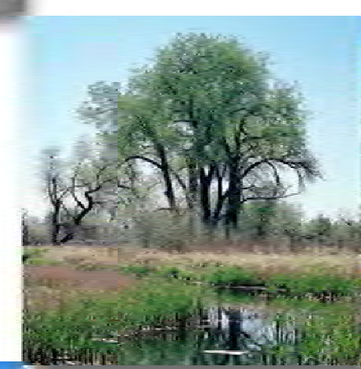
SOUTH BOULDER CREEK MAJOR DRAINAGEWAY PLAN–
DRAFT ALTERNATIVES ANALYSIS REPORT

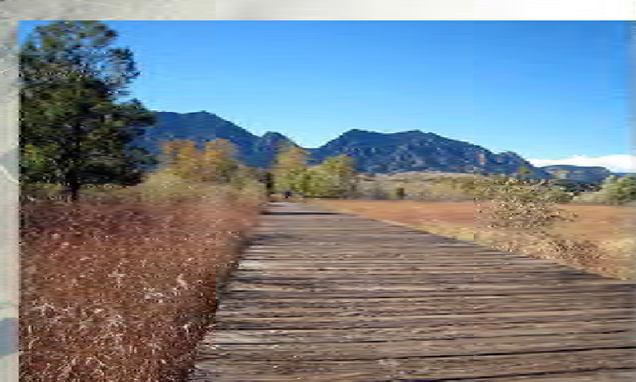
Prepared for:

CITY OF BOULDER

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

DRAFT JUNE 2012





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ACRONYMS

AC	ACRE
AF	ACRE-FEET
AG	AGRICULTURAL LANDUSE
BCA	BENEFIT COST ANALYSIS
BSDS	BASIN SPECIFIC DESIGN STORM
BVCP	BOULDER VALLEY COMPREHENSIVE PLAN
BVSD	BOULDER VALLEY SCHOOL DISTRICT
CB	COMMUNITY BUSINESS LANDUSE DESIGNATION
CDEM	COLORADO DEPARTMENT OF EMERGENCY MANAGEMENT
CDOT	COLORADO DEPARTMENT OF TRANSPORTATION
CFS	CUBIC FEET PER A SECOND
CMP	CORRUGATED METAL PIPE
CU	UNIVERSITY OF COLORADO
DC	DRY CREEK NO. 2 DITCH REACH
DFIRM	DIGITAL FLOOD INSURANCE RATE MAP
DHI	DANISH HYDROLOGIC INSTITUTE
DRCOG	DENVER REGIONAL COUNCIL OF GOVERNMENTS
EA	EACH
EIS	ENVIRONMENTAL IMPACT STATEMENT
EPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ES	EXECUTIVE SUMMARY
FEMA	FEDERAL EMERGENCY MANAGEMENT AGENCY
FFA	FLOOD FREQUENCY ANALYSIS
FIS	FLOOD INSURANCE STUDY
FT	FOOT
GIS	GEOGRAPHIC INFORMATION SYSTEM
G STORM	GENERAL STORM
HAZUS-MH	HAZARDS UNITED STATES MULTI HAZARD
HD	HIGH DENSITY RESIDENTIAL AND MOBILE HOME LANDUSE
HEC	HYDROLOGIC ENGINEERING CENTER
HWY	HIGHWAY
LD	LOW DENSITY AND RURAL RESIDENTIAL LANDUSE
LF	LINEAR FOOT
LS	LUMP SUM
MD	MEDIUM AND MIXED DENSITY RESIDENTIAL LANDUSE
MP	MASTER PLAN
NA	NOT APPLICABLE
NAD	NORTH AMERICAN DATUM
NAVD88	NORTH AMERICAN VERTICAL DATUM OF 1988
OHWM	ORDINARY HIGH WATER MARK
PAL	PROVISIONALLY ACCREDITED LEVEE
PKWY	PARKWAY
PMJM	PREBLES MEADOW JUMPING MOUSE
PU	PUBLIC LANDUSE
RB	REGIONAL BUSINESS LANDUSE
RCBC	REINFORCED CONCRETE BOX CULVERT
RCP	REINFORCED CONCRETE PIPE
RP	RETURN PERIOD

Acronyms (Continued)

RTD	REGIONAL TRANSPORTATION DISTRICT
SBC	SOUTH BOULDER CREEK
SF	SQUARE FOOT
SFHA	SPECIAL FLOOD HAZARD AREA
SWMM	STORM WATER MANAGEMENT MODEL
SY	SQUARE YARD
T STORM	DESIGN THUNDER STORM
U.S.	UNITED STATES
UDFCD	URBAN DRAINAGE AND FLOOD CONTROL DISTIRCT
USACE	UNITED STATES ARMY CORPS OF ENGINEERS
USDCM	URBAN STORMWATER DRAINAGE CRITERIA MANUAL
USFWS	UNTIED STATES FISH AND WILDLIFE SERVICE
VH	VERY HEAVY RIPRAP (D50 = 24")
W	WEST
WRAB	WATER RESOURCES ADVISORY BOARD
WV	WEST VALLEY REACH DESIGNATION

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ES. Executive Summary

Purpose and Scope

This Major Drainageway Planning Study was prepared as part of the *South Boulder Creek Flood Mitigation Study* (Study) authorized by the City of Boulder (Boulder) through Purchase Order 98 2009 DP005380 on December 23, 2009. The Urban Drainage and Flood Control District (District) was a financial participant in the project and provided oversight during the project execution.

South Boulder Creek is a major drainageway that conveys stormwater runoff from Eldorado Canyon west of the City of Boulder through the eastern portions of the City of Boulder. After leaving Eldorado Canyon and crossing Hwy 93 and US-36, South Boulder Creek follows several flow paths before reaching Boulder Creek. Development and other anthropogenic features subject the lower parts of the basin to periodic flooding because of overflows that propagate to one of the various flow paths. These overflows contribute to the flood hazard at areas far removed from the mainstem. In particular, much of the area known as the West Valley of South Boulder Creek (West Valley) lies along one of the historic low points and is subject to periodic flooding because of spills out of the main channel. The focus of this study is to address flooding problems in the lower portions of the basin within the City of Boulder, with a particular emphasis on the flooding problems through the area of the West Valley.

The project builds on the *Flood Mapping Study* (Mapping Study) completed by HDR Engineering, Inc. (HDR) in late 2008. That study produced floodplain maps. A *Risk Assessment Report (HDR, May 2009)* was also prepared that identified approximately $8.7 million dollars in annual damage from South Boulder Creek flooding and the addition of approximately 700 structures not previously identified as flood prone.

The focus of the Study is to define alternatives that address the flood problems in the West Valley, an area generally bounded by US-36 on the south, Mohawk Drive on the west, 55th Street on the east and Arapahoe Avenue on the North (Study Area). This area had been omitted from earlier flood maps prepared for the City. As such, much of the area was developed without consideration of the large flood threat from South Boulder Creek. The Study identifies drainage improvements that, in combination, provide the most beneficial means of addressing the identified flooding problems.

Planning Process

The process used to prepare the Study is to build a comprehensive master drainage plan using existing information, a suite of viable alternative elements and an evaluation of several alternative plans.

Existing information regarding the South Boulder Creek watershed was reviewed and stakeholders were engaged and asked to provide concerns and constraints. This information was used to develop a screening matrix to assess the effectiveness of the suite of potential solution approaches to address the identified problems. Alternatives elements that were patently infeasible, either for reasons of technical issues, cost, environmental issues or public input were eliminated and the remaining elements were then assembled into alternative plans.

Fifteen alternative plans were developed to address the identified problems in a holistic way, recognizing the benefits of certain upstream improvements to control downstream flood threats. These alternatives included a Status Quo alternative that proposed no improvements but did include the enforcement of the City's floodplain management and development regulations. Other alternatives included various structural components that provided improved storage, collection or conveyance of the flood flows, thereby reducing the flood threat. Sizing, alignments and costs were determined for each of the alternatives for a variety of discharges. Benefits were estimated using information developed previously in the Risk Assessment. Other considerations important to the City, such as preservation of Open Space and habitat areas, minimizing disruption to the community or conforming to broader City Policies were included in the evaluation of the alternatives. This information allowed a direct comparison among the alternatives and provided a foundation for the selection of Best Alternative Plans.

The nine Best Alternative Plans, described in Table ES-1, represent those plans from among the studied alternative plans that were able to address the flood hazard the most effectively. In many cases, these plans were not necessarily the least costly or the ones with the fewest environmental or public issues; rather, they were the plans that provided the greatest benefit for the investment and were felt to have other issues that could be mitigated.

TABLE ES-1

Best Alternative Plans

Alternative	Description
1	Status Quo
2	High Hazard Zone containment with critical structure flood proofing
3	Regional Detention at US-36 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
4	Regional Detention near Hwy-93 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
5	Distributed Regional Detention with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
6	Mainstem flow containment with local West Valley improvements
7	Dry Creek No. 2 Ditch pipeline
8	Bear Canyon Creek pipeline
9	Nuisance – Level Flood Improvement Protection

The evaluations conducted for these early alternatives were summarized and presented to key stakeholders representing major landowners and public infrastructure within the basin as well as the public, City Open Space and Mountain Parks (OSMP) Board, and the Water Resource Advisory Board (WRAB).

Based on recommendations from the Water Resources Advisory Board (WRAB) and Open Space and Mountain Parks (OSMP) staff, the Best Alternative Plans were reduced to five Best Alternate Plans that were to be refined based on additional interests and issues that were identified as being important in the selection and implementation of a selected alternative. The five alternatives identified for further evaluation include:

- Status Quo
- High Hazard Zone Mitigation
- Regional Detention at US-36
- Distributed Regional Detention
- Bear Canyon Creek Pipeline

The evaluation of each of the Best Alternative plans included many considerations. In addition to the financial and flood control elements implicit in the evaluation of the alternatives, the stakeholder involvement identified a number of other considerations that were assessed during the evaluation process. These issues are summarized below. Table ES-2 presents a summary of the findings of the Best Alternative Plan evaluation.

Benefit-Cost Analysis - The aggregated costs for each of the Best Alternative Plans were compared to the computed flood reduction benefits to determine a Benefit-Cost relationship for the alternative. This ratio provides a simple numeric measure of the return on investment but is not the sole basis for recommendation of a particular alternative.

Water Quality - All of the alternatives will continue to incorporate the ongoing measures already in place within the City to control impacts to water quality. In general, alternatives employing natural channels and detention storage will provide greater water quality benefits.

Natural Environment - Boulder has a longstanding tradition of nurturing, protecting and integrating greenways, Open Space lands, buffers, wetlands or other habitat areas. Areas containing high functioning wetlands have been avoided to the extent possible. In some cases, minor impacts to the fringes of these areas may have been unavoidable but the level of encroachment has been minimized.

Along South Boulder Creek, there are numerous areas where the groundwater table supplies an important water source for wetlands. Every effort was made to understand the nature of the groundwater near the proposed improvements and to avoid or minimize any potential adverse impacts.

Threatened and Endangered Species – The locations of threatened and endangered species consisting primarily of the orchid and the Preble's Meadow Jumping Mouse were investigated. The flood control measures proposed in the various Alternative Plans have been formulated to avoid these areas to the extent possible.

Open Space Lands - The alternatives identified in these plans were formulated to minimize the impacts to Open Space lands. However, since many of these lands fall in or near the conveyance areas of the channel, all impacts were unavoidable. The type and function of Open Space lands was considered in the layout of improvements associated with the Alternative Plans to limit physical improvements to the extent possible.

Social Impacts - Each of the projects, other than the Status Quo, has associated construction impacts that can generally be mitigated in the design and construction process. Efforts were made to minimize the potential permanent disruption to mature vegetation and existing sight lines.

The alignments identified for the various alternative plans were chosen to try to minimize the impact on private properties. Unfortunately, not all impacts to private property could be avoided. The costs for each of the plans include provisions for the purchase of easements or outright purchase of the property. The estimates are based on costs derived from the City's recent experience.

City Policies - During past studies of South Boulder Creek, the City identified guidelines that could be used as guidance in the development and evaluation of alternatives. Many of these reflect sound flood control principles while others reflect the collective interests of the community and its leadership. These issues, include avoiding channelization of South Boulder Creek, limiting the amount of private property necessary for the implementation of the alternatives, minimizing the use of large mainstem dams to control flooding, and a continued commitment to floodplain management are all incorporated to the extent possible.

TABLE ES-2
Best Alternative Plan Evaluation Summary

Alternative	Total Implementation Cost ($millions)	Present Worth of Benefits ($millions)	Benefit-to-Cost Ratio	Plan Elements	Significant Considerations
Status Quo	$0.00	$0.00	0	Maintains systems and processes as they are today.	Provides no enhanced flood protection anywhere in the system.
High Hazard Mitigation	$0.14	$0.00	0	Includes grading changes to eliminate structures from the designated High Hazard Zone.	Provides no substantive enhancement to level of flood protection anywhere in the system.
Regional Detention at US-36	$36.20	$77.30	2.14	Detention pond at US-36 reduces US-36 overtopping threat and eliminates 100-year floodplain within West Valley. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Meets defined objective of eliminating 100-year floodplain in West Valley. Some encroachment of facilities onto City-owned Open Space lands.
Distributed Regional Detention	$48.10	$75.90	1.58	Three detention ponds reduce US-36 overtopping threat to eliminate 100-year floodplain within West Valley and mitigate increased mainstem flows in channel downstream of US-36. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Meets defined objective of eliminating 100-year floodplain in West Valley. Significant encroachment of facilities onto Open Space lands and into identified habitat areas.
Bear Canyon Creek Pipeline	$46.80	$58.00	1.24	Inlets and pipelines to capture and convey overflows from US-36. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Generally addresses the objective of eliminating 100-year floodplain in West Valley with the exception of Apache Drive. Nominal impact to Open Space lands and identified habitat areas. Significant disruption to residential properties is expected during construction.

Engineer's Recommended Plan

The agreed upon scope of work requires the Engineer to provide a recommendation for City staff consideration. The Engineer's Recommended Plan is based on the described criteria and evaluations and represents the Engineer's best judgment. However, the Engineer may not be aware of issues or objectives that transcend the flood control objectives defined at the project's outset. As such, the Engineer's Recommended Plan should be viewed as a starting point to help the City understand the flood control issues, objectives and solutions and to allow City decision makers to refine, revise and modify the plan as necessary to achieve the broader community interests of the project.

Based on the refined analysis of the selected Best Alternative Plans, the **Regional Detention at US-36 Best Alternate Plan** was selected as the Engineer's Recommended Plan. The recommended plan includes a series of improvements to address the overtopping of US-36 and the flood concerns through the West Valley. This plan was selected because it removes approximately 700 structures from the 100-year floodplain, achieving the goals set at the onset of the project. In addition, this alternative has the highest Benefit-Cost Ratio of any of the alternatives reviewed.

The Engineer's Recommended Plan includes the following Features.

US-36 Detention Pond

The US-36 detention pond captures water from South Boulder Creek's west overbank south of US-36 eliminating the overtopping of US 36 during the 100-year event. The pond provides 560 AF of storage. The berm for the US-36 Pond parallels US-36, does have some impacts to OSMP land, and requires the inundation of a portion of the CU South Campus. The planned alignment and layout of the embankment features were designed to minimize the impacts to these areas to the extent possible.

Arapahoe Avenue Detention

The detention pond and associated outfall structures at Arapahoe Avenue take advantage of the Flatirons Golf Club golf course to provide 58 AF of storage that reduces the impact to downstream industrial and commercial properties. This facility also helps to collect shallow floodwaters that over top Arapahoe Road from the main stem of South Boulder Creek and the West Valley and convey them through two outlet channels below Arapahoe Avenue. The proposed west outfall will discharge flows to an existing flood channel that has adequate capacity while the east flood channel will require the construction of an outfall conveyance to return water to the South Boulder Creek mainstem. Both of these outfalls will work in tandem the detention to store and attenuate flows helping to alleviate flooding issues downstream of Arapahoe Road. There are some unavoidable impacts to City regulated wetlands that will require mitigation and the alternative requires the acquisition of some private property.

Improvements in the West Valley

Although the detention at US-36 eliminates the overtopping flooding from South Boulder Creek, facilities through the West Valley were still required to convey 100-year storm flows generated through the West Valley and discharged from the US-36 Detention outfalls. Improvements in the West Valley are either in the form of small detention facilities that are used to capture and attenuate flows or improvements to existing conveyance infrastructure. Alignments of all the facilities take full advantage of existing publically owned lands and minimize the number of individual property owners impacted and impacts to known utility lines.

- 25-AF of detention at Manhattan Middle School - Captures locally generated flows that can be discharged to the existing downstream infrastructure minimizing additional downstream system improvements.
- 9 AF Detention at the intersection of Foothills Parkway and Baseline Road - Collects flood flows at this intersection and discharges them to the channel parallel to Baseline Road taking advantage of the capacity of the downstream system.
- 2' Extension of the concrete retaining wall of along Baseline Road east of Foothills Parkway - Increase capacity of the channel and prevents overflows from entering the lower West Valley.
- Conveyance improvements to the New Anderson Ditch - Prevents overflows from entering the West Valley and conveys additional flow that results from the increased head generated by the storage above US-36.
- A wasteway structure for the Wellman Canal, east of Foothills Parkway - This will allow flood flows from Bear Canyon Creek that enter the Wellman canal to be discharged back into the Bear Canyon Creek historic channel. This improvement is required to help eliminate flood flows overtopping the Wellman Canal from causing additional flood hazards through the West Valley.
- 72 - Inch diameter pipe along Dry Creek No. 2 Ditch - This will convey 420 cfs of flows down the Dry Creek No. 2 Ditch corridor.

Engineer's Recommended Phasing

Implementation of the Recommended Plan will require the resolution of some issues that were outside the scope of the current Mitigation Planning Study. The study team believes these issues are not insurmountable and does not impose any fatal flaws on the Recommended Plan. Coordination with the University on the layout of the facilities associated with the US-36 Detention should continue. The proposed layout reflects early discussions but some further refinement may be desirable to optimize the use of the area while minimizing impacts from the berm. Similar refinements may be possible to further reduce the impact to Open Space lands. Working in concert with both CU and OSMP may provide further refinements that further optimize the use of the space.

Phasing of the elements of the Recommended Plan provides an opportunity to distribute the cost of implementation over a longer time and allows the community to reap benefits from the individual aspects of the improvements without full plan implementation. The elements of the Recommended Plan do allow for a phased implementation. The discussion below summarizes a possible Recommended Plan phased implementation recommendation.

