

Memorandum

TO: Ward Bauscher – City of Boulder, Greenways and Floodplains
 FROM: ICON Engineering Inc. (Craig Jacobson, PE, CFM & Brian LeDoux, PE, CFM)
 DATE: October 29, 2015
 RE: Fourmile Canyon Creek CEAP Mitigation Planning - Technical Summary

Purpose

This memorandum has been prepared by ICON Engineering Inc. to provide a summary of the technical feasibility, cost estimates, and avoided damage benefits of floodplain mitigation efforts along Fourmile Canyon Creek and Wonderland Creek upstream of 19th Street. This information will be used by the City of Boulder for the Community and Environmental Assessment Process (CEAP) and Capital Improvement Program (CIP) planning efforts.

Background

Fourmile Canyon Creek originates in the foothills west of the City of Boulder and has a total drainage area of approximately 10 square miles. Wonderland Creek has a total drainage area of approximately 2 square miles and begins at Wonderland Lake located on the western side of the city approximately 1300 feet west of Broadway. Both creeks flow east and south through the City of Boulder and eventually flow into Boulder Creek. A vicinity map of Fourmile Canyon Creek CEAP Mitigation Planning area is provided in **Figure 1** below.

Fourmile Canyon Creek and Wonderland Creek have been extensively studied by major drainageway planning, flood hazard area delineation, letter of map revision, and other special report studies. These studies include:

- 1969 Major Drainageway Storm Drainage Pilot Planning Study
- 1984 Major Drainageway Planning, Boulder and Adjacent County Drainageways, Phase A
- 1987 Flood Hazard Area Delineation, Boulder and Adjacent County Drainageways
- 2000 Fourmile Canyon Creek Major Drainageway Planning Phase A Report
- 2007 FEMA Letter of Map Revision (Case No. 06-08-B289P)
- 2007 Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning, Phase A
- 2008 Sediment Analysis Report, Fourmile Canyon Creek Downstream of 30th
- 2011 Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning, Final Plan
- 2012 Evaluation of Fourmile Canyon Creek Sediment Basin Alternatives
- 2014 Fourmile Canyon and Wonderland Creeks Discharge Estimates from the September 2013 Flood Event
- 2014 Fourmile Canyon and Wonderland Creeks FLO-2D Model Calibration to the September 2013 Flood



The 2007 LOMR identified significant spill flows (during the 50-year and larger events) from Fourmile Canyon Creek that leave the south bank of the channel between 10th Street (west of Broadway) and 19th Street. These spill flows travel overland to the south and east and ultimately the majority of the spill flows enter Wonderland Creek. This results in a significant increase in regulatory floodplain discharge for Wonderland Creek. As a result of this change in the regulatory floodplain, the City of Boulder and the UDFCD produced the 2007 (phase A) and 2011 (phase B / Final Plan) Major Drainageway Planning reports.

The 2011 MDP recommendations for Fourmile Canyon Creek upstream of 19th Street were limited to providing safe access to Crest View Elementary School via 19th Street and Upland Avenue, high hazard containment, flood proofing, and maintain existing conditions. No major floodplain mitigation projects were recommended. Excerpts from the 2011 MDP are included in **Appendix A**.

As a result of invasive crack willow trees, ponding water, and sediment burying sanitary sewer and storm drain manholes along Fourmile Canyon Creek, several sediment mitigation reports have been completed. The 2012 sediment basin alternative report recommended the installation of a sediment basin upstream of 7th Street. This 925 cubic yard basin would trap approximately 545 cubic yards of sediment annually and was estimated to cost \$435,360. Excerpts from the 2012 sediment basin alternative report are included in **Appendix E**.

The September 2013 flooding event caused significant flooding damage to homes, public infrastructure, and utilities and resulted in significant sediment transportation throughout the Fourmile Canyon Creek length. The peak discharge of this flooding event was estimated at approximately 1800 cfs at the canyon mouth which is between the 10-year and 50-year events. A FLO-2D model was created and calibrated in an effort to model the spill flow behavior between Fourmile Canyon Creek and Wonderland Creek for both this event and larger regulatory flood events. This 2D model confirmed the likelihood of spill flows leaving Fourmile Canyon Creek and entering Wonderland Creek during large flooding events as identified in the 2007 LOMR.

Community and Environmental Assessment Process (CEAP)

In early 2015 the City of Boulder began to review alternatives and plans for greenway trail extensions and connections along Fourmile Canyon Creek. At that time it was determined that potential improvements for the greenway trails could reasonably be combined with floodplain mitigation efforts and be made into a singular more beneficial project. In order to pursue any floodplain mitigation efforts, the City will go through its Community and Environmental Assessment Process. This memorandum has been prepared to document the technical feasibility, cost estimates, and estimated avoided damage benefits of floodplain mitigation efforts along Fourmile Canyon Creek and Wonderland Creek in the area upstream of 19th Street. The City will use the technical information presented in this memorandum in order to develop a qualitative assessment of the proposed mitigation alternatives and will ultimately present them to the general public. Public feedback and City staff recommendations will then be taken into consideration and if applicable a conceptual design will be pursued for one or more of the mitigation alternatives.

The following information has been developed to assist with the Fourmile Canyon Creek CEAP planning efforts.

2013 Flooding Event Sediment Volume Estimates

The City of Boulder's 2013 LiDAR topographic mapping (pre-flood) was compared to the USGS 2014 (post-flood) LiDAR topographic mapping. Significant areas of cut and fill along Fourmile Canyon Creek from the Canyon mouth to 47th Street were identified and average change in elevation values were computed using GIS raster data analysis tools. The average depth was then applied over the computed surface area to estimate the volume of material that was either eroded or deposited along Fourmile Canyon Creek. A total cut volume of 22045 CY and a total fill volume of 84617 CY was estimated resulting in a net fill of 62572 CY or around 38.8 ac-ft of sediment deposition.

The potential for a sediment basin at or downstream of 5th Street was reviewed with respect to the volume of sediment passing that point during the September 2013 flood event. It was estimated that the sediment basin would have had to capture nearly 40.1 ac-ft of sediment to eliminate downstream deposition.

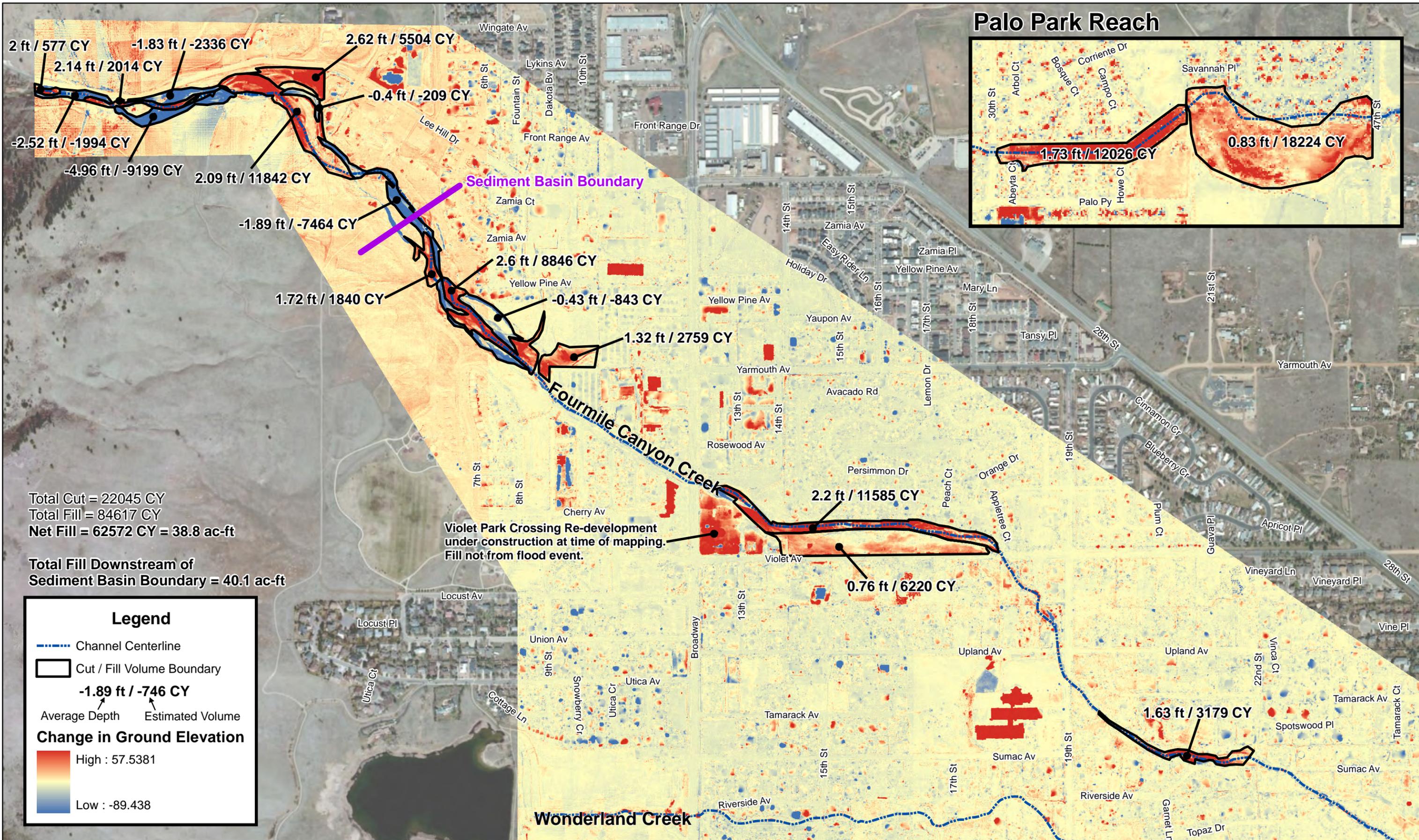
Figure 2 illustrates the comparison between the pre-flood and post-flood ground elevations and the locations of the major areas of cut and fill.

Spill Flows

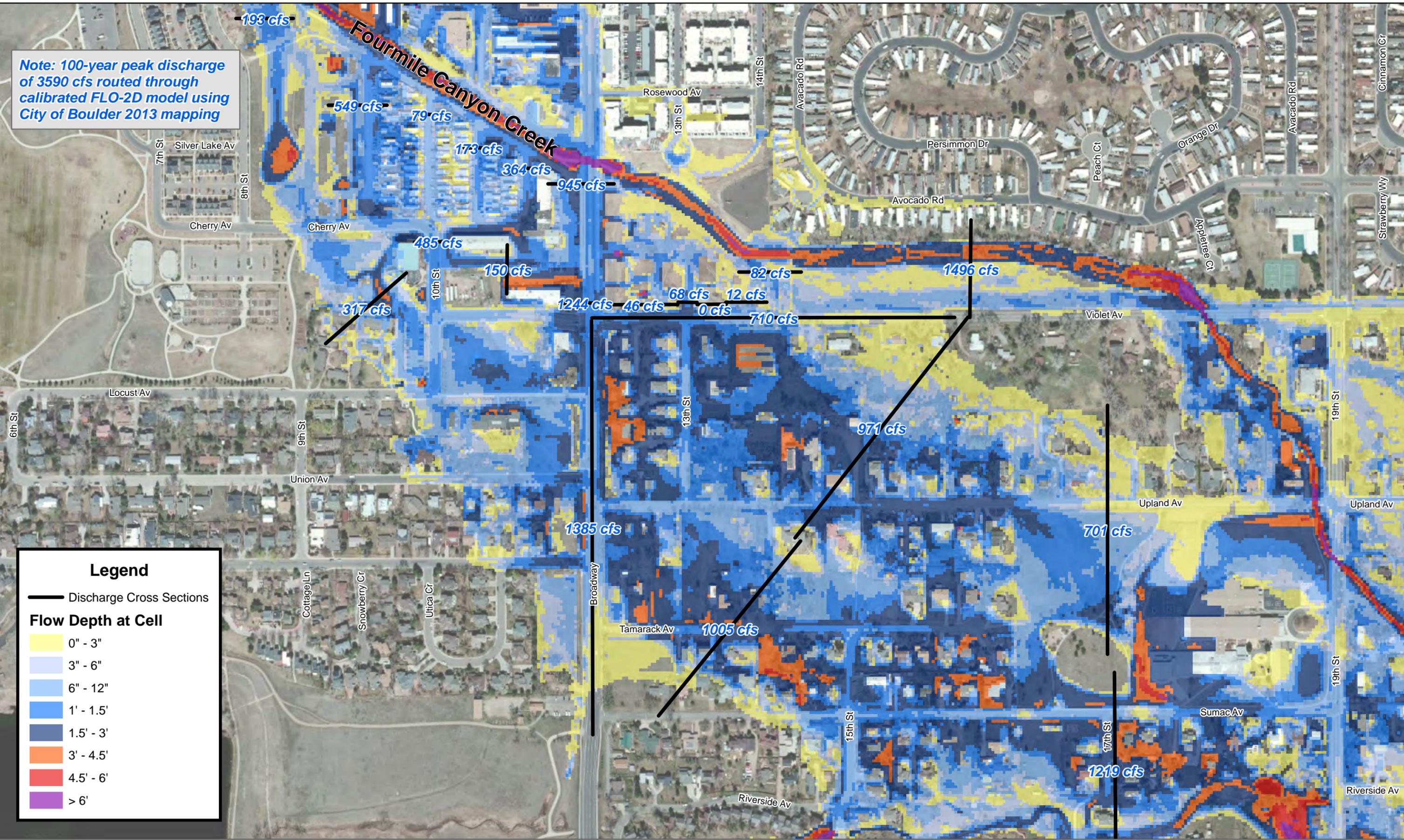
ICON Engineering Inc. previously developed the "Fourmile Canyon and Wonderland Creeks – FLO-2D Model Calibration to the September 2013 Flood" model and associated memorandum dated March 12, 2014. Utilizing the calibrated FLO-2D model from this effort (with revisions to reflect the Violet Crossing redevelopment) and running the 100-year design inflow hydrograph, additional cross sections were added to the 2D model in order to better define the spill flow discharge values. **Figure 3** illustrates the cross section locations and peak discharge values. The model confirms that approximately 2,100 cfs will spill into the area south of Violet Avenue and east of Broadway during the regulatory 100-year flood event.

Estimated Detention Volume

The potential for flood volume storage along Fourmile Canyon Creek has been identified as an alternative improvement strategy to mitigate flooding impacts. In order to estimate the required detention volume needed to attenuate Fourmile Canyon Creek discharges to the effective 100-year discharge downstream of 19th Street, the 2006 LOMR (Case no. 06-08-B289P) hydrology models (CUHP / UDSWMM 2000) were revised to include potential storage areas and to eliminate the spill flow diversion.



Note: 100-year peak discharge of 3590 cfs routed through calibrated FLO-2D model using City of Boulder 2013 mapping



Legend

— Discharge Cross Sections

Flow Depth at Cell

- 0" - 3"
- 3" - 6"
- 6" - 12"
- 1' - 1.5'
- 1.5' - 3'
- 3' - 4.5'
- 4.5' - 6'
- > 6'



Fourmile Canyon Creek - CEAP Mitigation Planning
 Figure 3: Spill Flow Discharge Values - 100-Year Regulatory Discharges

Diversion element 400 was revised in the updated hydrology models such that no diversion occurs, effectively eliminating the spill flows. Storage area 399 reflects a potential detention site near 7th Street, and storage area 401 reflects a potential detention site at the Violet Park location. The Violet Park location was estimated to have a maximum surface area size of 4 acres, thus the storage was limited to 11 ac-ft for the purposes of this analysis. The 7th Street location was left open ended and was allowed to be as large as necessary to meet the discharge requirements. **Figure 4** illustrates the effective hydrologic model and the revisions for this analysis.

Volume and discharge variables were adjusted such that the discharge at the SWMM node 312 (19th Street) was equal to 1597 cfs – the same as the LOMR’s value at this location with spill flows.

Using this approach it was determined that storage area 401 (Violet Park) only had a minimal effect on the required discharge value at SWMM node 312. Storage area 399 was found to require 214 ac-ft of storage in order for the resulting discharges at SWMM node 312 to equal 1597 cfs.

For comparison purposes, the volume of spill flows located west of Broadway as determined by the calibrated 2D model, was approximately 234 ac-ft demonstrating close conformity to the SWMM routing values.

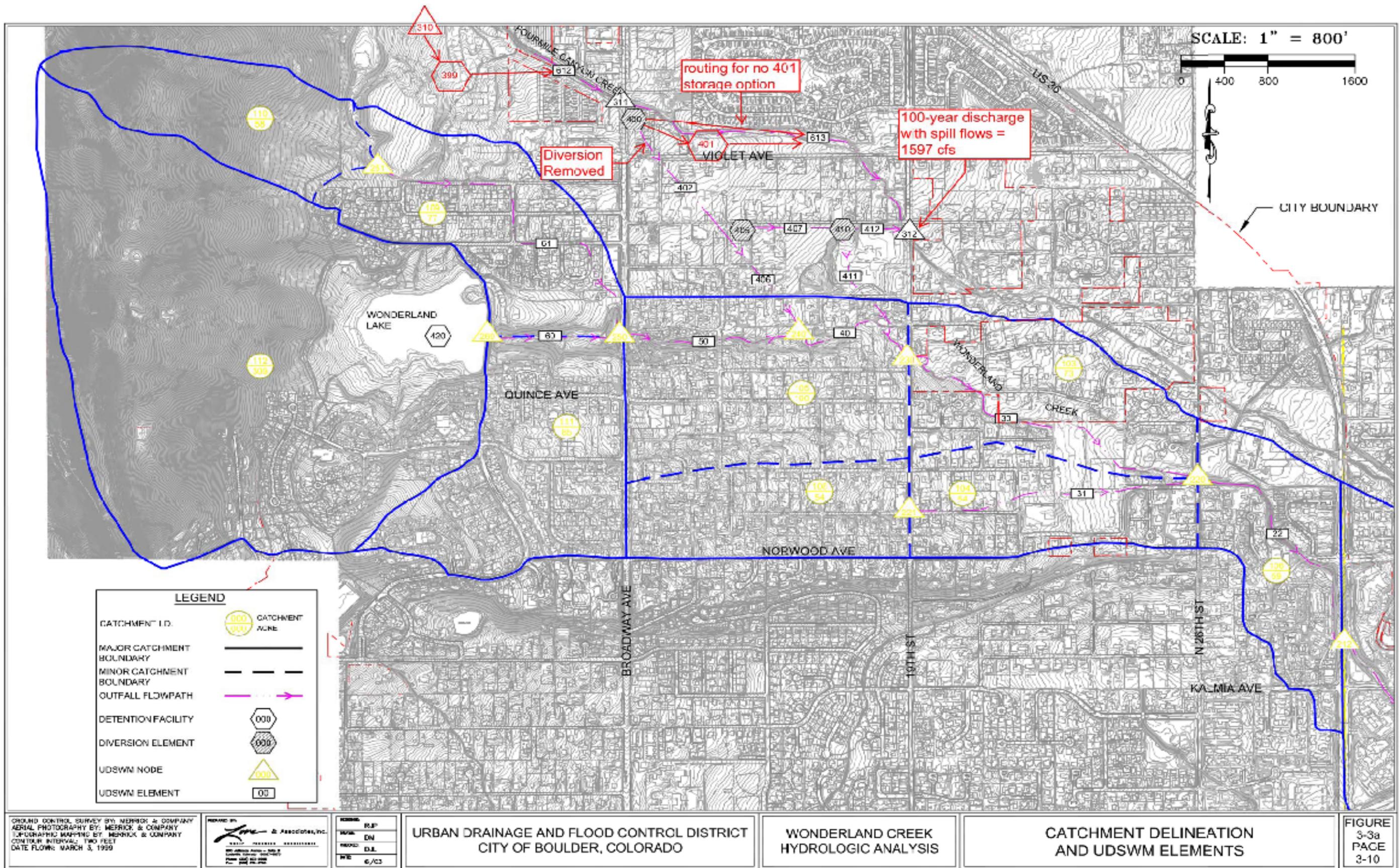
Revised hydrology model information is included in **Appendix B**.

Flood Damage Costs Determination

In order to develop benefit / cost ratios for the CEAP mitigation alternatives, the benefit of removal or reduction of the floodplain outside of the Fourmile Canyon Creek channel was determined using the calibrated 2D hydraulic model and FEMA’s Benefit Cost Analysis (v 5.1) software. The benefit for this study has been estimated as equivalent to the damages experienced during existing conditions, which would be eliminated or reduced as part of the mitigation project. No other benefits were considered for this study such as: displacement costs, roadway closures, debris and sediment clean up; property damage (non-structure damage), or human injury or loss of life. Additionally, for this study the structure damage analysis area was limited to structures west of 19th Street.

Building value data was provided by the City of Boulder and was also obtained directly from the Boulder County Assessor’s web site. The “actual value” of each structure was used as the basis of the damage calculations. No damage was calculated for the remainder of the property or for vacant parcels. Structures were classified into one of seven categories for depth-damage curves. These seven categories are as follows:

1. One story, no basement
2. One story, with basement
3. Split level, no basement
4. Split level, with basement
5. Two or more levels, no basement
6. Two or more levels, with basement
7. Mobile home



The depth-damage curves were obtained from the BCA software and incorporated into a spreadsheet file. The original depth-damage curves provide a % damage to structure and contents value at each whole foot interval. These curves were expanded and values were interpolated in order to have a corresponding % damage value at each tenth of a foot. Additionally, given the spill flow and shallow flooding nature of the floodplain adjacent to the Fourmile Canyon Creek channel, the % damage values at and below the 0 depth value were removed from the curves. Several other key assumptions were made for the damage estimates including:

- Lowest adjacent grade to finished floor height = 0.5 ft
- Content value = 50% of structure value
- Discount rate = 7%
- Project Life = 50 years

The flooding depth at each structure was obtained by identifying the greatest depth at cell from the 2D models adjacent to each structure for the 10-, 25-, 50-, and 100-year events. For the purposes of this study the anticipated change in flooding depths for the 500-year event was assumed to be negligible and was not considered in the damage estimates.

The flooding depths were then used to obtain a % damage value for both the structure and contents from the depth-damage curves. The resulting damage values were then annualized and calculated to a present worth value. The present worth values were totaled to determine the cost of damages, or the resulting benefit if the damages are avoided (i.e. with mitigation project in place).

It should be noted that the annualized values (and subsequently the present worth values) were calculated using two approaches. The first approach utilized the annualized loss calculations as provided in the Flood Risk Assessments – Guidance Document 15. The approach allows an interpolation of damages between the last zero damage value and first non-zero damage value. The second approach utilized the BCA software’s Damage-Frequency Assessment module. In this module the damage values are coded into the software and an annualized value is produced. The software does not allow for the interpolation of damages between the last zero damage value and the first non-zero damage value (i.e. if you have damage for the 50-year storm but not the 25-year storm, the BCA software calculates a zero damage value for the 25-year through the 49.9-year event). As a result, the damages calculated by the Guidance Document are approximately 1.5 times higher than those calculated by the BCA software.

The present worth of damages using the Guidance Document is approximately \$14.6 million dollars. The present worth of damages using the BCA software is approximately \$9.5 million dollars. Structure value and cost calculation data is included in **Appendix C**.

For mitigation Alternative 5 below (50-year design channel), the residual shallow flooding discharge during the 100-year event was estimated at 749 cfs, which is

between the existing discharge of 590 cfs for the 25-year event, and 1351 cfs for the 50-year event. In order to calculate the avoided damages for the 100-year event with the 50-year design channel in place, the damage value was interpolated from the existing conditions 25-year and 50-year values. The resulting total damages of \$13.2M were then annualized and calculated to a present value of \$2.7M. The difference in the existing damages at \$14.6M and the residual damages of \$2.7M result in the \$11.9M benefit for mitigation Alternative 5.

Mitigation Alternatives Capital Improvement Costs Determination

Each proposed mitigation alternative was evaluated in order to develop a cost estimate for the capital improvements. Project elements were integrated into the Urban Drainage and Flood Control District's "UD-MP Cost" spreadsheet (v2.2) and a total project cost was determined. Summary cost estimates are provided in **Appendix D**.

For mitigation alternatives that utilize City owned Open Space and Mountain Parks or Parks and Recreation properties, the cost of property acquisition or easements were not given a dollar figure and are listed as an additional cost element. All other private property acquisitions costs were estimated using \$30/sf for purchase and \$15/sf for easement. Purchase of a property was considered where either more than 60% of the property was required or where the existing structure is located was within the necessary property acquisition. All other property acquisition needs were considered to be accomplishable by drainage easement acquisition.

Mitigation Alternatives Operations and Maintenance Costs Determination

Each proposed mitigation alternative was evaluated in order to develop a cost estimate for the operations and maintenance over a 50-year life span. Existing conditions and proposed project elements were integrated into the UD-MP Cost spreadsheet to determine the operations and maintenance costs. Sediment removal was based on in-channel removal or removal within a sediment facility for projects that have detention or a dedicated sediment facility. In-channel sediment removal was estimated at \$38/CY, while sediment removal from a sediment capture facility was estimated at \$13/CY. Per the 2008 and 2012 sediment reports, the annual sediment load within Fourmile Canyon Creek was assumed to be 593 CY. This value was used for the purposes of calculating a sediment removal cost.

CEAP Mitigation Alternative 0 – No Action

The no action alternative would not institute any floodplain mitigation efforts. The cost of this alternative is \$0, with the exception to existing channel maintenance efforts. The flooding damages would not be reduced resulting in a \$0 benefit for the alternative.

CEAP Mitigation Alternative 0 Summary:

Cost = \$0

O&M (50-years) = \$740,942

Benefit = \$0

Pros:

- No capital improvement project needed
- No property acquisition
- No changes in regulatory discharge to Wonderland Creek

Cons:

- No revisions to regulatory floodplain
- Does not address flooding issues or multi-use trail construction

CEAP Mitigation Alternative 1 – Multiple Flood Detention Facilities

Several City of Boulder owned properties have been identified for potential detention facilities along Fourmile Canyon Creek including Violet Park, and between 4th and 10th Streets in areas predominately managed by the City's Open Space and Mountain Parks Department. A small area further south of the Fourmile Canyon Creek channel is within the Foothills Community Park managed by the City's Parks and Recreation Department. A small undeveloped area on the south bank is owned by Foothills Community LLC.

CEAP Mitigation Alternative 1 includes three detention facilities located within these undeveloped properties, one at Violet Park, and two west of 10th Street. In order to develop enough detention volume the two embankments west of 10th Street required 13 foot high embankments while the Violet Park embankment was limited to 10 feet in height. The general footprint locations of the proposed detention facilities are illustrated on **Figure 5**.

The resulting detention would reduce the 100-year discharge within Fourmile Canyon Creek to less than 1600 cfs at 19th Street. This would effectively eliminate the spill flow out of Fourmile Canyon Creek that flows into Wonderland Creek.

CEAP Mitigation Alternative 1 Summary:

Cost = \$24.3 M + City of Boulder land costs

O&M (50-years) = \$1.6 M

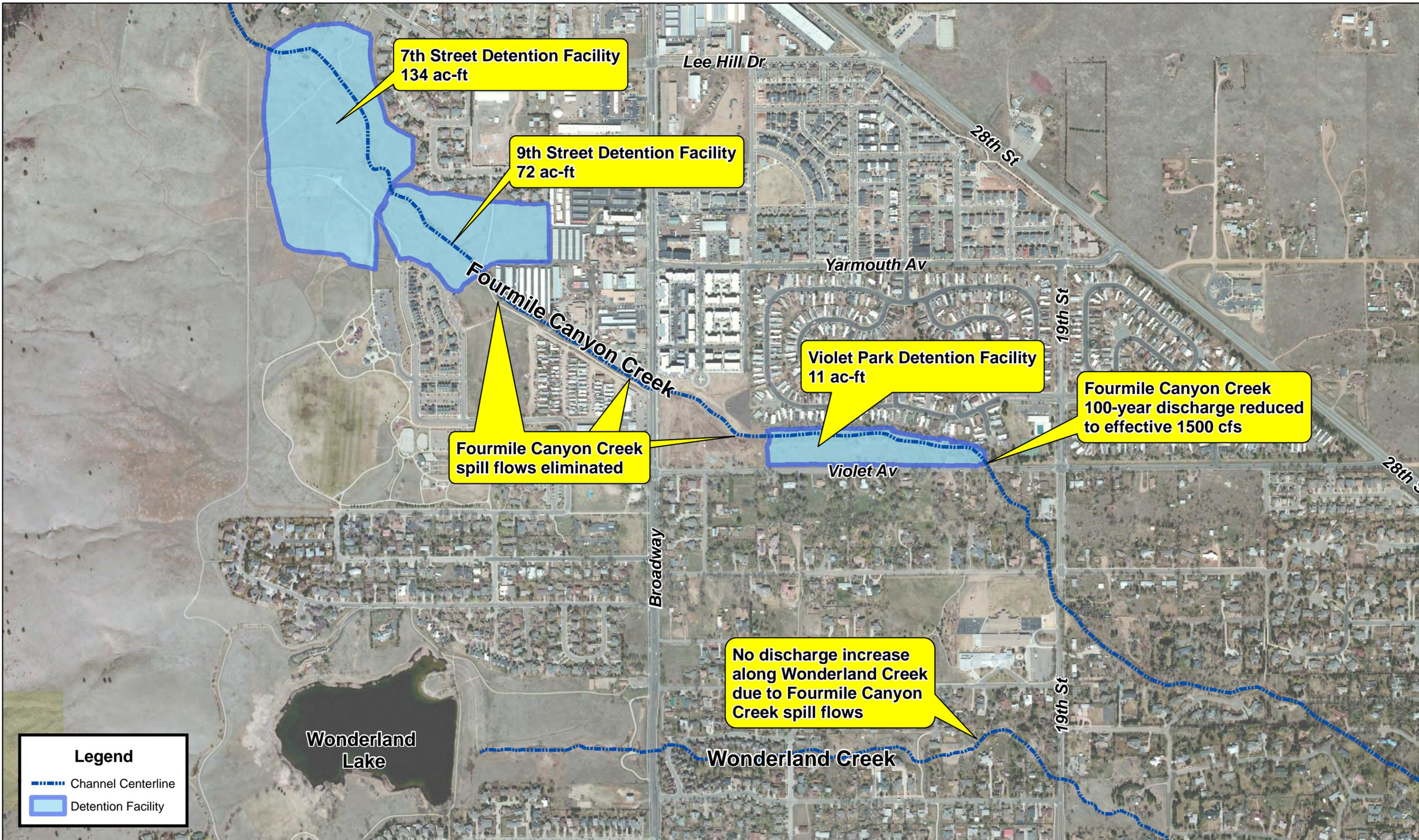
Benefit = \$14.6 M

Pros:

- Removes spill flows from Fourmile Canyon Creek between 10th and 19th Streets
- Removes regulatory floodplain from spill flow areas
- Reduces regulatory discharge along Wonderland Creek
- Ability to integrate sediment capture in facility

Cons:

- Requires use of City of Boulder OSMP and Parks and Recreation properties
- Visual impacts due to embankments
- Visual impacts due to areas of excavation
- Impacts to existing riparian areas
- Does not include options for Fourmile Canyon Creek multi-use path construction at Upland, Violet, or 19th
- State jurisdictional dam requirements
- Benefit / Cost ratio of less than 1



CEAP Mitigation Alternative 2 – Single Flood Detention Facility

This alternative combines the three detention facilities from alternative 1 into a single detention facility. This was accomplished by including the Ace Self Storage property and additional Foothills Community LLC property in the proposed foot print of the detention facility. Additionally, the embankment height was increased to 25 feet. Channel improvements are required between 10th Street and Broadway to contain the outlet discharge during the 100-year event. The general footprint location of the proposed detention facility and channel improvements are illustrated on **Figure 6**.

