 1860, Jonas Anderson and Marinus Smith dug the Anderson Ditch, which diverted water from Boulder Creek and then wound through the neighborhoods west of Broadway, over University Hill, and past Green Mountain Cemetery. Anderson and Smith were instrumental in bringing the university to Boulder and raised more than $16,000 in 1876 for this endeavor. This was the same year that that territory of Colorado became a state. Today, one-third of the Anderson Ditch rights are owned by CU Boulder and almost all of the remaining two-thirds are owned by the City of Boulder.

Anderson Ditch at 7th St.

Flatirons Elementary School

Flatirons Elementary School is located at 1150 7th St. on a 4.26 acre parcel bordered to the east by Columbia Cemetery, to the west by 7th St., to the south by College Ave. and to the north by Pleasant St. The Anderson Ditch runs along with northerly edge of the school property and Gregory Canyon Creek is to the west, on the opposite side of 7th St. Aside from the cemetery, the school is surrounded by single-family homes. The school was first constructed in 1956 and is a 43,857 square foot facility. The school has classes for students in kindergarten through 5th grade.

Flatirons Elementary School

Smith Park

Smith Park is a 1.12 acre neighborhood park located on the east side of Gilbert St. This land was donated to the City of Boulder in 1963 by Mildred Cromley Smith as a memorial for her late husband, Edward Sell Smith, for whom the park was later named. The park includes a small play structure, picnic tables and seating areas. Natural areas surround the park providing areas for wildlife. An unnamed tributary stream flows through the park and joins Gregory Canyon Creek immediately downstream of the park.

Smith Park

Flood History

Boulder is highly susceptible to flash flooding because it sits near the mouths of canyons in the foothills. In 1894, damaging floods were experienced in late May, during the time of spring runoff, when a heavy and constant spring rain was pinned against the western mountains by an upslope wind condition, dropping 5 to 8.54 inches of rain during that period (Floods in Boulder County, Colorado, A Historical Investigation; Sherry D. Oaks; 1982). During this event, the crest of the water on Sixth Street reached twelve feet and nearly every bridge along Boulder Creek was washed out. Historical accounts of the 1894 flood attribute flood damage near the Highlands School to Gregory Creek, which had also caused significant damage to homes and property many upstream locations. It is estimated that discharge in Boulder Creek was between 12,000 and 13,600 cfs during this event.

Significant flooding has also occurred in Boulder in 1896, 1906, 1909, 1916, 1921, 1938, 1969, and most recently, in September of 2013. Peak discharges during the major flood events have ranged from 2,500 cfs to 13,000 cfs, and most of the storms occurred in either May or June. Flooding in Boulder County typically occurs as a result of snowmelt combined with heavy spring rainfall. However, record setting rains were widespread across Boulder from Sept. 9 to 13, 2013 due to a moist tropical air mass from the Gulf of Mexico that was displaced into the region by air coming in from the south. An upper-level high-pressure system locked this storm against the mountains to the west, and rain fell for about a week. 17.6 inches of rain fell over a three day period, making 2013 the wettest year on record in Boulder.

During the September 2013 event, NOAA/NWS reported that 'worst case' 24-hour, 72-hour, and 7 day precipitation totals in many parts of the Boulder Creek watershed had annual exceedance probabilities on the order of 1/1,000 (0.1 percent), which is a 1,000-year rainfall event. The precipitation lasted from September 9 to September 15, 2013, with the most intense rainfall in the watershed occurring on September 11 and 13, when more than 6 inches of rain fell over a 24-hour period in many locations, including downtown Boulder (A September to Remember; Urban Drainage and Flood Control District, 2014).

During the 2013 storm, channels and culverts along Gregory Canyon Creek were filled with rocks and debris which had been transported from erosion in the steep, mountainous portions of the watershed, thus significantly reducing the conveyance capacity. Due to the undersized main channel and the plugged culverts, the streets served as the major drainage flow paths for Gregory Canyon Creek.

Street flooding at 7th St. and Arapahoe Ave., Sept. 2013

Sept. 2013 Approximate Flooding Extents

According to A September to Remember, "…the maximum 24-hour rainfall was approximately 8 inches within the Gregory Canyon Creek watershed. The rainfall was greater in the lower part of the watershed, with a maximum 24-hour rainfall return period between 500 and 1,000 years. There are no stream gages on Gregory Canyon Creek, so a peak flow was not estimated…Damages to property and transportation and drainage infrastructure in the watershed were severe…Gregory Canyon Creek dramatically demonstrated the urban drainage principle that every urban area has an initial and major drainage system whether or not actually planned and designed".

Wright Water Engineers prepared a "Rainfall-Runoff Analysis for the September 2013 Flood in the City of Boulder, Colorado", which was publicly released in Sept. of 2014. According to this study, during the 2013 flood, precipitation depths and intensities generally increased from west to east with total rainfall from Sept. 11-13 ranging 9.8 inches to 10.3 inches. It is estimated that the rainfall return periods the Gregory Canyon Creek drainage way ranged from a 40-50 year event for the worst case 2-hour duration. However, according to the Wright Water report, while the short-duration intensities reported are lower than those assumed in the 100-year design storm, "the rocky soils and shallow bedrock in the upper sub-watersheds limit infiltration, and intense periods of rainfall later in the event, when soils were saturated, produced significant runoff and debris flows." Because of the significant amount of rocks, sediment and debris blocking the culverts along Gregory Canyon Creek, the extent of flooding in September 2013 was beyond what would be normally mapped for a 25-50-year "clear water" flood.

To determine runoff during the September 2013 event, Wright Water analyzed the city's inundation mapping. According to the inundation maps, the runoff during the event was generally contained with the 100-year floodplain boundary, with the following notable exceptions:

- The culvert at Willowbrook Rd. was clogged with debris, causing floodwaters to run down the roadway and "Gregory Gulch" to Aurora St.
- Smith Park, which is outside of the 100-year floodplain saw flooding due to the flood flows along the unnamed tributary that crosses Gilbert St. and flows through the park.
- West of the intersection of Aurora and 6th St., hillside flows ran down Aurora Ave., Circle Dr. and Park Lane.
- At the intersection of College Ave. and 6th St., flood waters went north along 6th St. and then turned east and flowed along Pleasant St.
- Downstream of Pleasant St., flood waters continued north down 7th St. to Boulder Creek and spread throughout the area between 7th St. and 9th St.

The Anderson Ditch also runs across the Gregory Canyon Creek watershed and may have also contributed to the widespread flooding along Gregory Canyon Creek downstream of Pleasant St.

Along the creek, many culverts became partially or mostly clogged with rocks, sediment, and debris which forced the floodwaters to leave the stream banks and flow down the streets. A landslide occurred below Flagstaff Rd. and sent rocks and debris downhill. The storm sewer system and sanitary sewer systems were also overwhelmed due to the flood waters and elevated groundwater.

Damage Analysis from the 2013 Flood

After the September 2013 flood, the city commissioned a study to analyze the source of and amount of damage caused by the flood. The results are a compilation of data obtained via an online survey and also of claims submitted for FEMA for reimbursement. In the Gregory Canyon Creek watershed, it is estimated that the total amount of damages exceeded just over $7,000,000. The primary sources of damage we a result of major drainageway flooding, groundwater infiltration, and local drainage flooding. It is estimated that approximately $1,941,000 in damage was caused in the 100 year floodplain, $2,473,800 in damage was caused in the 500 year floodplain, and the remainder was outside of the designated floodplains.

Environmental Assessment

A survey was completed in 2010 along many of the Boulder Creek tributary reaches to update the aquatic habitat inventory. This inventory found the aquatic habitat along Gregory Canyon Creek to be in fair to poor condition. From Boulder Creek to College Ave., the native plant habitat was evaluated as being poor, but the overall vegetative structure was found to be excellent to good. Bird species richness in this stream reach were determined to be poor to very poor. South of College Ave. to the city limits at Baseline Rd., native plants are considered to be in good condition, with the vegetative structure being very good. Bird species richness is very good to good within this stream reach. The survey data sheet is included in **Appendix C**.

Wetlands

Gregory Creek is a steep, rocky intermittent stream that flows northward along the eastern edge of a Pierre shale bedrock formation and drains into Boulder Creek. According to the city's "Functional Evaluation Summaries for Individual Wetlands", included in **Appendix C**, the wetlands located along Gregory Creek east of Mountain Parks and south of Boulder Creek are characterized by a generally narrow active channel with a fairly steep gradient. Precipitation in the foothills to the west supports seasonal flows in the creek.

The maximum water depth is approximately 1.5 feet. Ninety percent of this wetland is covered by vegetation with five percent comprised of bare ground and five percent in water. The wetland vegetation is fairly dense along the creek and consists of narrowleaf cottonwood and mixed herbaceous trees and shrubs.

The geohydrologic map indicates groundwater recharge or discharge are possible. The effectiveness of the function is limited by impermeable bedrock near the surface, the narrow channel, and intermittent flows.

Previous Studies and Master Plans

The Boulder Valley Comprehensive Plan (BVCP), the Comprehensive Flood and Stormwater Utility Master Plan ("CFS"), the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual and the Greenways Master Plan all contain policies related to floodplain preservation, development, and mitigation. These documents guide flood mitigation master planning. Previous master plans, floodplain mapping studies and mitigation planning documents were also reviewed for this mitigation plan as described below.

Boulder Valley Comprehensive Plan
The following applicable policies are included in the BVCP:

3.19 Preservation of Floodplains
Undeveloped floodplains will be preserved or restored where possible through public land acquisition of high hazard properties, private land dedication and multiple program coordination. Comprehensive planning and management of floodplain lands will promote the preservation of natural and beneficial functions of floodplains whenever possible.

3.20 Flood Management
The city and county will protect the public and property from the impacts of flooding in a timely and cost-effective manner while balancing community interests with public safety needs. The city and county will manage the potential for floods by implementing the following guiding principles: a) Preserve floodplains b) Be prepared for floods c) Help people protect themselves from flood hazards d) Prevent unwise uses and adverse impacts in the floodplain e) Seek to accommodate floods, not control them. The city seeks to manage flood recovery by protecting critical facilities in the 500-year floodplain and implementing multi hazard mitigation and flood response and recovery plans.

3.21 Non-Structural Approach
The city and county will seek to preserve the natural and beneficial functions of floodplains by emphasizing and balancing the use of non-structural measures with structural mitigation. Where drainageway improvements are proposed, a non-structural approach should be applied wherever possible to preserve the natural values of local waterways while balancing private property interests and associated cost to the city.

3.22 Protection of High Hazard Areas
The city will prevent redevelopment of significantly flood-damaged properties in high hazard areas. The city will prepare a plan for property acquisition and other forms of mitigation for flood-damaged and undeveloped land in high hazard flood areas. Undeveloped high hazard flood areas will be retained in their natural state whenever possible. Compatible uses of riparian corridors, such as natural ecosystems, wildlife habitat and wetlands will be encouraged wherever appropriate. Trails or other open recreational facilities may be feasible in certain areas.

3.23 Larger Flooding Events
The city recognizes that floods larger than the 100-year event will occur resulting in greater risks and flood damage that will affect even improvements constructed with standard flood protection measures. The city will seek to better understand the impact of larger flood events and consider necessary floodplain management strategies including the protection of critical facilities.

Comprehensive Flood and Stormwater Utility Master Plan
The CFS contains the following guiding principles for flood management:

1. Preserve Floodplains (Preservation);
2. Be Prepared for Floods (Preparedness);
3. Help People Protect Themselves from Flood Hazards (Education);
4. Prevent Adverse Impacts and Unwise Uses in the Floodplain (Regulation);
5. Seek to Accommodate Floods, Not Control Them (Mitigation).

More detail about each of these guiding principles can be found in Chapter 3 of the CFS. The fifth principal, as listed above, is directly related to mitigation and, in the CFS, more completely states:

- Seek to accommodate floods, not control them through planned and monitored system maintenance, nonstructural flood proofing, opening non-containment corridors, overbank land shaping to train flood waters, and limited structural measures at constrained locations. Possible tools for implementation include:
    - Update mitigation master plans to emphasize nonstructural measures.
    - Re-evaluate mitigation priorities to eliminate bottlenecks, acquire land to avoid channel improvements, provide non-structural overbank grading, target limited flood protection improvements for high hazards, and research alternative mitigation approaches.
    - Assess any need for structural improvements with evaluation of multiple alternatives.
    - Focus on mitigating high hazard locations citywide and give priority to areas of the greatest risk.

Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual
The UDFCD Drainage Criteria Manual contains the following basic policies:

- The major drainageway system shall be capable of conveying water without flooding buildings and shall remain relatively stable during a 100-year flood.
- Public safety is fundamental to the major drainageway system.
- Public acceptance of the major drainageway system depends on a multitude of factors such as public perception of flood protection, channel aesthetics, right-of-way, open space preservation, and channel maintenance.
- Identify areas with potential for recreational use.
- Consider environmental impacts and benefits and examine the advantages and disadvantages.
- Open channels are more desirable than underground conduits in urban areas because they are closer in character to natural drainageways and offer multiple use benefits.
- Consider two-stage channels. In some cases, it may be desirable to balance the 100-year flow between a formal channel and the adjacent floodplain.

Greenways Master Plan
The Greenways Program in the City of Boulder was an outgrowth of the Boulder Creek Corridor Project. It was created on the basis of recognition that stream corridors are a vital link in the larger environmental system and that each stream is a natural and cultural resource. The purpose of the Greenways Program is to extend the stewardship of the City of Boulder to the important riparian areas along the tributaries of Boulder Creek. The objects of the Greenways Program include:

- Protect and restore riparian, floodplain and wetland habitat;
- Enhance water quality;
- Mitigate storm drainage and floods;
- Provide alternative modes of transportation routes or trails for pedestrians and bicyclists;
- Provide recreation opportunities;
- Protect cultural resources.

To date, there have been few improvements along Gregory Canyon Creek which facilitate the Greenways Program purpose and objectives. Considering the narrow channel of the creek and the development constraints, there have been no opportunities to construct pedestrian or bicycle facilities within the city limits along this stream reach. Recreationally, there is a trail that follows this tributary up a fairly steep incline through Chautauqua Park and then beyond and which is located within the Boulder Open Space and Mountain Parks lands. Additionally, Smith Park is located to the west of the main Gregory Canyon Creek Channel, but it has a small tributary that runs through it and which connects to the creek just below Euclid Ave. and 6th St.

Implementation of the recommendations included in this flood mitigation plan will aid in mitigating storm drainage and floods and help to restore riparian, floodplain, and wetland habitat in certain areas along with creek.

Major Drainageway Master Plan

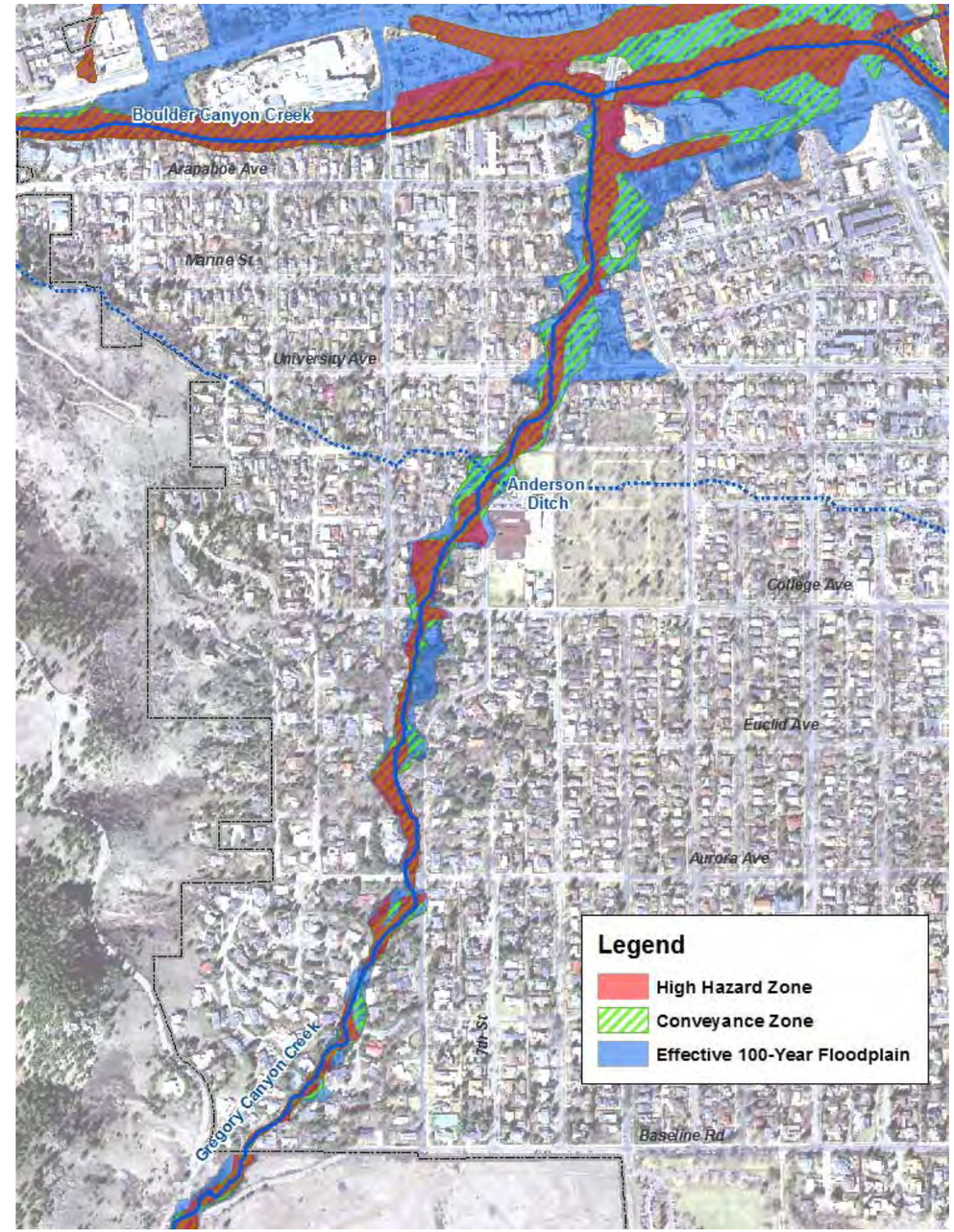
A Major Drainageway Master Plan was developed in 1987 by Greenhorn & O'Mara that identified flood mitigation improvements for Gregory Canyon Creek. Following the Master Plan, the following channel and culvert improvement projects were constructed:

- Culvert replacement at Willowbrook Rd. (1996)
- Channel widening, drop structure installation and rip-rap protection upstream of Aurora Ave. (1995)
- Culvert replacement at Aurora Ave. (1995)
- Culvert replacement at Pleasant St. (1995)
- Channel grading, tree removal and drop structures installed between Pleasant St. and University Ave. (1995)
- Channel grading and drop structure installation between Pennsylvania Ave. and 7th St.

Floodplain Mapping Study

The floodplain maps for Gregory Canyon Creek were updated in 2010 (Belt Collins West, 2010). The updated floodplain mapping established base flood elevations using detailed methods and incorporated improvements and changes along Gregory Canyon Creek. The figure to the right shows the 100-year floodplain, conveyance zone and high hazard zone delineated by the mapping study. The number of structures located in each floodplain zone are shown in the table below:

Flood Zone	Number of Structures
100-year Floodplain	98
Conveyance Zone	63
High Hazard Zone	32

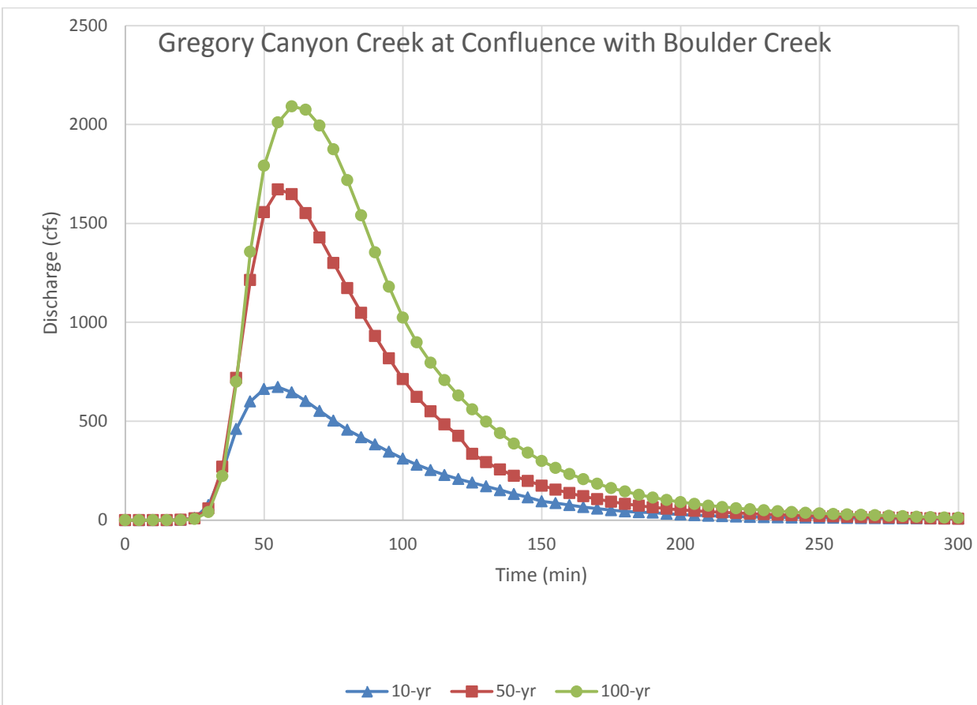


Floodplain Map

Gregory Canyon Creek Mitigation Studies

During the floodplain mapping analysis in 2010, several properties were newly identified as being within the high hazard flood zone. Prior to the adoption of the floodplain maps, a Mini-Master Plan was conducted to investigate the feasibility of mitigation options to remove the newly identified high hazard zone properties from the high hazard zone. None of the proposed projects identified in the Mini-Master Plan were implemented because the benefit to cost ratios did not justify moving forward and funding was allocated to other projects.

A Mitigation Analysis was conducted in 2012 to further investigate improvement options to remove structures from the high hazard zone. This analysis focused solely on high hazard zone modifications and did not assess improvements to reduce flood damages from more frequent storm events. The analysis did not identify any improvements that would be financially feasible compared to the benefits of the proposed work and concluded that purchasing properties, deconstructing structures and converting property to open space would be the best policy for flood mitigation along Gregory Canyon Creek.



Section 3-Hydrologic Analysis

A hydrologic analysis was not performed as part of this master plan. The information used in this master plan was derived from the previous hydrologic analysis performed for Gregory Canyon Creek. To date, one report has been published documenting the hydrology of Gregory Canyon Creek. The hydrologic study is described in detail in the following subsections and is referenced in the current Boulder County Flood Insurance Study (FIS) as the source for the FEMA effective hydrology.

Previous Studies

In accordance with an agreement with Urban Drainage and Flood Control District (UDFCD), the City of Boulder, and Boulder County, Greenhorne & O'Mara, Inc., completed a Major Drainageway Planning Study – Boulder and Adjacent County Drainageways for 11 drainageways in the Boulder area, including Gregory Canyon Creek, dated May 1987. As a part of the study, Greenhorne & O'Mara completed future conditions hydrology for the 2-, 5-, 10-, 50-, and 100-year storm events. The Colorado Urban Hydrograph Procedure (CUHP) was used to determine the runoff hydrographs for each storm event. These hydrographs were then routed through the US Army Corp of Engineers (USACE) Hydrologic Engineering Center (HEC) model, HEC-1. It was documented in the report that the rainfall data reflected the 1982 guidelines stated in the Urban Storm Drainage Criteria Manual. The study watershed for Gregory Canyon Creek was approximately 2.29 square miles with a 100-year peak discharge of 2,092 cfs at the confluence with Boulder Creek. The peak discharges from this study are documented in the current FEMA FIS, dated December 18, 2012, and have been the basis for each subsequent study completed for the City of Boulder for Gregory Canyon Creek.

Summary of Peak Discharges

Hydrographs from the CUHP and HEC-1 analysis (Greenhorne & O'Mara, 1987) were extracted from output for use in the two – dimensional hydraulic analysis that was performed as part of this study. The FEMA effective flows identified in the 2010 Letter of Map Revision (LOMR) (Belt Collins West, 2010) were used for the one – dimensional Hydrologic Engineering Center River Analysis System (HEC-RAS) hydraulic modeling. A summary of the discharges used in this study are shown below:

Peak Discharge for Gregory Canyon Creek (cfs)

Location	10-yr	50-yr	100-yr	500-yr
Confluence with Boulder Creek (XS 10 – XS 180)	673	1672	2092	3700
University Ave (XS 190 – XS 318)	600	1504	1900	3300
College Ave (XS 330 – XS 455)	495	1286	1700	3000
Willowbrook Road (XS 460 – XS 600)	400	1060	1450	2600

SECTION 4-HYDRAULIC ANALYSIS

EVALUATION OF EXISTING FACILITIES

The existing conveyance infrastructure within the project area was evaluated using the HEC-RAS version 4.1.0 and FLO-2D to determine the capacity of the infrastructure. In addition, EPA-SWMM version 5.0 was used to evaluate the capacity of the 7th Street culvert and to analyze the storm drain system on Willowbrook Road

The FEMA effective HEC-RAS hydraulic model was used as the baseline hydraulic condition for this analysis. This model was updated based on crossing information that was gathered on a site walk performed on July 17, 2014. The topography of Gregory Canyon Creek had been altered slightly by the storm event in September 2013, however it was agreed that the topography reflected in the 2010 LOMR was the best information available. City of Boulder Staff collected measurements for each public crossing. The majority of crossing infrastructure gathered in the field was reflected in the baseline study, however several crossings were updated to reflect current field conditions.

The geometry for the crossings was updated in the HEC-RAS model to reflect the conditions identified in the field maintaining the blockage assumption that was applied to the baseline hydraulic model. This was done by reducing the area of the crossing by the assumed percent blockage. These changes to the crossings had negligible impacts to the split flow reach and the model as a whole. A comparison between the Effective Model (2010 Floodplain Study Geometry) and the updated Existing Conditions Models (Updated Geometry) is depicted in the table to the right. No other changes were made to the baseline model to create the existing conditions HEC-RAS model for the purpose of this analysis.

Location	Percent Blockage Assumption	2010 Floodplain Study Geometry	Updated Geometry
Flagstaff Rd	50%	73.2" diameter	54" diameter
Private Drive at Old Baseline Road	100%	23" diameter	--
Pedestrian Bridge at Willowbrook Road Cul-de-sac	0%	Not Modeled	--
Private Drive at NW Corner of Willowbrook Road Cul-de-sac (705 Willowbrook Road)	50%	52.8" diameter	--
Private Drive at West Side of Willowbrook Road (777 Willowbrook Road)	50%	120" x 60" bridge	--
Willowbrook Road	50%	108" x 60" box culvert	--
Pedestrian Bridge at Willowbrook Road	0%	Not Modeled	--
Private Drive 550 Aurora	0%	192" x 84" box culvert	--
Aurora Crossing #1	0%	36" diameter	--
Aurora Crossing #2	0%	60" x 120" box culvert	--
Euclid Avenue	100%	48" diameter	--
College Avenue	50%	62.4 "x 72" arch culvert	72" x 78" arch culvert
Private Drive Wood Bridge DS of College Avenue	75%	Open Area = 77.4 sq. ft.	--
Pennsylvania Avenue	50%	56.4" x 36" arch culvert	--
7th Street	50%	48" diameter	--
Weir Split Flow Box DS of Anderson Ditch	0%	Not Modeled	--
704 Pleasant Street Patio	30%	66" x 34.8" arch culvert	--
Pleasant Street	20%	96" x 48" arch culvert	--
University Avenue	50%	72" x 60" arch culvert	--
8th street and Alley	50%	66" x 38.4" arch culvert	--
810 Marine Street	50%	48" x 36" box culvert	75" x 54" box culvert
Marine Street	50%	96" x 48" box culvert	104" x 48" box culvert
Alley Between Marine and Arapahoe	50%	62.4" x 42" arch culvert	--
Arapahoe Avenue	50%	120" x 36" box culvert	108" x 36" box culvert
Private Driveway To Old School	50%	42" diameter	48" diameter

FLO-2D Evaluation

During the September 2013 storm event, many residents along the Gregory Canyon Creek corridor witnessed flows along streets adjacent to Gregory Canyon Creek. To get a better understanding of the flow distribution outside the limits of the channel corridor, CH2M HILL developed a two-dimensional hydraulic model, using the FLO-2D V2009 model. A grid was built using 2013 LiDAR data provided by the City of Boulder for the project area. Manning's N values were adjusted based on the surrounding land use as recommended by the documentation in the FLO-2D reference, see the table below for all Manning's N assumptions for the FLO-2D hydraulic model.

Manning's N Documentation

Land use Description	Manning's N Value
Developed, Medium Intensity	0.7
Developed, Low Intensity	0.8
Open Space	0.6
Grassland	0.35
Forested Area	0.4
Developed Open Space	0.25
Streets	0.02

A summary of the HEC- 1 peak discharges and their approximate location in the two – dimensional analysis are located in the table below.

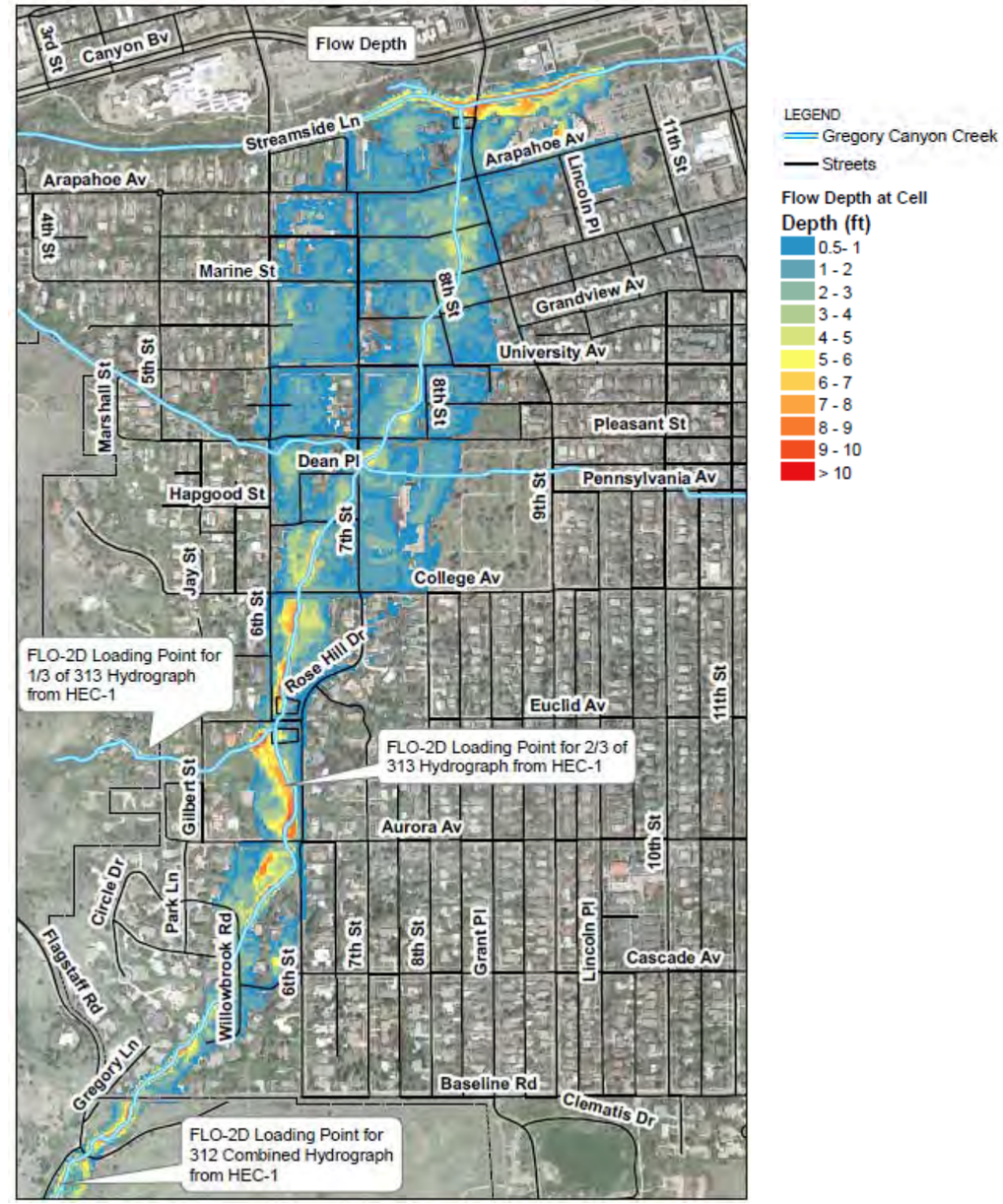
Peak Discharge Summary

Location	Return Interval (years), Peak Discharge (cfs)				
	2-yr	5-yr	10-yr	50-yr	100-yr
Approximately 150' upstream of Flagstaff Rd	32	168	328	937	1270
1/3 of discharge at Aurora Ave, with 2/3 placed on the local highpoint	168	269	485	959	1179

Once the FLO-2D geometry was created, the hydrographs from the HEC-1 Model (Greenhorne & O'Mara, 1987) were distributed at the appropriate flow change locations for the 2-, 5-, 10-, 50-, and 100-year storm events as documented in the figure to the right. The results of the existing 100-year storm event are shown in the figure to the right. The results of the FLO-2D analysis generally confirmed what was observed during the September 2013 storm event. Additional FLO-2D results including velocity vectors and a comparison to the September 2013 event is included in the Alternatives Analysis Memorandum **(Appendix A)**.

Flood Hazards

The City of Boulder and CH2M HILL staff conducted a site walk on July 17, 2014. City staff was able to convey to CH2M HILL observations during the flood event of September 2013 and identify potential areas for improvements. Some of the properties that had been damaged by flood waters had already been restored to pre-flood conditions or had improvements constructed such as flood walls to help prevent future flooding. The objective during the site walk was to identify alternatives to help mitigate flooding. In addition to the proposed improvements identified during the site walk, CH2M HILL noticed other deficiencies along Gregory Creek Canyon through detailed hydraulic modeling. The channel geometry between Euclid Avenue and College Avenue was identified as one of the existing sections that is unable to convey the 10–year storm event without causing infrastructure damage. Another section is the channel upstream of Euclid Avenue for approximately 200-feet. In addition, the crossing at Arapahoe Road is unable to convey the 10–year storm event that is being conveyed from the upstream channel section. These three areas were also considered for potential improvements during the alternative analysis. The alternatives are discussed in detail in the subsequent sections.



100-Year 2-D Analysis Flow Depths

Section 5-Alternative Analysis

Alternative Development Process

Typically, flood mitigation plans are developed with the intent to adequately convey a 100-year storm event, consistent with the policies of the Boulder Valley Comprehensive Plan, the Comprehensive Flood and Stormwater Utility Master Plan and the UDFCD Drainage Criteria Manual.

Due to the existing residential development, channel mitigation to convey a 100–year event would not be feasible unless many of the existing homes along the creek corridor were removed. Currently, the Gregory Canyon Creek channel does not have adequate capacity to contain a 10-year event. During the development of the alternatives, it was determined that improvements along the creek could be constructed which would facilitate flows from a 10-year event. Each culvert was evaluated for existing conditions, the size required to convey a 10-year event, and the maximum size that could feasibly be constructed without impacting existing buildings.

Since the topographical and development constraints along Gregory Canyon Creek prevent modification which would convey flows that are greater than a 10-year event, it was recognized that the streets in the neighborhoods could be modified to better convey floodwaters in larger events.

During the September 2013 event, floodwaters were observed in various roadways, with primary conveyance paths being 6th Street, 7th Street and 8th Street. The flood did significant damage to these roads and left behind large amounts of debris. Thus, street improvements were considered which would direct and retain water within the streets, protecting private properties.

Sept. 2013 Flood Damage at 7th St. and Pleasant St.

Additionally, areas for sediment traps and habitat improvements were evaluated as well as opportunities to implement other improvements based on observations from the 2013 Flood, such as a sanitary sewer main relocation and additional drainage inlets.

Alternative Categories

The alternatives analysis includes the following categories:

1. Channel and Culvert Improvements
2. Improvements Outside of the Channel
3. Property Acquisition
4. Detention
5. Other Improvements

Channel and Culvert Improvements

The Gregory Canyon Creek channel was assessed between the Boulder city limits on the upstream end to the confluence with Boulder Creek. Opportunities for culvert and channel improvements were identified from the culvert on private property at 705 Willowbrook Rd. to the culvert under the private drive leading to the historic Highlands School just north of Arapahoe Ave. Each culvert was evaluated for existing conditions, the size required to convey a 10-year event, and the maximum size that could feasibly be constructed without impacting existing buildings. Most culvert replacements would necessitate work in the channel directly upstream and directly below stream and in most situations, easements would need to be acquired from the property owners. The tables below summarize the evaluation of each culvert including the channel work required. Following is a brief discussion about each culvert and the recommendations for replacement.

Culvert C1-A: Private Culvert at 705 Willowbrook Road

Improvement	Size	Total Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	4.4'	4.4	Circular	34			337	<10	
10-yr	8' x 6'	8	Box	34	14	4	400	10	$114,814
Max	(2) 8' x 8'	16	Box	34	42	11	1,060	50	$233,313

The existing culvert is one of the smallest along Gregory Canyon Creek. During the September 2013 flood, there was significant scour across the southern (upstream) side of the culvert, resulting in sediment and rocks being carried downstream. The limited capacity of the culvert also resulted in floodwaters spilling out of the creek channel, across Willowbrook Court. A concrete wall was built around the culvert shortly after the flood. Replacing the culvert with a larger culvert would allow for more passage of flood waters. An easement would be required. Due to the topography and other development surrounding this culvert, access for maintenance would be difficult.

Post-Flood Repair

Sept. 2013 Flood Damage

Culvert C1: Willowbrook Rd.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	9' x 5'	9	Box				337	<10	
10-yr	9' x 7'	9	Box	140	24	6	400	10	$338,314
Max	(2) 9' x 7'	18	Box	140	36	9	1,187	50-100	$642,815

The existing culvert conveys slightly less than a 10- year storm. The culvert is 140 feet in length and was constructed in 1997.

The trash rack at the upstream end of this culvert clogged with debris during the September 2013 event, and flood waters overtopped Willowbrook Rd., onto private property, and ultimately into the usually dry Gregory Gulch, located between 860 and 870 Willowbrook Rd. The flood waters caused damage to property and structures and scoured a significant amount of sediment and rocks.

Sept. 2013 Flood Damage

After the flood, the trash rack was redesigned and replaced with one that meets current design standards and could be better maintained during a flood.

New Trash Rack

Rather than replace this culvert with one only slightly larger, it is recommended that drainage inlets be installed to help control water in the event the culvert capacity is exceeded. Additionally, adding grates over the culvert could aid in directing flood waters directly into the culvert and should be further evaluated, although due to existing utilities in the roadway this may not be feasible.

In order to accommodate future flood waters along "Gregory Gulch", the property owners at 860 and 870 Willowbrook Rd. have made landscaping improvements incorporating flood walls and other measures that will help protect their properties from future flood damage.

Sept. 2013 Flood Damage

Post-Flood Repair (Upper Gregory Gulch)

The feasibility of installing a pipe along Gregory Gulch was also analyzed. The pipe could convey about 240 cfs and would cost approximately $165,000 to construct. Since both property owners have already made modifications to their properties to better direct the floodwaters away from their homes, the installation of this pipe is not recommended.

Culvert C2: 6th and Aurora

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	(2) 10' x 5'	20	box	80			495	10	
10-yr							495		
Max	(4) 10' x 6'	40	box	80	80	20	1,696	50-100	$ 764,142

The existing culvert in this location was constructed in 1995. It is designed to convey the 10-year event at 495 cfs.

During the 2013 flood, the east side of this culvert filled with debris. A chained-link fence/gate on the downstream side of the culvert failed to swing open and collected debris. The fence/gate has since been removed.

Sept. 2013 Flood Damage

Because this culvert is designed to pass the 10-year event, it is not recommended that it be replaced. In order to accommodate water that may come onto Aurora Ave. from Gregory Gulch, it is recommended that improvements to the road be constructed which would direct flows across the roadway into the creek channel.

Existing Culvert

Culvert C3: Euclid Ave. at 6th St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	4'	4	circular				-	<10	
10-yr	(2) 8' x 6'	16	box	65	44	11	495	10	$291,126
Max	(3) 10' x 6'	31	box	65	108	27	1,268	50	$529,778

There are actually two drainages at 6th and Euclid; the formal Gregory Canyon Creek drainage, and a tributary that flows off of Smith Park and through the property at 580 Euclid before it passes through a small culvert under Euclid into Gregory Canyon Creek. There was significant flooding in 2013 in this area, but much of it was reported to have come from the Smith Park area, and not from the main Gregory Canyon Creek channel.

Existing Culvert

It is recommended that these two culverts be replaced with two 8' x 6' box culverts in order to convey the 10-year storm. In order to preserve existing trees in the area, it is recommended that alternate culvert alignments be investigated. It is also recommended that an alternate alignment of the creek channel downstream of the culvert be considered in order to better protect the home on the north side of Euclid.

Culvert C4: College Ave. and 6th St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	6' x 6.5'	6	arch				125	<10	
10-yr	(2) 7' x 6'	14	Box	55	32	8	495	10	$250,168
Max	(3) 11' x 6'	33	box	55	108	27	1,286	50	$500,731

This culvert was constructed in 1920 and, as designed, conveys 125 cfs. Where the culvert outlets to Gregory Canyon Creek, the creek makes a sharp turn to the east and then flows between two residential structures.

Existing Culvert

It is recommended that this culvert be replaced with two 7' x 6' box culverts and be re-aligned to where flows are directed further to the east and not directly toward the existing house. This would also result in a better alignment with the creek channel from that point north and alleviate the need for the water to make a sharp turn to the east, which can cause scour and erosion.

The property where the culvert outlets is located within the High Hazard Zone and the September 2013 flood did impact this property. The bridge, which serves as the driveway and main access to the home, was damaged and is in need of repair.

Damaged Bridge

Culvert C5: Pennsylvania Ave.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	4.75' x 3'	4.75	arch				42	<10	
10-yr	(2) 9' x 6'	18	box	45	53	13	600	10	$235,896
Max	(3) 12' x6'	36	box	45	121	30	1,469	10-50	$464,895
Pedestrian Bridge 30' bridge span / 10' deck width / 30" deck thickness / 4' handrails / 18' wide channel		18			53	13	600	10	$ 90,000

The road across Gregory Canyon Creek at Pennsylvania Ave. was completely washed out during the 2013 flood, exposing a culvert that that was severely damaged. The roadway was not immediately repaired because it looked like there was an opportunity to increase the flood conveyance capacity and improve the riparian habitat for what was initially considered to be a similar cost to replace the culvert pipe and repair the roadway. Therefore, prior to making repairs to the roadway, three different options were assessed:

Option 1: Replace the existing culvert and rebuild the roadway.

Option 2: Remove the culvert and damaged roadway above the creek, close the road to through traffic, and build a pedestrian bridge over the creek.

Option 3: Remove the culvert and construct a new roadway with a significantly larger culvert or a vehicular bridge over the creek.

An open house was held on Feb. 6, 2014 to obtain public input regarding these options. The public overwhelmingly supported Option 2; removing the culvert and building a pedestrian bridge over the creek. Closing the road to thru traffic on both sides of the bridge was also very much supported by the public. These options were then presented to the Greenways Advisory Committee (GAC). Due to the urgency of repairing the road in order to prevent more erosion and the accumulation of trash in the area, the GAC and utilities staff recommended that the culvert be replaced and the road repaired immediately and that Option 2 be further evaluated with the Gregory Canyon Creek Mitigation study.

Constructing a 30-foot long bridge across the creek, and maintaining an open channel under the bridge would convey 600 cfs, equivalent to conveying the 10-year event. Constructing this bridge is estimated to cost $90,000. In order to pass the 10-year event (600 cfs) under a vehicular road, two culverts at 9'x 6' would have to be constructed and would cost approximately $235,896. The consultants also determined that it was physically feasible to pass 1,469 cfs through three culverts sized at 12' x 6' with a construction cost of $464,895. Considering the public support of building the pedestrian bridge, and the fact that this is the least costly of the other alternatives, it is recommended that the bridge be considered the preferred alternative.

Sept. 2013 Flood Damage

Post Flood Repair

Culvert C6: 7th St. by Flatirons Elementary School

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	8' x 4.25'	8	circular				153	<10	
10-yr	(2) 10' x 6'	20	box	50	44	11	600	10	$278,764
Max	(2) 13' x 6'	26	box	50	72	18	1,339	10-50	$347,319

The trash rack at the upstream end of this culvert clogged with debris during the September 2013 event, and flood waters flowed south, down 7th St., damaging the roadway and properties in the area. During the flood, the trash rack was removed in order to help alleviate the flooding conditions, but the culvert filled with rocks and debris and flood waters continued to run down the street. Additionally, Anderson Ditch overtopped and filled with sediment.

Sept. 2013 Flood Damage

After the flood, the trash rack was redesigned and replaced with one that meets current design standards and could be better maintained during a flood.