Priority 1 – US-36 detention:

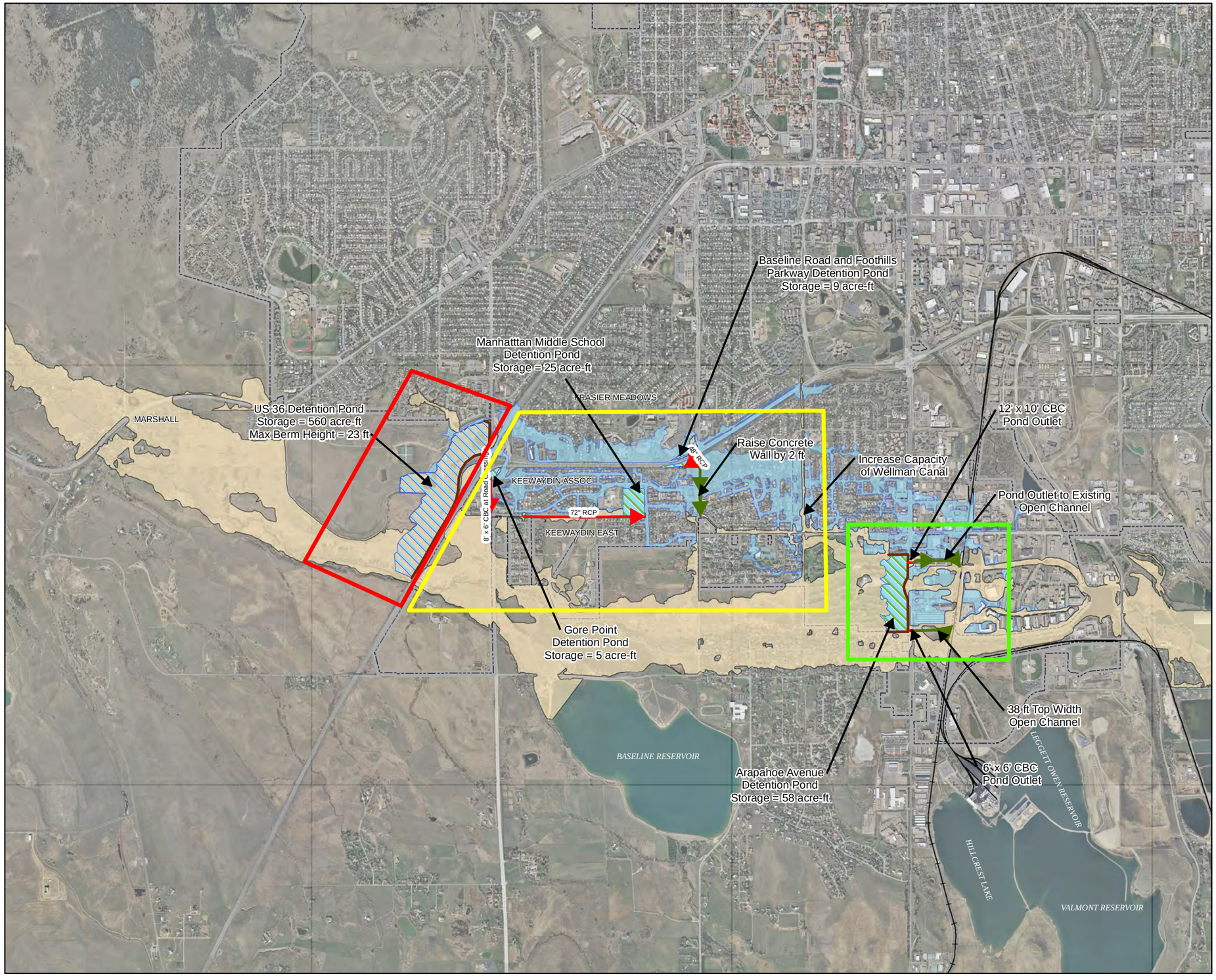
US-36 Detention is the recommended first element to be implemented. This project element fulfils the defined purpose of the project (reduce the flood hazard due to US-36 overtopping in the West Valley) without the need for further investment. In doing so, the flood insurance burden associated with the South Boulder Creek 100-year flood for those properties in the West Valley is eliminated and the real flood threat reduced to that of locally generated runoff flooding. . The proposed US-36 Detention facility has an element benefit-cost ratio of approximately 2.0 and an approximate capital cost of $13.3 million.

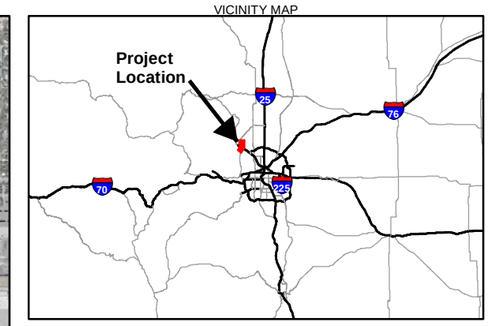
Priority 2 – Local West Valley Improvements

The proposed improvements in the West Valley address a number of different issues and are comprised of several smaller elements, including: local detention at Manhattan Middle School, Dry Creek No. 2 Ditch pipeline improvements, local detention at Baseline Road and Foothills Parkway, floodwall improvements along Baseline Road, improvements to the New Anderson Ditch and improvements to the Wellman Canal. Implementation of these elements should generally follow broad drainage facility implementation guidance. That is, detention can and should be implemented early in the process to fully exploit the flow reduction realized through these facilities. Then the flood control measures such as the pipeline improvements along Dry Creek No. 2 Ditch and along Baseline Road should be implemented to provide adequate conveyance of the remaining flows. The improvements to the other irrigation ditches are intended to prevent overflows and contain those flows in the original system. These can often be done independently of any other improvements and can be implemented as need or opportunities arise. In aggregate, these improvements are expected to cost $11.0 million to implement and result in a benefit-cost ratio of 3.2.

Priority 3 – Arapahoe Avenue Detention

The Arapahoe Avenue detention pond and associated downstream improvements provide considerable flood relief to those properties below Arapahoe Avenue however; the floodplain reduction associated with these improvements is relatively localized making this the last of the suggested implementation priorities. The improvements are estimated to cost $11.9 million and will result in a benefit-cost ratio of 1.3.





LEGEND

Conveyance Alignment

Category

- Open Channel Improvement
- Pipeline/Culvert Improvement
- Embankment
- Streams, Creeks and Ditches
- Detention at US 36
- Local Detention
- Post Project Floodplain
- Existing Floodplain

Notes:

1. Phase 1 Improvements
   US-36 Detention
   B/C Ratio = 2.0
2. Phase 2 Improvements
   West Valley Improvements
   B/C Ratio = 3.2
3. Phase 3 Improvements
   Arapahoe Avenue Detention
   B/C Ratio = 1.3

N

0 1,000 2,000 3,000 4,000
Feet

FIGURE ES-1
Regional Detention at US-36
South Boulder Creek Flood Mitigation Report

I. Introduction

The purpose of this report is to present the findings of the Major Drainageway Planning Study for South Boulder Creek. South Boulder Creek is a major drainageway that conveys stormwater runoff from Eldorado Canyon west of Boulder through the eastern portions of Boulder. The drainageway passes through areas outside the city limits within Boulder County. The focus of this study is to address flooding problems in the lower portions of the basin within the Boulder city limits, with a particular emphasis on the flooding problems through the area of the basin known as the West Valley.

Authorization

This Major Drainageway Planning Study was prepared as part of the *South Boulder Creek Flood Mitigation Study* (Study) authorized by the City of Boulder (Boulder) through a Purchase Order on December 23, 2009. The Urban Drainage and Flood Control District (District) was a financial participant in the project and provided oversight during the project execution. The Agreement authorizes CH2M HILL to develop a mitigation plan to address flooding along South Boulder Creek.

Purpose and Scope

The scope of the project builds on the Flood Mapping Study (Mapping Study) completed by HDR Engineering, Inc. (HDR) in late 2008. That project had a carefully developed scope that focused on the identification of flood issues along South Boulder Creek. Two important reports were developed during the Mapping Study, a *Climatology/Hydrology Report* (HDR, February 6, 2007) and a *Hydraulic Modeling Report* (HDR, December 30, 2008), both of which are important foundations for the development of the floodplain maps that were the ultimate product of the Mapping Study. In addition to the Mapping Study, HDR produced a *Risk Assessment Report* (HDR, May 2009) that assessed the flood risk caused by South Boulder Creek. This analysis identified approximately $8.7 million dollars average annual damage from South Boulder Creek flooding for all return periods studied and the addition of approximately 240 structures not previously identified as flood prone for a total of 700 individual structures located within the 100-year floodplain. This Study builds on the previous effort, identifies, and evaluates a number of alternatives to address the flood problems.

The focus of the Study is to define an alternative that will address the flood problems in the area known as the West Valley of South Boulder Creek (West Valley). This area is generally bounded by US-36 on the south, Mohawk Drive on the west, 55th Street on the east and Arapahoe Avenue on the North (Study Area). This area is the focus of the study because earlier studies did not identify a flood threat. As such, much of the area was developed without consideration of the large flood threat from South Boulder Creek. The Study identifies drainage improvements that, in combination, provide the most beneficial means of addressing the identified flooding problems. In some cases, the improvements identified provide benefits that extend beyond the limits of the West Valley and provide a broader benefit to other properties impacted by South Boulder Creek.

Planning Process

The process used to prepare the Study is to build a comprehensive master drainage plan using existing information, a suite of viable alternative elements, and an evaluation of several alternative plans. Engineering, economic and public interest evaluations were then considered before arriving at a recommended plan.

The planning process began with a careful review of the large body of existing information available regarding the South Boulder Creek watershed. Stakeholders were engaged and asked to provide concerns and constraints that they believed should be incorporated into the Study. This information provided a strong foundation of understanding of the flood hazard and its source. It also helped establish basic objectives against which all alternatives would be measured.

A screening matrix was developed that was used to assess the effectiveness of a suite of potential solution approaches to address the identified problems. This screening matrix was used to eliminate from further consideration the alternatives that were patently infeasible, either for reasons of technical issues, cost, environmental issues, or public input. The alternative elements that remained after the screening process were then assembled into alternative plans.

The alternative plans were built based on the screening process. The assembled elements were intended to address the identified problems in a holistic way, realizing the benefits of certain upstream improvements to control downstream flood threats. Sizing, alignments and costs were determined for each of the alternatives for a variety of discharges.

Benefits were estimated using information developed previously in the *Risk Assessment Report* (HDR, May 2009). This information provided a foundation for the comparison of the various alternatives and the selection of Best Alternative Plans.

The Best Alternative Plans represent those plans from among the studied alternative plans that were able to address the flood hazard the most effectively. In many cases, these plans were not necessarily the least costly or the ones with the fewest environmental or public issues; rather, they were the plans that provided the greatest benefit for the investment and were felt to have other issues that could be mitigated. These plans were refined to reflect a more detailed investigation of size, alignment, cost and potential mitigation requirements. Detailed hydraulic simulations were performed to generate a more refined estimate of the potential benefits associated with the various plans.

Using this information, a Recommended Plan (Plan) was identified. This Plan represents the plan that was deemed the most appropriate approach for the city to address the flood threat, particularly in the West Valley. The plan does not address every problem but does provide significant benefit relative to the estimated investment.

Public input was solicited and considered at each major step along the way. Key stakeholders representing major landowners and public infrastructure within the basin as well as Water Resources Advisory Board (WRAB) representatives were involved in periodic workshops that were used to review the various evaluation steps and support the selection of alternatives for future consideration.

In addition to the input from the city and Stakeholders, two public meetings were conducted to gather input and better understand the interests of the community. During the first public meeting, conducted on March 3, 2010 and attended by approximately 50 people, problem areas were identified and potential solutions were brought forward by members of the public. These comments generally identified areas where recurring flood problems had been observed and potential solutions that should be considered in the alternative development phase. The areas of concern and the potential solutions were both considered in the Study. A detailed summary of the first public meeting can be found in Appendix A.

The second public meeting was held on September 2, 2010. Staff presented a summary of the study progress to date and presented eight conceptual alternatives for public comment. Alternatives ranged from maintaining the status quo, constructing improvements to mitigate nuisance-flooding, protection of High Hazard Zone structures and critical facilities to constructing improvements to provide 100-year flood protection. Concept-level costs along with estimated benefits for each alternative were presented but it was emphasized that none of the alternatives have been ranked and no one alternative is currently recommended. One hundred seven (107) members of the public attended the meeting and 63 comment sheets were submitted. As a recommendation from this public meeting, a ninth alternative was introduced to include detention along the South Boulder Creek Mainstem from US-36 to Baseline Road. This alternative was proposed to prevent the impacts to private property at Highway 93 and at the Cu South Campus. A summary of this meeting with attached comment sheets can be found in Appendix A.

After the second public meeting and subsequent creation and refinement of the ninth alternative, identified in the second public meeting the first of Two WRAB meetings was conducted. At this meeting, the nine alternatives were presented to WRAB. After public comment and feedback from staff at the City of Boulder, WRAB recommended that four alternatives be moved forward for additional refinement before returning to WRAB with an Engineers recommended plan. The four alternatives selected for further refinement include:

- Status Quo Alternative
- High Hazard Mitigation and Flood Proofing
- Regional Detention at US-36
- Distributed Regional Detention

Upon the recommendations of OSMP a fifth alternative was added for additional refinement. This alternative is:

- Bear Canyon Creek Pipeline

OSMP wanted this alternative carried forward because it had the least impact to open space lands.

In response to public review and recommendations from WRAB, OSMP and city staff regarding the refinement of five alternatives, an additional Public Open House will be scheduled to review the five refined alternatives and the engineer's recommendations. Once this meeting has been held and public comments have been incorporated as necessary, the results of the refinement will be presented at one additional WRAB meeting and two City Council meetings for formal adoption.

Mapping

The mapping used in this study builds on the mapping developed as part of the Flood Mapping Study. One foot contour interval mapping surveyed in the North American Vertical Datum of 1988 (NAVD88) and the North American Datum of 1983 (NAD83) Colorado State Plane North Coordinates was developed in 2003 by Merrick and Company. Field surveys of major structures such as bridges and large culverts were provided by Merrick as part of the Mapping Study and were used in this work. Denver Regional Council of Governments (DRCOG) aerial photographs acquired in 2008 were used for this planning study.

Data Collection

Project data used for this study was provided by a number of different sources. Most of the data was obtained from the city's GIS databases and proved very useful in identifying constraints. Much of the city's data related to environmental overlays such as wetlands, Open Space and habitat areas. Similar data was obtained from Boulder County's (County) GIS database and supported the understanding of environmental conditions and constraints on County lands. The city's GIS databases were also used to obtain information related to the city's infrastructure as well as to update the property information used to estimate the financial implications of floods.

Other project stakeholders also provided information that was used in the formulation and evaluation of the various plans and plan elements. In particular, several past studies were reviewed as part of the flood Mapping Study. While some of these provided important background for the Flood Mapping Study, their application was limited for this project. However, the *South Boulder Creek Major Drainageway Planning Phase A Report*, (Taggert, 2001) completed by Taggert Engineering Associates (Taggert) in 2001 for the District provided important historical context for a better understanding of past planning efforts. Similarly, the US Army Corps of Engineers' (USACE) Reconnaissance Study, *Flood Risk Management and Ecosystem Restoration Study* (USACE, January 2010), provided some background on potential alternatives to address flooding along South Boulder Creek's mainstem and through the West Valley. Colorado Department of Transportation's (CDOT) *US-36 Corridor Final Environmental Impact Statement/Final Section 4(f) Evaluation* (EIS) (CDOT, October 2009), information related to the University of Colorado (CU) South campus planning efforts (South Campus Plan) were also provided and reviewed. A summary of data collected is given in Table 1-1, List of Gathered Data.

The collected data and information was used to understand the constraints that influence potential alternatives. In addition to the information described above that the city and the other Stakeholders provided, several meetings, primarily in the form of workshops, were conducted during which considerable discussion took place that was helpful in formulating plans and directing the project. These meetings proved to be invaluable in better understanding the information already collected and in securing additional information that supplemented the publically available information. Detailed summaries of these meetings are included in Appendix A. Several individual meetings were also held where project team members met with stakeholders to clarify and enhance the information provided.

In response to feedback received about one of the alternatives (a flood detention alternative that used private property near Hwy-93), staff was directed to develop and evaluate a ninth alternative for a flood detention facility that uses city Open Space property or private property with owners willing to sell.

TABLE 1-1
List of Gathered Data

Name	Author
South Boulder Creek Climatology/Hydrology Report February 2007	HDR Engineering, Inc.
South Boulder Creek Hydraulics Report 2008	HDR Engineering, Inc.

TABLE 1-1
List of Gathered Data

Name	Author
South Boulder Creek Risk Assessment 2009	HDR Engineering, Inc.
City of Boulder Stormwater Master Plan 2007	HDR Engineering, Inc.
1' Interval Topographic Map 2003	Merrick and Company
Structure Field Surveys 2003	Merrick and Company
Aerial Photography 2008	DRCOG
City of Boulder Greenways master Plan 2001	City of Boulder
City of Boulder Wetlands Maps	City of Boulder , GIS Mapping Services
City of Boulder Habitat Areas	City of Boulder , GIS Mapping Services
Critical Facilities	City of Boulder , GIS Mapping Services
Storm and Sanitary Sewer System Maps	City of Boulder , GIS Mapping Services
Boulder County Wetlands Maps	Boulder County , Geographic Information Services
Boulder County Habitat Areas	Boulder County , Geographic Information Services
Preble's Meadow Jumping Mouse Critical Habitat	Boulder County, Land Use Department
Cost Estimator for Master Planning 2010	Urban Drainage and Flood Control District
FEMA Benefit-Cost Analysis Software Version 4.5	Federal Emergency Management Agency
South Boulder Creek Phase A 2001	Taggert Engineering Inc.
South Boulder Reconnaissance Study 2010	USACE
US-36 Corridor EIS 2009	CDOT
South Campus Conceptual Master Plan	CU – Facilities Management

Planning Context, Laws, Regulations and Criteria

Other plans, laws, regulations and criteria that governed the development of the proposed alternatives included the following:

- *Boulder Valley Comprehensive Plan*
- *Boulder Revised Code*
- *Comprehensive Flood and Stormwater Master Plan- 2004*
- *Urban Drainage and Flood Control District (UDFCD) Urban Stormwater Drainage Criteria Manual (USDCM) (Volumes 1, 2, and 3),*
- *City of Boulder Comprehensive Flood and Stormwater Master Plan*
- *City of Boulder Design and Construction Standards*
- *City of Boulder Open Space and Mountain Parks Regulations*

South Boulder Creek and the riparian areas adjacent to the stream have been identified as having a number of wetland areas, many of which have been determined to be high functional. Work in these areas must be done in accordance with the city's *Stream, Wetland and Water Body Protection Ordinance*. Any work done along drainages that result in fill being placed below the Ordinary High Water Mark (OHWM) is required to be permitted by the United States Army Corps of Engineers (USACE) under *Section 404 of the Clean Water Act*. Any impacts to threatened and endangered species are

governed by requirements from the U.S. Fish and Wildlife Service (USFWS), the Colorado Division of Wildlife (CDOW) and city.