The resulting detention would reduce the 100-year discharge within Fourmile Canyon Creek to less than 1600 cfs at 19th Street. This discharge reduction and the associated channel improvements would effectively eliminate the spill flow out of Fourmile Canyon Creek.

CEAP Mitigation Alternative 2 Summary:

Cost = \$27.1 M + City of Boulder land costs

O&M (50-years) = \$898,729

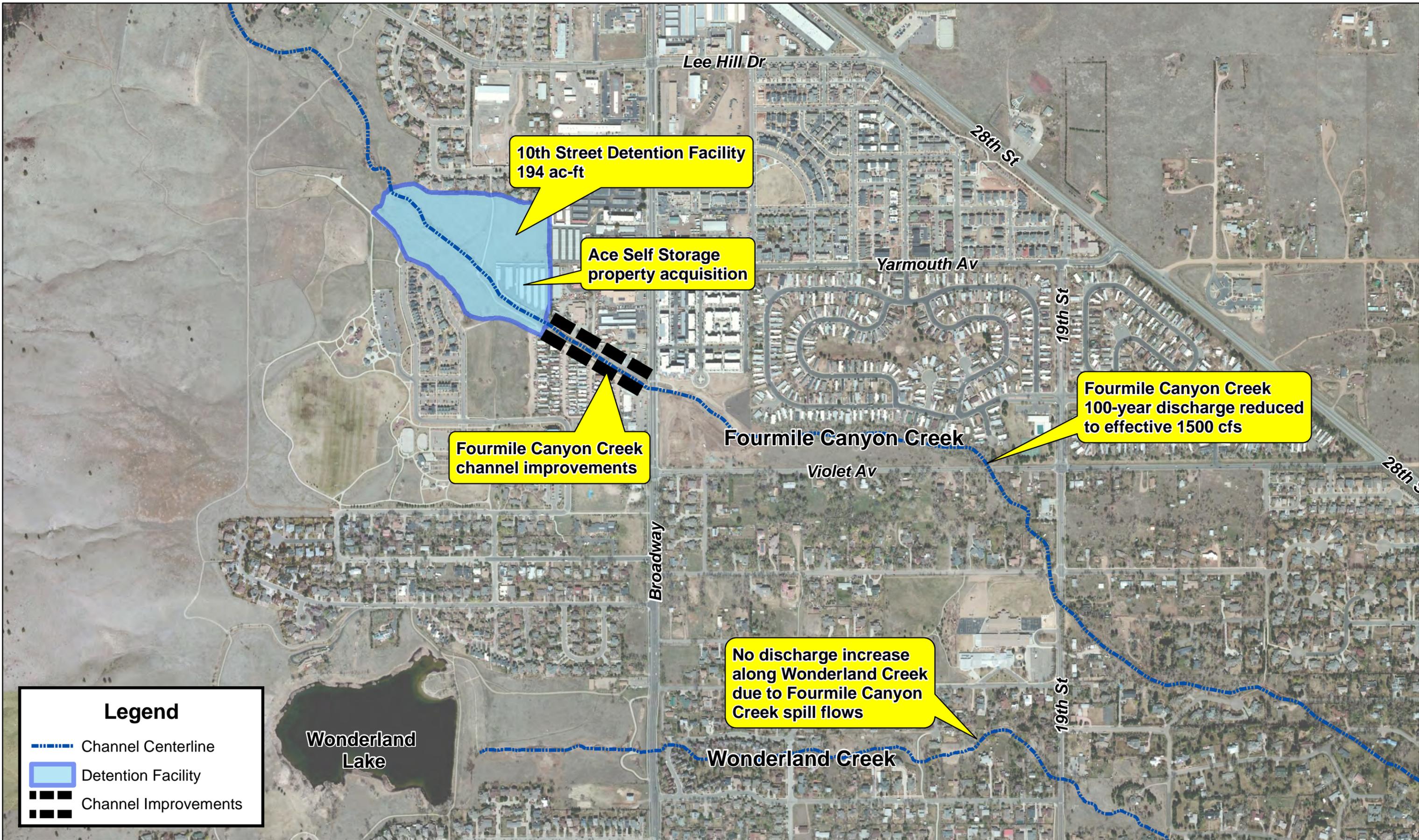
Benefit = \$14.6 M

Pros:

- Removes spill flows from Fourmile Canyon Creek between 10th and 19th Streets
- Removes regulatory floodplain from spill flow areas
- Reduces regulatory discharge along Wonderland Creek
- Ability to integrate sediment capture in facility
- Requires less City of Boulder OSMP and Parks and Recreation property than Alternative 1

Cons:

- Requires use of City of Boulder OSMP and Parks and Recreation properties
- Requires acquisition of Ace Self Storage property
- Requires additional acquisition of Foothills Community LLC property
- Visual impacts due to embankments
- Visual impacts due to areas of excavation
- Does not include options for Fourmile Canyon Creek multi-use path construction at Upland, Violet, or 19th
- Impacts to existing riparian areas
- State jurisdictional dam requirements
- Benefit / Cost ratio of less than 1



CEAP Mitigation Alternative 3 – Fourmile Canyon Creek Channel Improvements

This alternative does not include any detention but rather relies on channel improvements to Fourmile Canyon Creek between 10th Street and 19th Street. The channel improvements eliminate spill flow out of Fourmile Canyon Creek, however, without detention the historic spill flow discharge must be transferred to Wonderland Creek at the downstream limits of the channel improvements. This transfer is accomplished with a storm sewer system within the 19th Street right-of-way. The general location of the proposed channel and storm sewer improvements are illustrated on **Figure 7**.

CEAP Mitigation Alternative 3 Summary:

Cost = \$26.8 M

O&M (50-years) = \$1.1 M

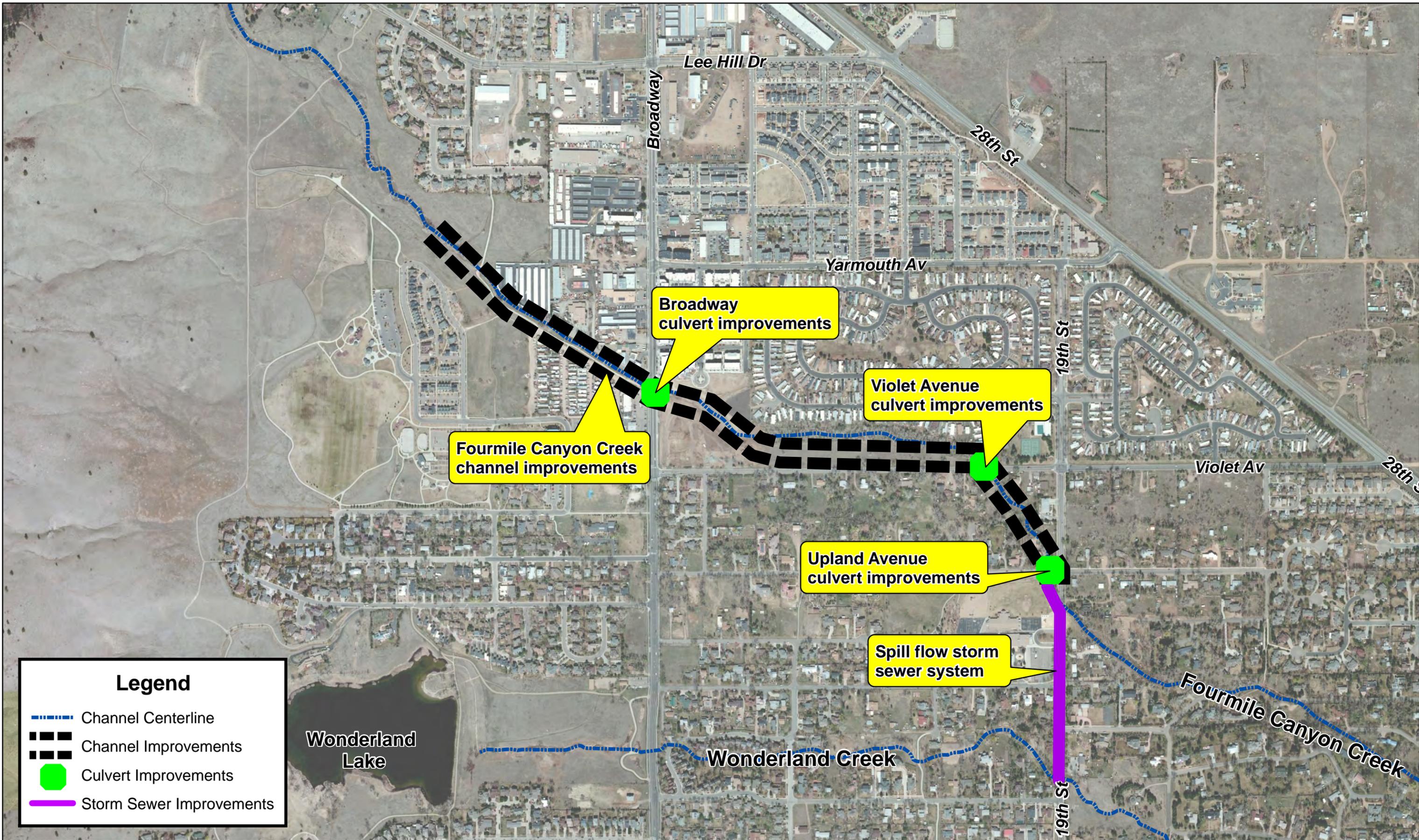
Benefit = \$14.6 M

Pros:

- Removes spill flows from Fourmile Canyon Creek between 10th and 19th Streets
- Removes regulatory floodplain from spill flow areas
- Channel improvements can be combined with multi-use path underpass construction
- Property acquisition can be combined to facilitate multi-use path construction

Cons:

- Requires a storm sewer system that does not operate until a 25-year or greater event
- Impacts to existing riparian areas
- Benefit / Cost ratio of less than 1



Legend

- - - - - Channel Centerline
- - - - - Channel Improvements
- Culvert Improvements
- Storm Sewer Improvements



CEAP Mitigation Alternative 4 – Spill Flow Diversion to Wonderland Creek

This alternative does not include any detention but rather relies on channel improvements to capture spill flows from Fourmile Canyon Creek and route them to Wonderland Creek. This alternative results in increased discharges along Wonderland Creek upstream of 19th Street resulting in some adverse impacts to the floodplain. These adverse impacts are limited to 10 structures which have been included in the project cost as property acquisitions. Alternatively, channel improvements may be an option to remove the adverse impacts at a lower cost than acquisition and should be analyzed in conceptual design should this alternative be pursued. The general location of the proposed channel improvements are illustrated on **Figure 8**.

CEAP Mitigation Alternative 4 Summary:

Cost = \$19.6 M

O&M (50-years) = \$1.1 M

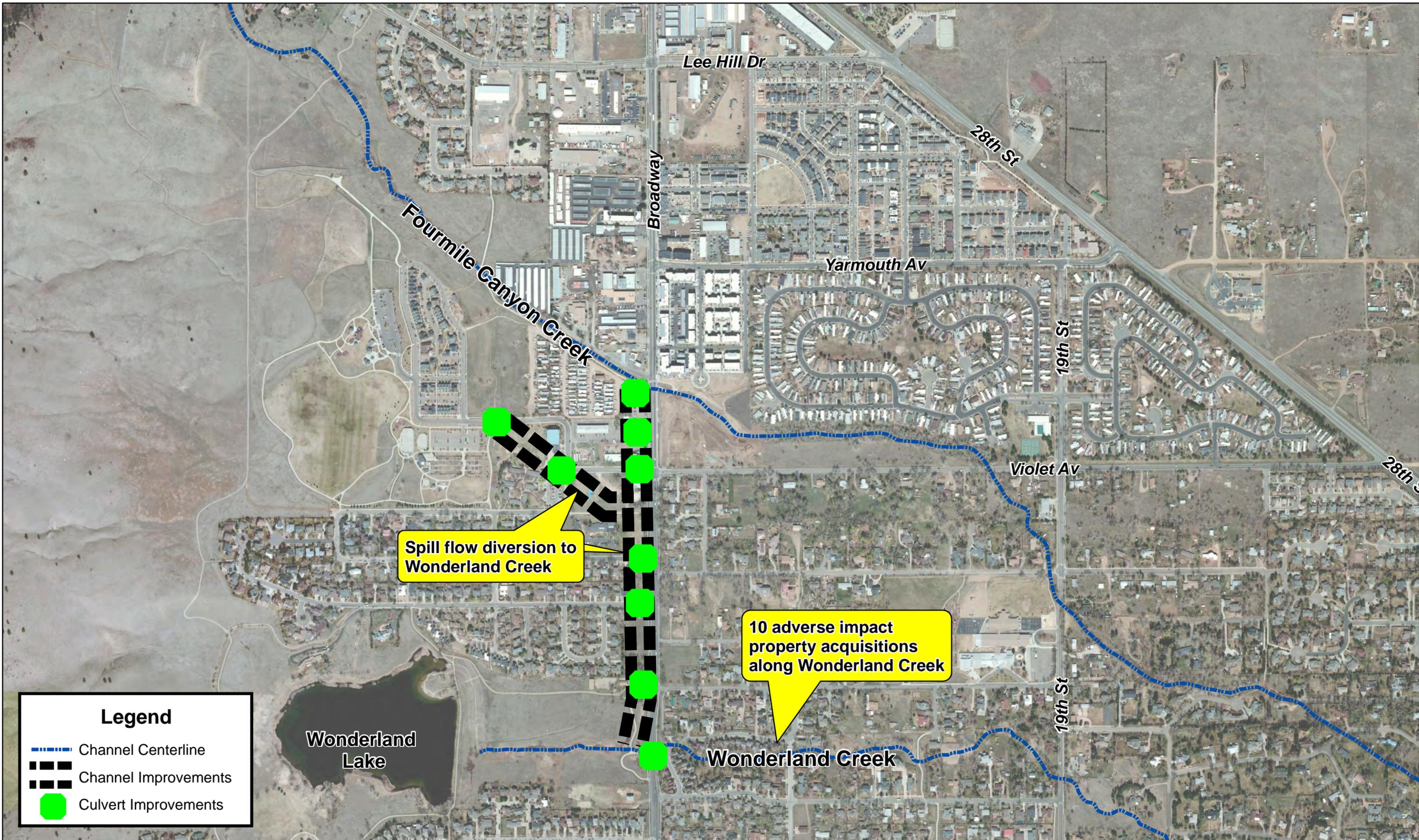
Benefit = \$14.6 M

Pros:

- Removes spill flows from Fourmile Canyon Creek between Broadway and 19th Streets
- Removes regulatory floodplain from spill flow areas between Broadway and 19th Streets
- Channel improvements can be combined with multi-use path underpass construction
- Property acquisition can be combined to facilitate multi-use path construction

Cons:

- Does not include options for Fourmile Canyon Creek multi-use path construction
- Impacts to existing riparian areas
- Benefit / Cost ratio of less than 1



Legend

-  Channel Centerline
-  Channel Improvements
-  Culvert Improvements

Fourmile Canyon Creek - CEAP Mitigation Planning
 Figure 8: CEAP Mitigation Alternative 4 - 100-Year Spill Flow Diversion to Wonderland Creek

CEAP Mitigation Alternative 5 – Fourmile Canyon Creek 50-Year Channel Improvements

This alternative does not include any detention but rather relies on 50-year channel improvements to Fourmile Canyon Creek between 10th Street and 19th Street. The channel improvements eliminate spill flow out of Fourmile Canyon Creek up to and including the 50-year event. As with the 100-year channel improvement (Alternative 3) the historic spill flow discharge must be transferred to Wonderland Creek at the downstream limits of the channel improvements. This transfer is accomplished with a storm sewer system within the 19th Street right-of-way. The general location of the proposed channel and storm sewer improvements are illustrated on **Figure 9**.

It should be noted that there exists a potential for the 50-year design channel upstream of 19th to cause adverse floodplain impacts during a 100-year event. This issue must be addressed during any conceptual or final design efforts as it is beyond the scope of this analysis.

CEAP Mitigation Alternative 5 Summary:

Cost = \$14.7 M

O&M (50-years) = \$1.1 M

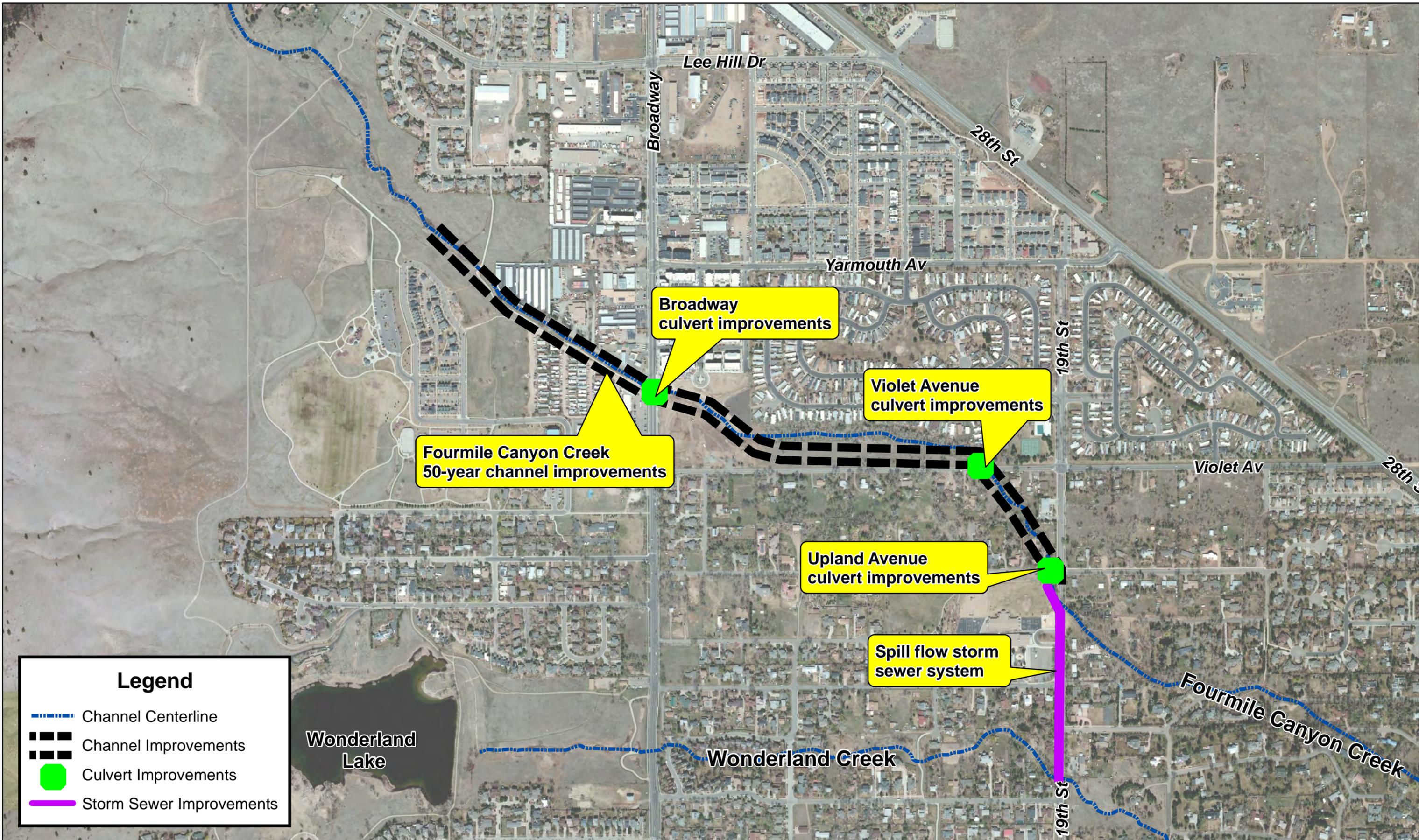
Benefit = \$11.9 M

Pros:

- Reduced cost for channel improvements compared to Alternative 3
- Channel improvements can be combined with multi-use path underpass construction
- Property acquisition can be combined to facilitate multi-use path construction

Cons:

- Requires a storm sewer system that does not operate until a 25-year or greater event
- Does not fully remove regulatory floodplain from spill flow areas
- Potential for adverse impacts caused by design channel during flooding events that are larger than the 50-year event
- Impacts to existing riparian areas
- Benefit / Cost ratio of less than 1



Legend

- - - Channel Centerline
- - - Channel Improvements
- Culvert Improvements
- Storm Sewer Improvements



CEAP Mitigation Alternative 6 – Fourmile Canyon Creek Sediment Capture Facility

This alternative does not address the spill flow flooding from Fourmile Canyon Creek. This alternative includes the recommended sediment capture facility from the 2012 Evaluation of Fourmile Canyon Creek Sediment Basin Alternatives. The sediment basin would reduce the amount of sediment available for transport downstream of 7th Street, but does not otherwise reduce or eliminate any regulatory floodplain. The general location of the proposed sediment capture facility is illustrated on **Figure 10**.

Violet Park has also been identified as an alternative location for the sediment capture facility. This location would remove the need to use City of Boulder OSMP property; however, it would also not address sediment issues upstream of Violet Avenue. The best location for a sediment capture facility should be addressed in conceptual design if this alternative is pursued further.

CEAP Mitigation Alternative 6 Summary:

Cost = \$435,360 (per 2012 study by others)

O&M (50-years) = \$434,262

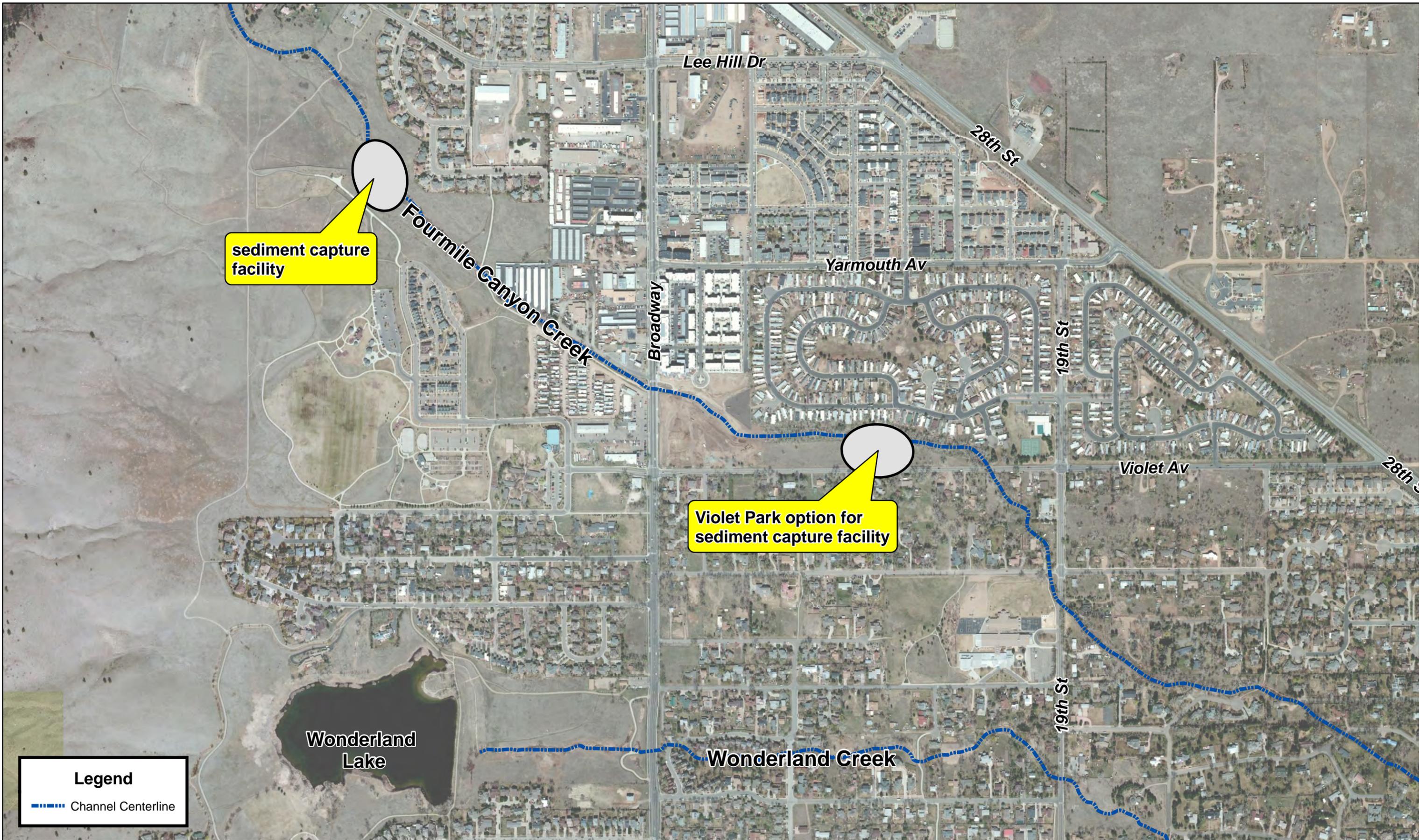
Benefit = \$306,680 (O&M for Alt 0 less O&M for Alt 6)

Pros:

- Reduced sediment load available downstream of 7th Street

Cons:

- Requires use of City of Boulder OSMP properties for 2012 recommended sediment facility location
- Does not address floodplain impacts
- Impacts to existing riparian area



sediment capture facility

Violet Park option for sediment capture facility

Legend
 - - - - Channel Centerline

CEAP Mitigation Alternative 7 – 2011 MDP Recommendations

This alternative includes the 2011 MDP recommendations of providing safe access to Crest View Elementary School via 19th Street and Upland Avenue, high hazard containment, flood proofing, and maintaining existing conditions. The general location of the safe access to Crest View Elementary School and the high hazard areas for Fourmile Canyon Creek and Wonderland Creek are illustrated on **Figure 11**.

CEAP Mitigation Alternative 7 Summary:

Cost = \$6.9 M (per 2011 MDP by others)

O&M (50-years) = \$740,942

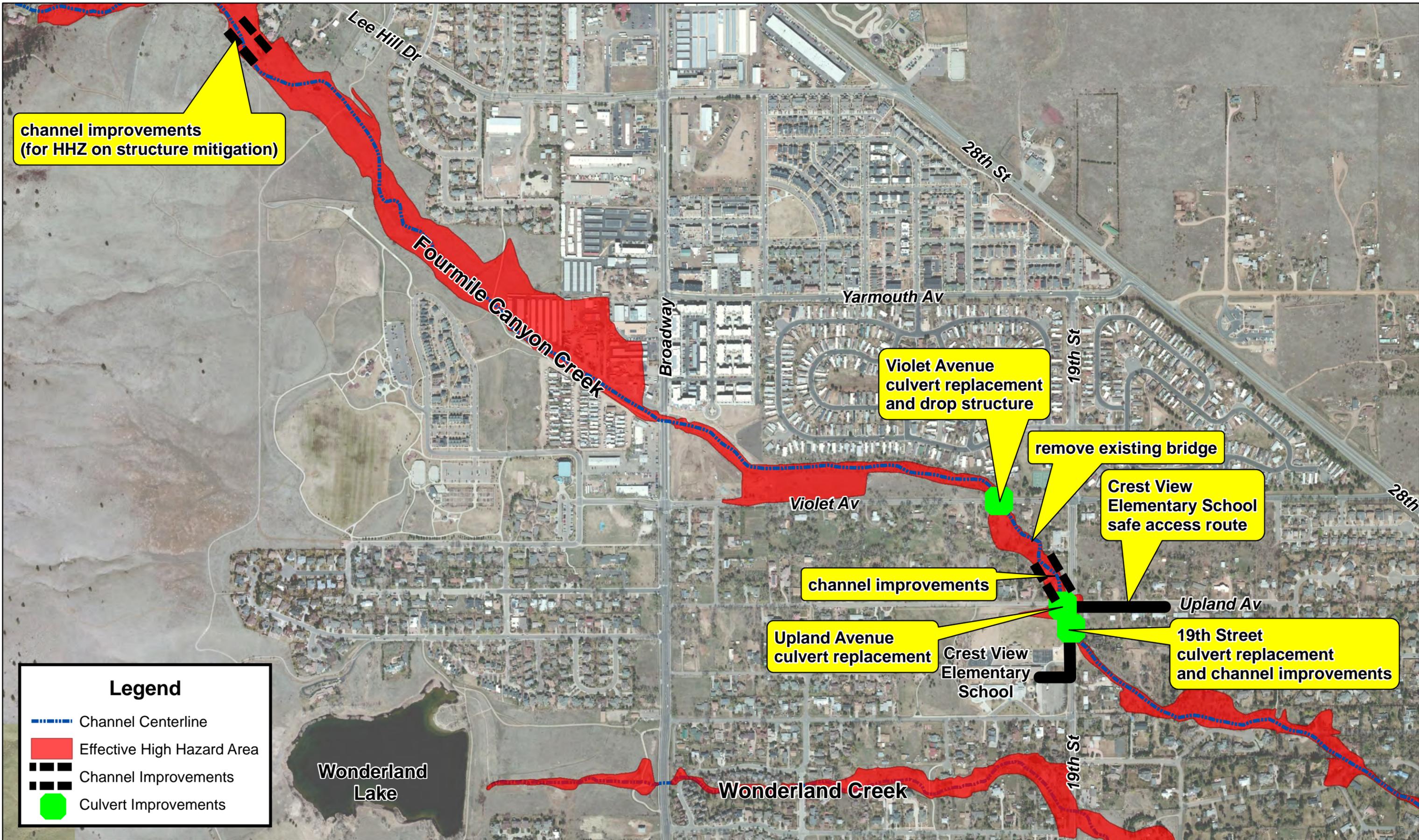
Benefit = not determined by this analysis

Pros:

- Provides safe access to critical facility
- Improves life safety by containing high hazard areas
- Channel and culvert improvements can be combined with multi-use path underpass construction

Cons:

- Does not address regulatory floodplain impacts



channel improvements
(for HHZ on structure mitigation)

Violet Avenue
culvert replacement
and drop structure

remove existing bridge

Crest View
Elementary School
safe access route

channel improvements

Upland Avenue
culvert replacement

19th Street
culvert replacement
and channel improvements

Legend

-  Channel Centerline
-  Effective High Hazard Area
-  Channel Improvements
-  Culvert Improvements

Roadway Conveyance

The potential shallow flooding mitigation of roadway conveyance was also investigated as part of this study. For this analysis the existing 2D model was modified to lower roadway elevations by up to 2 feet along:

- 13th Street between Violet Ave. and Upland Ave.
- Upland Ave. between Broadway and Crest View Elementary
- Tamarack Ave. between Broadway and Crest View Elementary

An open channel of similar dimension was also run from Upland Ave. at the northwest corner of the Crest View Elementary School property south to Wonderland Creek in order to convey the discharges collected by the lowered roadways. The 2D model indicated that the lowered roadways and open channel did collect and convey flooding, however, the extent to which the flooding was reduced was not significant enough for additional study.