New Trash Rack

The upstream end of this culvert is located on 637 Pennsylvania Ave. and the city holds a drainage easement on this property. Constructing a sediment trap upstream of this culvert has been identified as an additional alternative to help capture debris before it reaches the trash rack. The existing culvert only conveys 153 cfs. To convey the 10-year event (600 cfs) the culvert would need to be replaced with two 10' x 6' box culverts.

The downstream end of this culvert runs under the Anderson Ditch before it outlets at 704 Pleasant St. The creek then drains through a separate private culvert on this property before passing through an open channel until meeting Pleasant St.

Sept. 2013 Flood Damage (7th St. and Anderson Ditch)

The recommendation for this culvert is to replace it with the two 10' x '6 box culverts to convey the 10-year storm (600 cfs), but to also realign it more to the west before it outlets onto 704 Pleasant into an open channel, eliminating the need for the private culvert.

The feasibility of putting Anderson Ditch in a pipe from the point it currently daylights on the west side of 7th to the cemetery was also evaluated. The decreed and maintained water right flow for the ditch is 25 cfs. According to the city's stormwater agreement with the Anderson Ditch Company, the city has the right to use all of the excess capacity of the Anderson Ditch for the conveyance of storm water from lands within the corporate limits of the city. This agreement also states that the city has a right to make improvements to the Anderson Ditch, but that all such improvements must be constructed to convey a minimum of 25 cfs. A 23" RCP (Reinforced Concrete Pipe) would convey 25 cfs and cost approximately $23,450 to construct.

Culvert C6-B: Private Culvert on 704 Pleasant

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	5.5' x 2.9'	5.5	arch				11	<10	
10-yr	(2) 8' x 6'	16	box	180	62	16	600	10	$260,062
Max	(2) 12' x 6'	23	box	180	78	74	1,310	10-50	$307,347

As noted above, 704 Pleasant has a private culvert, along with the Anderson Ditch running along the southern edge of the property. This culvert only conveys 11 cfs. During the 2013 flood, this culvert filled with sediment. If this culvert were to be replaced instead of eliminated as recommended above, it could be replaced with two 8'x6' box culverts that would convey the 10-year storm (600 cfs).

2013 Flood Damage

Culvert C7: Pleasant St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	8' x 4.25'	8	arch				153	<10	
10-yr	(2) 10' x 6'	20	box	50	44	11	600	600	$295,163
Max	(2) 13' x 6'	26	box	50	72	18	1,339	10-50	$347,470

This culvert is located at Pleasant St., just east of 7th St. The properties just downstream of this culvert were impacted by flood waters in 2013. While this culvert was replaced in 1995, as designed, it has the capacity to only pass 153 cfs. It is recommended that this culvert be replaced with two 10' x 6' box culverts, totaling a width of 20 feet, to facilitate the passage of the 10-year storm (600 cfs).

Existing Culvert

Culvert C8: University Ave. at 8th St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	6' x 5'	6	arch				104	<10	
10-yr	(2) 9' x 6'	18	box	105	48	12	600	10	$475,753
Max	(2) 10' x 6'	20	box	105	56	14	1,237	10-50	$528,261

While flooding in 2013 was widespread throughout this drainage, the flooding extents became significantly more spread-out in this location and continued downstream, to the north until reaching Boulder Creek. In 2013 flooding spanned almost 950 feet down University (from 7th to 9th St.). This was also in large part due to the extreme crown on University that barred water from easily passing further north to Boulder Creek.

It was calculated that this culvert is only capable of conveying 104 cfs. It is recommended that this culvert be replaced with two 9'x 6' culverts with a combined width of 18-feet to facilitate the passage of the 10-year storm (600 cfs). Additionally, should any road improvements be considered for this section of University Ave., then it is recommended that improvements be made, such as removing the crown, to better facilitate drainage to the north, into Boulder Creek.

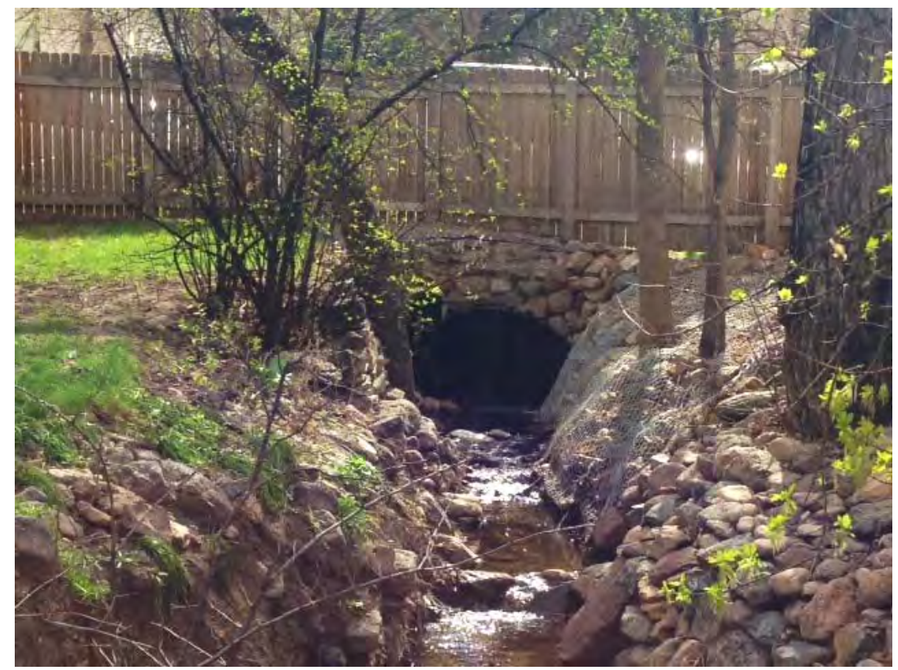
Existing Culvert

Culvert C9: 8th St. and the Alley

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	6' x 3.25'	6	arch				64	<10	
10-yr	(2) 9' x 6'	18	box	170	48	12	673	10	$278,520
Max	(2) 10' x 6'	20	box	170	56	14	1,092	10-50	$797,915

This culvert is located partially on private property between 745 University Ave. and 765 University Ave. The culvert was constructed in 1940 and can only convey 64 cfs. The culvert dog-legs across the alley, across 744 Marine, and then diagonally across 8th St. where it outlets onto 1544 8th St. Like much of the Gregory Canyon Creek corridor, the city does not currently hold any easements in this area.

During the 2013 flood event, flood waters were widely spread-out in this area and not contained within the main creek channel. Because of that, there were no specific issues with culvert blockage or overtopping. It is recommended that the culvert be replaced with two 9' x 6' culverts which will enable the passage of the 10-year storm (673 cfs). Replacing this culvert would require easements from all intervening property owners.



Existing Culvert

Culvert C10: Marine St. between 8th St. and 9th St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	8 x 5'4'	8.5	box				155	<10	
10-yr	(2) 9' x 6'	18	box	70	38	10	673	10	$342,101
Max	(3) 9' x 6'	27	box	70	74	19	1,576	10-50	$500,520

As with the majority of culverts along Gregory Canyon Creek, the existing culvert at Marine St. between 8th and 9th St. conveys far less than the 10-year event. In order to convey the 10-year storm (673 cfs), it is recommended that two 9'x 6' box culverts be constructed and higher capacity inlets be installed along the curbs over the new culvert.

Existing Culvert

Culvert C11: Ally between Marine and Arapahoe

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	5' x 3.5'	5	arch				45	<10	
10-yr	(2) 10' x 6'	20	box	45	60	15	673	10	$278,520
Max	(2) 10' x 6'	20	box	45	60	15	673	10	$280,871

This alley provides vehicular access to several multi-family units. During the 2013 flood, a portion of the road at the downstream (north) side the culvert was washed out. This culvert was constructed in 1940 and was not replaced after the flood, although it was noted to be in very poor condition. It is recommended that the culvert be replaced with two 10' x 6' culverts which would convey the 10-year storm (673 cfs).

Existing Culvert

Culvert C12: Arapahoe Ave. just west of 9th St.

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	9' x 3'	9	box				141	<10	
10-yr	(2) 11' x 5'	21	box	65	48	12	673	10	$340,761
Max	(3) 12' x 5'	37	box	65	112	28	1,350		$543,292

Arapahoe Ave. also has a high crown, but not to the extent as University Ave. The culvert under Arapahoe was built in 1930 and is far too undersized for the attenuation that occurs during even a 10-year event at this point along Gregory Creek. It is recommended that this culvert be replaced with two 11' x 5' culverts in order to convey the 10-year storm (673 cfs).

Existing Culvert

Culvert C13: Drive to the Highlands School

Improvement	Size	Width	Shape	Length of culvert (ft)	Upstream Grading (ft)	Downstream Grading (ft)	CFS	Storm Eq.	Cost
Existing	4'	4	circular				7	<10	
10-yr	15' x 6'	15	box	25	44	11	673	10	$146,625
Max	(2) 15' x 6'	30	box	25	104	26	1,447	10-50	$290,877
Bridge: 30' Bridge span/ 26'deck width/30" deck thickness							830	10-50	$108,675

This culvert was constructed in 1970, and only conveys 7 cfs. Considering that this is the last culvert before Gregory Canyon Creek's confluence with Boulder Creek, and thus attenuation will be at its highest at this location, increasing the capacity at this location should be a priority. Installing a 15' x 6' culvert would convey the 10-year storm (673 cfs). However, constructing a bridge at this location was determined to be a more cost effective solution and could present opportunities to create an entrance that reflects the history and character of Boulder as well as offering opportunities to work in partnership with the owner of this historic property. Doing so would allow the creek to pass through in an open channel rather than a culvert and thus 830 cfs could then be conveyed.

Existing Culvert

Channel Modifications

In order to achieve better capacity along the creek, channel modifications were considered. Improvements to achieve a 100-year design capacity were determined to be infeasible due to the existing development along the creek corridor, but improvements could be constructed to achieve a 10-year design capacity. Culvert replacements would also require a certain amount of channel improvements both on the upstream end and the downstream end, as noted in the tables associated with each culvert.

Through the engineering evaluation, the following areas were identified as requiring channel improvements in order to achieve 10-year design capacity:

- Upstream of Euclid (200-foot reach)
- Between Euclid and College (200-foot reach)
- Between Marine and 8th St. (65-foot reach)

Based on qualitative field observations of the existing conditions, the following additional areas were identified for potential channel improvements:

- Downstream of Euclid (100-foot reach)
- Unnamed tributary across Smith Park to Euclid (450-foot reach)
- Between Pennsylvania Ave. and 7th St. (200-foot reach)
- Four creek sections between University Ave. and Arapahoe Ave. (four different 200-foot reaches)

In most of these locations, easements will be needed to construct and maintain the improvements.

Improvements Outside of the Channel

Since the topographical and development constraints along Gregory Canyon Creek prevent modifications to the channel which would convey flows that are greater than a 10-year storm, it was recognized that the streets in the neighborhoods could potentially be modified to convey floodwaters for larger storm events. During the September 2013 event, floodwaters were observed in various roadways, with primary conveyance paths being 6th Street, 7th Street and 8th Street.

In some locations, such as along University Ave., crossing roadways acted as barriers to flood flows due to the high crown of the street. Therefore, potential street improvements were considered to help direct and retain water within the streets.

Existing Roadway Crown of University Ave. at 7th St.

The flow modeling used to formulate the mitigation measures showed that overflows from Gregory Canyon Creek onto the road system during a 100-year event could exceed 350 cfs for the roads identified for conveyance. Near Boulder Creek, the maximum achievable flow is 193 cfs which is approximately 50% of the modeled 100-year flows in the street. Street improvements would help to lessen flood damage during more frequent storm events.

Property Acquisition

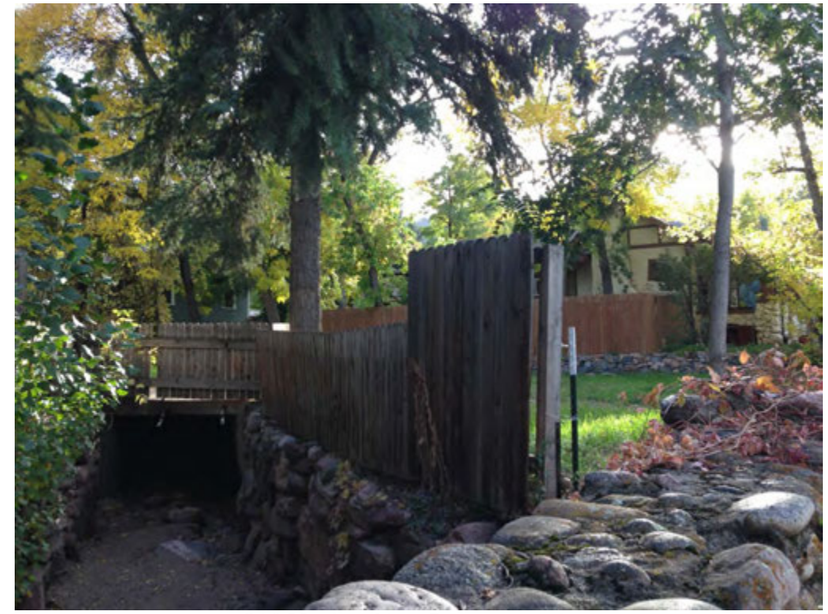
The city has a program in place to purchase properties located in designated high hazard zones when there is a willing seller. Opportunity-based property acquisition is a key element of the floodplain management program given the city's interest in working with a willing seller. The property acquisition program, in conjunction with flood mitigation improvements has been very successful over the years and has resulted in over one hundred structures being removed from the high hazard floodplain.

The property at 810 Marine St., which is located along Gregory Canyon Creek, was purchased by the city and the structure was removed in 2012 (see photographs next page). Along this creek, there are 32 structures located in the high hazard zone. Purchasing certain properties in the high hazard zone would not only remove the life-safety risk, but would also open up additional opportunities to improve flood conveyance in these areas.

810 Marine Before Acquisition

810 Marine After Deconstruction

810 Marine Before Acquisition



810 Marine After Deconstruction

Through this flood mitigation planning effort, the city has identified several properties in the high hazard zone along Gregory Canyon Creek which should be prioritized for purchase. There properties are along the downstream section of Gregory Canyon Creek, in close proximity to each other and to the recently purchased 810 Marine St. property, and therefore could facilitate a more consolidated and comprehensive flood mitigation planning effort. The properties identified for prioritization are listed in the table below:

Property Acquisition Priority Properties	
Address	**Assessed Value**
704 Pleasant St.	$676,000
755 Pleasant St.	$863,000
744 University	$520,000
765 University	$585,900
1544 8th	$398,600
802 Marine St.	$429,400
818 Marine St.	$450,000
833 Marine St.	$570,600
1639 9th St. #1	$289,600
1641 9th St. #2	$289,600
1643 9th St. #3	$289,600
1645 9th St. #4	$289,600
1647 9th St. #5	$289,600
1649 9th St. #6	$289,600
1655 9th St.	$123,600
Total	**$6,354,700**

Note: 755 Pleasant St. includes two properties under the same ownership. One property has a residential structure and the other is vacant.

These properties were prioritized due to the following factors:

- Amount of the structure located within the high hazard zone
- Proximity to the creek channel/opportunities for additional flood mitigation measures
- Age and condition of the structure

In addition to removing the life safety risks associated with properties in the high hazard zone, purchasing these properties and removing the structures could open up opportunities for better channel maintenance, additional flood mitigation measures and the potential of neighborhood pocket parks.

Considering the complexities involved in purchasing a multi-unit/multiple owner condominium building (Units #1-6 at 1647 9th St.), if these units were not included as a priority, the remaining value of the prioritized properties is $4,617,100.

Since the high hazard acquisition program purchases properties that are on the market, the ability to purchase these properties is limited. Thus, the ability to plan a comprehensive mitigation plan for this area is not currently feasible. It is acknowledged, though, that should one or more of these properties be listed and there is a willing seller to the city, then mitigation planning should commence.

DETENTION

An evaluation of detention along Gregory Canyon Creek was performed to identify possible areas where detention facilities could help improve flows by attenuation or other means. The following areas were reviewed for potential detention:

- Immediately upstream of Flagstaff Rd.
- Smith Park
- Flatirons Elementary School

Detention upstream of Flagstaff Rd. would hold .42 acre-feet. Significant impacts associated with detention in this location could include excavation on Open Space and Mountain Parks property, potential reconstruction of Flagstaff Rd. to act as a dam. Flagstaff Rd. is greater than 10 feet above Gregory Canyon Creek which would cause the detention facility to be classified a jurisdictional dam and subject to the regulation of the Colorado State Engineers Office (SEO). This would require the completion of a hazard Classification Report to classify the hazard of the structure and increased regulatory approval and oversight though all phases of the dam design, construction and operation which would significantly increase the cost of the design, construction and ongoing operations and maintenance for a facility that would provide limited benefit to reducing peak flows downstream. Due to these consideration, detention upstream of Flagstaff Rd. is not recommended.

Detention at Smith Park could provide approximately 1.59 acre feet of storage, but this would fill in approximately three minutes in a ten year storm. The detention would necessitate excavation at depths ranging from 10-feet to 18-feet. Due to the relative cost for construction and earthwork and the minimal benefits this facility would provide, detention at Smith Park is not recommended.

The open fields on the south west corner of the Flatirons Elementary School were suggested for detention. This site could potentially provide 2.89 acre-feet of storage at a depth of 6-feet. During a 10-year storm, this pond would fill in approximately six minutes and hold flows for up to 48 hours after an event. This site would require approximately 400 feet of RCP pipes to deliver flow from Gregory Canyon Creek to the pond and up to 450 feet of pipe to return the flow to Gregory Canyon Creek.

The site could be continued to be used for the school playground, but as noted, once the pond fills, it would be full for up to 48 hours in a flooding situation and could pose a flash flood hazard to the school. Considering the safety issues, costs of excavation and piping and the limited benefits that this pond would provide, this site is not recommended for detention.

In summary, options for detention along Gregory Canyon Creek do not appear viable and are therefore were not carried forward as feasible alternatives.

Other Improvements

Additionally, areas for sediment traps and habitat improvements were evaluated as well as opportunities to implement other improvements based on public input and observations from the 2013 Flood, such as a sanitary sewer main relocation and additional drainage inlets and possible grates.

Sewer Manhole Damage - Sept. 2013

Sediment Traps

The watershed contains natural areas with highly erodible soils. The 2013 flood resulted in unstable areas with loose rocks and debris. In order to better manage sediment, rocks and debris, sediment traps were considered. Areas identified for potential sediment traps include:

- Upstream of Culvert C1 (Willowbrook Rd.)
- Upstream of Culvert C2 (Aurora Ave.)
- Upstream of Culvert C6 (7th St. across from Flatirons School)
- Smith Park

These sites were selected because they were observed to have significant debris during the Sept. 2013 flood and they are adjacent to existing streets, providing for adequate maintenance access. The Willowbrook and Aurora sites would require easement acquisition.

Habitat Improvements

Protecting streams and enhancing wildlife habitat are important values of the community. Therefore, habitat improvements should be considered in addition to flood mitigation measures. Within the city limits, the majority of the Gregory Canyon Creek channel is located on private property. Property owners can work on their own or in conjunction with city staff to assess stream and riparian areas and identify habitat improvements such as:

- Removal of noxious weeds and non-native species
- Removal of hazardous trees
- Addition of native plants
- Water quality enhancements

Storm Drain and Sanitary Sewer Improvements

Although this is a major drainageway mitigation plan and is not focused on storm drainage system improvements or the sanitary sewer system, a few areas were highlighted where improvements could be beneficial during a major storm event:

- Additional storm drainage inlets on Willowbrook Dr. to help capture floodwaters that overtop the culvert
- Relocation of the sanitary sewer manhole and pipes currently located within the "Gregory Gulch", which washed-out during the Sept. 2013 flood.
- Installation of grates above culverts

Alternative Costs

Five alternatives were examined during the development of this mitigation plan, with four being developed by the consultant and one by the City. The first alternative included an upgrade of infrastructure for the 10-year storm event, which included adjacent channel grading to allow for proper expansion and contraction around the culvert; additionally, channel improvements through the corridor were included in this alternative. The second alternative examined what was termed as the maximum upgrade to infrastructure which included culvert sizes capable of handling flow between a 10-year and 50-year storm event, with similar channel grading for expansion and contraction; similarly, channel improvements through the reach were included as well. The third and fourth alternatives added additional improvements to the first and second alternatives by considering street conveyance enhancements throughout the corridor. The first alternative of 10-year infrastructure improvements was recommended by the consultant and City staff built upon this recommendation to develop their own recommended plan, or fifth alternative. This alternative includes select street conveyance improvements examined in the third and fourth alternatives, with additional work including sediment traps, habitat improvement, piping of Anderson ditch, and others. Cost estimates for the proposed alternatives are included in **Appendix A**.

Alternative Plans

The following figures graphically represent the alternatives considered in the analysis. The complete Alternative Analysis Memorandum with the Engineer's Recommended Plan is included in **Appendix A**.

LEGEND

- City Limits
- Creek
- Existing Sanitary Sewer
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- Overflow Path
- Street Improvements
- 10Yr Channel Grading
- Max Channel Grading
- Potential Storm Inlet
- Potential Sediment Trap
- Proposed Detention Pond

Infrastructure Improvement
Dimensions are width x height
Recommended Plan in Bold

Channel Improvement

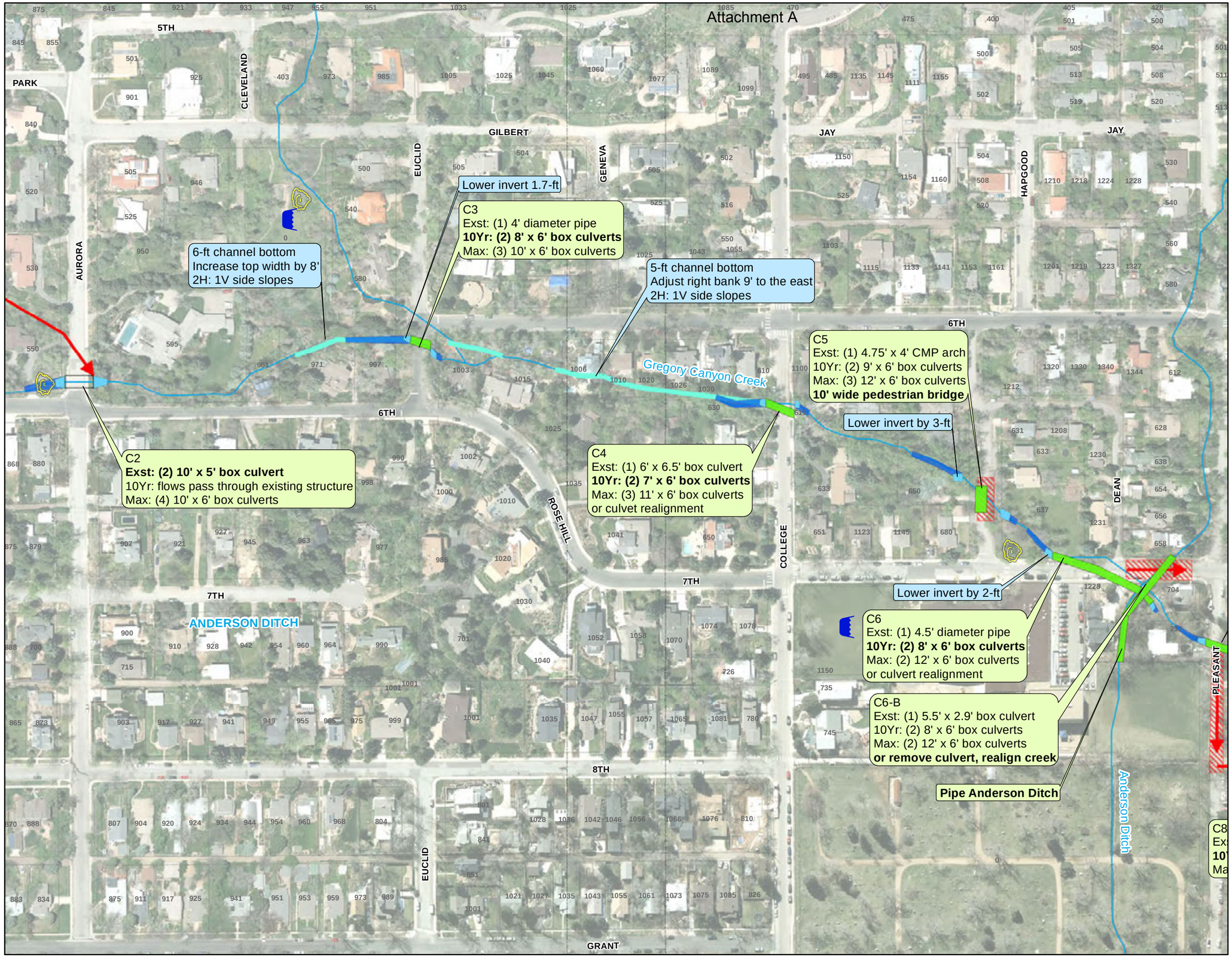
Gregory Canyon Creek Alternative Analysis Plan

Map 1 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/17/2015



LEGEND

- City Limits
- Creek
- Existing Sanitary Sewer
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- Overflow Path
- Street Improvements
- 10Yr Channel Grading
- Max Channel Grading
- Potential Storm Inlet
- Potential Sediment Trap
- Proposed Detention Pond

Infrastructure Improvement
Dimensions are width x height
Recommended Plan in Bold

Channel Improvement

Gregory Canyon Creek Alternative Analysis Plan

Map 2 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/17/2015

LEGEND

- City Limits
- Creek
- Existing Sanitary Sewer
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- Overflow Path
- Street Improvements
- 10Yr Channel Grading
- Max Channel Grading
- Potential Storm Inlet
- Potential Sediment Trap
- Proposed Detention Pond

Infrastructure Improvement
Dimensions are width x height
Recommended Plan in Bold

Channel Improvement

Gregory Canyon Creek Alternative Analysis Plan

Map 3 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/17/2015

Qualitative Evaluation Procedure

Typically, flood mitigation plans for the City of Boulder are developed with the intent to adequately convey a 100-year storm event. Due to the existing residential development along Gregory Canyon Creek, channel mitigation to convey a 100–year event would not be feasible unless many of the existing homes along the creek corridor were removed. Therefore, the following alternatives were assessed:

Do Nothing

This alternate maintains the existing floodplains and channel configurations. Debris cleanup and routine maintenance in the floodplain would be required at regular intervals and following flood events. Maintaining the existing floodplain is the alternative that is used for comparison against all other alternatives.

10-Year Improvements

Currently, the Gregory Canyon Creek channel does not have adequate capacity to contain a 10-year storm event. While assessing mitigation alternatives, it was determined that improvements along the creek could be constructed which would facilitate flows from a 10-year event.

Greater than 10-Year Improvements

This alternate includes improvements to culverts that could convey greater than the 10-year storm, the majority of which could convey 50- to 100-year storm events. While sections of the creek channel cannot be improved to convey an event greater than 10 years without the removal of existing houses, there are locations where culverts could be improved to convey 50- to 100-year events.

Improvements Outside of the Channel

Since the topographical and development constraints along Gregory Canyon Creek prevent modification which would convey flows that are greater than a 10-year event, it was recognized that the streets in the neighborhoods could be modified to better convey floodwaters in larger events. Therefore, the alternatives analysis also includes street improvements to direct and retain flood waters within the streets in order to protect private properties.

Property Acquisition

This alternate identifies structures located in hazardous areas with high flood damage potential. The city's current property acquisition program, in conjunction with flood mitigation improvements has been very successful over the years and has resulted in a significant decrease in the number of structures within the High Hazard Zone. Removing structures in the high hazard zone also allows for additional channel improvements in selected areas. Acquisition of all flood prone properties was rejected because of the high costs. The plan does identify priority properties for acquisition.

Detention

This alternate would provide flood storage to reduce the peak discharge of floodwaters and related flood damages downstream of the facility. A flood storage facility can also be designed to be multi-purpose with park lands, open space, and playing fields located within it.

The alternatives analysis investigated the following locations for detention facilities:

- Immediately upstream of Flagstaff Rd.
- Smith Park
- Flatirons Elementary School

It was determined that detention facilities along Gregory Canyon Creek would provide little benefit in attenuating peak flows, and would result in increased safety risks and/or significant environmental impacts. Therefore detention was determined to be an infeasible alternative for the basin and was not further evaluated.

Implement Non-Structural Methods

This alternate includes items currently implemented as part of the city's floodplain management program and flood preparation activities and includes:

- flash flood forecasting and warning systems
- flood hazard education programs
- development of evacuation plans
- flood insurance
- floodproofing of structures
- floodplain regulation enforcement

Non-structural methods should be considered as an interim solution (until the mitigation plan is implemented) and as a sub-alternate of every other alternate, not a "stand alone" alternate.

Evaluation

The alternatives were evaluated based on the cost of improvements, hydraulic calculations and benefits provided. They were also evaluated on qualitative aspects, including constructability, existing land use constraints, habitat impacts, public safety, public acceptance, and maintenance considerations. The feasibility of each alternative was also evaluated. The recommended alternative provides the highest benefit when considering quantitative and qualitative aspects of the project.

The first screening process of alternatives was the constructability, feasibility and overall benefit. If the improvements could not be feasibly constructed or would not result in any significant benefit, then there was no need for further investigation. Upon completion of the initial hydraulic analysis, the alternatives were evaluated based on how the costs compared to the benefits, and how well they could be implemented into the existing conditions. The remaining qualitative aspects were evaluated to develop the recommended plan. Each alternative and the corresponding advantages and disadvantages are included in the table below:

Comparison of Alternatives

Description	Advantages	Disadvantages
Do Nothing	- No construction impacts to wetlands and wildlife habitat - No land acquisition required - No construction costs	- No flood mitigation benefit - Aging infrastructure not replaced prior to failure
10-Year Improvements	- Increased drainage capacity - Greatest benefit/cost ratio - Minimal impacts to private property	- Requires work on private property - Requires easement acquisition - Wetland and wildlife habitat impacts - Does not provide 100-year flood protection
Greater than 10-Year Improvements	- Maximizes drainage capacity - Positive benefit/cost ratio	- Requires significant work on private property - Requires easement acquisition - Wetland and wildlife habitat impacts - Does not provide 100-year flood protection
Improvements Outside Of Channel	- Provides additional flood protection to private properties - Does not require work on private property - No construction impacts to wetlands and wildlife habitat - No land acquisition required*	- Low benefit cost ratio - Increased flood risk along streets - Does not provide 100-year flood protection
Property Acquisition	- Removes structures with highest flood risk - Provides opportunities for additional mitigation measures - Provides open space - Provides opportunities to enhance wetlands and wildlife habitat	- Low benefit cost ratio - Does not provide flood mitigation benefits to other properties - Requires private property acquisition

*Some land or easement acquisition could be beneficial in select locations.

SECTION 6-RECOMMENDED PLAN

PLAN DESCRIPTION

The Recommended Plan includes the following elements:

10-YEAR IMPROVEMENTS

The following improvements would facilitate flows from a 10-year event and are included in the Recommended Plan:

Culvert Improvements:	Cost
1. Culvert C1-A: Replace with a 8' x 6' box culvert	$114,814
2. Culvert C3: Replace with (2) 8' x 6' box culverts and assess alternate alignments	$291,126
3. Culvert C4: Replace with (2) 7' x 6' box culverts and assess alternate alignments	$250,168
4. Culvert C5: Replace with a 10-foot wide pedestrian bridge	$90,000
5. Culvert C6: Replace with (2) 8' x 6' box culverts and assess alternate alignments	$675,699
6. Culvert C6-B: Assess alternate creek alignment to eliminate culvert	$260,062
7. Culvert C7: Replace with (2) 10' x 6' box culverts	$295,163
8. Culvert C8: Replace with (2) 9' x 6' box culverts	$475,753
9. Culvert C9: Replace with (2) 9' x 6' box culverts	$717,875
10. 810 Marine: Remove existing culvert and daylight creek	TBD
11. Culvert C10: Replace with (2) 9' x 6' box culverts	$342,101
12. Culvert C11: Replace with (2) 10' x 6' box culverts	$278,520
13. Culvert C12: Replace with (2) 11' x 6' box culverts	$340,761
14. Culvert C13: Replace with a vehicular bridge	$108,675
Total:	$4,240,716

Creek Channel Improvements:	Cost
1. All improvements associated with the above culvert improvements	$212,910
2. Downstream of Euclid (100-foot reach)	$12,870
3. Unnamed tributary across Smith Park to Euclid (450-foot reach)	$11,115
4. Between Pennsylvania Ave. and 7th St. (200-foot reach)	$31,200
5. Between 7th St. and Pleasant St. (200-foot reach)	$31,200
6. Downstream of Pleasant St. (200-foot reach)	$31,200
7. Between 8th St. and Marine St. (200-foot reach)	$34,996
8. Between Marine St. and the Alley (200-foot reach)	$34,996
9. Between the Alley and Arapahoe Ave. (200-foot reach)	$34,996
Total:	$435,483

STREET CONVEYANCE

It is recommended that the flood mitigation street improvements be constructed in concert with other street construction projects. The street improvements proposed for 7th St. and Pleasant Ave. should be constructed

that the time that the culverts in this area are replaced. The following street conveyance improvements are included in the Recommended Plan:

Street Conveyance	Cost
1. Lowering the intersection of University Ave. and 7th St. by 1.5 feet	$343,674
2. Lowering the intersection of Arapahoe Ave. and 7th St. by 2 feet	$343,674
3. Lowering the intersection of University and 6th St. by 1.5 feet	$330,455
4. Lower the intersection of Arapahoe Ave. and 6th St by 2 feet	$310,628
5. Increase the crown to 2% in the following locations:	
a. 6th and Anderson Ditch	$62,091
b. 7th and Anderson Ditch	$101,830
c. 6th, between Geneva and Euclid	$217,319
d. 6th , between Euclid and Aurora	$372,546
6. Install a concrete gutter pan on the west side of the culvert at 6th and Aurora (C2) to better convey any street flows back into Gregory Canyon Creek	TBD
Total:	$2,082,217

PROPERTY ACQUISITION

Continue acquiring high hazard zone properties, focusing on the properties identified as priority structures:

Property Acquisition Priority Properties	
Address	**Assessed Value**
704 Pleasant St.	$676,000
755 Pleasant St.	$863,000
744 University	$520,000
765 University	$585,900
1544 8th	$398,600
802 Marine St.	$429,400
818 Marine St.	$450,000
833 Marine St.	$570,600
1639 9th St. #1	$289,600
1641 9th St. #2	$289,600
1643 9th St. #3	$289,600
1645 9th St. #4	$289,600
1647 9th St. #5	$289,600
1649 9th St. #6	$289,600
1655 9th St.	$123,600
Total	**$6,354,700**

OTHER IMPROVEMENTS

Additional improvements included in the recommended plan are listed below.

Other Improvements	Cost
7. Pipe the Anderson Ditch to the east of 7th St.	$23,450
8. Assess stream and riparian areas and identify habitat improvements	TBD
9. Provide sediment traps at the following locations:	
a. Upstream of Culvert C1 (Willowbrook Rd.)	$46,527
b. Upstream of Culvert C6 (7th St. across from Flatirons School)	$80,677
c. Smith Park	$63,766
10. Add new storm drainage inlets on Willowbrook Rd. to help capture floodwaters that overtop the culvert	$147,550
11. Relocate the sanitary sewer manhole and pipes currently located within the "Gregory Gulch".	TBD
12. Investigate installing grates above culverts	TBD
Total:	$361,970

IMPLEMENT NON-STRUCTURAL METHODS

Continue to implement non-structural measures and encourage property owners to prepare for floods and protect their properties and themselves.

The recommended plan is graphically depicted on the following pages:

LEGEND

- City Limits
- Creek
- Ditch
- Existing Sanitary Sewer
- Priority HHZ Property Aquisition
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- 10Yr Channel Grading
- Street Improvements
- Habitat Improvements
- Proposed Storm Inlet
- Potential Sediment Trap

Infrastructure Improvement Dimensions are width x height

Channel Improvement

DRAFT 2015

Gregory Canyon Creek
City of Boulder Staff Recommended Plan

Map 1 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/3/2015

LEGEND

- City Limits
- Creek
- Ditch
- Existing Sanitary Sewer
- Priority HHZ Property Aquisition
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- 10Yr Channel Grading
- Street Improvements
- Habitat Improvements
- Proposed Storm Inlet
- Potential Sediment Trap

Infrastructure Improvement Dimensions are width x height

Channel Improvement

DRAFT 2015

Gregory Canyon Creek City of Boulder Staff Recommended Plan

Map 2 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/3/2015

LEGEND

- City Limits
- Creek
- Ditch
- Existing Sanitary Sewer
- Priority HHZ Property Aquisition
- Channel Improvements
- Existing Culverts
- Culvert Improvement
- 10Yr Channel Grading
- Street Improvements
- Habitat Improvements
- Proposed Storm Inlet
- Potential Sediment Trap

Infrastructure Improvement Dimensions are width x height

Channel Improvement

DRAFT 2015
Gregory Canyon Creek
City of Boulder Staff Recommended Plan
Map 3 of 3

N

0 50 100 200 Feet

© 2015 City of Boulder, CO Subject to Revision - Revised: 4/3/2015

Section 7-Conceptual Design

Conceptual Design to be completed pending a recommendation from WRAB

Section 8-References

A September to Remember; Urban Drainage and Flood Control District, 2014.

Alternative Analysis - Pennsylvania Avenue Flood Repair / Improvement Alternative Analysis; City of Boulder, 2014.

The Anderson Ditch: http://bcn.boulder.co.us/basin/ditchproject/?Our_Ditches:Anderson_Ditch

Boulder Valley Comprehensive Plan; 2010; https://www-static.bouldercolorado.gov/docs/boulder-valley-comprehensive-plan-2010-1-201410091122.pdf

City of Boulder-Comprehensive Flood and Stormwater Utility Master Plan; 2004; https://bouldercolorado.gov/flood/comprehensive-flood-and-stormwater-master-plan

City of Boulder-Greenways Master Plan; 2010; https://www-static.bouldercolorado.gov/docs/2011-greenways-master-plan-update-1-201304221316.pdf

The Columbia Cemetery: https://bouldercolorado.gov/parks-rec/columbia-cemetery

Floods in Boulder County, Colorado, A Historical Investigation; Sherry D. Oaks; 1982.

Flood Hazard Area Delineation- Boulder and Adjacent County Drainageways; Greenhorne and O'Mara, 1987.

Hannah Barker House: http://www.historicboulder.org/the_hannah_barker_house.html

Highlands School: http://historichighland.com/building-grounds/history/

Hydraulic Mitigation Analysis - Gregory Canyon Creek High Hazard Zone Reanalysis – Mini - Master Plan; Belt Collins West, 2009.

Hydraulic Mitigation Analysis - Gregory Canyon Creek Mitigation Analysis; WH Pacific, 2012.

LOMR Determination - Gregory Canyon Creek LOMR Determination Data Reconciliation; Belt Collins West, 2010 (Approved by FEMA, 2010).

Major Drainageway Planning Study - Boulder and Adjacent County Drainageways 'Phase A'; Greenhorne and O'Mara, 1984.

Major Drainageway Planning Study - Boulder and Adjacent County Drainageways 'Phase B'; Greenhorne and O'Mara, 1987.

Rainfall-Runoff Analysis for the September 2013 Flood in the City of Boulder, Colorado; Prepared by Wright Water Engineers for the City of Boulder and released in Sept. of 2014.

Soil Survey of Boulder County Area, Colorad, United States Department of Agriculture Soil Conservation Service in cooperation with Colorado Agriculture Experiment Station, 1975

Summary Report of Private Property and Resident Flood Impact Survey and Analysis, September 2013 Flood Disaster prepared by the City of Boulder-Utilities Division; Dec. 3, 2014: https://www-static.bouldercolorado.gov/docs/summary-report-private-property-resident-september-2013-flood-impact-survey-analysis-1-201412031729.pdf

Appendices

Appendix A-Alternative Analysis Memorandum

Appendix B-Public Comments

Appendix C-Wetland and Habitat Evaluations

Appendix D-Conceptual Design Drawings

Conceptual Design Drawings to be developed after WRAB consideration of Recommended Plan

MEMORANDUM CH2MHILL®

Alternative Analysis Memorandum

PREPARED FOR: City of Boulder

COPY TO: Urban Drainage and Flood Control District

PREPARED BY: CH2M HILL

DATE: March 18, 2015

PROJECT NUMBER: 482330

In September 2013, the City of Boulder experienced an intense rainfall event between September 9 and September 18, approximately 10 days. This rainfall event generated flooding in and around the City of Boulder, including the area along and adjacent to Gregory Canyon Creek. Gregory Canyon Creek is a right bank tributary that enters Boulder Creek west of Broadway. During the storm event of 2013, many residents experienced damage to their property due to high flood waters as well as observed flooding in public roadways. The extents of the observed flooding is documented in **Figure 1.**

CH2M HILL was retained by the City of Boulder to evaluate potential alternatives to help alleviate flooding along Gregory Canyon Creek. The purpose of this Alternative Analysis Memorandum for the *Gregory Canyon Creek Major Drainageway Plan* (Study) is to present the findings of the hydraulic analysis, define problem areas, and develop preliminary categories to mitigate flood hazards within the basin.

Project Location

Gregory Canyon Creek watershed is located in the City of Boulder (City) and Boulder County. Gregory Canyon Creek originates in Boulder County Open Space in Boulder Mountain Park. As flow becomes more concentrated a well-defined channel is visible upstream of Flagstaff Road. At Flagstaff Road, Gregory Canyon Creek is conveyed into the City of Boulder via 60-inch RCP that is lined with a 54" PVC liner. From here, Gregory Canyon Creek is located entirely within the City of Boulder and is bounded by residential development until the confluence with Boulder Creek. The project watershed and study area are depicted in **Figure 2.**

Gregory Canyon Creek generally flows to the northeast direction through developed neighborhoods. The creek is conveyed through many crossings, both publically and privately constructed. Very few easements are dedicated to the City of Boulder throughout the channel corridor, with a number of crossings being owned and maintained by private property owners. In addition, as Gregory Canyon Creek exists on private property, homeowners are responsible for the channel maintenance. The lower portions of the channel are bounded by more dense residential housing, including multi-family development. Downstream of Arapahoe Road, the channel has recently been improved and appears to be stable prior to the confluence with Boulder Creek.

Description of Data Obtained

The City of Boulder provided CH2M HILL with current GIS data, topography information, reports, and as-built plans for Gregory Canyon Creek and surrounding areas. This information was used in the analysis presented in the memorandum. For a complete list of data provided please see **Table 1** in the attached technical appendix.

Acknowledgements

This memorandum was completed with the support and input from various individuals at the City of Boulder and Urban Drainage and Flood Control District (UDFCD). The key participants in the development of this memorandum are shown in **Table 2**.

TABLE 2
Project Contributors

Project Team Members	Affiliation	Role
Katie Knapp	City of Boulder	Project Manager
Annie Noble	City of Boulder	Stakeholder
Kristin Dean	City of Boulder	Stakeholder / Utilities Planner
Christin Shepard	City of Boulder	Stakeholder / GIS Analyst
Shea Thomas	UDFCD	Stakeholder
Alan Turner	CH2M HILL	Project Manager
Morgan Lynch	CH2M HILL	Project Engineer
Frans Lambrechtsen	CH2M HILL	Staff Engineer

Hydrology

A hydrologic analysis was not performed by CH2M HILL as part of this master plan. The information used in this master plan was derived from the previous hydrologic analysis performed for Gregory Canyon Creek. To date, one report has been published documenting the hydrology of Gregory Canyon Creek. The hydrologic study is described in detail in the following subsections and is referenced in the current Boulder County Flood Insurance Study (FIS) as the source for the FEMA effective hydrology.

Previous Studies

In accordance with an agreement with Urban Drainage and Flood Control District (UDFCD), the City of Boulder, and Boulder County, Greenhorne & O'Mara, Inc., completed a Major Drainageway Planning Study – *Boulder and Adjacent County Drainageways* for 11 drainageways in the Boulder area, including Gregory Canyon Creek, dated May 1987. As a part of the study, Greenhorne & O'Mara completed future conditions hydrology for the 2-, 5-, 10-, 50-, and 100-year storm events. The Colorado Urban Hydrograph Procedure (CUHP) was used to determine the runoff hydrographs for each storm event. These hydrographs were then routed through the US Army Corp of Engineers (USACE) Hydrologic Engineering Center (HEC) model, HEC-1. It was documented in the report that the rainfall data reflected the 1982 guidelines stated in the Urban Storm Drainage Criteria Manual. The study watershed for Gregory Canyon Creek was approximately 2.29 square miles with a 100-year peak discharge of 2,092 cfs at the confluence with Boulder Creek. The peak discharges from this study are documented in the current FEMA FIS, dated December 18, 2012, and have been the basis for each subsequent study completed for the City of Boulder for Gregory Canyon Creek.

Summary of Peak Discharges

Hydrographs from the CUHP and HEC-1 analysis (Greenhorne & O'Mara, 1987) were extracted from output for use in the two – dimensional hydraulic analysis that was performed as part of this study. The FEMA effective flows identified in the 2010 Letter of Map Revision (LOMR) (Belt Collins West, 2010) were used for the one – dimensional Hydrologic Engineering Center River Analysis System (HEC-RAS) hydraulic modeling.