Finally, one of the *Boulder Valley Comprehensive Plan* (BVCP) general policies states that the City of Boulder is committed to the preservation of Open Space and the use of Open Space buffers to define the community. Lands owned by the City of Boulder Open Space and Mountain Parks (OSMP) include restrictions and requirements for improvements that will need to be carefully considered and incorporated in the alternatives analysis and conceptual design.

Acknowledgements

This Study was completed with support and input from a variety of city staff representing many different city departments and public and private stakeholders, including the District, CU, CDOT and USACE. In addition, WRAB was represented throughout the project. Many of the key participants are shown in Table 1-2, Project Contributors.

TABLE 1-2

Project Contributors

Project Team Members	**Affiliation**	***Role***
Kurt Bauer	City	*Project Manager*
Bob Harberg	City	*Project Coordinator*
Jeff Arthur	City	*Director of Public Works for Utilities*
Ned Williams	City	*Former Director of Public Works for Utilities*
Annie Noble	City	*Greenways Coordinator*
Don D'Amico	City	*Open Space Representative*
Chuck Howe	City	*WRAB Representative*
Shea Thomas	District	*Project Sponsor*
Ken MacKenzie	District	*Project Sponsor*
Dave Webster	Boulder County	*Boulder County Floodplain Administrator*
Jeff Lipton	CU	*Stakeholder*
Steve Griffin	CDOT	*Stakeholder*
Bob Hays	CDOT	*Stakeholder*
Kayla Eckert Uptmor	USACE	*Stakeholder*
Mark Nelson	USACE	*Stakeholder*
Chris Fassero	USACE	*Stakeholder*
Mark Glidden	CH2M HILL	*Project Manager*
Alan Turner	CH2M HILL	*Assistant Project Manager*
Aaron Cook	CH2M HILL	*Staff Engineer*
Alan Taylor	Alan Taylor Consulting	*Sub-Consultant*
Eric Fontenot	DHI	*Sub-Consultant*
Mark Taylor	Architerra Group	*Sub-Consultant*

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II. Study Area Description

Study Area

The South Boulder Creek basin is located in southern Boulder County and crosses the southern and eastern edges of the City of Boulder. The watershed covers approximately 136 square miles, starting at the Continental Divide, and extends over 27 miles to the confluence with Boulder Creek. Gross Reservoir lies in the basin and collects runoff from the upper 90 square miles. The basin below Gross Reservoir does not contain a similar major control structure but is crossed by several roadway corridors and numerous active irrigation canals that affect the flow patterns in the basin. Figure 2-1, Basin Delineation, depicts the watershed and the Study Area.

The basin flows out of the mountains and foothills near Eldorado Springs and enters a broad alluvial valley. Here flows work their way to the north to the confluence with Boulder Creek. The channel has followed several historic flow paths before reaching its current alignment. Development and other anthropogenic features have resulted in less channel migration but have subjected the lower parts of the basin to periodic flooding because of overflows that propagate to one of the historic flow paths. These overflows contribute to the flood hazard at areas far removed from the mainstem. These areas are generally in the lower parts of the watershed and extend across much of the alluvial valley below US-36. In particular, much of the area known as the West Valley lies along one of the historic low points and is subject to periodic flooding because of spills out of the main channel.

South Boulder Creek lies adjacent to Bear Canyon Creek and is often impacted by overflows from that basin. Undersized infrastructure along Bear Canyon Creek results in flows spilling out of the channel and flowing along other flow paths to join South Boulder Creek. These flows, while not native to South Boulder Creek, do cause impacts.

After the completion of the Flood Mapping study by HDR and subsequent delineation of the revised floodplain boundaries for South Boulder Creek, many additional residences were identified as being located within the Special Flood Hazard Area (SFHA). The delineation of the South Boulder Creek Floodplain indicated that over 1,200 dwelling units (700 structures) along South Boulder Creek were being inundated by the revised 100-year flood plain. Currently there are approximately 460 identified structures in the existing 100-year floodplain (approximately 500 dwelling units). The South Boulder Creek Flood Study identified approximately 240 additional structures that were previously unidentified as being within the 100-year floodplain. Figure 2-2, Revised Regulatory Floodplain, depicts the 100-year revised floodplain for South Boulder Creek and includes the structures impacted by the revised floodplain.

The Mitigation Study focuses on the watershed below Hwy-93 within the city limits and, in particular, the areas subjected to flooding through the West Valley.

Land Use

The upper parts of the South Boulder Creek basin are undeveloped and relatively rugged. Rocky outcrops, trees and forest vegetation dominate the watershed above Gross Reservoir. In fact, the area below Gross Reservoir but above Eldorado Springs has similar characteristics.

Once below Eldorado Springs, the character of the watershed changes dramatically. Either large tracts of Open Space exist, in the form of agricultural lands or city owned Open Space, some of which is being leased for agricultural purposes. There are also areas of very low-density residential development.

Highway 93 marks a shift from agricultural and Open Space to more traditional urban development. The segment between Highway 93 and US-36 is transitional with large areas of Open Space along the channel, more dense residential developments along the floodplain fringe and the University of Colorado South Campus immediately adjacent to US-36. The channel has been generally left undisturbed but the overbanks exhibit the effects of past development.

Downstream of US-36, the floodplain is almost fully covered with residential properties or designated Open Space areas. The residential areas, with minor pockets of commercial and industrial development, are generally along the western portion of the floodplain and include the West Valley. This area has formal drainage conveyance via storm drain systems that are sized to convey local “nuisance” flows with major flood flows being conveyed along streets and irrigation canals such as the Dry Creek No. 2 Ditch.

The areas adjacent to the mainstem of Boulder Creek have a much lower level of development and are dominated by publically owned Open Space lands. A few enclaves of development, largely in unincorporated areas of Boulder County, encroach into the mainstem floodplain.

There is a shift from residential to commercial and industrial development near Arapahoe Avenue. Immediately upstream of Arapahoe Avenue is the Flatirons Golf Course and adjacent residential developments. On the downstream side (north) is an area of commercial and industrial development that extends across much of the floodplain and down to the confluence with Boulder Creek almost a mile downstream.

The city and county have both made significant investments in acquisition of Open Space lands and the development of an extensive network of trails and other recreational facilities. While representing a small fraction of the overall lower basin area, these Open Space lands do dominate the floodplain near the mainstem.

Figure 2-3, Lower Basin Land Use, depicts the lands uses across the floodplain of South Boulder Creek through the Study Area.

Reach Descriptions

The Study Area has been subdivided into several reaches representing differing flood hazards and land use conditions. Figure 2-4, Reach Designation, shows these various reaches in the Study Area.

Reach 1

The mainstem channel between Highway 93 and US-36 is designated Reach M1. The overbanks of the floodplain are largely undeveloped with the exception of a small trailer park adjacent to Marshall Road downstream of Highway 93 and several single family homes around Marshall Road. Much of the land along this reach has been designated as Open Space. In the area immediately upstream of US-36, the University of Colorado has a large parcel of land designated as the South Campus. The area sits on the reclaimed site of a former gravel mining operation and is protected from the mainstem by a currently Provisionally Accredited Levee (PAL).

In addition, several threatened and endanger species have been identified on land south of US-36. These include an important occurrence of the federally threatened plant species, *Spiranthes diluvialis* or Ute lady's tresses orchid; an important population of the federally threatened animal species, Preble’s Meadow Jumping Mouse (PMJM); a population of an amphibian under status review by the U.S. Fish and Wildlife Service for listing as a federally threatened species, Northern Leopard Frog; a population of two native fish species believed in decline in Colorado, Plains Topminnow and Orange-Spotted Sunfish; and a population of a declining grassland nesting bird, Boblink.

Finally, one of the Boulder Valley Comprehensive Plan (BVCP) general policies states that the City of Boulder’s commitment to the preservation of Open Space and the use of Open Space buffers to define the community. Lands south of US-36 include lands with high ecological resources and land owned by the City of Boulder OSMP. These properties include an important remnant of the plains cottonwood riparian ecosystem; relicts of the tall grass prairie ecosystem; and wetlands that are considered to be among the best preserved and most ecologically significant in Boulder Valley. Careful design and restoration would be required to minimize environmental impacts and mitigate for impacts should an alternative that would affect these resources be selected.

Reach 2

Below US-36, three parallel alignments convey flow to the confluence with Boulder Creek. These three alignments are acknowledged in the reach designation. Reach WV2 represents the West Valley flows from US-36 to Baseline Road. This area is generally west of Foothills Parkway and is characterized by flow down existing residential streets. The primary conveyance is Thunderbird Drive where flow collects and is conveyed to the north. Numerous residential properties, both single and multifamily are subject to flooding because of flows in Reach WV2.

Reach DC2 is centered on the Dry Creek No. 2 Ditch. This represents one of the historic flow paths and serves as both a collection for, and a source of, flooding in the area. The reach consists of both open channel sections and closed conduits and crosses several roadways, including South Boulder Road and Tenino Avenue. Flooding along this reach is primarily to single family residential structures and is caused by both mainstem South Boulder Creek flooding as well as overflows from Dry Creek No. 2 Ditch during more frequent local floods

The final alignment is the Mainstem, Reach M2. This reach is largely natural with a well-defined main channel and a broad undeveloped overbank area. A crossing of South Boulder Road and the South Boulder Community Center are the only two material improvements along this reach. The floodplain, while broad through this area, has little impact on developed properties.

Reach 3

The area between Baseline Road and the Wellman Canal (approximately Colorado Avenue extended) also has three relatively distinct alignments. West Valley Reach 3 (WV3) crosses Foothills Parkway and Baseline Road near that intersection and flows to the north along McIntyre Street and Brooklawn Drive. There is limited flood conveyance infrastructure and the majority of the flow is conveyed on the surface of the street system. Structures along this reach are primarily single family residential.

Reach DC3 follows the alignment of Dry Creek No. 2 Ditch through residential areas, eventually reaching Arapahoe Avenue to the north. The conveyance through this reach is primarily through an open channel with large culverts at major crossings such as 55th Street. Once again, the flood threat to the adjacent properties comes from both South Boulder Creek flows and local runoff captured and conveyed that exceed the available capacity in the ditch and local storm drain system.

The channel through reach M3 is natural and areas of Open Space lands lie to the west of the main channel and provide considerable overbank conveyance. However, the area immediately to the east of the mainstem consists of residential structures along Gaptor Road that are subject to periodic flooding from even relatively small events with residences experiencing flooding during 10-year storm events. Anecdotal evidence from residents of the area has indicated that damage from the 1969 flood occurred from both channel flooding and groundwater flooding. The South Boulder Creek channel through this area has a very limited capacity with homes located against the banks.

Reach 4

The channel between the Wellman Canal (approximately Colorado Avenue extended) and Arapahoe Avenue comprises Reach 4. In this reach, the three conveyance paths remain, but they tend to be less distinct and flooding from one path has a tendency to affect the others.

Reach WV4 extends to the north and east, eventually reaching Eisenhower Drive and Arapahoe Avenue. Once again, there is limited infrastructure to convey flood flows, so they flow on the surface of the street and across grassed areas. The southern portion of the reach is dominated by single-family residential properties while those areas closer to Arapahoe Avenue are generally multifamily.

Reach DC4 follows 55th Street north to Centennial Trail and then extends northwest across Flatirons Golf Course to Arapahoe Avenue just west of the entrance to the golf course property.

Flows in the mainstem, Reach M4, travel north following an alignment parallel to the eastern boundary of the golf course but between Old Tale Road and Cherryvale Road. Much of the flood hazard is contained within the golf course but properties along both Old Tale Road and Cherryvale Road are subject to periodic flooding from the 100-year flood event.

Reach 5

Below Arapahoe, the West Valley Reach (WV5) extends north through commercial and industrial properties and joins Boulder Creek considerably upstream of the confluence of the South Boulder Creek mainstem with Boulder Creek. These flows follow an undersized conveyance and are largely conveyed across the surface of the ground on streets and paved parking areas.

Reach DC5 is a well-defined channel with mature vegetation that crosses the railroad track and several local roads along the western boundary of Flatirons Industrial Park before joining the mainstem of South Boulder Creek at the north end of the Flatirons Industrial Park.

The mainstem of South Boulder Creek (Reach M5) crosses under the railroad track and then follows the west boundary of Flatirons Industrial Park before extending to the north under Valmont Road and then joining the floodplain of Boulder Creek. This channel is very well defined and has mature vegetation along the invert.

Flood History

Flooding along South Boulder Creek has not been common over the last 100 years. However, the floods that have occurred were widespread and had significant impacts ranging from structure damage in Eldorado Springs to residential flooding and roadway overtopping in the city and the West Valley. The three events that appear to have caused the most disruption occurred in 1938, in the 1950s and in 1969. Each has been attributed to a different source.

The 1938 flood generated the highest recorded peak flow at the Eldorado Springs Stream gage. The HDR *Climatology/Hydrology Report (HDR, February 6, 2007)* characterized this storm as one with subtropical origins. This flood was the result of an estimated 5 – 7 inches of rainfall over a 6-hour period. The resulting flood caused great damage in Eldorado Springs and resulted in flooding that damaged several bridges downstream through Boulder.

The floods in the 1950s were described by Taggert in the *South Boulder Creek Major Drainageway Planning Phase A Report*. In that characterization, it was noted that no major flood events were recorded at the Eldorado Springs Stream gage, but that the West Valley experienced floods on numerous occasions. These floods were attributed to development in the lower basin and the impacts from the resulting flow increases on existing drainage infrastructure, including irrigation ditches serving as drainage channels. Large flows that overwhelmed drainage facilities on Bear Canyon Creek had similar impacts and caused localized flooding.

In 1969, a flood resulting from what the HDR *Climatology/Hydrology Report (HDR, February 6, 2007)* described as a long duration, low intensity general rain. This storm was widespread across the basin and resulting in up to 13 inches of rain over 72 hours. Flood flows at US-36 backed up and eventually overtopped the highway, spreading into the West Valley. Taggert, in the *South Boulder Creek Major Drainageway Planning Phase A Report* indicated that local drainage from many of the local tributaries to South Boulder Creek was likely to have contributed to the overflow and West Valley flooding.

Wetland and Riparian Zones

The Study Area has a number of designated wetland and riparian zones. These identified areas contain important functional values that warrant special consideration. It is the intent of the city to preserve, protect, restore and enhance the quality and diversity of wetlands and water bodies. Streams, wetlands and water bodies are indispensable and fragile natural resources with significant development constraints due to high groundwater, flooding, erosion and soil limitations. Development activities in and around these wetlands may pose a threat these resources. The preservation of streams, wetlands and water bodies under the *Streams, Wetlands and Water Body Protection Ordinance (9-3-9)* is consistent with the goal of wetland protection set forth in the Boulder Valley Comprehensive Plan.

The city has defined two wetland and water body designations as adopted on regulatory maps. These two designations are High Functioning and Low Functioning and are defined below:

- High Functioning: The additive value of all adopted functional value ratings, excluding recreation, equals twenty-six or more; or at least one function, excluding recreation, is rated high or very high.
- Low Functioning: The additive value of all adopted functional value ratings, excluding recreation, equals twenty-five or below.

The functions of all regulated stream, wetland and water bodies within the city limits have been evaluated and are described in the *City of Boulder, Comprehensive Wetlands Remapping Project* by Land Stewardship Consulting, October 18, 2004. The *Streams, Wetlands and Water Body Protection Ordinance (9-3-9)* outlines buffer areas for all regulated streams, wetlands and water bodies. These buffer zones vary based on stream wetland or water body designation as defined above. Buffer widths for each designation are defined below:

- The buffer area width for High Functioning streams, wetlands and water bodies shall be fifty feet and shall include an inner and outer buffer area.
  - The inner buffer area width shall be twenty-five feet from each point on the stream, wetland or water body boundary.

- The outer buffer area width shall be twenty-five feet from each point on the inner buffer area boundary.

- The total buffer area width for Low Functioning streams, wetlands and water bodies shall be twenty-five feet from each point on the stream, wetland or water body boundary and shall be considered an outer buffer area.

High and low functioning wetlands are depicted on Figure 2-5, Wetland and Riparian Zones, and specific requirements for projects involving these areas have been established. Wetlands identified on Figure 2-5 impacted by any proposed alternative would have to provide the following:

- The proposed alternative shall not result in a significant change to the hydrology affecting the stream, wetland or water body. Percolation of storm runoff on-site through vegetated swales, permeable paving materials or other similar methods to slow and clean runoff being discharged directly into the wetland, stream or water body may be required.

- The proposed activity shall demonstrate that the alternative is designed and located to minimize direct or indirect impacts to the adjacent wetland, stream or water body.

- The alternative shall demonstrate that if unavoidable direct and indirect impacts to vegetation, pervious surface or hydrology affecting the adjacent stream, wetland or water body then the direct and indirect impacts can be successfully mitigated through design of the alternative or by compensating for the impact. Alternative shall demonstrate protection of species and demonstrate that the alternative will not jeopardize the continued existence of habitat for the following species:

  - Plant, animal or other wildlife species listed as threatened or endangered by the United States Fish and Wildlife Service;

  - Plant, animal or other wildlife species listed by the State of Colorado as rare, threatened or endangered, species of special concern;

  - Plant, animal or other wildlife species listed in the Boulder County Comprehensive Plan as critical; and

  - Plant, animal or other wildlife species listed in the Boulder Valley Comprehensive Plan as a Species of Local Concern.

All wetlands within the Project Area are category A or category B and would be required to be mitigated or enhanced if disturbed by the recommended plan.

Flora, Fauna and Threatened and Endangered Species

South Boulder Creek has many areas that are identified as important habitat areas. In some cases, these areas have been formally designated. In others, these areas have been preserved and protected by Open Space through habitat conservation areas or habitat conservation easements as defined in Figure 2-6, Identified Preble's Jumping Meadow Mouse Habitat and Proposed Conservation Corridor and Figure 2-7, Designated Habitat Conservation Areas.

As discussed previously, many of the areas along the mainstem of South Boulder Creek have been identified as areas of known habitat for several threatened and endanger species. These species include Ute lady's tresses orchid; Preble's Meadow Jumping Mouse (PMJM); Northern Leopard Frog; two native fish species believed in decline in Colorado, Plains Topminnow and Orange-Spotted Sunfish; and a grassland nesting bird, the Boblink. Lands south of US-36 include lands with high ecological resources and land owned by the City of Boulder OSMP. These properties include an important remnant of the plains cottonwood riparian ecosystem; relicts of the tall grass prairie ecosystem; and wetlands that are considered to be among the best preserved and most ecologically significant in Boulder Valley. Specific mapped areas for all of the endangered species are currently not available. However, an understanding of the presence of these habitat areas dictates that any potential improvements must carefully consider potential impacts. In many case, the city and County have been proactive and have identified general areas of critical habitat and has designated these for special oversight. These areas are shown in Figure 2-7, Designated Habitat Conservation Areas.