Conclusions and Recommendations

As noted by the study, the potential costs of all Fourmile Canyon Creek flood mitigation projects exceed the expected benefits from reduced flooding on buildings and structures as described previously. Although other benefits for each project may exist in the form of: displacement costs, roadway closures, debris and sediment clean up, property damage (non-structure damage), or human injury or loss of life. With exception to possibly Alternatives 4 and 5, it is not anticipated that further quantification of these items would yield benefit cost ratios greater than 1.0. Additionally, many of the mitigation alternatives presented in this memorandum have other significant obstacles including:

- Use of Open Space and Mountain Parks property for flood detention facility
- High cost of desirable property adjacent to the Broadway corridor
- State jurisdictional requirements of detention facilities
- Potential acquisition of structures along Wonderland Creek
- Potential unintended consequences of disruption to sediment transport balance – requires additional analysis for downstream impacts
- Potential adverse impacts to 100-year regulatory floodplains as a result of 50-year design limitations

It should be noted that the 2007 and 2011 MDP reports also investigated detention options along Fourmile Canyon Creek upstream of Broadway. However, detention alternatives were rejected in both planning efforts due to the “enormity of the project, extensive construction cost and the negative impacts it would have on park or open space lands”.

Based on the analysis presented in this memorandum our primary recommendation is that the City of Boulder continue to pursue the recommendations of the 2011 Major Drainageway Plan which include providing safe access to Crest View Elementary School via 19th Street and Upland Avenue, high hazard containment, flood proofing, and maintaining existing conditions. This approach allows for uninterrupted access to a critical facility and the potential for the Fourmile Canyon Creek multi-use trail to be integrated into the improvements including trail underpasses at Violet Ave., Upland Ave., and 19th Street. With the exception to the expected benefit/cost ratio of less than 1.0, the recommended plan from the 2011 MDP does not have a significant obstacle to overcome as noted above for the other alternatives.

If the CEAP includes significant feedback from the community that additional flooding mitigation is desired to address the spill flow, our secondary recommendation is for the City to pursue the 50-year channel improvements to Fourmile Canyon Creek (Alternative 5). This alternative had the benefit/cost ratio closest to 1.0 of any floodplain mitigation project and would eliminate the spill flows for up to and including the 50-year event. It should be noted however, that this alternative must be completed without any adverse floodplain impacts and would require further investigation from that perspective.

Prior to the 2013 flooding event, sediment issues along Fourmile Canyon Creek were identified and evaluations were completed to address sediment capture. As discussed, in 2013, the sediment load far exceeded the initial estimates and the sediment ponds, as proposed, would not have been effective in preventing deposition within the basin downstream. Regardless, given ongoing sediment problems within the basin, it is recommended that the City pursue reviewing options to address sediment capture and/or improved sediment transport. Should a sediment management facility be pursued, current sediment transport potential and depositional volumes from the upstream watershed should be reviewed along with the anticipated response to changes in sediment supply within the downstream reaches.

Appendix A – 2011 MDP Report Excerpts

FOURMILE CANYON CREEK AND WONDERLAND CREEK MAJOR DRAINAGEWAY PLANNING



FINAL PLAN

May 2011

CITY OF BOULDER
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT



**FOURMILE CANYON CREEK AND WONDERLAND CREEK
MAJOR DRAINAGEWAY PLANNING
FINAL PLAN**

March 2011

Prepared by:

City of Boulder
Department of Public Works
Utilities Division

Based on:

Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning
Phase A Report Alternatives Analysis May 2007
Prepared by Belt Collins West

10.0 FINAL PLAN

The public process resulted in numerous changes to the Phase A recommendations. **Table 10.1** presents a comparison between the Phase A Study recommendations and the Final Plan Recommendations. The Final Plan is meant only to provide a long-range plan for future flood mitigation projects along Fourmile Canyon Creek and Wonderland Creek. Each proposed flood mitigation projects will be evaluated and refined through the city’s Community and Environmental Assessment Process (CEAP) and Capital Improvement Program (CIP) processes. **Figure 10.1** presents a map showing the Final Plan recommendations. **Table 10.2** presents a summary of estimated concept-level costs for the Final Plan recommendations. The appendices presents more detailed cost estimate information. The remainder of this section presents existing conditions and Final Plan recommendations for each of the stream reaches.

Table 10.1 Phase A Study versus Final Plan Recommendations

Stream Reach	Reach ID	Phase A Recommendation	Revised Recommendation
<i>Fourmile Canyon Creek</i>			
▪ City limits to Lee Hill Drive	6c	Maintain Existing	No revisions
▪ Lee Hill Drive to 7 th Street	6b	HHZ Containment / Floodproofing	No revisions
▪ 7 th Street to Broadway	6a	Floodproofing	HHZ Containment / Floodproofing
▪ Broadway to Violet Avenue	5	HHZ Containment / Floodproofing	No revisions
▪ Violet Avenue to 26 th Street	4	100-year Containment	HHZ Containment with Floodproofing and Safe Access to Crestview Elementary School via 19 th Street and Upland Avenue ²
▪ 26 th Street to 28 th Street	3	HHZ Containment / Floodproofing	No revisions
▪ 28 th Street to 30 th Street	2b	100-year Containment	No recommendation (reach in Boulder County)
▪ 30 th Street to Pleasant View Soccer Fields	2a	Maintain Existing	No recommendation (reach in Boulder County)
▪ Pleasant View Soccer Fields to BNSF Railroad	1b	Maintain Existing	No revisions
▪ BNSF Railroad to Boulder Creek	1a	HHZ Containment / Floodproofing	No recommendation (reach in Boulder County)
<i>Wonderland Creek</i>			
▪ Wonderland Lake to Broadway	8	Maintain Existing	No revisions
▪ Broadway to 19 th Street	7	Maintain Existing	Safe Access to Crestview Elementary School via 19 th Street ²
▪ 19 th Street to 26 th Street	6	HHZ Containment /	HHZ Containment /

Stream Reach	Reach ID	Phase A Recommendation	Revised Recommendation
		Floodproofing	Floodproofing ¹
▪ 26 th Street to 28 th Street	5	100-year Containment	HHZ Containment / Floodproofing unless substantial outside funding is provided for 100-year Containment
▪ 28 th Street to Diagonal Hwy	4	100-year Containment	
▪ Diagonal Hwy to Foothills Parkway	3	HHZ Containment / Floodproofing	No revisions
▪ Foothills Parkway to Valmont Road	2	Floodproofing	
▪ Valmont to Goose Creek	1	Maintain Existing	No revisions

¹ Revised method for high hazard zone (HHZ) containment that reduces the estimated cost by approximately \$600,000 from Phase A HHZ containment alternative

² Channel modifications at 19th Street required to provide safe access to Crestview Elementary School

Table 10.2 Concept-Level Cost Estimates for Final Plan Recommendations

Stream Reach	Reach ID	Final Plan Recommendation	Concept-Level Cost Estimates ⁴				
			ROW	Construction	Total Public (no O&M)	O&M	Private (floodproofing)
<i>Fourmile Canyon Creek</i>							
▪ City limits to Lee Hill Drive	6c	Maintain Existing	\$0	\$0	\$0	\$173,000	\$0
▪ Lee Hill Drive to 7 th Street	6b	HHZ Containment / Floodproofing	\$55,000	\$86,000	\$141,000	\$454,000	\$908,000
▪ 7 th Street to Broadway	6a	HHZ Containment / Floodproofing	\$0	\$2,551,000	\$2,551,000	\$290,000	\$3,131,000
▪ Broadway to Violet Avenue	5	HHZ Containment / Floodproofing	\$0	\$120,000	\$120,000	\$310,000	\$726,000
▪ Violet Avenue to 26 th Street	4	HHZ Containment with Safe Access to Crestview Elementary School via 19 th Street and Upland Avenue ²	\$1,512,000	\$2,582,000	\$4,094,000	\$513,000	\$5,349,000
▪ 26 th Street to 28 th Street	3	HHZ Containment / Floodproofing	\$0	\$2,077,000	\$2,077,000	\$336,000	\$495,000
▪ 28 th Street to 30 th Street	2b	100-year Containment	\$0 ³	\$0 ³	\$0 ³	\$0 ³	\$0 ³
▪ 30 th Street to Pleasant View Soccer Fields	2a	Maintain Existing	\$0 ³	\$0 ³	\$0 ³	\$0 ³	\$0 ³
▪ Pleasant View Soccer Fields to BNSF Railroad	1b	Maintain Existing	\$0	\$0	\$0	\$921,000	\$0
▪ BNSF Railroad to Boulder Creek	1a	HHZ Containment / Floodproofing	\$0 ³	\$0 ³	\$0 ³	\$0 ³	\$0 ³
Total:			\$1,567,000	\$7,416,000	\$8,983,000	\$2,997,000	\$10,609,000
<i>Wonderland Creek</i>							
▪ Wonderland Lake to Broadway	8	Maintain Existing	\$0	\$0	\$0	\$289,000	\$0
▪ Broadway to 19 th Street	7	Safe Access to Crestview Elementary School via 19 th Street ²	\$0	\$30,000	\$30,000	\$807,000	\$0
▪ 19 th Street to 26 th Street	6	HHZ Containment / Floodproofing ¹	\$206,000	\$2,104,000	\$2,310,000	\$253,000	\$2,390,000
▪ 26 th Street to 28 th Street	5	HHZ Containment / Floodproofing unless substantial outside funding is provided for 100-year Containment	\$0 (HHZ), \$510,000 (100-yr)	\$119,000 (HHZ), \$3,110,000 (100-yr)	\$119,000 (HHZ), \$3,620,000 (100-yr)	\$493,000 (HHZ), \$282,000 (100-yr)	\$2,528,000 (HHZ), \$0 (100-yr)
▪ 28 th Street to Diagonal Hwy	4		\$359,000 (HHZ), \$589,000 (100-yr)	\$2,924,000 (HHZ), \$3,663,000 (100-yr)	\$3,283,000 (HHZ), \$4,252,000 (100-yr)	\$774,000 (HHZ), \$479,000 (100-yr)	\$3,117,000 (HHZ), \$0 (100-yr)
▪ Diagonal Hwy to Foothills Parkway	3		\$560,000 (HHZ), \$742,000 (100-yr)	\$5,256,000 (HHZ), \$5,833,000 (100-yr)	\$5,816,000 (HHZ), \$6,575,000 (100-yr)	\$434,000 (HHZ), \$216,000 (100-yr)	\$3,506,000 (HHZ), \$0 (100-yr)
▪ Foothills Parkway to Valmont Road	2	Maintain Existing	\$0	\$0	\$0	\$0	\$0
▪ Valmont to Goose Creek	1	Maintain Existing	\$0	\$0	\$0	\$618,000	\$0
Total:			\$1,125,000 (HHZ), \$2,047,000 (100-yr)	\$10,433,000 (HHZ), \$14,740,000 (100-yr)	\$11,558,000 (HHZ), \$16,787,000 (100-yr)	\$3,668,000 (HHZ), \$2,944,000 (100-yr)	\$11,541,000 (HHZ), \$2,390,000 (100-yr)
Total both Creeks:			\$2,692,000 (HHZ), \$3,614,000 (100-yr)	\$17,849,000 (HHZ), \$22,156,000 (100-yr)	\$20,541,000 (HHZ), \$25,770,000 (100-yr)	\$6,665,000 (HHZ), \$5,941,000 (100-yr)	\$22,150,000 (HHZ), \$12,999,000 (100-yr)

¹ Revised method for high hazard zone (HHZ) containment that reduces the estimated cost by approximately \$600,000 from Phase A HHZ containment alternative

² Channel modifications at 19th Street required to provide safe access to Crestview Elementary School

³ No cost to the city, reach located within Boulder County, see appendices for cost estimates

⁴ Includes 40% contingency

⁵ Yearly operation and maintenance costs converted to present value assuming a 3% discount rate (6% interest rate minus 3% inflation rate) and a 50-year life span.

10.1 Fourmile Canyon Creek

Fourmile Canyon Creek Reach 6c – City Limits to Lee Hill Drive

Final Plan – Maintain Existing Condition (\$0 public)

Reach 6c is the furthest upstream reach of the Fourmile Canyon Creek study reaches. The existing 100-year floodplain extends beyond the creek banks through this reach but the floodplain does not impact any structures. This reach is located entirely within city limits. Consistent with the Phase A Study, the Final Plan recommends maintaining status quo for this reach. **Figure 10.2** presents existing conditions for this reach. **Figure 10.3** presents the Final Plan recommendation.

Fourmile Canyon Creek Reach 6b – Lee Hill Drive to 7th Street Final Plan – High Hazard Zone Containment with Floodproofing (\$141,000 public)

As shown on **Figure 10.2**, the floodplain limits extend beyond the creek banks along this reach of Fourmile Canyon Creek. Consistent with the Phase A Study, the Final Plan recommends High Hazard Zone Containment and floodproofing for this reach. This alternative would maintain the existing channel configuration for the majority of the reach, excavate two feet in an area located south of the extension of 47th Street and recommend floodproofing of all structures located within the 500-year floodplain to two feet above the 100-year floodplain at private cost. Reach 6b improvements would narrow the high hazard zone so that the structure located on parcel 4854 4th Street would be located outside the high hazard zone. **Table 10.3** presents total estimated concept-level costs for proposed improvements along Reach 6b. **Figure 10.4** shows the location of the excavation, the individual structures recommended for floodproofing, and the post-project floodplain limits.



Trail crossing along Reach 6b

The Phase A Study had recommended floodproofing of structures along this reach with no channel improvements. The public process resulted in changes to this recommendation to accommodate future development west of Broadway. The Final Plan now recommends High Hazard Zone Containment with Floodproofing for Reach 6a. **Figure 10.5** shows the proposed improvements that include:

- A flood interceptor channel located at the upstream end of the reach to limit flood spills to the east
- Removal and replacement of an existing trail crossing located at the western extent of Yarmouth Avenue
- Modification of approximately 1,350 feet of existing channel including 15 drop structures to contain the High Hazard Zone between the extent of Yarmouth Avenue and Broadway. The channel modifications will need to be carefully designed to not change the spill flows or distribution from Fourmile Canyon Creek south to Wonderland Creek.
- Relocation of Rosewood Avenue to provide vehicular access to the commercial / industrial land uses.
- Floodproofing of all structures located within the 500-year floodplain to two feet above the 100-year floodplain at private cost.

Reach 6a improvements would narrow the high hazard zone so that the structures located on the following parcels would be located outside the high hazard zone:

- 4501 North Broadway
- 4525 North Broadway
- 4535-4537 North Broadway
- 4545 North Broadway
- 4571 North Broadway
- 4635 North Broadway
- 1027 Rosewood Avenue
- 1025 Rosewood Avenue



Reach 6a shortly after channel improvements

Table 10.3 Concept-Level Cost Estimates for Fourmile Canyon Creek Reach 6b

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$86,000	\$55,000	\$454,000	\$908,000	\$0	\$0

Fourmile Canyon Creek Reach 6a –7th Street to North Broadway

Final Plan – High Hazard Zone Containment with Floodproofing (\$2,551,000 public)

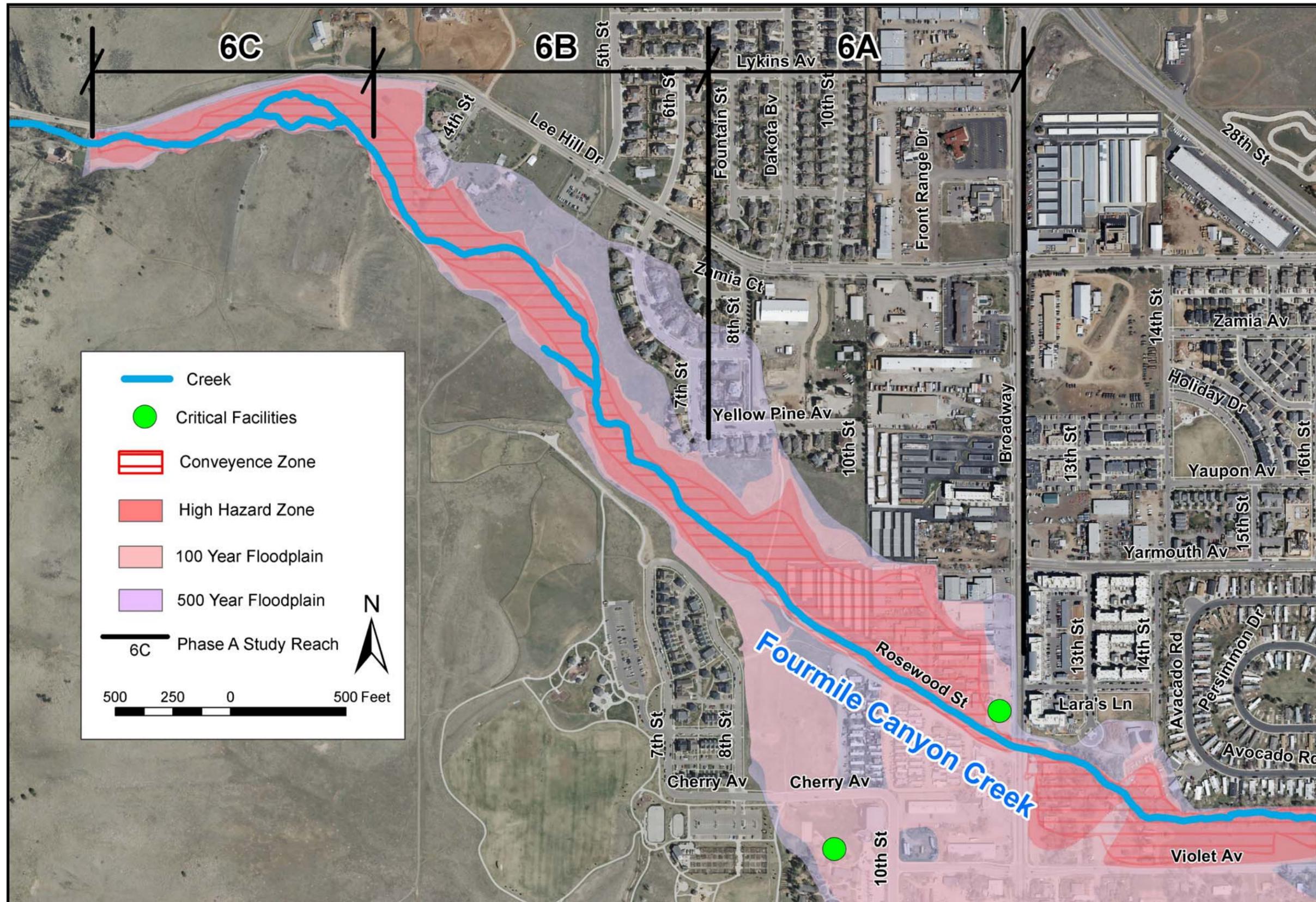
This reach of Fourmile Canyon Creek has an extensive floodplain under existing conditions that includes the western extent of the spill to Wonderland Creek. **Figure 10.2** shows the existing floodplain limits along this reach. The High Hazard Zone limits currently extend north into existing commercial / industrial development located on the north side of Rosewood Street. This reach also contains two critical facilities; the North Broadway Silo Gas facility located on the northwest corner of the intersection of Broadway and Rosewood Street and the Shining Path Waldorf School located on the southwest corner of the intersection of Cherry Avenue and 10th Street. The location of these facilities is indicated by green dots on **Figure 10.2**.

Table 10.4 presents total estimated concept-level costs for proposed improvements along Reach 6a. The resulting floodplain depths would be shallow enough to allow safe access to the Shining Path Waldorf School.

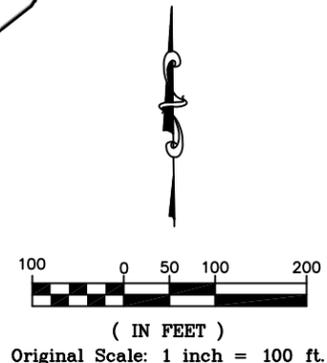
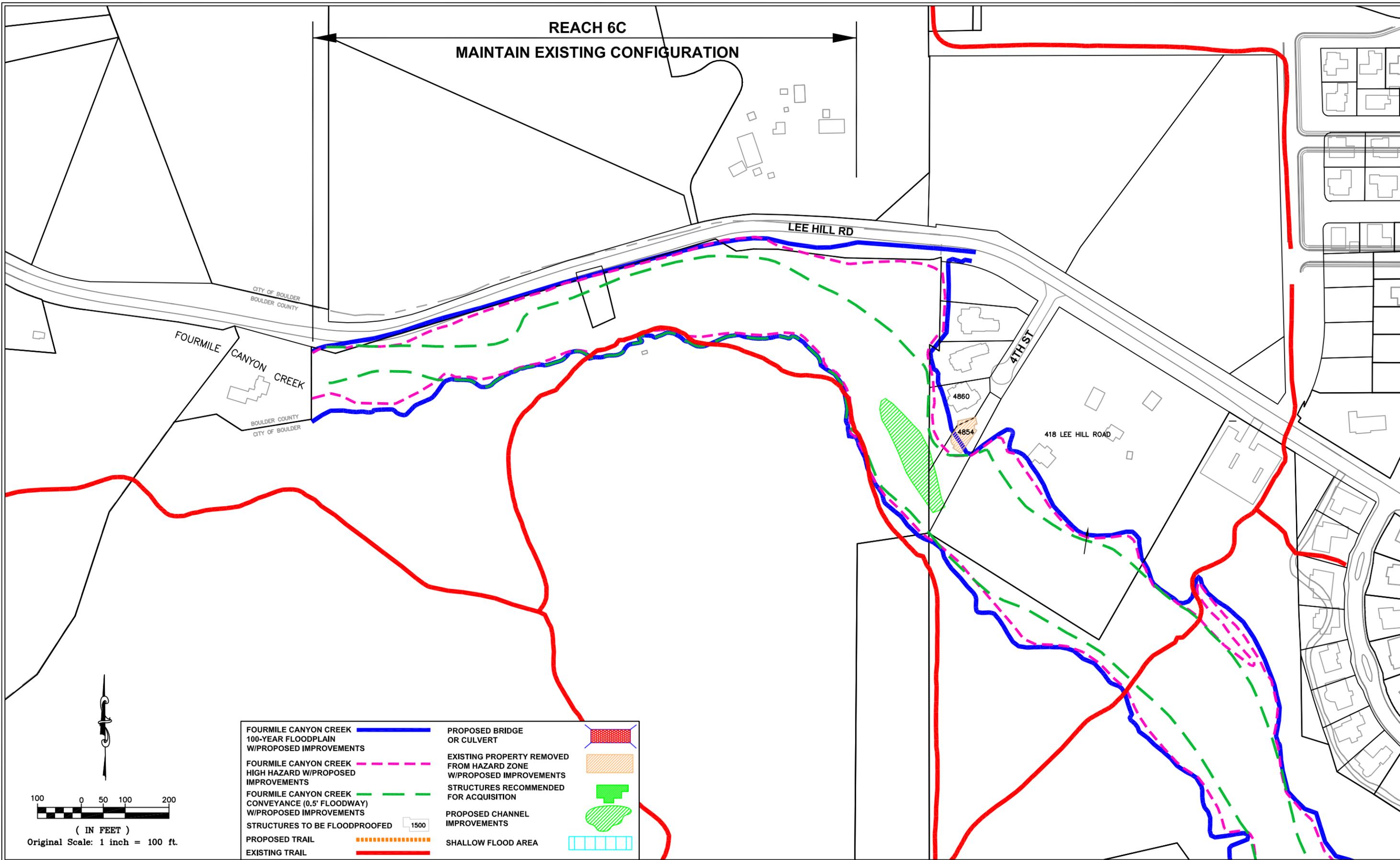
Table 10.4 Concept-Level Cost Estimates for Fourmile Canyon Creek Reach 6a

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$2,551,000	\$0	\$290,000	\$3,131,000	\$0	\$0

Figure 10.2 Existing Conditions Fourmile Canyon Creek Reaches 6C, 6B, 6A



REACH 6C
 MAINTAIN EXISTING CONFIGURATION



FOURMILE CANYON CREEK 100-YEAR FLOODPLAIN W/PROPOSED IMPROVEMENTS		PROPOSED BRIDGE OR CULVERT	
FOURMILE CANYON CREEK HIGH HAZARD W/PROPOSED IMPROVEMENTS		EXISTING PROPERTY REMOVED FROM HAZARD ZONE W/PROPOSED IMPROVEMENTS	
FOURMILE CANYON CREEK CONVEYANCE (0.5' FLOODWAY) W/PROPOSED IMPROVEMENTS		STRUCTURES RECOMMENDED FOR ACQUISITION	
STRUCTURES TO BE FLOODPROOFED		PROPOSED CHANNEL IMPROVEMENTS	
PROPOSED TRAIL		SHALLOW FLOOD AREA	
EXISTING TRAIL			

GROUND CONTROL SURVEY BY: MERRICK & COMPANY
 AERIAL PHOTOGRAPHY BY: MERRICK & COMPANY
 TOPOGRAPHIC MAPPING BY: MERRICK & COMPANY
 CONTOUR INTERVAL: ONE FEET
 DATE FLOWN: 2003
 DATUM: HORIZONTAL - NAD83, COLORADO STATE PLANE COORD. - NORTH, VERTICAL - NAVD88

PREPARED BY:
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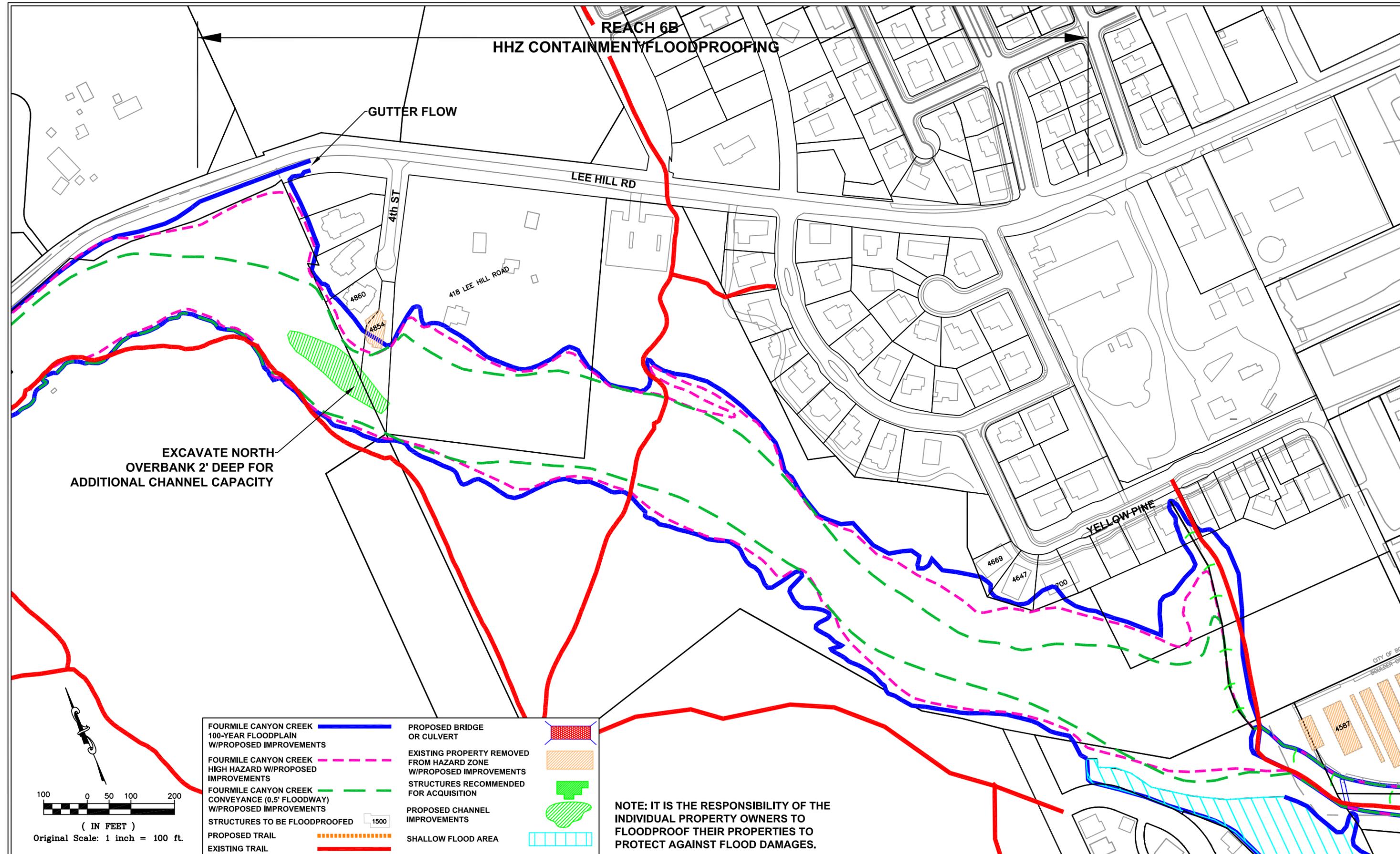
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 DRAWN: PEM
 CHECKED: DJL
 DATE: 8/27/10

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

RECOMMENDED ALTERNATE
 REACH 6C
 FOURMILE CANYON CREEK

Fig
 10.3



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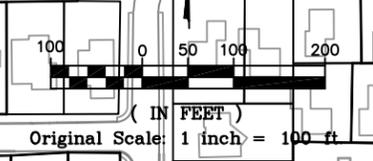
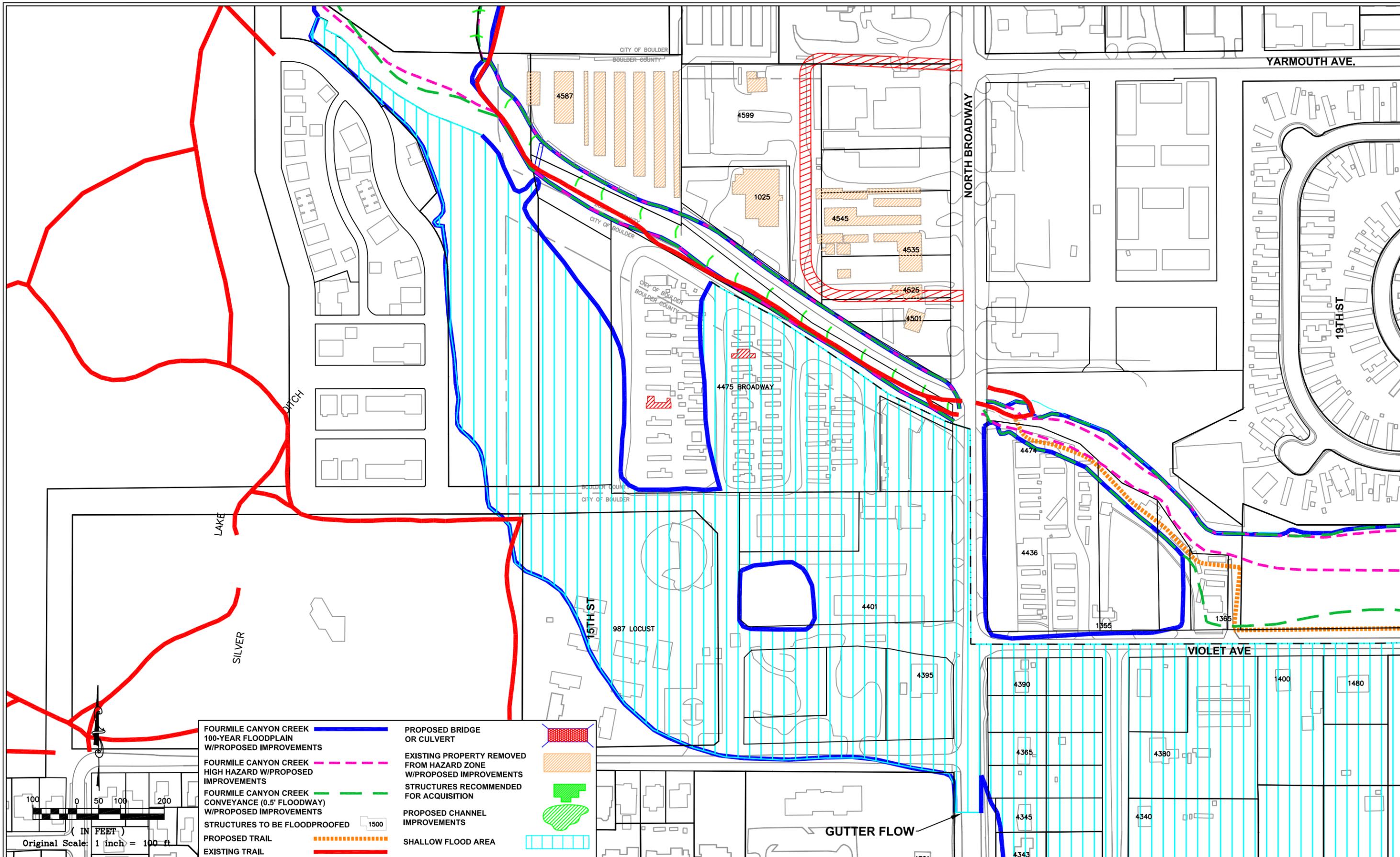
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URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