Hydraulics

For this memorandum, it was concluded that a detailed look at the hydraulic function of Gregory Canyon Creek was needed to better understand the natural flow paths. Through this understanding the City of Boulder formulates and CH2M HILL analyzed improvement elements into categories to decrease the flood risk to properties as part of the deliverable for the this analysis. These categories are described in detail in subsequent sections.

Previous Studies

In addition to the hydrologic analysis documented in the Major Drainageway Planning Study – *Boulder and Adjacent County Drainageways*, six other studies have been done along Gregory Canyon Creek. The most recent hydraulic analysis was completed by Belt Collins West (2007) to analyze the 100-year floodplain, the 0.5-ft rise floodway, and the high hazard zone for the City of Boulder. The study was based on the 1987 hydrology completed by Greenhorne & O'Mara as part of the Major Drainageway Planning Study – *Boulder and Adjacent County Drainageways*. The original hydraulic study was performed using HEC-2 but was never adopted by FEMA. Belt Collins West (2007) used HEC-RAS version 3.1.3 to update the floodplains along Gregory Canyon Creek. This analysis incorporated updated topography, dated 2007. Debris blockage at bridges and culverts were applied to the hydraulic analysis and a model for the split flow reach that was identified at Marine Street was developed to better define the floodplain in this area. This study was later updated in 2009 to define the structures in or adjacent to the high hazard zone with additional cross-sections and 1-ft ground survey. Alternatives to remove seven structures from the high hazard zone were documented in the 2009 report. The floodplain and floodway identified by Belt Collins *Gregory Canyon Creek LOMR Determination Data Reconciliation* in the 2010 analysis reflects the effective conditions published in the Boulder County FIS, dated December 18, 2012. The effective studies as well as the other studies performed along Gregory Canyon Creek are documented in **Table 3**.

TABLE 3
Previous Studies

Document Type	Source	Description
Major Drainageway Planning Study	Greenhorne and O'Mara, 1984	Boulder and Adjacent County Drainageways "Phase A"
Major Drainageway Planning Study	Greenhorne and O'Mara, 1987	Boulder and Adjacent County Drainageways "Phase B"
Flood Hazard Area Delineation	Greenhorne and O'Mara, 1987	Boulder and Adjacent County Drainageways
Hydraulic Mitigation Analysis	Belt Collins West, 2009	Gregory Canyon Creek High Hazard Zone Reanalysis – Mini - Master Plan
LOMR Determination	Belt Collins West, 2010	Gregory Canyon Creek LOMR Determination Data Reconciliation (Approved by FEMA, 2010)
Hydraulic Mitigation Analysis	WH Pacific, 2012	Gregory Canyon Creek Mitigation Analysis
Alternative Analysis	City of Boulder, 2014	Pennsylvania Avenue Flood Repair / Improvement Alternative Analysis

Evaluation of Existing Facilities

The existing conveyance infrastructure within the project area was evaluated using the HEC-RAS version 4.1.0 and FLO-2D to determine the capacity of the infrastructure. In addition, EPA-SWMM version 5.0 was used to evaluate the capacity of the 7th Street culvert and to analyze the storm drain system on Willowbrook Road

The FEMA effective HEC-RAS hydraulic model was used as the baseline hydraulic condition for this analysis. This model was updated based on crossing information that was gathered on a site walk performed on July 17, 2014. The topography of Gregory Canyon Creek had been altered slightly by the storm event in September 2013, however it was agreed that the topography reflected in the 2010 LOMR was the best information available. City of Boulder Staff collected measurements for each public crossing. The majority of crossing infrastructure gathered in the field was reflected in the baseline study, however several crossings were updated to reflect current field conditions. A summary of the existing crossings are located in **Table 4**. The geometry for the crossings was updated in the HEC-RAS model to reflect the conditions identified in the field maintaining the blockage assumption that was applied to the baseline hydraulic model. This was done by reducing the area of the crossing by the assumed percent blockage. These changes to the crossings had negligible impacts to the split flow reach and the model as a whole. A comparison between the Effective Model and the updated Existing Conditions Models is located in **Table 5** in the technical appendix. No other

changes were made to the baseline model to create the existing conditions HEC-RAS model for the purpose of this analysis.

Table 4
Existing Crossing Summary

Location	Percent Blockage Assumption	Belt Collins Geometry, 2010	Updated Geometry
Flagstaff Rd	50%	73.2” diameter	54” diameter
Private Drive at Old Baseline Road	100%	23” diameter	--
Pedestrian Bridge at Willowbrook Road Cul-de-sac	0%	Not Modeled	--
Private Drive at NW Corner of Willowbrook Road Cul-de-sac (705 Willowbrook Road)	50%	52.8” diameter	--
Private Drive at West Side of Willowbrook Road (777 Willowbrook Road)	50%	120” x 60” bridge	--
Willowbrook Road	50%	108” x 60” box culvert	--
Pedestrian Bridge at Willowbrook Road	0%	Not Modeled	--
Private Drive 550 Aurora	0%	192” x 84” box culvert	--
Aurora Crossing #1	0%	36” diameter	--
Aurora Crossing #2	0%	60” x 120” box culvert	--
Euclid Avenue	100%	48” diameter	--
College Avenue	50%	62.4 “x 72” arch culvert	72” x 78” arch culvert
Private Drive Wood Bridge DS of College Avenue	75%	Open Area = 77.4 sq. ft.	--
Pennsylvania Avenue	50%	56.4” x 36” arch culvert	--
7th Street	50%	48” diameter	--
Weir Split Flow Box DS of Anderson Ditch	0%	Not Modeled	--
704 Pleasant Street Patio	30%	66” x 34.8” arch culvert	--
Pleasant Street	20%	96” x 48” arch culvert	--
University Avenue	50%	72” x 60” arch culvert	--
8th street and Alley	50%	66” x 38.4” arch culvert	--
810 Marine Street	50%	48” x 36” box culvert	75” x 54” box culvert
Marine Street	50%	96” x 48” box culvert	104” x 48” box culvert
Alley Between Marine and Arapahoe	50%	62.4” x 42” arch culvert	--
Arapahoe Avenue	50%	120” x 36” box culvert	108” x 36” box culvert
Private Driveway To Old School	50%	42” diameter	48” diameter

Detention Evaluation

An evaluation of detention along Gregory Canyon Creek was performed to identify possible areas where detention facilities could help improve flows by attenuation or other means. The following areas were reviewed for potential detention:

- Immediately upstream of Flagstaff Road;
- Smith Park;
- and Flatirons Elementary School.

Detention Upstream of Flagstaff Road

One foot contours from the 2013 LiDAR set were utilized to develop an Area-Storage relationship for this location. **Figure 7** in the technical appendix shows the Area-Storage curve. The proposed detention pond would hold 0.42 acre-feet. Using this curve and detention volume, a SWMM model was developed using the existing culvert as pipe conduit at the invert, and an overflow weir elevation that matched the road elevation. This minor attenuation in flows is the result of storage volume upstream of Flagstaff Road being filled on the rising limb of the hydrograph prior to the peak discharge arriving at Flagstaff Road, at which point the peak flows overtopped the road. To achieve additional attenuation, earth work would need to be completed including excavation upstream on Open Space and Mountain Parks property which is not desired.

Additional consideration for this site includes the requirement of a geotechnical analysis and potential reconstruction of Flagstaff Road to act as a dam. Flagstaff road is greater than 10 feet above Gregory Canyon Creek thalweg which would cause the detention facility to be classified a jurisdictional dam and subject to the regulation of the Colorado State Engineers Office (SEO). This would require the completion of a Hazard Classification Report to classify the hazard of the structure and increased regulatory approval and oversight through all phases of the dam design, construction and operation which would significantly increase the cost of the design, construction and ongoing operations and maintenance for a facility that would provide limited benefit to reducing peak flows down stream

Detention at Smith Park

The slope of Smith Park drops approximately 30 feet from Gilbert Street on the west to the Gregory Canyon Creek Channel. To accommodate an offline detention facility at Smith Park, a 10 foot excavation would be required to provide storage volume. This would extend to 18’ deep on the west sides of the detention facility. This area would provide approximately 1.59 ac-ft. of storage and would fill during a 10 year storm in approximately 3 minutes providing very little attenuation to flow rates in the downstream direction. **Figure 8** in the technical appendix shows the Area-Storage curve. Due to the relative cost for construction and earthwork and the minimal benefits this facility would provide it was not moved forward for further consideration.

Detention at Flatirons Elementary School

The open fields on the south west corner of the school were suggested as a potential site for detention of flows from Gregory Canyon Creek. This site could potentially provide a maximum of 2.89 ac-ft of storage on the school open space at a depth of 6 feet deep. **Figure 9** in the technical appendix shows the Area-Storage curve. This pond would fill in approximately 6 minutes during a 10 year event and hold flows for up to 48 hours after an event. This would again provide very little attenuation of the peak flows down the mainstem of Gregory Canyon Creek as the pond would fill during the rising limb of the hydrograph. In addition, this site would require approximately 400 feet of RCP pipes to deliver flow from Gregory Canyon Creek to the pond and up to 450 feet of pipe to return the flow to Gregory Canyon Creek.

This site could continue to be used for a playground for the school but would fill and be full for up to 48 hours in a flooding situation and could pose a flash flood hazard to the school due to the proximity of the pond to

the school. Due to the potential safety issues, cost of excavation and piping and limited benefits from the pond, this pond alternative was not considered further.

Due to the relative expense and limited impacts of full detention on the peak flows along Gregory Canyon Creek, detention was determined to be an infeasible alternative for the basin. However, these sites and other small open areas can provide opportunities for sediment and debris traps which are discussed below.

Sediment Traps

One of the issues seen during the 2013 storm event was significant amounts of sediment and debris being transported by flood waters. The City requested that an analysis be performed to determine the feasibility of sediment traps being installed along the channel corridor. Potential locations for sediment traps include:

- Upstream of the Willowbrook Rd. culvert
- Upstream of Aurora Avenue culvert
- Between Pennsylvania Ave. and 7th St.

The open area at the corner of 7th Street and Pennsylvania Avenue was analyzed to determine the effectiveness of a sediment trap.

A sedimentation study prepared by Moser & Associates, in the nearby Fourmile Canyon, was conducted in 2008 for UDFCD title *Sediment Analysis Report – Four Mile Canyon Creek Downstream of 30th Street.* This report along with Muller's report *Evaluation of Fourmile Canyon Creek Sediment Basin Alternatives* completed in 2012 for the City of Boulder are the foundation for this analysis. According to these reports, sediment basins are useful for 2-year flows when sediment loads are the greatest. When considering a sediment basin, potential impacts to the floodplain should always be kept in mind so as to avoid increases in the regulatory floodplain.

Moser & Associates, in their 2008 report, stated that sediment loads for Fourmile Canyon were on the magnitude of 100 tons per square mile per year. While the study was developed for Fourmile Canyon Creek, Gregory Canyon Creek is located in a similar geographic region and may see similar loads. Under this assumption, 100 tons per square mile per year for Gregory Canyon Creek equaled a sediment load of 229 tons per year. This equates to 116 cubic yards.

With approximately 10,000 square feet available three sediment trap alternatives are proposed. One inline basin of 1,100 square feet, and two offline basins of 1,700 and 2,500 square feet. The efficiency of the basin is a function of the 2-year peak flow and the surface area of the basin; large flat basins are more efficient. The efficiencies, amount of sediment trapped, and estimated costs are shown for the 2-year peak flow of 161 cfs in **Table 6**. Cost assumptions came from Muller's report as an average cost per cubic yard of approximately $898.00 per cubic yard trapped. The Gregory Canyon Creek Master Plan contingency used for other costs developed in this study was applied and increased the cost per cubic yard to $1,616.00. Note that cost for sediment basins are a function of their overall efficiency. A consideration for impacts to property should also be considered. If space or easement acquisition is limited, an inline basin may be more effective. **Figure 10** in the technical appendix shows these proposed alternatives at this location.

TABLE 6

Sediment Trap Analysis

Alternate	7th St - Alt 1	7th St - Alt 2	7th St - Alt 3	Euclid Avenue	Willowbrook Road
Surface Area	2500	1100	1700	1700	1200
n (1 = inline, 2 = offline)	2	1	2	2	1
Vs (settlement velocity, fine sand)	0.059	0.059	0.059	0.059	0.059
R (efficiency)	0.53	0.29	0.42	0.42	0.31

TABLE 6
Sediment Trap Analysis

Alternate	7th St - Alt 1	7th St - Alt 2	7th St - Alt 3	Euclid Avenue	Willowbrook Road
Sediment Trapped (Ton)	121	66	96	96	70
Sediment Trapped (CY)	90	49	71	71	52
Estimated Cost ($)	$80,677.01	$43,762.94	$63,765.36	$63,765.36	$46,526.23

FLO-2D Evaluation

During the storm event that occurred in September 2013, many residents along the Gregory Canyon Creek corridor witnessed flows along streets adjacent to Gregory Canyon Creek. To get a better understanding of the flow distribution outside the limits of the channel corridor, CH2M HILL developed a two-dimensional hydraulic model, using the FLO-2D V2009 model, to better understand the flow paths of larger storm events. A grid was built using 2013 LiDAR data provided by the City of Boulder for the project area. Manning's N values were adjusted based on the surrounding land use as recommended by the documentation in the FLO-2D reference, see **Table 7** for all Manning's N assumptions for the FLO-2D hydraulic model. A summary of the HEC- 1 peak discharges and their approximate location in the two – dimensional analysis are located in **Table 8**.

TABLE 7
Manning's N Documentation

Landuse Description	Manning's N Value
Developed, Medium Intensity	0.7
Developed, Low Intensity	0.8
Open Space	0.6
Grassland	0.35
Forested Area	0.4
Developed Open Space	0.25
Streets	0.02

TABLE 8
Peak Discharge Summary

Location	Return Interval (years), Peak Discharge (cfs)				
	2-yr	5-yr	10-yr	50-yr	100-yr
Approximately 150' upstream of Flagstaff Rd	32	168	328	937	1270
1/3 of discharge at Aurora Ave, with 2/3 placed on the local highpoint	168	269	485	959	1179

Once the FLO-2D geometry was created, the hydrographs from the HEC-1 Model (Greenhorne & O'Mara, 1987) were distributed at the appropriate flow change locations for the 2-, 5-, 10-, 50-, and 100-year storm events as documented in **Table 8**. The results of the existing 100-year storm event are shown in **Figure 3** in the technical appendix. The results of the FLO-2D analysis confirmed what was observed by homeowners

during the September 2013 storm event. A comparison to the September 2013 event is also shown in **Figure 4**.

Flood Hazards

The City of Boulder and CH2M HILL staff conducted a site walk on July 17, 2014. City staff was able to convey to CH2M HILL observations during the flood event of September 2013 and identify potential areas for improvements. Some of the properties that had been damaged by flood waters had already been restored to pre-flood conditions or had improvements constructed such as flood walls to help prevent future flooding. The objective during the site walk was to identify alternatives to help mitigate flooding. These alternatives are discussed in detail in the subsequent sections. The potential improvements identified during the site walk are located in **Table 9**.

TABLE 9
Potential Improvement Summary

Location	Proposed Improvement	Number of Properties Impacted
Upstream of Willowbrook Road Cul-de-Sac	Bank Stabilizations	3
Private Crossing on 711 Willowbrook Road	Culvert Improvements	2
Crossing at Willowbrook Road	Trash Rack / Culvert Entrance	0
Willowbrook Road at Gregory Gulch	Reconfigure Drainage Inlets	3
Crossing at Aurora Avenue	Culvert / Channel Improvements	3
Adjacent to 6th Street	Channel Improvements	1
6th Street North of Aurora Avenue	Increase Roadway Conveyance	Varies - Residential Drives
Euclid Avenue	Culvert Improvements	2
7th Street Past Rose Hill Drive	Increase Roadway Conveyance	Varies – Residential Drives
Crossing at College Avenue	Maximize Culvert Capacity / Alignment	4
1100 6th Street	Sidewalk Repair	1
Crossing at Pennsylvania Avenue	Culvert Repair / Removal	Varies – Potential Reroute of Traffic
7th Street at Anderson Ditch	Maximize Roadway Conveyance and Pipe Irrigation Ditch	Multiple with Street construction / Located adjacent to school
Between Pleasant Street and University Avenue	Bank Stabilization	2
University Avenue to Marine Street	Increase Culvert Capacity / Channel Improvements	Multiple
Alley Between Arapahoe Road and Marine Street	Increase Channel Capacity / Replace Aging Culvert	5
North of Arapahoe Road	Upsize Culvert / Construct Bridge	1
7th Street at Arapahoe Avenue	Increase Roadway Conveyance	Varies - Residential Drives

In addition to the proposed improvements identified during the site walk, documented in **Table 9**, CH2M HILL noticed other deficiencies along Gregory Creek Canyon through detailed hydraulic modeling. The channel geometry between Euclid Avenue and College Avenue is one of the existing sections that is unable to convey the 10 – year storm event without causing infrastructure damage. Another section is the channel upstream

of Euclid Avenue for approximately 200-feet. In addition, the crossing at Arapahoe Road is unable to convey the 10 – year storm event that is being conveyed from the upstream channel section. These three areas were also considered for potential improvements during the alternative analysis.

Alternative Analysis

Flood hazards within the Gregory Canyon Creek watershed are primarily due to undersized channel geometry and culvert crossings. The watershed is considered to be fully developed with the channel corridor located almost entirely on private property. The narrow channel corridor, lack of drainage easements, and narrow right-of-way, limits the flood control elements that can be proposed. Knowing these constraints, the City of Boulder directed CH2M HILL to look at categories of improvements that could mitigate flooding risks while working within the horizontal constraints of the existing channel. In addition to these constraints, criteria that were considered while developing the proposed alternatives are documented in **Table 10**.

TABLE 10
Design Criteria

Source	Document
City of Boulder	Design and Construction Standards – Storm Water Design, 2005
City of Boulder	Design and Construction Standards – Transportation Design, 2009
Urban Drainage and Flood Control District	Urban Storm Drainage Criteria Manual – Volume 2, 2008

Due to the horizontal and vertical constraints along Gregory Canyon Creek proposed improvements will likely require easements and impact adjacent property owners. The City of Boulder staff requested that CH2M HILL evaluate two different categories of elements

- Category One – Channel and Culvert Improvements;
- Category Two –Improvements Outside of the Channel.

The intent of the proposed categories is to mitigate flooding risk with Category One being confined along the main channel corridor and Category Two including improvements to accommodate spill flows that escape the channel. It is recommended that the City of Boulder work with the residents and property owners along Gregory Canyon Creek to clear channel brush and debris located in the floodway and stabilize channel banks. The following describes the categories of elements that were evaluated. Design Criteria and assumptions for the development and analysis of the alternatives and categories can be found in **TABLE 17** in the technical appendix.

Category One – Channel and Culvert Improvements. This category was envisioned to provide recommendations for improvements along the creek centerline along with brush and debris clearing. The existing culvert infrastructure was reviewed to recommend replacements and improvements to the aging infrastructure along Gregory Canyon Creek to ensure that the culvert crossings could pass flow contained within the Gregory Canyon Creek channel and identify required modifications to the channel. Due to the current condition of these culverts, it is assumed that culvert replacement along Gregory Canyon Creek may occur to replace any damaged or aging infrastructure. Hydraulically the channel capacity is limited to approximately the 10-year flow rate. Culverts were sized in this category to pass the ten year flow rate. Channel improvements in the immediate vicinity of new culverts would be needed to accommodate the larger culvert size, and are included in the project scope of each individual culvert. In addition, channel deficiencies were noted in areas with severely reduced capacity that did not meet the 10 year criteria by the majority of the channel or the surrounding infrastructure. In addition, if a larger culverts could be constructed based on

visual horizontal and vertical constraints these larger culvert sizes were analyzed. These maximum culvert sizes and constraints are in **Table 11** in the technical appendix. The improvements associated with Category One are illustrated in **Figure 5** in the technical appendix.

Category Two –Improvements Outside of the Channel. For the purposes of this analysis, Category Two builds on the channel optimization of the Gregory Canyon Creek channel presented in Category One and seeks to maximize the flood conveyance of the major overflow paths while adhering to the local criteria and constraints. Category Two includes proposed roadway sections to proactively convey floodwater that exceed the Gregory Canyon Creek channel in identified roadways. During the storm event in September 2013, floodwaters were observed in various roadways with primary conveyance paths being 6th Street, 7th Street and 8th Street. These flow paths were identified as potential options for conveying larger storm events in places where Gregory Creek is physically constrained by adjacent structures. A FLO-2D model was developed to understand how the streets conveyed flow during larger storm events. These flow paths are shown in **Figure 3**. Based on these models, 6th Street, 7th Street, 8th Street and Willowbrook were identified as major water courses and were then formalized and optimized as drainage routes. It became clear that the overflows from Gregory Canyon Creek into the road system during the 100-year event could exceed 350 cfs for the roads identified for conveyance. As 6th Street, 7th Street and 8th Street approach Boulder Creek, the grades of the roads flatten from almost 6% grade in the upper watershed to closer to 1% in the lower watershed. The flatter slope was used to understand the maximum flow that could be achieved in the street sections without exceeding the city's 12 – inches maximum flood criteria. Near Boulder Creek the maximum achievable flow is 193 cfs which is approximately 50% of the modeled 100 year flows in the street. This conveyance capacity is achieved by installing 30-foot wide roads, 6-inch curb and gutter, a four-foot sidewalk with an additional 6-inch curb on the back end. This category, while not solving the 100-year flooding problem could go a long way to help alleviate flood damage.

It is recommended that the City work with local emergency agencies to identify safety and access issues along these routes during flood events and to provide signage to indicate that the roads are designed as flood conveyance facilities. The roadway flood conveyance was assumed to have a typical gutter depth of 6-inches for each residential street. Flows were not allowed to exceed the City's 12-inch maximum requirement of depth of flow in the street. The improvements associated with Category Two are located in **Figure 6** in the technical appendix.

After the Public Open House and WRAB meeting on October 20, 2014 which provided public input on the categories, the city staff organized the elements into 15 alternatives. These alternatives are identified in **Table 12** below. The alternatives were used to develop benefit/cost relationships to help understand the most cost effective alternative in the basin to help improve public health and safety and minimize flood damages. Of the 15 alternatives the following alternatives were analyzed for the benefit cost analysis because they reflected the effects of all the infrastructure improvements on the Gregory Canyon Creek System.

- 10 Year Culvert and Channel Improvements.
  - Includes 10 Year culvert and channel improvements from Category 1
- Maximum Culvert Improvements with localized channel improvements.
- Includes maximum culverts and channel improvements from Category 1 10 Year Culvert and Channel Improvements with overflow path improvements
  - Includes 10-year culvert and channel improvements from Category 1, with roadway and overflow path improvements from category 2
- Maximum Culvert Improvements with localized channel improvements and roadway conveyance
  - Includes maximum culverts and localized channel improvements from Category 1, with roadway and overflow path improvements from category 2

The remainder of the alternatives identified by city staff are intended to reflect phasing of the alternatives to further analyze the system.

TABLE 12

Gregory Canyon Creek Alternatives

	Lower Reach			Middle Reach			Upper Reach		
	Culvert and Channel Improvements		Street Conv.	Culvert and Channel Improvements		Street Conv.	Culvert and Channel Improvements		Street Conv.
	10 yr	Max		10 yr	Max		10 yr	Max	
Alternative 1	x								
Alternative 2		x							
Alternative 3	x		x						
Alternative 4		x	x						
Alternative 5	x			x					
Alternative 6		x			x				
Alternative 7	x		x	x		x			
Alternative 8		x	x		x	x			
Alternative 9	x			x			x		
Alternative 10		x			x			x	
Alternative 11	x		x	x		x	x		x
Alternative 12		x	x		x	x		x	x
Alternative 13	Gregory Gulch Pipe								
Alternative 14	Piping Anderson Ditch								

All of the defined alternatives were built into the effective HEC-RAS models to determine the depth of flow throughout the system which was used to determine benefits. All figures and tables in the technical appendix have been updated to capture the revised alternatives. **Table 13** is a summary of the alternatives and their respective costs. Line items for Gregory Gulch Pipe at Willowbrook Road and the piping of Anderson Ditch are included separately.

TABLE 13
Summary of Alternative Costs

Alternative	Cost	Notes
10-year	$ 4,692,167.00	**Includes:** 10-year culvert improvements, adjacent channel improvements for culverts, and channel improvements in other areas to increase to 10-year capacity.
10-year With Overflow Conveyance	$ 8,505,643.00	**Includes:** 10-year culvert improvements, adjacent channel improvements for culverts, channel improvements in other areas to increase to 10-year capacity, and street conveyance in critical areas. Also includes the Gregory Gulch pipe.
Maximum	$ 7,876,974.00	**Includes:** Maximum culvert improvements, adjacent channel improvements for culverts, and channel improvements in other areas to increase to 10-year capacity.
Max With Overflow Conveyance	$ 11,690,450.00	**Includes:** Max culvert improvements, adjacent channel improvements for culverts, channel improvements in other areas to increase to 10-year capacity, and street conveyance in critical areas. Also includes the Gregory Gulch pipe.
Anderson Ditch Pipe	$ 23,450.00	**Includes:** Piping of Anderson Ditch.

Benefit Cost Analysis

A benefit cost analysis was performed to analyze the alternatives as outlined above. The following four primary alternatives were analyzed:

- 10-year culvert improvements
- 10-year culvert improvements with street conveyance improvements
- Maximum culvert improvements
- Maximum culvert improvements with street conveyance improvements

Data Collection

The primary resource for allocating data to develop the benefit cost analysis was the Federal Emergency Management Agency (FEMA) HAZUS – MH computer program and the FEMA BCA tool. A HAZUS-MH database produced by FEMA that categorized the structures, foundation types, first floor elevation identification number, structure value and contents value created in response to the 2013 flood, provided the base information to determine benefits for each of the alternatives. This data included information on the first floor elevation value, foundation, type, structure type, and the number of stories. Additional data included assessor data from Boulder County which included a descriptor of the basement type to help identify how to modify the lowest adjacent grade to compute first floor elevation.

Methodology

In order to determine the benefit costs to the proposed alternatives, an analysis was performed using water surface elevations based on the HEC-RAS models developed for each alternative. Lowest adjacent grades for

the homes were interpolated from a surface based on 1-ft contours using ArcGIS, and first floor elevations were assigned based on the county assessor information with specific attention given to basement type. The lowest adjacent grades were modified based on basement type using the values in Table 18 in the Appendix. If a basement type was "unfinished" then the structure was assumed to act as a slab on grade structure. This elevation was compared against the water surface elevations for the 10-, 50-, 100-, and 500-yr recurrence interval storms to develop the depth of flooding relative to the first floor elevation of all impacted structures. This analysis resulted in a list of structures within the floodplain for each storm event, and each alternative.

Depth-damage functions were pulled from the BCA Tool 5.1 program developed by FEMA. These functions provide a damage percentage of both the structure value and contents value of a structure based on the depth of flooding experienced at the structure. Both structure and contents values were included in the BCA analysis. The structure information acquired from FEMA included differing categories of structures. These included

- Structure type
  - Residential
  - Commercial
  - Industrial
  - Governmental
  - Education
- Number of stories
- Foundation Type
  - Basement
  - Crawl space
  - Slab on grade
- Basement Type
  - Walk-out (finished/unfinished)
  - Subterranean (finished/unfinished)
  - Garden (finished/unfinished)

These structure categories formed a unique identifier that corresponded to a specific depth – damage function from the BCA Tool model. A separate depth damage function was created separately for Garden and Subterranean basements to modify when damage began to occur. A lookup table was setup to match structure, with the assigned water depth, to determine the percentage of damage for each return period and alternative. Damages for each alternative were compared to existing conditions damages to determine the benefits of each alternative.

Average annual damages were determined for each alternative by multiplying the damages by the probability of recurrence. In addition, all costs for the alternatives were converted average annual costs. This was done by taking a 7% amortization rate and assuming a fifty year project lifespan per the guidance from the FEMA BCA guidance.

Table 14 presents a summary of the damages calculated for existing conditions and the alternatives. **Table 15** presents a summary of the benefit cost ratios. **Table 16**, in the technical appendix, provides a more detailed view of the damages per alternative.

TABLE 14
Summary of Damages (Structure and Contents) for Existing Conditions and Alternatives

Probability	Storm Event	Damage from Storm Event				
		Existing	10-yr	10-yr w/ Street	Max	Max w/ Street
0.2	5-yr	$0.00	$0.00	$0.00	$0.00	$0.00
0.1	10-yr	$39,885,504	$28,624,736	$28,624,736	$26,807,549	$26,532,135
0.02	50-yr	$44,871,121	$36,296,256	$35,953,292	$35,388,630	$34,657,034
0.01	100-yr	$45,713,907	$37,709,166	$36,703,945	$36,511,272	$35,407,533
0.002	500-yr	$50,081,200	$41,610,872	$41,289,544	$41,132,626	$39,726,175

TABLE 15
Summary of Annualized Damage Costs, Benefits, Alternative Costs, and Benefit Cost Ratios

Conditions	Existing	10-yr	10-yr w/ Street	Max	Max w/ Street
Annualized damage	$4,430,766.00	$3,521,538.00	$3,492,949.00	$3,415,439.00	$3,345,260.00
Benefit	-	$909,228.00	$937,817.00	$1,015,327.00	$1,085,506.00
Annualized Alternative Cost (7% Amortization, 50-yr Life Span)	-	$339,994.00	$616,318.00	$570,764.00	$847,088.00
Benefit Cost Ratio	-	2.67	1.52	1.78	1.28

Engineers Recommended Plan

Introduction

The Engineer's Recommended Plan to minimize the identified flooding issues along Gregory Canyon Creek is the 10-year alternative (Recommended Plan). This Recommended Plan is offered for consideration based on feedback from public meetings, project stakeholders, staff input and preliminary discussions with WRAB.

The Engineer's Recommended Plan is only the first step in the adoption process. Several additional endorsement or approvals must be secured before any implementation is initiated. At each step, adjustments to the Recommended Plan may be identified that address specific concerns expressed by the reviewing entity or the Recommended Plan can be dismissed in favor of another alternative. At the end of the process, the city may choose to adopt a single plan that consolidates the refinements or selects an entirely different option, either studied as part of this Mitigation Planning Study or developed based on other criteria.

The Engineer's Recommended Plan has been presented to city staff. Comments by the group have been addressed and refinements incorporated into the Recommended Plan as necessary. The Recommended Plan, once reviewed and approved by city staff, is now ready to be presented to WRAB. It is also expected that a

presentation will be made to the public and other stakeholders that describes the planning process and the elements of the Recommended Plan. In addition to these presentations, the team intends to present the Recommended Plan to City Council for formal consideration and adoption. Once the plan has been adopted, City Public Works Utilities staff will incorporate the recommendations into a long term Capital Improvements Program.

Plan Description

The Recommended Plan focuses on alleviating flooding along Gregory Canyon Creek, without affecting adjacent structures, minimizing Right – of – way takes while providing the greatest level of service throughout the corridor in the most cost effective way possible. This alternative focuses on making channel improvements to convey the 10-year storm event and replacing culverts along the channel to also convey the 10-year storm event. These improvements will provide additional protection from more frequent flooding events but will not eliminate the 100-year flood hazard. Additional options could be included at the City's discretion including sediment and debris traps, improvements to irrigation facilities or improvements to roads that could help contain and convey higher flow events along the roads within the basins.

Other Features of the Recommended Plan

The Recommended Plan also recognizes the City's considerable efforts to manage and control flood hazards. The City has an extensive body of floodplain and floodway protections built into the zoning, land use and development regulations. Physical infrastructure to warn citizens of an impending flood threat exists through sirens and other warning mechanisms and an impressive body of master planning exists for many of the city's drainageways.

In addition, the City also has regulations that are in place to protect the environmental values the community finds so valuable. Stormwater quality regulations have been adopted to assure that future construction activities do not create adverse environmental impacts. Existing stormwater discharge permits issued under the State's Stormwater NPDES program also include programs that promote public education and control other sources of pollution. These are intended to remain in place and are implicitly incorporated into the Recommended Plan.

Basis for Selection

The primary objective defined at the outset of the study was to reduce the flood impacts on properties along Gregory Canyon Creek with as little disturbance to private properties as possible. The Recommended Plan does reduce the flood hazard throughout the watershed for 40 structures for the 10-yr condition and 18 structures for the 100-yr condition. This reduced hazard provides much better access for emergency vehicles during flood events.

The Recommended Plan has the highest benefit-cost ratio among the plans evaluated. This means that the City's investment in infrastructure to address flooding generates a favorable return by reducing the average annual flood damages by a factor of 2.67 over the investment cost.

The Recommended Plan does create some unavoidable impacts to private properties. However, the elements of the Recommended Plan have been laid out to minimize these impacts.

List of Figure and Tables

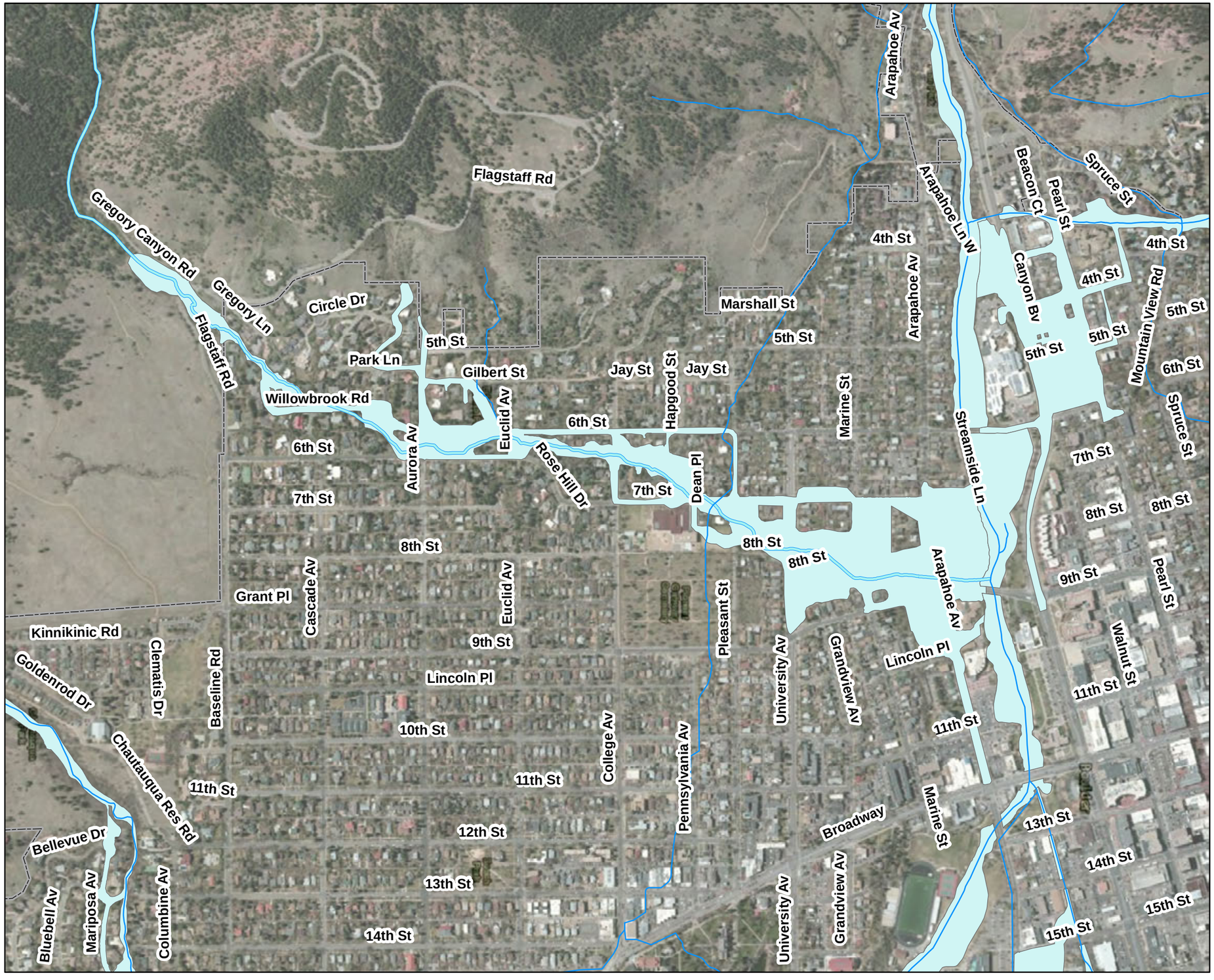
Figures **17**
Figure 1: September 2013 Flood Extents *18*
Figure 2: Area of Interest *19*
Figure 3: Existing 100 – year 2-D Analysis Floodplain *20*
Figure 4: Comparison to September 2013 Event *21*
Figure 5: Category One – Channel and Culvert Improvements *22-24*
Figure 6: Category Two – Improvements Outside of the Channel *25-27*
Figure 7: Flagstaff Road Detention Stage Storage Curve *28*
Figure 8: Smith Park Stage Storage Curve *29*
Figure 9: Flatirons Elementary School Stage Storage Curve *30*
Figure 10: 7th Street Sediment Trap Alternatives *31*
Figure 11: Flowmaster Output – Tiered Curb *32*

Tables **33**
Table 1: Data Received From City of Boulder *34*
Table 5: Effective and Existing Hydraulic Output *36*
Table 11: Culvert Improvements *42*
Table 16: Damage Assessment *44*
Table 17: Design Criteria and Assumptions *45*
Table 18: Lowest Adjacent Grade Basement Type Modifier Values *46*

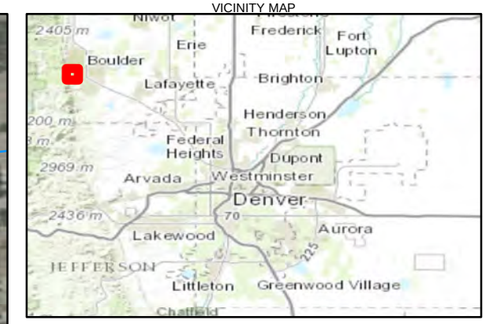
Acronyms and Abbreviations **47**

Technical Appendix

Figures



VICINITY MAP



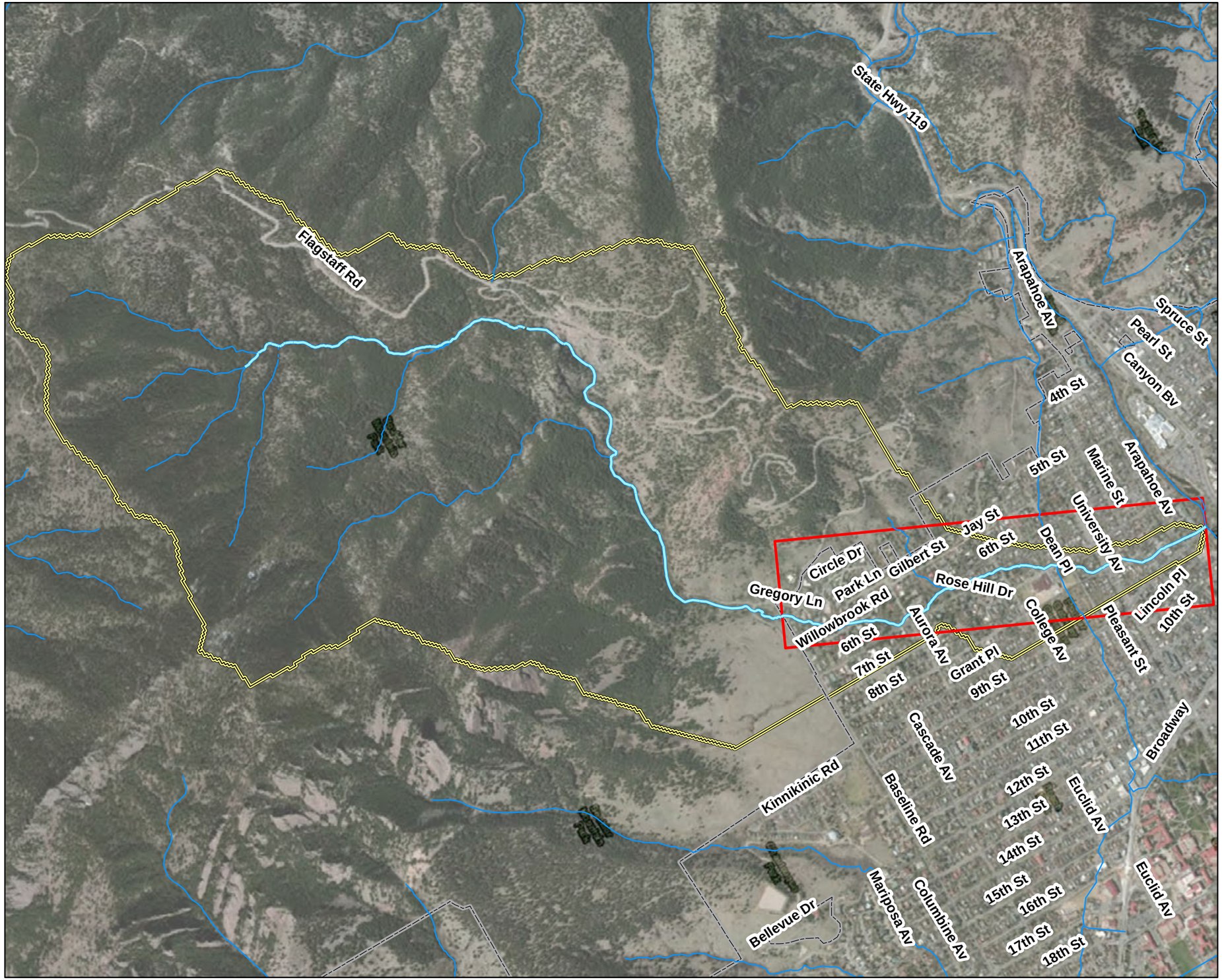
LEGEND
- Creeks and Streams
- Gregory Creek
- September 2013 Flood Extents
- City Limits

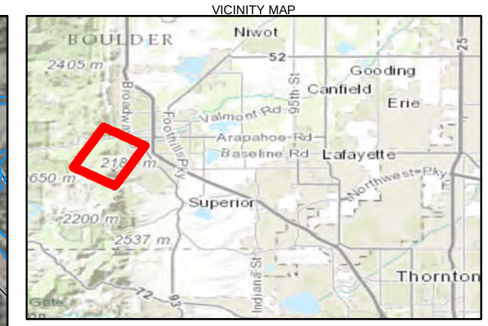
Notes:
1. Area of interest subject to change.

0.15 0.075 0 0.15 Miles

FIGURE 1
Spetember 2013 Flood Extents
Gregory Canyon Creek Flood Mitigation

CH2MHILL.