Both the city and County also recognize that lands within the Study Area offer great benefit for a number of other natural uses. This recognition has resulted in a considerable amount of land having an Open Space designation. These lands are commonly owned by the city and are intended to be left in their natural state to preserve the important natural functions already identified. These functions may range from providing a natural buffer between riparian corridors and adjacent developed properties to preserving important floodplain functions such as flood storage and providing habitat to important plant and animals. Open Space lands have been indentified in Figure 2-8, Open Space Lands.

In addition to the areas specifically designated as having important habitat or Open Space values, or even designated wetland areas, the Study Area has other amenities that are found to be of great value to the community. This area of Boulder has a long history of development and environmental stewardship by landowners and numerous aesthetic enhancements have been incorporated over the years. The most obvious among these is the mature vegetation that lines many of the area's drainageways.

Previous Studies

The South Boulder Creek basin has been the subject of many studies. Most have focused on the definition of the flood threat. The most recent of these is the HDR Flood Mapping Study. Several studies have attempted to identify mitigation measures to address the flood threat along South Boulder Creek.

US Army Corps of Engineers *Boulder Creek and South Boulder Creek Floodplain Information, Volume II, Boulder Metropolitan Area* 1969 was among the first to look at the watershed comprehensively. This proved to be the foundation for much of the early planning. This study acknowledges the broad floodplain and even notes that once flows leave the mainstem, they often flow in parallel channels that are below the elevation of the mainstem. However, the study failed to fully capture the high flow rates or the nature or extent of the threat to the West Valley.

The Wright McLaughlin Engineers *South Boulder Major Drainageways* (1970) looked at drainageways in the South Boulder area but not at the South Boulder Creek mainstem. The report did look at Viele and Bear Canyon Creek. The Viele Channel is an important tributary to South Boulder Creek. The report included a number of recommended improvements to the channel. The report also included proposed improvements along Bear Canyon Creek. While not intentionally tributary to South Boulder Creek, Bear Canyon Creek overflows do affect Sought Boulder Creek flooding.

R.W. Beck *Major Drainageway Planning Study, South Boulder Creek Volume II*, prepared for the District in 1973, defined the floodplain along the mainstem and proposed improvements, including several large detention ponds. This report also did not identify the significant flood threat through the West Valley.

Simons Li & Associates *Major Drainageway Planning Boulder Creek and South Boulder Creek Confluence Area*, prepared in 1983 focused on the area below Arapahoe Avenue. The report concluded there was little flood threat in this area based on improvements around the Flatirons Industrial Park area that were deemed adequate at the time. Subsequent interpretations of the adequacy of the facilities suggest a greater flood threat.

The Greenhorne & O'Mara *South Boulder Creek Flood Hazard Area Delineation* 1996 was the basis for the regulatory floodplain until the recent HDR studies. This study correctly identified the overflows of Hwy-93 and the limited capacity of the Dry Creek No. 2 Ditch system. They carefully delineated the resulting floodplain associated with these spills. However, the study did not include any overtopping of US-36 and the subsequent flood hazard to the West Valley. The flow rates used for this study closely resemble those of previous studies but there were slight variations in the final flow rates.

A *Floodplain Analysis of South Boulder Creek at the Flatiron Property in Boulder County, Colorado* 1996, prepared by Love and Associates was commissioned by the University of Colorado to provide a review of impacts on South Boulder Creek by the levee constructed to protect the property acquired by the University. This study was the first to identify and evaluate the significant spills that occur into the West Valley.

Taggert Engineering Associates was engaged to conduct a comprehensive evaluation of the flood threat along South Boulder Creek and to prepare a series of alternative mitigation measures for consideration. The reports *South Boulder Creek Interim Hydrology Study* 2000 and *South Boulder Creek Major Drainageway Planning Phase A Report* 2001, present the findings of these studies. These documents identify the hazard along the mainstem as well as that in the West Valley. The studies also identified a number of alternatives to address the flood threat. The report was never fully accepted by the city and the recommendations were not implemented.

The recommended plan from the Taggert Study of South Boulder Creek Completed in January of 2012 included the following improvements.

- Relocation of 90 Residences in Marshall out of the South Boulder Creek Floodplain
- Stream restoration and spill stabilization above Highway 93
- Culvert replacement with a multiple cell box at Highway 93 with drainage improvements to convey flow through the downstream property
- South Boulder Creek Spill Structure upstream of U.S. 36 along the west bank of South Boulder Creek to force additional flows to remain in the South Boulder Creek channel
- Flood storage at US 36 using a 10 - 13 foot high embankment and excavation on the CU south campus property
- Construction of a large stormsewer from Thunderbird Lane and discharging to an open waterway at Flatirons Crossing Golf Course
- Construction of a 7,000 linear foot meandering wetlands waterway from South Boulder Creek at 1,500 feet upstream of Baseline Road to the Flatirons Crossing Golf course. This channel will be constructed primarily on City of Boulder Parks and Open Space property and would require multiple culverts under Baseline Road and a new flume at the Wellman Canal.

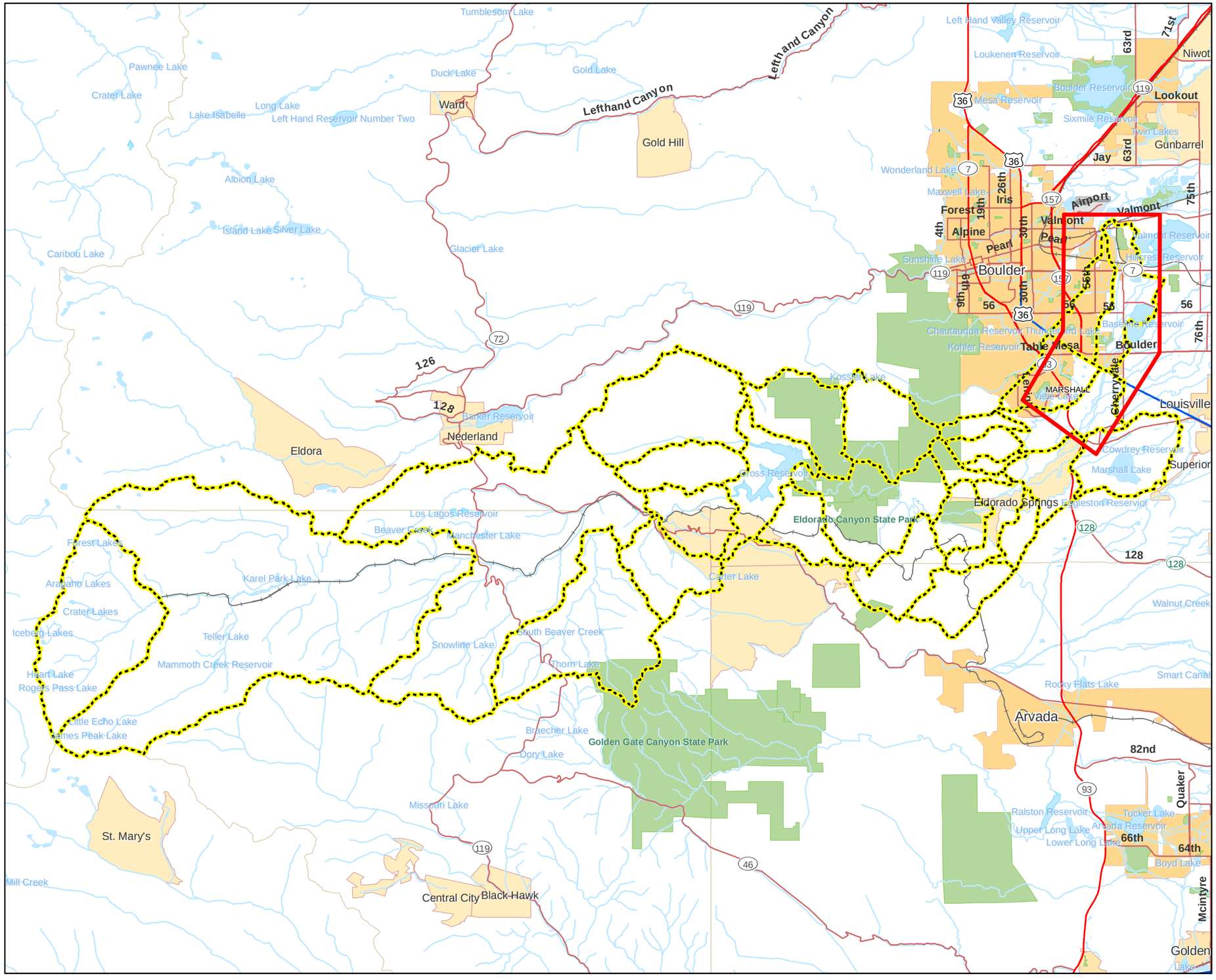
The estimated total cost of the Taggert flood mitigation alternative was estimated at $135,600,000 in 2001. This included land purchase costs, residual flood damages, flood hazard management, operation and maintenance costs and capital costs.

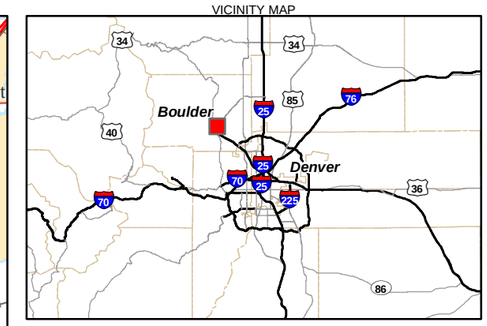
HDR recently completed the comprehensive Flood Mapping Study that includes three reports, *Climatology/Hydrology Report* (HDR, February 6, 2007), *Hydraulic Modeling Report* (HDR, December 30, 2008) and *Risk Assessment Report* (HDR, May 2009). These studies provided a comprehensive summary of the most recent hydrologic studies and the resulting floodplain and are currently being accepted by the Federal Emergency Management Agency (FEMA) as the regulatory flood studies for South Boulder Creek. These reports affirmed some of the flood threat along the mainstem and further defined the flood threat in the West Valley described earlier by Taggert and Love.

The US Army Corps of Engineers recently completed a *Reconnaissance Study Section 905(b) Preliminary Analysis Report, South Boulder Creek Boulder, Colorado, Flood Risk Management and Ecosystem Restoration Study*, 2010. This study focused on possible mitigation measures to address the flood issues along the mainstem and through the West Valley. This study was commissioned to determine the potential Federal interest in constructing one or more flood control projects along South Boulder Creek. This report heavily utilized the Taggert 2001 study as the primary source for evaluation alternatives and development of costs. The USACE evaluation of the Taggert report determined that Alternative 4 from the Taggert report could be economically feasible. This plan features the following flood control improvements:

- Additional storage in Gross Reservoir
- The construction of a 1,950 acre foot reservoir with a 54 foot high dam at Highway 93
- Channel improvements to South Boulder Creek from Highway 93 to downstream of Marshal Road
- South Boulder Creek Spill Structure upstream of U.S. 36 along the west bank of South Boulder Creek to force additional flows to remain in the South Boulder Creek channel
- A flood easement on the CU South Campus property for extreme floods
- Construction of a large stormsewer from Thunderbird Lane and discharging to an open waterway at Flatirons Crossing Golf Course

The total cost of Alternative 4 is $124,600,000. The USACE has completed an initial "Maximum Supportable Cost." This cost is estimated to be $185,000,000. This report concluded there would be a Federal interest in construction a flood control project focusing primarily on storage.





LEGEND

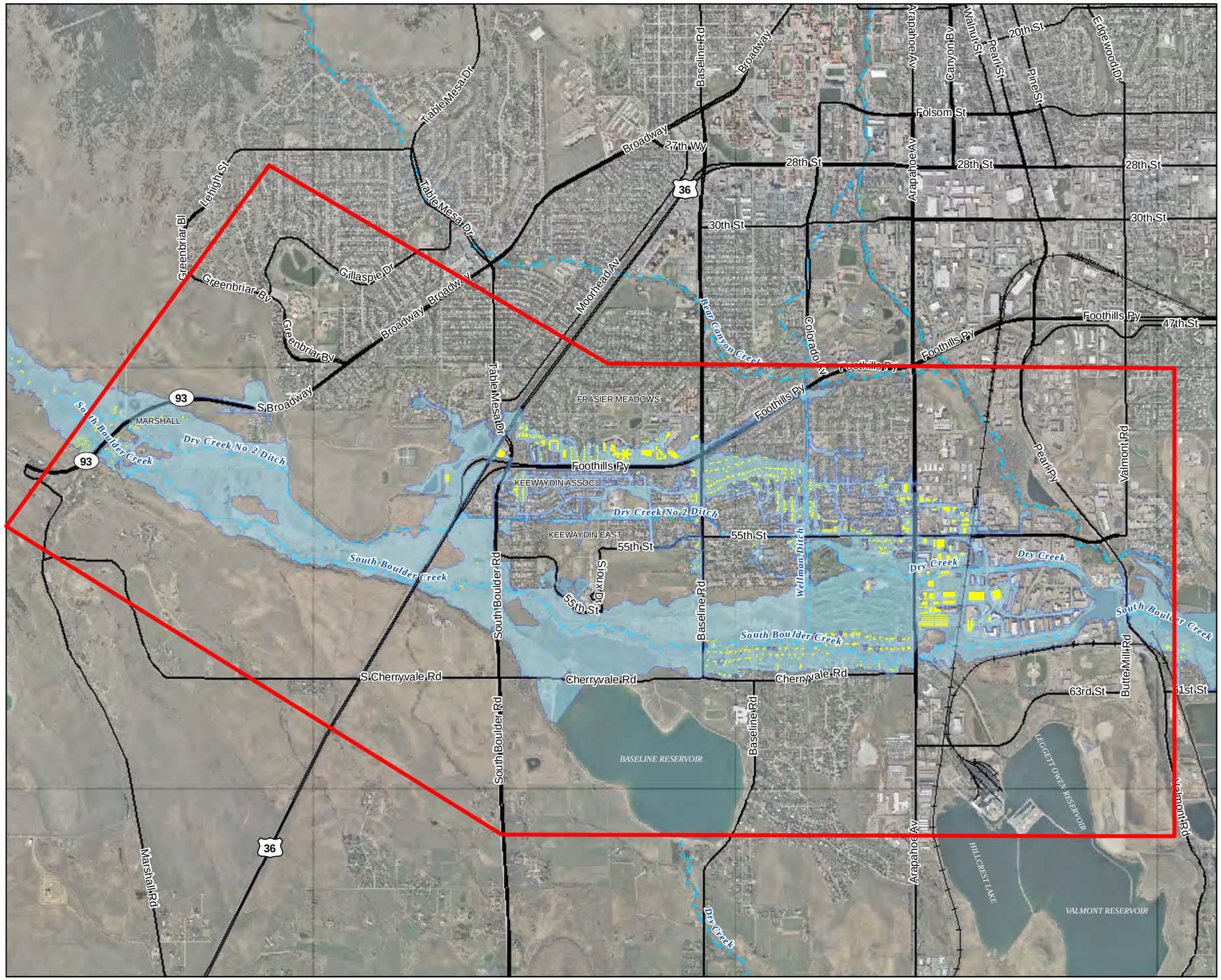
- South Boulder Creek Sub-Watersheds
- Primary Limited Access
- Primary US & State Highways
- Secondary State & County
- Railroads (150 to 50k)
- Rivers (150 to 50k)
- Airport Areas (150 to 50k)
- National Park - Forest
- State Park or Forest
- Local Park
- City Areas (5 to 3mil)
- County Boundaries (150 to 50k)

Notes:
1. Area of Interest

N

0 1 2 3 4
Miles

FIGURE 2-1
Basin Delineation
South Boulder Creek Flood Mitigation Report



VICINITY MAP

LEGEND

Structures within Revised Regulatory Floodplain

Revised Regulatory Floodplain

Streams, Creeks and Ditches

Streams, Creeks and Ditches

Boulder County

Notes:

1. Area of Interest
2. Revised regulatory floodplain impacts 1,253 structures

N

0 1,000 2,000 3,000 4,000 5,000

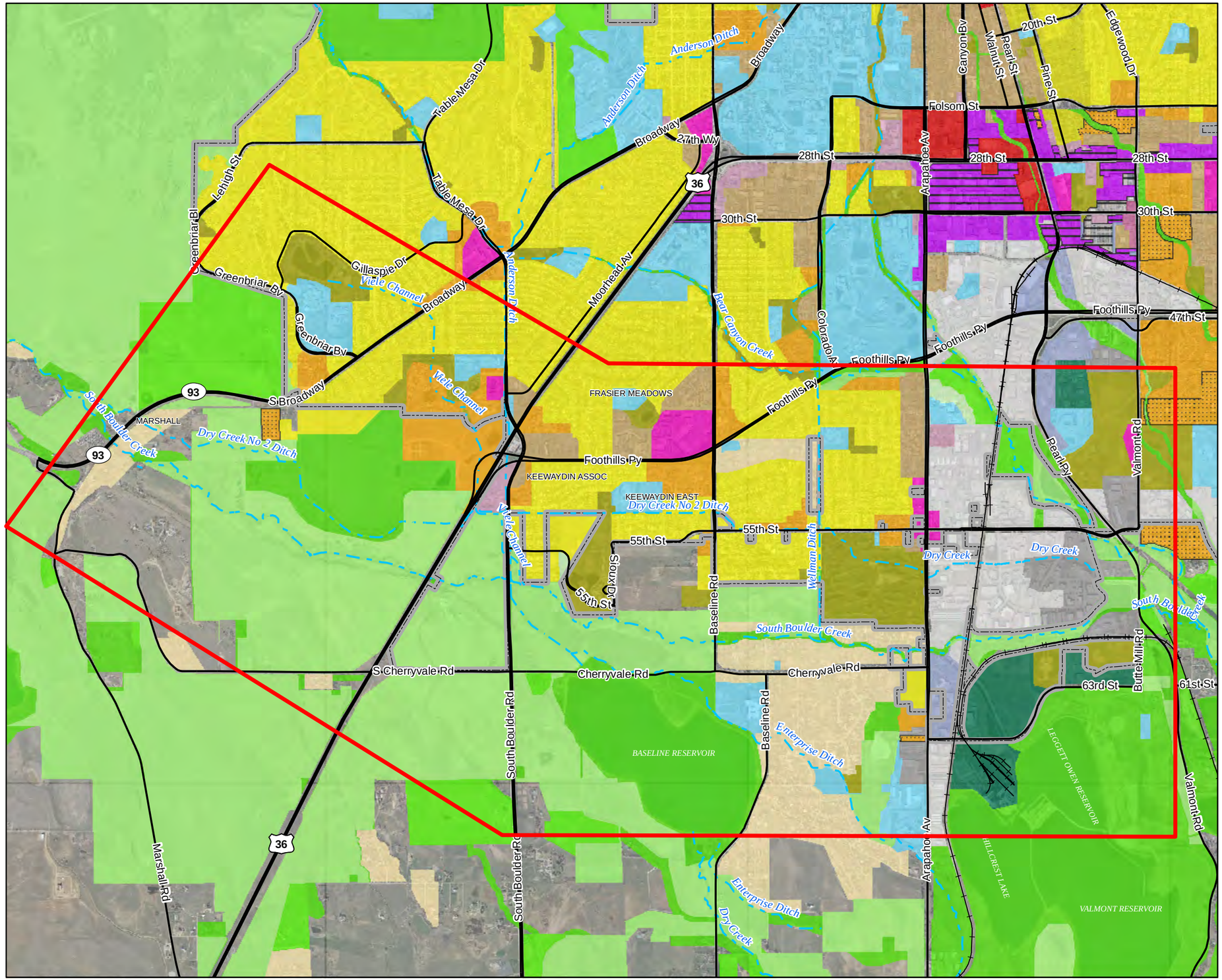
Feet

FIGURE 2-2

Revised Regulatory Floodplain

South Boulder Creek Flood Mitigation Report

South Boulder Creek Flood Mitigation Project



LEGEND

- Streams, Creeks and Ditches
- Boulder County Boundary

Residential

- Very Low Density Residential
- Low Density Residential
- Manufactured Housing
- Medium Density Residential
- Mixed Density Residential
- High Density Residential