RECOMMENDED ALTERNATE
 REACH 6B
 FOURMILE CANYON CREEK

Fig
 10.4



FOURMILE CANYON CREEK 100-YEAR FLOODPLAIN W/PROPOSED IMPROVEMENTS		PROPOSED BRIDGE OR CULVERT	
FOURMILE CANYON CREEK HIGH HAZARD W/PROPOSED IMPROVEMENTS		EXISTING PROPERTY REMOVED FROM HAZARD ZONE W/PROPOSED IMPROVEMENTS	
FOURMILE CANYON CREEK CONVEYANCE (0.5' FLOODWAY) W/PROPOSED IMPROVEMENTS		STRUCTURES RECOMMENDED FOR ACQUISITION	
STRUCTURES TO BE FLOODPROOFED		PROPOSED CHANNEL IMPROVEMENTS	
PROPOSED TRAIL		SHALLOW FLOOD AREA	
EXISTING TRAIL			

GROUND CONTROL SURVEY BY: MERRICK & COMPANY
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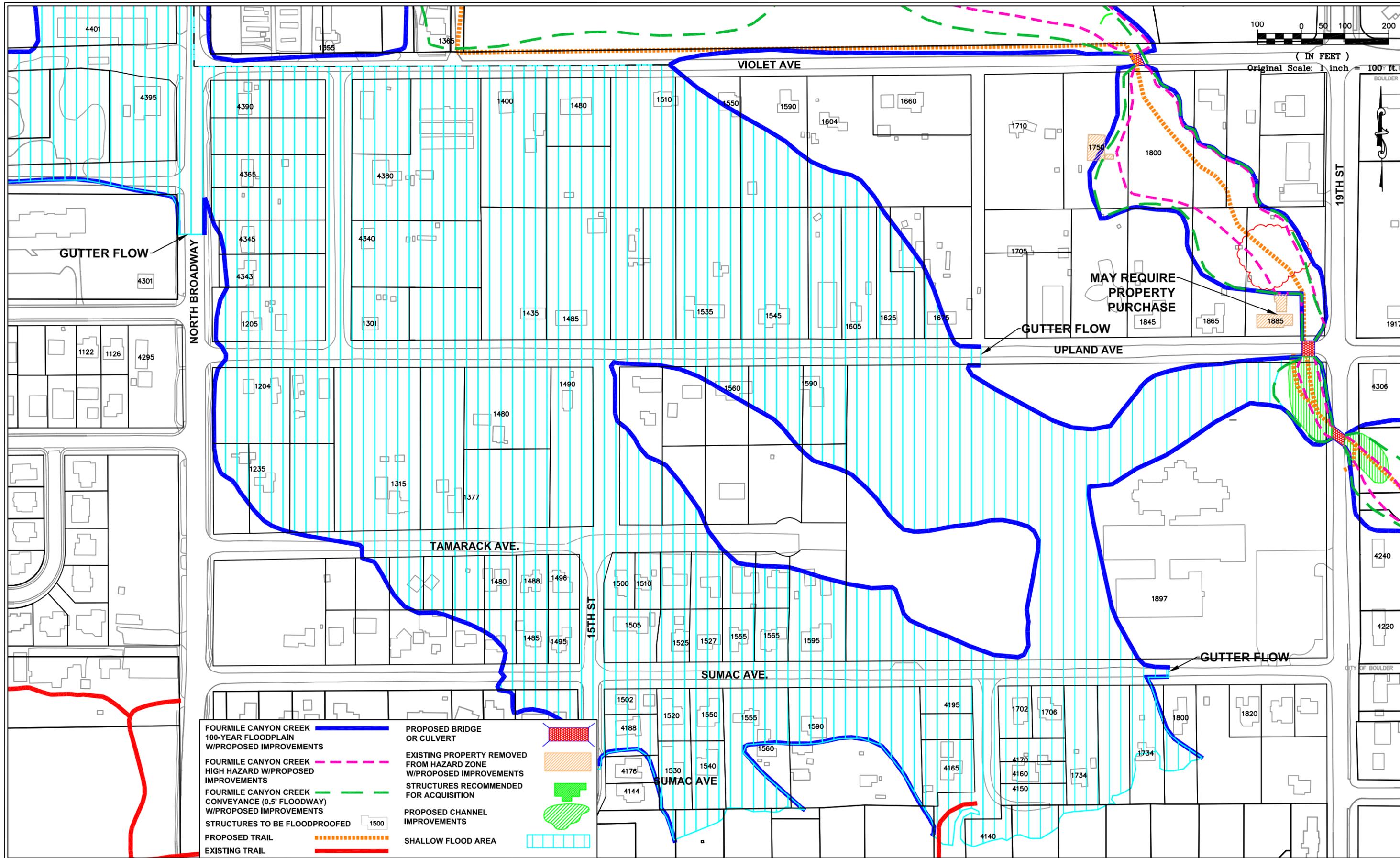
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URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

REACH 6A SPILL
 FOURMILE CANYON CREEK

Fig
 10.5



FOURMILE CANYON CREEK 100-YEAR FLOODPLAIN W/PROPOSED IMPROVEMENTS	PROPOSED BRIDGE OR CULVERT	
FOURMILE CANYON CREEK HIGH HAZARD W/PROPOSED IMPROVEMENTS	EXISTING PROPERTY REMOVED FROM HAZARD ZONE W/PROPOSED IMPROVEMENTS	
FOURMILE CANYON CREEK CONVEYANCE (0.5' FLOODWAY) W/PROPOSED IMPROVEMENTS	STRUCTURES RECOMMENDED FOR ACQUISITION	
STRUCTURES TO BE FLOODPROOFED	PROPOSED CHANNEL IMPROVEMENTS	
PROPOSED TRAIL	SHALLOW FLOOD AREA	
EXISTING TRAIL		

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URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

REACH 6A SPILL
 FOURMILE CANYON CREEK

Fourmile Canyon Creek Reach 5 – North Broadway to Violet Avenue Final Plan – High Hazard Zone Containment with Floodproofing (\$120,000 public)

This reach of Fourmile Canyon Creek has an extensive floodplain under existing conditions that includes the majority of the spill to Wonderland Creek. **Figure 10.6** shows the existing floodplain limits along this reach. Several critical facilities are located near the downstream of the end of this reach but are listed in Reach 4. No changes were made to the recommended alternative for Reach 5 from the Phase A Study. Recommended work within this reach is located just upstream of Violet Avenue and would include:



Reach 5 looking west

- Construction of an approximately two feet deep drop structure to stabilize existing headcut in the stream channel
- Stabilization of approximately 250 linear feet of stream bank
- Construction of an on-stream sediment capture facility and wetland mitigation

Figure 10.7 presents the Final Plan recommendations. Reach 5 improvements would narrow the high hazard zone so that the structure located at 1750 Violet Avenue would be located outside the high hazard zone. **Table 10.4** presents total estimated concept-level costs for proposed improvements along Reach 5.

Table 10.4 Concept-Level Cost Estimates for Fourmile Canyon Creek Reach 5

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$120,000	\$0	\$310,000	\$726,000	\$169,000	\$0

Fourmile Canyon Creek Reach 4 –Violet Avenue to 26th Street Final Plan – High Hazard Zone Containment with Floodproofing with Safe Access to Crestview Elementary School via 19th Street and Upland Avenue (\$4,094,000 public)

The existing conditions floodplain of Reach 4 extends well beyond the stream banks but no longer spills to Wonderland Creek as shown on **Figure 10.6**. Several critical facilities are located within the upstream end of this reach including:

- Boulder Meeting of Friends located at 1825 Upland Avenue
- Congregate Care (at-risk population) located at 1825 Upland Avenue
- Boulder Fire Station 5 located at 4365 19th Street
- Crestview Elementary School located at 1897 Sumac Avenue

The public process resulted in modification of the Phase A Study recommendation of HHZ Containment with Floodproofing to include upgraded road crossings at Upland Avenue and 19th Street to provide safe access to Crestview Elementary School. Final Plan recommendations for this reach include:

- Replacing the existing Violet Avenue bridge with a 38’ W x 8’ H RCB with multi-use underpass

- Removing an existing culvert located approximately 250 feet upstream of the Upland Avenue and 19th Street intersection and constructing open channel
- Constructing approximately 110 linear feet of wall just upstream of Upland Avenue on parcel 1885 upland to convey flood waters to a new 38’ W x 8’ H RCB with multi-use underpass at Upland Avenue
- Excavating approximately two feet of existing channel between Upland Avenue and 19th Street to provide a flow transition for a new 20’ W x 9’ H RCB with multi-use underpass at 19th Street that includes an upstream drop
- Excavating approximately 450 linear feet of the north overbank by two feet between Sumac Avenue and Topaz Drive to increase conveyance and remove and relocate an existing driveway on parcel 2446 Sumac
- Replacing the existing culvert under Topaz Drive with twin 12’ W x 6’ H RCB with new channel transitions
- Design and construction of channel improvements (north side of channel only) between Topaz Drive and 26th Street that increase channel capacity to narrow the floodplain to the south side of Topaz Drive but save the majority of the trees in the riparian corridor
- Constructing eight two-foot high channel drop structures along the channel between Topaz Drive and 26th Street

The city has purchased properties along Fourmile Canyon Creek Reach 4 to facilitate recommended improvements including:

- 2446 Sumac Avenue
- 0 Topaz Street (just west of parcel 2435 Topaz Drive)
- 2400 Topaz Drive



Reach 4 looking west

Two more properties, 4097 26th Street and 2500 Topaz Drive, are recommended for acquisition.

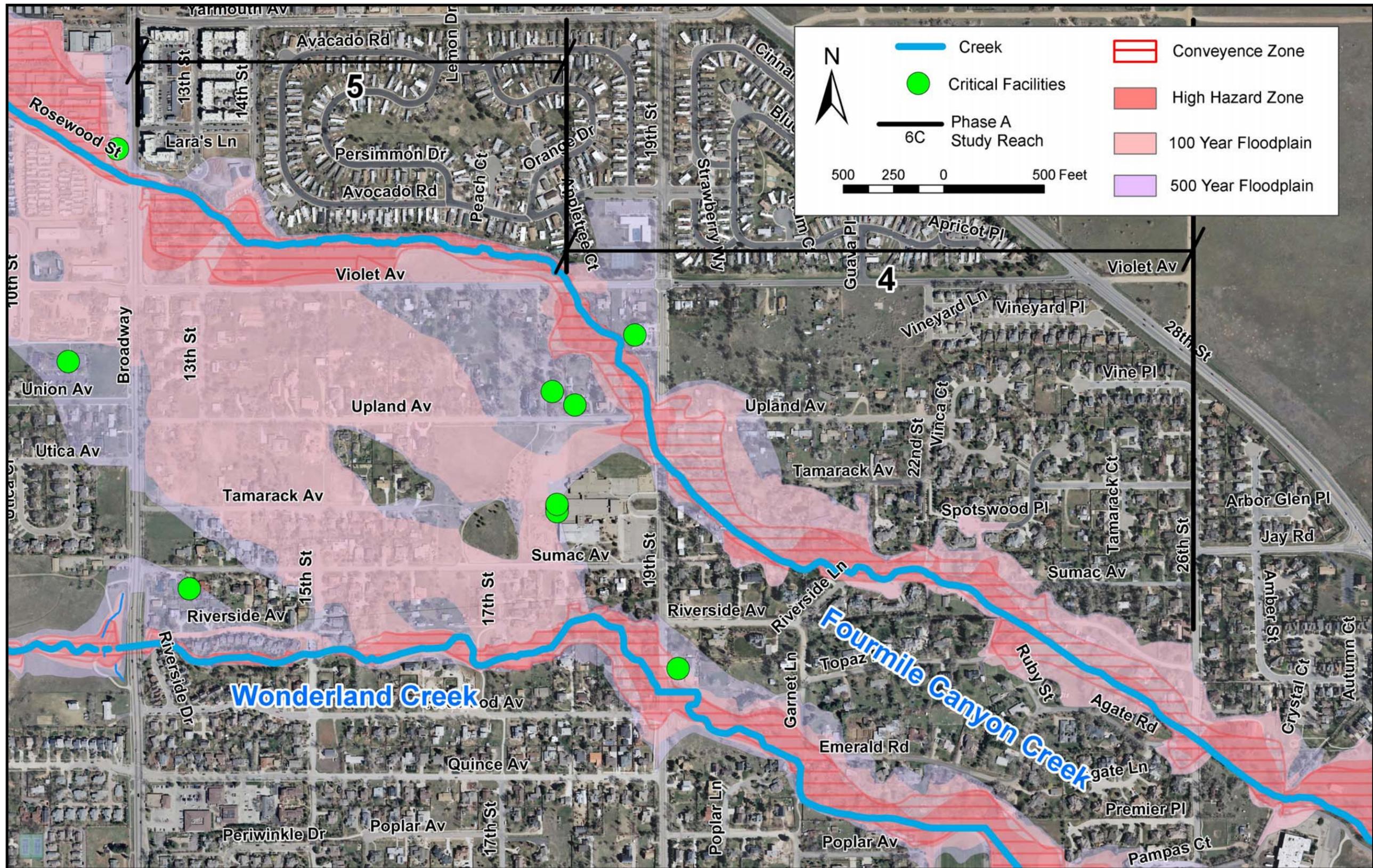
Reach 4 improvements would narrow the high hazard zone so that the structures located at 2455 Sumac Avenue and 1885 Upland Avenue would be located outside the high hazard zone.

Figure 10.8 presents the Final Plan recommendations for Reach 4 including the flood hazard limits and structures that would be removed from the High Hazard Zone following implementation. **Table 10.5** presents total estimated concept-level costs for proposed improvements along Reach 4.

Table 10.5 Concept-Level Cost Estimates for Fourmile Canyon Creek Reach 4

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$2,582,000	\$2,582,000	\$513,000	\$5,349,000	\$87,000	\$0

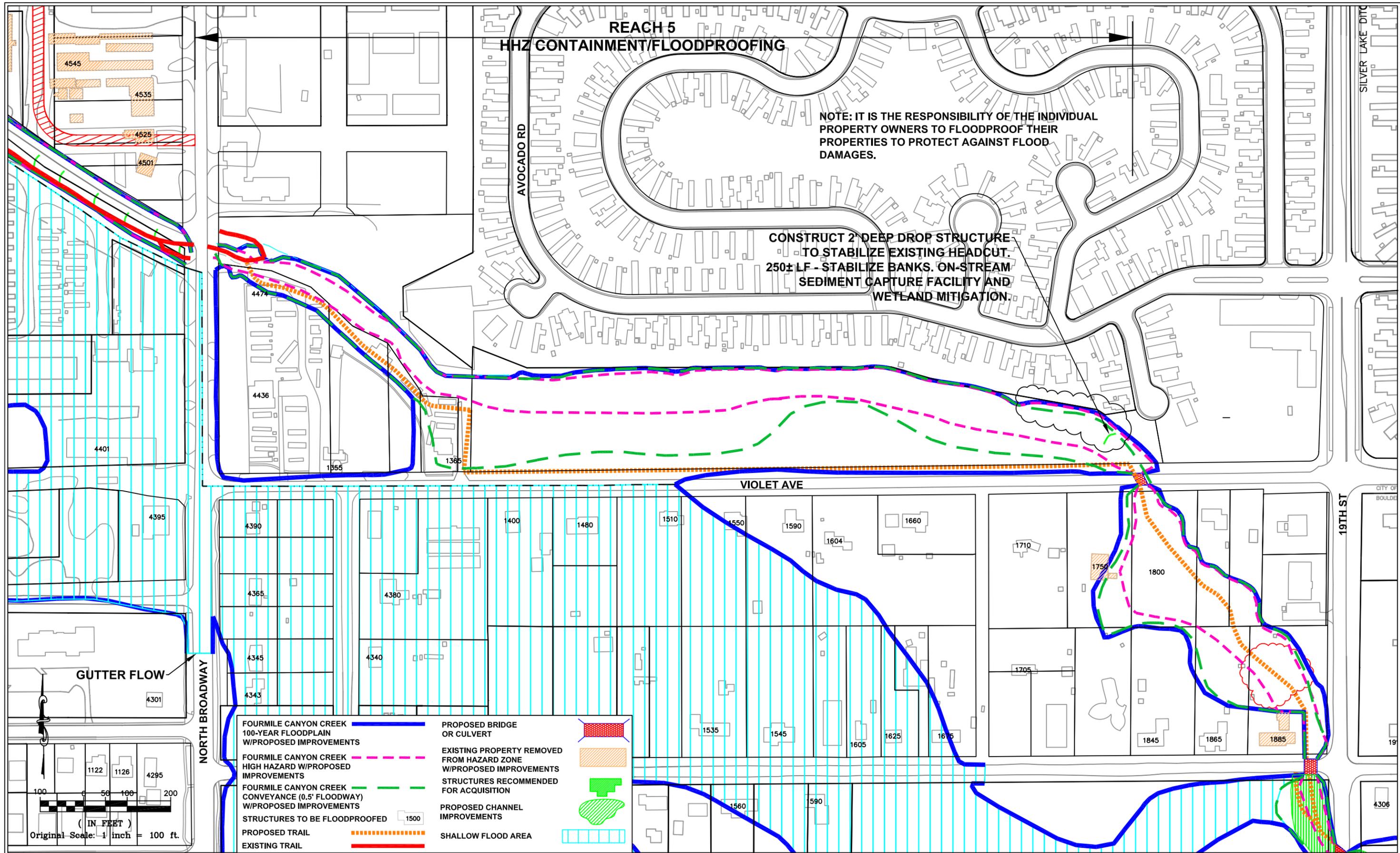
Figure 10.6 Existing Conditions Fourmile Canyon Creek Reaches 5, 4



**REACH 5
HHZ CONTAINMENT/FLOODPROOFING**

NOTE: IT IS THE RESPONSIBILITY OF THE INDIVIDUAL PROPERTY OWNERS TO FLOODPROOF THEIR PROPERTIES TO PROTECT AGAINST FLOOD DAMAGES.

CONSTRUCT 2' DEEP DROP STRUCTURE TO STABILIZE EXISTING HEADCUT. 250± LF - STABILIZE BANKS. ON-STREAM SEDIMENT CAPTURE FACILITY AND WETLAND MITIGATION.



GUTTER FLOW

NORTH BROADWAY

VIOLET AVE

19TH ST

CITY OF BOULDER

- | | | | |
|--|--|--|--|
| FOURMILE CANYON CREEK 100-YEAR FLOODPLAIN W/PROPOSED IMPROVEMENTS | | PROPOSED BRIDGE OR CULVERT | |
| FOURMILE CANYON CREEK HIGH HAZARD W/PROPOSED IMPROVEMENTS | | EXISTING PROPERTY REMOVED FROM HAZARD ZONE W/PROPOSED IMPROVEMENTS | |
| FOURMILE CANYON CREEK CONVEYANCE (0.5' FLOODWAY) W/PROPOSED IMPROVEMENTS | | STRUCTURES RECOMMENDED FOR ACQUISITION | |
| STRUCTURES TO BE FLOODPROOFED | | PROPOSED CHANNEL IMPROVEMENTS | |
| PROPOSED TRAIL | | SHALLOW FLOOD AREA | |
| EXISTING TRAIL | | | |

GROUND CONTROL SURVEY BY: MERRICK & COMPANY
AERIAL PHOTOGRAPHY BY: MERRICK & COMPANY
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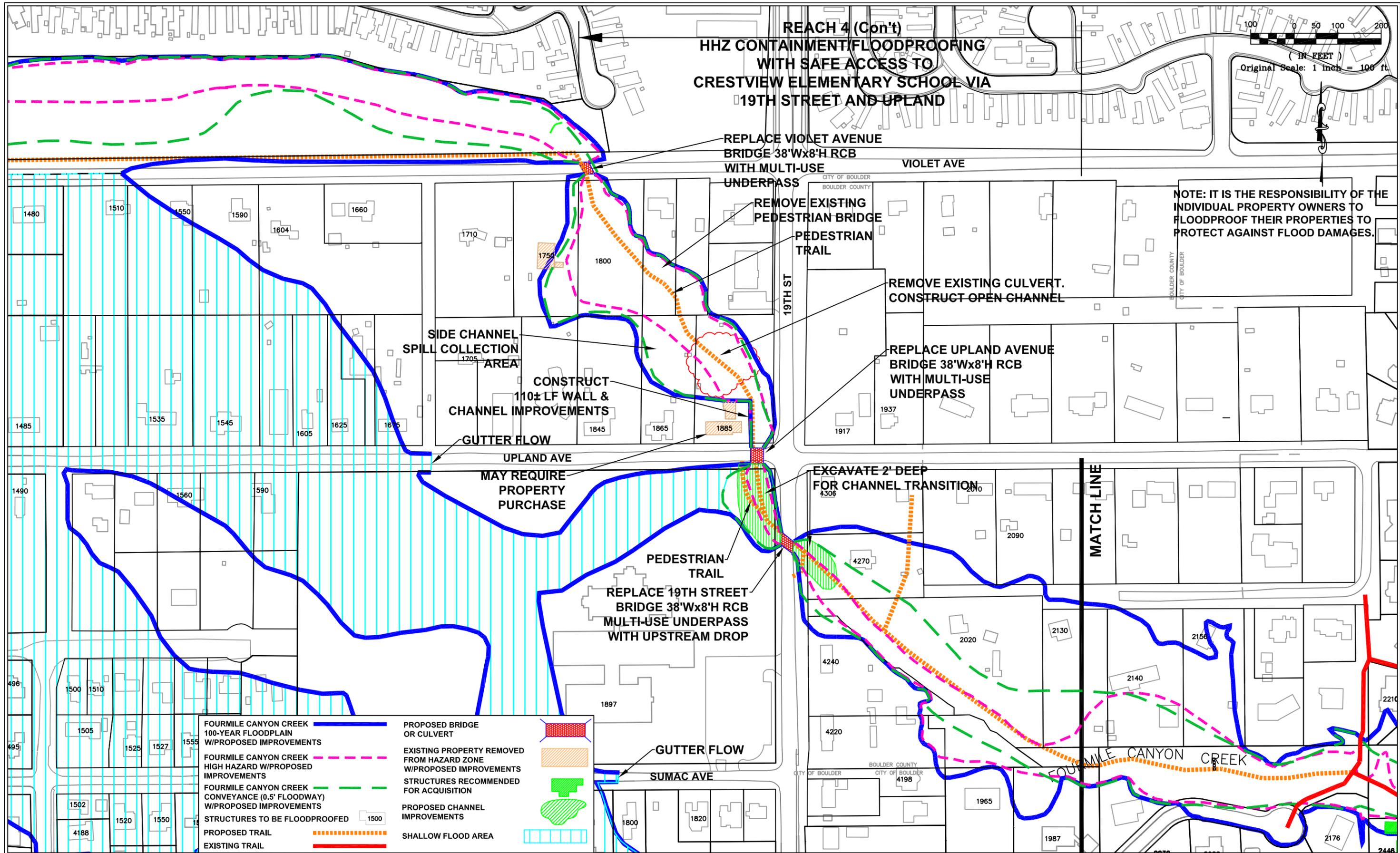
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URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
AND WONDERLAND CREEK
MASTER PLAN

RECOMMENDED ALTERNATE
REACH 5
FOURMILE CANYON CREEK

Fig
10.7



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 DRAWN: PEM
 CHECKED: DJL
 DATE: 8/27/10

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

RECOMMENDED ALTERNATE
 REACH 4
 FOURMILE CANYON CREEK

Fig
 10.8

10.2 Wonderland Creek

Wonderland Creek Reach 8 – Wonderland Lake to North Broadway

Final Plan – Maintain Existing Condition (\$0 public)

The floodplain extends beyond the creek banks under existing conditions but impacts only open space lands between Wonderland Lake and North Broadway. The Phase A Study and Final Plan recommends maintaining existing conditions. **Figure 10.16** shows the Wonderland Creek Reach 8 existing conditions. **Figure 10.17** presents the Final Plan for Wonderland Creek Reach 8.



Reach 8 looking east at Broadway

Wonderland Creek Reach 7 –North Broadway to 19th Street

Final Plan – Maintain Existing Condition with Safe Access to Crestview Elementary School via 19th Street (\$30,000 public)

The Wonderland Creek floodplain along Reach 7 includes the extensive spill from Fourmile Canyon Creek from the north. One critical facility, a Congregate Care (at-risk population), is located along this reach of Wonderland Creek at 1286 Sumac Avenue. **Figure 10.16** shows the existing conditions floodplain limits along with the location of the critical facility.

The public process modified the Phase A Study recommendation of maintaining existing conditions to include safe access to Crestview Elementary School. Providing safe access would include constructing a two-foot deep horseshoe drop structure and constructing approximately 80 linear feet of two feet deep channel transition just upstream of the new crossing at 19th Street (the crossing at 19th Street is included in Reach 6). **Figure 10.18** presents the Final Plan recommendations for Reach 7. **Table 10.9** presents total estimated concept-level costs for proposed improvements along Reach 7.



Reach 7 at 15th Street

Table 10.9 Concept-Level Cost Estimates for Wonderland Creek Reach 7

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$30,000	\$0	\$807,000	\$0	\$0	\$0

Wonderland Creek Reach 6 – 19th Street to 26th Street

Final Plan – High Hazard Containment with Flood Proofing (\$2,310,000 public)

Figure 10.19 shows the extent of the existing floodplain along Wonderland Creek Reach 6. As shown on this figure, the floodplain extends well beyond the creek banks, particularly on the north side of the channel. One critical facility, a day care center located at 4072 North 19th Street just east of 19th Street

is located on the study reach. The public process resulted in modifications to the HHZ containment alternative for this reach. Final Plan recommended improvements include:

- Replacing the existing 19th Street crossing with a triple 16' W x 5' H RCB
- Excavating two feet of both banks of the existing channel for approximately 160 linear feet on the downstream side of the proposed 19th Street culverts to provide increased channel capacity and channel transition
- Excavating two feet of existing channel for approximately 650 linear feet on north and south channel banks to increase channel capacity beginning approximately 400 feet upstream of Garnet Lane
- Removing and replacing pedestrian bridge with approximately 220 feet-long structure or low-water crossing with two-foot deep horseshoe drop structure directly south of Garnet Lane
- Constructing an approximately 1,100 feet long, five feet deep overflow channel beginning approximately half way along the study reach



Reach 6 upstream of 26th Street

Proposed improvements would narrow the high hazard zone so that the structures located at the following parcels would be located outside the high hazard zone:

- 4081 Garnet Lane
- 2100 Emerald Road
- 2300 Emerald Road
- 2195 Poplar Avenue
- 2155 Poplar Avenue

Reach 6 downstream of
Centennial Middle School

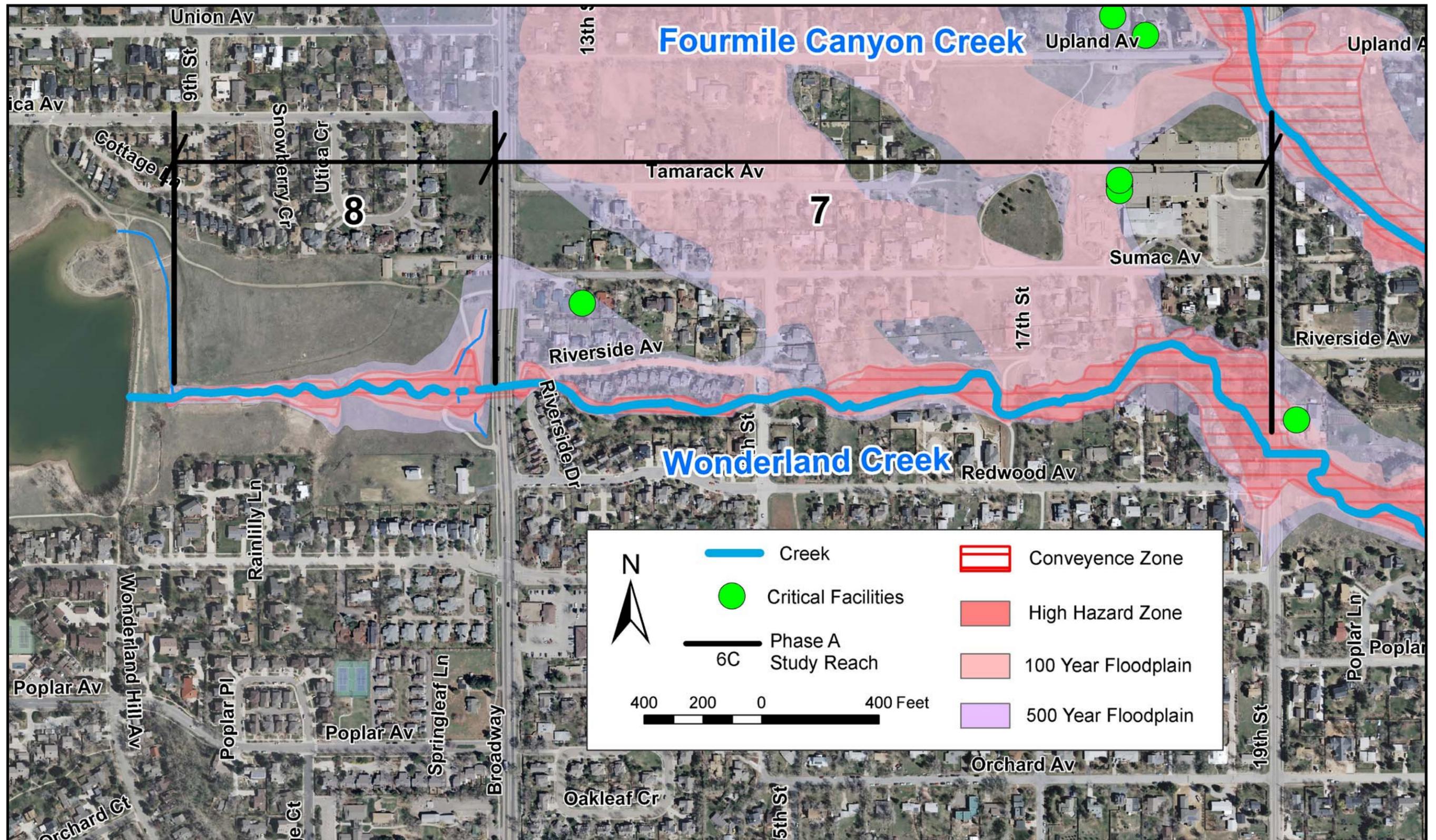


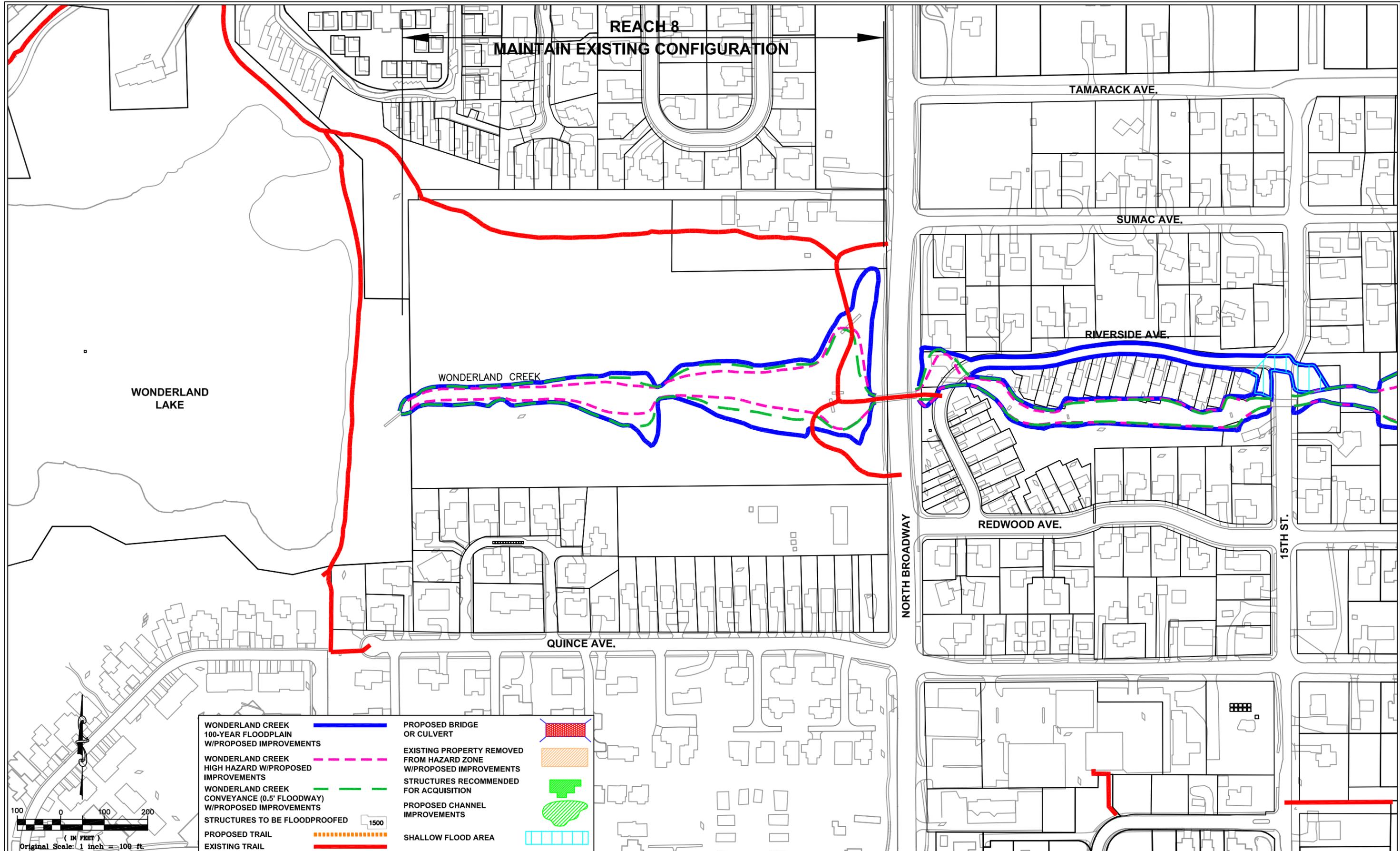
Figure 10.20 presents the Final Plan recommendations for Reach 6. **Table 10.10** presents total estimated concept-level costs for proposed improvements along Reach 6.