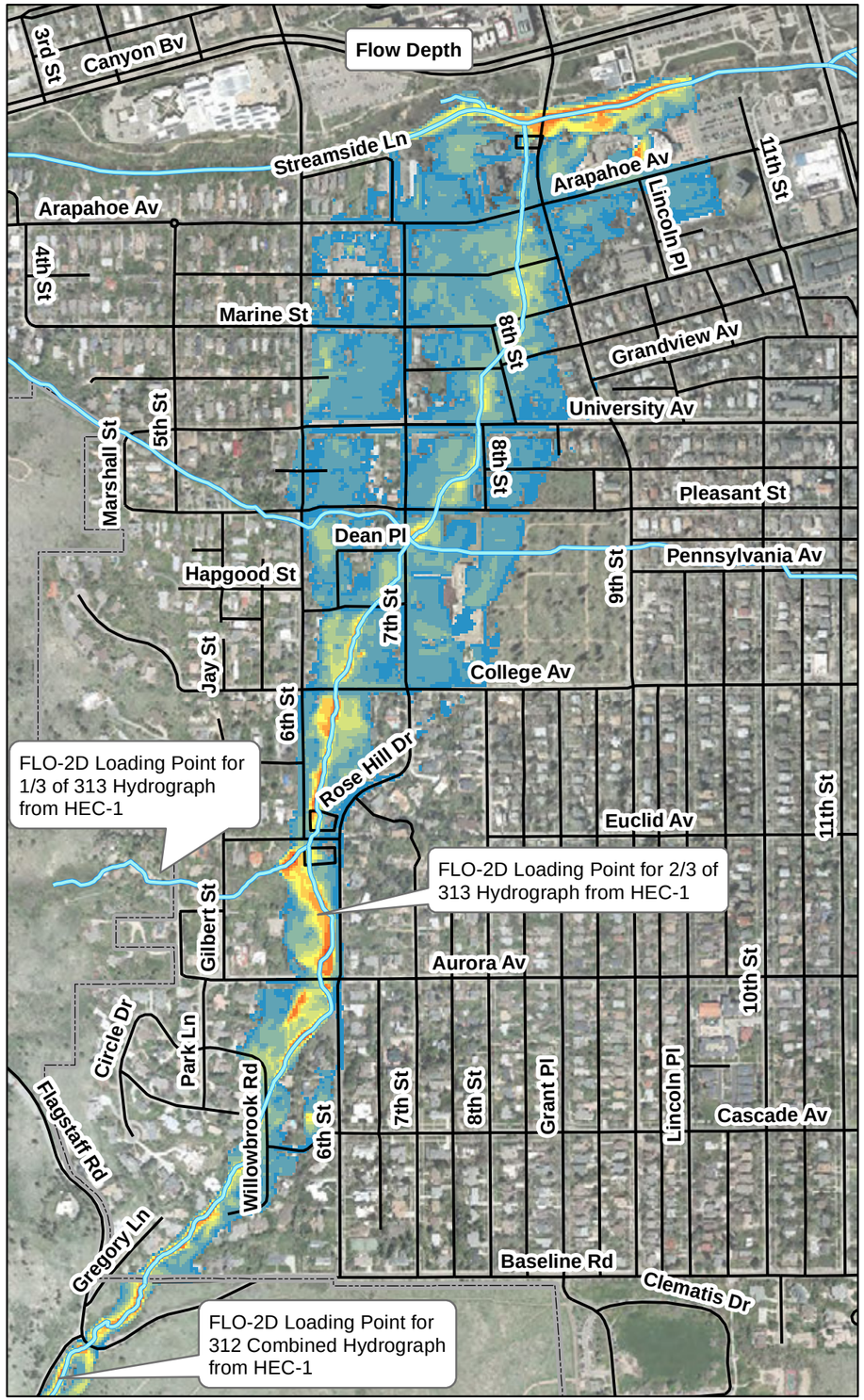
LEGEND
- Creeks and Streams
- Gregory Creek
- Area of Interest
- City Limits
- Gregory Creek Watershed

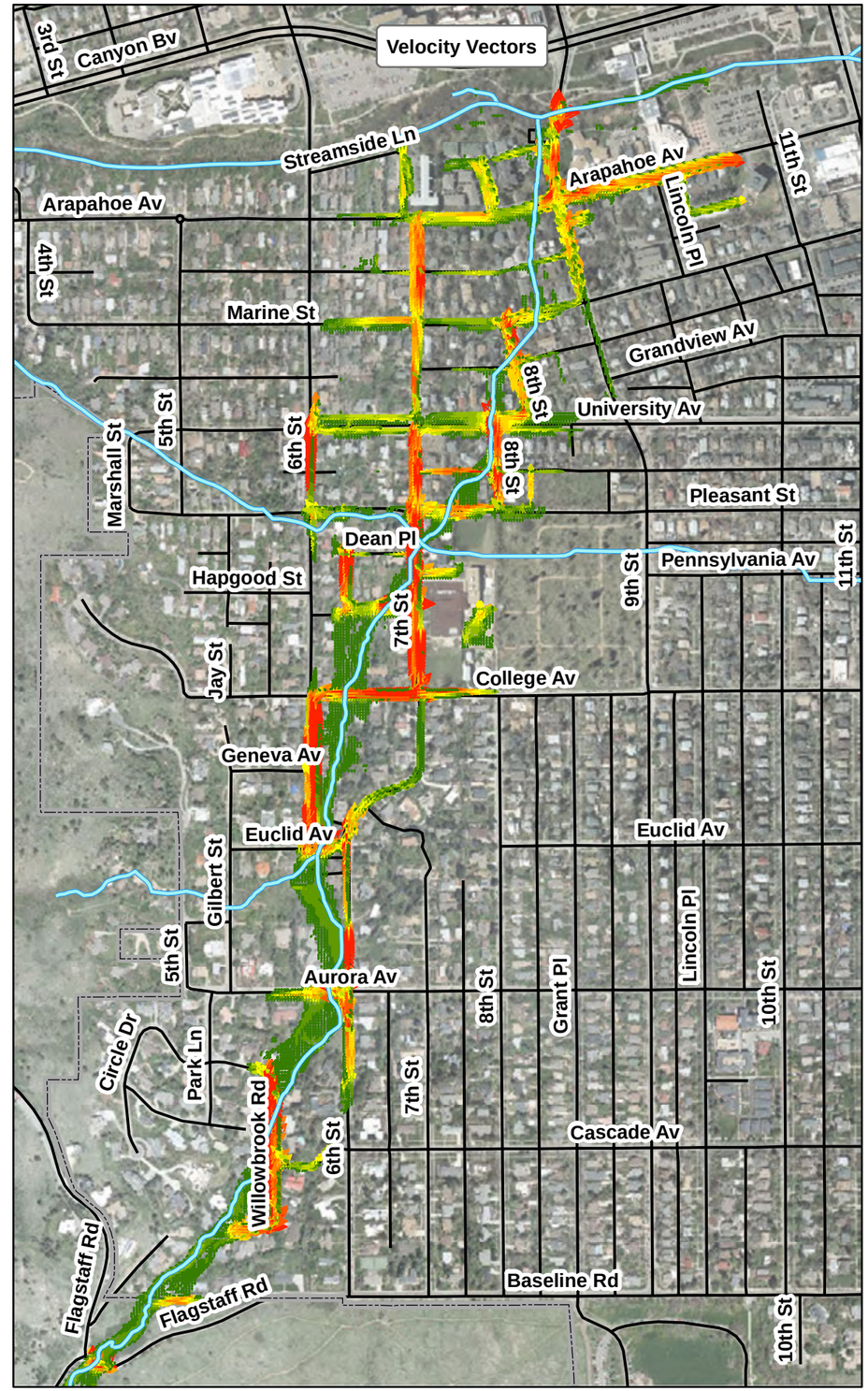
Notes:
1. Area of interest subject to change.

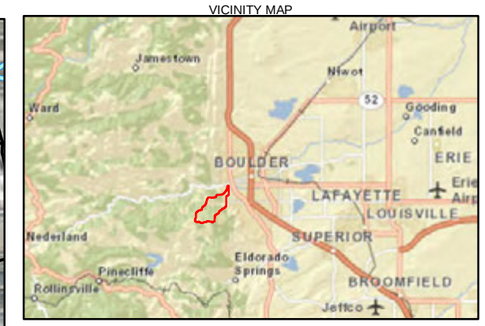
0.25 0.125 0 0.25 Miles

FIGURE 2
Area of Interest
Gregory Canyon Creek Flood Mitigation

CH2MHILL.







LEGEND

Gregory Canyon Creek

Streets

Flow Depth at Cell

Depth (ft)

- 0.5- 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- > 10

Velocity at Cell (Vectors)

Velocity Vectors (fps)

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 -8
- 8 - 9
- 9 - 10
- > 10

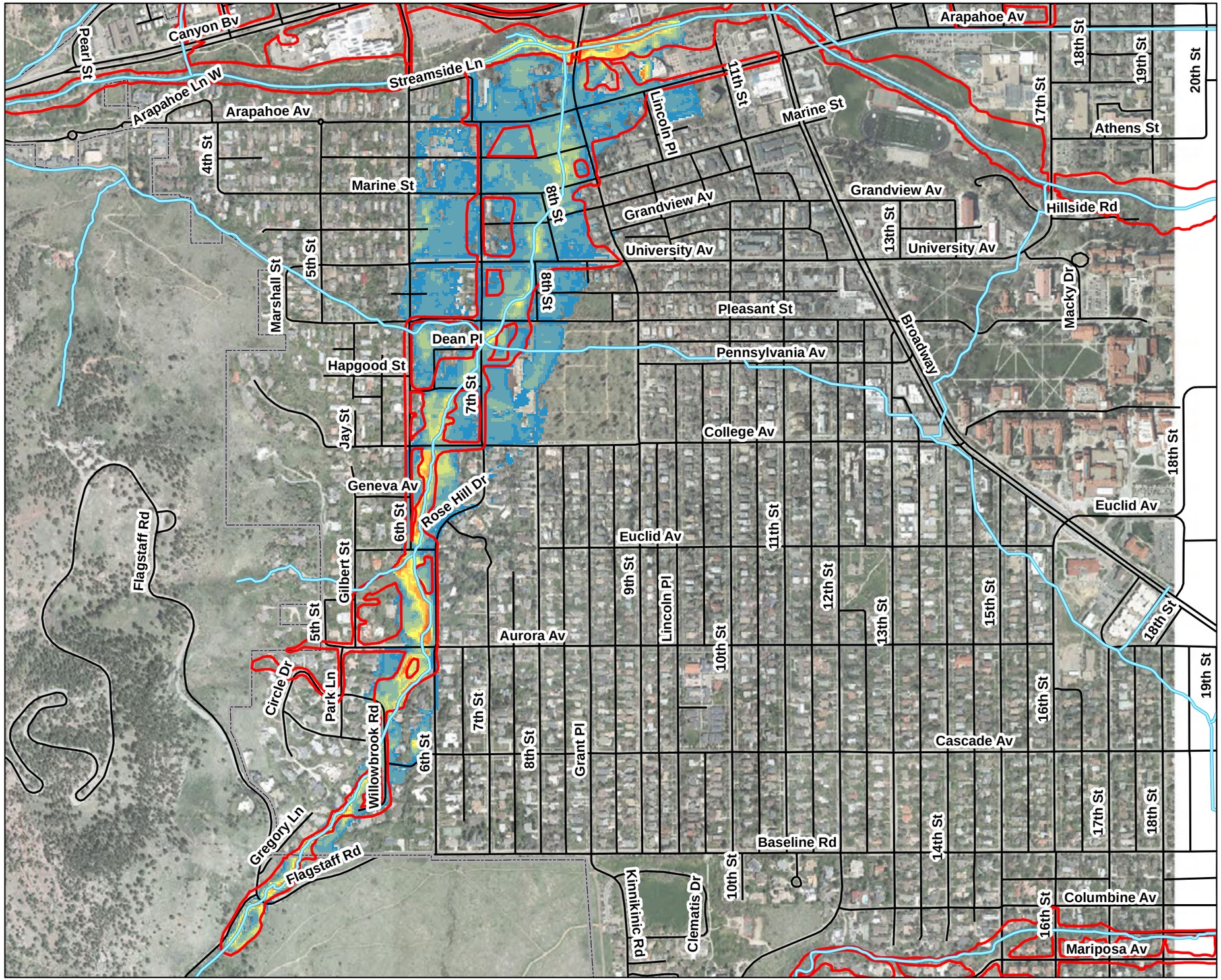
Notes:
1. Velocity in street is represented by velocity vectors.

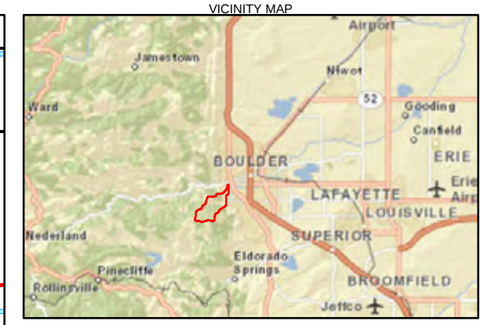
N

0 25 50 100
Feet

FIGURE 3
Existing 100-year 2-D Analysis Floodplain
Gregory Canyon Creek Flood Mitigation

CH2MHILL.





LEGEND

- Sept2013_UrbanFloodExtents
- Gregory Canyon Creek
- Streets

Flow Depth at Cell

Depth (ft)

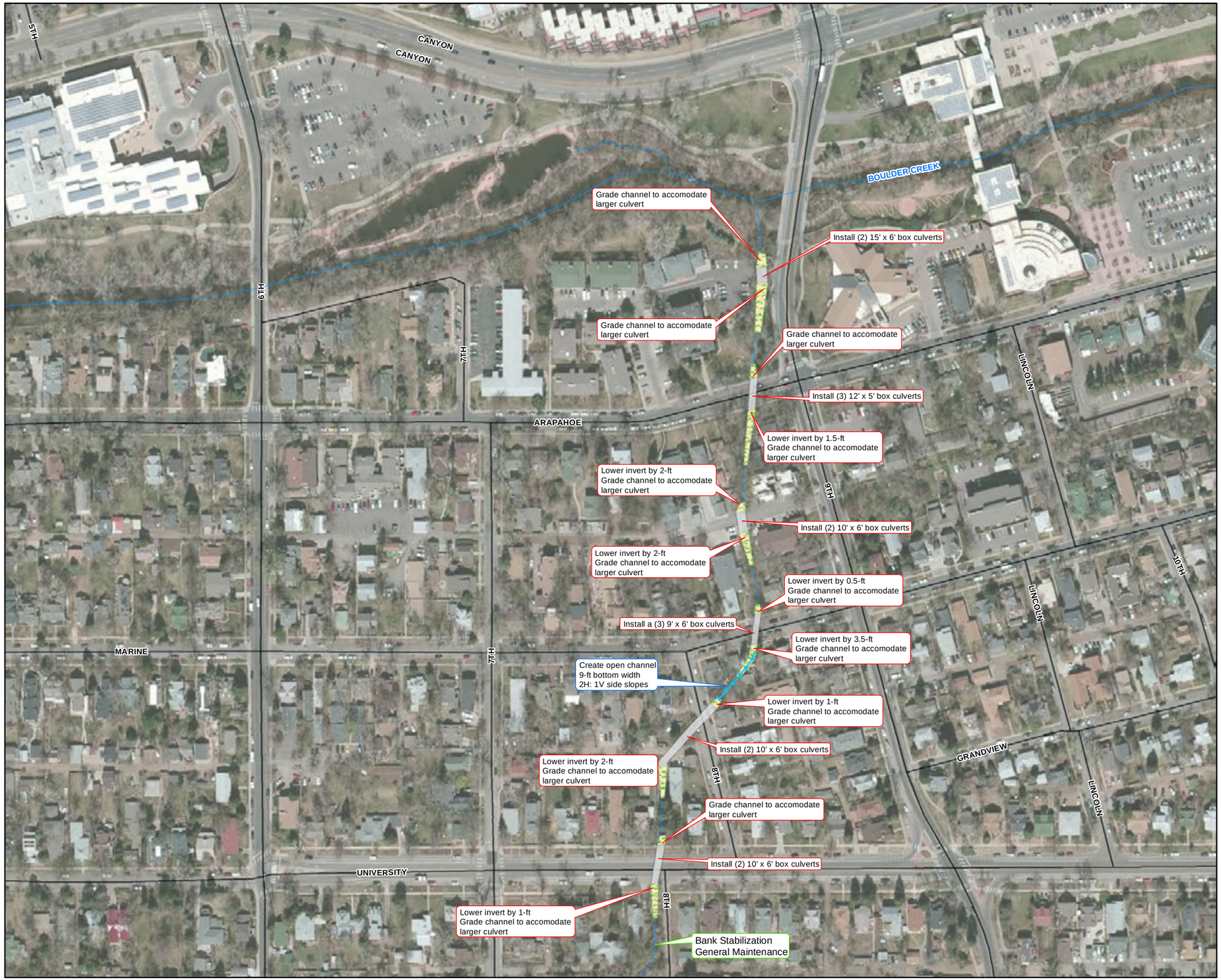
- 0.5- 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- > 10

N

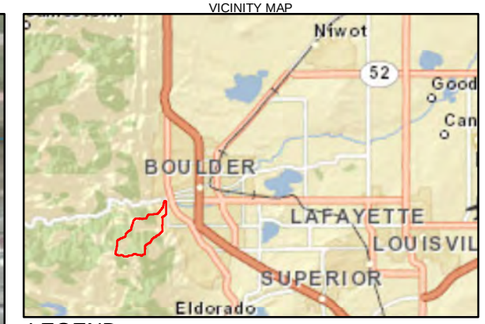
0 25 50 100
Feet

FIGURE 4
Comparison to September 2013 Event
Gregory Canyon Creek Flood Mitigation

CH2MHILL.



VICINITY MAP



LEGEND

- Existing Easements
- Culvert Improvements
- Channel Improvements
- Channel Grading

Notes:

1. Culvert dimensions are width x height (span x rise)

CALLOUT LEGEND

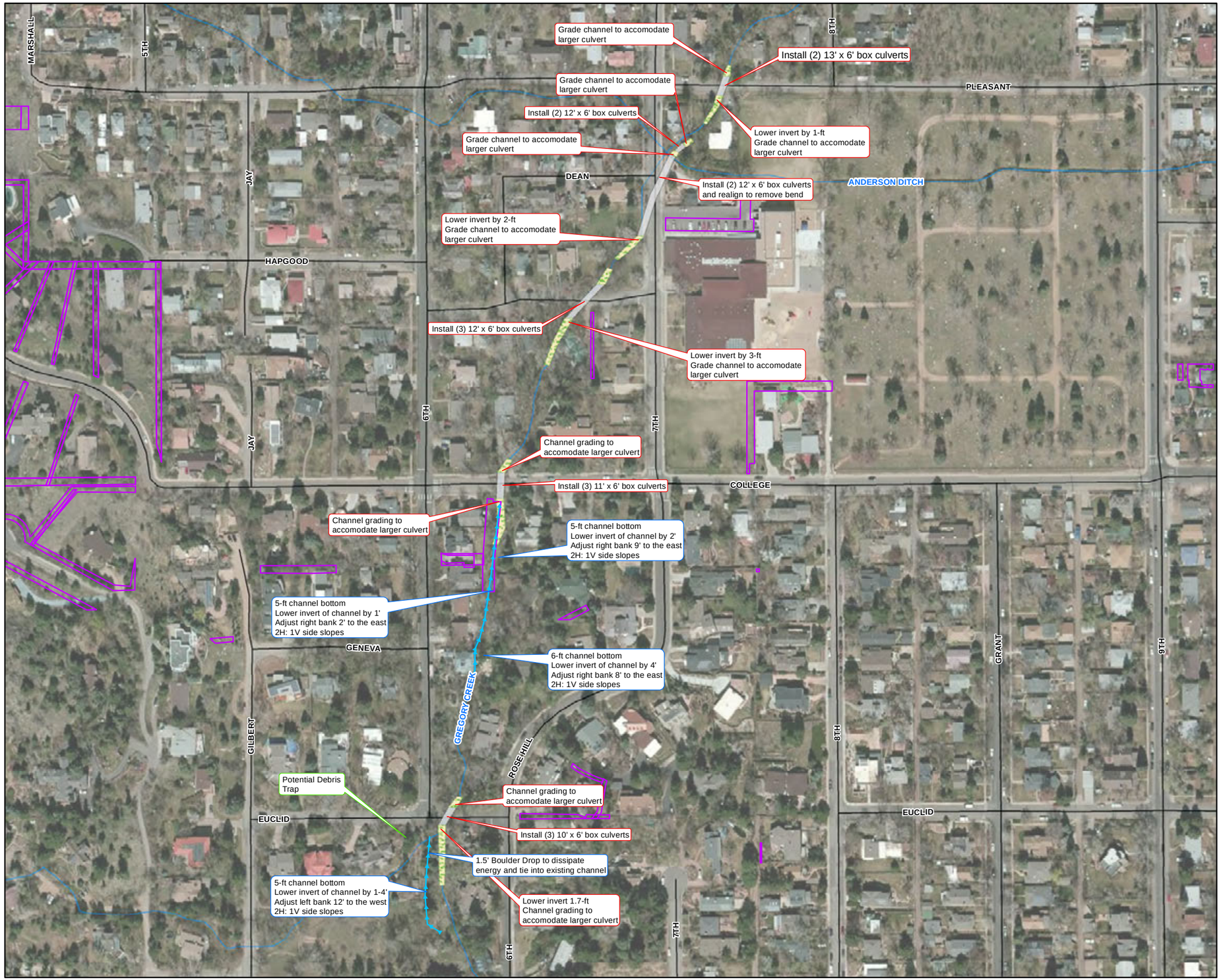
- Infrastructure
- Channel
- General Note

N

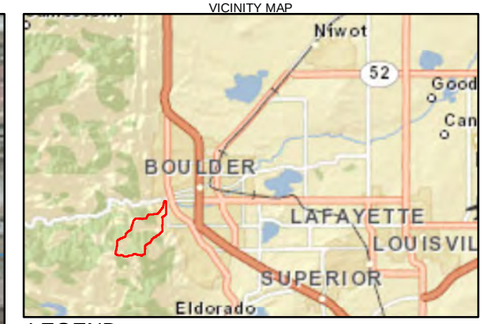
0 100 200 400
Feet

FIGURE 5 (1 of 3)
Category One - Culvert and Channel Improvements
Gregory Canyon Creek Flood Mitigation

CH2MHILL.



VICINITY MAP



LEGEND

- Channel Improvements
- Existing Easements
- Culvert Improvements
- Channel Grading

Notes:
1. Culvert dimensions are width x height (span x rise)

CALLOUT LEGEND

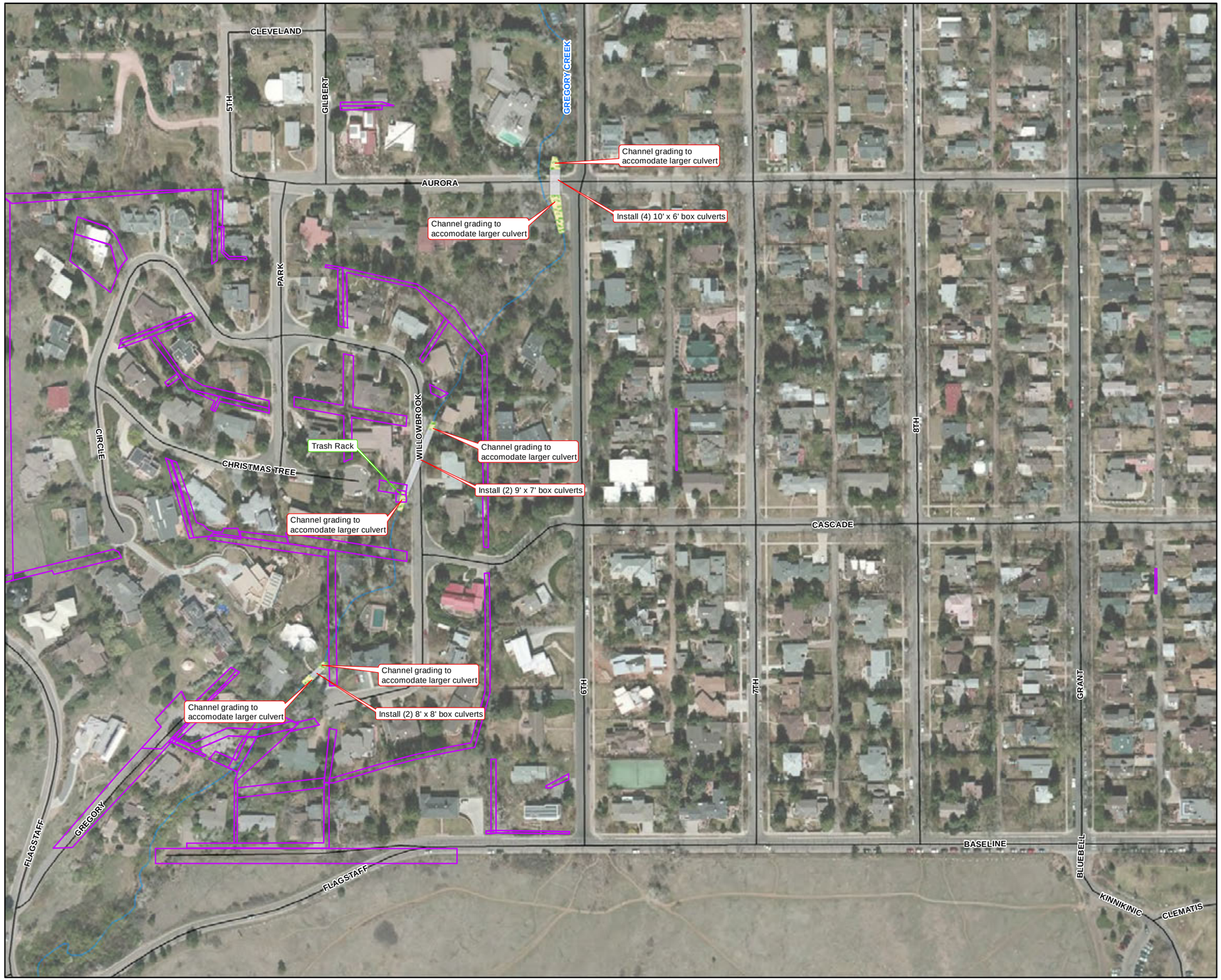
- Infrastructure
- Channel
- General Note

N

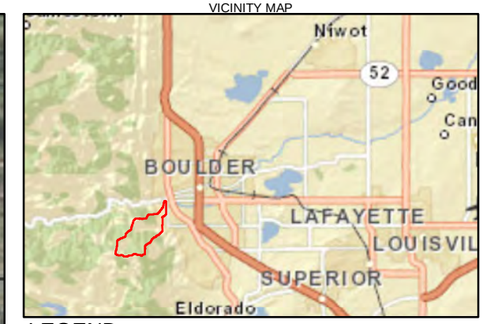
0 100 200 400
Feet

FIGURE 5 (2 of 3)
Category One - Culvert and Channel Improvements
Gregory Canyon Creek Flood Mitigation

CH2MHILL.



VICINITY MAP



LEGEND

- Channel Improvements
- Existing Easements
- Culvert Improvements
- Channel Grading

Notes:
1. Culvert dimensions are width x height (span x rise)

CALLOUT LEGEND

- Infrastructure
- Channel
- General Note

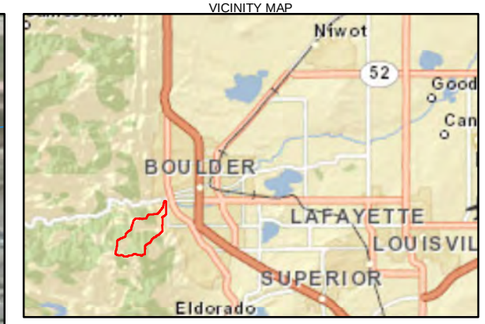
N

0 100 200 400
Feet

FIGURE 5 (3 of 3)
Category One - Culvert and Channel Improvements
Gregory Canyon Creek Flood Mitigation

CH2MHILL.

VICINITY MAP



LEGEND

- Easements
- Street Improvements
- Street Overflows

CALLOUT LEGEND

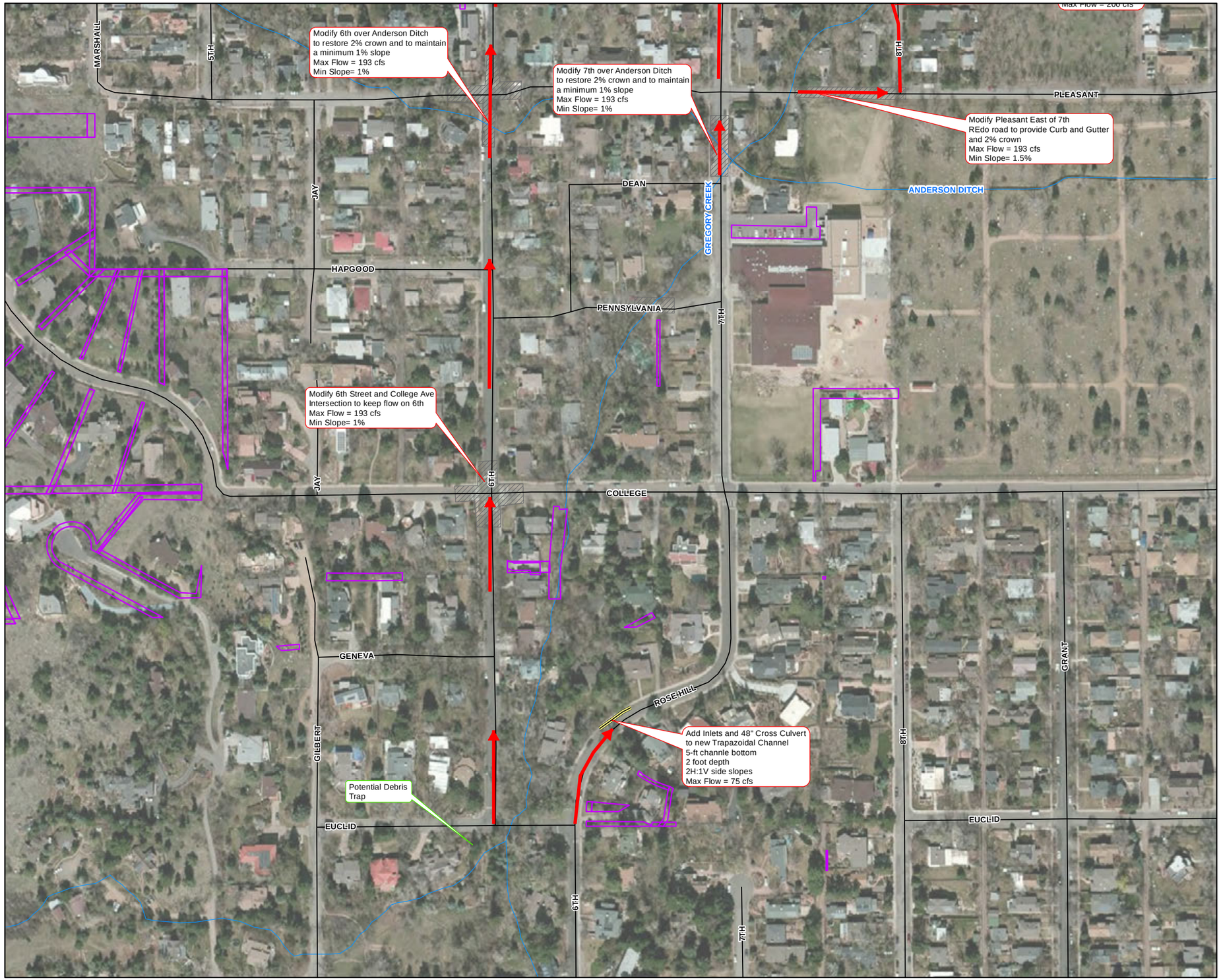
- Infrastructure
- Channel
- General Note

N

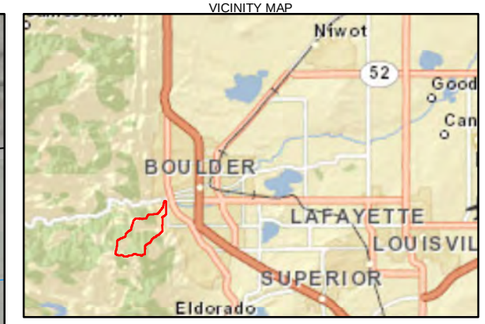
0 100 200 400
Feet

FIGURE 6 (1 of 3)
Category Three - Improvements Outside of the Channel
Gregory Canyon Creek Flood Mitigation

CH2MHILL.



VICINITY MAP



LEGEND

- Easements
- Street Overflows
- Storm_Inlets
- Street Improvements

CALLOUT LEGEND

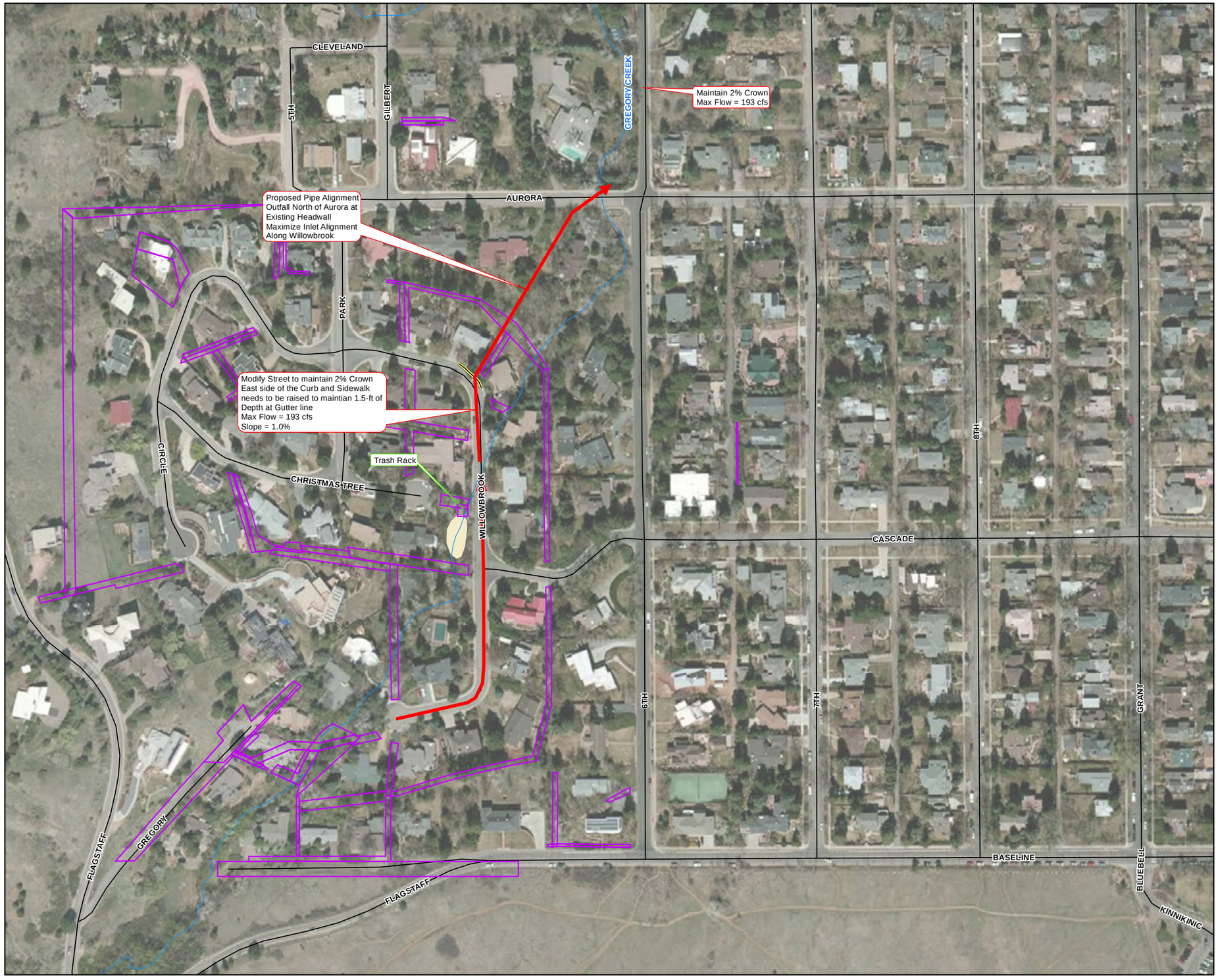
- Infrastructure
- Channel
- General Note

N

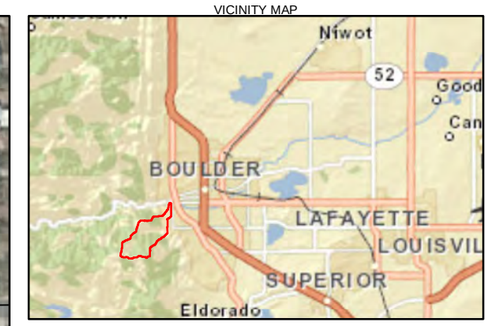
0 100 200 400
Feet

FIGURE 6 (2 of 3)
Category Three - Improvements Outside of the Channel
Gregory Canyon Creek Flood Mitigation

CH2MHILL.



VICINITY MAP



LEGEND

- Easements
- Street Overflows
- Storm_Inlets
- Sediment Trap Locations

CALLOUT LEGEND

- Infrastructure
- Channel
- General Note

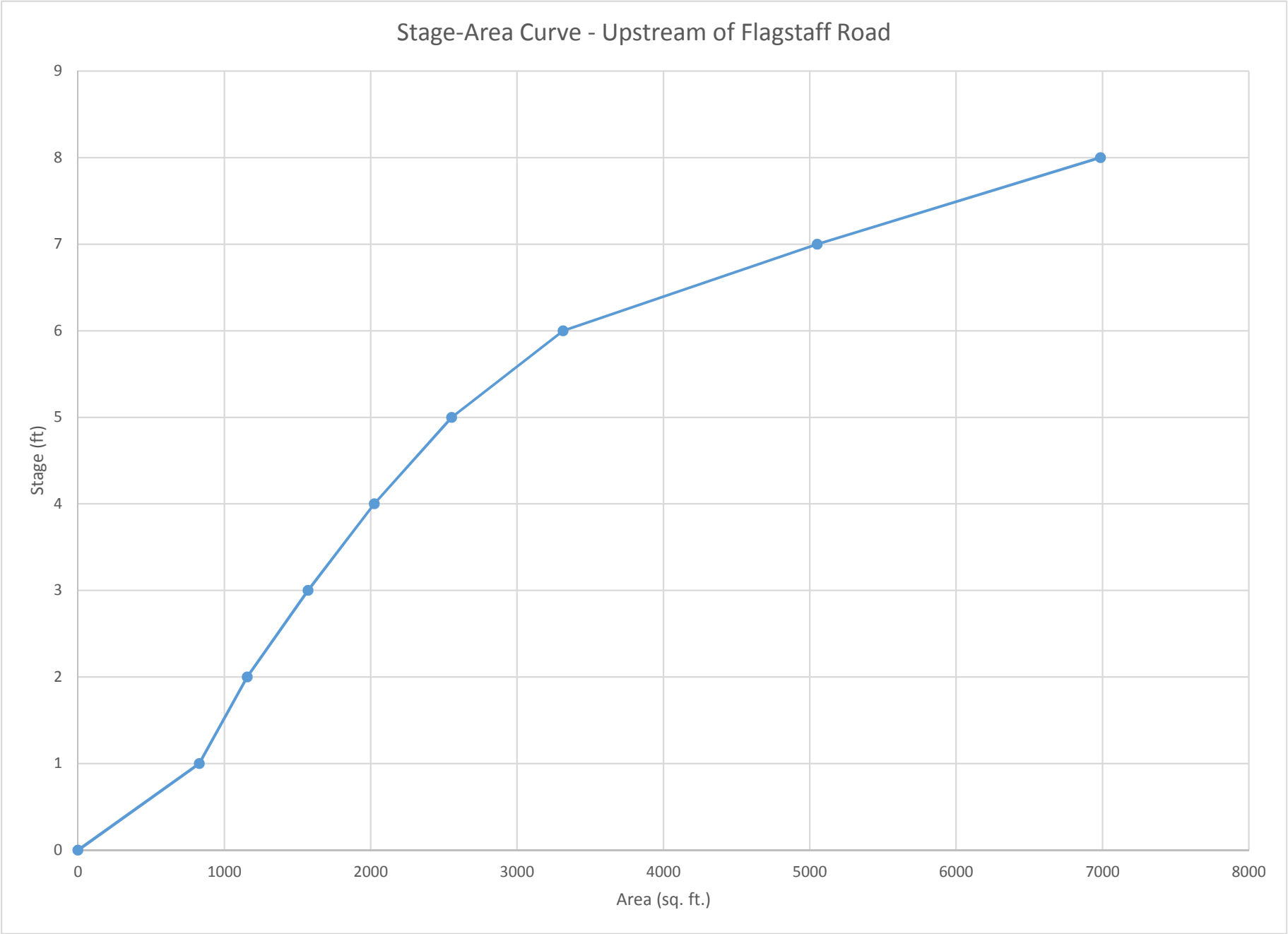
N

0 100 200 400
Feet

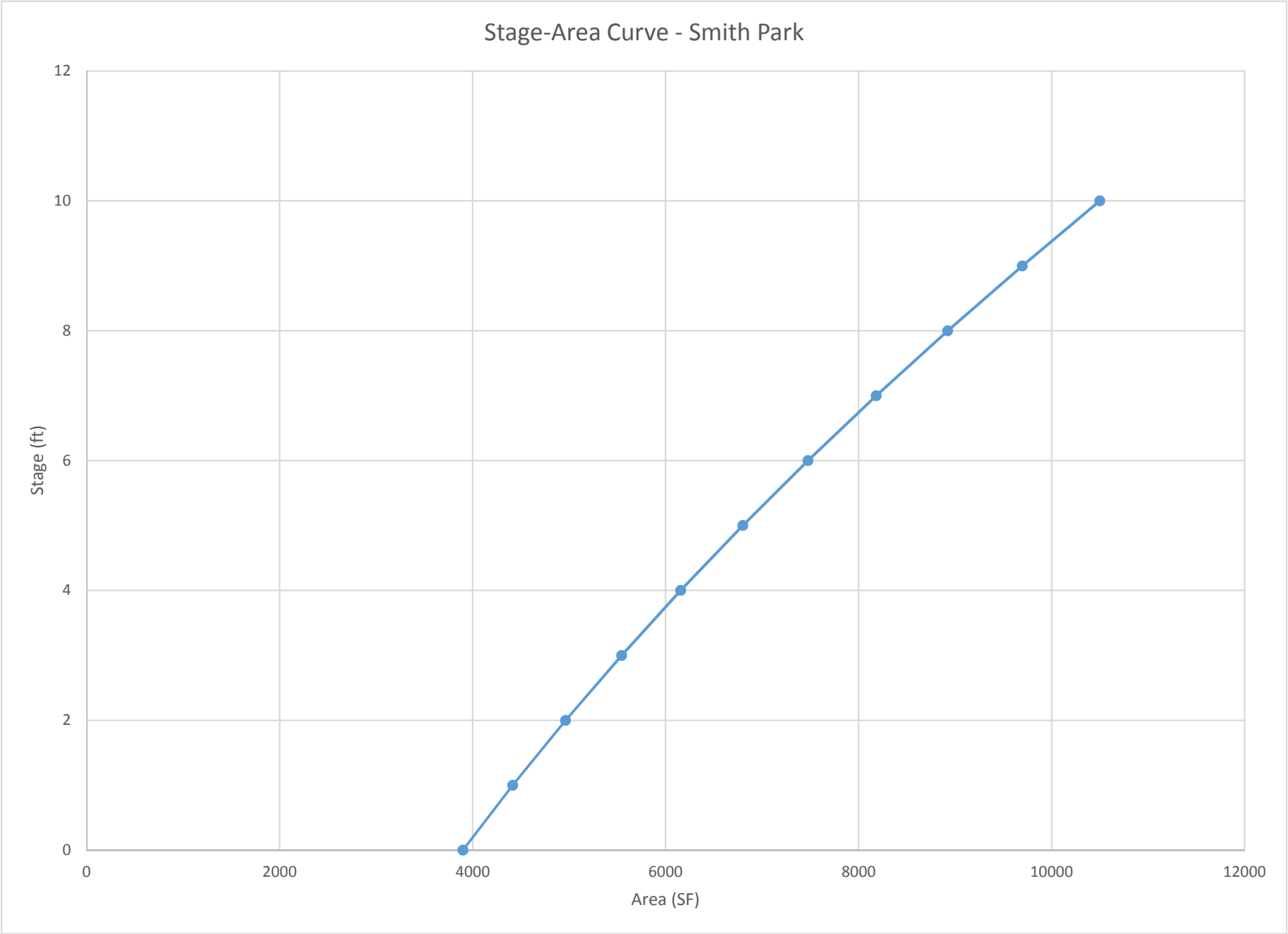
FIGURE 6 (3 of 3)
Category Three - Improvements Outside of the Channel
Gregory Canyon Creek Flood Mitigation

CH2MHILL.

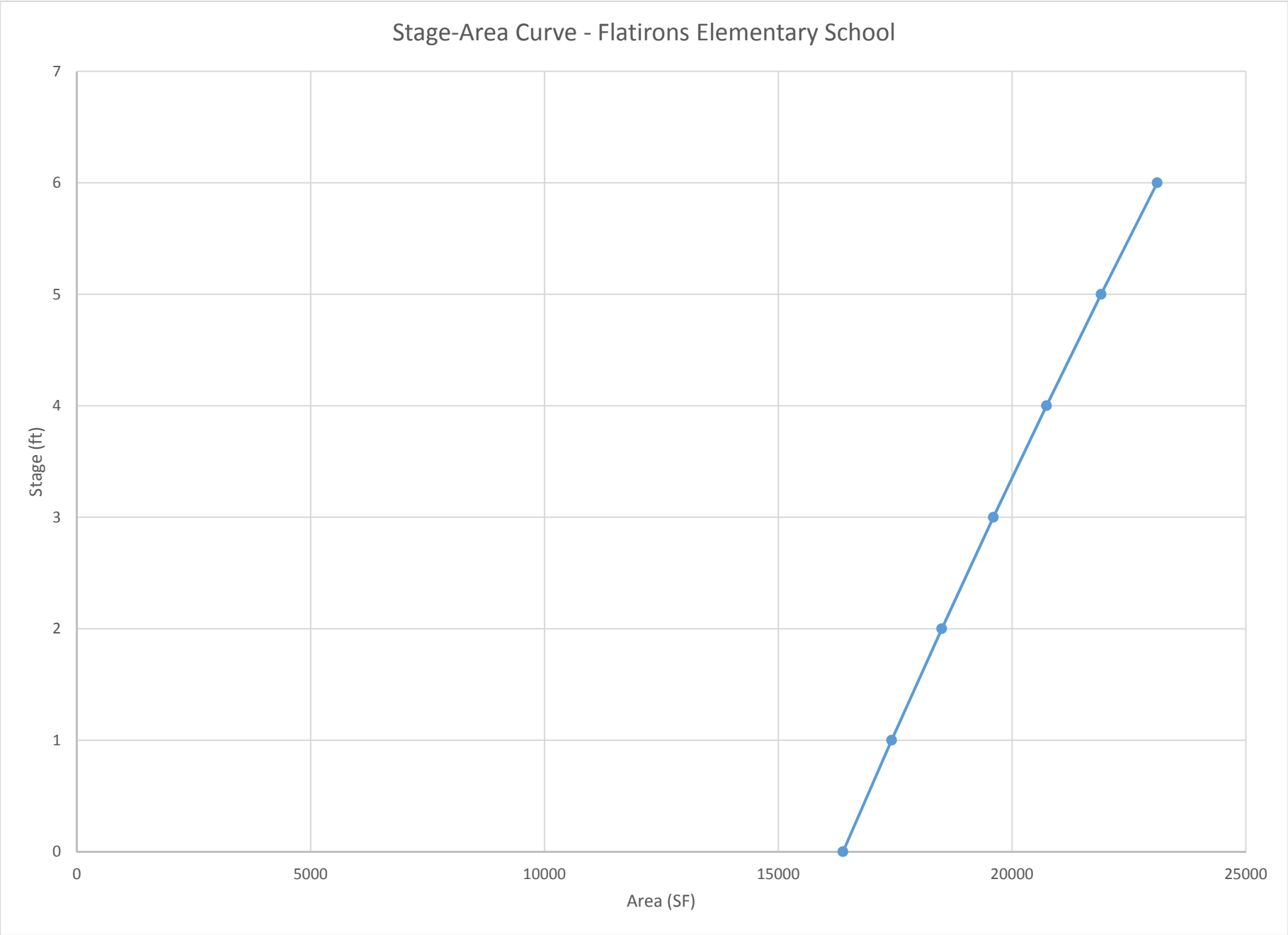
Appendix A


Stage-Area Curve - Upstream of Flagstaff Road
Stage (ft)
0
1
2
3
4
5
6
7
8
9
0
1000
2000
3000
4000
5000
6000
7000
8000
Area (sq. ft.)