Business

- Community Business
- General Business
- Service Commercial
- Transitional Business
- Regional Business

Industrial

- Community Industrial
- General Industrial
- Light Industrial
- Performance Industrial

Mixed Use

- Mixed Use Business
- Mixed Use Industrial
- Mixed Use Residential

Open Space and Mountain Parks

- Open Space, Aquired
- Open Space, Development Rights
- Open Space, Other

Other

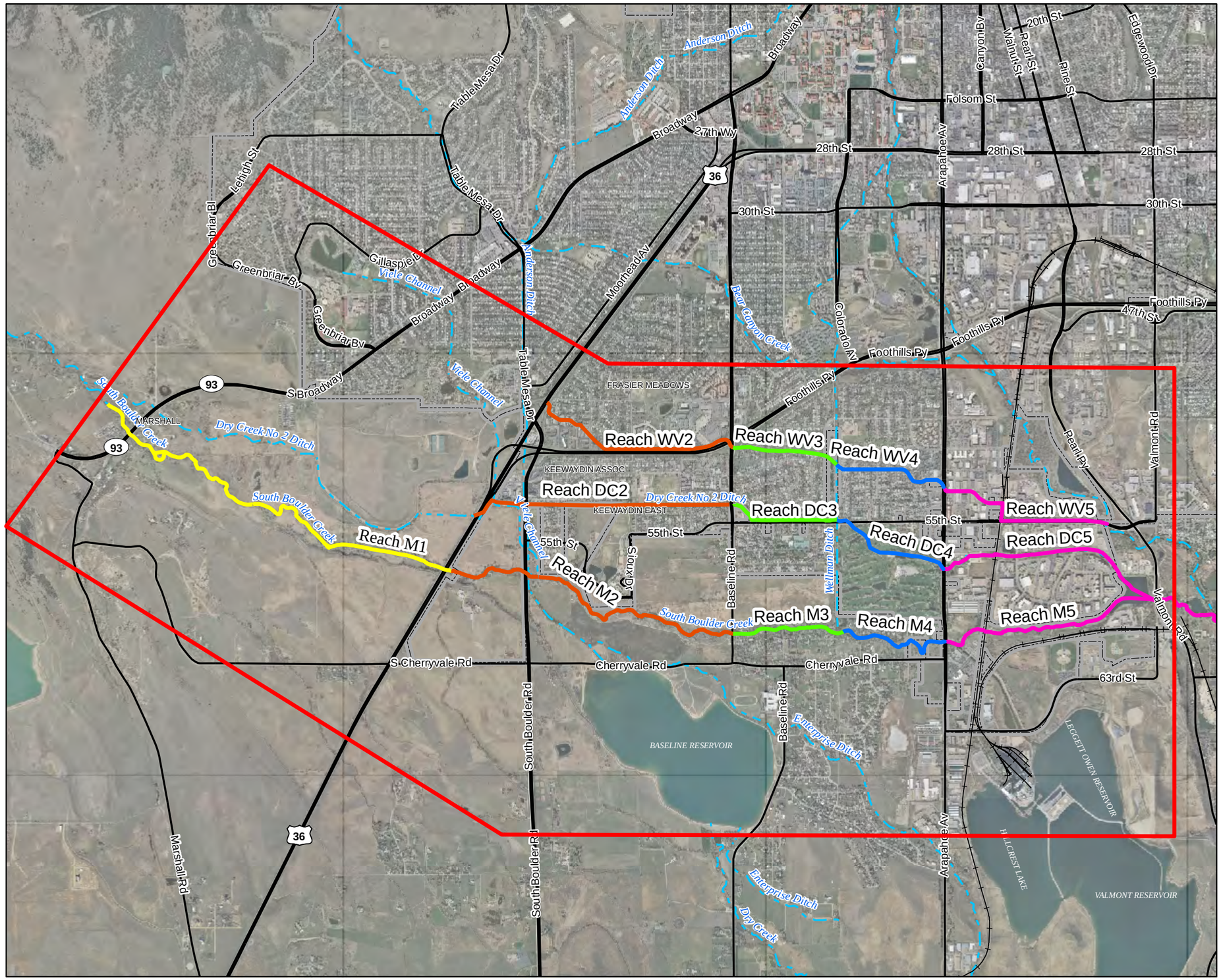
- Agricultural
- Park, Urban and Other
- Public
- Environmental Preservation

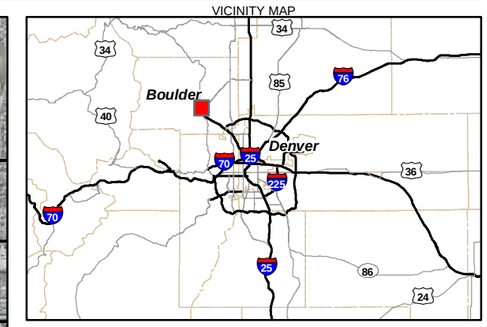
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 2-3
Lower Basin Land Use
South Boulder Creek Flood Mitigation Report
From the Boulder Valley Comprehensive Plan, 2009





LEGEND

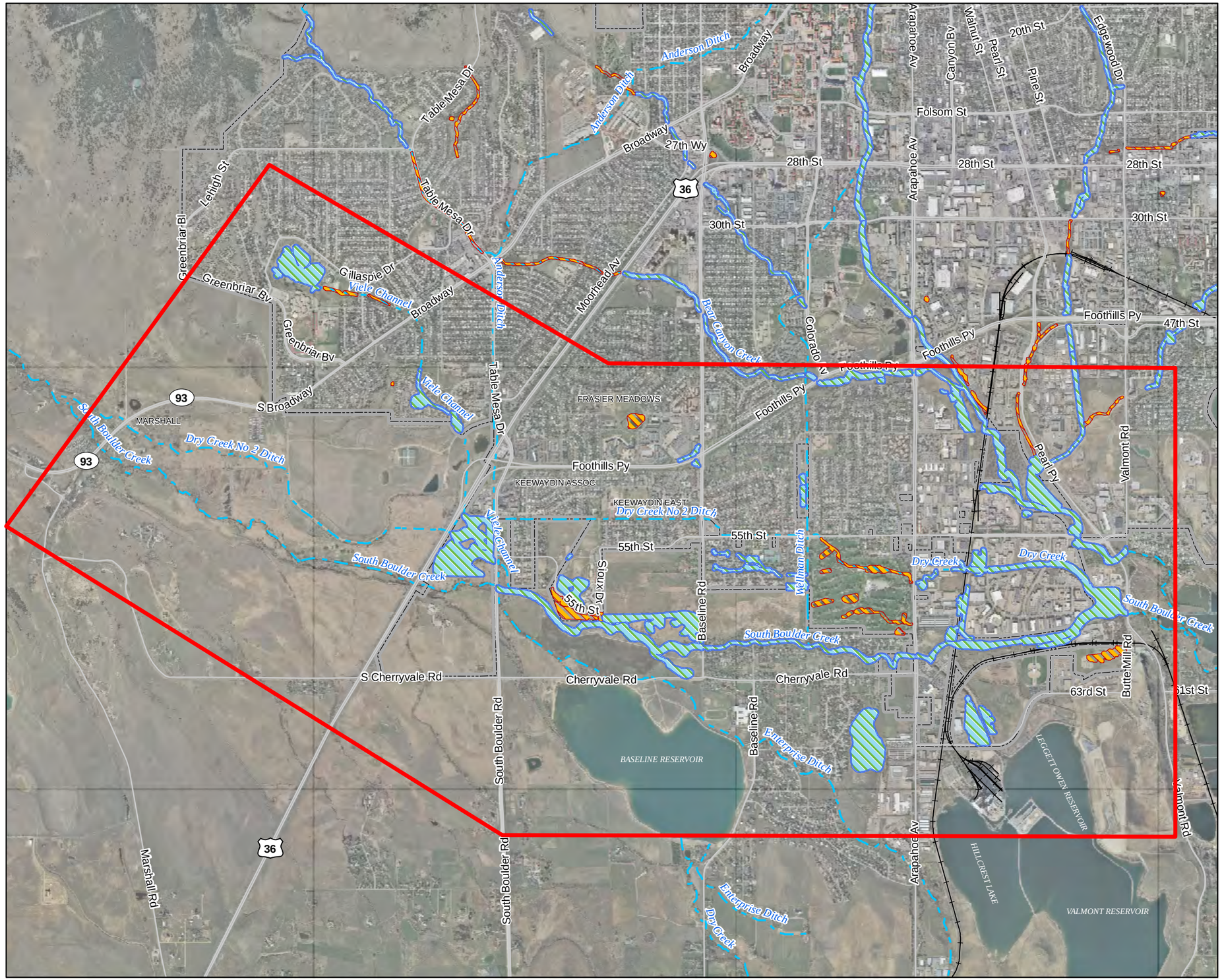
- SBC Reach 1
- SBC Reach 2
- SBC Reach 3
- SBC Reach 4
- SBC Reach 5
- Main Road
- railroad
- Streams, Creeks and Ditches
- Boulder County

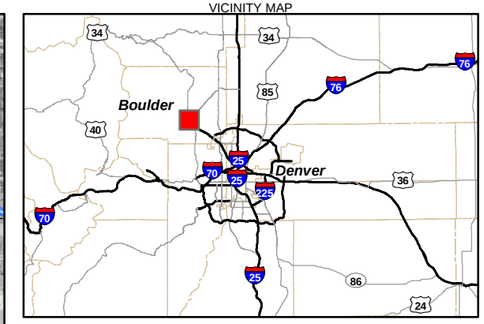
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000
Feet

FIGURE 2-4
Reach Designation
South Boulder Creek Flood Mitigation Report





LEGEND

City of Boulder Wetlands

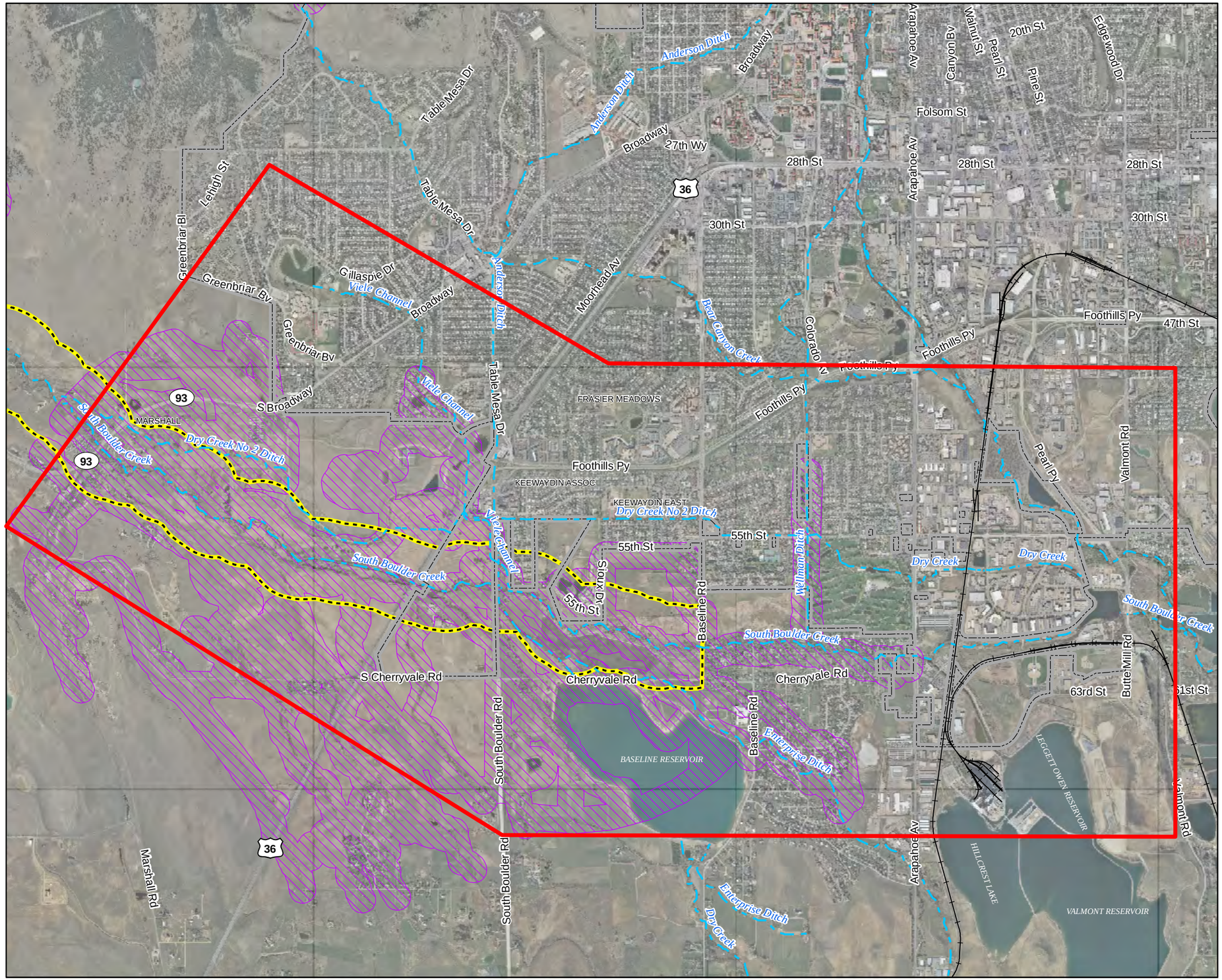
Wetlands Catagory

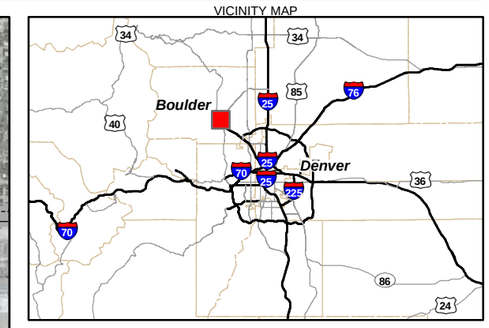
- High Functioning
- Low Functioning
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 2-5
Wetland and Riparian Zones
South Boulder Creek Flood Mitigation Report





LEGEND

- Streams, Creeks and Ditches
- Boulder County
- PMJM Critical Habitat 12-14-2010
- PMJM Occupied Range

Notes:

1. Area of Interest
2. PMJM Critical Habitat Area from the U.S. Fish and Wildlife Service
3. PMJM Occupied Area from the Colorado Department of Wildlife

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 2-6
Preble's Meadow Jumping Mouse Habitat Areas
South Boulder Creek Flood Mitigation Report

CH2MHILL

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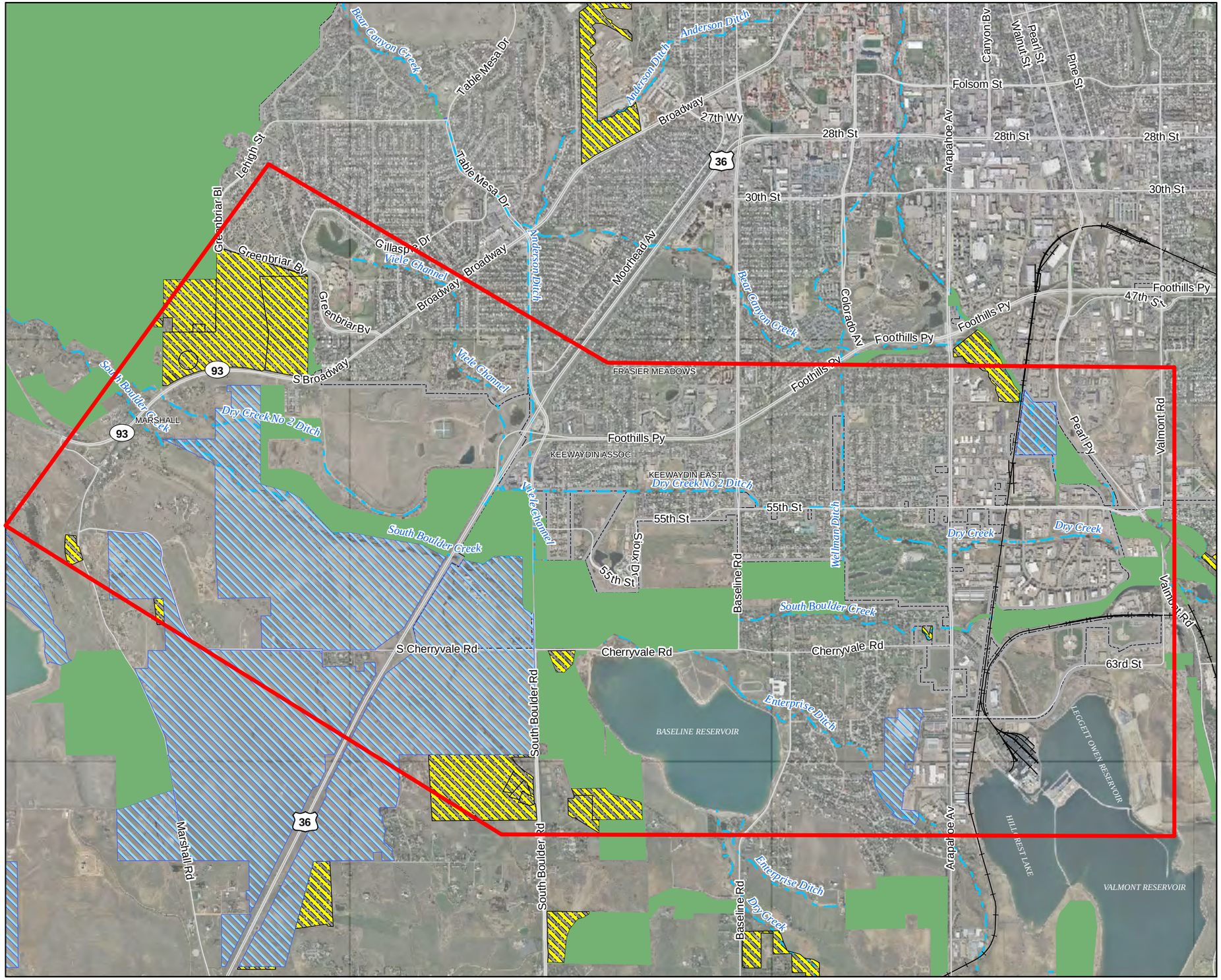
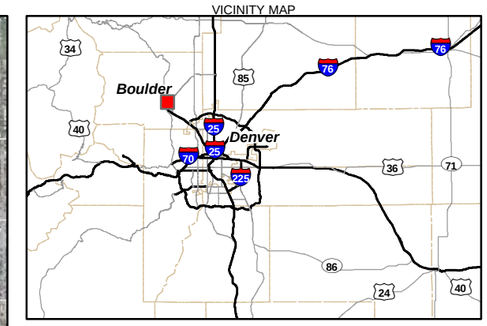