Table 10.10 Concept-Level Estimates for Wonderland Creek Reach 6

Flood Control Improvements			Floodproofing (Private Cost)	Non Flood Mitigation Improvements	
Construction	ROW	O&M		Construction	ROW
\$2,104,000	\$206,000	\$253,000	\$2,390,000	\$102,000	\$0

Figure 10.16 Existing Conditions Wonderland Creek Reach 8, 7





<p>WONDERLAND CREEK 100-YEAR FLOODPLAIN W/PROPOSED IMPROVEMENTS</p> <p>WONDERLAND CREEK HIGH HAZARD W/PROPOSED IMPROVEMENTS</p> <p>WONDERLAND CREEK CONVEYANCE (0.5' FLOODWAY) W/PROPOSED IMPROVEMENTS</p> <p>STRUCTURES TO BE FLOODPROOFED</p> <p>PROPOSED TRAIL</p> <p>EXISTING TRAIL</p>	<p>PROPOSED BRIDGE OR CULVERT</p> <p>EXISTING PROPERTY REMOVED FROM HAZARD ZONE W/PROPOSED IMPROVEMENTS</p> <p>STRUCTURES RECOMMENDED FOR ACQUISITION</p> <p>PROPOSED CHANNEL IMPROVEMENTS</p> <p>SHALLOW FLOOD AREA</p>
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GROUND CONTROL SURVEY BY: MERRICK & COMPANY
 AERIAL PHOTOGRAPHY BY: MERRICK & COMPANY
 TOPOGRAPHIC MAPPING BY: MERRICK & COMPANY
 CONTOUR INTERVAL: ONE FEET
 DATE FLOWN: 2003
 DATUM: HORIZONTAL - NAD83, COLORADO STATE
 PLANE COORD. - NORTH, VERTICAL - NAVD88

PREPARED BY:
 BELT COLLINS WEST
 water resource consultants
 4909 Pearl East Circle, Suite 300
 Boulder, Colorado 80501-9100
 Phone: 303-442-4588
 Fax: 303-788-8026

DESIGNED: SDL
 DRAWN: PEM
 CHECKED: DJL
 DATE: 8/27/10

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
 CITY OF BOULDER, COLORADO

FOURMILE CANYON CREEK
 AND WONDERLAND CREEK
 MASTER PLAN

RECOMMENDED ALTERNATE
 REACH 8
 WONDERLAND CREEK

Fig
 10.17

Appendix B – Hydrologic Models

Alternative 1 - Hydrology Output

URBAN DRAINAGE STORM WATER MANAGEMENT MODEL - 32 BIT VERSION 1998
 REVISION BY UNIVERSITY OF COLORADO AT DENVER

*** ENTRY MADE TO RUNOFF MODEL ***

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
 xxx-yr event

NUMBER OF TIME STEPS 90
 INTEGRATION TIME INTERVAL (MINUTES), 5.00

25.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH
 1

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
 xxx-yr event

HYDROGRAPHS FROM CUHPF MODEL ARE LISTED FOR THE FOLLOWING 19 SUBCATCHMENTS

TIME(HR/MIN)	100 111	101 112	102 1	106 2	103 3	104 41	108 42	105 5	109 6	110
0 0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0 5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0 10.	2.	2.	2.	2.	1.	1.	2.	3.	1.	0.
0 15.	12.	8.	8.	7.	5.	4.	7.	12.	3.	0.
0 20.	31.	24.	25.	15.	12.	11.	15.	29.	8.	0.
0 25.	74.	57.	64.	41.	40.	33.	36.	73.	28.	7.
0 30.	183.	138.	151.	115.	121.	104.	100.	201.	92.	44.
0 35.	334.	265.	294.	178.	187.	153.	162.	328.	152.	81.
0 40.	402.	375.	456.	181.	198.	152.	165.	332.	172.	94.
0 45.	376.	399.	537.	163.	185.	137.	147.	290.	167.	94.
0 50.	328.	370.	523.	143.	166.	121.	127.	246.	156.	93.
0 55.	281.	330.	481.	123.	146.	105.	108.	205.	142.	89.
1 0.	239.	291.	431.	106.	129.	91.	92.	171.	129.	83.
1 5.	207.	256.	384.	93.	116.	81.	81.	148.	118.	78.
1 10.	179.	226.	341.	79.	100.	68.	67.	124.	105.	71.
1 15.	147.	195.	301.	63.	83.	55.	53.	96.	90.	63.
1 20.	116.	161.	257.	50.	68.	43.	40.	73.	77.	56.
1 25.	91.	132.	214.	37.	54.	33.	27.	54.	64.	49.
1 30.	71.	107.	177.	26.	44.	22.	20.	38.	54.	43.
1 35.	55.	88.	146.	19.	35.	16.	15.	29.	46.	37.
1 40.	42.	73.	123.	15.	24.	13.	12.	23.	39.	33.
1 45.	34.	61.	104.	13.	18.	10.	10.	20.	33.	29.
1 50.	30.	51.	89.	11.	15.	8.	9.	17.	27.	25.
1 55.	27.	40.	77.	10.	12.	7.	8.	16.	19.	22.
2 0.	25.	34.	68.	9.	11.	6.	7.	15.	15.	19.
2 5.	22.	29.	59.	7.	9.	5.	6.	12.	12.	16.
2 10.	17.	24.	47.	5.	6.	3.	4.	8.	9.	10.
2 15.	11.	18.	36.	4.	4.	2.	3.	6.	6.	7.
2 20.	8.	13.	27.	3.	3.	2.	2.	4.	5.	5.
2 25.	6.	10.	21.	2.	2.	0.	1.	3.	3.	3.
2 30.	4.	7.	15.	0.	2.	0.	0.	2.	2.	2.
2 35.	3.	5.	12.	0.	0.	0.	0.	0.	2.	2.
2 40.	2.	4.	9.	0.	0.	0.	0.	0.	0.	0.
2 45.	0.	3.	6.	0.	0.	0.	0.	0.	0.	0.

Alternative 1 - Hydrology Output

	0.	0.	41.	17.	0.	0.	0.	0.	0.	0.	23.
6 25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	38.	16.	0.	0.	0.	0.	0.	0.	22.
6 30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	36.	14.	0.	0.	0.	0.	0.	0.	21.
6 35.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	34.	13.	0.	0.	0.	0.	0.	0.	20.
6 40.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	32.	12.	0.	0.	0.	0.	0.	0.	19.
6 45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	30.	8.	0.	0.	0.	0.	0.	0.	18.
6 50.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	28.	5.	0.	0.	0.	0.	0.	0.	17.
6 55.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	26.	4.	0.	0.	0.	0.	0.	0.	16.
7 0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	24.	3.	0.	0.	0.	0.	0.	0.	15.
7 5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	23.	2.	0.	0.	0.	0.	0.	0.	14.
7 10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	21.	0.	0.	0.	0.	0.	0.	0.	9.
7 15.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	20.	0.	0.	0.	0.	0.	0.	0.	6.
7 20.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	19.	0.	0.	0.	0.	0.	0.	0.	4.
7 25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	18.	0.	0.	0.	0.	0.	0.	0.	3.
7 30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	2.

1

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
xxx-yr event

GUTTER NUMBER	GUTTER CONNECTION	NDP	NP	WIDTH OR DIAM (FT)	LENGTH (FT)	INVERT SLOPE (FT/FT)	SIDE SLOPES HORIZONTAL TO VERTICAL	MANNING N	OVERBANK/SURCHARGE DEPTH (FT)	JK
300	610	0	3	.0	1.	.0010	.0 .0	.001	10.00	0
610	611	0	4	CHANNEL	27.0	4500.	.0420 2.5 2.5	.056	5.30	0
				OVERFLOW	104.0	4500.	.0420 3.0 3.0	.075	10.00	
611	310	0	4	CHANNEL	27.0	4500.	.0420 2.5 2.5	.056	5.30	0
				OVERFLOW	104.0	4500.	.0420 3.0 3.0	.075	10.00	
310	399	0	3	PIPE	.0	1.	.0010	.0 .0	10.00	0
399	612	3	2	PIPE	.0	0.	.0001	.0 .0	.01	0
RESERVOIR STORAGE IN ACRE-FEET VS SPILLWAY OUTFLOW										
612	311	0	4	CHANNEL	24.0	5600.	.0300 4.3 4.3	.056	16.00	0
				OVERFLOW	181.0	5600.	.0300 3.0 100.0	.075	10.00	
311	400	0	3	CHANNEL	.0	1.	.0010	.0 .0	10.00	0
613	312	0	4	CHANNEL	25.0	3354.	.0230 3.5 3.5	.056	4.00	0
				OVERFLOW	203.0	3354.	.0230 3.0 10.0	.075	10.00	
312	999	0	3	CHANNEL	.0	1.	.0010	.0 .0	10.00	0
614	313	0	4	CHANNEL	25.0	4773.	.0190 3.5 3.5	.056	4.00	0
				OVERFLOW	203.0	4773.	.0190 3.0 10.0	.075	10.00	
313	999	0	3	CHANNEL	.0	1.	.0010	.0 .0	10.00	0
615	616	0	4	CHANNEL	40.0	1180.	.0120 4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120 3.0 3.0	.075	10.00	
616	617	0	4	CHANNEL	40.0	1180.	.0120 4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120 3.0 3.0	.075	10.00	
617	618	0	4	CHANNEL	40.0	1180.	.0120 4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120 3.0 3.0	.075	10.00	
618	619	0	4	CHANNEL	40.0	1180.	.0120 4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120 3.0 3.0	.075	10.00	
619	314	0	4	CHANNEL	40.0	1180.	.0120 4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120 3.0 3.0	.075	10.00	
314	999	0	3	CHANNEL	.0	1.	.0010	.0 .0	10.00	0
620	621	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
621	622	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
622	623	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
623	624	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
624	625	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
625	626	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
626	627	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
627	628	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
628	629	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
629	315	0	4	CHANNEL	26.0	1140.	.0100 6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100 3.0 3.0	.055	10.00	
315	999	0	3	CHANNEL	.0	1.	.0010	.0 .0	10.00	0
400	401	5	3	PIPE	.0	1.	.0010	.0 .0	10.00	402
DIVERSION TO GUTTER NUMBER 402 - TOTAL Q VS DIVERTED Q IN CFS										
401	613	0	2	PIPE	.0	0.	.0001	.0 .0	.01	0
RESERVOIR STORAGE IN ACRE-FEET VS SPILLWAY OUTFLOW										
402	405	0	1	CHANNEL	.0	1667.0	.0	5000.0		
405	407	4	3	CHANNEL	600.0	1151.	.0240 20.0 20.0	.100	10.00	0
				OVERFLOW	.0	1.	.0010	.0 .0	.001	10.00
DIVERSION TO GUTTER NUMBER 406 - TOTAL Q VS DIVERTED Q IN CFS										
407	410	0	1	CHANNEL	1292.0	1182.0	2103.0 1789.0	5122.0 3621.0	.100	10.00
410	412	4	3	CHANNEL	300.0	743.	.0230 20.0 20.0	.100	10.00	0
				OVERFLOW	.0	1.	.0010	.0 .0	.001	10.00
DIVERSION TO GUTTER NUMBER 411 - TOTAL Q VS DIVERTED Q IN CFS										
412	312	0	1	CHANNEL	110.0	109.0	323.0 298.0	1500.0 1147.0	.100	10.00
406	240	0	1	CHANNEL	300.0	547.	.0220 20.0 20.0	.100	10.00	0
411	230	0	1	CHANNEL	400.0	1316.	.0270 20.0 20.0	.100	10.00	0
200	998	0	3	CHANNEL	300.0	1471.	.0180 20.0 20.0	.100	10.00	0
210	10	0	3	CHANNEL	.0	1.	.0010	.0 .0	.001	10.00
211	20	0	3	CHANNEL	.0	1.	.0010	.0 .0	.001	10.00
212	21	0	3	CHANNEL	.0	1.	.0010	.0 .0	.001	10.00
220	22	0	3	CHANNEL	.0	1.	.0010	.0 .0	.001	10.00
221	31	0	3	CHANNEL	.0	1.	.0010	.0 .0	.001	10.00

Alternatives 1 - Hydrology Output											
615	0	0	0	0	0	0	0	0	0	0	0
616	615	0	0	0	0	0	0	0	0	0	0
617	616	0	0	0	0	0	0	0	0	0	0
618	617	0	0	0	0	0	0	0	0	0	0
619	618	0	0	0	0	0	0	0	0	0	0
620	0	0	0	0	0	0	0	0	0	0	0
621	620	0	0	0	0	0	0	0	0	0	0
622	621	0	0	0	0	0	0	0	0	0	0
623	622	0	0	0	0	0	0	0	0	0	0
624	623	0	0	0	0	0	0	0	0	0	0
625	624	0	0	0	0	0	0	0	0	0	0
626	625	0	0	0	0	0	0	0	0	0	0
627	626	0	0	0	0	0	0	0	0	0	0
628	627	0	0	0	0	0	0	0	0	0	0
629	628	0	0	0	0	0	0	0	0	0	0

1

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
xxx-yr event

*** PEAK FLOWS, STAGES AND STORAGES OF GUTTERS AND DETENTION DAMS ***

CONVEYANCE ELEMENT	PEAK (CFS)	STAGE (FT)	STORAGE (AC-FT)	TIME (HR/MIN)
420	253.	.0	22.0	1 25.
251	94.	(DI RECT FLOW)		0 45.
260	253.	(DI RECT FLOW)		1 25.
61	82.	1.3		1 0.
60	252.	2.1		1 30.
250	531.	(DI RECT FLOW)		0 50.
50	528.	2.8		0 55.
406	0.	.0		0 0.
240	528.	(DI RECT FLOW)		0 55.
40	522.	2.5		1 5.
411	0.	.0		0 0.
620	0.	.0		0 0.
300	1722.	(DI RECT FLOW)		1 20.
221	165.	(DI RECT FLOW)		0 40.
230	721.	(DI RECT FLOW)		0 50.
621	0.	.0		0 0.
610	1701.	4.0		1 25.
31	132.	1.2		0 50.
30	655.	2.7		1 10.
622	0.	.0		0 0.
611	1680.	4.0		1 30.
220	970.	(DI RECT FLOW)		1 0.
623	0.	.0		0 0.
310	3296.	(DI RECT FLOW)		1 20.
22	959.	3.0		1 5.
624	0.	.0		0 0.
399	1574.	.0	213.9	2 25.
212	1055.	(DI RECT FLOW)		1 0.
625	0.	.0		0 0.
615	0.	.0		0 0.
402	0.	.0		0 0.
612	1568.	4.1		2 35.
21	1014.	3.4		1 10.
626	0.	.0		0 0.
616	0.	.0		0 0.
405	0.	(DI RECT FLOW)		0 0.
311	1613.	(DI RECT FLOW)		2 25.
211	1014.	(DI RECT FLOW)		1 10.
627	0.	.0		0 0.
617	0.	.0		0 0.
407	0.	.0		0 0.
400	1613.	(DI RECT FLOW)		2 25.
20	933.	3.7		1 25.
628	0.	.0		0 0.
618	0.	.0		0 0.
410	0.	(DI RECT FLOW)		0 0.
401	-3.	.0	0	0 10.
210	1396.	(DI RECT FLOW)		1 10.
629	0.	.0		0 0.
619	0.	.0		0 0.
614	0.	.0		0 0.
412	0.	.0		0 0.
613	1597.	4.3		2 40.
10	1346.	3.5		1 20.
315	0.	(DI RECT FLOW)		0 0.
314	0.	(DI RECT FLOW)		0 0.
313	0.	(DI RECT FLOW)		0 0.
312	1598.	(DI RECT FLOW)		2 40.
200	1477.	(DI RECT FLOW)		1 15.
999	2649.	(DI RECT FLOW)		0 45.
998	1477.	(DI RECT FLOW)		1 15.

Alternati ve 2 - Hydrology Output

URBAN DRAINAGE STORM WATER MANAGEMENT MODEL - 32 BIT VERSION 1998
 REVISED BY UNIVERSITY OF COLORADO AT DENVER

*** ENTRY MADE TO RUNOFF MODEL ***

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
 xxx-yr event

NUMBER OF TIME STEPS 90
 INTEGRATION TIME INTERVAL (MINUTES), 5.00

25.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH
 1

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
 xxx-yr event

HYDROGRAPHS FROM CUHPF MODEL ARE LISTED FOR THE FOLLOWING 19 SUBCATCHMENTS

TIME(HR/MIN)	100 111	101 112	102 1	106 2	103 3	104 41	108 42	105 5	109 6	110
0 0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0 5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0 10.	2.	2.	2.	2.	1.	1.	2.	3.	1.	0.
0 15.	12.	8.	8.	7.	5.	4.	7.	12.	3.	0.
0 20.	31.	24.	25.	15.	12.	11.	15.	29.	8.	0.
0 25.	74.	57.	64.	41.	40.	33.	36.	73.	28.	7.
0 30.	183.	138.	151.	115.	121.	104.	100.	201.	92.	44.
0 35.	334.	265.	294.	178.	187.	153.	162.	328.	152.	81.
0 40.	402.	375.	456.	181.	198.	152.	165.	332.	172.	94.
0 45.	376.	399.	537.	163.	185.	137.	147.	290.	167.	94.
0 50.	328.	370.	523.	143.	166.	121.	127.	246.	156.	93.
0 55.	281.	330.	481.	123.	146.	105.	108.	205.	142.	89.
1 0.	239.	291.	431.	106.	129.	91.	92.	171.	129.	83.
1 5.	207.	256.	384.	93.	116.	81.	81.	148.	118.	78.
1 10.	179.	226.	341.	79.	100.	68.	67.	124.	105.	71.
1 15.	147.	195.	301.	63.	83.	55.	53.	96.	90.	63.
1 20.	116.	161.	257.	50.	68.	43.	40.	73.	77.	56.
1 25.	91.	132.	214.	37.	54.	33.	27.	54.	64.	49.
1 30.	71.	107.	177.	26.	44.	22.	20.	38.	54.	43.
1 35.	55.	88.	146.	19.	35.	16.	15.	29.	46.	37.
1 40.	42.	73.	123.	15.	24.	13.	12.	23.	39.	33.
1 45.	34.	61.	104.	13.	18.	10.	10.	20.	33.	29.
1 50.	30.	51.	89.	11.	15.	8.	9.	17.	27.	25.
1 55.	27.	40.	77.	10.	12.	7.	8.	16.	19.	22.
2 0.	25.	34.	68.	9.	11.	6.	7.	15.	15.	19.
2 5.	22.	29.	59.	7.	9.	5.	6.	12.	12.	16.
2 10.	17.	24.	47.	5.	6.	3.	4.	8.	9.	10.
2 15.	11.	18.	36.	4.	4.	2.	3.	6.	6.	7.
2 20.	8.	13.	27.	3.	3.	2.	2.	4.	5.	5.
2 25.	6.	10.	21.	2.	2.	0.	1.	3.	3.	3.
2 30.	4.	7.	15.	0.	2.	0.	0.	2.	2.	2.
2 35.	3.	5.	12.	0.	0.	0.	0.	0.	2.	2.
2 40.	2.	4.	9.	0.	0.	0.	0.	0.	0.	0.
2 45.	0.	3.	6.	0.	0.	0.	0.	0.	0.	0.

Alternative 2 - Hydrology Output

		0.	0.	41.	17.	0.	0.	0.	0.	0.	23.
6	25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	38.	16.	0.	0.	0.	0.	0.	22.
6	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	36.	14.	0.	0.	0.	0.	0.	21.
6	35.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	34.	13.	0.	0.	0.	0.	0.	20.
6	40.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	32.	12.	0.	0.	0.	0.	0.	19.
6	45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	30.	8.	0.	0.	0.	0.	0.	18.
6	50.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	28.	5.	0.	0.	0.	0.	0.	17.
6	55.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	26.	4.	0.	0.	0.	0.	0.	16.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	24.	3.	0.	0.	0.	0.	0.	15.
7	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	23.	2.	0.	0.	0.	0.	0.	14.
7	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	21.	0.	0.	0.	0.	0.	0.	9.
7	15.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	20.	0.	0.	0.	0.	0.	0.	6.
7	20.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	19.	0.	0.	0.	0.	0.	0.	4.
7	25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	18.	0.	0.	0.	0.	0.	0.	3.
7	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		0.	0.	17.	0.	0.	0.	0.	0.	0.	2.

1

Wonderland w/spill frm 4Mile 3/15/05 0217C2 Love and Associates
xxx-yr event

GUTTER NUMBER	GUTTER CONNECTION	NDP	NP		WIDTH OR DIAM (FT)	LENGTH (FT)	INVERT SLOPE (FT/FT)	SIDE SLOPES HORIZ TO VERT L R	OVERBANK/SURCHARGE MANNING N	DEPTH (FT)	JK
300	610	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
610	611	0	4	CHANNEL	27.0	4500.	.0420	2.5 2.5	.056	5.30	0
				OVERFLOW	104.0	4500.	.0420	3.0 3.0	.075	10.00	
611	310	0	4	CHANNEL	27.0	4500.	.0420	2.5 2.5	.056	5.30	0
				OVERFLOW	104.0	4500.	.0420	3.0 3.0	.075	10.00	
310	399	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
399	612	4	2	PI PIPE	.0	0.	.0001	.0 .0	.001	.01	0
				RESERVOIR STORAGE IN ACRE- FEET VS SPILLWAY OUTFLOW							
		0	0		2.0	500.0	194.0	1600.0	195.0	4000.0	
612	311	0	4	CHANNEL	24.0	5600.	.0300	4.3 4.3	.056	16.00	0
				OVERFLOW	181.0	5600.	.0300	3.0 100.0	.075	10.00	
311	400	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
613	312	0	4	CHANNEL	25.0	3354.	.0230	3.5 3.5	.056	4.00	0
				OVERFLOW	203.0	3354.	.0230	3.0 10.0	.075	10.00	
312	999	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
614	313	0	4	CHANNEL	25.0	4773.	.0190	3.5 3.5	.056	4.00	0
				OVERFLOW	203.0	4773.	.0190	3.0 10.0	.075	10.00	
313	999	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
615	616	0	4	CHANNEL	40.0	1180.	.0120	4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120	3.0 3.0	.075	10.00	
616	617	0	4	CHANNEL	40.0	1180.	.0120	4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120	3.0 3.0	.075	10.00	
617	618	0	4	CHANNEL	40.0	1180.	.0120	4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120	3.0 3.0	.075	10.00	
618	619	0	4	CHANNEL	40.0	1180.	.0120	4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120	3.0 3.0	.075	10.00	
619	314	0	4	CHANNEL	40.0	1180.	.0120	4.3 4.3	.056	4.60	0
				OVERFLOW	680.0	1180.	.0120	3.0 3.0	.075	10.00	
314	999	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
620	621	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
621	622	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
622	623	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
623	624	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
624	625	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
625	626	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
626	627	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
627	628	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
628	629	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
629	315	0	4	CHANNEL	26.0	1140.	.0100	6.3 6.3	.036	2.40	0
				OVERFLOW	750.0	1140.	.0100	3.0 3.0	.055	10.00	
315	999	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
400	613	5	3		.0	1.	.0010	.0 .0	.001	10.00	402
				DI VERSION TO GUTTER NUMBER 402 - TOTAL Q VS DI VERTED Q IN CFS							
		0	0		790.0	0	3590.0	.0 6900.0	.0		
402	405	0	1	CHANNEL	600.0	1151.	.0240	20.0 20.0	.100	10.00	0
405	407	4	3		.0	1.	.0010	.0 .0	.001	10.00	406
				DI VERSION TO GUTTER NUMBER 406 - TOTAL Q VS DI VERTED Q IN CFS							
		0	0		1292.0	1182.0	2103.0	1789.0	5122.0	3621.0	
407	410	0	1	CHANNEL	300.0	743.	.0230	20.0 20.0	.100	10.00	0
410	412	4	3		.0	1.	.0010	.0 .0	.001	10.00	411
				DI VERSION TO GUTTER NUMBER 411 - TOTAL Q VS DI VERTED Q IN CFS							
		0	0		110.0	109.0	323.0	298.0	1500.0	1147.0	
412	312	0	1	CHANNEL	300.0	547.	.0220	20.0 20.0	.100	10.00	0
406	240	0	1	CHANNEL	400.0	1316.	.0270	20.0 20.0	.100	10.00	0
411	230	0	1	CHANNEL	300.0	1471.	.0180	20.0 20.0	.100	10.00	0
200	998	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
210	10	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
211	20	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
212	21	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
220	22	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
221	31	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
230	30	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
240	40	0	3		.0	1.	.0010	.0 .0	.001	10.00	0
250	50	0	3		.0	1.	.0010	.0 .0	.001	10.00	0