Appendix A


Stage-Area Curve - Smith Park
Stage (ft)
Area (SF)
0
2
4
6
8
10
12
0
2000
4000
6000
8000
10000
12000

Appendix A


Stage-Area Curve - Flatirons Elementary School
Stage (ft)
0
1
2
3
4
5
6
7
0
5000
10000
15000
20000
25000
Area (SF)

LEGEND

Creek Centerline

1' Contours (2013)

CountyParcels

Sediment Trap Alternatives

Alt 1 - Offline

Alt 2 - Inline

Alt 3 - Offline

Gregory Canyon Creek Drainage Area = 2.29 sq. miles
2-year Q = 161 cfs
Sediment Load = 229 Tons (116 CY)

Alt 1 Area - 2500 sq. ft, 2' deep, 53% Efficiency (Fine Sand)
Alt 2 Area - 1150 sq. ft, 3' deep, 29% Efficiency (Fine Sand)
Alt 3 Area - 1700 sq. ft, 2' deep, 42% Efficiency (Fine Sand)

N

0 25 50 100
Feet

Sediment Trap Analysis (DRAFT)
Gregory Canyon Creek MDP

CH2MHILL.

Cross Section for Tiered Curb - Irregular Section - 1

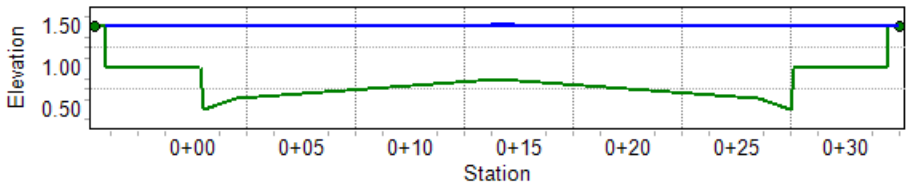
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.01000	ft/ft
Normal Depth	1.00	ft
Discharge	193.06	ft^3/s

Cross Section Image



Technical Appendix

Tables

Table 1: Data Received From City of Boulder

Gregory Creek Master Plan
CH2M Hill
Location: W:\498924_Gregory_Creek\02_Recievables

Description	Filename	From	File Type	Location/Folder	No. of Files	Date Received
Master Plan Calendar	Master Plan Calendar	City of Boulder	PDF	2014.07.22_FromBoulder		7/22/2014
Instructions for Scanning Form	Instructions for Scanning Form	City of Boulder	PDF	Historic Documents		7/22/2014
Asbuilt of 7th street up to Pleasant St	7th_st	City of Boulder	TIFF	As-builts		7/22/2014
Asbuilt of trash rack replacement from 800 Block of Willobrook Rd to 16th St and Iris Ave	2014-04-08_COBTrashRacks_Stamped_Final Submittal	City of Boulder	PDF	As-builts		7/22/2014
Asbuilt of culvert and pipe work along Gregory Creek (1977)	09461	City of Boulder	PDF	As-builts		7/22/2014
Asbuilt of Willowbrook Rd culvert replacement and sewer replacement	22804_22811-GregoryCanyon-WillbrookRd	City of Boulder	PDF	As-builts		7/22/2014
Asbuilt of culvert installations for Aurora Ave, creek improvements along 8th street from university to pleasant	Gregory-Aurora to University	City of Boulder	PDF	As-builts		7/22/2014
Flood Hazard Area Delineation Report for Boulder Creek	Boulder Creek FHAD 1983	City of Boulder	PDF	Mapping		7/22/2014
Letter to Mayor of Boulder and Chair of Boulder County Board of Commissioners regarding LOMR	FEMA Approval Final	City of Boulder	PDF	GCC Final As Approved		7/22/2014
Letter to City of Boulder Utilities reconciling LOMR with LOD from FEMA -- Also the request for letter of map revision	Final LOMR Report Rectified to LOD	City of Boulder	PDF	GCC Final As Approved		7/22/2014
Topo survey from XXXX	ACAD-SURVEY	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Topo survey from 2004	ACAD-SURVEY_2004	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Floodway, 100yr, 500yr firm	ANNO-FIRM-REV-032210	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Floodplain map with HHZ, Floodway, 100yr, 500yr layers	FLOODPLAIN-LAYERS-FINAL-091510	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Floodplain map with HHZ, Floodway, 100yr, 500yr layers - contours are added along with Boulder Creek confluence and floodplain	LOMR-BASEMAP-FINAL-091510	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Main reach profile with 10yr, 50yr, 100yr, 500yr profiles	MAIN-REACH-PROFILE	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Spill reach profile with 10yr, 50yr, 100yr, 500yr profiles	SPILL-REACH-PROFILE	City of Boulder	AutoCAD DWG	CAD		7/22/2014
Boulder Creek Effective model	Bldr-Crk-Effective	City of Boulder	HEC-RAS	HEC-RAS\Bldr-Crk-Effective	2	7/22/2014
Flood Hazard Area Delineation model	FHAD-Model	City of Boulder	HEC-RAS	HEC-RAS\FHAD-Model	2	7/22/2014
Main channel post-project floodway analysis (including HEC-RAS files, text files, and microstation reference file)	MAIN-FW	City of Boulder	HEC-RAS	POST-PROJECT-MODELS\MAIN-FW	7	7/22/2014
Main channel post-project multi-profile analysis (including HEC-RAS files, text files, and microstation reference file)	MAIN-MP	City of Boulder	HEC-RAS	POST-PROJECT-MODELS\MAIN-MP	11	7/22/2014
Spill channel post-project floodway analysis (including HEC-RAS files, text files, and microstation reference file)	SPILL-FW	City of Boulder	HEC-RAS	POST-PROJECT-MODELS\SPILL-FW	12	7/22/2014
Spill channel post-project multi-profile analysis (including HEC-RAS files, text files, and microstation reference file)	SPILL-MP	City of Boulder	HEC-RAS	POST-PROJECT-MODELS\SPILL-MP	14	7/22/2014
FHAD versus Post Project cross sections and water surface elevations	FHAD-vs-Revised	City of Boulder	PDF	POST-PROJECT-MODELS\Supplemental-Models&Tables		7/22/2014
FlowMaster report of rectangular channels showing hydraulic information	FlowMaster-Report	City of Boulder	PDF	POST-PROJECT-MODELS\Supplemental-Models&Tables		7/22/2014
Flow path delineation for water that leaves the main the channel and flows through streets, etc.	Flow-Path Delineations	City of Boulder	PDF	POST-PROJECT-MODELS\Supplemental-Models&Tables		7/22/2014
Table of shallow flooding areas with cross section and location	Shallow-Flooding-Table	City of Boulder	PDF	POST-PROJECT-MODELS\Supplemental-Models&Tables		7/22/2014

Flowmaster shallow flooding sections file	SHALLOW-FLOOD-SECTIONS.FM2	City of Boulder	Flowmaster (.FM2)	POST-PROJECT-MODELS\Supplemental-Models&Tables		7/22/2014
High Hazard Zone ReAnalysis prepared by Belt Collins West in 2010	HHZ-Final as Approved	City of Boulder	PDF	HHZ		7/22/2014
Spreadsheet for older High Hazard Zone Analysis for downstream end performed by Love & Associates, Inc. (Belt Collins West)	HHZ Cross Section Output Gregory Main Channel DS Half 2-2-9	City of Boulder	Excel (XLSX)	HHZ\OLD HHZ 2-2-9		7/22/2014
Spreadsheet for older High Hazard Zone Analysis for upstream end performed by Love & Associates, Inc. (Belt Collins West)	HHZ Cross Section Output Gregory Main Channel US Half 2-2-9	City of Boulder	Excel (XLSX)	HHZ\OLD HHZ 2-2-9		7/22/2014
Spreadsheet for older High Hazard Zone Analysis for spill channel performed by Love & Associates, Inc. (Belt Collins West)	HHZ Cross Section Output Gregory Spill 2-2-9	City of Boulder	Excel (XLSX)	HHZ\OLD HHZ 2-2-9		7/22/2014
Major Drainageway Planning Phase A from July 1984 performed by Greenhorne & O'Mara, Inc.	Boulder Adj County MDP Ph A 1984	City of Boulder	PDF	Master planning documents		7/22/2014
Major Drainageway Planning Phase B from May 1987 performed by Greenhorne & O'Mara, Inc.	Boulder Adj County MDP Ph B 1987	City of Boulder	PDF	Master planning documents		7/22/2014
Flood Hazard Area Delineation for Boulder and Adjacent County Drainageways from May 1987 performed by Greehorne & O'Mara Inc.	Boulder and Adjacent County Drainageways FHAD 1987	City of Boulder	PDF	Master planning documents		7/22/2014
Creek Mitigation Analysis for Gregory Creek performed by WHPacific in July 2012	Gregory Canyon Creek Mitigation Analysis	City of Boulder	PDF	Master planning documents		7/22/2014
Mini Master Plan performed by Belt Collins West in March 2009	HHZ Mini Master Plan - Final as Approved	City of Boulder	PDF	Master planning documents		7/22/2014
Pennsylvania Avenue Flood Repair/Improvement Alternative Analysis performed by XXXXX in April 2014	Penn Ave Alt Analysis	City of Boulder	PDF	Master planning documents		7/22/2014
Field verification of culvert structures along Gregory Creek provided by City of Boulder	BoulderFieldChecks	City of Boulder	Shapefile (.shp)	Culvert Verification	8	8/4/2014
LiDar data in CAD format	328	City of Boulder	AutoCAD DWG	LiDAR		8/5/2014
LiDar data in CAD format	349	City of Boulder	AutoCAD DWG	LiDAR		8/5/2014
LiDar data in CAD format	350	City of Boulder	AutoCAD DWG	LiDAR		8/5/2014
LiDar data in CAD format	371	City of Boulder	AutoCAD DWG	LiDAR		8/5/2014
LiDar data in CAD format	372	City of Boulder	AutoCAD DWG	LiDAR		8/5/2014
Lidar data in GIS format	328	City of Boulder	Shapefile (.shp)	LiDAR	10	8/5/2014
Lidar data in GIS format	349	City of Boulder	Shapefile (.shp)	LiDAR	10	8/5/2014
Lidar data in GIS format	350	City of Boulder	Shapefile (.shp)	LiDAR	10	8/5/2014
Lidar data in GIS format	371	City of Boulder	Shapefile (.shp)	LiDAR	10	8/5/2014
Lidar data in GIS format	372	City of Boulder	Shapefile (.shp)	LiDAR	10	8/5/2014
LiDar data in Digital Elevation Model (DEM) format	328	City of Boulder	DEM	LiDAR	10	8/5/2014
LiDar data in Digital Elevation Model (DEM) format	349	City of Boulder	DEM	LiDAR	10	8/5/2014
LiDar data in Digital Elevation Model (DEM) format	350	City of Boulder	DEM	LiDAR	10	8/5/2014
LiDar data in Digital Elevation Model (DEM) format	371	City of Boulder	DEM	LiDAR	10	8/5/2014
LiDar data in Digital Elevation Model (DEM) format	372	City of Boulder	DEM	LiDAR	10	8/5/2014
Gregory Creek Colorado Urban Hydrograph Procedure (CUHP) developed in 1986	Gregory Creek CUHP 1986	UDFCD	PDF			8/6/2014
HEC1 input and output for the Gregory Creek CUHP model	Gregory Creek HEC1 1986	UDFCD	PDF			8/6/2014
Hydrographs pulled from HEC1 model used for Gregory Creek	HEC1 1986 Hydrographs	UDFCD	Excel (XLSX)			8/6/2014
Notes from the site walk with City of Boulder, UDFCD and CH2M HILL examining the structures and discussing potential solutions for alternatives	Site walk notes	City of Boulder	PDF			8/11/2014
September 2013 flood extents	Sept2013_UrbanFloodExtents	City of Boulder	Shapefile (.shp)		6	8/19/2014

Appendix A

Table 2a: Effective 100-year Hydraulic Output

HEC-RAS Plan: Multi-profil River: RIVER-1 Reach: Reach-1 Profile: 100-year

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	600	100-year	1450.00	5750.20	5756.85	5756.85	5758.45	0.038880	10.98	175.50	60.17	0.82
Reach-1	590	100-year	1450.00	5718.23	5735.87	5730.31	5735.92	0.000876	2.53	973.97	161.14	0.11
Reach-1	585		Culvert									
Reach-1	580	100-year	1450.00	5717.80	5729.90	5729.90	5735.89	0.040251	19.64	73.82	88.34	1.00
Reach-1	560	100-year	1450.00	5684.47	5694.47	5693.18	5694.75	0.011242	5.70	419.85	133.66	0.36
Reach-1	555		Culvert									
Reach-1	550	100-year	1450.00	5683.10	5690.53	5690.53	5693.07	0.009648	14.73	168.71	48.50	1.02
Reach-1	540	100-year	1450.00	5660.98	5668.23	5668.23	5669.92	0.024603	11.70	156.41	46.95	1.04
Reach-1	530	100-year	1450.00	5652.10	5660.01	5660.01	5661.83	0.018625	10.93	141.55	46.24	0.94
Reach-1	520	100-year	1450.00	5645.52	5658.50	5657.66	5658.86	0.003028	6.00	528.70	144.84	0.31
Reach-1	515		Culvert									
Reach-1	510	100-year	1450.00	5643.57	5654.01	5654.01	5654.54	0.003467	6.31	339.68	80.77	0.36
Reach-1	508	100-year	1450.00	5640.03	5646.62	5646.62	5648.30	0.037649	10.49	146.30	49.62	0.98
Reach-1	507	100-year	1450.00	5639.21	5645.29	5645.29	5646.87	0.033230	10.35	158.98	54.52	0.95
Reach-1	505	100-year	1450.00	5638.27	5644.00	5644.00	5645.41	0.032480	10.18	185.63	75.13	0.94
Reach-1	500	100-year	1450.00	5625.60	5635.37	5634.97	5636.39	0.022416	9.78	276.81	125.14	0.55
Reach-1	495		Bridge									
Reach-1	490	100-year	1450.00	5624.40	5634.00	5634.00	5635.06	0.026436	9.96	264.01	125.71	0.57
Reach-1	470	100-year	1450.00	5607.68	5621.07	5614.06	5621.42	0.003823	5.22	439.53	128.91	0.26
Reach-1	465		Culvert									
Reach-1	460	100-year	1450.00	5603.33	5612.65	5612.65	5617.29	0.020842	17.28	83.92	96.84	1.00
Reach-1	455	100-year	1700.00	5596.39	5604.21	5604.21	5606.38	0.028299	11.84	148.33	39.92	0.98
Reach-1	450	100-year	1700.00	5590.81	5599.19	5599.19	5600.78	0.026792	10.27	182.25	106.22	0.93
Reach-1	440	100-year	1700.00	5587.69	5593.97	5593.97	5595.25	0.023836	9.76	254.43	136.04	0.89
Reach-1	436	100-year	1700.00	5578.63	5584.23	5584.23	5585.08	0.016562	9.62	410.40	224.64	0.78
Reach-1	431	100-year	1700.00	5571.70	5581.24	5578.80	5581.77	0.006021	6.76	494.40	217.07	0.40
Reach-1	425		Culvert									
Reach-1	420	100-year	1700.00	5571.10	5578.20	5578.20	5581.68	0.022498	14.97	113.58	124.36	0.99
Reach-1	410	100-year	1700.00	5565.61	5573.36	5570.92	5573.99	0.007520	6.39	266.98	59.28	0.50
Reach-1	405		Culvert									
Reach-1	400	100-year	1700.00	5563.35	5568.13	5566.97	5569.13	0.012078	8.04	211.36	59.64	0.67
Reach-1	398	100-year	1700.00	5563.39	5566.67	5566.67	5568.18	0.055920	12.44	216.26	89.81	1.33
Reach-1	395	100-year	1700.00	5555.00	5560.98	5560.98	5562.73	0.037266	10.61	161.08	48.30	1.01
Reach-1	390	100-year	1700.00	5551.40	5556.73	5556.73	5557.87	0.035820	10.19	257.62	108.50	0.98
Reach-1	389	100-year	1700.00	5550.00	5554.69	5554.69	5555.84	0.040472	10.35	249.04	105.65	1.04
Reach-1	385	100-year	1700.00	5537.75	5541.85	5541.85	5542.85	0.082417	11.83	240.83	115.58	1.35
Reach-1	380	100-year	1700.00	5529.50	5537.31	5536.86	5537.73	0.011916	6.26	389.63	203.44	0.56
Reach-1	375		Culvert									
Reach-1	370	100-year	1700.00	5527.68	5534.13	5534.13	5534.57	0.006855	5.88	465.53	213.82	0.46
Reach-1	360	100-year	1700.00	5511.80	5518.90	5518.90	5520.81	0.034722	11.20	162.13	49.18	0.95
Reach-1	352	100-year	1700.00	5507.30	5515.91	5514.42	5516.76	0.009700	8.62	308.02	138.43	0.56
Reach-1	351	100-year	1700.00	5506.80	5513.84	5513.84	5516.23	0.038249	12.41	140.01	63.47	0.97
Reach-1	350	100-year	1700.00	5503.40	5510.38	5510.38	5512.43	0.036908	11.49	147.99	36.51	1.01
Reach-1	342	100-year	1700.00	5494.95	5501.69	5501.69	5503.95	0.039860	13.71	182.40	53.93	1.08
Reach-1	340	100-year	1700.00	5493.14	5500.02	5500.02	5500.92	0.021112	8.73	341.61	219.50	0.75
Reach-1	334	100-year	1700.00	5488.11	5496.03		5497.34	0.017928	9.62	232.16	85.62	0.72
Reach-1	330	100-year	1700.00	5485.84	5495.23	5495.07	5496.17	0.018433	8.72	331.63	179.63	0.66
Reach-1	325		Culvert									
Reach-1	318	100-year	1900.00	5485.27	5493.73	5493.73	5494.51	0.024436	10.31	420.16	211.85	0.70
Reach-1	304	100-year	1900.00	5484.40	5491.10	5489.24	5491.69	0.007839	6.33	357.61	178.90	0.48
Reach-1	303		Bridge									
Reach-1	302	100-year	1900.00	5483.05	5487.95	5487.95	5489.29	0.032033	10.47	254.27	90.82	0.93
Reach-1	301	100-year	1900.00	5479.08	5484.81	5484.81	5486.17	0.022681	9.81	258.28	121.68	0.82
Reach-1	300	100-year	1900.00	5475.10	5479.93	5479.93	5480.86	0.031059	8.66	318.58	168.21	0.90
Reach-1	295	100-year	1900.00	5470.26	5474.88	5474.88	5475.76	0.039266	8.31	314.26	211.21	0.98
Reach-1	291	100-year	1900.00	5468.09	5472.49	5472.49	5473.34	0.026610	9.41	396.31	222.86	0.87
Reach-1	290	100-year	1900.00	5464.32	5470.48	5470.48	5471.36	0.018903	9.14	411.06	248.01	0.75
Reach-1	285		Culvert									
Reach-1	280	100-year	1900.00	5461.70	5467.89	5467.89	5468.21	0.009471	6.37	578.03	218.68	0.53
Reach-1	270	100-year	1900.00	5451.44	5458.04	5458.04	5459.11	0.012260	9.60	381.62	187.38	0.72
Reach-1	265		Culvert									
Reach-1	260	100-year	1900.00	5438.86	5447.50	5444.67	5448.11	0.004071	6.42	361.09	113.91	0.43
Reach-1	255		Culvert									
Reach-1	250	100-year	1900.00	5438.24	5446.48	5445.29	5447.11	0.006830	6.86	400.50	154.29	0.53
Reach-1	231	100-year	1900.00	5434.97	5444.40	5444.40	5445.82	0.032961	12.40	287.97	99.55	0.73
Reach-1	230	100-year	1900.00	5434.90	5443.56	5443.56	5444.92	0.026172	11.89	302.12	99.93	0.74
Reach-1	225		Culvert									
Reach-1	220	100-year	1900.00	5433.65	5440.67	5440.67	5441.57	0.029064	10.50	376.40	177.34	0.80
Reach-1	219	100-year	1900.00	5431.60	5437.71	5437.71	5438.59	0.041552	9.33	318.30	162.35	0.99
Reach-1	200	100-year	1900.00	5420.59	5427.24	5427.24	5428.76	0.039580	9.91	192.75	66.66	1.01
Reach-1	190	100-year	1900.00	5414.10	5423.33	5420.31	5423.54	0.004739	3.67	596.46	310.94	0.36
Reach-1	185		Culvert									
Reach-1	180	100-year	2092.00	5410.57	5420.01	5420.01	5420.11	0.003214	3.18	1217.59	674.14	0.30
Reach-1	175	100-year	2092.00	5408.70	5415.83	5415.83	5416.40	0.030651	7.26	483.53	374.88	0.85
Reach-1	170	100-year	2092.00	5404.97	5411.47	5409.06	5411.71	0.003619	4.38	828.55	481.65	0.34
Reach-1	165		Culvert									
Reach-1	160	100-year	2092.00	5398.60	5404.81		5405.04	0.003637	4.21	732.13	281.54	0.34
Reach-1	152	100-year	2092.00	5396.42	5403.72	5403.72	5404.48	0.027475	8.45	435.92	262.55	0.84
Reach-1	151		Culvert									

Table 2a: Effective 100 - year Hydraulic Output

HEC-RAS Plan: Multi-profil River: RIVER-1 Reach: Reach-1 Profile: 100-year (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	150	100-year	2092.00	5393.63	5401.77	5401.77	5402.53	0.029509	10.54	468.31	242.77	0.67
Reach-1	130	100-year	2092.00	5393.48	5401.19	5401.19	5401.77	0.015732	8.97	667.32	476.01	0.60
Reach-1	125		Culvert									
Reach-1	120	100-year	2092.00	5389.00	5398.53	5398.53	5399.54	0.025696	8.70	358.11	229.03	0.80
Reach-1	119.9		Lat Struct									
Reach-1	110	100-year	2092.00	5387.39	5394.36	5394.36	5395.46	0.027042	10.34	365.31	167.32	0.88
Reach-1	100	100-year	2078.55	5383.00	5390.52	5390.52	5391.42	0.020586	10.43	454.21	234.73	0.73
Reach-1	95		Culvert									
Reach-1	90	100-year	2078.55	5383.14	5388.97	5388.97	5389.95	0.025933	10.61	392.68	183.54	0.86
Reach-1	89.9		Lat Struct									
Reach-1	60	100-year	1020.47	5374.50	5381.27	5379.67	5381.81	0.008189	6.30	241.21	135.42	0.48
Reach-1	55		Culvert									
Reach-1	50	100-year	1020.47	5372.70	5378.87	5378.87	5379.49	0.013344	7.46	235.74	97.87	0.56
Reach-1	49.9		Lat Struct									
Reach-1	45	100-year	883.31	5369.49	5375.46	5375.46	5376.58	0.025955	8.72	124.72	75.98	0.82
Reach-1	40	100-year	866.48	5363.57	5372.92	5370.77	5373.14	0.004936	4.09	303.93	153.24	0.36
Reach-1	35		Culvert									
Reach-1	30	100-year	866.48	5362.31	5370.77	5370.77	5370.93	0.002204	3.22	308.31	130.74	0.26
Reach-1	10	100-year	866.48	5356.30	5361.42	5360.20	5362.11	0.011073	6.77	141.35	44.00	0.58

Appendix A

Table 2b: Ch2M HILL Existing 100 - year Hydraulic Output

HEC-RAS Plan: MP Exist 072014 River: RIVER-1 Reach: Reach-1 Profile: 100-year

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	600	100-year	1450.00	5750.20	5756.85	5756.85	5758.45	0.038880	10.98	175.50	60.17	0.82
Reach-1	590	100-year	1450.00	5718.23	5735.89	5730.31	5735.94	0.000868	2.52	977.51	161.26	0.11
Reach-1	585		Culvert									
Reach-1	580	100-year	1450.00	5717.80	5729.90	5729.90	5735.89	0.040251	19.64	73.82	88.34	1.00
Reach-1	560	100-year	1450.00	5684.47	5694.47	5693.18	5694.75	0.011242	5.70	419.85	133.66	0.36
Reach-1	555		Culvert									
Reach-1	550	100-year	1450.00	5683.10	5690.54	5690.54	5693.07	0.009615	14.71	169.00	48.60	1.01
Reach-1	540	100-year	1450.00	5660.98	5668.23	5668.23	5669.92	0.024603	11.70	156.41	46.95	1.04
Reach-1	530	100-year	1450.00	5652.10	5660.01	5660.01	5661.83	0.018610	10.92	141.60	46.25	0.94
Reach-1	520	100-year	1450.00	5645.52	5658.56	5657.67	5658.90	0.002927	5.91	537.13	145.29	0.31
Reach-1	515		Culvert									
Reach-1	510	100-year	1450.00	5643.57	5654.01	5654.01	5654.54	0.003470	6.31	339.48	80.69	0.36
Reach-1	508	100-year	1450.00	5640.03	5646.63	5646.63	5648.30	0.037525	10.48	146.46	49.64	0.98
Reach-1	507	100-year	1450.00	5639.21	5645.29	5645.29	5646.87	0.033293	10.36	158.87	54.52	0.95
Reach-1	505	100-year	1450.00	5638.27	5644.00	5644.00	5645.41	0.032480	10.18	185.63	75.13	0.94
Reach-1	500	100-year	1450.00	5625.60	5635.37	5634.97	5636.39	0.022426	9.78	276.75	125.14	0.55
Reach-1	495		Bridge									
Reach-1	490	100-year	1450.00	5624.40	5634.00	5634.00	5635.06	0.026436	9.96	264.01	125.71	0.57
Reach-1	470	100-year	1450.00	5607.68	5621.13	5614.06	5621.46	0.003719	5.16	446.33	129.14	0.25
Reach-1	465		Culvert									
Reach-1	460	100-year	1450.00	5603.33	5612.65	5612.65	5617.29	0.020842	17.28	83.92	96.84	1.00
Reach-1	455	100-year	1700.00	5596.39	5604.21	5604.21	5606.38	0.028330	11.85	148.27	39.91	0.98
Reach-1	450	100-year	1700.00	5590.81	5599.19	5599.19	5600.78	0.026792	10.27	182.25	106.22	0.93
Reach-1	440	100-year	1700.00	5587.69	5593.98	5593.98	5595.25	0.023797	9.75	254.63	136.18	0.89
Reach-1	436	100-year	1700.00	5578.63	5584.23	5584.23	5585.08	0.016562	9.62	410.40	224.64	0.78
Reach-1	431	100-year	1700.00	5571.70	5581.24	5578.80	5581.77	0.006021	6.76	494.40	217.07	0.40
Reach-1	425		Culvert									
Reach-1	420	100-year	1700.00	5571.10	5578.20	5578.20	5581.68	0.022498	14.97	113.58	124.36	0.99
Reach-1	410	100-year	1700.00	5565.61	5573.36	5570.92	5573.99	0.007520	6.39	266.98	59.29	0.50
Reach-1	405		Culvert									
Reach-1	400	100-year	1700.00	5563.35	5568.13	5566.97	5569.13	0.012078	8.04	211.36	59.64	0.67
Reach-1	398	100-year	1700.00	5563.39	5566.67	5566.67	5568.18	0.055920	12.44	216.26	89.81	1.33
Reach-1	395	100-year	1700.00	5555.00	5560.98	5560.98	5562.73	0.037266	10.61	161.08	48.30	1.01
Reach-1	390	100-year	1700.00	5551.40	5556.74	5556.74	5557.87	0.035761	10.19	257.78	108.53	0.98
Reach-1	389	100-year	1700.00	5550.00	5554.69	5554.69	5555.84	0.040472	10.35	249.04	105.65	1.04
Reach-1	385	100-year	1700.00	5537.75	5541.85	5541.85	5542.85	0.082357	11.82	240.89	115.59	1.34
Reach-1	380	100-year	1700.00	5529.50	5537.37	5536.86	5537.76	0.010956	6.07	401.46	203.84	0.54
Reach-1	375		Culvert									
Reach-1	370	100-year	1700.00	5527.68	5534.13	5534.13	5534.57	0.006872	5.88	465.00	213.79	0.46
Reach-1	360	100-year	1700.00	5511.80	5518.90	5518.90	5520.81	0.034734	11.20	162.11	49.18	0.95
Reach-1	352	100-year	1700.00	5507.30	5515.91	5514.42	5516.76	0.009700	8.62	308.02	138.43	0.56
Reach-1	351	100-year	1700.00	5506.80	5513.84	5513.84	5516.23	0.038249	12.41	140.01	63.47	0.97
Reach-1	350	100-year	1700.00	5503.40	5510.38	5510.38	5512.43	0.036908	11.49	147.99	36.51	1.01
Reach-1	342	100-year	1700.00	5494.95	5501.69	5501.69	5503.95	0.039860	13.71	182.40	53.93	1.08
Reach-1	340	100-year	1700.00	5493.14	5500.02	5500.02	5500.92	0.021216	8.74	340.76	219.42	0.75
Reach-1	334	100-year	1700.00	5488.11	5496.05	5495.56	5497.35	0.017688	9.58	233.71	86.02	0.72
Reach-1	330	100-year	1700.00	5485.84	5495.16	5495.07	5496.17	0.019843	8.97	319.14	178.29	0.68
Reach-1	325		Culvert									
Reach-1	318	100-year	1900.00	5485.27	5493.73	5493.73	5494.51	0.024523	10.32	419.54	211.79	0.70
Reach-1	304	100-year	1900.00	5484.40	5491.10	5489.24	5491.69	0.007839	6.33	357.61	178.90	0.48
Reach-1	303		Bridge									
Reach-1	302	100-year	1900.00	5483.05	5487.95	5487.95	5489.29	0.032033	10.47	254.27	90.82	0.93
Reach-1	301	100-year	1900.00	5479.08	5484.81	5484.81	5486.17	0.022681	9.81	258.28	121.68	0.82
Reach-1	300	100-year	1900.00	5475.10	5479.93	5479.93	5480.86	0.031059	8.66	318.58	168.21	0.90
Reach-1	295	100-year	1900.00	5470.26	5474.88	5474.88	5475.76	0.039266	8.31	314.26	211.21	0.98
Reach-1	291	100-year	1900.00	5468.09	5472.49	5472.49	5473.34	0.026536	9.40	396.74	222.91	0.87
Reach-1	290	100-year	1900.00	5464.32	5470.48	5470.48	5471.36	0.018903	9.14	411.06	248.01	0.75
Reach-1	285		Culvert									
Reach-1	280	100-year	1900.00	5461.70	5467.89	5467.89	5468.21	0.009494	6.37	577.50	218.60	0.53
Reach-1	270	100-year	1900.00	5451.44	5458.04	5458.04	5459.11	0.012260	9.60	381.62	187.38	0.72
Reach-1	265		Culvert									
Reach-1	260	100-year	1900.00	5438.86	5447.50	5444.67	5448.11	0.004070	6.42	361.15	113.91	0.43
Reach-1	255		Culvert									
Reach-1	250	100-year	1900.00	5438.24	5446.48	5445.29	5447.11	0.006830	6.86	400.50	154.29	0.53
Reach-1	231	100-year	1900.00	5434.97	5444.40	5444.40	5445.82	0.032961	12.40	287.97	99.55	0.73
Reach-1	230	100-year	1900.00	5434.90	5443.56	5443.56	5444.92	0.026172	11.89	302.12	99.93	0.74
Reach-1	225		Culvert									
Reach-1	220	100-year	1900.00	5433.65	5440.67	5440.67	5441.57	0.029030	10.49	376.58	177.36	0.80
Reach-1	219	100-year	1900.00	5431.60	5437.71	5437.71	5438.59	0.041552	9.33	318.30	162.35	0.99
Reach-1	200	100-year	1900.00	5420.59	5427.24	5427.24	5428.76	0.039499	9.90	192.91	66.70	1.01
Reach-1	190	100-year	1900.00	5414.10	5423.33	5420.31	5423.53	0.004766	3.67	594.82	307.97	0.36
Reach-1	185		Culvert									
Reach-1	180	100-year	2092.00	5410.57	5420.01	5420.01	5420.11	0.003225	3.19	1215.94	673.86	0.30
Reach-1	175	100-year	2092.00	5408.70	5415.83	5415.83	5416.40	0.030651	7.26	483.53	374.88	0.85
Reach-1	170	100-year	2092.00	5404.97	5411.47	5409.06	5411.71	0.003619	4.38	828.55	481.65	0.34
Reach-1	165		Culvert									
Reach-1	160	100-year	2092.00	5398.60	5404.81		5405.04	0.003637	4.21	732.13	281.54	0.34
Reach-1	152	100-year	2092.00	5396.42	5403.72	5403.72	5404.48	0.027475	8.45	435.92	262.55	0.84
Reach-1	151		Culvert									

Table 2b: Ch2M HILL Existing 100 - year Hydraulic Output

HEC-RAS Plan: MP Exist 072014 River: RIVER-1 Reach: Reach-1 Profile: 100-year (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	150	100-year	2092.00	5393.63	5401.77	5401.77	5402.53	0.029509	10.54	468.31	242.77	0.67
Reach-1	130	100-year	2092.00	5393.48	5401.26	5401.26	5401.82	0.015066	8.84	701.86	486.33	0.59
Reach-1	125		Culvert									
Reach-1	120	100-year	2092.00	5389.00	5398.53	5398.53	5399.54	0.025696	8.70	358.11	229.03	0.80
Reach-1	119.9		Lat Struct									
Reach-1	110	100-year	2092.00	5387.39	5394.36	5394.36	5395.46	0.027028	10.34	365.40	167.33	0.88
Reach-1	100	100-year	2078.55	5383.00	5390.52	5390.52	5391.42	0.020586	10.43	454.21	234.73	0.73
Reach-1	95		Culvert									
Reach-1	90	100-year	2078.55	5383.14	5388.97	5388.97	5389.95	0.025933	10.61	392.68	183.54	0.86
Reach-1	89.9		Lat Struct									
Reach-1	60	100-year	1016.68	5374.50	5381.29	5379.62	5381.81	0.008006	6.24	243.47	136.79	0.48
Reach-1	55		Culvert									
Reach-1	50	100-year	1016.68	5372.70	5378.87	5378.87	5379.48	0.013277	7.44	235.50	97.86	0.56
Reach-1	49.9		Lat Struct									
Reach-1	45	100-year	878.35	5369.49	5375.45	5375.45	5376.57	0.026049	8.71	123.76	75.73	0.82
Reach-1	40	100-year	864.89	5363.57	5372.90	5370.77	5373.12	0.005008	4.11	301.39	152.95	0.36
Reach-1	35		Culvert									
Reach-1	30	100-year	864.89	5362.31	5370.77	5370.77	5370.92	0.002200	3.21	307.99	130.67	0.26
Reach-1	10	100-year	864.89	5356.30	5361.42	5360.20	5362.11	0.011033	6.76	141.35	44.00	0.58

Table 2c: Effective 100 - year Hydraulic Output at Lateral Weir

HEC-RAS Plan: Multi-profil River: RIVER-1 Reach: Reach-1 Profile: 100-year

Reach	River Sta	Profile	Q US	Q Leaving Total	Q DS	Q Weir	Q Gates	Wr Top Wdth	Weir Max Depth	Weir Avg Depth	Min El Weir Flow	E.G. US.	W.S. US.	E.G. DS	W.S. DS
			(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Reach-1	119.9	100-year	2092.00	13.45	2078.55	13.45		18.51	0.94	0.47	5389.58	5399.54	5398.53	5391.42	5390.52
Reach-1	89.9	100-year	2078.55	1061.02	1020.47	1061.02		192.00	2.97	1.92	5380.40	5389.95	5388.97	5381.81	5381.27
Reach-1	49.9	100-year	1020.47	153.44	866.48	153.44		175.57	2.17	0.44	5372.50	5379.49	5378.87	5373.14	5372.92

Table 2d: CH2M HILL Existing 100 - year Hydraulic Output at Lateral Weir

HEC-RAS Plan: MP Exist 072014 River: RIVER-1 Reach: Reach-1 Profile: 100-year

Reach	River Sta	Profile	Q US	Q Leaving Total	Q DS	Q Weir	Q Gates	Wr Top Wdth	Weir Max Depth	Weir Avg Depth	Min El Weir Flow	E.G. US.	W.S. US.	E.G. DS	W.S. DS
			(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Reach-1	119.9	100-year	2092.00	13.46	2078.55	13.46		18.52	0.94	0.47	5389.58	5399.54	5398.53	5391.42	5390.52
Reach-1	89.9	100-year	2078.55	1066.95	1016.68	1066.95		192.00	2.97	1.93	5380.40	5389.95	5388.97	5381.81	5381.29
Reach-1	49.9	100-year	1016.68	150.41	864.89	150.41		175.57	2.17	0.43	5372.50	5379.48	5378.87	5373.13	5372.90

Appendix A

Channel and Culvert Improvements

Location	ID	Existing						10-yr Proposed									Max Proposed									Notes
		Size	Material	Shape	Capacity (cfs)	Blockage (%)	Storm Eq (Year)	Size	Length	Easements Needed per Culvert	Material	Shape	Capacity (cfs) **	Blockage (%)	Storm Eq (Year)	Total Cost (Engineering, Legal, Management, Contingency)	Size	Length	Easements Needed per Culvert	Material	Shape	Capacity (cfs) **	Blockage (%)	Storm Eq (Year)	Total Cost (Engineering, Legal, Management, Contingency)	
Drive to School (North of Arapahoe Avenue)	C13	4'	RCP	Circular	7.4	50%	< 10-yr	15' x 6'	25	1	RCBC	Box	673	20%	10-yr	$ 161,657.82	(2) 15' x 6'	25	1	RCBC	Box	1,447	20%	10-50yr	$ 290,877.27	Culvert upstream has less capacity and may not convey all 1,400 cfs. Additionally, the channel upstream cannot convey all of the 1,400 cfs.
	Bridge															$ 108,675.00	30' bridge span / 26' deck width / 30" deck thickness		3	Steel	Bridge	830	0%	10-50yr	$ 108,675.00	Bridge to replace culvert crossing. Possibily converted to a covered bridge at expense of property owner.
Arapahoe Avenue	C12	9' x 3'	RCBC	Box	141	50%	< 10-yr	(2) 11' x 5'	65	2	RCBC	Box	673	20%	10-yr	$ 340,760.70	(3) 12' x 5'	65	2	RCBC	Box	1,350	20%	10-50yr	$ 543,291.99	Culvert upstream has less capacity and may not convey 1,200 cfs. The channel cannot convey1,200 cfs as well, which may cause flooding on nearby properties.
Alley between Marine Street and Arapahoe	C11	5' x 3.5'	CMP	Arch	45	50%	< 10-yr	(2) 10' x 6'	45	3	RCBC	Box	673	20%	10-yr	$ 278,519.58	(2) 10' x 6'	45	3	RCBC	Box	673	20%	10-yr	$ 280,871.26	Culvert is limited due to nearby homes. The channel may not be able to contain greater than a 10yr flow, and nearby homes may experience flooding.
Marine Street	C10	8.5' x 4'	RCBC	Box	155	50%	< 10-yr	(2) 9' x 6'	70	2	RCBC	Box	673	20%	10-yr	$ 342,101.19	(3) 9' x 6'	70	2	RCBC	Box	1,576	20%	10-50yr	$ 500,520.18	Culvert upstream cannot convey all 1,462 cfs and is limiting. Channel also cannot convey all 1,462 cfs to culvert. Nearby homes may experience flooding.
8th Street and Alley	C9	6' x 3.25'	CMP	Arch	64	50%	< 10-yr	(2) 9' x 6'	170	5	RCBC	Box	673	20%	10-yr	$ 717,874.74	(2) 10' x 6'	170	5	RCBC	Box	1,092	20%	10-50yr	$ 797,915.33	Culvert is limited due to nearby homes. Channel cannot convey all 915 cfs and nearby properties may experience flooding.
University Avenue	C8	6' x 5'	RCBC	Arch	104	50%	< 10-yr	(2) 9' x 6'	105	2	RCBC	Box	600	20%	10-yr	$ 475,753.14	(2) 10' x 6'	105	2	RCBC	Box	1,237	20%	10-50yr	$ 528,260.93	Culvert is limited due to location between structure and road. Channel may not be able to contain all 1,078 cfs; nearby homes may experience flooding.
Pleasant Street	C7	8' x 4.25'	RCBC	Arch	153	20%	< 10-yr	(2) 10' x 6'	50	2	RCBC	Box	600	20%	10-yr	$ 295,163.10	(2) 13' x 6'	50	2	RCBC	Box	1,339	20%	10-50yr	$ 374,740.00	Culvert upstream may not be able to convey all 1,227 cfs. Channel may also not be able to contain greater than a 10yr flow. Nearby properties may experience flooding.
704 Pleasant Street - Patio	C6-B	5.5' x 2.9'	CMP	Arch	65	30%	< 10-yr	(2) 8' x 6'	42	3	RCBC	Box	600	20%	10-yr	$ 260,061.51	(2) 12' x 6'	42	3	RCBC	Box	982	20%	10yr-50yr	$ 307,347.24	Culvert is located on private property and should be replaced to fully optimize the 7th Street culvert. Easements will need to be obtained by nearby property owners and the Anderson Ditch company.
7th Street	C6	4.5'	RCP	Circular	11	50%	< 10-yr	(2) 8' x 6'	180	4	RCBC	Box	600	20%	10-yr	$ 675,699.33	(2) 12' x 6'	180	4	RCBC	Box	1,310	20%	10yr-50yr	$ 973,871.58	Culvert is limited due to nearby infrastructure and homes. The broken style culvert is limiting the capacity, so to achieve full efficiency the culvert should be re-aligned. Channel capacity cannot convey all 1,165 cfs. Flooding may be experienced by nearby homes/properties. Utilities to be considered. Possible sediment basin upstream of culvert.
Pennsylvania Avenue	C5	4.75' x 3'	CMP	Arch	42	50%	< 10-yr	(2) 9' x 6'	45	3	RCBC	Box	600	20%	10-yr	$ 253,896.01	(3) 12' x 6'	45	3	RCBC	Box	1,469	20%	10-50yr	$ 464,894.90	Culvert downstream cannot convey same capacity of 1,203 cfs. Channel capacity is less than 1,203 cfs and nearby homes and properties may experience flooding.
	Pedestrian Bridge*	4.75' x 3'	CMP	Arch	42	50%	< 10-yr	30' bridge span / 6' deck width / 30" deck thickness / 4' handrails		3	Wood / Steel	Box / Arch	600	0%	10-yr	$ 90,000.00										Cost estimate from Pennsylvania Avenue Flood Repair/Improvement Alternative Analysis report (2014)
College Avenue	C4	6' x 6.5'	Brick	Arch	125	50%	< 10-yr	(2) 7' x 6'	55	3	RCBC	Box	495	20%	10-yr	$ 250,167.85	(3) 11' x 6'	55	3	RCBC	Box	1,286	20%	50-yr	$ 500,731.35	Channel upstream does not convey the 10yr flow but may flow within the overbanks. Homes/properties may experience flooding.
Euclid Avenue	C3	4'	RCP	Circular	0	100%	< 10-yr	(2) 8' x 6'	65	0	RCBC	Box	495	20%	10-yr	$ 291,125.52	(3) 10' x 6'	65	0	RCBC	Box	1,286	20%	50-yr	$ 529,777.95	Culvert size is limited due to nearby properties and homes. Channel capacity may not convey 1,286 cfs to culvert; nearby properties/homes may see flooding. Proposed channel improvements extend 250' upstream of the culvert to accommodate new flow. A 1.5' drop structure is proposed 20' upstream of the channel to dissipate energy.
Aurora Avenue	C2	(2) 10' x 5'	RCBC	Box	495	0%	< 50-yr									-	(4) 10' x 6'	80	2	RCBC	Box	1,696	20%	50-100yr	$ 794,609.26	Culvert upstream may not pass all 1,700 cfs. Additionally, channel capcity is limited and cannot convey 1,700 cfs.
Willowbrook Road	C1	9' x 5'	RCBC	Box	337	50%	< 10-yr	9' x 7'	140	3	RCBC	Box	400	20%	10-yr	$ 338,314.14	(2) 9' x 7'	140	3	RCBC	Box	1,187	20%	50-100yr	$ 642,814.91	Culvert is limited due to nearby properties. Channel upstream is limited in capacity and cannot convey 1,450 cfs. Nearby properties and homes may experience flooding. Utilities to be considered.
705 Willowbrook Court - Private	C1-A	4.4'	CMP	Circular	125	50%	< 10-yr	8' x 6'	34	1	RCBC	Box	400	30%	10-yr	$ 114,814.47	(2) 8' x 8'	34	1	RCBC	Box	1,060	20%	50-yr	$ 233,312.53	Culvert is limited due to nearby properties. Channel upstream is limited in capacity and cannot convey 1,450 cfs. Nearby properties and homes may experience flooding. Utilities to be considered.
															Total Improvement Costs for 10-yr Culverts:	$ 4,579,030.00								Total Improvement Costs for Max Culverts:	$ 7,763,837.00	

* - Cost estimate based on information from *Big R Bridge*

** - Capacity is potential capacity and may not experience stated capacity during a storm event

Notes:

- Culvert sizes will need to be confirmed during final design/construction
- Culvert sizes have been increased to their maximum limits without adversely affecting homes/properties
- Where culvert inverts have been lowered, utilities will need to be verified to identify possible relocation
- Channels adjacent to culverts will require alterations to transition to new culvert size

Appendix A

Improvements Outside of Public Right of Way

Channel Improvements Location (Length)	Existing Channel Dimensions (Typ.) Width	Depth	Slopes (L / R)	Capacity (cfs)	Storm Eq (Year)	Proposed Channel Dimensions Width	Depth	Slopes (L / R)	Capacity (cfs)	Storm Eq (Year)	Cost Quantity	Unit	Unit Cost	Cost	Notes
997 6th St & 580 Euclid Ave (200')	2	3	3 / 1.3		< 10-yr	5	5	2	495	10-yr	99000	L.F. / Q	$ 0.26	$ 46,332.00	Altering channel by creating 5-6' bottom width, lowering channel inverts by 1-4', pushing west bank further west by 12', with 2H:1V side slopes.
1010 N to 1030 N 6th Street (200')	3	4	4		< 10-yr	5	4.5	2	495	10-yr	99000	L.F. / Q	$ 0.26	$ 46,332.00	Altering channel by creating 5-6' bottom width, lowering channel inverts by 1-4', pushing east bank further east by 2-9', with 2H:1V side slopes.
810 Marine Street (65')	6	4	1.5		< 10-yr	9	4.5	2	673	10-yr	43745	L.F. / Q	$ 0.26	$ 20,473.00	Create open channel with 9' bottom width and 2H:1V side slopes.
														$ 113,137.00	

Other Improvements	Existing Size	Material	Type	Capacity (cfs)	Proposed Size	Material	Type	Capacity (cfs)	Reinforced Concrete Pipe Quantity	Unit	Unit Cost	Flared End Section Quantity	Unit	Unit Cost	Cost	
Anderson Ditch	6' x 2'	RCBC	Box	36	36-inch	RCP	Circular	25	64	L.F.	$ 139.00	2	EA	$ 2,066.00	$ 23,450.00	Piping Anderson Ditch alternative. Slope is 0.102%.
Gregory Gulch Pipe Alignment	-	-	-	-	48-inch	RCP	Circular	240	480	L.F.	$ 185.00	1	EA	$ 2,643.00	$ 164,597.00	Storm sewer pipe alignment. Slope is 7%.