LEGEND

Boulder County

Streams, Creeks and Ditches

Boulder County Management Areas

Habitat Conservation Area

Natural Area

Boulder OSMP Conservation Areas

Conservation Easement

Notes:

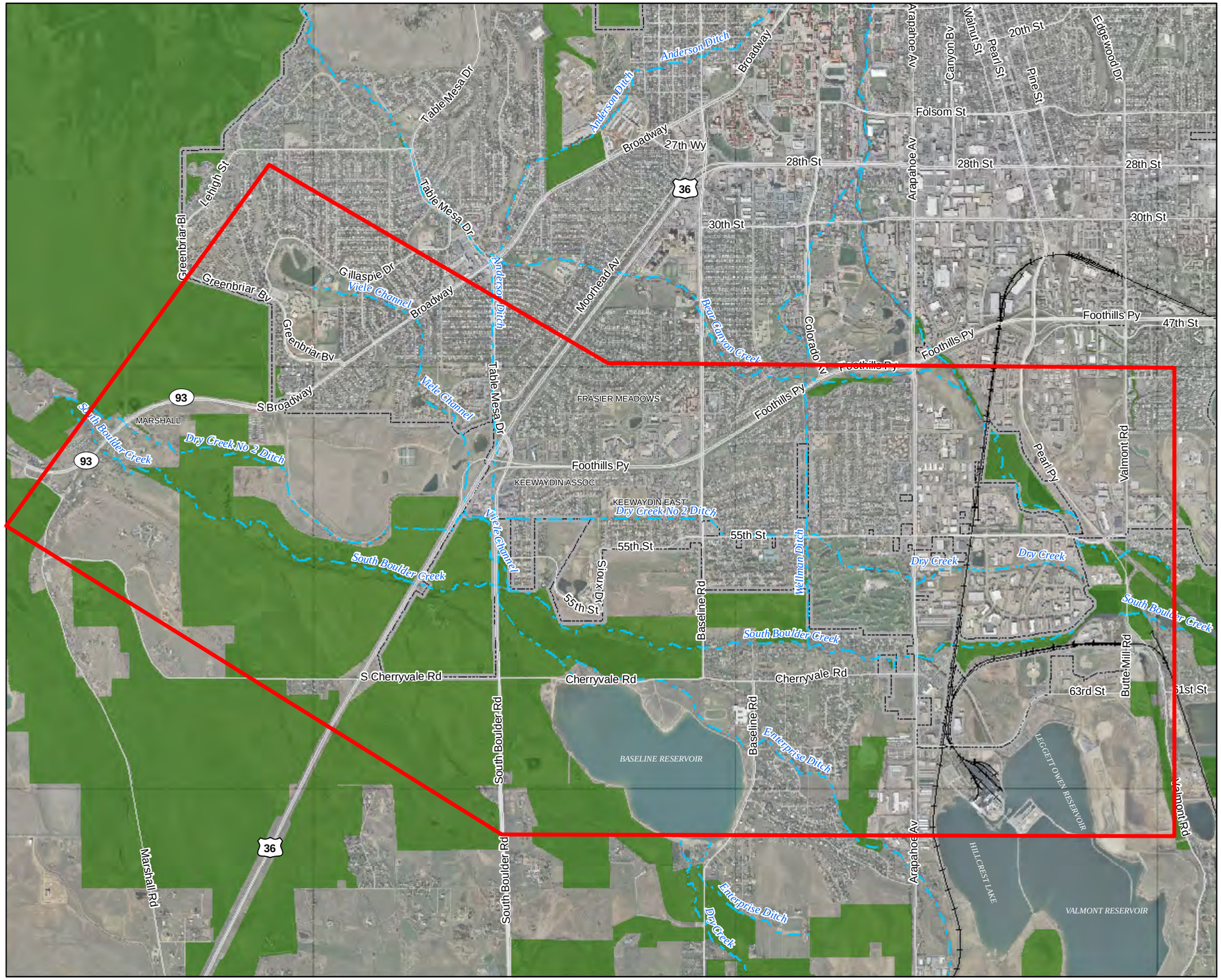
1. Area of Interest

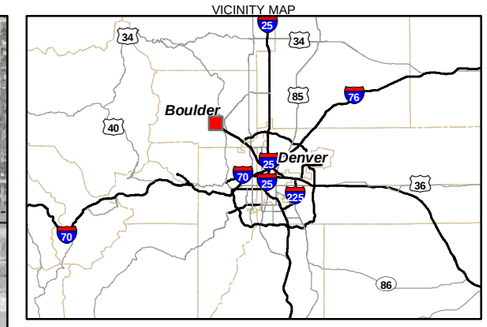
N

0 1,000 2,000 3,000 4,000 5,000

Feet

FIGURE 2-7
Designated Habitat Conservation Areas
South Boulder Creek Flood Mitigation Report





LEGEND

- Main Road
- neighborhood
- railroad
- Streams, Creeks and Ditches
- LAKES
- Boulder County
- City of Boulder Open Space

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 2-8
Open Space Lands
South Boulder Creek Flood Mitigation Report

III. Hydrologic Analysis

Overview

An extensive hydrologic analysis for the Study Area was conducted as part of the Mapping Study. This analysis was based on a comprehensive scope of services developed by the city with the input of a number of city staff and members of the public. The Mapping Study included hydrologic analyses based on recorded stream gage data, paleohydrologic flood estimates and a comprehensive rainfall/runoff computer model.

The rainfall/runoff computer model was developed using a proprietary software package developed by DHI called MIKEFLOOD. This model provided a vehicle to conduct exhaustive simulations of various basin conditions and various rainfall inputs to represent the complex hydrologic response of the watershed. The model incorporated a sophisticated algorithm to compute infiltration losses and simulates the runoff from a number of sub-basins. The model assembles the runoff from these individual sub-basins using a simplified routing algorithm that accounts for minor storage and attenuation of the individual hydrographs. The model also uses a sophisticated approach to routing and combining flow from individual sub-basins by accounting for floodplain storage and the impacts of drainage features within the watershed.

Another important differentiator between the hydrologic studies done for this study and the standard approach is the careful attention to calibration. The results of the stream gage analysis and the paleohydrologic flood study were used to adjust model parameters to assure that the simulated results reflected actual recorded basin responses.

The Mapping Study included a *Climatology/Hydrology Report* (HDR, February 6, 2007) that looked at the nature of rainfall in the South Boulder Creek watershed. That study concluded that two distinct types of storms were common in the watershed, a general storm and a thunderstorm. The Mapping Study reported the thunderstorm resulted in the highest flows along the mainstem of South Boulder Creek.

The focus of the hydrologic evaluation was on the flows in the mainstem of South Boulder Creek. The combination of rainfall and basin assumptions used in the Mapping Study produced the most critical conditions and resulted in the highest flows along the mainstem. However, that study, as well as the current Study, recognizes that other rainfall events may result in higher flood flows and a higher consequent hazard to areas within the tributary basin. This Study relies on other work to identify those other critical storms and the resulting flows and to assess the potential effectiveness of proposed improvements to address the flood threat associated with those flows. These other investigations include the flows reported in an HDR memorandum (*Lower Storm Center memorandum*) developed during the Mapping Study that addressed the lower basin storms. A subsequent study, also prepared by HDR that focused on the local stormwater collection system, the *City of Boulder Stormwater Master Plan* (Stormwater MP) was published in 2007. The Lower Storm Center Memorandum and the Stormwater MP provided estimates of local tributary flows for the South Boulder Creek Watershed that were utilized to complete initial sizing of stormwater and flood control facilities throughout the West Valley and to allow for the preliminary comparison of the various alternatives.

Design Rainfall

The South Boulder Creek Flood Mapping Study was unique among projects in the District in that a Basin Specific Design Storm (BSDS) was developed. The development of the storm is described in detail in the HDR *Climatology/Hydrology Report* (HDR, February 6, 2007). In fact, two such storms were developed that reflected differing climatologic conditions a thunderstorm and a general storm. The regulatory floodplain for South Boulder Creek is based on the BSDS Thunderstorm.

Basin Specific Design Storm Thunderstorm

An exhaustive evaluation of historic rainfall events was initiated as part of the Mapping Study. The evaluation concluded that climatologic conditions in South Boulder Creek are such that the typical assumption of a uniform spatial distribution of rainfall across the entire watershed was not appropriate. Rather, a rainfall event having a defined spatial footprint and with a defined spatial distribution of rainfall intensities and depth was more appropriate. The study defined three unique distributions based on the probabilities for a particular storm. In general, the footprint of the rainfall and the point precipitation values increased as the probability of the storm decreased.

The adopted 100-year BSDS Thunderstorm for South Boulder Creek had a spatial footprint of approximated 75 square miles, a six hour storm duration, and a maximum rainfall depth of 3.89 inches. Rainfall events smaller than the 100-year design thunderstorm, had a smaller footprint and lower rainfall depths. Larger storms had larger footprints and depths. All thunderstorms were six hours in duration. Rainfall intensities over the six-hour storm duration differed between the various storms events but generally followed a pattern similar to the distribution recommended by the District in the USDCM Volume 1 and 2. A summary of the size and maximum point precipitation for each of the study storms is presented in Table 3-1, South Boulder Creek (SBC) Basin Specific Design Storm Return Frequency Values and Table 3-2, South Boulder Creek Basin Specific Design Storm Thunderstorm Spatial Distribution summarize the important design thunderstorm characteristics that the flood hydrology is based upon.

TABLE 3-1
South Boulder Creek Basin Specific Design Storm Return Frequency Values
Taken from Table 5, Climatology and Hydrology Report, HDR February 6, 2007

Return frequency	SBC 6-hr Total Rainfall (in)
2-yr	1.65
5-yr	2.23
10-yr	2.57
25-yr	3.06
50-yr	3.46
100-yr	3.89
200-yr	4.25
500-yr	4.78

TABLE 3-2
South Boulder Creek Basin Specific Design Storm Thunderstorm Spatial Distribution
Taken from Table 11, Climatology and Hydrology Report, HDR February 6, 2007

Rainfall Depth[1] (in)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
Spatial Distribution Area (Sq. MI.)	74.57	69.32	64.30	58.16	33.15	15.00	7.41	2.96	0.00

[1]*Note: Peak rainfall depth is 3.89"*

Another unique quality of the BSDS Thunderstorm adopted for the South Boulder Creek basin was its spatial orientation. The climatologic studies determined that wind patterns and other conditions would result in a storm location that was generally centered over the lower portion of the watershed. This location is shown in Figure 3-1, 100-year South Boulder Creek Basin Specific Design Thunderstorm Location. To assure that this storm resulted in the most critical flood threat, the storm was simulated in the hydrologic model in critical locations across the basin. The resulting analysis showed that the mainstem flows resulting from the BSDS Thunderstorm represented the highest predicted discharges.

General Storm

The evaluation of historic floods on South Boulder Creek noted there was also a flood threat from a large regional storm that had a longer duration but lower intensity than the BSDS Thunderstorm. Once again, the analysis described in the *Climatology/Hydrology Report* (HDR, February 6, 2007) indicated that the characteristics of this storm differed from the normal assumption of a uniformly distributed rainfall event lasting 24-hours. Instead, the General Storm had a duration of 72-hours with a maximum rainfall depth of 6.54 inches. The climatologic evaluations identified a spatial distribution of rainfall depths across the basin that reflected some decrease in peak intensity and depth farther away from the storm

center and recognized a similar decrease as elevation increased. Moreover, the evaluation concluded that precipitation falling above elevation 8000 feet was likely to fall as snow and not contribute directly to immediate storm runoff.

Sub-watershed Characteristics

Details of the sub-watersheds comprising the South Boulder Creek basin can be found in the *Climatology/Hydrology Report* (HDR, February 6, 2007). In general terms, the watershed was sub-divided into 27 sub-basins as shown on Figure 3-2, South Boulder Creek Basin Delineation. The sub-basins lower in the watershed are generally smaller to better capture the response to high intensity rainfall events.

The upper portions of the watershed have minor development, few roads or structures, are generally above 10,000 feet in elevation, and extend to the continental divide. These basins (Sub-watersheds C26 and C27) are characterized by HDR as Mountainous – High basins. Paleoflood studies conducted as part of the Mapping Study indicated that runoff from this area is characterized by snowmelt runoff and that there is minor potential for flooding.

Below the upper watersheds described above, exist The Mountainous – Low the watershed that can be divided into two regions. The upper part of the watershed (that include Sub-watersheds C18, C20-25) lies at elevations above about 8000 feet and The lower part of the Mountainous – Low region (that include Sub-watersheds C9-C10, C13-C15, C17, and C19) lie above Eldorado Springs and the mouth of Eldorado Canyon. These sub-watersheds have minor development, few roads or structures and are tributary to Gross Reservoir. Heavy precipitation over these sub-watersheds generally falls as snow and there is a minor danger of flooding. In addition, these sub-watersheds also have an extensive network of irrigation ditches. This part of the watershed often includes steep, narrow tributary watersheds that have a high potential for flooding. Moreover, it is over this area of the watershed where the highest intensity precipitation occurs during the BSDS Thunderstorm.

The plains portion of the watershed sits between Eldorado Canyon and the developed parts of the city. These sub-watersheds (C4 – C8) still have minor development although the extent of structural development immediately adjacent to the channel increases lower in the watershed. This area is subject to moderate to low intensity rainfall and does represent an increased flood hazard, although the limited extent of development minimizes the threat.

The main channel of South Boulder Creek throughout the upper reaches of the basin as described above is generally capable of conveying flood flows. There may be localized areas where water gets out of the main channel and enters the overbank, but these are limited and flow quickly returns to the channel.

The lower portion of the watershed (Sub-watersheds C1 – C3) is the area of the watershed that is most highly developed. Sub-watersheds C1 and C2 in particular are fully developed with much urban land. At the western edge of these sub-watersheds, major roadways such as Hwy-93 and US-36 cross South Boulder Creek. There is considerable development adjacent to and downstream of the crossing of these roadways over the creek. A number of diversion channels divert water from the creek and cross the floodplain, often influencing the flow characteristics of the channel and the overbanks.

The channel through the lower portion of the basin is often overtopped with water entering the overbank floodplain. The broad nature of the floodplain causes the flood flows to inundate property and roadways not in the immediate vicinity of the channel. The extensive network of irrigation ditches furthers the spread of the water away from the channel. The channel through this area is perched on an alluvial floodplain and the channel is often higher than the land adjacent to the channel. As such, water leaving the channel sometimes travels great distances downstream along Alternative flow paths before it reenters the mainstem. These Alternative flow paths are often down residential streets or through developments for which no significant flood control facilities exist.

Table 3-3, South Boulder Creek Sub-watershed Characteristics, contains the important basin characteristics that define the runoff characteristics input in to the hydrologic model to determine the rainfall runoff response of the South Boulder Creek watershed.

TABLE 3-3
South Boulder Creek Sub-watershed Characteristics
Taken from Table 18, Climatology and Hydrology Report, HDR February 6, 2007

Sub-basin ID	Sub-basin Area (Acres)	Elevation Zone Range (ft)	Predominant Land Cover	Sub-basin Slope (%)
C1	1,800	5,000-5,500	Highly developed, urbanized land use	0.88
C2	2,700	5,000-6,000	Highly developed, urbanized land use	2.48
C3	1,710	5,500-6,000	Moderate development, borders the City of Boulder	3.56
C4	2,300	5,500-6,000	Minor development, a large pond comprises majority of sub-basin	1.35
C5	1,330	5,500-6,000	Moderate development, homes in floodplain of South Boulder Creek	4.28
C6	480	5,500-8,500	Minor development present, roads, isolated homes and structures	19.30
C7	630	5,500-8,500	Minor development present, roads, isolated homes and structures	23.66
C8	230	5,500-7,000	Minor development present, roads, isolated homes and structures	15.11
C9	480	5,500-8,500	Minor development present, roads, isolated homes and structures	20.18
C10	1,060	5,500-8,000	Minor development present, roads, isolated homes and structures	23.48
C11	1,070	5,500-8,500	Minor development present, roads, isolated homes and structures	14.76
C12	630	5,500-6,500	Minor development present, roads, isolated homes and structures	4.49
C13	2,400	6,500-8,500	Minor development present, roads, isolated homes and structures	8.48
C14	3,380	6,000-9,000	Minor development present, roads, isolated homes and structures	2.48
C15	1,850	6,000-9,000	Minor development present, roads, isolated homes and structures	10.31
C16	1,490	6,000-9,000	Minor development present, roads, isolated homes and structures	15.94
C17	2,430	6,500-8,500	Minor development present, roads, isolated homes and structures	9.66
C18	2,320	7,000-9,000	Predominately Gross Reservoir, almost no development	9.88
C19	1,330	7,000-8,500	Minor development present, roads, isolated homes and structures	12.39
C20	4,550	7,500-9,000	Minor development present, roads, isolated homes and structures	5.72
C21	1,680	7,500-8,500	Minor development present, roads, isolated homes and structures	6.76
C22	1,730	7,500-9,000	Minor development present, roads, isolated homes and structures	10.83
C23	1,980	8,000-10,500	Minor development present, roads, isolated homes and structures	14.99
C24	14,280	8,000-11,000	Minor development present, roads, single homes, alpine lakes	6.35
C25	5,600	8,000-10,500	Minor development present, roads, single homes, alpine lakes	6.07
C26	21,820	8,500-13,500	Undeveloped alpine terrain, presence of alpine lakes	6.32
C27	5,710	9,000-13,500	Undeveloped alpine terrain, presence of alpine lakes	12.67

Hydrograph Routing

Hydrology for this project was developed as part of the Mapping Study. Details of that work effort are described in the *Climatology/Hydrology Report* (HDR, February 6, 2007). The hydrologic analysis consisted of three distinct approaches, a statistical evaluation, a paleoflood analysis, and a rainfall/runoff modeling effort. The statistical evaluation and the

paleoflood analysis both were used to support the model development and were not directly a part of the regulatory hydrologic model. The hydrologic modeling was performed using DHI's software MIKEFLOOD, but in two distinct phases.