Appendix C – Avoided Damages Calculations

1: One Story, No Basement			2: One Story, With Basement			3: Split Level No Basement			4: Split Level With Basement			5: Two Or More Levels No Basement			6: Two Or More Levels With Basement			7: Mobile Home		
Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents	Depth	% Damage Structure	% Damage Contents
-8	0	0	-8	0	0	-8	0	0	-8	0	0	-8	0	0	-8	0	0	-8	0	0
-7	0	0	-7	0	0	-7	0	0	-7	0	0	-7	0	0	-7	0	0	-7	0	0
-6	0	0	-6	0	0	-6	0	0	-6	0	0	-6	0	0	-6	0	0	-6	0	0
-5	0	0	-5	0	0	-5	0	0	-5	0	0	-5	0	0	-5	0	0	-5	0	0
-4	0	0	-4	0	0	-4	0	0	-4	0	0	-4	0	0	-4	0	0	-4	0	0
-3	0	0	-3	0	0	-3	0	0	-3	0	0	-3	0	0	-3	0	0	-3	0	0
-2.9	0	0	-2.9	0.0	0.0	-2.9	0	0	-2.9	0	0	-2.9	0	0	-2.9	0.0	0.0	-2.9	0	0
-2.8	0	0	-2.8	0.0	0.0	-2.8	0	0	-2.8	0	0	-2.8	0	0	-2.8	0.0	0.0	-2.8	0	0
-2.7	0	0	-2.7	0.0	0.0	-2.7	0	0	-2.7	0	0	-2.7	0	0	-2.7	0.0	0.0	-2.7	0	0
-2.6	0	0	-2.6	0.0	0.0	-2.6	0	0	-2.6	0	0	-2.6	0	0	-2.6	0.0	0.0	-2.6	0	0
-2.5	0	0	-2.5	0.0	0.0	-2.5	0	0	-2.5	0	0	-2.5	0	0	-2.5	0.0	0.0	-2.5	0	0
-2.4	0	0	-2.4	0.0	0.0	-2.4	0	0	-2.4	0	0	-2.4	0	0	-2.4	0.0	0.0	-2.4	0	0
-2.3	0	0	-2.3	0.0	0.0	-2.3	0	0	-2.3	0	0	-2.3	0	0	-2.3	0.0	0.0	-2.3	0	0
-2.2	0	0	-2.2	0.0	0.0	-2.2	0	0	-2.2	0	0	-2.2	0	0	-2.2	0.0	0.0	-2.2	0	0
-2.1	0	0	-2.1	0.0	0.0	-2.1	0	0	-2.1	0	0	-2.1	0	0	-2.1	0.0	0.0	-2.1	0	0
-2	0	0	-2	0	0	-2	0	0	-2	0	0	-2	0	0	-2	0	0	-2	0	0
-1.9	0	0	-1.9	0.0	0	-1.9	0	0	-1.9	0.0	0.0	-1.9	0	0	-1.9	0.0	0	-1.9	0	0
-1.8	0	0	-1.8	0.0	0	-1.8	0	0	-1.8	0.0	0.0	-1.8	0	0	-1.8	0.0	0	-1.8	0	0
-1.7	0	0	-1.7	0.0	0	-1.7	0	0	-1.7	0.0	0.0	-1.7	0	0	-1.7	0.0	0	-1.7	0	0
-1.6	0	0	-1.6	0.0	0	-1.6	0	0	-1.6	0.0	0.0	-1.6	0	0	-1.6	0.0	0	-1.6	0	0
-1.5	0	0	-1.5	0.0	0	-1.5	0	0	-1.5	0.0	0.0	-1.5	0	0	-1.5	0.0	0	-1.5	0	0
-1.4	0	0	-1.4	0.0	0	-1.4	0	0	-1.4	0.0	0.0	-1.4	0	0	-1.4	0.0	0	-1.4	0	0
-1.3	0	0	-1.3	0.0	0	-1.3	0	0	-1.3	0.0	0.0	-1.3	0	0	-1.3	0.0	0	-1.3	0	0
-1.2	0	0	-1.2	0.0	0	-1.2	0	0	-1.2	0.0	0.0	-1.2	0	0	-1.2	0.0	0	-1.2	0	0
-1.1	0	0	-1.1	0.0	0	-1.1	0	0	-1.1	0.0	0.0	-1.1	0	0	-1.1	0.0	0	-1.1	0	0
-1	0	0	-1	0	0	-1	0	0	-1	0	0	-1	0	0	-1	0	0	-1	0	0
-0.9	0.0	0	-0.9	0	0	-0.9	0	0.0	-0.9	0	0	-0.9	0.0	0	-0.9	0	0	-0.9	0.0	0
-0.8	0.0	0	-0.8	0	0	-0.8	0	0.0	-0.8	0	0	-0.8	0.0	0	-0.8	0	0	-0.8	0.0	0
-0.7	0.0	0	-0.7	0	0	-0.7	0	0.0	-0.7	0	0	-0.7	0.0	0	-0.7	0	0	-0.7	0.0	0
-0.6	0.0	0	-0.6	0	0	-0.6	0	0.0	-0.6	0	0	-0.6	0.0	0	-0.6	0	0	-0.6	0.0	0
-0.5	0.0	0	-0.5	0	0	-0.5	0	0.0	-0.5	0	0	-0.5	0.0	0	-0.5	0	0	-0.5	0.0	0
-0.4	0.0	0	-0.4	0	0	-0.4	0	0.0	-0.4	0	0	-0.4	0.0	0	-0.4	0	0	-0.4	0.0	0
-0.3	0.0	0	-0.3	0	0	-0.3	0	0.0	-0.3	0	0	-0.3	0.0	0	-0.3	0	0	-0.3	0.0	0
-0.2	0.0	0	-0.2	0	0	-0.2	0	0.0	-0.2	0	0	-0.2	0.0	0	-0.2	0	0	-0.2	0.0	0
-0.1	0.0	0	-0.1	0	0	-0.1	0	0.0	-0.1	0	0	-0.1	0.0	0	-0.1	0	0	-0.1	0.0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	2.3	1.3	0.1	3.2	1.9	0.1	0.9	0.47	0.1	2.32	1.38	0.1	1.5	0.9	0.1	2.2	1.38	0.1	4.4	6.6
0.2	4.7	2.7	0.2	6.4	3.8	0.2	1.9	0.94	0.2	4.64	2.76	0.2	3.0	1.7	0.2	4.5	2.76	0.2	8.8	13.2
0.3	7.0	4.0	0.3	9.6	5.7	0.3	2.8	1.41	0.3	6.96	4.14	0.3	4.6	2.6	0.3	6.7	4.14	0.3	13.2	19.8
0.4	9.3	5.3	0.4	12.8	7.6	0.4	3.8	1.88	0.4	9.28	5.52	0.4	6.1	3.5	0.4	8.9	5.52	0.4	17.6	26.4
0.5	11.7	6.7	0.5	16	9.5	0.5	4.7	2.35	0.5	11.6	6.9	0.5	7.6	4.4	0.5	11.2	6.9	0.5	22.0	33.0
0.6	14.0	8.0	0.6	19.2	11.3	0.6	5.6	2.82	0.6	13.92	8.28	0.6	9.1	5.2	0.6	13.4	8.28	0.6	26.4	39.6
0.7	16.3	9.3	0.7	22.4	13.2	0.7	6.6	3.29	0.7	16.24	9.66	0.7	10.6	6.1	0.7	15.6	9.66	0.7	30.8	46.2
0.8	18.6	10.6	0.8	25.6	15.1	0.8	7.5	3.76	0.8	18.56	11.04	0.8	12.2	7.0	0.8	17.8	11.04	0.8	35.2	52.8
0.9	21.0	12.0	0.9	28.8	17.0	0.9	8.5	4.23	0.9	20.88	12.42	0.9	13.7	7.8	0.9	20.1	12.42	0.9	39.6	59.4
1	23.3	13.3	1	32	18.9	1	9.4	4.7	1	23.2	13.8	1	15.2	8.7	1	22.3	13.8	1	44	66
1.1	24.2	13.8	1.1	32.67	19.2	1.1	9.8	4.98	1.1	23.7	14.03	1.1	15.8	9.05	1.1	22.8	14.0	1.1	45.9	68.4
1.2	25.1	14.2	1.2	33.34	19.5	1.2	10.1	5.26	1.2	24.2	14.26	1.2	16.3	9.4	1.2	23.2	14.2	1.2	47.8	70.8
1.3	25.9	14.7	1.3	34.01	19.8	1.3	10.5	5.54	1.3	24.7	14.49	1.3	16.9	9.75	1.3	23.7	14.4	1.3	49.7	73.2
1.4	26.8	15.1	1.4	34.68	20.1	1.4	10.8	5.82	1.4	25.2	14.72	1.4	17.5	10.1	1.4	24.2	14.6	1.4	51.6	75.6
1.5	27.7	15.6	1.5	35.35	20.4	1.5	11.2	6.1	1.5	25.7	14.95	1.5	18.1	10.45	1.5	24.7	14.8	1.5	53.5	78.0
1.6	28.6	16.1	1.6	36.02	20.6	1.6	11.5	6.38	1.6	26.2	15.18	1.6	18.6	10.8	1.6	25.1	14.9	1.6	55.4	80.4
1.7	29.5	16.5	1.7	36.69	20.9	1.7	11.9	6.66	1.7	26.7	15.41	1.7	19.2	11.15	1.7	25.6	15.1	1.7	57.3	82.8
1.8	30.3	17.0	1.8	37.36	21.2	1.8	12.2	6.94	1.8	27.2	15.64	1.8	19.8	11.5	1.8	26.1	15.3	1.8	59.2	85.2
1.9	31.2	17.4	1.9	38.03	21.5	1.9	12.6	7.22	1.9	27.7	15.87	1.9	20.3	11.85	1.9	26.5	15.5	1.9	61.1	87.6
2	32.1	17.9	2	38.7	21.8	2	12.9	7.5	2	28.2	16.1	2	20.9	12.2	2	27	15.7	2	63	90
2.1	32.9	18.31	2.1	39.38	22.1	2.1	13.4	7.86	2.1	28.72	16.3	2.1	21.4	12.5	2.1	27.5	15.9	2.1	64.0	90.0
2.2	33.7	18.72	2.2	40.06	22.4	2.2	13.8	8.22	2.2	29.24	16.5	2.2	22.0	12.9	2.2	28.0	16.1	2.2	65.0	90.0
2.3	34.5	19.13	2.3	40.74	22.7	2.3	14.3	8.58	2.3	29.76	16.7	2.3	22.5	13.2	2.3	28.5	16.3	2.3	66.0	90.0
2.4	35.3	19.54	2.4	41.42	23.0	2.4	14.7	8.94	2.4	30.28	16.9	2.4	23.1	13.5	2.4	29.0	16.5	2.4	67.0	90.0
2.5	36.1	19.95	2.5	42.1	23.3	2.5	15.2	9.3	2.5	30.8	17.2	2.5	23.6	13.9	2.5	29.5	16.7	2.5	68.0	90.0
2.6	36.9	20.36	2.6	42.78	23.5	2.6	15.6	9.66	2.6	31.32	17.4	2.6	24.1	14.2	2.6	29.9	16.9	2.6	69.0	90.0
2.7	37.7	20.77	2.7	43.46	23.8	2.7	16.1	10.02	2.7	31.84	17.6	2.7	24.7	14.5	2.7	30.4	17.1	2.7	70.0	90.0
2.8	38.5	21.18	2.8	44.14	24.1	2.8	16.5	10.38	2.8	32.36	17.8	2.8	25.2	14.8	2.8	30.9	17.3	2.8	71.0	90.0
2.9	39.3	21.59	2.9	44.82	24.4	2.9	17.0	10.74	2.9	32.88	18.0	2.9	25.8	15.2	2.9	31.4	17.5	2.9	72.0	90.0
3	40.1	22	3	45.5	24.7	3	17.4	11.1	3	33.4	18.2	3	26.3	15.5	3	31.9	17.7	3	73	90
3.1	40.8	22.4	3.1	46.2	25.0	3.1	17.9	11.5	3.1	33.9	18.4	3.1	26.8	15.8	3.1	32.4	17.9	3.1	73.5	90.0
3.2	41.5	22.7	3.2	46.8	25.2	3.2	18.5	11.9	3.2	34.4	18.6	3.2	27.3	16.1	3.2	32.9	18.1	3.2	74.0	90.0
3.3	42.2	23.1	3.3	47.5	25.5	3.3	19.0	12.4	3.3	35.0	18.8	3.3	27.8	16.4	3.3	33.4	18.3	3.3	74.5	90.0
3.4	42.9	23.5	3.4	48.2	25.8	3.4	19.6	12.8	3.4	35.5	19.0	3.4	28.3	16.7	3.4	33.9	18.5	3.4	75.0	90.0
3.5	43.6	23.9	3.5	48.9	26.1	3.5	20.1	13.2	3.5	36.0	19.2	3.5	28.9	17.0	3.5	34.4	18.8	3.5	75.5	90.0
3.6	44.3	24.2	3.6	49.5	26.3	3.6	20.6	13.6	3.6	36.5	19.4	3.6	29.4	17.3	3.6	34.9	19.0	3.6	76.0	90.0
3.7	45	24.6	3.7	50.2	26.6	3.7	21.2	14.0												

5.0 Annualized Loss Calculations

Whether calculated structure-by-structure, or aggregated at the census block level, annualized losses are helpful when comparing the magnitude or impacts of one hazard against another, and in estimating the potential flood losses over a defined period of time. Although current and/or future versions of Hazus may have the ability to calculate annualized flood losses from within the software directly, the annualized loss formula is included below. This formula should be used individually for every loss calculation, such as residential structure losses or commercial contents losses.

$$\begin{aligned}
 \text{Annualized Loss} &= (10\% - 4\%) * (\text{Loss } 10\% + \text{Loss } 4\%) / 2 + \\
 &\quad (4\% - 2\%) * (\text{Loss } 4\% + \text{Loss } 2\%) / 2 + \\
 &\quad (2\% - 1\%) * (\text{Loss } 2\% + \text{Loss } 1\%) / 2 + \\
 &\quad (1\% - 0.2\%) * (\text{Loss } 1\% + \text{Loss } 0.2\%) / 2 + \\
 &\quad 0.2\% * \text{Loss } 0.2\%
 \end{aligned}$$

Modified to remove 0.2% terms

Where “Loss 10%” equals the flood loss value associated with the 10% annual chance flood event, “Loss 4%” equals the flood loss value associated with the 4% annual chance flood event, and so on. For example, assume a census block or structure has the following loss values:

- 10% annual chance event = \$0
- 4% annual chance event = \$0
- 2% annual chance event = \$2,000
- 1% annual chance event = \$30,000
- 0.2% annual chance event = \$80,000

The annualized loss would be calculated as follows:

$$\begin{aligned}
 \text{Annualized Loss} &= (0.10 - 0.04) * (0 + 0) / 2 + \\
 &\quad (0.04 - 0.02) * (0 + 2000) / 2 + \\
 &\quad (0.02 - 0.01) * (2000 + 30000) / 2 + \\
 &\quad (0.01 - 0.002) * (30000 + 80000) / 2 + \\
 &\quad 0.002 * 80000
 \end{aligned}$$

$$\text{Annualized Loss} = 0 + 20 + 160 + 440 + 160 = \$780/\text{yr}$$

Annualized losses can also be communicated in terms of estimated damages over a period of time. Using the example above of \$780/yr in annualized flood losses, one could estimate that over the period of 30 years, the total damages could generally be expected to be in the neighborhood of \$23,000 (i.e. \$780 * 30, and then rounded).

Structure Address	Structure Type			Pre-Detection Flooding				Pre-Detection % Damage (BCA)								Pre-Detection Damages (BCA)				Annualized Loss (BCA) by formula (\$)	Annualized Loss (BCA) by software (\$)	formula / software ratio	Present Value of Total Avoided Damages Over Project Life (BCA) by formula (\$)	Present Value of Total Avoided Damages Over Project Life (BCA) by software (\$)		
	Description	No.	Structure Size (sf)	Structure Value (\$)	Content Value (\$)	10-Year Depth (ft)	25-Year Depth (ft)	50-Year Depth (ft)	100-Year Depth (ft)	10-Year		25-Year		50-Year		100-Year		10-Year Damages (\$)	25-Year Damages (\$)						50-Year Damages (\$)	100-Year Damages (\$)
										Structure	Contents	Structure	Contents	Structure	Contents	Structure	Contents									
1025 ROSEWOOD AV	DISTRIBUTION WAREHOUSE	1	12580	\$136,000	\$68,000	-0.25	0.52	0.95	1.21	0.0	0.0	11.7	6.7	21.0	12.0	25.1	14.2	\$0	\$20,366	\$36,659	\$43,751	\$2,021	\$1,384	1.46	\$27,888	\$19,100
1070 UNION AV	1 STORY - RANCH	1	1218	\$105,000	\$52,500	-0.50	-0.34	0.85	1.18	0.0	0.0	0.0	0.0	18.6	10.6	24.2	13.8	\$0	\$0	\$25,158	\$32,613	\$867	\$612	1.42	\$11,959	\$8,446
1075 UTICA AV	2 - 3 STORY	5	1964	\$135,700	\$67,850	-0.50	-0.50	-0.16	0.14	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.9	\$0	\$0	\$0	\$2,653	\$40	\$27	1.47	\$549	\$373
1095 UTICA AV	2 - 3 STORY	6	2458	\$368,800	\$184,400	-0.50	-0.50	0.14	0.39	0.0	0.0	0.0	0.0	2.2	1.4	6.7	4.1	\$0	\$0	\$10,769	\$32,307	\$646	\$510	1.27	\$8,917	\$7,038
1101 UNION AV	1 STORY - RANCH	1	2273	\$181,300	\$90,650	-0.50	-0.40	0.35	0.91	0.0	0.0	0.0	0.0	7.0	4.0	21.0	12.0	\$0	\$0	\$16,290	\$48,869	\$977	\$771	1.27	\$13,489	\$10,640
1112 UNION AV	2 - 3 STORY	6	2145	\$276,000	\$138,000	-0.50	-0.50	0.02	0.03	0.0	0.0	0.0	0.0	0.0	0.0	8.9	5.5	\$0	\$0	\$0	\$32,237	\$484	\$322	1.50	\$6,673	\$4,444
1119 UTICA AV	2 - 3 STORY	6	2563	\$380,200	\$190,100	-0.50	-0.50	0.03	0.26	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.8	\$0	\$0	\$0	\$22,204	\$333	\$222	1.50	\$4,596	\$3,064
1120 UNION AV	2 - 3 STORY	5	1849	\$243,400	\$121,700	-0.50	-0.46	0.21	0.57	0.0	0.0	0.0	0.0	3.0	1.7	7.6	4.4	\$0	\$0	\$9,517	\$23,792	\$500	\$388	1.29	\$6,895	\$5,355
1121 UTICA AV	2 - 3 STORY	5	1500	\$150,100	\$75,050	-0.50	-0.50	0.19	0.82	0.0	0.0	0.0	0.0	1.5	0.9	12.2	7.0	\$0	\$0	\$2,934	\$23,476	\$396	\$318	1.25	\$5,467	\$4,389
1122 UNION AV	2 - 3 STORY	5	1888	\$186,700	\$93,350	-0.50	0.00	0.72	1.11	0.0	0.0	0.0	0.0	10.6	6.1	15.8	9.1	\$0	\$0	\$25,550	\$37,891	\$952	\$690	1.38	\$13,133	\$9,523
1125 UTICA AV	1 STORY - RANCH	1	1534	\$121,000	\$60,500	-0.50	0.16	1.38	2.13	0.0	0.0	2.3	1.3	25.9	14.7	32.9	18.3	\$0	\$3,624	\$40,269	\$50,887	\$1,512	\$1,204	1.26	\$20,871	\$16,616
1126 UNION AV	2 - 3 STORY	5	1536	\$158,500	\$79,250	-0.50	0.25	0.90	1.48	0.0	0.0	3.0	1.7	12.2	7.0	17.5	10.1	\$0	\$6,197	\$24,789	\$35,710	\$1,155	\$903	1.28	\$15,945	\$12,462
1179 UNION AV	SCHOOL	1	0	\$740,000	\$370,000	-0.50	0.40	1.76	2.64	0.0	0.0	9.3	5.3	29.5	16.5	36.9	20.4	\$0	\$88,652	\$279,128	\$348,392	\$12,959	\$9,748	1.33	\$178,842	\$134,530
1204 UPLAND AV	1 STORY - RANCH	1	861	\$69,700	\$34,850	-0.50	0.53	1.25	1.90	0.0	0.0	11.7	6.7	25.1	14.2	31.2	17.4	\$0	\$10,438	\$22,422	\$27,838	\$1,171	\$834	1.40	\$16,166	\$11,510
1205 UPLAND AV	1 STORY - RANCH	1	1440	\$101,800	\$50,900	-0.50	0.57	1.01	1.26	0.0	0.0	11.7	6.7	23.3	13.3	25.1	14.2	\$0	\$15,245	\$30,489	\$32,749	\$1,558	\$1,074	1.45	\$21,506	\$14,822
1235 TAMARACK AV	1 STORY - RANCH	1	1292	\$102,600	\$51,300	-0.50	0.75	1.83	2.66	0.0	0.0	16.3	9.3	30.3	17.0	36.9	20.4	\$0	\$21,510	\$39,840	\$48,304	\$2,183	\$1,507	1.45	\$30,121	\$20,798
1300 TAMARACK AV	2 - 3 STORY	5	2376	\$542,700	\$271,350	-0.50	-0.50	-0.28	0.27	0.0	0.0	0.0	0.0	0.0	0.0	3.0	1.7	\$0	\$0	\$0	\$21,220	\$318	\$212	1.50	\$4,393	\$2,920
1301 UPLAND AV	1 STORY - RANCH	1	762	\$85,600	\$42,800	-0.50	0.38	0.68	0.85	0.0	0.0	7.0	4.0	14.0	8.0	18.6	10.6	\$0	\$7,691	\$15,382	\$20,510	\$846	\$601	1.41	\$11,676	\$8,294
1303 SUMAC AV	2 - 3 STORY	5	1669	\$323,100	\$161,550	-0.50	-0.50	-0.26	-0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1304 TAMARACK AV	2 - 3 STORY	5	2555	\$593,900	\$296,950	-0.50	0.06	0.84	1.44	0.0	0.0	0.0	0.0	12.2	7.0	17.5	10.1	\$0	\$0	\$92,886	\$133,806	\$3,400	\$2,453	1.39	\$46,928	\$33,853
1305 SUMAC AV	1 STORY - RANCH	2	1489	\$242,000	\$121,000	-0.50	-0.50	-0.40	-0.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1315 TAMARACK AV	1 STORY - RANCH	1	1404	\$146,200	\$73,100	-0.50	1.36	1.96	2.57	0.0	0.0	25.9	14.7	31.2	17.4	36.1	20.0	\$0	\$48,655	\$58,392	\$67,362	\$3,833	\$2,367	1.62	\$52,892	\$32,666
1352 TAMARACK AV	2 - 3 STORY	5	1755	\$307,700	\$153,850	-0.50	-0.03	0.69	1.32	0.0	0.0	0.0	0.0	9.1	5.2	16.9	9.8	\$0	\$0	\$36,093	\$67,032	\$1,547	\$1,162	1.33	\$21,348	\$16,036
1360 SUMAC AV	TOOL SHED	1	0	\$317,400	\$158,700	-0.50	-0.50	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1377 TAMARACK AV	2 - 3 STORY	5	3164	\$567,000	\$283,500	-0.50	0.64	1.08	1.48	0.0	0.0	9.1	5.2	15.2	8.7	17.5	10.1	\$0	\$66,509	\$110,849	\$127,745	\$6,239	\$4,184	1.49	\$86,107	\$57,742
1400 VIOLET AV	1 STORY - RANCH	1	1372	\$114,100	\$57,050	-0.50	0.06	0.62	0.92	0.0	0.0	0.0	0.0	14.0	8.0	21.0	12.0	\$0	\$0	\$20,504	\$30,756	\$769	\$559	1.38	\$10,611	\$7,715
1415 RIVERSIDE AV	1 STORY - RANCH	2	1247	\$246,100	\$123,050	-0.50	-0.50	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1425 UPLAND AV	2 - 3 STORY	5	4116	\$1,189,700	\$594,850	-0.50	0.86	1.25	1.46	0.0	0.0	12.2	7.0	16.3	9.4	17.5	10.1	\$0	\$186,069	\$250,313	\$268,039	\$15,218	\$9,586	1.59	\$210,020	\$132,294
1431 UPLAND AV	2 - 3 STORY	5	4728	\$911,200	\$455,600	-0.50	1.97	2.58	2.86	0.0	0.0	20.3	11.9	23.6	13.9	25.2	14.8	\$0	\$239,236	\$278,144	\$297,416	\$18,203	\$11,009	1.65	\$251,212	\$151,932
1435 SUMAC AV	2 - 3 STORY	5	2854	\$393,000	\$196,500	-0.50	-0.50	-0.30	0.25	0.0	0.0	0.0	0.0	0.0	0.0	3.0	1.7	\$0	\$0	\$0	\$15,366	\$230	\$154	1.50	\$3,181	\$2,125
1435 UPLAND AV	2 - 3 STORY	5	5114	\$1,059,700	\$529,850	-0.50	1.84	2.40	2.66	0.0	0.0	19.8	11.5	23.1	13.5	24.1	14.2	\$0	\$270,329	\$316,003	\$330,944	\$20,517	\$12,389	1.66	\$283,155	\$170,977
1445 RIVERSIDE AV	STUDIO	1	0	\$348,400	\$174,200	-0.50	-0.50	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1447 SUMAC AV	2 - 3 STORY	5	1588	\$292,100	\$146,050	-0.50	-0.19	0.83	1.57	0.0	0.0	0.0	0.0	12.2	7.0	18.1	10.5	\$0	\$0	\$45,684	\$67,986	\$1,705	\$1,237	1.38	\$23,531	\$17,072
1455 RIVERSIDE	2 - 3 STORY	5	3455	\$666,100	\$333,050	-0.50	-0.50	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1472 SUMAC AV	2 - 3 STORY	5	2787	\$385,000	\$192,500	-0.50	-0.50	-0.50	-0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1480 SUMAC AV	1 STORY - RANCH	2	1758	\$134,400	\$67,200	-0.50	0.14	0.51	0.85	0.0	0.0	3.2	1.9	16.0	9.5	25.6	15.1	\$0	\$5,571	\$27,854	\$44,567	\$1,309	\$1,047	1.25	\$18,067	\$14,449
1480 UPLAND AV	2 - 3 STORY	6	4584	\$1,582,900	\$791,450	-0.50	-0.41	-0.30	-0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1480 VIOLET AV	1 STORY - RANCH	2	1316	\$115,200	\$57,600	-0.50	-0.40	-0.40	-0.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0	
1485 UPLAND AV	1 STORY - RANCH	1	2210	\$145,500	\$72,750	-0.50	0.36	0.78	1.00	0.0	0.0	7.0	4.0	16.3	9.3	23.3	13.3	\$0	\$13,073	\$30,504	\$43,577	\$1,634	\$1,200	1.36	\$22,552	\$16,561
1488 TAMARACK AV	2 - 3 STORY	6	2382	\$443,700	\$221,850	-0.50	0.85	1.80	2.50	0.0	0.0	17.8	11.0	25.6	15.1	29.5	16.7	\$0	\$103,648	\$147,109	\$167,719	\$8,868	\$5,718	1.55	\$122,390	\$78,913
1490 RIVERSIDE AV	2 - 3 STORY	5	2147	\$356,900	\$178,450	-0.50	0.85	2.40	2.97	0.0	0.0	12.2	7.0	23.1	13.5	25.8	15.2	\$0	\$55,819	\$106,428	\$119,008	\$5,614	\$3,857	1.46	\$77,482	\$53,229
1490 UPLAND AV	2 - 3 STORY	5	5072	\$1,518,900	\$759,450	-0.50	1.08	1.46	1.66	0.0	0.0	15.2	8.7	17.5	10.1	18.6	10.8	\$0	\$296,945	\$342,208	\$364,840	\$22,484	\$13,556	1.66	\$310,289	\$187,083
1495 SUMAC AV	SPLIT LEVEL	4	2368	\$439,400	\$219,700	-0.50	0.98	1.89	2.50	0.0	0.0	20.9	12.4	27.2	15.6	30.8	17.2	\$0	\$119,033	\$153,878	\$173,014	\$9,665	\$6,069	1.59	\$133,380	\$83,757
1496 TAMARACK AV	2 - 3 STORY	6	2331	\$421,700</																						