	Size	Type	Capcity	Quantity	Size	Type	Capacity (cfs)	Quantity	Length	Unit	Unit Cost	Cost	Notes
Willowbrook Rd Storm Sewer Inlets	-	-	-	-	3' x 2'	Denver No. 13 Combination	240	20	60	L.F.	$ 1,475.50	$ 159,354.00	Inlets located at the North end of Willowbrook road.

Notes:
- Existing channel dimensions are represented as a trapezoidal channel for simplification
- Unit cost for channel improvements is based on a cost per linear foot, per design flow (Q)

Improvements to Street Conveyance

Location - From	To	Storm Eq (Year)	Quantity	Unit	Curb and Gutter Area (SF)	CY	Unit Cost	Cost	Excavation Area (SF)	CY	Unit Cost	Cost	Asphalt Area (SY)	Unit Cost	Cost	Cost Summary	Notes
Cul-de-sac Willowbrook Road	Gregory Gulch	10-yr / 50-yr	820	L.F.	2.81	171	$ 770.00	$ 131,425.00	15	460	$ 40.00	$ 18,400.00	2735	$ 63.65	$ 174,083.00	$ 323,908.00	To carry street flow from overtopping of private drive located in the cul-de-sac of Willowbrook Road.
Euclid Ave (6th Street)	Boulder Creek	10-yr / 50-yr	1351	L.F.	2.81	281	$ 770.00	$ 216,530.00	15	757	$ 40.00	$ 30,262.00	4503	$ 63.65	$ 286,637.00	$ 533,429.00	To carry street flow from overtopping of 6th Street culvert due to backwater occurring at Euclid Ave.
7th Street Culvert	Boulder Creek	10-yr / 50-yr	1521	L.F.	2.81	317	$ 770.00	$ 243,777.00	15	960	$ 40.00	$ 38,400.00	5745	$ 63.65	$ 365,669.00	$ 647,846.00	To carry street flow from overtopping of 7th Street culvert due to backwater effects occurring because of the private culvert on the property of 714 Pleasant Street.
Pleasant Street	8th Street	50-yr	408	L.F.	2.81	85	$ 770.00	$ 65,392.00	15	230	$ 40.00	$ 9,200.00	1360	$ 63.65	$ 86,564.00	$ 161,156.00	To carry street flow from overtopping of Pleasant Street culvert.
8th Street	Marine Street Culvert	50-yr	675	L.F.	2.81	141	$ 770.00	$ 108,185.00	15	375	$ 40.00	$ 15,000.00	2250	$ 63.65	$ 143,213.00	$ 266,398.00	To carry street flow from overtopping of Univeristy Avenue culvert.
9th Street at Alley b/w Arapahoe and Marine	Arapahoe Road	10-yr / 50-yr	470	L.F.	2.81	98	$ 770.00	$ 75,329.00	15	265	$ 40.00	$ 10,600.00	1570	$ 63.65	$ 99,931.00	$ 185,860.00	To carry street flow from overtopping of the culvert at the alley between Arapahoe and Marine.

Subtotal Street Conveyance Improvements Cost:		$ 2,118,597.00
Engineering:	15%	$ 317,790.00
Legal/Administrative:	5%	$ 105,930.00
Contract/Construction Management:	10%	$ 211,860.00
Contingency:	50%	$ 1,059,299.00
Total Improvement Costs:		$ 3,813,476.00

Notes:
- Storm equivalent is based on when the designated street will likely see significant street conveyance
- Costs reflect street conveyance improvements of 12-inches of depth
- Street improvements include a 6" curb, 4' sidewalk, and 6" curb for a total of 12"

Appendix A

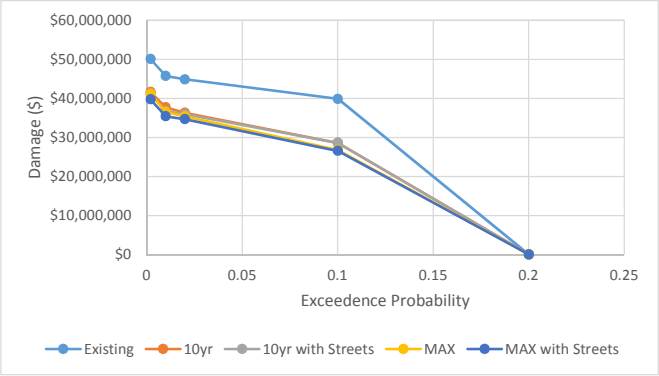
Cost Benefit Analysis
Gregory Canyon Creek Master Plan
March 13th, 2015

Alternative	Cost	Damage Costs Under Existing Conditions 10yr	50yr	100yr	500yr	Damage Costs Under Proposed Alternative 10yr	50yr	100yr	500yr
10yr	$4,692,167					$28,624,736	$36,296,256	$37,709,166	$41,610,872
10yr w/ Streets	$8,505,643	$39,885,504	$44,871,121	$45,713,907	$50,081,200	$28,624,736	$35,953,292	$36,703,945	$41,289,544
Max	$7,876,974					$26,807,549	$35,388,630	$36,511,272	$41,132,626
Max w/ Streets	$11,690,450					$26,532,135	$34,657,034	$35,407,533	$39,726,175
		0.1	0.02	0.01	0.002				

Probability	Storm Event	Damage from Storm Event				
		Existing	10yr	10yr w/ Street	MAX	MAX w/ Streets
0.2	5yr	0	0	0	0	0
0.1	10yr	$39,885,504	$28,624,736	$28,624,736	$26,807,549	$26,532,135
0.02	50yr	$44,871,121	$36,296,256	$35,953,292	$35,388,630	$34,657,034
0.01	100yr	$45,713,907	$37,709,166	$36,703,945	$36,511,272	$35,407,533
0.002	500yr	$50,081,200	$41,610,872	$41,289,544	$41,132,626	$39,726,175

	Existing	10yr	10yr w/ Street	MAX	MAX w/ Streets
Annualized damage	$4,430,765.96	$3,521,537.92	$3,492,949.38	$3,415,438.65	$3,345,259.57
Benefit		$909,228.04	$937,816.58	$1,015,327.31	$1,085,506.39
Annualized Alternative Cost (7% Amortization, 50-yr Life Span)		$339,993.71	$616,317.61	$570,764.35	$847,088.25
Benefit Cost Ratio		2.67	1.52	1.78	1.28

Rate 0.07



Gregory Canyon Creek Criteria and Assumptions

Gregory Canyon Creek

Table 17

Parameter		Criteria / Assumption
Street	Flow depth	Per the City's criteria, maximum allowable depth is 12" at the deepest point.
	Improvement Location	Street improvements, where proposed, were only deemed necessary at intersections where the slope was greater than 4%. Street improvements for the length of the street were proposed for slopes less than 4%.
	Slope	The most conservative slope of 1% found in the basin was used to determine the maximum safe street conveyance
Cost	Culverts	Costs for culvert and pipes were developed using the Urban Drainage Master plan cost estimation spreadsheet.
	Channel	A unit cost of $0.26 per length of channel per discharge was used for channel improvements.
	Streets	Cost for street improvements were developed using unit rates pulled from Urban Drainage's Bid Tabs.
Culvert	Blockage	Per the City's direction, a blockage assumption of 20% was used to model the culvert improvements.
FLO-2D	Flow rates	Flow rates for the FLO-2D model were pulled from the HEC-1 data provided for basins 212 and 213.
	Terrain	Terrain data used for the 2D modeling was developed from the 2013 LiDAR data provided by the City.
	Manning's n	Roughness values for the 2D modeling were developed using a combination of land use and street locations.
	Cost	The cost for the sediment traps is an average of the costs provided in Muller's Site Source report on Fourmile Canyon.
Sediment Trap	Modeling	The modeling of the detention upstream of Flagstaff Road used the blockage assumption for the Flagstaff culvert from the Effective FEMA model of 50%.
Detention	Widths	The width of channel grading improvements was assumed to be the width of proposed culverts. It is assumed that retaining wall/wingwalls would be used to limit the encroachment on adjacent properties.
Channel Grading	Expansion and Contraction	Channel improvement lengths were based on the following assumptions: 1. Upstream of Culvert barrels an expansion of 4:1 was used to transition from the existing channel to the 2. Downstream of the culverts a contradiction of 1:1 was used to move from the culvert barrels to the existing channel. These ratios were taking from HEC-RAS modeling guidance.

Acronyms and Abbreviations

BCA	Benefit Cost Analysis
cfs	cubic feet per second
CUHP	Colorado Urban Hydrograph Procedure
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
HAZUS-MH	Hazards United States *(FEMA)* Multi-Hazard
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Centers River Analysis System
LOMR	Letter of Map Revision
UDFCD	Urban Drainage and Flood Control District
USACE	U.S. Army Corps of Engineers
WRAB	Water Resources Advisory Board

Appendix B

Gregory Canyon Creek Mitigation Study
Open House
March 30, 2015
Summary of Public Comments Received

Purpose of Meeting

The purpose of the March 30, 2015 Open House was to present the Engineer's Recommended Plan and Staff's Recommended Plan for the Gregory Canyon Creek Flood Mitigation Study and to receive feedback from the public. City staff and the project consultants are assimilating the comments and suggestions received at the open house, as well as additional comments received by the public, in order to continue to refine and identify the recommended alternative.

Summary of Open House Comments:

Approximately 15 people attended the open house. The majority of the residents are in support of Staff's recommended plan. Additional comments received are as follows:

- It was suggested that the storm inlets on Willowbrook cover the same area north of the culvert as well as above the culvert.
- Appreciation was expressed in regards to the channel improvements proposed in the lower creek.
- There was support for acquisition of the properties within the High Hazard Zone Priority Area. The city should contact those property owners to see if they are willing to sell.
- It is a well researched, well intentioned plan.
- The efforts are supported, but it is understood that individual property owners will draw conclusions based on impacts to their own properties.
- The streets should include signs which convey the high risk of flooding during a 10 to 100-year storm.
- A fence has been constructed on private property across the creek channel. Was this permitted by the city? If not, please have the city investigate.
- Thank you for the hard work.
- Impressed with the professionalism and creativity by staff.

Appendix B
Gregory Canyon Creek Flood Mitigation Study
March 30, 2015 Open House
March - April 2015 Online Questionnaire
Public Comments

1. Are you supportive of the City of Boulder Staff Recommended Plan?

   a. Yes, overall. I am relieved to see channel improvements proposed in the lower creek, as well as prioritized HHZ properties to acquire. I have lots of questions about the details, but I understand those are not well-defined yet. (J. Jimenez)
   b. The comments I made to the 15 people doing the walk were lost. My idea is to make the storm intake across Willowbrook cover the same area north of the culvert as well as above the culvert. (J.Imig)
   c. I think it is a well researched, well intentioned plan. I support the efforts but understand that individual property owners (myself included) will draw conclusions based on impact to their own properties. (K. Campbell)
   d. Yes. (L. McGowan)
   e. Yes. (M. Moench)
   f. Yes. (J. Butcher)
   g. Yes. (D. Schouten)
   a. Yes. We attended the open house on March 30, and appreciated the opportunity to talk with staff about the draft proposal. Since my home is next to the Anderson Ditch, I support making that a pipeline, running below ground. During the flood, it filled to the top with silt next to my home. (R. Roser)

2. What other improvements do you suggest?
   b. Spoke to Christen Shepard and Franz to explain the idea (also on a blue sticky note). (J. Imig)
   c. Signs on potential risk on streets where flow is likely to be high in 10 year or 100 year events. (M. Moench)
   d. Continued vigilance of Willowbrook culvert. (J. Butcher)
   e. 1. Bury overhead lines along 7th St. which would also prevent downed lines in big snow storms. 2. Raise the retaining wall in the Flatirons School parking lot, north side next to my property. (R. Roser)

3. Do you have comments about specific improvements proposed?
   a. I would like personal feedback as to whether this idea will be considered and a detailed explanation of why or why not. (J. Imig)
   b. I suggest contacting the owners of HHZ properties that the city desires to acquire, as they may not be aware of this. Chances are a couple of them might be interested in selling to the city in the next couple of years, and that may open up more options in specific areas. (J. Jimenez)
   c. I would like to point out that the property owner at the NW corner of 6th and Aurora has constructed a fence across the creek channel. If this was permitted by the city, I would like to ask, why? If it was not permitted, I would ask the city to investigate. (K. Campbell)
   d. Thank you for all your hard work. Looks great. (L. McGowan)
   e. All makes sense. (M. Moench)
   f. I continue to be impressed with the professionalism & creativity of the staff. (J. Butcher)
   g. I would be pleased to discuss sharing costs of retaining wall (or solid fencing) of the school parking lot on the property line. (R. Roser)

Appendix B

Gregory Canyon Creek Mitigation Study
Open House and WRAB Meeting
October 20, 2014
Summary of Public Comments Received

Purpose of Meeting

The purpose of the October 20, 2014 Open House and Water Resources Advisory Board (WRAB) meeting was to present the preliminary alternatives for the Gregory Canyon Creek Flood Mitigation Study and to receive feedback from the public and board members. City staff and the project consultants are assimilating the comments and suggestions received at these meetings, as well as additional comments received by the public, in order to continue to refine and identify the best alternatives.

Summary of Open House Comments:

- We live in a beautiful city. We are fortunate to live near running water, but everything has a price! I think we should start whatever we end by deciding to do from Boulder creek going south. The culvert on highland school land is 36"!! Since Canyon Blvd. is going to be impassable during a Boulder Creek 100 year flood, we need to ensure that Arapahoe is passable. Hence we need to expand the Arapahoe culvert first, and hopefully when we do others. As a stakeholder, I am willing to walk with City staff, grant an easement, be taxed or whatever it takes to finish the project & help the Civic Area designers glam our Gregory Creek is not going to be forgotten.

- How are the alternatives going to be chosen? How will city decide when or how to purchase identified properties in hazard area? How does the city decide how big to make the different box culverts?

- The 31'x6' culvert at Euclid is a major concern to us. This is a major physical intervention that would impact us visually, aesthetically, and in the way we use our property in a significant way.

- I am concerned with the accuracy of the modeling. At no time was the culvert at 6th and Euclid, which is presently ~ 4ft diameter, at capacity in the 50-75 year event of 2013. Water flowed primarily down 6th and Euclid and down from Edward Smith Park. I don't see any attempt at mitigation of the Smith Park overflow.

- To truly utilize a 31' wide culvert at 6th and Euclid one would need to deepen the creek. That would destroy the deer/fox habitat along with removal of significant trees and vegetation. Occasional flooding would be preferred to this kind of destruction.

- BOTTOM LINE: the engineers have addressed lots of issues that I and neighbors have been thinking. Putting in large box culverts will be a big improvement and "buy insurance" against rock/vegetation clogs. Modifying road grades/crowns (eg directing flow down 7th street) is exactly right.

- Good job at making the effort to reach out and educate the neighborhoods. Consider the following financing proposal: There may be home owners who are retired and thus "asset rich" and "income poor". They may be willing to make improvements to their properties, but not be able to afford them from current income. This could be accommodated by a grant to the owner for the improvements and a lien on the property to be paid off when the owner moves or by their estate. This would fit in the philosophy of "public-private partnership".

- All three alternatives seem viable and reasonable. However no particular improvement has increased priority, nor do the recommendations align with the 2001 Belt Collins problem areas. The 2012 mitigation suggestions or the actual observations from Sept. 2013.

Summary of Open House Suggestions:

- The storm drains in front of 833 Marine are old, and are inadequate for the kind of debris that cover them up. We've been cleaning up the drains for 60 years because they are too small.

- It appears that the SECOND culvert under Euclid Ave, about 30'-40' to the west of the proposed 31'x6' culvert has been overlooked in the study. It likely should be considered as part of any flood mitigation- maybe two smaller culverts?

- What about the 100 year trees that border the creek? What care would the city take to maintain their health?

- A) The city should be aware that a high flow event down 7th street (Univ. - Arapahoe) will destroy the paving and curbs. This is not against doing the redirection, just a heads up on future repairs.

  B) As a property owner, I have invested in flood mitigation measures. The ones I did prior to 2013 worked well. I believe that this is a "private" or "public project" not just a city project.

- 1.) Strongly suggest purchasing the property in the high hazard at 1655 9th street. There are 2 houses, one of which is 2ft from the creek channel and should be the highest priority.

  2.) The culvert enlargements should be considered at the same time as the up-and downstream channel enlargement.

- I liked the Pennsylvania roadway removal plan that was considered.

Summary of WRAB Meeting Comments:

- Lives near Flatirons Elementary School, really appreciates where city is going with their plan and agrees that conveying a 100 year flood out of the question. Read study in its entirety. Alternatives proposed do not necessarily match what actually happened on the ground during the flood. Problematic area during this event that may not adequately be addressed at 7th. Does not have a strong feeling on option three in the roadway. Feels that spending money to make the roads convey without hurting property is money well spent. People are open to having flood mitigation done on their properties, but there are possible challenges there. Impressed with how accurately earlier studies match up with what was seen during the flood event. May be able to leverage earlier studies going forward.

- Lives midway on creek and has specific question regarding two maps and noticed there is a chart in attachment A that shows different culverts and what improvements would look like in a 10-year plan or maximum culvert (35x6). The 10 and 50 year maps only show maximum 50-year extent. Comments were heard during open house questioning this finding showing 35 foot culverts on the 10-year map, which isn't actual benchmark for 10-year event. Requests clarification whether the maps reflect 10-year or maximum numbers and asks if maps need updating.

- Wants to thank the board for hearing the neighborhood last year and putting neighborhood's name out there for potential for growth, which shows a lot of thought. Concerns about map showing 35-foot culvert and hopes that Board will take closer look at document from CH2M Hill to address and consider street conveyance. Appreciates Board taking a closer look at this creek and looks forward to the future.

- Didn't have problems like University and 7th. Suggests putting energy into conveyance because Mother Nature is going to decide, not what planners decide. Water went back into Gregory Creek because a car diverted it. This area is packed with cars and not enough parking.

- Lives on College and appreciates looking into this issue. Mentioned culvert at College Avenue, which was filled with fences and BBQ grills that were piled into culvert, forcing water to run over

the creek onto other properties. Suggests looking at this issue and better advising people not to put objects in the creek bed. Mentioned 22-foot wide culvert at Aurora and feels that a 35-foot culvert is too excessive.

- Lives on College, family built house in 1950. At height of flood, banks took all the flood waters, bank to bank and held a 1.5 – 2 feet of water before touching his foundation. Some of the street did have water conveying and he built diversion with 2x4's which diverted water down College, past Flatiron Elementary School. According to charts – what happened on College is being compared to what happened on Pennsylvania, which are not comparable. Stone bridge on his property has weathered 3 major storm events in his lifetime, which is a good model.

- Lives below Anderson Ditch. Asks what kind of incentive programs are being considered for property owners to keep stream beds clean?

- Lives at 7th and Pleasant and thinks that street conveyance is a good idea. With some work on 7th, a lot of the damage could have been avoided. East side was severely damaged. Could make a difference in the future with better street conveyance.

Gregory Canyon Creek Open House Comments: June 12, 2014

Name	Address	flooding problems	suggestions	dedicate easement	comments
Charlotte Smokler	742 Marine St.	My entire lawn, front and back, was flooded.		I would need more details . My back yard has beautiful trees. I would hate to see them uprooted. But I need more details what an easement would involve.	

Online Comments Received June to October 2014

name	address	flooding problems	suggestions	dedicate easement	comments
Eric Cornell	745 University Ave.	1. There was extensive flooding at the entrance to the culvert at the northeast corner of our property (745 University Ave.) The water overtopped the culvert opening and flowed, swift and deep, over the surface, off in the direction of 8th and Marine. 2. There was water streaming over the surface along the property line that runs along the west side of our property, between our house and our neighbors to the west. 3. There was a lot of water running along University Ave and the adjacent sidewalk in front (south) of our house, flowing east. As it passed our house it turned left (north) and flowed over the property of our neighbor to the east, Stewart Machle, and then along his foundation, damaging his yard and his house.	My main concern is that mitigation should proceed from Boulder Creek up, and not from Chautauqua Meadows down. If you enlarge a bunch of culverts and broaden a bunch of channels upstream from University Ave before you do that for University Ave and downstream, the flood will hit the culvert under University Ave with explosive force and could cause major structural damage or loss of life in the houses nearby.	yes	I would want to see the plan before dedicating the easement, but I am very open to the idea.
H R Totten	633 College Ave, Boulder, CO 80302	I witnessed Gregory Creek at both Pennsylvania and College Ave... What a world of difference between the design of the two waterways... The people who built the College Bridge in the 40's had it ""right""... wide enough to not accumulate debris (would snap almost anything spanning the opening). High enough to handle all that came at it with room to spare (almost bank to bank in the channel)... At Pennsylvania, the two culverts simply collected debris and ""self destructed"". (Kudos to the engineers of days past for the College Ave bridge. Too bad someone paved over the original storm drain within in the structure though)... Just an observation which you may wish to ponder... Thanks for all you do and for all the hard work! Hal	I think you have plenty to do without additions...	no	
Keith L Pearen	637 Pennsylvania Ave	Pennsylvania Avenue and 7th street culverts were problem areas during past flood events.	Pennsylvania Ave pedestrian bridge.	yes	If flood improvements bring my house out of FEMA 100yr floodplain.

Jean Dubofsky	1000 Rosehill Dr.	The Sept. flood and all of your maps come along the bottom of our driveway. During the flood, the city diverted water down 6th St. and onto Rosehill Dr. This flooded some of the houses below us on Rosehill. I walked to 6th and Euclid and told the bulldozer driver that his efforts to prevent so much water going along Gregory Creek were creating additional problems along Rosehill. He didn't know what to do other than what he'd been told to do.			
Charles Corfield	1366 Seventh St.				Please pass on my thanks (to Jerry Weitzel amongst others) for the recent repairs to the alley on the south side of my house. The new entry across the sidewalk and the layer of blacktop look great.
Kirk Watson	828 University	Shallow flooding < 12"" during event.	YES!!! Nowhere in this study dos t indicate an analysis of the predictive nature of the model wand the REALITY of what happened during the flood event. Most residents could indicate depths of water during the flood at maximum height and approximate times. Didn't you ask to SEE IF THE MODEL WAS CORRECT??? This is a waste of money unless correlated with reality . I cannot believe the statement on pg.4: ""No other changes were made to the baseline model to create the existing conditions HEC-RAS model for the purpose of this analysis.""	no	You should check to see if neighbors have increased the elevation of their property since the 1987 mapping to see if they increase or decrease risk of property damage to neighbors. Since the flood I notice flood walls being erected. What is that going to do to the model?
Paul Shankman	704 pleasant	7th near pleasant	Enlarge the culvert, and reshape 7th so water flows down the middle of the road, no just to the east side.	maybe depending on easement plans	

Online Comments Received October 2014 to February 2015

name	address	open house comments	suggestions	dedicate easement	comments
Julia Wrapp	932 Arapahoe, boulder, CO. 80302	I missed the open house but would request consideration of Gregory creek flowing out of its banks, running down 9th street, flowing into the historic church property (law office at 9th / Arapahoe) collections in the NE corner of the parking lot and then flooding 932 arapahoe		yes	It would be nice if the city encouraged neighbors to work together on mitigation issues. My neighbors will not even speak to me concerning this ongoing flood problem generated from drainage issues in their parking lot.

Online Comments Received March 2015 to April 2015

name	address	Support Draft Plan	Draft Plan Comments	Other Improvements	Comments on Specific Improvements
Rebecca J. Roser	1228 7th St.	yes	We attended the open house on March 30, and appreciated the opportunity to talk with staff about the draft proposal. Since my home is next to the Anderson Ditch, I support making that a pipeline, running below ground. During the flood, it filled to the top with silt next to my home.	1. Bury overhead lines along 7th St. which would also prevent downed lines in big snow storms. 2. Raise the retaining wall in the Flatirons School parking lot, north side next to my property.	I would be pleased to discuss sharing costs of retaining wall (or solid fencing) of the school parking lot on the property line.

Gregory Creek Channel and Culvert Improvements at Euclid Avenue

In the aftermath of the September 2013 flood, we very much appreciate the City of Boulder's concern, prompt attention, and devotion of staff resources to developing alternative ways to alleviate future flooding along existing channels and crossings along Gregory Creek.

As more detailed designs of these mitigation efforts evolve, we hope the City project team will be open to our communication, suggestions, and feedback as "stakeholders" in the design outcomes. Design professionals ourselves, we understand the project team will be required to meet both budgets and timelines. That said, we request the City project team give the recommended design outcomes that follow serious consideration. We are making --and will make--every effort to keep these and future suggestions reasonable. We hope the project team will respond to us regarding our recommendations, subsequently consider our timely feedback, and be open to considering our possible alternative recommendations on various specific issues.

The recommendations that follow arise from our concern that a number of the project team's February 13 Revised Alternatives Memo and Figures show significant proposed alterations to both the channel that runs through our back yard as well as the culvert beneath Euclid Avenue that is immediately adjacent to our back yard. Both are in full view of our large, west-facing living room windows. So, we do indeed have a stake in how this proposed intervention turns out, as it will significantly influence the character of our immediate living area.

The ultimate location and plan layout of the Euclid Avenue culvert enhancements will have impacts not only on their cost, but will also aesthetically impact adjacent properties as well as the character of the street itself. The arrangement of inlets and wing walls will affect the survival probability of important mature trees that currently exist on both the public ROW (as part of the street tree inventory) as well as our property.

Additionally, we have concerns about the nature of the "max channel grading" recommended for the portion of Gregory Creek channel that runs through the mature wooded area of our immediate backyard property. This particular intervention could have deleterious effects on the root systems of these existing trees that could result in their degradation and ultimate loss. We walked the site with an arborist, whose review and comments can be found on the last sheet of this document, page 14. That said, we think there are opportunities worth discussing for channel enhancement to the north and west of these mature trees.

The following pages show specific plan layouts based on the project team's proposed culvert sizes as shown in the February 13, 2015 Revised Alternatives Figures. The impacts of these different layouts are indicated in red in the plan views. Additionally, we have illustrated the visual impacts of some of the possible culvert layouts as seen from our property and Euclid Avenue.

Ellen Burgess
Michael Doyle
997 Sixth Street
720-470-7754
med2347@gmail.com

Summary of Our Requests for Proposed Culvert Improvements

Establish a contact person:

Establish a *knowledgeable* contact person *on the design team* with whom property owners can communicate questions and concerns during design, construction, and post-construction.

Inclusive design review process:

Establish a design review process with private property owner(s) that (a) allows sufficient time for owners to consider and discuss design approach(es) with design team as well as (b) the opportunity to suggest reasonable design revisions or alternative approaches

Preserve valued and mature trees:

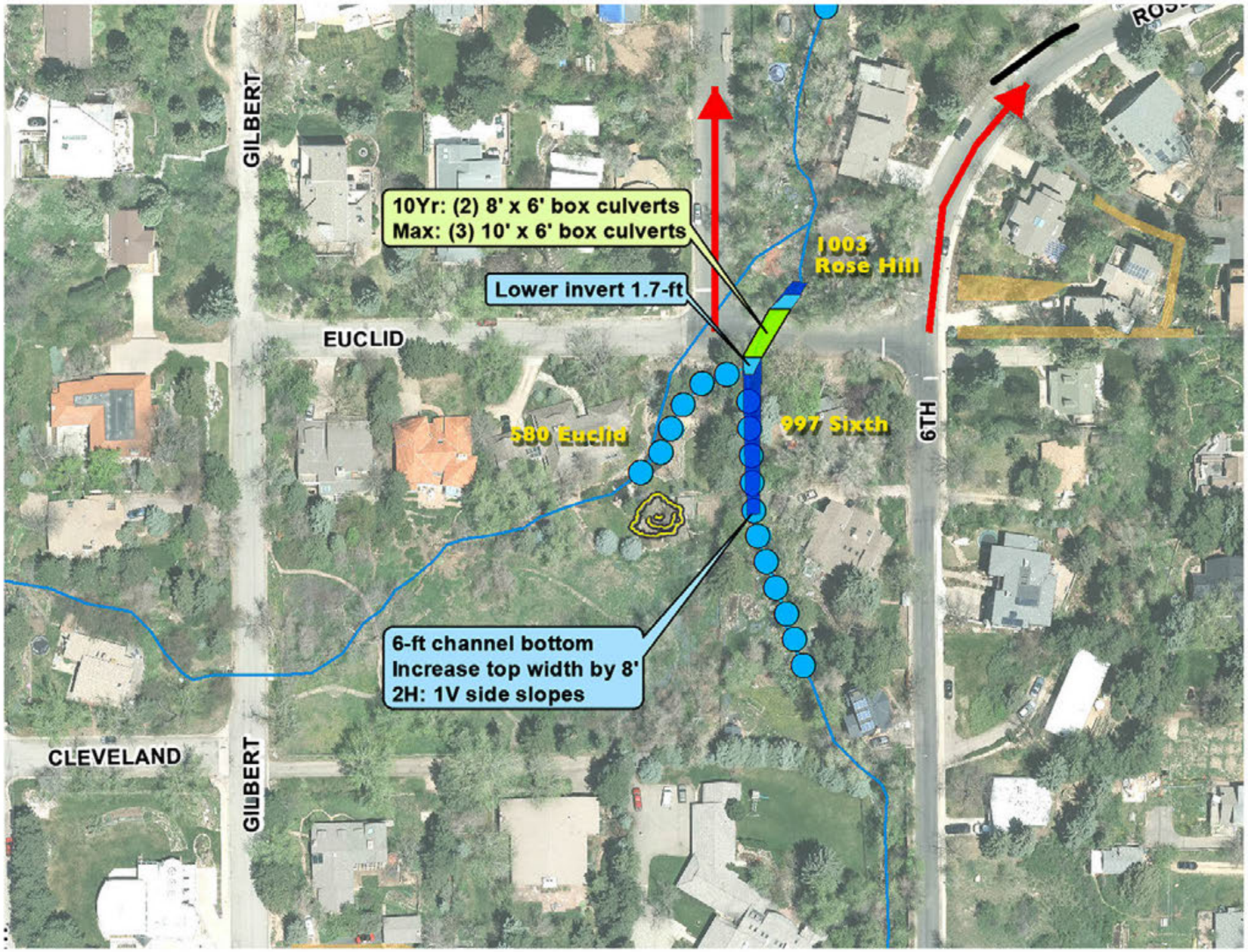
Create design(s) and establish limits-of-work that ensure the survival and vitality of indicated valued trees on both private property as well as the city rights-of-way (see sheets 4, 5, 6 and 8)

Approach to channel and catchment work:

Establish culvert components, catchment development, and channel enhancements on city right-of-way. Any design and work limits of transition to creek channel on private property to be discussed and established with property owner. An execution of proposed grades in both public ROW and on private property that blend harmoniously with existing grades to create a more "natural" looking channel/catchment area.

Use architectural finishes that acknowledge context:

Utilize recommended concrete color admixture for all exposed concrete surfaces. Further, use a natural stone veneer on large, exposed surfaces (wing walls, crowns, balustrades, etc.) that is the same color mix and size as the indigenous stone walls and residential applications nearby (see sheets 7, 10, 12, and 13)



LEGEND

- Existing Trash Rack
- Culvert Improvements
- Overflow Path
- Street Improvements
- 10Yr Channel Grading
- Max Channel Grading
- Channel Improvements
- Potential Storm Inlet
- Potential Sediment Trap
- Existing Easements
- Creek

Notes:
1. Culvert dimensions are width x height (span x rise)

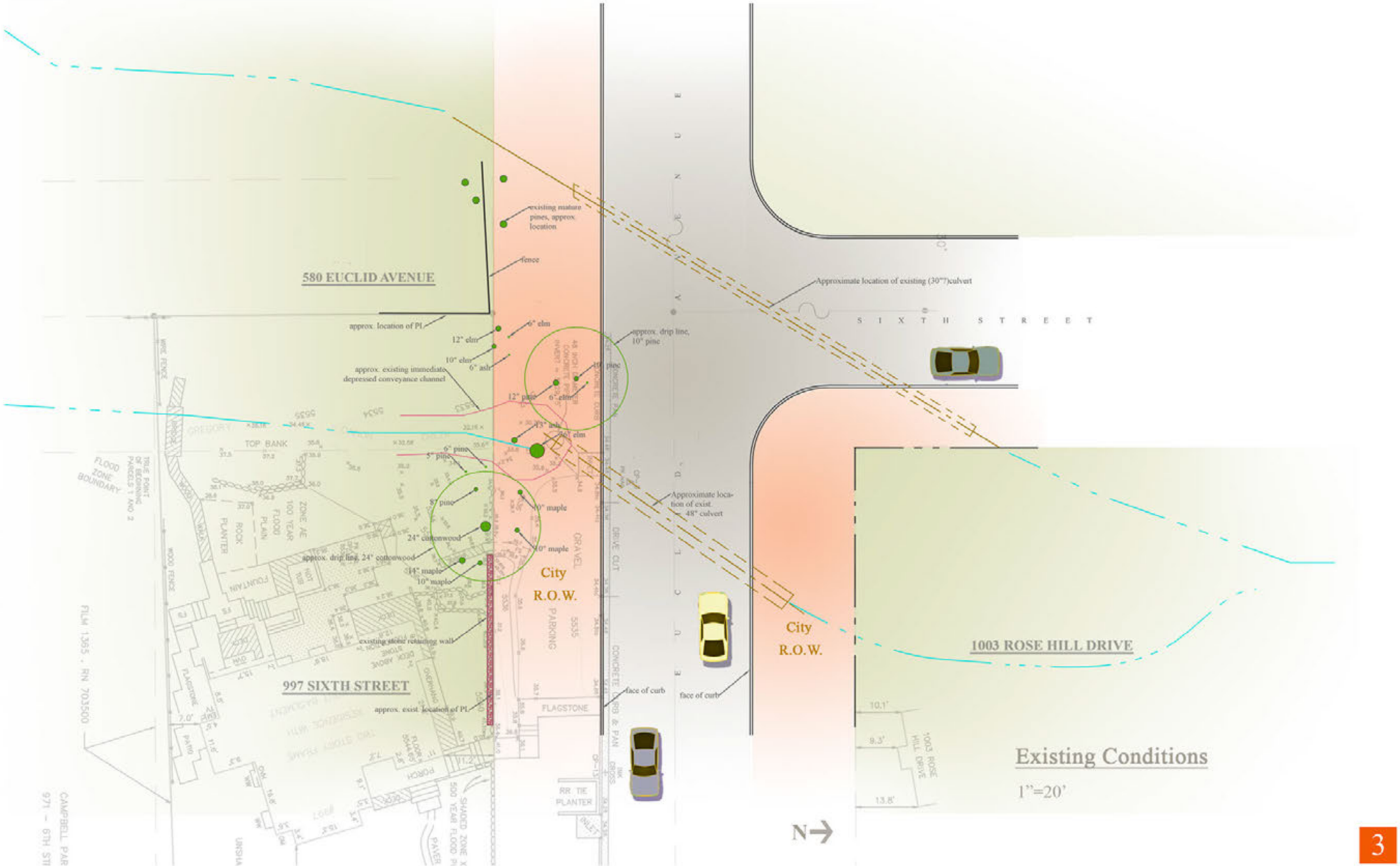
CALLOUT LEGEND

- Infrastructure Improvement
- Channel Improvement

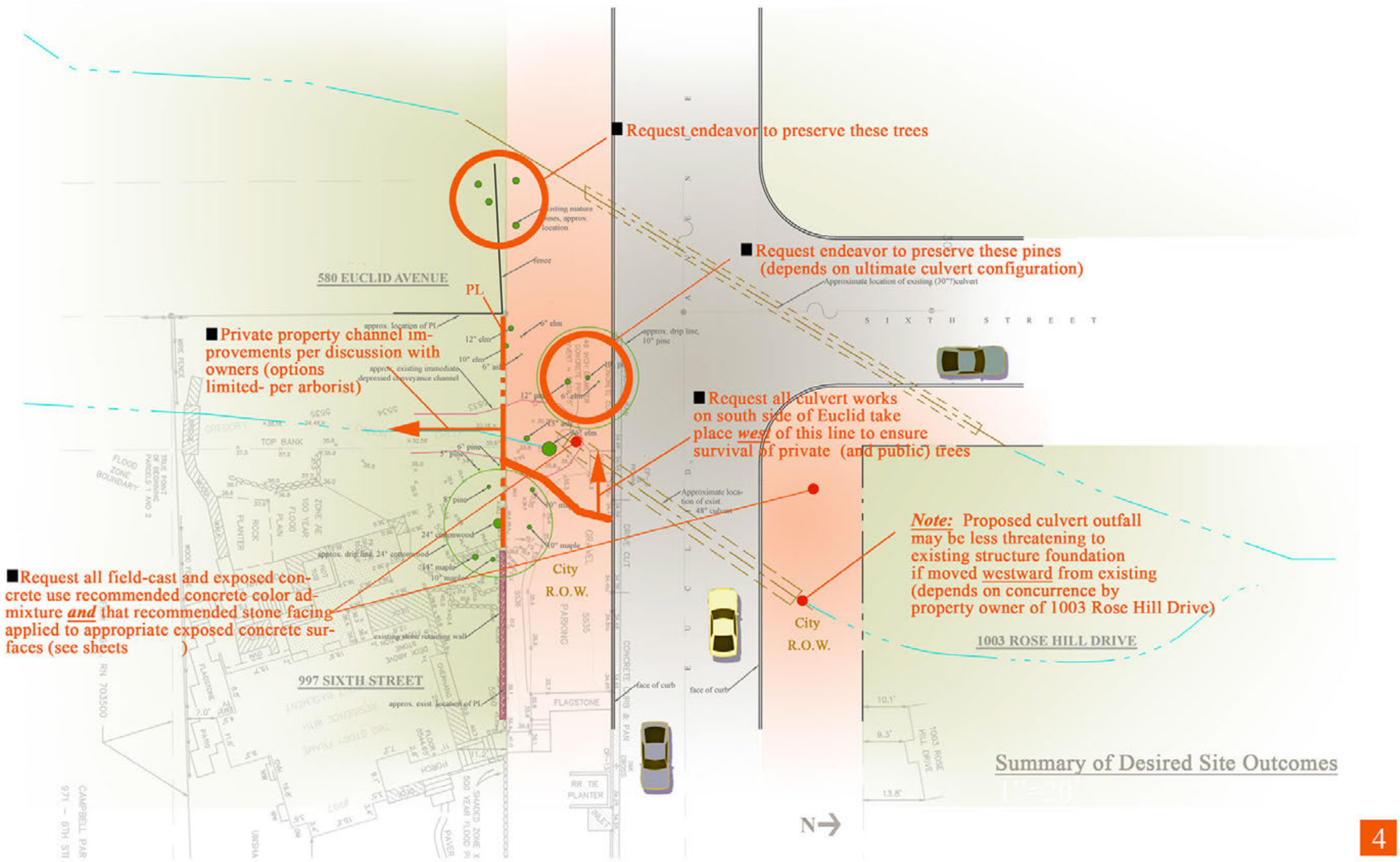
Proposed Modifications

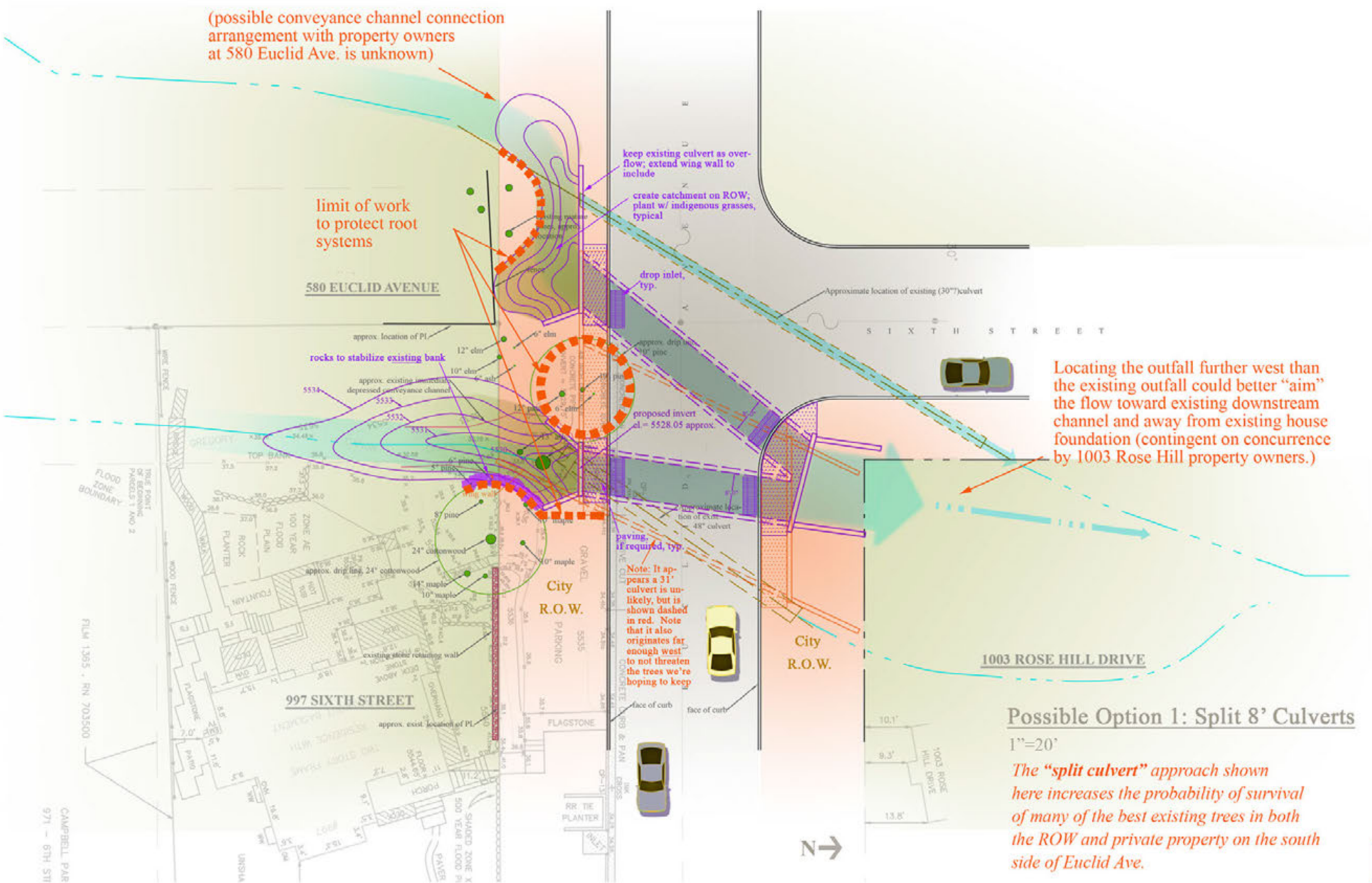
Note: This image and legend excerpted from Feb. 13, 2015 Revised Alternatives Figures by City of Boulder [addresses added by this author]