The initial hydrologic model development was conducted using the MIKE 11 model. This model is described by HDR as:

> "MIKE 11 is a conceptual model in that it represents the watershed with a series of sub-basins each represented by basin specific topography, soils and ground cover. The model applies rainfall to each sub-basin, computes losses resulting from vegetation evapotranspiration and infiltration, and estimates the water reaching the stream through a combination of surface flows and base flows. The model combines the runoff from various sub-basins to generate a complete representation of flow in the overall watershed. Flow is combined and routed down the channel in a series of channel segments each defined by specific cross sectional geometry, longitudinal channel slope, and surface roughness."

MIKE 11 is a fully dynamic, 1-D hydrologic model. That is, the model generates and routes the full hydrograph through the watershed considering backwater effects from culverts and undersized channels but it does so using the assumption of one-dimensional flow. This approach differs from the District's prevailing standard of practice that generally assumes no backwater effects and less flood peak attenuation. The results of this modeling effort provided a preliminary estimate of the flood peaks and hydrograph that was used for calibration and verification for both the BSDS Thunderstorm and General Storm.

An updated hydrologic analysis was incorporated into the two-dimensional floodplain analysis using MIKEFLOOD. In this package, MIKE 11 runoff results are routed using both the 1-D channels captured by MIKE 11 and a 2-D representation of the flow in the floodplain using the MIKE 21 capability of MIKEFLOOD. HDR described the linked capability as follows:

> "The MIKE 11 computer model is a part of an even more comprehensive package called MIKEFLOOD. MIKEFLOOD uses the information developed in the MIKE 11 model and combines it with a sophisticated two-dimensional floodplain model (MIKE 21) to provide a detailed representation of the watershed reflecting where water is generated, how it travels down well-defined channels, and how it moves out of the channel and across the broad floodplain. Flows move down the channel and are attenuated because of hydraulic features within the channel. The MIKE 11 model accounts for channel backwater and other localized phenomena, but cannot represent floodplain storage. However, the impacts of floodplain storage are obvious along South Boulder Creek and will be addressed within the MIKE 21 model that has the capability to simulate these conditions."

The use of an approach with this kind of detail and resolution is uncommon in the District. However, the Mapping Study scope and execution were directed by the city and done to address specific concerns expressed by the community regarding the accuracy and detail of past studies. The Mapping Study and the MIKEFLOOD based hydrology has been adopted as the regulatory floodplain delineation document. FEMA anticipates the formal adoption of the revised mapping study through the Digital Flood Insurance Rate Map Modification (DFIRM) process in mid to late 2012.

While the use of the MIKEFLOOD model to generate flood flows is well founded and provides an uncharacteristic level of understanding of the development and propagation of the flood wave, it does present some complications for floodplain managers and administrators. Any physical changes in the upstream watershed, whether on channel or in the overbank areas, have the potential to significantly alter the flood flows because of the models sensitivity to not only peak flow but also flow volume. This complication requires extreme diligence when assessing the impacts of proposed improvements along the drainageway or in the floodplain.

Results of Analysis

The hydrologic study conducted as part of the Mapping Study generated two sets of results, related but with entirely different application. The first results were derived from the MIKE 11 analysis that generated runoff hydrographs from the sub-watersheds. These values were very important and became the hydrologic input into the MIKEFLOOD hydraulic model and were useful in some of the initial calibration and validation efforts. In particular, the MIKE 11 analysis allowed a comparison of the BSDS Thunderstorm and General Storm to be compared with the statistical peak flow rates and volumes at the Eldorado Springs Stream gage calculated by the USACE Hydrologic Engineering Center (HEC)-Flood Frequency Analysis (FFA) program. A summary of the results of the MIKE 11 analysis and the statistical analysis of the stream gages computed by FFA are presented in Tables 3-4, MIKE 11 Model Peak Flow Results, and 3-5, MIKE 11 Model Volume Comparison.

TABLE 3-4
Mike 11 Peak Flow Results
Taken from Table 22, Climatology/Hydrology Report, (HDR February 6, 2007)

		Simulated Discharge (cfs)									
Event	**FFA Discharge**	**Eldorado Gage**		**Hwy-93**		**US-36**		**Baseline Road**		**Confluence**	
		TStorm	**GStorm**	**TStorm**	**GStorm**	**TStorm**	**GStorm**	**TStorm**	**GStorm**	**TStorm**	**GStorm**
2-yr	550	670	1000	870	1350	910	1420	1020	1580	1020	1610
5-yr	952	1060	1330	1300	1930	1390	2040	1680	2260	1680	2310
10-yr	1360	1310	1520	1770	2270	1950	2400	2400	2660	2440	2720
25-yr	1910	2280	1800	3270	2760	3510	2930	3980	3240	4020	3320
50-yr	2910	2640	2020	3770	3130	4030	3330	4560	3690	4620	3780
100-yr	3970	4520	2230	7120	3490	7690	3710	8770	4120	8910	4220
200-yr	5360	6210	2450	9520	3870	10090	4120	11090	4580	11100	4690
500-yr	7930	7400	2735	11360	4360	12030	4640	13170	5160	13130	5290

TABLE 3-5
Mike 11 Model Volume Comparison
Taken from Table 21, Climatology/Hydrology Report, (HDR February 6, 2007)

Recurrence Interval	Thunderstorm Volume (million cubic feet)	General Storm Volume (million cubic feet)	FFA Volume (million cubic feet)
2-yr	46.8	66.0	38.2
5-yr	58.2	81.0	56.7
10-yr	64.7	90.6	69.5
20-yr	NA	NA	81.9
25-yr	81.9	105.5	NA
50-yr	89.4	117.1	98.5
100-yr	121.6	128.3	111.0
200-yr	143.7	139.5	124.0
500-yr	163.0	154.2	142.0

The hydrologic analysis was refined using MIKE 21 within MIKEFLOOD to route the sub-watershed hydrographs and to reflect overland and floodplain storage. This was deemed important in the South Boulder Creek watershed because of the unique alluvial character of the drainageway below Eldorado Canyon and because of the public's demand for a comprehensive hydrologic study that reflected "actual" conditions in the watershed. As one would expect, the MIKE 21 representation resulted in a significant attenuation of flows. The MIKE 21 hydrologic analysis results are summarized in Table 3-6, 100-year Routed Flow Summary Table. These flows reflect the regulatory flood flows and are the basis for planning studies.

TABLE 3-6
100 Year Thunderstorm Peak Hydrologic Discharges vs. Routed Hydraulic Peak Discharges (cfs)
Taken from Table 2, Hydraulic Modeling Report,(HDR December 30, 2008)

100 Year Thunderstorm Peak Hydrologic Discharges vs. Routed Hydraulic Peak Discharges (cfs)		
Location	**MIKE11 Hydrologic Model**	**MIKE21 Hydraulic Model**
Eldorado Springs	4520	4520
HWY-93	7120	6630
US-36	7690	7250
Baseline Road	8770	5010
Confluence	8910	4570

Alternate Hydrology

There have been several other studies completed recently that have developed hydrology for the West Valley. Because this Flood Mitigation Study focused on the West Valley flood problems, the focus of the review of these additional hydrologic studies was to compile flow rates for the C2 Basin. The C2 Basin is a large sub-basin to South Boulder Creek that primarily drains flow through the West Valley. Figure 3-2, South Boulder Creek Basin Delineation, displays the sub-basin location and shows the significance of the C2 Basin on the West Valley. The goal of reviewing the studies was to determine the most conservative flow rates for infrastructure design throughout the West Valley for storm flows ranging from the 5-year to the 500-year recurrence interval storms. The reports reviewed are listed below.

- *South Boulder Creek, Climatology/Hydrology Report*, HDR, CH2M HILL and DHI, February 6, 2007.
- *Technical Memorandum: South Boulder Creek Lower Urbanized Storm Center - 100 Year Flood Impacts, HDR, March 2007.*
- *City of Boulder Stormwater Master Plan*, HDR Engineering, June 2007

The South Boulder Creek *Climatology/Hydrology Report* (SBC Hydrology Report) developed a Basin Specific Design Storm (BSDS) thunderstorm centered over the South Boulder Creek watershed below Gross Reservoir in Eldorado Canyon that was used in the Flood Mapping Study. The location of the BSDS thunderstorm maximized the peak flow rates along the mainstem of South Boulder Creek. These flows were the focus of the alternatives outlined in this Master Plan Report. Flows in the C2 Basin for the BSDS Thunderstorm are relatively low because of the rainfall distribution pattern.

The Technical Memorandum*: South Boulder Creek Lower Urbanized Storm Center - 100 Year Flood Impacts*, (Lower Storm Center TM) presents a "Lower Storm Center" Design thunderstorm that moved an earlier iteration of the BSDS thunderstorm described above and centered it over the West Valley. This storm was only run for the 100-year storm event and was created to understand the impacts of a thunderstorm centered over the West Valley of South Boulder Creek and West Valley Neighborhoods. In general, the flow rates along the South Boulder Creek Mainstem generated by the Lower Storm Center Design Storm were less than the flows presented for the BSDS Thunderstorm. However, flow rates generated by the Lower Storm Center Design Storm were higher than the BSDS Thunderstorm for the C2 Basin. For the Lower Storm Center Design Storm, the C2 Basin flow rates were evaluated for use in this study.

Finally, the *City of Boulder Stormwater MP* developed a design storm based on Urban Drainage and Flood Control District criteria for the water quality, 2–year, and 5-year storms only. The Stormwater MP Design Storm was compared to the BSDS Thunderstorm. The design storms from both reports generally exhibited the same duration and developed similar runoff volumes to each other. However, the peak flows were different and the Stormwater MP flows were evaluated for use in this study.

West Valley and C2 Basin Hydrograph Loading

For the design of infrastructure improvements in the West Valley, the City has indicated that infrastructure needs to be adequately sized to convey the most conservative flow expected for the location. As described above, three studies were reviewed to determine the controlling hydrology specifically for the West Valley basin. This included the SBC Hydrology Study, the Stormwater MP, and the Lower Storm Center TM storms. Table 3-7 below identifies the flood recurrence interval that each study focused on.

TABLE 3-7
Recurrence Intervals Studied by Hydrologic Reports for the South Boulder Creek Watershed

Study	**Recurrence Interval Studied**							
	2-year	5-year	10-year	25-year	50-year	100-year	200-year	500-year
SBC Hydrology Report	NA	NA	X	X	X	X	X	X
Lower Storm Center TM	NA	NA	NA	NA	NA	X	NA	NA
City of Boulder Stormwater Master Plan,	X	X	NA	NA	NA	NA	NA	NA

Based on the review of the studies, the flow rates generated by the Regulatory MIKEFLOOD model, as reported in the SBC Hydrology Report, would control facilities related to mainstem flooding because there was insufficient information from the other studies to cover all the recurrence intervals required as part of this flood mitigation study. However, there were two additional specific conditions that were studied to determine the controlling flow rate.

1. Did the 5-year recurrence interval flow rates from the Stormwater MP exceed the flow rates from the Flood Mapping Study for the C2 Basin?
2. Did the 100-year recurrence interval flow rates from the Lower Storm Center TM exceed the 100-year flow rates from the Flood Mapping Study for the C2 Basin.

Comparable flow rates were taken directly from the Stormwater MP Hydrologic Models and the C2 Basin Loading points from the Flood Mapping Study. The Lower Storm Center TM developed one single flow for the entire C2 Basin. This flow was apportioned across the C2 Basin loading points utilizing ratios based on subwatershed areal contributions developed during the Flood Mapping Study.

Based on the review of the hydrology from the three studies for the C2 Basin the following rules were developed determining the use of hydrology for this Flood Mitigation Project.

1. If there was no overtopping of US-36, the flows from the Lower Storm Center TM controlled the 100-year flooding through the West Valley and C2 Basin. This essentially represented the local flood threat and was unrelated to the mainstem flows entering the West Valley.
2. If there was over topping of US-36, then the BSDS Thunderstorm from the Flood Mapping Study controlled the 100-year flooding through the West Valley and C2 Basin.
3. For recurrence intervals less than the 50-year flood, the 5-year flow rate from the Stormwater MP was found to be the largest controlling flow. Because it was the only published flow for small events in the West Valley, this 5-year recurrence interval C2 Basin flow loading was also used for the 10-, 25- and 50-year recurrence interval flows.

Hydrologic inflows, regardless of the study in which they were defined, were not the singular basis for facility sizing decisions in the Flood Mitigation Study. The hydraulics of the South Boulder Creek System was also considered in addition to the subbasin hydrologic loading. The hydraulic calculations are further described in Section 4, however the interaction of floodwaters leaving the mainstem of South Boulder Creek and entering the West Valley can have a profound effect on the peak flow rates and the sizing of infrastructure throughout the basin. This hydrologic analysis provided a foundation on which the hydraulics could be built and hydraulics and infrastructure sizing could begin.

Rather than recreate the rainfall/runoff computations, tributary hydrographs developed in both the Mapping Study and Stormwater MP were input into the hydraulic model. This reduced the computation time and assured that the inflow from the tributaries would remain unchanged from previous studies. Hydrographs were loaded into the main channel upstream of Hwy-93 and at five locations in the downstream watershed representing major sub-watersheds within the C2 basin. In addition, the overflows from Bear Canyon Creek that enter the basin via the new Anderson Ditch and the Wellman Canal were input into the hydraulic model.

An analysis of the tributary basin inflow hydrographs was completed to determine the most conservative peak flow loadings for each of the C2 Basin sub-loading points and overflows from Bear Canyon Creek. It was determined that for storms less than the 50 – year design storm for South Boulder Creek, the Stormwater MP flows were greater than the flows from the Flood Mapping Study and represented the most conservative flow estimate. For storms greater than the 50-year return period, the Mapping Study and Lower Storm Center tributary inflows controlled through the C2 Basin and were used for the 100-, 200- and 500-year return period. Figure 4-3, Tributary Basin Loading Points and Table 3-8, Tributary Basin Discharge Loading present the location of the C2 basin inflows and the peak values for a variety of storm events.

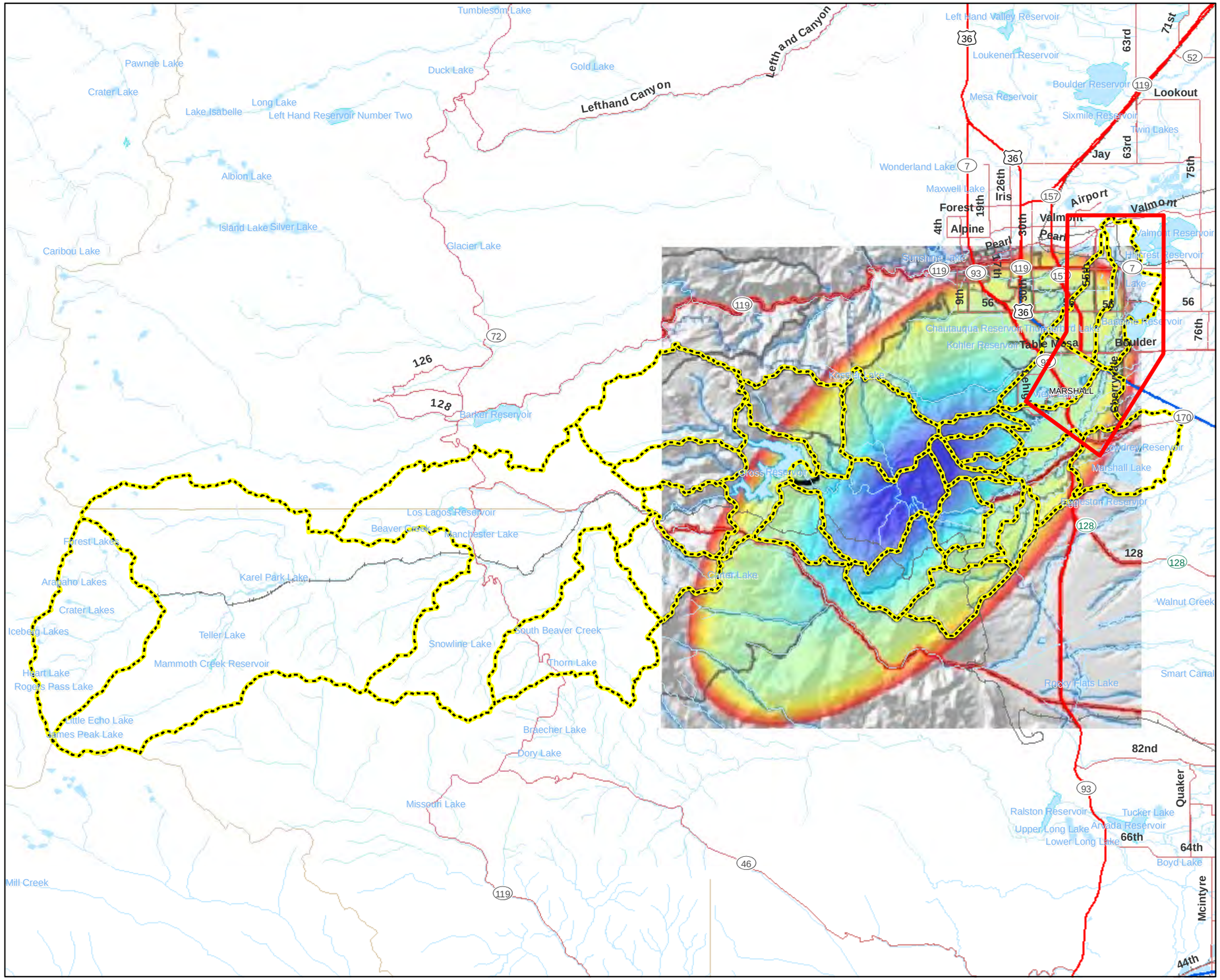
TABLE 3-8
Tributary Basin Discharge Loading

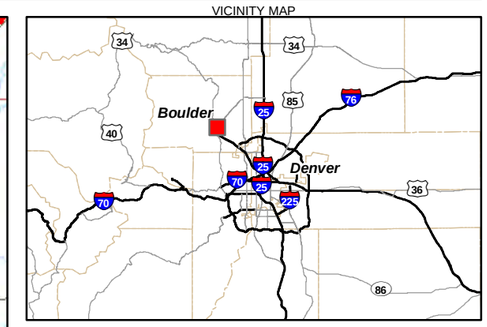
Sub-basin/ Loading Point	Intersection Location	[1]Q_2 (cfs)	[1]Q_5 (cfs)	[2]Q_{100} With US-36 Overtopping (cfs)	[2]Q_{100} Without US-36 Overtopping (cfs)	[2]Q_{200} (cfs)	[2]Q_{500} (cfs)
C2A	W. Moorehead Cir. and Viele Channel	70	110	700	920	700	700
C2B	Foothills Parkway and Baseline Road	120	180	140	190	140	140
C2C	Tenino Drive and Oneida Street	50	70	120	160	120	120
C2D	Arapahoe Avenue at Dry Creek Ditch No. 2	110	140	230	300	230	230
C2E	Dry Creek Ditch No. 2 South of Flatiron Parkway	100	130	70	90	70	70
Table Mesa Drive/ Bear Canyon Creek	Table Mesa Drive and South Loop Drive	50	80	110	110	110	110
Wellman Canal/ Bear Canyon Creek	Foothills Parkway and Colorado Avenue	60	80	200	200	200	200
C-2 Basin Total		450[3]	630[3]	1230[3]	1660[3]	1230[3]	1230[3]

[1] Values obtained from the *City of Boulder Stormwater Master Plan* completed by HDR in June, 2007. These flow rates control for designs storms less than the 50-year recurrence interval for the West Valley.