Structure Address	Structure Type		Structure Size (sf)	Structure Value (\$)	Content Value (\$)	Pre-Detention Flooding				Pre-Detention % Damage (BCA)								Pre-Detention Damages (BCA)				Annualized Loss (BCA) by formula (\$)	Annualized Loss (BCA) by software (\$)	formula / software ratio	Present Value of Total Avoided Damages Over Project Life (BCA) by formula (\$)	Present Value of Total Avoided Damages Over Project Life (BCA) by software (\$)
	Description	No.				10-Year Depth (ft)	25-Year Depth (ft)	50-Year Depth (ft)	100-Year Depth (ft)	10-Year Structure	10-Year Contents	25-Year Structure	25-Year Contents	50-Year Structure	50-Year Contents	100-Year Structure	100-Year Contents	10-Year Damages (\$)	25-Year Damages (\$)	50-Year Damages (\$)	100-Year Damages (\$)					
1660 VIOLET AV	1 STORY - RANCH	1	1600	\$112,500	\$56,250	-0.50	-0.50	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1675 UPLAND AV	2 - 3 STORY	5	2346	\$166,100	\$83,050	-0.50	-0.50	-0.50	-0.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1702 SUMAC AV	2 - 3 STORY	5	1408	\$281,600	\$140,800	-0.50	0.83	2.06	2.84	0.0	0.0	12.2	7.0	20.9	12.2	25.2	14.8	\$0	\$44,042	\$76,032	\$91,914	\$4,281	\$2,912	1.47	\$59,079	\$40,188
1706 SUMAC AV	2 - 3 STORY	6	2202	\$368,800	\$184,400	-0.50	0.62	1.93	2.70	0.0	0.0	13.4	8.3	26.5	15.5	30.4	17.1	\$0	\$64,614	\$126,443	\$143,758	\$6,638	\$4,594	1.44	\$91,603	\$63,401
1725 UPLAND AV	2 - 3 STORY	5	5155	\$1,253,500	\$626,750	-0.50	-0.50	-0.40	-0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1740 SUMAC AV	1 STORY - RANCH	2	2600	\$808,600	\$404,300	-0.50	0.70	1.51	2.17	0.0	0.0	22.4	13.2	35.4	20.4	39.4	22.1	\$0	\$234,615	\$368,115	\$407,737	\$21,022	\$13,829	1.52	\$290,125	\$190,851
1750 VIOLET AV	1 STORY - RANCH	2	1976	\$129,100	\$64,550	-0.50	-0.25	0.08	0.28	0.0	0.0	0.0	0.0	0.0	0.0	6.4	3.8	\$0	\$0	\$0	\$10,702	\$161	\$1,477	1.50	\$2,216	\$1,477
1790 SUMAC AV	1 STORY - RANCH	2	736	\$103,000	\$51,500	-0.50	2.51	3.70	4.31	0.0	0.0	42.1	23.3	50.2	26.6	54.1	28.2	\$0	\$55,337	\$65,390	\$70,256	\$4,248	\$2,584	1.64	\$58,628	\$35,661
1800 SUMAC AV	2 - 3 STORY	5	3991	\$358,100	\$179,050	-0.50	1.99	2.65	2.95	0.0	0.0	20.3	11.9	24.1	14.2	25.8	15.2	\$0	\$94,019	\$111,835	\$119,408	\$7,229	\$4,401	1.64	\$99,771	\$60,737
1820 SUMAC AV	STUDIO	1	0	\$202,400	\$101,200	-0.50	1.22	1.61	1.80	0.0	0.0	25.1	14.2	28.6	16.1	29.5	16.5	\$0	\$65,112	\$74,099	\$76,345	\$4,861	\$2,904	1.67	\$67,087	\$40,077
1825 UPLAND AV	WORSHIP	1	0	\$663,000	\$331,500	-0.50	-0.50	-0.50	-0.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1840 SUMAC AV	2 - 3 STORY	5	2622	\$253,200	\$126,600	-0.50	1.30	1.56	1.67	0.0	0.0	16.9	9.8	18.1	10.5	18.6	10.8	\$0	\$55,160	\$58,932	\$60,819	\$4,003	\$2,347	1.71	\$55,240	\$32,390
1840 VIOLET AV	1 STORY - RANCH	2	1500	\$115,100	\$57,550	-0.47	-0.34	-0.28	-0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1845 UPLAND AV	1 STORY - RANCH	1	2262	\$156,000	\$78,000	-0.50	-0.40	-0.50	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
1865 UPLAND AV	2 - 3 STORY	5	2645	\$173,800	\$86,900	0.56	0.77	0.98	1.13	7.6	4.4	10.6	6.1	13.7	7.8	15.8	9.1	\$16,989	\$23,785	\$30,580	\$35,273	\$2,449	\$2,426	1.01	\$33,796	\$33,481
1870 VIOLET AV	1 STORY - RANCH	1	486	\$58,600	\$29,300	-0.06	0.06	0.12	0.18	0.0	0.0	0.0	0.0	2.3	1.3	2.3	1.3	\$0	\$0	\$1,755	\$1,755	\$53	\$36	1.46	\$727	\$497
1880 SUMAC AV	1 STORY - RANCH	2	1718	\$351,400	\$175,700	-0.50	1.64	1.85	1.93	0.0	0.0	36.0	20.6	37.4	21.2	38.0	21.5	\$0	\$162,839	\$168,567	\$171,430	\$11,614	\$6,728	1.73	\$160,275	\$92,851
1885 UPLAND AV	2 - 3 STORY	5	3102	\$170,100	\$85,050	1.64	2.03	2.36	2.60	18.6	10.8	20.9	12.2	22.5	13.2	24.1	14.2	\$40,858	\$45,927	\$49,525	\$53,122	\$4,603	\$4,597	1.00	\$63,518	\$63,442
1890 SUMAC AV	2 - 3 STORY	5	2531	\$651,500	\$325,750	-0.50	1.75	2.01	2.12	0.0	0.0	19.2	11.2	20.9	12.2	21.4	12.5	\$0	\$161,344	\$175,905	\$180,498	\$11,800	\$6,956	1.70	\$162,846	\$95,998
4095 19TH ST	2 - 3 STORY	5	2403	\$314,000	\$157,000	-0.50	-0.39	0.85	1.62	0.0	0.0	0.0	0.0	12.2	7.0	18.6	10.8	\$0	\$0	\$49,110	\$75,423	\$1,868	\$1,363	1.37	\$25,780	\$18,810
4140 17TH ST	2 - 3 STORY	6	2826	\$445,600	\$222,800	-0.50	-0.40	-0.40	-0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
4150 17TH ST	2 - 3 STORY	5	2810	\$563,200	\$281,600	-0.50	0.14	1.24	1.86	0.0	0.0	1.5	0.9	16.3	9.4	19.8	11.5	\$0	\$11,011	\$118,497	\$143,672	\$4,373	\$3,464	1.26	\$60,350	\$47,806
4157 19TH ST	2 - 3 STORY	6	2728	\$442,000	\$221,000	-0.43	1.33	2.57	3.37	0.0	0.0	23.7	14.4	29.5	16.7	33.4	18.3	\$0	\$136,556	\$167,076	\$188,137	\$10,790	\$6,675	1.62	\$148,916	\$92,120
4160 17TH ST	2 - 3 STORY	5	2935	\$510,000	\$255,000	-0.50	0.56	1.90	2.69	0.0	0.0	7.6	4.4	20.3	11.9	24.1	14.2	\$0	\$49,853	\$133,901	\$159,273	\$6,392	\$4,687	1.36	\$68,210	\$64,684
4165 17TH ST	2 - 3 STORY	5	3032	\$797,100	\$398,550	-0.50	1.29	2.29	2.91	0.0	0.0	16.3	9.4	22.0	12.9	25.8	15.2	\$0	\$167,710	\$226,456	\$265,793	\$14,092	\$9,009	1.56	\$194,482	\$124,331
4176 15TH ST	2 - 3 STORY	5	2144	\$354,900	\$177,450	-0.50	0.59	1.38	1.93	0.0	0.0	7.6	4.4	16.9	9.8	20.3	11.9	\$0	\$34,691	\$77,315	\$93,179	\$3,945	\$2,817	1.40	\$54,445	\$38,877
4188 15TH ST	BI-LEVEL	3	2195	\$215,900	\$107,950	-0.50	1.35	2.11	2.63	0.0	0.0	10.5	5.5	13.4	7.9	15.6	9.7	\$0	\$28,542	\$37,308	\$44,108	\$2,363	\$1,500	1.58	\$32,610	\$20,701
4195 17TH ST	2 - 3 STORY	5	2379	\$520,200	\$260,100	-0.50	0.28	1.24	1.84	0.0	0.0	3.0	1.7	16.3	9.4	19.8	11.5	\$0	\$20,340	\$109,450	\$132,703	\$4,446	\$3,476	1.28	\$61,357	\$47,971
4215 BROADWAY	2 - 3 STORY	6	960	\$158,100	\$79,050	-0.50	-0.50	-0.50	-0.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
4295 BROADWAY	2 - 3 STORY	6	5182	\$887,500	\$443,750	-0.50	0.62	1.29	1.90	0.0	0.0	13.4	8.3	23.2	14.2	26.5	15.5	\$0	\$155,490	\$269,179	\$304,279	\$14,821	\$9,997	1.48	\$204,547	\$137,966
4340 13TH ST	1 STORY - RANCH	1	1056	\$189,900	\$94,950	-0.50	0.32	0.69	0.89	0.0	0.0	7.0	4.0	14.0	8.0	18.6	10.6	\$0	\$17,063	\$34,125	\$45,500	\$1,877	\$1,332	1.41	\$25,902	\$18,383
4341 13TH ST	2 - 3 STORY	5	2705	\$394,000	\$197,000	-0.34	1.30	1.84	2.12	0.0	0.0	16.9	9.8	19.8	11.5	21.4	12.5	\$0	\$85,833	\$100,509	\$109,158	\$6,578	\$3,997	1.65	\$90,786	\$55,162
4343 13TH ST	2 - 3 STORY	5	2231	\$317,300	\$158,650	-0.50	1.37	2.04	2.36	0.0	0.0	16.9	9.8	20.9	12.2	22.5	13.2	\$0	\$69,124	\$85,671	\$92,382	\$5,436	\$3,353	1.62	\$75,017	\$46,274
4345 13TH ST	1 STORY - RANCH	1	1056	\$96,100	\$48,050	0.00	2.18	2.93	3.35	0.0	0.0	32.9	18.3	39.3	21.6	42.2	23.1	\$0	\$40,415	\$48,141	\$51,659	\$3,114	\$1,898	1.64	\$42,970	\$26,194
4347 13TH ST	2 - 3 STORY	5	2692	\$460,600	\$230,300	-0.50	1.25	1.88	2.19	0.0	0.0	16.3	9.4	19.8	11.5	21.4	12.5	\$0	\$96,910	\$117,499	\$127,609	\$7,553	\$4,634	1.63	\$104,238	\$63,953
4361 13TH ST	2 - 3 STORY	5	2738	\$437,400	\$218,700	-0.50	0.90	1.46	1.76	0.0	0.0	12.2	7.0	17.5	10.1	19.2	11.2	\$0	\$68,409	\$98,546	\$108,322	\$5,839	\$3,758	1.55	\$80,588	\$51,863
4363 13TH ST	2 - 3 STORY	5	2822	\$352,000	\$176,000	-0.47	1.82	2.47	2.86	0.0	0.0	19.8	11.5	23.1	13.5	25.2	14.8	\$0	\$89,795	\$104,966	\$114,893	\$6,890	\$4,189	1.64	\$95,083	\$57,811
4365 13TH ST	1 STORY - RANCH	1	1056	\$134,400	\$67,200	-0.20	1.79	2.48	2.90	0.0	0.0	29.5	16.5	35.3	19.5	39.3	21.6	\$0	\$50,696	\$60,574	\$67,328	\$3,946	\$2,420	1.63	\$54,463	\$33,398
4365 19TH ST	FIRE STATION (STAFFED)	5	0	\$242,200	\$121,100	-0.49	-0.40	-0.40	-0.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0	\$0	\$0	\$0	\$0	\$0	--	\$0	\$0
4367 13TH ST	2 - 3 STORY	5	2509	\$518,800	\$259,400	-0.50	0.85	1.47	1.79	0.0	0.0	12.2	7.0	17.5	10.1	19.2	11.2	\$0	\$81,140	\$116,886	\$128,481	\$6,926	\$4,458	1.55	\$95,585	\$61,524
4380 13TH ST	2 - 3 STORY	5	2342	\$140,500	\$70,250	-0.50	0.89	1.38	1.62	0.0	0.0	12.2	7.0	16.9	9.8	18.6	10.8	\$0	\$21,974	\$30,608	\$33,748	\$1,844	\$1,177	1.58	\$25,453	\$16,243
4390 13TH ST	2 - 3 STORY	5	1544	\$111,300	\$55,650	-0.50	0.77	1.11	1.29	0.0	0.0	10.6	6.1	15.8	9.1	16.3	9.4	\$0	\$15,231	\$22,588	\$23,418	\$1,299	\$835	1.56	\$17,932	\$11,524
4390 BROADWAY	EQUIPMENT (SHOP) BUILDING	1	0	\$62,000	\$31,000	-0.50	0.95	1.63	1.99	0.0	0.0	21.0	12.0	28.6	16.1	31.2	17.4	\$0	\$16,712	\$22,698	\$24,763	\$1,380	\$875	1.58	\$19,051	\$12,076
4391 13TH ST	2 - 3 STORY	5	2466	\$377,200	\$188,600	-0.50	0.97	1.59	1.91	0.0	0.0	13.7	7.8	18.1	10.5	20.3	11.9	\$0	\$66,368	\$87,793	\$99,034	\$5,457	\$3,449	1.58	\$75,313	\$47,599
4393 13TH ST	2 - 3 STORY	5	2218	\$320,700	\$160,350	-0.40	0.83	1.47	1.88	0.0	0.0	12.2	7.0	17.5	10.1	19.8	11.5	\$0	\$50,157	\$72,254	\$81,811	\$4,317	\$2,791	1.55	\$59,581	\$38,518
4395 BROADWAY	SCHOOL	1	0	\$299,300	\$149,650	-0.33	0.61	1.10	1.37	0.0	0.0	14.0	8.0	24.2	13.8	25.9	14.7	\$0	\$53,784	\$92,963	\$99,607	\$5,040	\$3,372	1.49	\$69,555	\$46,536
4397 13TH ST	2 - 3 STORY	5	2289	\$333,700	\$166,850	-0.50	0.32	0.85	1.12	0.0	0.0	4.6	2.6	12.2	7.0	15.8	9.1	\$0	\$19,572	\$52,191	\$67,724	\$2,582	\$1,911	1.35	\$35,628	\$26,373
4475 B																										

Appendix D – Cost Estimates

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT : Fourmile Canyon Creek - CEAP Mitigation Planning
 DRAINAGEWAY : Fourmile Canyon Creek
 REACH : Alt0
 JURISDICTION : City of Boulder
 REACH ID: FCC-ReachAlt0 ICON Engineering Inc. (Brian LeDoux) DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Master Plan Capital Improvement Cost Summary					
Capital Improvement Costs					
Pipe Culverts and Storm Drains				\$0.00	
Concrete Box Culverts				\$0.00	
Hydraulic Structures				\$0.00	
Channel Improvements				\$0.00	
Detention/Water Quality Facilities				\$0.00	
Removals				\$0.00	
Landscaping and Maintenance Improvements				\$0.00	
Special Items (User Defined)				\$0.00	
Subtotal Capital Improvement Costs				\$0.00	
Additional Capital Improvement Costs					
Dewatering		L.S.		\$0.00	
Mobilization	5%			\$0.00	
Traffic Control		L.S.		\$0.00	
Utility Coordination/Relocation		L.S.		\$0.00	
Stormwater Management/Erosion Control	5%			\$0.00	
Subtotal Additional Capital Improvement Costs				\$0.00	
Land Acquisition Costs					
ROW/Easements				\$0.00	
Subtotal Land Acquisition Costs				\$0.00	
Other Costs (percentage of Capital Improvement Costs)					
Engineering	15%			\$0.00	
Legal/Administrative	5%			\$0.00	
Contract Admin/Construction Management	10%			\$0.00	
Contingency	25%			\$0.00	
Subtotal Other Costs				\$0.00	
Total Capital Improvement Costs				\$0.00	

Master Plan Operation and Maintenance Cost Summary					
Description	Quantity	Unit	Unit Cost	Total Annual Cost	
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	127	L.F.	\$1.00	\$127.00	
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	3	EA	\$610.00	\$1,830.00	
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	5000	L.F.	\$2.00	\$10,000.00	
Sediment Removal (from channel) <---User Defined Items	593	CY	\$38.00	\$22,534.00	
Total Annual Operation and Maintenance Cost				\$34,491.00	
Effective Interest Rate				4.00%	
Total Operation and Maintenance Costs Over 50 Years				\$740,942.00	

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT :	Fourmile Canyon Creek - CEAP Mitigation Planning		
DRAINAGEWAY :	Fourmile Canyon Creek		
REACH :	Alt 1		
JURISDICTION :	City of Boulder		
REACH ID :	FCC-ReachAlt 1	ICON Engineering Inc. (Brian LeDoux)	DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Hydraulic Structures					
Sloping Drop Structures					
Height (ft)	Bottom Width (ft)	Yn (ft)			
5	100	5	6	EA	\$247,296.15
					\$1,483,777.00
Detention/Water Quality Facilities					
Detention (Complete-in-Place)					
Detention Facility 1 (Complete-in-Place)	134	AC-FT	\$55,600.00	\$7,450,400.00	
Detention Facility 2 (Complete-in-Place)	72	AC-FT	\$55,600.00	\$4,003,200.00	
Detention Facility 3 (Complete-in-Place)	11	AC-FT	\$55,600.00	\$611,600.00	
Land Acquisition					
Temporary Easements	71000	EA	\$15.00	\$1,065,000.00	1 EA = 1 sf; channel easement (not temporary)

Master Plan Capital Improvement Cost Summary

Capital Improvement Costs				
Pipe Culverts and Storm Drains				\$0.00
Concrete Box Culverts				\$0.00
Hydraulic Structures				\$1,483,777.00
Channel Improvements				\$0.00
Detention/Water Quality Facilities				\$12,065,200.00
Removals				\$0.00
Landscaping and Maintenance Improvements				\$0.00
Special Items (User Defined)				\$0.00
Subtotal Capital Improvement Costs				\$13,548,977.00
Additional Capital Improvement Costs				
Dewatering	\$50,000.00	L.S.		\$50,000.00
Mobilization	5%			\$677,449.00
Traffic Control	\$0.00	L.S.		\$0.00
Utility Coordination/Relocation	\$10,000.00	L.S.		\$10,000.00
Stormwater Management/Erosion Control	5%			\$677,449.00
Subtotal Additional Capital Improvement Costs				\$1,414,898.00
Land Acquisition Costs				
ROW/Easements				\$1,065,000.00
Subtotal Land Acquisition Costs				\$1,065,000.00
Other Costs (percentage of Capital Improvement Costs)				
Engineering	15%			\$2,244,581.00
Legal/Administrative	5%			\$748,194.00
Contract Admin/Construction Management	10%			\$1,496,388.00
Contingency	25%			\$3,740,969.00
Subtotal Other Costs				\$8,230,132.00
Total Capital Improvement Costs				\$24,259,007.00

Master Plan Operation and Maintenance Cost Summary

Description	Quantity	Unit	Unit Cost	Total Annual Cost
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	127	L.F.	\$1.00	\$127.00
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	9	EA	\$610.00	\$5,490.00
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	3800	L.F.	\$2.00	\$7,600.00
Detention/WQ Maintenance (e.g. sediment & debris removal, mucking out, tree & weed removal, etc.)	30	ACRE	\$1,829.00	\$54,870.00
Sediment Removal (from facility)	593	CY	\$13.00	\$7,709.00
				<----User Defined Items
Total Annual Operation and Maintenance Cost				\$75,796.00
Effective Interest Rate				4.00%
Total Operation and Maintenance Costs Over 50 Years				\$1,628,264.00

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT : Fourmile Canyon Creek - CEAP Mitigation Planning
 DRAINAGEWAY : Fourmile Canyon Creek
 REACH : Alt 2
 JURISDICTION : City of Boulder
 REACH ID : FCC-ReachAlt 2 ICON Engineering Inc. (Brian LeDoux) DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS		
Hydraulic Structures							
Sloping Drop Structures							
Height (ft)	Bottom Width (ft)	Yn (ft)					
5	100	5	5	EA	\$247,296.15	\$1,236,481.00	Upstream of Pond
5	75	5	3	EA	\$202,975.46	\$608,926.00	Between 10th and Broadway
Channel Improvements							
Excavation, Mid Range	3100	C.Y.	\$29.00	\$89,900.00			
Detention/Water Quality Facilities							
Detention (Complete-in-Place)							
Detention Facility 1 (Complete-in-Place)	194	AC-FT	\$55,600.00	\$10,786,400.00			
Land Acquisition							
Temporary Easements	140495	EA	\$15.00	\$2,107,425.00	1 EA = 1 sf; channel easement (not temporary)		
Easement/ROW Acquisition	2.48	ACRE	\$1,306,800.00	\$3,240,864.00			

Master Plan Capital Improvement Cost Summary

Capital Improvement Costs				
Pipe Culverts and Storm Drains				\$0.00
Concrete Box Culverts				\$0.00
Hydraulic Structures				\$1,845,407.00
Channel Improvements				\$89,900.00
Detention/Water Quality Facilities				\$10,786,400.00
Removals				\$0.00
Landscaping and Maintenance Improvements				\$0.00
Special Items (User Defined)				\$0.00
Subtotal Capital Improvement Costs				\$12,721,707.00
Additional Capital Improvement Costs				
Dewatering	\$30,000.00	L.S.		\$30,000.00
Mobilization	5%			\$636,085.00
Traffic Control	\$0.00	L.S.		\$0.00
Utility Coordination/Relocation	\$50,000.00	L.S.		\$50,000.00
Stormwater Management/Erosion Control	5%			\$636,085.00
Subtotal Additional Capital Improvement Costs				\$1,352,170.00
Land Acquisition Costs				
ROW/Easements				\$5,348,289.00
Subtotal Land Acquisition Costs				\$5,348,289.00
Other Costs (percentage of Capital Improvement Costs)				
Engineering	15%			\$2,111,082.00
Legal/Administrative	5%			\$703,694.00
Contract Admin/Construction Management	10%			\$1,407,388.00
Contingency	25%			\$3,518,469.00
Subtotal Other Costs				\$7,740,633.00
Total Capital Improvement Costs				\$27,162,799.00

Master Plan Operation and Maintenance Cost Summary

Description	Quantity	Unit	Unit Cost	Total Annual Cost
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	127	L.F.	\$1.00	\$127.00
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	11	EA	\$610.00	\$6,710.00
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	4500	L.F.	\$2.00	\$9,000.00
Detention/WQ Maintenance (e.g. sediment & debris removal, mucking out, tree & weed removal, etc.)	10	ACRE	\$1,829.00	\$18,290.00
Sediment Removal (from facility)	<----User Defined Items	CY	\$13.00	\$7,709.00
Total Annual Operation and Maintenance Cost				\$41,836.00
Effective Interest Rate				4.00%
Total Operation and Maintenance Costs Over 50 Years				\$898,729.00

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT :	Fourmile Canyon Creek - CEAP Mitigation Planning
DRAINAGEWAY :	Fourmile Canyon Creek
REACH :	Alt 3
JURISDICTION :	City of Boulder
REACH ID :	FCC-ReachAlt 3
ICON Engineering Inc. (Brian LeDoux)	DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS		
Pipe Culverts and Storm Drains							
Circular Pipes							
Diameter (in)	Length (ft)	No. of Barrels					
84-inch	1235	3	3705	L.F.	\$512.00	\$1,896,960.00	
Headwalls							
Diameter (in)	Applicable	No. of Barrels					
84-inch	Yes	3	2	EA	\$6,608.71	\$13,217.00	
Wingwalls (includes concrete apron)							
Diameter (in)		No. of Barrels					
84-inch		3	2	EA	\$22,197.50	\$44,395.00	
Manholes and Inlets							
Type B Manhole (Pipe Dia. 48" and larger, deflection < 10 degrees)			4	EA	\$14,632.00	\$58,528.00	
Concrete Box Culverts							
Box Culvert Pipe							
Individual Box Span (ft)	Box Height (ft)	No. of Barrels	Length (ft)				
8	5	3	70	L.F.	\$2,501.51	\$175,106.00	Broadway
10	10	1	70	L.F.	\$1,327.74	\$92,942.00	Broadway
8	5	3	40	L.F.	\$2,501.51	\$100,060.00	Violet
10	10	1	40	L.F.	\$1,327.74	\$53,110.00	Violet
8	5	3	30	L.F.	\$2,501.51	\$75,045.00	Upland
10	10	1	30	L.F.	\$1,327.74	\$39,832.00	Upland
Headwall and Towealls							
Individual Box Span (ft)	No. of Barrels	Total Span (ft)					
8	3	27.00	2	EA	\$2,287.44	\$4,575.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
8	3	27.00	2	EA	\$2,287.44	\$4,575.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
8	3	27.00	2	EA	\$2,287.44	\$4,575.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
Wingwalls (includes wingwalls on either side of channel and concrete apron)							
Individual Box Span (ft)	Box Rise (ft)	No. of Barrels					
8	5	3	2	EA	\$14,864.03	\$29,728.10	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
8	5	3	2	EA	\$14,864.03	\$29,728.10	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
8	5	3	2	EA	\$14,864.03	\$29,728.10	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
Hydraulic Structures							
Sloping Drop Structures							
Height (ft)	Bottom Width (ft)	Yn (ft)					
4	142	5	6	EA	\$301,935.98	\$1,811,616.00	7th to 10th
4	142	5	4	EA	\$301,935.98	\$1,207,744.00	10th to Broadway
4	142	5	3	EA	\$301,935.98	\$905,808.00	Broadway to Violet Park
4	142	5	6	EA	\$301,935.98	\$1,811,616.00	Violet Park to Violet Ave.
4	142	5	3	EA	\$301,935.98	\$905,808.00	Violet Ave. to 19th Street
Channel Improvements							
Excavation, Mid Range		93408		C.Y.	\$29.00	\$2,708,832.00	
Landscaping and Maintenance Improvements							
Reclamation & seeding (native grasses)		21		ACRE	\$1,219.00	\$25,599.00	
Land Acquisition							
Temporary Easements		215368		EA	\$15.00	\$3,230,520.00	1 EA = 1 sf; channel easement (not temporary)
Easement/ROW Acquisition		1.80		ACRE	\$1,306,800.00	\$2,352,240.00	

Master Plan Capital Improvement Cost Summary

Capital Improvement Costs				
Pipe Culverts and Storm Drains				\$2,013,100.00
Concrete Box Culverts				\$810,430.00
Hydraulic Structures				\$6,642,592.00
Channel Improvements				\$2,708,832.00
Detention/Water Quality Facilities				\$0.00
Removals				\$0.00
Landscaping and Maintenance Improvements				\$25,599.00
Special Items (User Defined)				\$0.00
Subtotal Capital Improvement Costs				\$12,200,553.00
Additional Capital Improvement Costs				
Dewatering	\$80,000.00	L.S.		\$80,000.00
Mobilization	5%			\$610,028.00
Traffic Control	\$50,000.00	L.S.		\$50,000.00
Utility Coordination/Relocation	\$120,000.00	L.S.		\$120,000.00
Stormwater Management/Erosion Control	5%			\$610,028.00
Subtotal Additional Capital Improvement Costs				\$1,470,056.00
Land Acquisition Costs				
ROW/Easements				\$5,582,760.00
Subtotal Land Acquisition Costs				\$5,582,760.00
Other Costs (percentage of Capital Improvement Costs)				
Engineering	15%			\$2,050,591.00
Legal/Administrative	5%			\$683,530.00
Contract Admin/Construction Management	10%			\$1,367,061.00
Contingency	25%			\$3,417,652.00
Subtotal Other Costs				\$7,518,834.00
Total Capital Improvement Costs				\$26,772,203.00

Master Plan Operation and Maintenance Cost Summary

Description	Quantity	Unit	Unit Cost	Total Annual Cost	
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	4265	L.F.	\$1.00	\$4,265.00	
Manhole and Inlet Maintenance (e.g. sediment & debris removal, structural repairs, etc.)	4	EA	\$61.00	\$244.00	
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	22	EA	\$610.00	\$13,420.00	
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	5000	L.F.	\$2.00	\$10,000.00	
Mowing (e.g. channels, ponds, etc.)	21	ACRE	\$61.00	\$1,281.00	
Sediment Removal (from channel)	<---User Defined Items	593	CY	\$38.00	\$22,534.00
Total Annual Operation and Maintenance Cost				\$51,744.00	
Effective Interest Rate				4.00%	
Total Operation and Maintenance Costs Over 50 Years				\$1,111,574.00	

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT :	Fourmile Canyon Creek - CEAP Mitigation Planning
DRAINAGEWAY :	Fourmile Canyon Creek
REACH :	Alt 4
JURISDICTION :	City of Boulder
REACH ID :	FCC-ReachAlt 4
ICON Engineering Inc. (Brian LeDoux)	DATE :
	2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS		
Pipe Culverts and Storm Drains							
<i>Circular Pipes</i>							
Diameter (in)	Length (ft)	No. of Barrels					
60-inch	60	1	60	L.F.	\$293.00	\$17,580.00	Cherry Ave.
60-inch	220	2	440	L.F.	\$293.00	\$128,920.00	10th Street
60-inch	60	4	240	L.F.	\$293.00	\$70,320.00	Business Access
<i>Headwalls</i>							
Diameter (in)	Applicable	No. of Barrels					
60-inch	Yes	1	2	EA	\$1,956.20	\$3,912.00	
60-inch	Yes	2	2	EA	\$3,334.68	\$6,669.00	
60-inch	Yes	4	2	EA	\$5,930.64	\$11,861.00	
<i>Wingwalls (includes concrete apron)</i>							
Diameter (in)		No. of Barrels					
60-inch		1	2	EA	\$10,913.41	\$21,827.00	
60-inch		2	2	EA	\$12,828.86	\$25,658.00	
60-inch		4	2	EA	\$16,659.77	\$33,320.00	
Concrete Box Culverts							
<i>Box Culvert Pipe</i>							
Individual Box Span (ft)	Box Height (ft)	No. of Barrels	Length (ft)				
7	5	2	60	L.F.	\$1,573.62	\$94,417.00	Business Access
7	5	2	100	L.F.	\$1,573.62	\$157,362.00	Violet Ave.
7	5	2	60	L.F.	\$1,573.62	\$94,417.00	Union Ave.
9	5	2	60	L.F.	\$1,837.64	\$110,258.00	Ulita Ave.
9	5	2	110	L.F.	\$1,837.64	\$202,140.00	Parking Lot
9	5	2	100	L.F.	\$1,837.64	\$183,764.00	Broadway
<i>Headwall and Toewalls</i>							
Individual Box Span (ft)	No. of Barrels	Total Span (ft)					
7	2	17.00	2	EA	\$1,433.44	\$2,867.00	
7	2	17.00	2	EA	\$1,433.44	\$2,867.00	
7	2	17.00	2	EA	\$1,433.44	\$2,867.00	
9	2	21.00	2	EA	\$1,779.12	\$3,558.00	
9	2	21.00	2	EA	\$1,779.12	\$3,558.00	
9	2	21.00	2	EA	\$1,779.12	\$3,558.00	
<i>Wingwalls (includes wingwalls on either side of channel and concrete apron)</i>							
Individual Box Span (ft)	Box Rise (ft)	No. of Barrels					
7	5	2	2	EA	\$12,230.28	\$24,460.60	
7	5	2	2	EA	\$12,230.28	\$24,460.60	
7	5	2	2	EA	\$12,230.28	\$24,460.60	
9	5	2	2	EA	\$13,188.01	\$26,376.00	
9	5	2	2	EA	\$13,188.01	\$26,376.00	
9	5	2	2	EA	\$13,188.01	\$26,376.00	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS		
Hydraulic Structures							
<i>Sloping Drop Structures</i>							
Height (ft)	Bottom Width (ft)	Yn (ft)					
4	5	2.5	2	EA	\$41,146.26	\$82,293.00	Channel 1
3.5	5	3.3	2	EA	\$49,939.54	\$99,879.00	Channel 2
2.8	9	4.5	1	EA	\$68,184.76	\$68,185.00	Channel 3
4	17	5	1	EA	\$93,943.17	\$93,943.00	Channel 4
0.7	17.5	5	1	EA	\$74,113.53	\$74,114.00	Channel 5
2.6	18.1	5	1	EA	\$86,916.66	\$86,917.00	Channel 6
1.3	28.5	5	1	EA	\$92,941.76	\$92,942.00	Channel 7
1.4	29.1	5	1	EA	\$94,515.70	\$94,516.00	Channel 8
3	29.5	5	3	EA	\$107,174.99	\$321,525.00	Channel 10

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Channel Improvements					
Excavation, Mid Range	19622	C.Y.	\$29.00	\$569,038.00	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS	
Special Items (User Defined)						
Structure Acquisition	<--User Defined Items	1	EA	\$677,900.00	\$677,900.00	1200 Sumac Av >> all structures include \$40,000 for removal and seeding
Structure Acquisition	<--User Defined Items	1	EA	\$674,100.00	\$674,100.00	1225 Riverside Ave
Structure Acquisition	<--User Defined Items	1	EA	\$543,500.00	\$543,500.00	4170 Riverside Drive
Structure Acquisition	<--User Defined Items	1	EA	\$541,800.00	\$541,800.00	4160 Riverside Drive
Structure Acquisition	<--User Defined Items	1	EA	\$679,700.00	\$679,700.00	1245 Riverside Ave
Structure Acquisition	<--User Defined Items	1	EA	\$533,100.00	\$533,100.00	1300 Riverside Ave
Structure Acquisition	<--User Defined Items	1	EA	\$634,900.00	\$634,900.00	1490 Riverside Ave
Structure Acquisition	<--User Defined Items	1	EA	\$658,100.00	\$658,100.00	4165 15th Street
Structure Acquisition	<--User Defined Items	1	EA	\$845,500.00	\$845,500.00	4414 15th Street
Structure Acquisition	<--User Defined Items	1	EA	\$987,600.00	\$987,600.00	4140 17th Street

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Land Acquisition					
Temporary Easements	167406	EA	\$15.00	\$2,511,090.00	1 EA = 1 sf. channel easement (not temporary)

Master Plan Capital Improvement Cost Summary					
Capital Improvement Costs					
Pipe Culverts and Storm Drains				\$320,067.00	
Concrete Box Culverts				\$1,014,143.00	
Hydraulic Structures				\$1,014,314.00	
Channel Improvements				\$569,038.00	
Detention/Water Quality Facilities				\$0.00	
Removals				\$0.00	
Landscaping and Maintenance Improvements				\$0.00	
Special Items (User Defined)				\$6,676,200.00	
Subtotal Capital Improvement Costs				\$9,593,762.00	
Additional Capital Improvement Costs					
Dewatering	\$50,000.00	L.S.		\$50,000.00	
Mobilization	5%			\$479,688.00	
Traffic Control	\$50,000.00	L.S.		\$50,000.00	
Utility Coordination/Relocation	\$350,000.00	L.S.		\$350,000.00	
Stormwater Management/Erosion Control	5%			\$479,688.00	
Subtotal Additional Capital Improvement Costs				\$1,409,376.00	
Land Acquisition Costs					
ROW/Easements				\$2,511,090.00	
Subtotal Land Acquisition Costs				\$2,511,090.00	
Other Costs (percentage of Capital Improvement Costs)					
Engineering	15%			\$1,650,471.00	
Legal/Administrative	5%			\$550,157.00	
Contract Admin/Construction Management	10%			\$1,100,314.00	
Contingency	25%			\$2,750,785.00	
Subtotal Other Costs				\$6,051,727.00	
Total Capital Improvement Costs				\$19,565,955.00	