2


580 EUCLID AVENUE
997 SIXTH STREET
1003 ROSE HILL DRIVE
City R.O.W.
City R.O.W.
S I X T H S T R E E T
E U C L I D A V E N U E
existing mature pines, approx. location
fence
approx. location of PL
12" elm
6" elm
10" elm
6" ash
approx. existing immediate depressed conveyance channel
approx. drip line, 10" pine
Approximate location of existing (30"?)culvert
Approximate location of exist. 48" culvert
24" cottonwood
approx. drip line, 24" cottonwood
14" maple
10" maple
existing stone retaining wall
approx. exist. location of PL
face of curb
face of curb
FLAGSTONE
TOP BANK
FLOOD ZONE BOUNDARY
FILM 1365 , RN 703500
CAMPBELL PAR
971 - 6TH STI
Existing Conditions
1"=20'
N

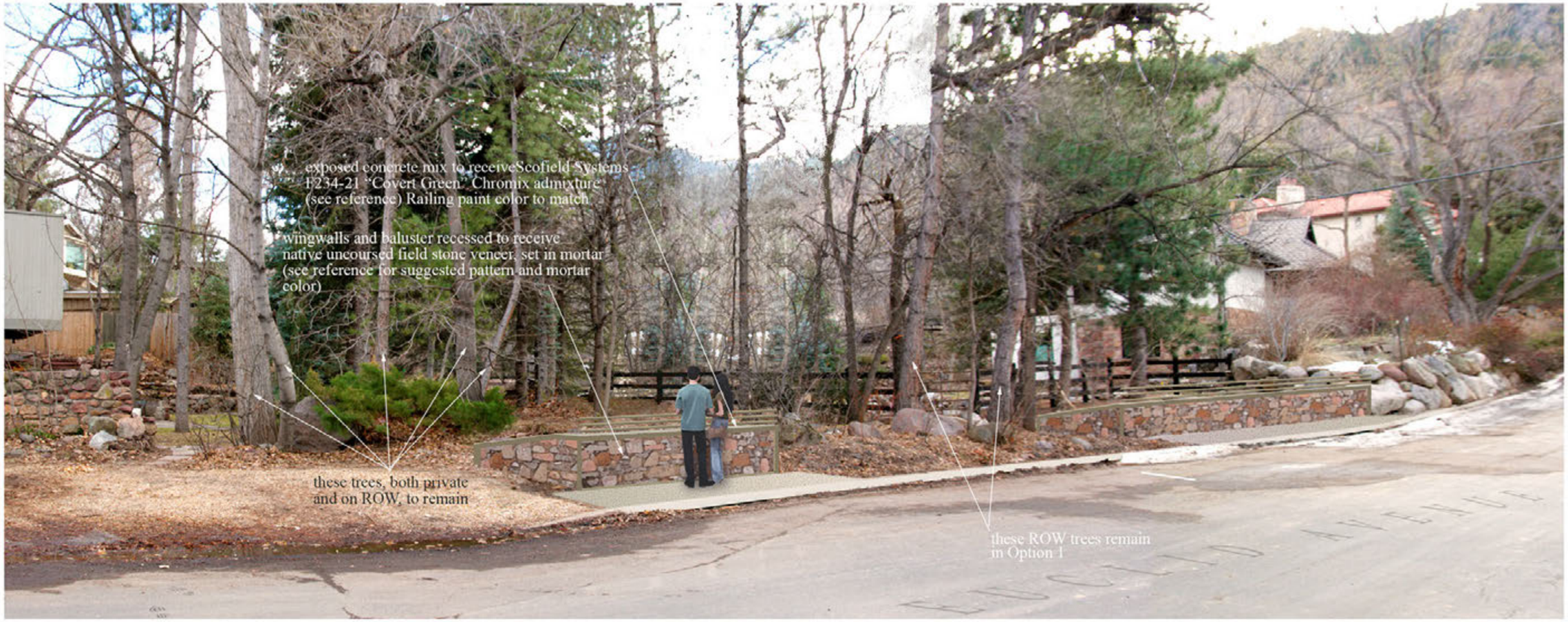
3


Request endeavor to preserve these trees
Request endeavor to preserve these pines (depends on ultimate culvert configuration)
580 EUCLID AVENUE
PL
Private property channel improvements per discussion with owners (options limited- per arborist)
Request all culvert works on south side of Euclid take place west of this line to ensure survival of private (and public) trees
Note: Proposed culvert outfall may be less threatening to existing structure foundation if moved westward from existing (depends on concurrence by property owner of 1003 Rose Hill Drive)
City R.O.W.
City R.O.W.
1003 ROSE HILL DRIVE
Request all field-cast and exposed concrete use recommended concrete color admixture and that recommended stone facing applied to appropriate exposed concrete surfaces (see sheets)
997 SIXTH STREET
S I X T H S T R E E T
Summary of Desired Site Outcomes
N
4


(possible conveyance channel connection arrangement with property owners at 580 Euclid Ave. is unknown)
limit of work to protect root systems
580 EUCLID AVENUE
keep existing culvert as over-flow; extend wing wall to include
create catchment on ROW; plant w/ indigenous grasses, typical
drop inlet, typ.
Approximate location of existing (30"?)culvert
S I X T H S T R E E T
rocks to stabilize existing bank
approx. existing immediate depressed conveyance channel
proposed invert el = 5528.05 approx.
Locating the outfall further west than the existing outfall could better "aim" the flow toward existing downstream channel and away from existing house foundation (contingent on concurrence by 1003 Rose Hill property owners.)
paving, if required, typ.
Note: It appears a 31' culvert is unlikely, but is shown dashed in red. Note that it also originates far enough west to not threaten the trees we're hoping to keep
City R.O.W.
City R.O.W.
1003 ROSE HILL DRIVE
997 SIXTH STREET
face of curb
face of curb
FLAGSTONE
approx. exist. location of PL
N
Possible Option 1: Split 8' Culverts
1"=20'
The "split culvert" approach shown here increases the probability of survival of many of the best existing trees in both the ROW and private property on the south side of Euclid Ave.
5

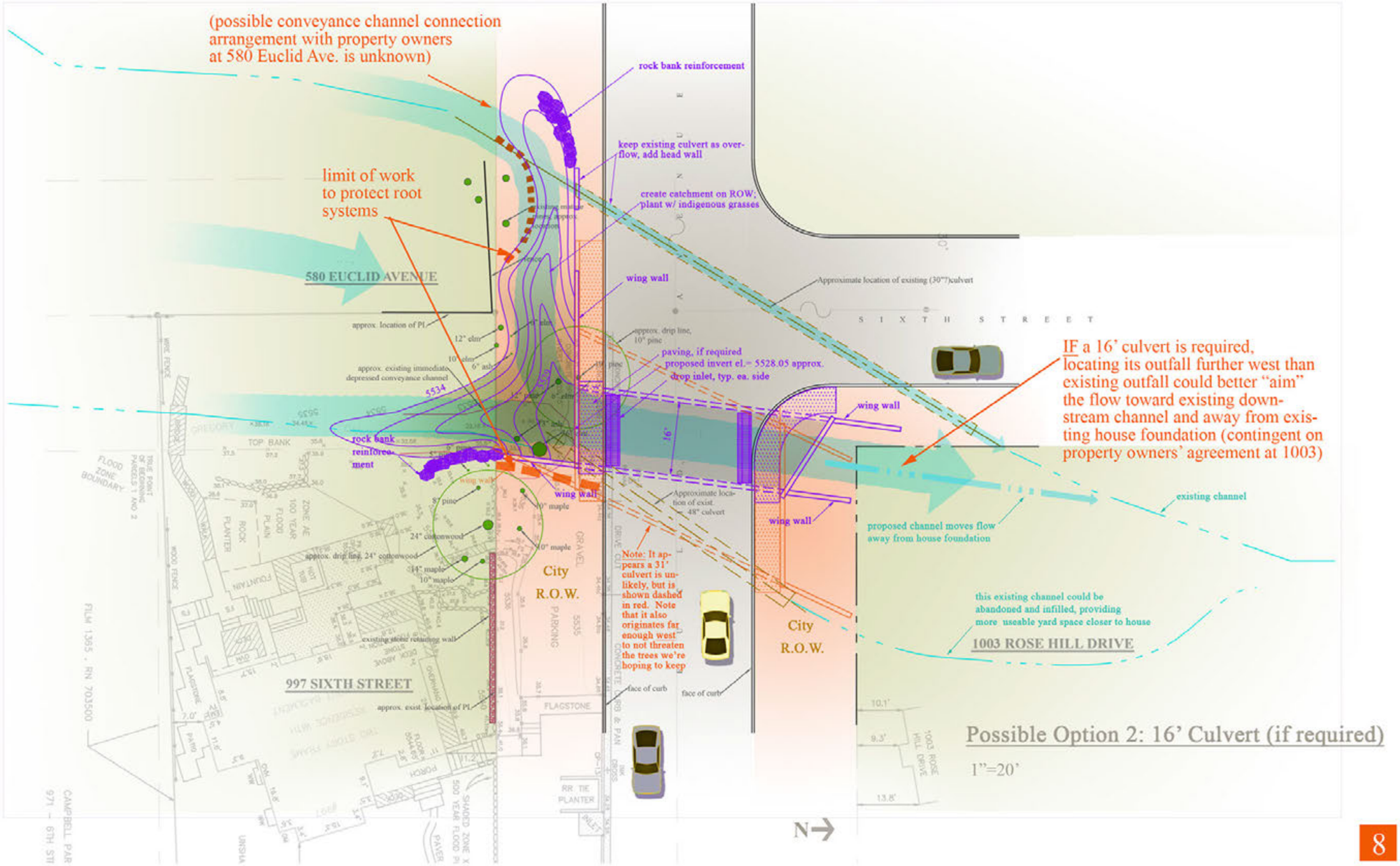
Existing View looking Southwest on Euclid Avenue

6



View of Option 1 (Split 8'Culverts) looking Southwest from Euclid Avenue
(other options would have similar streetside finishes)

7


(possible conveyance channel connection arrangement with property owners at 580 Euclid Ave. is unknown)
rock bank reinforcement
keep existing culvert as over-flow, add head wall
create catchment on ROW; plant w/ indigenous grasses
limit of work to protect root systems
580 EUCLID AVENUE
wing wall
Approximate location of existing (30"?)culvert
S I X T H S T R E E T
approx. location of PL
approx. drip line, 10" pine
paving, if required
proposed invert el.= 5528.05 approx.
drop inlet, typ. ea. side
approx. existing immediate depressed conveyance channel
5534
rock bank reinforcement
wing wall
IF a 16' culvert is required, locating its outfall further west than existing outfall could better "aim" the flow toward existing down-stream channel and away from exis-ting house foundation (contingent on property owners' agreement at 1003)
existing channel
proposed channel moves flow away from house foundation
Approximate loca-tion of exist. 48" culvert
Note: It ap-pears a 31' culvert is un-likely, but is shown dashed in red. Note that it also originates far enough west to not threaten the trees we're hoping to keep
City R.O.W.
this existing channel could be abandoned and infilled, providing more useable yard space closer to house
1003 ROSE HILL DRIVE
997 SIXTH STREET
face of curb
FLAGSTONE
Possible Option 2: 16' Culvert (if required)
1"=20'
N
8

Existing View looking Northwest from 997 Sixth Street

9

Proposed View of Option 2 (16 ' Culvert) from 997 Sixth Street

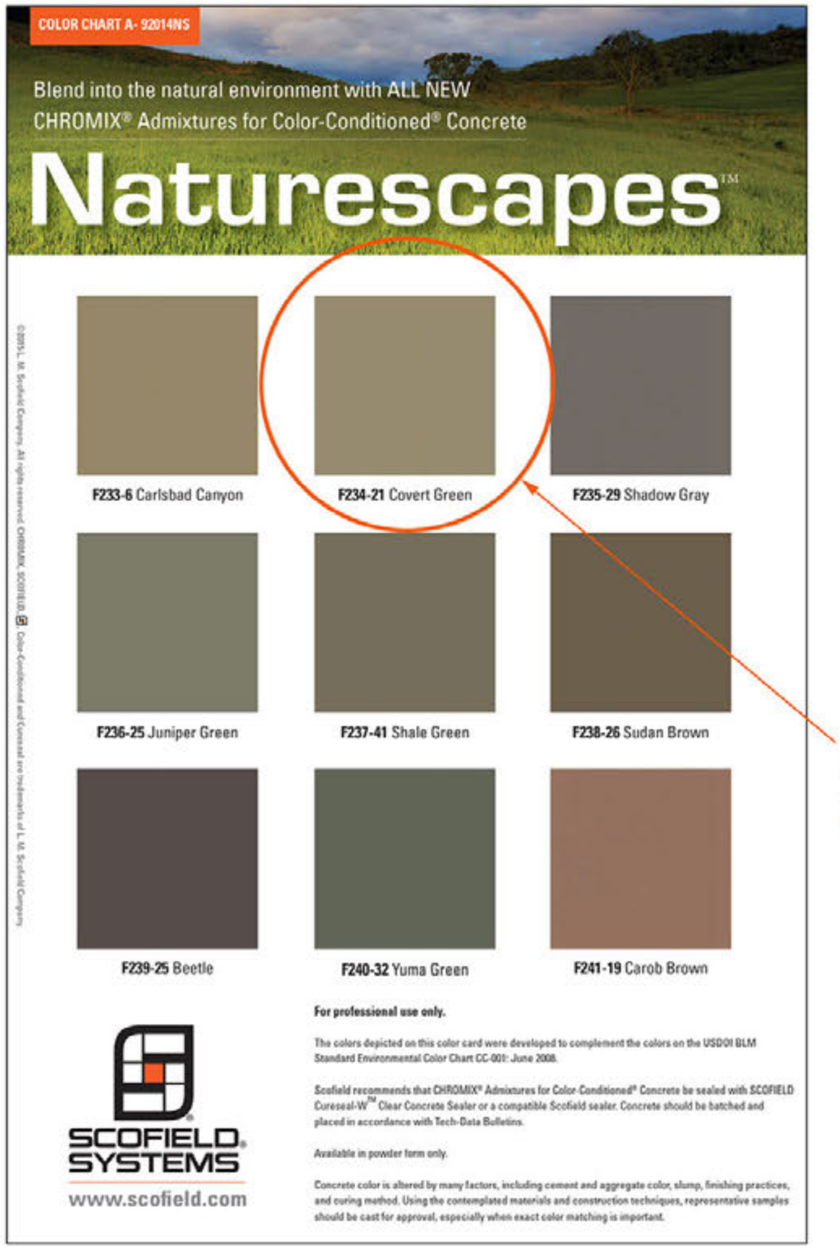
10

Existing View looking North from 997 Sixth Street Property

11

Proposed View of Option 2 (16' Culvert) looking from 997 Sixth Street Property
(finishes for other options would be similar)

12

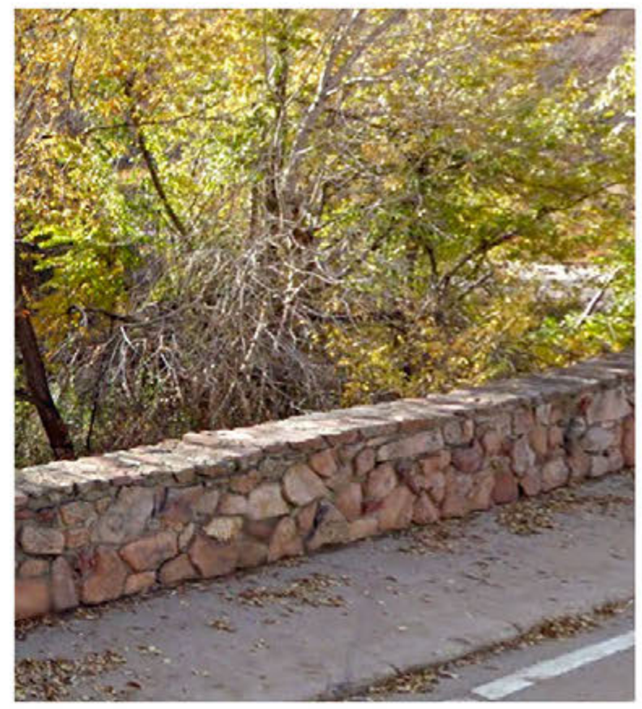


recommended color of admixture for field-cast and exposed concrete

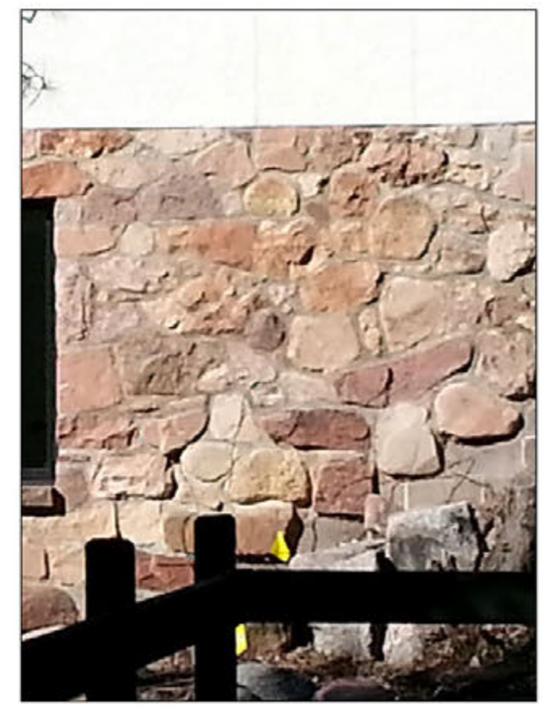
Recommend **F234-21 "Covert Green,"** circled above

Street wall at 997 Sixth Street

Residence at 971 Sixth Street



Balustrade at Baseline Road over Gregory Creek



Residence at 580 Euclid Avenue

Note: *We request this proposed intervention on Gregory Creek and the neighborhood use finishes that help to mitigate its visual impacts and relate it to its context. To that end, we recommend using a color admixture for exposed concrete surfaces and indigenous uncoursed native fieldstone veneer similar in size and shape to the examples shown here*

Requested Finishes at Culvert : Crowns, Balustrades, and Wing Walls

13

Tree Preservation Recommendations for the Doyle/Burgess Back Yard, 997 6th St., Boulder

Before discussing the specifics of tree preservation on the site, I am including a short description and dicussion of the types of risks that construction generally poses for trees on a site. There are three ways in which projects commonly damage trees:

1) Roots get severed or compromised. This impacts trees in two ways, which are in turn related to the two basic functions of roots. The first is mechanical: They serve to anchor trees in the earth. Roots mainly act in tension in this respect; so, the removal of roots on one side of a tree increases the risk that it will fall in the opposite direction. Tree roots generally are found in the top foot or two of soil. The likelihood of a tree falling due to severed roots increases the closer the damage gets to the trunk. Arborists use a rule of thumb for distance from the trunk at which roots can safely be cut on one side of a tree: 5 times the trunk's diameter distance from the trunk. However, in our local weather environment, where West winds often measure above 100 mph, this rule must be disregarded. I have looked at a tree that blew over soon after its West roots were cut at a distance of at least 15 times trunk diameter.

The Second negative impact on trees due to root cutting has to do with their role in drawing water and elements from the soil, and conveying them to other parts of the system. Severing roots deprives trees of water and essential elements, and causes stress, which can lead to infestation, disease, and death. Again, the rule of thumb for cutting on one side of the tree is 5 times diameter. But, again, this rule of thumb must be discarded when cutting on the West sides of trees in the Front Range.

2) Soil becomes compacted. Soil compaction can be thought of as a squeezing of oxygen out of the pore spaces between the grains. Trees need to absorb oxygen through their roots, so that they can metabolize the sugars they manufacture. In other words, they can't burn their own stored energy without soil oxygen, and they become stressed relative to the extent of compaction.

3) Machines batter trunks, causing wounds and decay. Of the three, this is the easiest to conceptualize, since the damage is right in front of our eyes, but is also perhaps the hardest to control. Operators are frequently, if not usually, unable to be vigilant at all times about the trunks of trees, especially when feeling time pressure, or when fatigued, etc. Suffice it to say, most construction in areas with trees results in wounds to trunks. Wounds result in decay, and decay causes mechanical weakness in wood, as well as stress in tree systems. Decaying trees eventually pose a safety risk to people and property.

The proposed culvert and stream-enlarging project West of the Doyle/Burgess house threatens their trees in all three ways discussed above. First and foremost, the proposed widening and deepening of the stream bed, and the construction of concrete "wing walls" to funnel flood waters into the culvert, threatens the roots, and therefore the stability, of several of their trees, especially, due to prevailing West winds, those located on the East side of the stream. The west roots of these Cottonwoods, Norway maples and Spruces all presumably reach well beyond their trees' drip lines on that side. Since they can find most everything they seek, including water, near the surface in this intermittent stream environment, the west roots of these trees are almost certainly as near or nearer the surface than are those of the average tree.

It should be noted that the Colorado Blue Spruce, despite its status as State Tree in this very windy state, is not wind tolerant. It evolved in thick stands that are located in valley bottoms, out of the wind; trees in natural Spruce groves absorb wind as a group, rather than individually, and individual trees graft their roots onto one another, so that most are "pinned down" by their neighbors' roots. In Front Range urban environments, these trees usually lack the protection of the group, and frequently blow over without any "help" from humans cutting their roots. Any practicing arborist in Boulder can attest to this phenomenon.

My recommendation is that, to minimize root severing, there be no stream bed excavation on the East side of Gregory Creek behind the house. Further, the proposed wing walls should be positioned radially, rather than tangentially, to the trunks of trees. And, to protect trees on the west side of the stream, widening and deepening should occur at a distance of 5 times diameter from any tree on that side.

To avoid soil compaction in the yard, widening and deepening of the stream should be done by hand, rather than with heavy machinery. If heavy machinery is used, it should access the yard over, and be stationed on, a layer of mulch at least 12 inches deep, to cushion the load.

Finally, to protect them, the trunks of trees near any machinery should be wrapped twice, to a height of 8 feet where possible, with snow fencing.

I hope this has been helpful; please feel free to contact me with any questions.

Fred A Berkelhammer
President, Berkelhammer Tree Experts, Inc.
ISA Certified Arborist # RM0102
303-440-1233 berkeltree@earthlink.net

From: Pearen, Keith L
To: Knapp, Katie
Subject: Gregory Canyon Alternatives Analysis
Date: Tuesday, October 21, 2014 3:12:20 PM

Katie,

First, great job last night. Well thought out presentation. I think your line of thinking on how to go about this project is spot on! I think your approach to get the WRAB involved early and often is great. Totally agree that it is not feasible to upgrade all for 100yr flows and a 10yr approach is reasonable.

My impression, the culvert widths with 10yr flow and 20% blockage are still large (14' to 20') relative to the stream bed (12' max) and Sept '13 demonstrated need.

I had a few more thoughts after listening to the full discussion last night:

First, Is it possible to update the % blockage for some of the existing structures (Table 5 and 'Improvements in Public Right of Way' Table) that performed adequately in the Sept '13 flood? It makes little sense to prioritize those structures that performed well in Sept '13. If we revise the Blockage % down from 50% to 20% or 0% can they (Aurora, College, Pleasant, University, 8th, Marine, Arapahoe) be shown to accommodate the 10 year flow? If we can show them by analysis to be good for 10yr, then perhaps money can be focused elsewhere.

Second, it makes sense to Utilize a phased approach to Gregory Creek Improvements:

- Phase 0: Obtain easements that are necessary for Phase 1 improvements
  - Obtain easements for:
    - Private Drive at Old Baseline
    - Private Drive at NW Corner of Willowbrook Cul-de-sac
    - Drive to School North of Arapahoe
  - Have easements obtained prior to WRAB reconvene – Project is a non-starter without them

- Phase 1: High Need improvements in public right of way and in easements obtained in Phase 0
  - Focus on structures that are unable to convey 10yr flow and experienced issues during the Sept '13 event
    - Private Drive at Old Baseline
    - Willowbrook improvements (culvert and regrade)
    - Euclid Culvert
    - Pennsylvania Road Removal (Pedestrian Bridge)
    - 7th Avenue
    - Drive to School North of Arapahoe

- The following were all OK during Sept'13 (Aurora, College, Pleasant, University, 8th, Marine, Arapahoe)

- Phase 2: Street Conveyance Measures
  - Implement proposed street conveyance measures
    - Willowbrook street mods and new pipe
    - 6th street from Euclid down (or Rosehill to 7th as shown in the mini-master, but this makes less sense because of flow combination with 7th at Anderson Ditch) Either way, Euclid should be identified as a creek to surface street transition. This is not shown in the CH2M report and should be added.
    - 7th street from Anderson Ditch down
    - 8th street from Pleasant down (Questionable cost/benefit with numerous major changes)

- Phase 3: Debris traps, Channel Enhancements, Property Acquisition and Re-mapping
  - Obtain easements for channel enhancements in areas that will not convey 10yr flow
    - Install debris traps
    - Bank stabilization
  - Property acquisition for High Hazard Properties
  - Re-Mapping

Thanks,
Keith

This message is intended only for the use of the intended recipient. If you are not an intended recipient, you are hereby notified that any use, dissemination, disclosure or copying of this communication is strictly prohibited. If you have received this communication in error please destroy all copies of this message and its attachments and notify the sender immediately.

From: Keith Pearen
To: Knapp, Katie
Subject: Re: Gregory Alternatives
Date: Thursday, October 09, 2014 2:27:32 PM

Katie,

Thanks again for keeping us in the loops as this process progresses. I had a chance to read the report and have some comments in addition to your comment on the proposed removal of Pennsylvania Ave culvert (thanks!):

1. Page 1, Paragraph 1: Gregory creek is identified as a "left bank" tributary of Boulder Creek. Should be right or south. These things are assigned looking downstream.
2. Table 3: the location of "1/3 of discharge at Aurora Ave, with 2/3 placed on the local highpoint" makes no sense.
3. Table 3: Should confluence with Boulder creek be included in this table (2092 cfs with 100 yr return interval)?
4. Table 3: Consider a more readable format with location in the first column and return intervals of 2, 5, 10, 50 and 100 as columns 2 - 6.
5. Page 3, Hydraulics Section: Mixed tense and "deliverable for the this analysis." makes no sense.
6. General: LOMR is never defined.
7. Table 8: Good list of potential improvements. No indication that they were evaluated at any point in this report. Are some recommended? All?
8. Page 7: "Channel Geometry between Euclid and College is unable to convey the 10 – year storm event without causing infrastructure damage." Really? Haven't seen a model, but this seems like one of the larger channel sections. Surprising Conclusion! This is not consistent with Sept '13 observations.
9. Figures 5 - 7: Red, green, and blue boxes mean? CH2M Recommendations?
10. Figures 5 - 8: Potential improvements listed in Table 8 are largely ignored. If not included, why not? Were they evaluated?
11. Figure 5: "Install a 23' x 6' box culvert" under 7th street near flagstaff Elementary is inconsistent with physical geometry of site. Existing culvert is at least 100' in length.
12. Figures 6 and 7: Please remove the improvements that were already proposed in Figure 5 (Option 1) from these figures.
13. Figure 6: "5-ft channel bottom 4.5-ft depth 2H: 1V side slopes" proposed between Euclid and College already exists.
14. Table 2a and 2b: Map needed to correlate river stations used in the tabular data.
15. Table 2c and 2d: Discussion of the "Lateral Weir" seems to be missing entirely from test. These tables are never referenced in text.
16. Table 10: Is it possible to prioritize these Culvert Improvements or determine an order of operation in which these are to be done so the least capacity conveyance is always highest priority?

I know it is an initial draft, but I would expect a little better from CH2M (I used to work for them)...

Thanks again for keeping us in the loop,

Keith

On Wed, Oct 8, 2014 at 4:36 PM, Knapp, Katie <KnappK@bouldercolorado.gov> wrote:

> Hi Keith,
>
> There is a link to a "very" draft alternatives analysis on the upper right corner of the project website. I have already provided the engineering consultant with a list of comments, so this will be revised prior to the meeting. One of my comments was to include the pedestrian bridge option, which they do not currently show. Please feel free to provide comments at any time or at the meeting.
>
> Katie
>
> ---
>
> **From:** Keith Pearen [redacted]
> **Sent:** Friday, October 03, 2014 12:24 PM
> **To:** Knapp, Katie
> **Subject:** Gregory Alternatives
>
> Katie,
>
> Is there something that shows the potential alternatives for Gregory Creek that we can see prior to the meeting on Oct 20th? I checked the website and it has been updated to show the Oct. 20th meeting, but didn't see any new proposed alternative.
>
> Thanks,
>
> Keith

From: Laz Nemeth
To: Knapp, Katie
Subject: Gregory creek
Date: Tuesday, October 14, 2014 1:18:55 PM

You want to put in multiple 30 feet by 6 feet box culverts?
the concrete really ugly ones?

laz

From: Laz Nemeth
To: Knapp, Katie
Subject: Re: Gregory creek
Date: Tuesday, October 14, 2014 1:28:53 PM

---

oh yeah and please explain how the math on the last table makes sense.

specifically 7th, pen, college and euclid

culverts of multiple different sizes are claiming 100-50% blockage, to me it reads like enron accounting.

laz

From: Helen El Mallakh
To: Knapp, Katie
Cc: Dean, Kristin
Subject: Re: Incorrect reporting of Willowbrook Rd Culvert Dimensions on the Alternative Analysis Memorandum
Date: Friday, January 23, 2015 12:36:26 PM

Hi Katie,

I think that you are wrong about the width times height. That may be what was supposed to be done in this memorandum, but these numbers make no sense. So I want to make sure that I understand this recommendation for Willowbrook Rd., the recommendation is for a culvert 18 feet wide by 7 feet high? That is not physically possible given where the home on the intake portion of the culvert would be. Moreover, the recommendation is for a 40-foot wide culvert at 6th and Aurora? There is utterly no need for these recommendations to be even brought forward.

This is completely questionable. For the Willowbrook and Aurora culverts, the culverts far exceed the width of the creek beds on the properties.

Where does Gregory Creek even approach 40-feet in width inside the city limits? No where.

Whether these are low probability projects or not- they aren't feasible without absolutely ruining people's property. The fact that no new hydrological analysis was undertaken is also undermining the memorandum's recommendations.

What is so disturbing is that there are areas along Gregory Creek that are in DIRE need of flood control improvements. These neighborhoods want projects. We didn't need a larger culvert during the last flood at Willowbrook. We needed a different trash rack, but what we really needed was for the city to remove the trash rack about 24 hours before it did.

Helen El Mallakh
850 Willowbrook Rd.

On Jan 23, 2015, at 8:59 AM, Knapp, Katie <KnappK@bouldercolorado.gov> wrote:

> Hi Helen,
>
> The call-outs do not indicate past projects, but what could be constructed at each location. The culvert dimensions are width x height, and do not show lengths. Because there have already been improvements constructed at Willowbrook and Aurora, I don't anticipate that improvements at those locations will be high priorities. The next submittal from CH2MHill will include benefit/cost ratios that will help us come up with a recommended plan.
>
> Katie

From: Helen El Mallakh [mailto:elmallak@swbell.net]
Sent: Friday, January 23, 2015 4:49 AM
To: Knapp, Katie; Dean, Kristin
Subject: Incorrect reporting of Willowbrook Rd Culvert Dimensions on the Alternative Analysis Memorandum

Hi Katie and Kristin

The culvert on Willowbrook is already 18' by 9' (length by width) and it is 5' in height. So I believe that a mistake was made on figure 5 (3 of 3) page 17 which has written "18' by 7' box culvert" . Suggested change: culvert dimensions from "18' by 7'" to "18' by 9'"

I would assume that this is a mistake and that the suggestion is not to place a smaller culvert in place on Willowbrook.

I think that there's also a problem with the legend and that the red-bordered text boxes are projects that have already taken place. You will find that the culvert at Aurora and 6th street "Install 40' by 6' Box Culvert" was installed in 1995/96. The legend is not clear enough and the wording could confuse the public. I would recommend using "installed" instead of "install." Perhaps it would be useful to indicate to the public that these were past flood upgrades.

Thanks

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

From: Helen El Mallakh
To: Knapp, Katie
Cc: Dean, Kristin
Subject: Re: Easement at 850 Willowbrook Road
Date: Thursday, January 22, 2015 5:08:43 PM

Hi Katie

Last question for you and Kristin is on page 17, under Category 1 of Channel and Facility Maintenance, there are two text boxes on our property: "Channel Grading to Accommadate Larger Culvert" and "18' by 7' Culvert box." Does this mean that we would be getting a new larger culvert on our property, because I think that our existing culvert is 18' by 7'? Also, our property already have some of the deepest channel grading along Gregory Creek. Can you guys please explain this? I think it might have been what took place in the 1996/97 Flood Control?

Thanks
Helen

On Thursday, January 22, 2015 4:08 PM, "Knapp, Katie" <KnappK@bouldercolorado.gov> wrote:

Hi Helen;

I'm looking into your easement question, but I suspect that the temporary easement was incorrectly shown as an existing easement. Thanks for bringing that to my attention. If this is the case we will see that it is corrected. If that is not the case, I will let you know.

I will ask our consultants to include a legend for the maps in the next submittal. All of the call-outs indicate proposed improvements. The green call-outs were for items considered maintenance/repairs or items to facilitate maintenance, such as debris traps. The red items were for improvements that would help accommodate flood waters.

Assuming there is no existing easement, the city has access to the edge of the right-of-way, shown on the attached plan in red. Although, there is a provision for access during a declared disaster:

> 2-2.5-10. Authority to Enter a Property.
>
> During the period of a declared disaster emergency, a city employee or authorized agent may enter onto or upon private property if the employee or authorized agent has reasonable grounds to believe that an emergency situation exists and that an entry on private property is required in order to protect life or minimize an imminent threat to property.

Sorry to hear you will be out of town when we are scheduled to meet. I appreciate your input and feedback.

Katie

From: Helen El Mallakh [mailto:elmallak@swbell.net]
Sent: Thursday, January 22, 2015 3:28 PM
To: Knapp, Katie
Cc: Dorothea H. El-Mallakh
Subject: Re: Easement at 850 Willowbrook Road

Hi Katie

After magnifying pages 20 and 23, I think the issue might be that the easement for the culvert was drawn too far out on these figures. But I may be wrong. Anyway, can you also clarify how many feet outside of the culvert the city automatically has access to on our property, that would be very helpful.

Helen

On Thursday, January 22, 2015 3:11 PM, Helen El Mallakh <elmallak@swbell.net> wrote:

Hi Katie

When I was reviewing the Gregory Creek Draft Alternative Analysis, I found that two of the figures have an easement marked out for our property at 850 Willowbrook Road, Boulder, CO 80302. You told us when we had work done in the spring of 2014 that there was no easement on the property; thus, we had to give the City of Boulder permission to clean out the culvert. Furthermore, you informed us that the easement was only a temporary one that was from the 1990s when there was the flood control project on Gregory Creek. On page 20 of the attached document (Figure 6 - 3 of 3) and on page 23 (Figure 7 - 3 of 3) it indicates an easement on the property. Can you clarify this for us and what type of easement that this is or are the figures incorrect.

Last, a recommendation for the draft alternative analysis: can your consultants give a legend of the figures so that we know what the inserted caption/text boxes mean that are in surrounded by green highlighting versus red. I believe that the green means the proposed alternatives, while the red is descriptions of past projects?

Thanks

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

From: Helen El Mallakh
To: Dean, Kristin; Knapp, Katie
Subject: Re: Credibility Issue with this process
Date: Wednesday, March 25, 2015 5:18:25 AM

Dear Kristin,

Regarding the Gregory Creek Feb. 13 Revised Alternative Analysis, the consultants still have not put in the HEC-RAS variables and their parameters that they used to make the suggestions on the culvert sizes. Can you please have them send these variables and parameters to me so we can have them for our neighborhood organization - even if they are not included in the analysis itself?

Also, the maps in the Feb. 13 Revised Alternative Figures are not drawn to scale in regards to the size of the culverts. This causes confusion and is misleading.

Lastly, given that so many of the sewer lines broke going into people's houses, there is no mention of what the city is doing related to this problem.

Regards

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

On Friday, January 30, 2015 6:20 PM, Helen El Mallakh <elmallak@swbell.net> wrote:

Hi Kristin

Having used HEC-RAS, I find that the underlying variables and assumptions are critical. It is fundamentally driven -as is all modeling software - on the validity, scope, and rigor of the inputs. Since many of us have had to hire our own hydrologists, I think that in the memorandum the key variables, their parameters, underlying assumptions, and various cases/scenarios that were fed into the model should be listed. This information would be useful for our hydrologists. Moreover, the sediment assumptions are very important for this particular creek. This should not be very difficult to add to the updated report.

Thanks
Helen El Mallakh

On Friday, January 30, 2015 4:26 PM, "Dean, Kristin" <DeanK@bouldercolorado.gov> wrote:

Hello Helen,
The proposed culverts were modeled using the HEC-RAS floodplain analysis software, available on this website:
http://www.hec.usace.army.mil/software/hec-ras/

There is a significant amount of information that goes into the modeling. Are you interested

in reviewing the input files, or are there any specific variables that you would like us to provide?

Also, when you do return from travelling, we would be happy to meet with you

Best Regards,
Kristin Dean, AICP
Utilities Planner
City of Boulder, Public Works - Utilities
303.441.4289

From: Helen El Mallakh [mailto:elmallak@swbell.net]
Sent: Friday, January 30, 2015 5:01 AM
To: Dean, Kristin
Subject: Re: Credibility Issue with this process

Hi Kristin

I am traveling and am unable to meet. Can you please include the equations, variables, and assumptions used by CH2M Hill to determine their suggested culvert sizes in the next report.

Thanks

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302

On Monday, January 26, 2015 9:58 AM, "Dean, Kristin" <DeanK@bouldercolorado.gov> wrote:

Hi Helen,
Perhaps it would be best if we set up a time to meet you at your property. Please let me know your availability over the next week or so and I would be happy to set that up.

Best Regards,
Kristin Dean, AICP
Utilities Planner
City of Boulder, Public Works - Utilities
303.441.4289

From: Helen El Mallakh [mailto:elmallak@swbell.net]
Sent: Saturday, January 24, 2015 7:21 AM
To: Knapp, Katie; Dean, Kristin
Subject: Credibility Issue with this process

Hi Katie and Kristin,

I did get Kristin's voice mail on Friday explaining that the numbers for the culverts on Willowbrook and Aurora are accurate as presented in the memorandum. This memorandum seems to be somewhat lacking in presenting an integrated plan, rather it is a "scatter-gun" approach of throwing out ideas lacking rationals and methodologies within a a report filled with inaccuracies (such as easements). Moreover, there is a lack of an approach to even dealing with the sediment issues and the larger upstream issues of Gregory Creek on county property. Given what is missing and what is included in this report, I see this process as undermined in terms of credibility.

Helen El Mallakh
850 Willowbrook Rd.

From: Helen El Mallakh
To: Knapp, Katie; Dean, Kristin
Subject: Engineers Preferred Alternative -new storm inlet in front of 850 Willowbrook Road
Date: Thursday, March 26, 2015 7:51:45 AM
Attachments: 1996-Willowbrook-Culvert-Replacement.pdf

Dear Katie and Kristin

I just reviewed the Engineers Preferred Alternative for Gregory Creek. Please be advised that the location as drawn for the new storm inlet in front of 850 Willowbrook Rd. would interfere with our sewer line connection. In fact, the idea of a storm inlet in front of 850 Willowbrook Road was already evaluated and deemed as infeasible because of the sewer line issues in the 1996 Willowbrook Road Culvert Replacement project as part of flood control. Moreover, due to the somewhat odd connection angle with our sewer line coming into the city sewer line(due to the culvert and 1996 flood control project), there have been numerous problems, including its breaking in the 2013 flood event.

You should probably speak with public works as they have more detailed records of this including having to repair issues.

Regards

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

From: Helen El Mallakh
To: Knapp, Katie
Cc: Dean, Kristin
Subject: Re: Engineers Preferred Alternative -new storm inlet in front of 850 Willowbrook Road
Date: Thursday, March 26, 2015 8:43:17 AM

Hi Katie and Kristin

I wanted to give you the contact at Public Works who had to fix our sewer line/inspect it. His name is David Garcia and his phone number is 303-441-3350. He can better explain the issues around the sewer line connection. I really would not want the city to do anything that would further compromise the sewer line connection unless David Garcia was consulted first.

Regards

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

On Thursday, March 26, 2015 8:28 AM, "Knapp, Katie" <KnappK@bouldercolorado.gov> wrote:

Helen,

Thank you for this information. I will forward your email to CH2M Hill, our engineering consultant to make sure they are also aware of this issue. At this phase, the plan is very schematic. Utility conflicts will be evaluated with the development of the conceptual plans.

Katie

From: Helen El Mallakh [mailto:elmallak@swbell.net]
Sent: Thursday, March 26, 2015 7:52 AM
To: Knapp, Katie; Dean, Kristin
Subject: Engineers Preferred Alternative -new storm inlet in front of 850 Willowbrook Road

Dear Katie and Kristin

I just reviewed the Engineers Preferred Alternative for Gregory Creek. Please be advised that the location as drawn for the new storm inlet in front of 850 Willowbrook Rd. would interfere with our sewer line connection. In fact, the idea of a storm inlet in front of 850 Willowbrook Road was already evaluated and deemed as infeasible because of the sewer line issues in the 1996 Willowbrook Road Culvert Replacement project as part of flood control. Moreover, due to the somewhat odd connection angle with our sewer line coming into the city sewer line(due to the culvert and 1996 flood control project), there have been numerous problems, including its breaking in the 2013 flood event.

You should probably speak with public works as they have more detailed records of this including having to repair issues.

Regards

Helen El Mallakh

850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

From: Helen El Mallakh
To: Dean, Kristin; Knapp, Katie
Subject: Re: Concerns regarding proposed storm inlets on Willowbrook Road Culvert - Gregory Creek Draft Staff Recommended Plan
Date: Monday, March 30, 2015 8:13:40 AM

As a follow up comment, I am not sure that when the storm inlet on the Willowbrook culvert was suggested it was realized that, in the event the storm inlet was plugged up, we would have a very difficult time getting out of our driveway with water pooling/flooding which would hinder vehicular exiting. This is based on how the storm inlet has been drawn on the draft staff recommendation. It may be that the storm inlet would not be as wide as indicated on your figure, however, staff does need to keep in mind the ability for property owners to be able to physically leave their homes (i.e., ingress and egress) in a flood by vehicle is critical. In fact, in this entire draft, there is not one other property besides 850 Willowbrook Road where the ingress/egress is potentially being hampered by a proposed flood control mechanism.

I would appreciate a written response clarifying the width of the proposed storm inlet in front of the 850 Willowbrook Road driveway and what you would do to minimize ingress/egress concerns along with our sewer line issues.

Regards

Helen and Dorothea El Mallakh
850 Willowbrook Road
Boulder, CO 80302
303-442-4014

On Monday, March 30, 2015 6:06 AM, Helen El Mallakh <elmallak@swbell.net> wrote:

I am writing you to express my opposition to and concerns regarding the two proposed storm inlets on the Willowbrook culvert (one to the west side of the culvert on 445 Christmas Tree and the other to ease side of the culvert in front of my family's property at 850 Willowbrook Road) as outlined in the Draft-Staff Recommended Plan for Gregory Creek.

As I will most likely not be able to attend the meeting at Flatirons Elementary School this afternoon, I am offering my concerns to you both via email and cc'ing the owner of 445 Christmas Tree (Scott Pluzynski) on this email. The concerns expressed here are my own and I do not speak for the owner of 445 Christmas Tree. I would like this email to be entered into the "emails received - public comments."

(1) SEDIMENT & CARRYING CAPACITY CONCERNS: The idea of storm inlets located where staff is now proposing them was ruled out in the 1996 flood plan by engineers from the City of Boulder. That was because there were concerns about (a) adding greater sediment and debris into the culvert, which would reduce the culvert's

carrying capacity, (b) the belief that inlets located at these locations would fill with debris very quickly, and (c) by adding more water into the system at these locations, you'd have a greater for potential for water to "back up." There had been smaller storm inlets on these two properties before the 1996 flood control initiative so the engineers were aware of water flow issues.

(2) ENGINEERING PROBLEMS WITH EXISTING SEWER CONNECTIONS AND SEWER LINE BREAKS: A storm inlet on the eastern side of the culvert will be highly difficult to engineer due to the problems with the existing hook up of the 850 Willowbrook Road home sewer line to the city sewer line. Please speak with David Garcia in Public Works who can explain the challenges with this and problems that occurred during the last flood. Like other parts of the city, we experienced problems with the sewer line breaking so these issues are extremely relevant.

(3) INEFFECTIVE IN DIVERTING FLOOD WATERS OFF OF THE STREETS: The existing storm inlets on Willowbrook Road filled up very quickly (within hours of the flood) and were overall ineffective in carrying flood waters off of the streets. In addition, it took around 12 hours for Public Works to clean out the sediment from one of the storm inlets.

(4) POTENTIAL TO DO MORE HARM WITH LIMITED UPSIDE: Adding more sediment into the culvert area when we know that the area is already a debris trap really doesn't make a lot of sense. The driveway on 850 Willowbrook is made of gravel, which will easily and quickly fill up the inlet in a flood. While storm inlets are not particularly costly, there seems limited upside and the potential to do more harm.

(5) EASEMENT ISSUES: When the city first did this flood analysis, the consultant's memo had erroneously marked 850 Willowbrook as having an easement. That was the temporary easement from the 1996 flood control and not a permanent easement. While there probably are ways that the city could work around not having an easement on 850 Willowbrook to install a storm inlet, ultimately, the likelihood of the property owner on 850 Willowbrook granting another easement for a storm inlet to be constructed is extremely small. This lack of willingness is based on the fact that the city ran out of money in the 1996 flood control effort leaving large parts of the property on 850 Willowbrook destroyed and not burying the natural gas line as was promised to the homeowner in return for the loss of property due to the flood control effort and as documented in the city's own plans.

(6) FUNDS ARE BETTER SPENT ON OTHER PARTS OF GREGORY CREEK: Because the city's 1996 flood control project on Gregory Creek ran over budget and out of money far earlier than anticipated, other areas along the creek that were promised flood control improvements never received them. Nearly two decades later, it seems that it would be best to spend the money on areas such as near Flatirons School that are in dire need of upgrades. While working with the grassroots Gregory Creek improvement organization, I have come to understand how my neighbors downstream are resentful of the amount of resources and money that have been spent on two culverts (Aurora and Willowbrook), while other areas of the creek have been neglected.

Helen and Dorothea El Mallakh
850 Willowbrook Road
Boulder, CO 80302
303-442-4014

From: Helen El Mallakh
To: Dean, Kristin; Knapp, Katie
Subject: Storm Inlets cannot be placed in front of driveways - Draft Proposal for Gregory Creek
Date: Monday, March 30, 2015 10:05:16 AM

Dear Kristin and Katie

I thought this would be useful to include with the comments at today's open house. The individual most familiar with our sewer problems has left public works, however, I just spoke with another water distribution operator from Boulder's Utility Maintenance who assisted us during the flood. He informed me that storm inlets cannot be placed in front of driveways. Thus, as proposed by the Gregory Creek draft staff recommendation, the storm inlet cannot be implemented as demarcated in front of 850 Willowbrook Road due to our driveway. I am attaching the PDF of staff's plans with my comments and area of concern indicated by a red circle.

Thanks

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302
303-442-4014

From: noreply@bouldercolorado.gov
To: Dean, Kristin
Subject: Gregory Canyon Creek Flood Mitigation Study Form Submission
Date: Wednesday, April 01, 2015 5:42:44 AM

---

support_draft_plan: no
draft_plan_comments: I do not support the proposed storm inlets on the Willowbrook culvert in front of 445 Christmas Tree & 850 Willowbrook Rd. One of proposed inlet is in the driveway of 850 Willowbrook and inlets aren't supposed to be placed in front of driveways. Additionally, storm inlets fill quickly. Thus, there is limited upside to this proposal. After the flood, a new trash rack was already installed on this culvert. This new trash rack at the Willowbrook culvert should address the problems we had during the 2013 flood.
other_improvements: The City's sewer lines and problems aren't really addressed in this proposal. However, I support relocating the sewer line out of the Gregory Creek Gulch where it is now situated and relocated out of the gulch path. In the last flood, the sewer line washed out in the Gregory Creek Gulch and many properties were adversely affected by sewer line breaks upstream (damages paid 100% by the property owners).
specific_improvements: In the flood plan, it should be indicated what has already been done to address issues. For example, we have a new trash rack on the Willowbrook Culvert, but that isn't indicated. I think it's necessary to note where improvements have already been made.
name: Helen El Mallakh
address: 850 Willowbrook Rd.
email: elmallak@swbell.net

From: Helen El Mallakh
To: Dean, Kristin; Knapp, Katie
Subject: Trash Rack/Culvert Entrance Improvement on Willowbrook Rd in the Alternative Analysis Memorandum
Date: Thursday, January 22, 2015 5:43:32 PM

Hi Katie

Another quick question for you since I won't be able to go with Kristen on the walk-through, on table 8 Potential Improvement Summary (page 6) and in some of the figures (pages 17, 20, 23) there is a proposal for an "improvement on the trash rack/culvert entrance." The City just put the new trash rack in last spring. Is this a proposal for a new trash rack? Do you think that the consultants knew that a new trash rack was already installed? I was under the impression when CHDMHill came to the neighborhood that they didn't know that that was the new trash rack was installed.

Thanks

Helen El Mallakh
850 Willowbrook Rd.
Boulder, CO 80302

From: Knapp, Katie
To: Jack Jewell
Cc: Dean, Kristin
Subject: RE: Email list - FW: Gregory Canyon Creek Mitigation Study Open House
Date: Tuesday, January 27, 2015 9:58:55 AM

Hi Jack;

Thanks for contacting us and providing your comments, questions, and observations. Your input is very helpful and appreciated. In response to your questions:

- Table 5 illustrates what is shown in the current floodplain model for Gregory Canyon Creek. This model was developed by Belt Collins, was adopted in 2010 and is what the current floodplain boundaries are based on.
- Our records show that there are 2 different crossings at Aurora: a smaller 36" diameter pipe (Crossing #1) and a big double box culvert (Crossing #2).
- Figure #1, the 2013 flood extents, is based on information collected in the field, aerial imagery, and personal accounts of what was observed. We have received conflicting information in some locations and understand that there are discrepancies. We continue to revise and refine this data as we are able to verify information. The detailed mapping you provided was very helpful in putting together this mapping and we will reassess the 6th St. area above Aurora.
- The different alternatives being evaluated include improvements to street sections that could help convey flood spills down streets instead of across private properties. Included in this evaluation is also a new pipe alignment that would collect flood waters that flow down Willowbrook Road and enter your property. This option includes a drainage inlet at the Willowbrook bend and a pipe that would convey water under the Gregory Gulch and under Aurora, back to Gregory Creek on the downstream side of Aurora.

We are expecting to receive a more complete evaluation of the costs and benefits of the different alternatives from CH2MHill soon and will be updating the website. We will then work on developing a preferred alternative based on costs, benefits and input from the neighborhood. I hope you will be in town for one of the site walks and/or the open house. The input from you and your neighbors is so important in helping us develop a successful mitigation plan to guide future improvements. Please feel free to contact me to further discuss the study.

Katie

Katie Knapp, P.E., CFM
Engineering Project Manager
City of Boulder, Public Works - Utilities
303-441-4077

From: Dean, Kristin
Sent: Monday, January 26, 2015 9:41 AM
To: Jack Jewell
Cc: Knapp, Katie
Subject: RE: Email list - FW: Gregory Canyon Creek Mitigation Study Open House

Hello Mr. Jewell,
I did some research and found that you are on the city's Boulder Flood Info email list, but that you were not on the email list for the Gregory Canyon Creek Mitigation Study list. I have now added you to that list.

I have cc'd Katie Knapp, the project manager for this project, on this email. She can answer the questions you posed below.

I assure you that we will not be walking on your property during the site walks. We do hope you can attend one of them, though. We anticipate receiving refinements to the alternatives analysis in the very near future and will post the updated proposal on the web once they are received.

Please do not hesitate to contact me with any further questions.

Best Regards,

Kristin Dean, AICP
Utilities Planner
City of Boulder, Public Works - Utilities
303.441.4289

From: Jack Jewell [mailto:jack@greenvcsel.com]
Sent: Saturday, January 24, 2015 2:37 PM
To: Dean, Kristin
Subject: Email list - FW: Gregory Canyon Creek Mitigation Study Open House

Hello Kristin,
The email below, and a document titled Gregory_Creek_Alternative_Analsis_Memorandum-1-201410151026, were brought to my attention by a neighbor. I also heard about it from another neighbor. I don't know why I am not on the email list, as I am straight in the affected area, my address being 550 Aurora Avenue. Please add me to the list and keep me on it (or relay this information to appropriate person). I used to receive notifications by email, and so I don't understand my apparent removal.
Though traveling has prevented me from attending many recent meetings, I attended several that followed the flood. In those meetings, I presented a large-format detailed topographic survey map of my property, showing accurately where the flood water flowed, both in Gregory Canyon Creek and in "Gregory Canyon Gulch" on the western side of my property. Officials were keenly interested and I allowed them to scan the survey map with my water-flow regions. I also submitted a presentation for a Dec 2013 meeting (delivered by a neighbor) in which a 1941 survey showed "Gregory Canyon Gulch" that aligned precisely with the 2013 floodwater that I mapped (unaware at the time of the 1941 survey). More recently, I provided a 15-minute video that I shot all over my property on the Thursday Sept 12, 2013, just before dark (highest daylit floodwaters) to the city historical society. I took many still photos as well.
A quick scan of the aforementioned Memorandum reveals some inaccuracies and large concerns. I see my driveway is included in Table 5, but don't know what "Belt Collins Geometry 2010" means. Also I don't know to what "Aurora Crossing #1" and "Aurora Crossing #2" refer. Figure 1 shows floodwater flowing down 6th Street above Aurora Ave, which is plainly incorrect. Figure 4 is similarly incorrect, and my topographic survey map shows the flood extent on my property more accurately. The proposed 40'x6' culvert underneath Aurora Ave (Fig 5) is of great concern and unjustified in my opinion. In Fig 7 (3 of 3) I do not know what is meant by "Proposed Pipe Alignment Outfall North of Aurora at Existing Headwall Maximize Inlet Alignment Along Willowbrook," but it is of great concern. I also need to know what is meant by "Street Overflows." Precise meaning of terms is very important in such matters!

I do not know if I will be in town Feb 9 or 10. If so, I will certainly participate in the Site Walk detailed below. In either case, I do NOT want people walking through my private property. I hope to be in town for the March 30 Open House and April 20 WRAB meeting. Please feel free to contact me by email or phone on any matters that concern my property - same goes for other persons relating to the planning or projects.
Sincerely,
Jack Jewell
303-921-1710
550 Aurora Avenue
Boulder, CO 80302

Date: Friday, January 23, 2015 at 3:43 PM
To: Jack Jewell <jack@greenvcsel.com>
Subject: Fw: Gregory Canyon Creek Mitigation Study Open House

On Thursday, January 22, 2015 2:13 PM, City of Boulder <deank@bouldercolorado.gov> wrote:

Gregory Canyon Creek

Flood Mitigation Study

Opportunities for Public Involvement

Site Walks with City Staff

City Staff welcomes you to join us as we walk Gregory Canyon Creek and discuss the recommendations for flood mitigation. We plan to conduct these walks on two separate dates in an effort to accommodate everyone's schedule. Come join us for the entire walk or just your area of interest:

Monday, Feb. 9 at 3 p.m.
Tuesday, Feb. 10 at 11 a.m.
We will start at the Willowbrook Rd. cul-de-sac and then walk the creek to its confluence with Boulder Creek.
If you cannot attend either of these dates, staff may be available to set up individual meetings.

For more details, please contact Kristin Dean at 303-441-4289 or deank@bouldercolorado.gov

Open House

An Open House to review the revised alternatives for the mitigation plan will be held on March 30, 2015 from 4:30 to 6:00 at the Flatirons Elementary School Library

Water Resources Advisory Board

This project will be reviewed at the April 20, 2015 Water Resources Advisory Board (WRAB) meeting at 7 p.m.
City Municipal Services Center, 5050 Pearl St.

For More Information
Please visit: https://bouldercolorado.gov/flood/gregory-canyon-creek-flood-mitigation-study

Forward this email

STAY CONNECTED

Forward this email

This email was sent to elmallak@swbell.net by deank@bouldercolorado.gov | Update Profile/Email Address | Rapid removal with SafeUnsubscribe™ | Privacy Policy.

City of Boulder | 1739 Broadway | Boulder | CO | 80301

From: Marjorie K. McIntosh
To: Knapp, Katie; Dean, Kristin
Cc: Dick McIntosh
Subject: Thanks
Date: Wednesday, February 04, 2015 8:39:47 AM

Good morning, ladies. Thanks for coming to our house yesterday to talk about plans for flood mitigation work along this section of Gregory Creek. We were relieved to hear that the pipe option is not being considered seriously and that you do not intend to encourage water at the top (cul-de-sac) end of Willowbrook Road to come up onto the road, rather than staying in its normal bed as long as possible.

We continue to feel that getting as much water as possible back into the creek bed immediately below the main culvert under Willowbrook Road, before it gets to the bottom of the road, makes excellent sense. It seems worth considering ways to channel water back into the creek bed across a distance of no more than 20 feet, as opposed to figuring out what to do with it once it reaches the bottom of the road, where it has to cover the full stretch between Willowbrook and Aurora, going through our and Jack's properties. Yes, of course some of the water will do that, but we hope strenuously it will be no more than happened in 2013.

We hope you will also bear in mind our suggestion about turning our property into a publicly owned area that could be landscaped to slow the flow of water, though a series of large steps across the entire front of the property, and then allow it to settle along the back before moving on down towards Aurora. Would it be worth just asking Curt about this idea?

Jack left his jump stick with Dick, who will get another one, transfer the relevant movies and photos onto it, and have it ready for Kristin at the Walk next Monday.

We are fortunate to have people like you in charge of this process, willing to listen to local property owners' concerns.

with thanks,

Marjorie

To: Katie Knapp, as Project Manager for Mitigation Planning for Gregory Creek

From: Marjorie K. and J. Richard McIntosh, 870 Willowbrook Road, Boulder

Re: The proposed street-based plan for Gregory Creek at the north end of Willowbrook Road

Date: January 26, 2015

A. The Damage to Our Property and a Sewer Line Caused by the 2013 Flood

- Our house and yard were badly damaged by the 2013 flood. After the culvert under Willowbrook Road became blocked, much of the water that came down the lower section of the street crossed over into our yard. It ate away the dirt around the foundations of our house on the south and southeast sides, undermined two 60-ft Spruce trees, and dug a trench 10 feet deep at its lowest. The foundation plate of our house was exposed, and for a while it was not clear that the building could be saved.
- Some of the water coming down Willowbrook Road from the blocked culvert flowed into the driveway of our neighbors to the east before it reached our yard. From their driveway, that water went immediately back into the normal creek bed. What came through our yard was only part of the total volume of Gregory Creek.
- The water going through our yard flowed directly above a sewer line that extends along the eastern boundary of our property from the street to our NE corner. At the back of the yard, it destroyed a concrete manhole and a segment of the sewer line itself. These had to be repaired on an emergency basis by a city crew while the rain was still coming down, and a permanent replacement was installed later.
- The entire lower level of our house's interior was flooded, to a depth of 3 feet, and had to be rebuilt from scratch.
- Because water also flowed rapidly around the west and north sides of the house, all the surveyor's marks at the corners of our property were washed away.
- Since the flood, we have paid for three visits from a structural engineer to see whether any permanent damage was done to the foundation or walls of the house. His final opinion is that the house is still structurally sound, but only because the house was so solidly built in the 1950s.

B. The Steps We Have Taken To Protect Our Property in the Event of a Future Flood

- In developing a plan that is likely to protect our house in the case of a future flood, we worked with a water engineer (Curtis Stevens), a hydrologist, a surveyor, and a landscaper, and we sought legal advice from our attorney.
- The resulting plan was based upon the volume and speed of the water (measured as cubic feet per second) that came through our yard in the 2013 flood. We paid a substantial amount of our own money to install the walls, concrete channel, detachable fencing, and landscaping needed to implement that plan.

C. The Plans Produced by the City's Consultant for Gregory Creek

- The consultants hired by the City to produce various plans for mitigating future damage in the Gregory Creek area never contacted us.
- No one from the City has ever spoken with us about those plans.
- When we saw the three plans on the website, we assumed that the street-based version that shows all of Gregory Creek's water coming down Willowbrook Road and through our yard was so ludicrous that the City would immediately discard it. We therefore paid little attention to it.
- We were shocked to receive the recent notice about a walk led by a City officer through this area, following the street-based plan.

D. Problems with the Street-Based Plan from Our Perspective

- The plan shows all the flood water being diverted onto Willowbrook Road at the top of the cul-de-sac, rather than remaining in its normal bed until the culvert.
- It does not show any water passing down our neighbor's driveway and back into the normal creek bed.
- Instead, the entire volume of water would come straight down Willowbrook Road, picking up speed as it passed over the smooth paved surface, until it hit the curve at the bottom of the hill.
- At that point, the map shows the entire flow going through our yard.
- The water moving through our yard according to this plan would be larger in quantity and faster in speed than was the case in 2013, when the water had come down the road for a shorter distance, and some of it had already been diverted.
- Because the foundation of our house barely survived the 2013 flood, any additional volume and speed of water flowing past it is likely to cause the building to fail.
- The additional amount and velocity of water flowing down through our yard are likely to do even more damage to the underground sewer line that lies beneath that route.
- Increased flow and speed of the water as it exits our yard at the NE corner will have seriously detrimental effects for the two property owners directly downhill from us: Jack Jewel, on the SW corner of Aurora and 6th Streets, and Jane Butcher on the NW corner.

E. Our Response

- During the 2013 flood and its aftermath, City officials were consistently helpful in addressing the problems that resulted. We have been strong defenders of your response, in the face of disgruntled neighbors who were furious with the City for failure to keep the culvert open and thereby protect their property.
- But we are utterly unwilling to give the City permission to use our property as the designated watercourse for the entirety of Gregory Creek in the event of another flood. Any such plan would place us, our house, and our possessions at grave risk and would lower the value of our property dramatically.

- The legal implications of the City's proposed plan are obvious. We hope that action of that kind will not become necessary.

Copied to: Curtis Stevens, The Sanitas Group
Constance Eyster, esq., Hutchison, Black, and Cook

Pennsylvania Avenue Flood Repair Public Comments

05.12.2014

Purpose

- *Pennsylvania Avenue was damaged during the September 2013 flood and the City of Boulder is evaluating different options for repairs of the section of road between 6th and 7th streets, where Gregory Canyon Creek crosses the roadway. We asked members of the community to choose one of three alternatives or share another alternative with us.*
    - *Alternative 1: Replace the existing culvert (drainage pipe) and rebuild the roadway to pre-flood conditions.*
    - *Alternative 2: Remove the culvert and roadway above the creek, close the road to through traffic and build a pedestrian bridge over the creek.*
    - *Alternative 3: Remove the culvert and construct a new roadway with a significantly larger culvert or a vehicular bridge over the creek.*

Summary of Public Comments

General Comments

- **Alternative 1:** 4 in favor
    - Traffic on the road and school access is better mitigated on option 1. Option 2 looks like it would cause more blockage.
    - There would be through traffic, less congestion, a paved road, and less mud. School parking traffic will be decreased if back to pre-flood conditions. There would be less speeding traffic to suddenly stop at the closed road and dead end to turn around.

- **Alternative 2:** 114 in favor
    - Alternative two is much better for our neighborhood.
    - The culvert will continue to get clogged and spill over.
    - This has the greatest opportunity to mitigate future property damage from structure blockage and volume.
    - The culvert narrowing the creek bed at Pennsylvania caused the flooding west of the creek; Therefore if it is restored as it was there will be a problem of liability. It also seems that option two is less expensive.
    - Regardless of the alternative, the type of maintenance upstream to the head waters is critical for safety. The flood in September 2013 highlighted the limitations of culverts. Alternative two is consistent with City Council's goals of encouraging pedestrian traffic as opposed to vehicular traffic.

- I would like the peaceful space and green belt. There would be calmer traffic during school when kids are walking and a significant water flow improvement during flood episodes.
- It's very nice to see the creek again from the bridge. We can manage very well without this street and have been doing so since mid-September. Thank you for finding some funding to get started on the Gregory Creek flood plain mitigation. We know there are lots of mitigation needs elsewhere, but please don't forget that Gregory Creek needs more attention sometime in the future.
- Adequate access exists without Pennsylvania. Why rebuild it?
- The chance of the road washing out again will be lessened. A pedestrian bridge would be nice for the neighborhood. We walk our dog in the neighborhood a lot. Option two is a safer alternative. The children at Flatiron Elementary will have to contend with less traffic on Pennsylvania. Option one would risk rocks getting caught in the culvert again.
- If option two is selected, please move the west-side cul-de-sac further west.
- Great for habitat/wildlife restoration and a safe route for bikes, pedestrians and flood mitigation.
- Use the east side of the bridge area as a family meeting area for walking and cycling families. Pennsylvania can be a riding route to 6th. 6th should be a marked bike route to University and down to the Boulder Creek Path. Benches and bike racks should be provided. Thanks!
- This will not eliminate future flooding. The culvert under 7th gets blocked every time we have a severe thunderstorm. The grate catches debris and blocks very quickly.
- Pedestrian friendly.
- Better neighborhoods.
- This street hardly has any traffic to begin with. The pedestrian bridge close to the school would be a great addition!
- Option #2 sounds like a much better fit for the neighborhood!
- This would be so nice for walking my kids to school!
- This culvert caused my house to flood! Rebuilding it the same way is just plain stupid! Having a pedestrian bridge and cul-de-sac is the best idea I have heard from the city in years!
- I think a pedestrian bridge here would be a great addition for no extra cost! These kinds of options continue to make Boulder the special place it is.
- It seems like option 2 is clearly the right solution. Why rebuild something that will be blown out again? Let the stream run naturally as it was intended. Thanks for the opportunity to provide this input.
- I visit the neighborhood often and would enjoy walking over the foot bridge and seeing the stream below. There doesn't seem to be enough traffic to warrant rebuilding the road/culvert.
- Having seen firsthand the devastation that the clogged culverts caused throughout Boulder with the floods in September, I'm inclined to say where

there is an opportunity to allow water to flow in a more natural manner and still allow access to communities, this is the appropriate way to proceed.

- I am a fan of anything to improve pedestrian access to our beautiful creek.
- As someone who grew up in the neighborhood and still lives in town I like the second idea. Seems to be a much better idea for flood control and the idea of an open creek bed through there seems kind of nice. If it floods again you're going to have the exact same problem if you build it back.
- Let the stream flow!
- The pedestrian bridge option is a great one for this neighborhood!
- Pennsylvania Ave has a number of issues that make for an accident waiting to happen. These issues include: Icy conditions - due to lack of snow removal and direct sunlight, steep grades - west side, blind corners - Dean Pl. Reducing the amount of traffic by replacing the culvert with a foot bridge would lessen the risk of an accident on this street.
- I live on Pennsylvania and Gregory Creek goes under my deck. I would LOVE Option 2 with a pedestrian bridge. I think it offers a safe route to school for students walking or biking as well as slows down and/or lessens the traffic impact before and after school. In terms of emergency vehicles, since Pennsylvania only runs between 6th and 7th, it is already confusing and difficult to find so improved mapping and signage could effectively bring attention as to how to reach us on the West side via 6th or Dean Place. I also really like that this option allows for better wildlife and habitat restoration along with flood mitigation, in particular for the folks downstream.
- I am a big proponent of Alternative Two. I think any chance to restore a stream corridor should be capitalized on. There are ecological/habitat benefits, safety benefits regarding flood control and aesthetic benefits for those living there. I'm all for number 2!
- Very hopeful that we can begin a small step of prioritizing people traffic over car traffic.
- This is a really great opportunity to decrease flood risk while re-building! The extra cost of a pedestrian bridge is absolutely worth it for the downstream flood reduction.
- This seems like a great opportunity to increase multi-use pathways in Boulder. I have been in this area often and agree that drivers often speed through, even though there is a school nearby. It is such a beautiful area, would love to see it become more pedestrian friendly.
- I live at 637 Pennsylvania Ave and would like the pedestrian bridge please
- Given the proximity to the school building I think it makes sense to reduce some traffic in this area.
- Option #2 would improve the pedestrian character of the neighborhood and provide important flood relief that could not easily be obtained by a culvert.
- It seems like an option to take into account future flooding would be a good idea. Does local traffic require a bridge?

- Option 2 is a nice compromise. Flood improvements for future storms but at more than half the cost of a vehicular bridge.
- #2 has the most positive attributes.
- great job with some good alternatives --thanks staff
- Versus option 1, Option 2 seems like the better long-term compromise that's potentially a good investment capable of preventing damage otherwise in the future. With flooding though, it's a zero-sum game---every link of the chain would need to be more robust in order to prevent problems. Making one link stronger may have little net positive effect to the city. If this is one of the weakest links, then by all means, please treat as such.
- As a parent of students at Flatirons Elementary, I love the idea of closing this dangerous street to vehicles and walking my kids to school over a pedestrian bridge.
- It is imperative to our neighborhood that Alternative TWO is implemented, since the pre-flood condition is the one which enabled the flooding in the first place. The cost to restore our home is now close to $50,000, and we know that others in our area have spent as much or more. We are asking the city in good conscience and good faith to help us to keep this from happening again.
- It is option number two which is most beneficial to our neighborhood, as it would allow more flood conveyance AND, very importantly, would interrupt the speeding and dangerous driving on Pennsylvania. The school already has good access on nearby streets, and the pedestrian bridge would be available for everyone. Thanks for your work on this.
- I live adjacent to the existing culvert and am in strong support of increasing the flood conveyance capacity. Option 2 is the most reasonable cost option that accomplishes this.
- Alt. 2 has, by far, the strongest support from those effected by this problem - those who were directly flooded by the breech of Penn. Ave. It does feel like the estimate for this repair could be greatly reduced by looking at simpler options for the bridge. Perhaps a use of pressure treated lumber beams instead of metal. The city cannot really choose Alt. 1 since that would put it in the position of intentionally creating a greater risk of flood and the possible liability. And since it is 7 months since the flood and nothing has been done, I see no value at this point of its being the fastest fix. That time is long past. It also seems the estimate for this job is way too low. Alt. 3 is too expensive and there is no good reason to do it. A final cheapest alternative would be to simply remove the ton of gravel that the city dumped in the hole, which raised the likelyhood of further flooding, and fence the whole creek gap off on both sides at Penn. Ave. and have no access.
- Yes to a pedestrian bridge!
- Pedestrian Bridge seems wonderful!
- I hope this can still be received. I live on Pennsylvania and think this option is the best solution; for pedestrian/bike safety and access, wildlife habitat and flood mitigation.

- **Alternative 3:** 7 in favor
  - Car bridge or better yet, a draw bridge.
  - Square opening (rock wall exposed in flood) with roadway over (open to cars).
  - Build a vehicular/pedestrian bridge or street and keep flow way open.
  - Car bridge.
  - Re-engineer the culvert to convey flow consistent with expected flow from culverts above and open street to vehicle traffic as well as pedestrian traffic. Flatirons Elementary School has been open well over 50 years and will be most affected by the decision. It is considered by Flatirons staff that closing the street would have a negative effect on the traffic flow relative to school operations.
  - The biggest push to close the street thus far has come from a resident who moved in to the neighborhood 8 months ago and has stated he was "tired of having cars from the school park on Pennsylvania" and was going to try to get the street shut down.
  - I actually prefer alternative 2 EXCEPT the fact that Flatirons Elementary School is located in the area. Students with special needs, combined with the occasional presence of bears and mountain lions, makes it critical for fast emergency response times.
  - I support alternative 3 because it is the most comprehensive and it is the best for the nearby elementary school due to the access for emergency vehicles (which is negatively impacted by alter #2). This culvert was supposed to be replaced in 1996, but the project ran out of money. It is long overdue. Also, given that mountain lions have begun to hunt around gregory creek in town, it is a bad idea to create an ""attractive"" environment for wildlife as suggested by alter. 2. Due to the school and the number of small children, we must put public safety first and select option 3. The price is commensurate with the benefits.

- **Other options:** 4 in favor
  - Reduce parking on east side of stream. Turn that area into a gathering place for kids and parents. Allow residents to access their drives, but reduce traffic and parking.
  - I'm not advocating for any particular solution, but do have the following concern: if the capacity at Pennsylvania is increased, does that just mean that the flooding as the Creek goes under 7th will be that much worse? Or further down, as it goes under Pleasant? Or University? Or Eighth? It seems to me that having the creek top over and go sluicing down broad streets during a flood is not the worst solution -- it keeps the flood shallow enough not to drown anyone, or to cause major structural damage (just wet basements, which one can recover from.)
  - alternative 2 is probably best, but i would like a draw bridge.
  - alternative two or alternative 3 with a drawbridge.

APPENDIX C

REACH INVENTORIES, PROJECTS AND OPPORTUNITIES

Stream: **Gregory Canyon Creek**
Reach: **1** (GRC 05, 06, 07, 08, 09, 10)
Location: **Boulder Creek to College Avenue**

Habitat conditions:

Vegetation structure:	Excellent to good
Native plant habitat:	Poor
Bird habitat:	Poor to very poor
Aquatic habitat:	Fair to poor
Primary (streambed):	Fair to poor
Secondary (channel morphology):	Poor
Tertiary (bank stabilization):	Fair
Vegetative bank stability:	Fair

Other conditions:

- Creek runs through residential yards
- Creek is narrow and channelized
- Most of reach is deeply entrenched with vertical walls

Opportunities:

Flood Management:

- Significant split flows occur at University Avenue and Marine Street causing several properties to be added to the floodplain.
- Arapahoe Avenue, Marine Street, 8th Street, University Street, Pleasant Street, Pennsylvania Avenue and College Avenue are all overtopped by 100-year discharge.
- Channel is small, incised and located on private property
- Acquire properties in the High Hazard Zone according to the city's pre-flood acquisition program.
- Outreach to adjacent neighborhoods to raise awareness of flood hazards

Habitat protection:

- Low priority for restoration due to location in residential yards
- Homeowner education to improve conditions for native species coupled with an incentive program or technical assistance
- Revegetation / re-channelization downstream of University Avenue

Water quality:

- Develop and implement stream habitat improvement matching grant program for adjacent properties
- Educate adjacent neighborhoods to encourage backyard management to protect habitat, wetlands and enhance water quality

APPENDIX C

REACH INVENTORIES, PROJECTS AND OPPORTUNITIES

Stream: **Gregory Canyon Creek**
Reach: **2** (GRC 01, 02, 03)
Location: **College Avenue to city limits**

Habitat conditions:

Vegetation structure:	Very good
Native plant habitat:	Good
Bird habitat:	Very good to good
Aquatic habitat:	Fair to poor
Primary (streambed):	Fair to poor
Secondary (channel morphology):	Fair to poor
Tertiary (bank stabilization):	Excellent to poor
Vegetative bank stability:	Excellent to poor

Other conditions:

- Creek runs through residential yards
- Creek is narrow and channelized
- Dyer's Woad occurrence in Smith Park

Opportunities:

Flood management:

- Flagstaff Road, Willowbrook Road, Aurora Avenue and Euclid Avenue are overtopped by 100-year discharge.
- 100-year floodplain has less split flow and is located in proximity to the channel in this reach.
- There are a few structures in this reach that are highly impacted by the High Hazard Zone. Acquire properties in the High Hazard Zone according to the city's pre-flood acquisition program.
- Outreach to adjacent neighborhoods to raise awareness of flood hazards

Habitat protection:

- Landowner and homeowner education about the threat of exotic ornamentals (*Brunnera, Vinca minor, Vinca major)*
- Russian Olive removal
- Eradicate Dyer's Woad occurrence in Smith Park
- Some planting of native cotton woods might restore the balance of species composition

Water quality:

- Develop and implement stream habitat improvement matching grant program for adjacent properties
- Educate adjacent neighborhoods to encourage backyard management to protect habitat, wetlands and enhance water quality

Wetland Evaluation

Wetland #: 40502 **Former #:** 14 **T_R_S:** T1NR71WS36

Investigator: A. Carpenter, C. Browne **Date of Visit:** 7/2/2004 **Obs. Method:** Viewed from property boundary

General Location: Gregory Creek east of Mountain Parks and south of Boulder Creek

Description: Steep, rocky intermittent stream that flows northward along eastern edge of a Pierre shale bedrock formation, draining into Boulder Creek. Characterized by generally narrow active channel with fairly steep gradient. Precipitation in foothills to the west supports seasonal flows in creek. (Includes tributary to Gregory Creek which flows in from the west along the north edge of Smith Park, between Aurora and Euclid Streets.)

Wetland Origin: Natural **Primary Water Source:** Creek

Hydroperiod: Intermittently flooded **Max WaterDepth (ft):** 1.5

Major plant communities present	% of wetland area
narrow leaf cottonwood/ mixed herbacous	35
urban tree/ mixed herbacous	60
open water	5

% Vegetated: 90
% Bare ground: 5
% Water: 5

FUNCTION AND VALUE ASSESSMENT

Ratings: 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = no Confidence in rating: c = high, b = medium, a = low

Groundwater recharge	1	b	Geohydrologic map indicates groundwater recharge or discharge are possible. Effectiveness of the
Recharge			function is limited by impermeable bedrock near surface, narrow channel, and intermittentflows. Uncertain
the			extent to which infiltration into fractures recharges water in deeper formations.
Groundwater Discharge	2	b	Local discharge of rainwater infiltration into creek likely but the thin overburden limits opportunity.
Flood Storage / Floodflow Alteration	2	b	Rough streambed slows flows somewhat and small pools in lower section offer minor storage benefits.
Shoreline Anchor. / Stabilization	3	b	Fairly dense understory and tree cover along banks, though rocks are significant factor in erosion control.
Sediment Trapping / residence	2	b	High velocity flows likely to transport sediments through the system, though small pockets of short
Retention			sediments were observed in pockets along the bank and in pools.
Nutrient Retention (long-term)	2	b	Abundance of trees and understory
Nutrient Retention (short-term)	2	b	
Food Chain Support may	3	b	Good supply of leaf litter from overhanging vegetation and good export flows. Grates and control structures
(export)			trap some of larger material.
Food Chain Support (within basin)	3	b	
Fish Habitat / Aquatic Diversity	1	b	
Wildlife Habitat	3	b	deer observed and diversity of trees and understory offers food and shelter, but narrow buffer reduces effectiveness
Active Recreation	1	b	
Passive Rec / Heritage Value	3	b	

Comments: Gregory Creek runs though residential back yards starting at edge of Mountain Parks and flows north to Boulder Creek (access to the creek was generally limited to where it intersected with city streets)

Attachment B

CITY OF BOULDER, COLORADO
BOARDS AND COMMISSIONS MEETING MINUTES

Name of Board / Commission: Water Resources Advisory Board

Date of Meeting: 20 October 2014

Contact Information of Person Preparing Minutes: Andrea Flanagan 303.413.7372

Board Members Present: Vicki Scharnhorst, Mark Squillace, Lesley Smith, Ed Clancy
Board Members Absent: Dan Johnson

Staff Present: Jeff Arthur, Director of Public Works for Utilities
Robert Harberg, Principal Engineer - Utilities
Katie Knapp, Engineering Project Manager
Annie Noble, Flood and Greenways Engineering Coordinator
Kristin Dean, Utilities Planner
Bret Linenfelser, Water Quality and Environmental Services Manager
Chris Douville, Wastewater Treatment Manager
Andrea Flanagan, Board Secretary

Cooperating Agencies Present:
Alan Turner, Senior Project Manager, CH2M HILL

Meeting Type: Regular

Agenda Item 1 – Call to Order **[7:00 p.m.]**

Agenda Item 2 – Approval of the 15 September 2014 Meeting Minutes: **[7:01 p.m.]**
Motion to approve minutes as amended from September 15th as presented.
Page
Moved by: **Squillace;** Seconded by: **Smith**
Vote: 4:0

Agenda Item 3 – Public Participation and Comment **[7:02 p.m.]**
Public Comment: None
Board follow up: None

Agenda Item 4 – **[7:03 p.m.]**
Public Hearing and Discussion of Gregory Creek Mitigation Alternatives
Katie Knapp and Utilities staff presented the item to the board, which included a Prezi presentation.

Executive Summary from the Packet Materials:
The purpose of this memorandum is to provide a general summary of the preliminary proposal for flood mitigation measures to facilitate improved flood conveyance along Gregory Canyon Creek as it traverses the City of Boulder from Flagstaff Rd. to its confluence with Boulder Creek.

The city has retained CH2MHill to evaluate potential alternatives to help alleviate future flooding along Gregory Canyon Creek. CH2MHill has conducted a study of the creek corridor and developed three sets of categorical options which would improve flood conveyance. These categories include:

1. Improvements in Public Right-of-Way and Easements;
2. Improvements outside Public Right-of-Way and Easements; and,
3. Improvements for street conveyance.

CH2MHill's Alternative Analysis Memorandum ("Analysis") is included as Attachment A. This analysis contains a detailed description of the data and models used to determine the improvements which would help flood conveyance along Gregory Canyon Creek. The intent of the draft mitigation plan is to identify various types of improvements which could be constructed along the creek corridor in order to discern the costs and benefits associated with each improvement, or group of improvements, and to prioritize these improvements.

WRAB Discussion Included:

- Questions about whether or not there has been a cost benefit analysis performed yet?
- Questions regarding staff's sense of potential merits of using street conveyance as an option?
- Suggestion to consider alternative safety signage in the event of a flood to prevent bottle necks and involve the University through outreach to student housing.
- Discussion regarding private culverts and if there is a potential plan to address this.

- Questions about whether there has been positive feedback about the drainageways and easements.
- Comments about the need to clear cars, grills and fences from areas that are prone to flooding. Questions as to what thought is given to providing instructions and educational programs for people when there is a flood?
- Questions about whether smaller group meetings could take place with property owners/ early adopters interested in getting larger culverts, driven by neighborhood groups rather than city government. Possible way to get more people on board to consider this plan for street conveyance.
- Discussion about looking into smaller detention and viable ways to help keep culverts clear.
- Questions about if smaller detentions on open space a viable option?
- Questions about how many private culverts exist?
- Questions to the board about whether the approach to smaller culverts is reasonable or should larger culverts be considered.
- Discussion around how the city gets buy-in for the city to maintain a conveyance system, as there are reservations for the city to spend money without buy-in from the residents who would benefit.
- Question if city has talked to residents about setting up a watershed focus group to discuss watersheds that the city could cooperate with.
- Mention of potential to provide incentives for community and city to work together to clean out streams and keep trees down to collectively solve issues.
- Question about costs associated with clearing areas around houses in high hazard zone.
- Statement that street conveyance option has broad support among community and appears to be a cost-effective option. Is this a fair guess of what we are likely to see?
- Question about if this watershed will flash quickly during a storm event?
- Question about whether the city has spoken with landowners in the Willow Brook area about ideas on how to better protect their properties?
- Discussion of putting soccer field in the low-lying area where the major flow would take place.
- Request to see more discussion about outreach to community in advance and during rain events.

Public Comment:

- **Keith Pearen –** Lives near Flatirons Elementary School, really appreciates where city is going with their plan and agrees that conveying a 100 year flood out of the question. Read study in its entirety. Alternatives proposed do not necessarily match what actually happened on the ground during the flood. Problematic area during this event that may not adequately be addressed at 7th. Does not have a strong feeling on option three in the roadway. Feels that spending money to make the roads convey without hurting property is money well spent. People are open to having flood mitigation done on their properties, but there are possible challenges there. Impressed with how accurately earlier studies match up with what was seen during the flood event. May be able to leverage earlier studies going forward.
- **Justin Hoffenberg –** Lives midway on creek and has specific question regarding two maps and noticed there is a chart in attachment A that shows different culverts and what improvements would look like in a 10-year plan or maximum culvert (35x6). The 10 and 50 year maps only show maximum 50-year extent. Comments were heard during open house questioning this finding showing 35 foot culverts on the 10-year map, which isn't actual benchmark for 10-year event. Requests clarification whether the maps reflect 10-year or maximum numbers and asks if maps need updating.
- **Scott Hoffenberg –** Wants to thank the board for hearing the neighborhood last year and putting neighborhood's name out there for potential for growth, which shows a lot of thought. Concerns about map showing 35-foot culvert and hopes that Board will take closer look at document from CH2M Hill to address and consider street conveyance. Appreciates Board taking a closer look at this creek and looks forward to the future.
- **Laszlo Nemeth –** Didn't have problems like University and 7th. Suggests putting energy into conveyance because Mother Nature is going to decide, not what planners decide. Water went back into Gregory Creek because a car diverted it. This area is packed with cars and not enough parking.
- **Tom Manteuffel –** Lives on College and appreciates looking into this issue. Mentioned culvert at College Avenue, which was filled with fences and BBQ grills that were piled into

culvert, forcing water to run over the creek onto other properties. Suggests looking at this issue and better advising people not to put objects in the creek bed. Mentioned 22-foot wide culvert at Aurora and feels that a 35-foot culvert is too excessive.

- **Hal Totten –** Lives on College, family built house in 1950. At height of flood, banks took all the flood waters, bank to bank and held a 1.5 – 2 feet of water before touching his foundation. Some of the street did have water conveying and he built diversion with 2x4's which diverted water down College, past Flatiron Elementary School. According to charts – what happened on College is being compared to what happened on Pennsylvania, which are not comparable. Stone bridge on his property has weathered 3 major storm events in his lifetime, which is a good model.
- **Brad Sclar -** Lives below Anderson Ditch. Asks what kind of incentive programs are being considered for property owners to keep stream beds clean?
- **Paul Shankman -** Lives at 7th and Pleasant and thinks that street conveyance is a good idea. With some work on 7th, a lot of the damage could have been avoided. East side was severely damaged. Could make a difference in the future with better street conveyance.

No Board action was requested at this time.

Agenda Item 5 – Matters **[8:11 p.m.]**

From the Board:

Board Member Smith brought up the below matter(s):

- Question regarding businesses and water bills, would there be incentive and/or adjustment to stormwater bills if these large surface areas can be converted from pavement to a more pervious surface area, which could potentially be reflected in their bill?

Board Member Clancy brought up the below matter(s):

- Requested to extend water quality report warning on fluoride in city's drinking water for seven individual groups of vulnerable populations to address more specifics surrounding fluoride in infant formula. Asking that a CDC warning be included on the report and on the city's website, modeling that of other city municipalities.
- Feels that people should be properly noticed.
- Expressed concerns for higher risks of fluorosis in infants due to fluoride in water.
- Asked the question if there exists an annual report on wastewater treatment effluent that is made available to the public?
- Noticed that Boulder Reservoir water levels are low. Asked if this is something the city controls and monitors?

Board member Scharnhorst brought up the below matter(s):

- Questioned whether a utility bill insert would suffice as a means to providing information about CDC's opinion on study of fluoride in drinking water that may affect infant baby formula.
- Expressed that if we start down the path of providing information to the public about fluoride, then Council should be prepared to put the topic back on the ballot.

Board member Squillace brought up the below matter(s):

- Expressed concern that if a recommendation is made to the public about fluoride in water, that it could create a fury for people to react to, which should be carefully considered.
- Suggests before making any recommendations, that all consequences be considered and caution should be exercised to prevent triggering reactions in the general public.

From Staff: **[8:31p.m.]**

- **Chris Douville and Bret Linenfelser will provide some brief updates on wastewater treatment and nutrients.** *Topics included:*
  - Permit compliance items regarding energy efficiency
  - Nutrient Management Grant
  - Nitrogen Upgrades Design Project
  - Permit renewal due and will expire in April, 2016
  - EnerNOC Demand Response Program
  - Alternative energy and options to modify and modernize cogeneration
  - Process optimization studies
- **South Boulder Creek**: Still waiting for additional information from CH2M Hill about scenarios involving University property.
- **Wonderland Creek Mitigation**: Funding is not atypical, need Council's authorization for potential imminent domain. First reading in November and second reading in December, which would be a last resort for negotiations.

- **Lower Bear Canyon Creek**: Board approved a motion recommending approval of the mapping study. It will be presented to Council at a later time.
- **Boulder Slough**: Board approved a motion recommending approval of the mapping study. It will be presented to Council at a later time.
- **Skunk, Bluebell, King's Gulch**: Additional work was completed on 15th and Mariposa and this topic will be revisited with the board at a later time with notable updates.
- **Frasier Meadow's Neighborhood**: Lining the wastewater collection system appears to be effectively reducing infiltration. Suggestion made for staff to put together outreach materials for residents.
- **Budget**: Recommendation for rate increases go to City Council on October 21st.

Agenda Item 6 – Future Schedule **[9:00p.m.]**

- Possible November 8th WRAB retreat to be scheduled to discuss priorities and interests for 2015.
- November: Update on Upper Twomile Goose Creek
- December: Update on Betasso CIP
- January 26th meeting is scheduled for 4th Monday rather than 3rd for WRAB board meeting, due to Martin Luther King Jr. holiday
- February 23rd meeting is scheduled for 4th Monday rather than 3rd for WRAB board meeting, due to Presidents' Day holiday.

Adjournment **[9:27 p.m.]**

There being no further business to come before the Board at this time, by motion regularly adopted, the meeting was adjourned at 9:27 p.m.

Motion to adjourn by: Squillace; **Seconded by:** Smith

Motion Passes 4:0

Date, Time, and Location of Next Meeting:

The next WRAB meeting will be Monday, 17 November 2014 at 7:00 p.m., in the Council Chambers, 1777 Broadway, 80302.

APPROVED BY:

Board Chair

11/17/14

Date

ATTESTED BY:

Board Secretary

11-17-2014

Date

An audio recording of the full meeting for which these minutes are a summary, is available on the Water Resources Advisory Board web page.