Master Plan Operation and Maintenance Cost Summary					
Description	Quantity	Unit	Unit Cost	Total Annual Cost	
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exst, structural repairs, etc.)	1847	L.F.	\$1.00	\$1,847.00	
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	16	EA	\$610.00	\$9,760.00	
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	7650	L.F.	\$2.00	\$15,300.00	
Sediment Removal (from channel)	<--User Defined Items	593	CY	\$38.00	\$22,534.00
Total Annual Operation and Maintenance Cost				\$49,441.00	
Effective Interest Rate				4.00%	
Total Operation and Maintenance Costs Over 50 Years				\$1,062,101.00	

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT :	Fourmile Canyon Creek - CEAP Mitigation Planning
DRAINAGEWAY :	Fourmile Canyon Creek
REACH :	Alt 5
JURISDICTION :	City of Boulder
REACH ID :	FCC-ReachAlt 5
	ICON Engineering Inc. (Brian LeDoux) DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS		
Pipe Culverts and Storm Drains							
Circular Pipes							
Diameter (in)	Length (ft)	No. of Barrels					
84-inch	1235	2	2470	L.F.	\$512.00	\$1,264,640.00	
Headwalls							
Diameter (in)	Applicable	No. of Barrels					
84-inch	Yes	2	2	EA	\$4,729.76	\$9,460.00	
Wingwalls (includes concrete apron)							
Diameter (in)		No. of Barrels					
84-inch		2	2	EA	\$19,302.77	\$38,606.00	
Manholes and Inlets							
Type B Manhole (Pipe Dia. 48" and larger, deflection < 10 degrees)			4	EA	\$14,632.00	\$58,528.00	
Concrete Box Culverts							
Box Culvert Pipe							
Individual Box Span (ft)	Box Height (ft)	No. of Barrels	Length (ft)				
8	5	2	70	L.F.	\$1,667.67	\$116,737.00	Broadway
10	10	1	70	L.F.	\$1,327.74	\$92,942.00	Broadway
8	5	2	40	L.F.	\$1,667.67	\$66,707.00	Violet
10	10	1	40	L.F.	\$1,327.74	\$53,110.00	Violet
8	5	2	30	L.F.	\$1,667.67	\$50,030.00	Upland
10	10	1	30	L.F.	\$1,327.74	\$39,832.00	Upland
Headwall and Trowalls							
Individual Box Span (ft)	No. of Barrels	Total Span (ft)					
8	2	19.00	2	EA	\$1,609.68	\$3,219.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
8	2	19.00	2	EA	\$1,609.68	\$3,219.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
8	2	19.00	2	EA	\$1,609.68	\$3,219.00	
10	1	12.00	2	EA	\$1,085.04	\$2,170.00	
Wingwalls (includes wingwalls on either side of channel and concrete apron)							
Individual Box Span (ft)	Box Rise (ft)	No. of Barrels					
8	5	2	2	EA	\$12,709.15	\$25,418.30	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
8	5	2	2	EA	\$12,709.15	\$25,418.30	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
8	5	2	2	EA	\$12,709.15	\$25,418.30	
10	10	1	2	EA	\$27,486.01	\$54,972.00	
Hydraulic Structures							
Sloping Drop Structures							
Height (ft)	Bottom Width (ft)	Yn (ft)					
4	72	5	6	EA	\$185,459.43	\$1,112,757.00	7th to 10th
4	72	5	4	EA	\$185,459.43	\$741,838.00	10th to Broadway
4	72	5	3	EA	\$185,459.43	\$556,378.00	Broadway to Violet Park
4	72	5	6	EA	\$185,459.43	\$1,112,757.00	Violet Park to Violet Ave.
4	72	5	3	EA	\$185,459.43	\$556,378.00	Violet Ave. to 19th Street
Channel Improvements							
Excavation, Mid Range		39304		C.Y.	\$29.00	\$1,139,816.00	
Landscaping and Maintenance Improvements							
Reclamation & seeding (native grasses)		13		ACRE	\$1,219.00	\$15,725.00	
Land Acquisition							
Temporary Easements		63290		EA	\$15.00	\$949,350.00	1 EA = 1 sf; channel easement (not temporary)
Easement/ROW Acquisition		0.77		ACRE	\$1,306,800.00	\$1,006,236.00	

Master Plan Capital Improvement Cost Summary

Capital Improvement Costs				
Pipe Culverts and Storm Drains				\$1,371,234.00
Concrete Box Culverts				\$676,696.00
Hydraulic Structures				\$4,080,108.00
Channel Improvements				\$1,139,816.00
Detention/Water Quality Facilities				\$0.00
Removals				\$0.00
Landscaping and Maintenance Improvements				\$15,725.00
Special Items (User Defined)				\$0.00
Subtotal Capital Improvement Costs				\$7,283,579.00
Additional Capital Improvement Costs				
Dewatering	\$80,000.00	L.S.		\$80,000.00
Mobilization	5%			\$364,179.00
Traffic Control	\$50,000.00	L.S.		\$50,000.00
Utility Coordination/Relocation	\$100,000.00	L.S.		\$100,000.00
Stormwater Management/Erosion Control	5%			\$364,179.00
Subtotal Additional Capital Improvement Costs				\$958,358.00
Land Acquisition Costs				
ROW/Easements				\$1,955,586.00
Subtotal Land Acquisition Costs				\$1,955,586.00
Other Costs (percentage of Capital Improvement Costs)				
Engineering	15%			\$1,236,291.00
Legal/Administrative	5%			\$412,097.00
Contract Admin/Construction Management	10%			\$824,194.00
Contingency	25%			\$2,060,484.00
Subtotal Other Costs				\$4,533,066.00
Total Capital Improvement Costs				\$14,730,589.00

Master Plan Operation and Maintenance Cost Summary

Description	Quantity	Unit	Unit Cost	Total Annual Cost	
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	2890	L.F.	\$1.00	\$2,890.00	
Manhole and Inlet Maintenance (e.g. sediment & debris removal, structural repairs, etc.)	4	EA	\$61.00	\$244.00	
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	22	EA	\$610.00	\$13,420.00	
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	5000	L.F.	\$2.00	\$10,000.00	
Mowing (e.g. channels, ponds, etc.)	13	ACRE	\$61.00	\$793.00	
Sediment Removal (from channel)	<---User Defined Items	593	CY	\$38.00	\$22,534.00
Total Annual Operation and Maintenance Cost				\$49,881.00	
Effective Interest Rate				4.00%	
Total Operation and Maintenance Costs Over 50 Years				\$1,071,553.00	

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT : Fourmile Canyon Creek - CEAP Mitigation Planning
 DRAINAGEWAY : Fourmile Canyon Creek
 REACH : Alt 6
 JURISDICTION : City of Boulder
 REACH ID : FCC-ReachAlt 6 ICON Engineering Inc. (Brian LeDoux) DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Master Plan Capital Improvement Cost Summary					
Capital Improvement Costs					
Pipe Culverts and Storm Drains				\$0.00	
Concrete Box Culverts				\$0.00	
Hydraulic Structures				\$0.00	
Channel Improvements				\$0.00	
Detention/Water Quality Facilities				\$0.00	
Removals				\$0.00	
Landscaping and Maintenance Improvements				\$0.00	
Special Items (User Defined)				\$0.00	
Subtotal Capital Improvement Costs				\$0.00	
Additional Capital Improvement Costs					
Dewatering		L.S.		\$0.00	
Mobilization	5%			\$0.00	
Traffic Control		L.S.		\$0.00	
Utility Coordination/Relocation		L.S.		\$0.00	
Stormwater Management/Erosion Control	5%			\$0.00	
Subtotal Additional Capital Improvement Costs				\$0.00	
Land Acquisition Costs					
ROW/Easements				\$0.00	
Subtotal Land Acquisition Costs				\$0.00	
Other Costs (percentage of Capital Improvement Costs)					
Engineering	15%			\$0.00	
Legal/Administrative	5%			\$0.00	
Contract Admin/Construction Management	10%			\$0.00	
Contingency	25%			\$0.00	
Subtotal Other Costs				\$0.00	
Total Capital Improvement Costs				\$0.00	

Master Plan Operation and Maintenance Cost Summary						
Description	Quantity	Unit	Unit Cost	Total Annual Cost		
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	127	L.F.	\$1.00	\$127.00		
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	3	EA	\$610.00	\$1,830.00		
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	5000	L.F.	\$2.00	\$10,000.00		
Detention/WQ Maintenance (e.g. sediment & debris removal, mucking out, tree & weed removal, etc.)	0.3	ACRE	\$1,829.00	\$549.00		
Sediment Removal (from facility)	<---User Defined Items	593	CY	\$13.00	\$7,709.00	
Total Annual Operation and Maintenance Cost				\$20,215.00		
Effective Interest Rate				4.00%		
Total Operation and Maintenance Costs Over 50 Years				\$434,262.00		

MASTER PLAN COST ESTIMATE FOR INDIVIDUAL REACH

PROJECT : Fourmile Canyon Creek - CEAP Mitigation Planning
 DRAINAGEWAY : Fourmile Canyon Creek
 REACH : Alt 7
 JURISDICTION : City of Boulder
 REACH ID : FCC-ReachAlt 7 ICON Engineering Inc. (Brian LeDoux) DATE : 2015-10-21

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	USER COMMENTS
Master Plan Capital Improvement Cost Summary					
Capital Improvement Costs					
Pipe Culverts and Storm Drains				\$0.00	
Concrete Box Culverts				\$0.00	
Hydraulic Structures				\$0.00	
Channel Improvements				\$0.00	
Detention/Water Quality Facilities				\$0.00	
Removals				\$0.00	
Landscaping and Maintenance Improvements				\$0.00	
Special Items (User Defined)				\$0.00	
Subtotal Capital Improvement Costs				\$0.00	
Additional Capital Improvement Costs					
Dewatering		L.S.		\$0.00	
Mobilization	5%			\$0.00	
Traffic Control		L.S.		\$0.00	
Utility Coordination/Relocation		L.S.		\$0.00	
Stormwater Management/Erosion Control	5%			\$0.00	
Subtotal Additional Capital Improvement Costs				\$0.00	
Land Acquisition Costs					
ROW/Easements				\$0.00	
Subtotal Land Acquisition Costs				\$0.00	
Other Costs (percentage of Capital Improvement Costs)					
Engineering	15%			\$0.00	
Legal/Administrative	5%			\$0.00	
Contract Admin/Construction Management	10%			\$0.00	
Contingency	25%			\$0.00	
Subtotal Other Costs				\$0.00	
Total Capital Improvement Costs				\$0.00	
Master Plan Operation and Maintenance Cost Summary					
Description	Quantity	Unit	Unit Cost	Total Annual Cost	
Culvert Maintenance (e.g. sediment & debris removal, erosion at entrance/exit, structural repairs, etc.)	127	L.F.	\$1.00	\$127.00	
Hydraulic Structure Maintenance (e.g. debris removal, erosion, structural repairs, etc.)	3	EA	\$610.00	\$1,830.00	
Channel Maintenance (e.g. sediment & debris removal, erosion, tree & weed removal, etc.)	5000	L.F.	\$2.00	\$10,000.00	
Sediment Removal (from channel) <----User Defined Items	593	CY	\$38.00	\$22,534.00	
Total Annual Operation and Maintenance Cost				\$34,491.00	
Effective Interest Rate				4.00%	
Total Operation and Maintenance Costs Over 50 Years				\$740,942.00	

Appendix E – Sediment Basin Evaluation Excerpts

MEMORANDUM

To: David Skuodas / UDFCD
Christie Coleman / City of Boulder

From: Jim Wulliman / Muller Engineering Company
Derek Johns / Muller Engineering Company

Date: September 19, 2012

Project #: 12-033.01

Re: Evaluation of Fourmile Canyon Creek Sediment Basin Alternatives



Muller Engineering Company, Inc.
Consulting Engineers

777 S. Wadsworth Blvd. #4-100
Lakewood, Colorado 80226
303/988-4969 FAX
303/988-4939
www.mullereng.com

Introduction

This memorandum documents an evaluation of alternatives to create a sediment basin along Fourmile Canyon Creek upstream of Broadway Street. Four potential locations/configurations for a sediment basin were examined. Conceptual layouts of the four alternatives were drawn and the alternatives were compared in terms of basin volume and surface area, sediment trap efficiency, probable construction cost, utility impacts, and property issues.

Alternatives

Appendix A includes a key map indicating the locations of the four alternative sediment basins and drawings showing each alternative configuration, described briefly as follows.

Alternative 1. Alternative 1 is located immediately upstream of the trailer park at Rosewood Street and is proposed as an off-line basin south of the creek. The basin would be constructed just south of the existing concrete trail and north of the new Rosewood residential development, currently in the planning stages. The conceptual layout of this basin shows an inlet and outlet conduit sized for the 2-year peak flow (58 cfs). Flows greater than the 2-year event would generally bypass the sediment basin (some flow in excess of the 2-year event would pass through the basin due to higher headwater at the inlet conduit). The basin would normally be empty, but would fill to a depth of approximately three feet or more during storms and drain over a period up to about 40 hours. Emergency flows would pass over a low point in the concrete trail and enter Fourmile Canyon Creek. The basin would be provided with a hard-lined forebay and combined micropool/water quality outlet structure.

Alternative 2. Alternative 2 is also located immediately upstream of the trailer park at Rosewood Street, but is proposed as an on-line basin, allowing all the creek flows to pass through it. The basin would be constructed as a wider section of the creek with a reduced slope and a nominally three foot high downstream sill. The existing concrete trail would be relocated to the south, closer to the new Rosewood residential development, to allow more room for the sediment basin. The conceptual layout of this basin shows a drop structure at the upstream end and the sill at the downstream end. The basin would normally be empty, but would fill to a depth of approximately three feet or more during storms and drain over a period up to about 40 hours. Emergency flows would pass over the downstream sill. The basin would be provided with a hard-lined forebay and combined micropool/water quality outlet structure.

Alternative 3. Alternative 3 is located upstream of Alternatives 1 and 2 east of 8th Street and north of an existing irrigation ditch. Alternative 3 is proposed as an off-line basin and is

essentially a much larger version of Alternative 1. The basin would be constructed just south of the existing concrete trail and north and east of an existing residential development. Like Alternative 1, the conceptual layout of this basin shows an inlet and outlet conduit sized for the 2-year peak flow (58 cfs). Flows greater than the 2-year event would generally bypass the sediment basin (some flow in excess of the 2-year event would pass through the basin due to higher headwater at the inlet conduit). The basin would normally be empty, but would fill to a depth of approximately three feet or more during storms and drain over a period up to about 40 hours. Emergency flows would pass over a low point in the concrete trail and enter Fourmile Canyon Creek. The basin would be provided with a hard-lined forebay and combined micropool/water quality outlet structure.

Alternative 4. Alternative 4 is located furthest upstream of the four alternatives within Boulder Open Space property. Alternative 4 is proposed as an on-line basin, allowing all the creek flows to pass through it. The basin would be constructed with a six-foot drop structure leading into it and a four-foot drop at the downstream end, directing flows back into the creek. The basin bottom would be excavated to a point approximately three feet below the crest of the downstream drop structure. The basin would normally be empty, but would fill to a depth of approximately three feet or more during storms and drain over a period up to about 40 hours. Emergency flows would pass over the downstream drop. The basin would be provided with a hard-lined forebay and combined micropool/water quality outlet structure.

Floodplain Considerations

Each of the four alternative configurations for the proposed Fourmile Canyon Creek sediment basin is located within the 100-year floodplain according to the Phase A report for the Fourmile Canyon Creek and Wonderland Creek Master Plan. This report was prepared in 2006 by Love and Associates for UDFCD and the City of Boulder. The report shows several spills from the Fourmile Canyon Creek floodplain south to the Wonderland Creek floodplain in the vicinity of the proposed sediment basin and generally recommends maintaining these spills, neither significantly increasing nor decreasing them. The report also shows structures in the Fourmile Canyon Creek floodplain and in the spill zones in the vicinity of Alternatives, 1, 2, and 3.

Because each of the alternatives is located within the floodplain and since structures are in the floodplain and the predicted spills are so sensitive, any sediment basin alternative would need to undergo detailed hydraulic modeling and design analysis to ensure that any floodplain impacts are either avoided or minimized and addressed. Of the alternatives, the design of Alternative 3 may be the most challenging from a floodplain impact perspective, since it is located right at one of the major spill points.

Appendix B includes a figure from the Phase A report of the master plan that shows the Fourmile Canyon Creek floodplain and spill points. The four alternative sediment basin locations have been sketched on this figure.

Sediment Trap Efficiency

A study of sedimentation in Fourmile Canyon Creek was documented in a report entitled *Sediment Analysis Report – Four Mile Canyon Creek Downstream of 30th Street* prepared by Moser & Associates in October, 2008 for UDFCD and the City of Boulder. The report provided calculations that indicated that a sediment basin surface area of 1400 SF would be necessary to capture 95% of inflowing sands and gravels during an 80th percentile event. The report also

provided a rough estimate of sediment load from the upstream watershed of 100 tons per square mile per year.

Upon review of the trap efficiency equation used in the sediment analysis report, it was found that the equation is based on ideal settling conditions. An alternate equation for trap efficiency is presented in an EPA document entitled *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality*, dated September, 1986. This equation, shown below, includes a parameter, n, that reflects the degree of turbulence or short-circuiting, which tends to reduce removal efficiency.

$$\text{Trap Efficiency } R = 1 - (1 + 1/n * v_s / (Q/A))^{-n}$$

where Q/A = rate of applied flow divided by surface area of basin (overflow rate)

v_s = settling velocity of particles

n = turbulence or short circuiting parameter

The document suggests these values for n.

n=1	Very poor performance
n=3	Good performance
n=5	Very good performance
n>100	Ideal performance

For the purposes of this evaluation, n=1 was used for online sediment basins and n=2 was used for off-line basins. Trap efficiency was calculated for coarse (0.7 mm) sand (same as 2008 study) and was also checked for medium (0.354 mm) sand and very fine (0.177 mm) sand. Curves of trap efficiency based on a 2-year runoff event (58 cfs based on the 2008 study) and these sediment sizes are shown in Appendix C.

Based on the sediment loading rate of 100 tons per square mile identified in the 2008 report, a watershed area of approximately 8 square miles, and an assumed sediment unit weight of 100 pounds per CF, the annual sediment load in Fourmile Canyon Creek is approximately 593 CY per year. Since the sediment yield estimate in the 2008 report was made before the fire, there is a chance that this load could be exceeded.

Trap efficiency estimates for each of the four alternatives and information on surface area and volume of the basins are shown in the table on the next page. For the two off-line alternatives, it was assumed that 70 percent of the inflowing sediment load would enter the basins through the 2-year inflow conduit and 30 percent would bypass during larger events. The summary table shows that the smallest amount of sediment trapped would be associated with Alternative 1 and progressively more would be captured in Alternatives 3, 2, and 4, respectively.

Opinion of Probable Costs

Concept-level opinions of probable construction costs were developed for each sediment basin alternative. A breakdown of these costs, including a 20% contingency allowance, is provided in Appendix D. The probable costs are summarized in the table on the next page.

Table 1. Fourmile Canyon Creek Sediment Basin Alternative Comparison

Alternative	1	2	3	4
Type	Offline	Online	Offline	Online
n	2	1	2	1
Surface Area, SF	1885	6152	20956	12318
Basin Volume, CY	81	363	1703	925
Sediment Size	Very Fine Sand	Very Fine Sand	Very Fine Sand	Very Fine Sand
Trap Efficiency	74%	86%	95%	92%
Annual Sediment Load, CY	593	593	593	593
Annual Sediment Load Entering Basin, %	70%	100%	70%	100%
Annual Sediment Load Entering Basin, CY	415	593	415	593
Annual Sediment Trapped, CY	307	510	394	545
Annual Sediment Bypassed, CY	286	83	199	47
Effective Trap Efficiency	52%	86%	67%	92%
Volume of Annual Sediment Trapped as Percent of Basin Volume	380%	140%	23%	59%
Concept-level Opinion of Probable Cost	\$275,790	\$365,250	\$454,860	\$435,360
Cost per CY of Annual Sediment Load Trapped	\$898	\$717	\$1,154	\$799

Utility Impacts

Appendix E shows existing water (in blue) and sewer (in yellow) utilities in the vicinity of the sediment basin alternatives. Existing water and sewer lines in the area are in closest proximity to Alternative 3. The approximate locations of water and sewer lines are shown on the drawing of Alternative 3 in Appendix A. The sewer line, since it crosses under Fourmile Canyon Creek, is likely to be low enough not to be impacted by the construction of the Alternative 3 sediment basin. However, it is possible that the proposed configuration could conflict with or reduce cover over the water line.

Property Issues

Appendix E also indicates City of Boulder limits in the vicinity of the proposed sediment basins. The limits are shown on the sediment basin concept drawings in Appendix A. A portion of Alternative 1, 2, and 3 lie outside of City limits within Boulder County jurisdiction. It needs to be determined how significant this inter-jurisdictional issue is.

The portion of Alternative 3 that is in City property lies within a drainage and floodplain tract associated with the residential development located along 7th and 8th Streets. Alternative 4 lies wholly within the City, but on land managed by Boulder Open Space. One of the next steps in the evaluating the feasibility of the four sediment basin locations is to assess the property issues associated with each alternative.

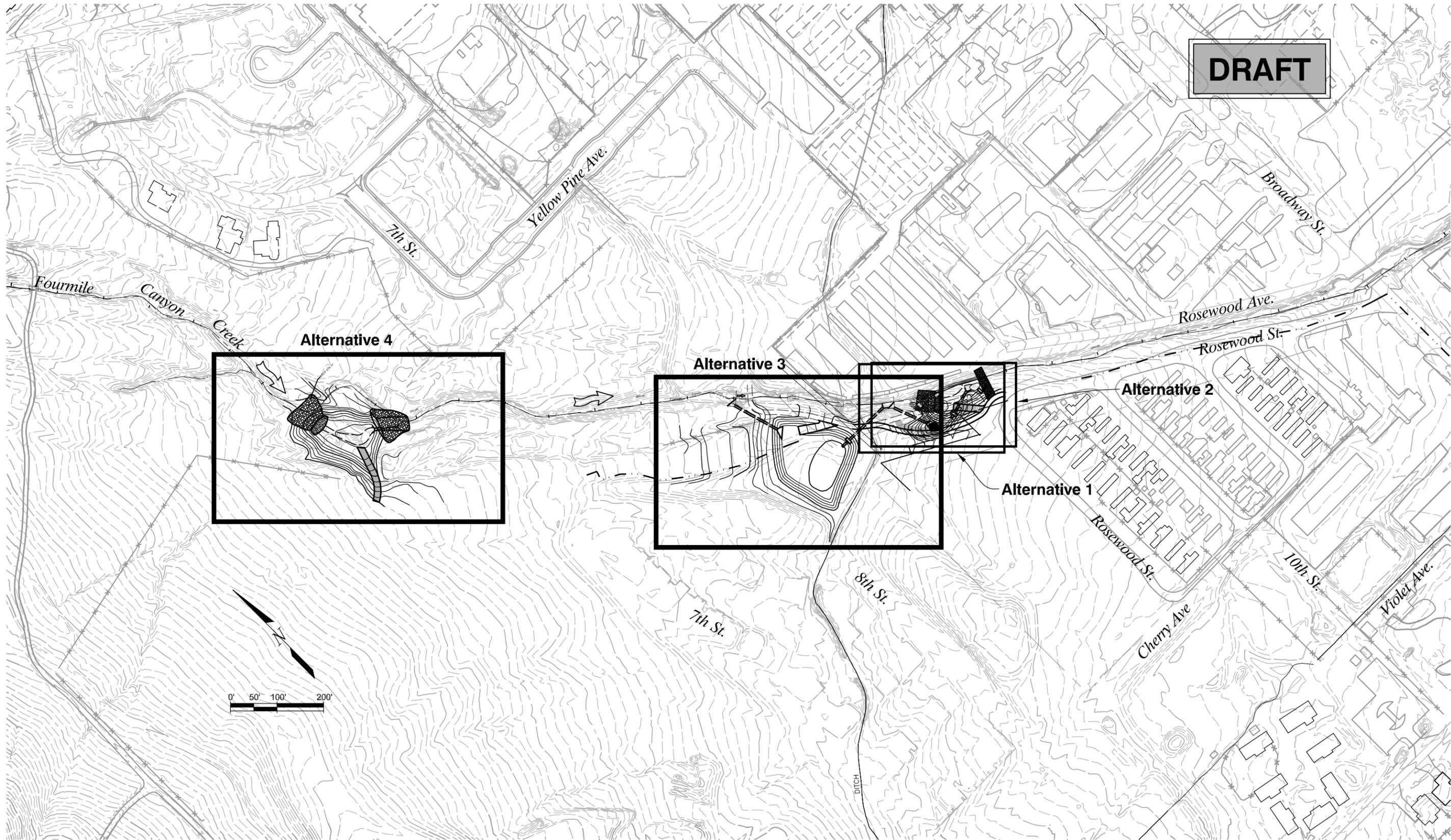
Conclusions

Property issues aside, the evaluation indicates that the preferred sediment basin configuration is Alternative 4, followed by Alternative 2. Alternative 1 is very small and has limited sediment trapping potential. Alternative 3 faces design challenges associated with being located at a floodplain spill point.

Alternative 4 has the greatest estimated overall trap efficiency and, compared to Alternative 2, has more capacity to store accumulated sediment, reducing the required frequency of cleaning. Alternative 4 is located in an open area furthest away from existing buildings and trails. Alternative 4 could be laid out to preserve the riparian vegetation associated with the existing creek and the facility itself could be designed to appear fairly natural. Alternative 4 requires coordination with the property owner, Boulder Open Space and Mountain Parks, to see if the sediment basin would be an acceptable use of the land.

Alternative 2 seems to be the second best choice for a sediment basin location. It would provide the second greatest sediment trapping efficiency, but is smaller and more constrained than Alternative 4, may present more challenges in avoiding floodplain impacts, and disturbs the mainstem reach of the creek more than Alternative 4. Alternative 2 has less sediment storage capacity than Alternative 4 and would need to be maintained more often. On the other hand, Alternative 2 has a lower opinion of probable cost than Alternative 4. Alternative 2 requires coordination with Boulder County to make sure that a sediment basin can be built in an area split between City and County jurisdiction.

DRAFT



NAME: P:\12033.01_Four Mile Canyon Creek - LDFED\CAD\12033.01_Key Map.dwg DATE: SEP 17, 2012 TIME: 3:05 PM

No.	DATE	REVISIONS	APPR.

MULLER ENGINEERING CO., INC.
CONSULTING ENGINEERS
 777 S. WADSWORTH BLVD. STE. 4-100
 LAKEWOOD, COLORADO 80226
 (303) 988-4939

MULLER

MEC PROJECT No. 12033.01

DESIGN
DRAWN
CHECK

PREPARED FOR:
 URBAN DRAINAGE AND
 FLOOD CONTROL
 DISTRICT



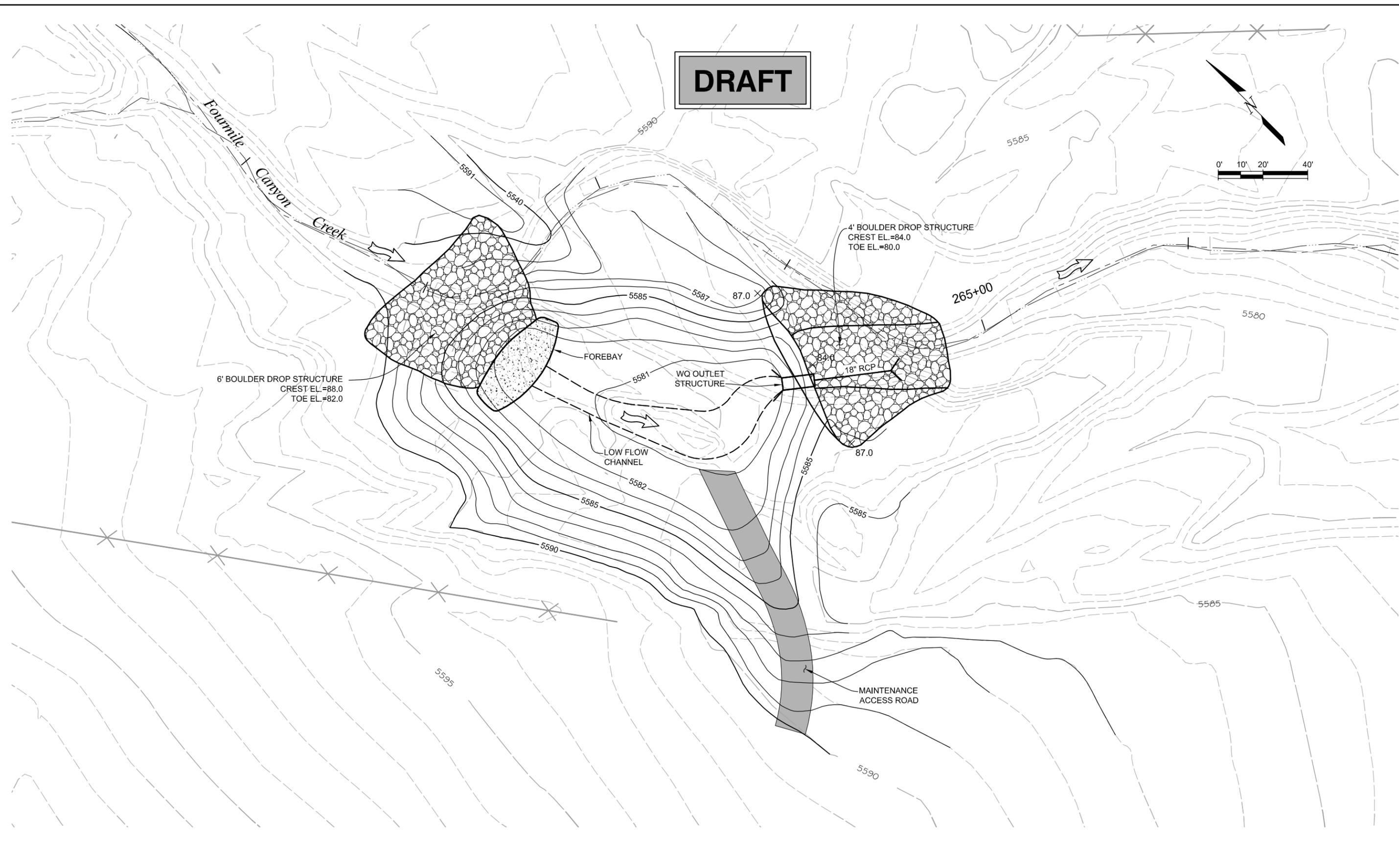
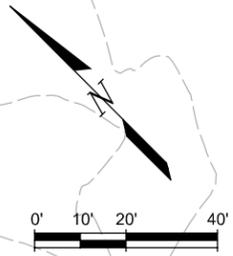
CITY OF BOULDER

**FOURMILE CANYON CREEK
 UPSTREAM OF BROADWAY**

**Sediment Basin
 Key Map**

DATE	SEPT. 13, 2012
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MULLER ENGINEERING CO., INC.
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 LAKEWOOD, COLORADO 80226
 (303) 988-4939

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 FLOOD CONTROL
 DISTRICT



CITY OF BOULDER

**FOURMILE CANYON CREEK
 UPSTREAM OF BROADWAY**

**Sediment Basin
 Alternative 4**

DATE
 SEPT. 13, 2012
 DRAWING NO.
 SHEET NO.
 5 OF 5

MEC PROJECT No. 12033.01