[2] Values obtained from the *Climatology and Hydrology Report*, Completed by HDR, February 6, 2007

[3] Values do not include Bear Canyon Creek Discharges or any spills from the mainstem that will be considered in facility sizing





LEGEND

- South Boulder Creek Sub-Watersheds
- Primary Limited Access
- Primary US & State Highways
- Secondary State & County
- Railroads (150 to 50k)
- Rivers (150 to 50k)
- County Boundaries (150 to 50k)

South Boulder Creek Basin Specific Design Storm

Low: 0.00" of Rainfall

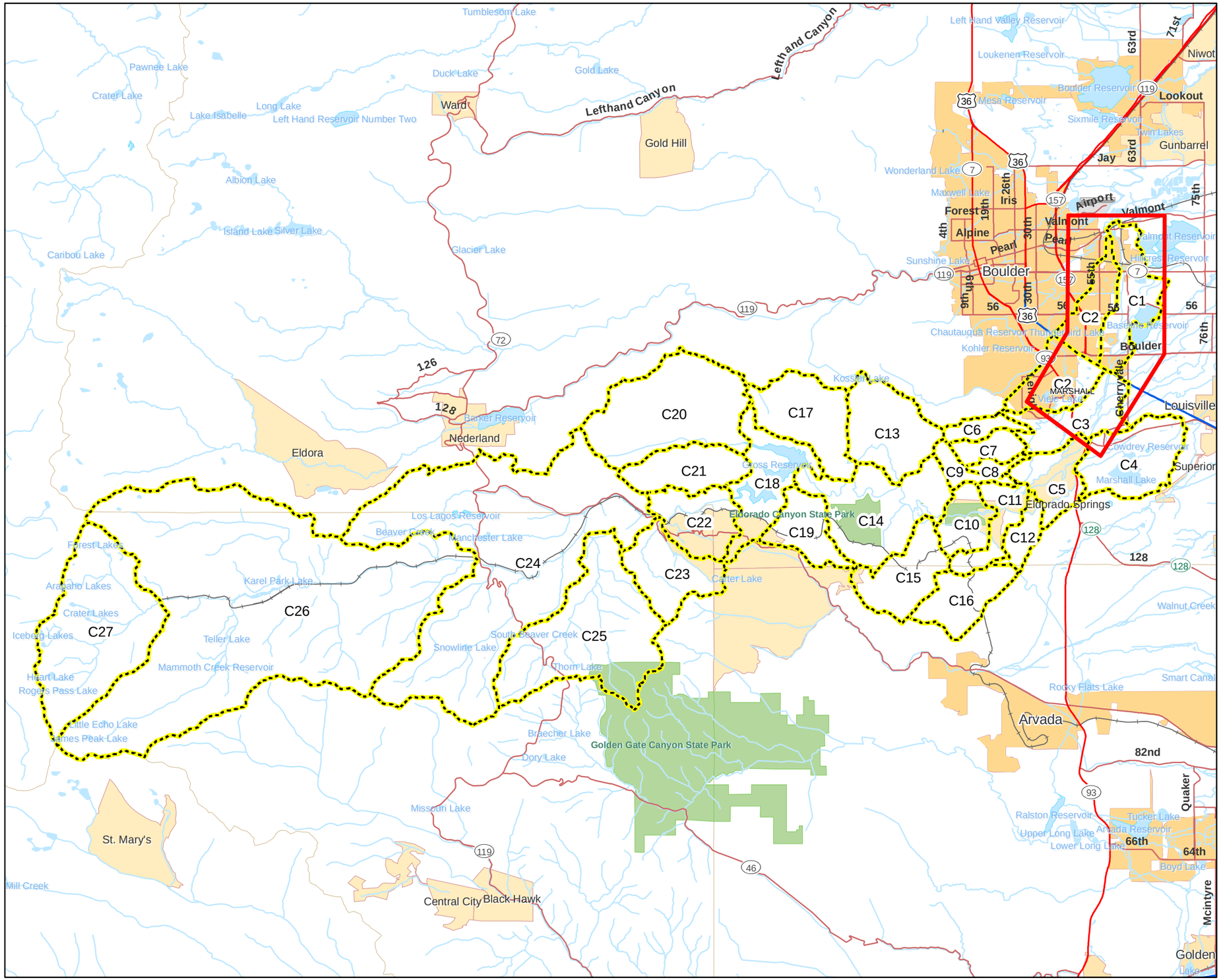
High: 4.00" of Rainfall

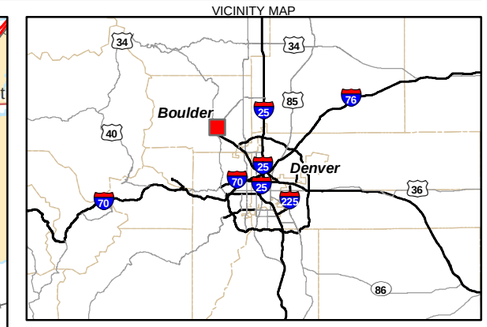
Notes:
1. Area of Interest

N

0 1 2 3 4
Miles

FIGURE 3-1
South Boulder Creek
Basin Specific Design Storm
South Boulder Creek Flood Mitigation Report





LEGEND

- South Boulder Creek Sub-Watersheds
- Primary Limited Access
- Primary US & State Highways
- Secondary State & County
- Railroads (150 to 50k)
- Rivers (150 to 50k)
- Airport Areas (150 to 50k)
- National Park - Forest
- State Park or Forest
- Local Park
- City Areas (5 to 3mil)
- County Boundaries (150 to 50k)

Notes:
1. Area of Interest

N

0 1 2 3 4
Miles

FIGURE 3-2
South Boulder Creek Basin Delineation
South Boulder Creek Flood Mitigation Report

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IV. Hydraulic Analysis

Hydraulic analyses were conducted along South Boulder Creek to determine the extent of the flood threat, the source of the threat and the performance of the existing infrastructure in response to large flood events. Much of the existing understanding of the flood hazard was established in the Mapping Study. The objective of the *Flood Mapping Study* was to define the flood problem, not solve it and included the development of a comprehensive two-dimensional floodplain model using MIKEFLOOD. This model is not only the basis of the regulatory floodplain but also serves as the foundation for the evaluations of various alternative flood mitigation measures.

The MIKEFLOOD analysis conducted as part of the Mapping Study used a coupled combination of a MIKE 11 one-dimensional (1-D) representation of major channels and culverts along the mainstem and its major tributaries and a MIKE 21 two-dimensional (2-D) representation of the overbanks and floodplain. This coupled model enables water to move between the channel and the overbank floodplain, simulating the actual hydraulic performance of the complete system. A more traditional simulation would limit the analysis to a 1-D representation of the channel and floodplain and may misrepresent the movement of water across the floodplain.

The 1-D analysis was limited to the channel and hydraulic structures along the mainstem and major tributaries where flow could reasonably be expected to flow parallel to the channel centerline. These areas were simulated using cross sections that were generally perpendicular to the direction of flow. While this approach is very consistent with the general standard of practice, the analysis in the Mapping Study did use the full hydrograph rather than the conventional steady state approach used in most studies. This was an important consideration along South Boulder Creek because of the significant interaction between the channel and the overbanks and the resulting floodplain storage. The more traditional steady state analysis does not consider the floodplain storage impacts that are so important in this watershed. The extent of the 1-D hydraulic analyses is shown on Figure 4-1, Area of Flood Mapping Study 1-D Hydraulic Model Analysis.

The 2-D analysis differs from the 1-D analysis in that it uses a network of pixels to represent the terrain rather than defining a series of predetermined flow paths. This 2-D grid consisted of over two million pixels, each representing an area four meters square. Figure 4-2, Graphic Extent of Flood Mapping Study 2-D Hydraulic Simulation Area. The 2-D hydraulic modeling approach addressed the concerns, expressed by the community during the Mapping Study, that the analysis not be skewed by preconceived notions of the problems and their cause. The use of the 2-D pixels enabled the model to predict the movement of water across the floodplain based on hydraulic and topographic conditions rather than being based on predetermined assumptions of how the water moved. The resulting floodplain delineation demonstrated a far more complex interaction between channel and floodplain than might have been predicted using a more conventional 1-D approach alone. The final MIKEFLOOD model used in the Mapping Study is commonly referred to as the Regulatory Model.

The analysis in the Mapping Study focused on the overall floodplain impacts based on the drainage system response and included the response of both the major 1-D elements that included drainage / irrigation ditches, streams and major culverts/bridges with a size greater than 36” in diameter, and the 2-D overbank areas outside of the 1-D elements. In addition, debris blockage was reviewed as part of the Mapping Study based on vegetative cover and potential for debris production for each stream reach. This was included in the MIKEFLOOD model and caused blockages of between 30% to 75% depending on structure and upstream conditions.

The city conducted a study of the existing drainage infrastructure to determine the ability of this system to handle minor floods. The *Stormwater MP* looked at minor storms and the capacity of the city’s infrastructure to handle these storms. The analyses and information provided in the Stormwater MP was not used directly in the hydraulic analysis but did provide a strong understanding of the minor system and the impacts on the larger flood events.

Evaluation of Existing Facilities

The hydraulic analysis used for this Study built on the foundation of the MIKEFLOOD analysis but limited the level of resolution and the geographic extent of the analysis. The details of the input necessary to execute a simulation are largely unchanged from the earlier study and are described in detail in the Flood Mapping Study *Hydraulics Report*. The primary change was to limit the extent of the analysis to that area included in the scope of this Study. The 1-D model was modified to limit the extent of the channels being evaluated to those below Hwy-93. The level of resolution and the details of the 1-D analysis were unchanged beyond the geographic extent. The 2-D simulation area was unchanged but the 2-D grid resolution was changed from a 4-meter grid to an 8-meter grid. This reduced the computational requirements by a factor of four, from nearly two-weeks for the 4-meter regulatory model to three days for the revised 8-meter grid model. Some minor changes in the linkage between the 1-D and 2-D models were required when the model gird was converted from the 4-meter grid to the 8-meter grid, but this did not materially affect the analysis. The resulting model (Coarse Grid Model) became the basis for all subsequent alternative evaluations including refinements to the recommended plan and creation of final benefit - cost ratio.

The hydraulic evaluation was initiated by using the Coarse Grid model to establish a new baseline flood condition that could be compared to the Regulatory Model. This assured that the difference in resolution between the 4-meter Regulatory Model and the 8-meter Coarse Grid model would not materially alter the representation of the floodplain. The reliability of the Coarse Grid model to represent the flood conditions was established. Some minor differences were noted but they generally tended to make the results of the Coarse Grid Model a bit more conservative. That is, the Coarse Grid model slightly overstated the flood hazard. This was determined to be appropriate for planning purposes.

South Boulder Creek Master Plan Hydraulic Evaluations

Hydraulic evaluations were conducted for each of the alternatives at each phase of project development. This included the Alternative Development Phase described in Section 5, the Conceptual Alternative Plan Development described in Section 6, and the development of the Best Alternative Plans described in Section 7. Given the varied nature of the alternatives and the different levels of evaluation used in each part of the planning process, a number of different techniques for conducting hydraulic analyses were used.

At the foundation, the hydraulic analysis is built on the regulatory MIKEFLOOD model developed during the Flood Mapping Study. This model provides a high level of detail and a clear understanding of the types of flood problems, their source, and the extent of the problem. Unfortunately, this model is extremely complex and unwieldy for use as a planning tool. The simulation times necessary to execute the regulatory MIKEFLOOD model run with its 4-meter gird size is approximately 2 weeks making the use of the tool for planning level evaluations impractical. The project team therefore developed alternative approaches to conduct hydraulic simulations of various stages of alternative evaluation.

A process was developed upon which project elements could be sized and evaluated outside of the MIKEFLOOD model. For the initial sizing and evaluation of independent project elements (Section 5 of this report) and the initial 15 Conceptual Alternative plans (Section 6 of this report), flows were obtained from the Regulatory 4-meter MIKEFLOOD Model as reported in the Hydrology Report, the Lower Storm Center TM and the Stormwater MP. These flows were evaluated to determine the most conservative flow rate for each return period and peak flow estimates along each of the main tributaries were developed. These peak flows were a combination of reported flows or summations of inflow peaks to create estimates of flow for the preliminary sizing of facilities. These initial flow rates are conservative in nature, as they do not reflect floodplain storage or the interaction of flood control elements. Although these flows are conservative, they provide a quick methodology for sizing alternatives and evaluating system performance outside of MIKEFLOOD. It was concluded this approximate approach was sufficient for the preliminary evaluation of alternatives and that a reasonable comparison of the alternatives could be conducted using this information.

A modified version of the MIKEFLOOD regulatory model was developed to support the analysis of the interaction between the various components of the 9 best alternative plans (Section 7 of this report). The regulatory MIKEFLOOD models used a 4-meter grid cell for the analysis. The modified model, named herein as the “Coarse Grid Model,” used an 8-meter grid cell in its analysis. The Coarse Grid Model was used to simulate the residual floodplain resulting from the various alternatives because the runtimes for this model were less than three days which was significantly less than the two week run times required by the regulatory model. The results of the Coarse Grid Model were reviewed and did not differ significantly from the flood plain depth and floodplain extents determined in the regulatory model. The Coarse Grid Model was also used to represent some of the other elements in the lower part of the watershed that might be influenced by flow from several sources including interchange between the mainstem and the West Valley that would have proven difficult to analyze using the more simplified tools.

Several alternatives rely on the storage and detention of floodwaters to control downstream flooding. A simplified version of MIKEFLOOD was developed to determine the volume of water required to be stored to eliminate the overtopping of US-36. This model herein named as the "Cut off Model ", was based on the 8 meter Coarse Grid Model and simulated the benefits of storage by computing the change in the inflow hydrograph above Hwy-93 as it moved downstream through the areas upstream of US 36 where regional detention might be practical. The model captured the complicated hydraulic flow pattern and timing and helped to size and refine possible storage locations but did not simulate flows below US 36.

Alternative Development Hydraulic Evaluations

In general, the flood control elements that were defined and sized as part of the Alternative Development were evaluated using simplified tools to establish the overall effectiveness of the alternative to address the flood threat in the West Valley. As such, specific elements of the alternative and the hydraulic performance and flow rates used to develop the alternatives might change with subsequent refinements and analyses. In fact, the complexity and interaction between some of the improvements and the floodplain suggest that further changes to specific assumed flow rates based on subsequent more detailed evaluations is inevitable. However, the level of the evaluation was determined to be sufficient to understand the overall element performance, to allow comparisons between alternatives and to make decisions about which alternatives should be taken forward for additional evaluation.

The United States Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) Version 5.0, Bentley CulvertMaster, and Bentley FlowMaster were used to conduct simplified hydraulic analyses of infrastructure downstream through the floodplain. SWMM and FlowMaster were used to simulate bridges and open channel systems that could be represented as simple 1-D flow elements. CulvertMaster was used to understand the performance of culverts and other roadway crossings. These tools lacked the resolution of the MIKEFLOOD simulation but served to determine facility size and the relative impacts of localized capacity improvements on the overall system.

The representation of underground conveyance systems and simple elements farther down in the watershed was accomplished using SWMM. SWMM has a similar hydraulic analysis engine to MIKEFLOOD. SWMM can simulate unsteady flow and provide the ability to link systems and elements and route flow more accurately than FlowMaster and CulvertMaster. SWMM also has the capability of routing flows through storage elements and determining the impacts to downstream flow that result. This capability in SWMM was used to test and evaluate some of the local detention facilities and proposed infrastructure identified.

Together, these tools facilitated the evaluation of alternative elements relatively quickly and efficiently. Using the evaluations of the various plan elements to better understand the floodplain impacts, the various components were assembled into Alternative Plans. These Alternative Plans were eventually incorporated into the Coarse Grid Model version of MIKEFLOOD to confirm performance consistent with earlier assumptions. In some cases, refinement of the alternatives was necessary to achieve the level of performance desired. This refined Coarse Grid MIKEFLOOD model became the basis for the determination of project benefits and the visual representation of the residual floodplain.

Conceptual Plan Hydraulic Evaluations

In general, Conceptual Alternative Plans were evaluated using the previously developed MIKEFLOOD evaluations for existing conditions, as well as the simplified modeling tools discussed in Section 5. The understanding of the existing conditions allowed the team to identify more simplistic tools to size the facilities and to estimate residual flood extents. The Coarse Grid MIKEFLOOD Model was used to establish the flow distribution across the floodplain.

Sizing of Conveyance Facilities

Because of the complex nature of the flooding along South Boulder Creek, it was necessary to combine and sum flow rates from the Coarse Grid MIKEFLOOD Model grid cells along existing flood prone conveyance channels to define a flow along each of the established sub-reaches. The results of this analysis are presented in Table 4-1, Design Flows by Sub-Reach. This table provides a summary of the 100-year design flow target for improvements along specific conveyance channels and corridors throughout the South Boulder Creek floodplain.

TABLE 4-1

Design Flow by Sub-Reach

Profile	Reach	100-Year Peak Flow
West Valley	US-36 to Baseline Road	1,259
West Valley	Baseline Road to Wellman Canal	1,137
West Valley	Wellman Canal to Arapahoe Avenue	1,350
West Valley	Below Arapahoe Avenue	371
Dry Creek No. 2 Ditch	US-36 to Baseline Road	695
Dry Creek No. 2 Ditch	Baseline Road to Wellman Canal	389
Dry Creek No. 2 Ditch	Wellman Canal to Arapahoe Avenue	2,844
Dry Creek No. 2 Ditch	Below Arapahoe Avenue	2,038

Sizing of Storage Facilities

Storage facilities were sized based on volume and discharge information determined during the development of the "Cut-off Model." Storage facilities were evaluated for a variety of recurrence intervals. The Flow rates reported in Table 4-2, West Valley Peak Flow Rates For Preliminary Sizing of Storage Facilities, differ from those reported in Section 3 because they represent the summation of overflows from US-36, flows in Dry Creek No. 2 Ditch and overflows from the South Boulder Creek Channel that enter the West Valley between the Wellman Canal and Arapahoe Road. Overflows were estimated from the "Cut-off Model", but because it did not include areas below US 36, needed to be combined with the C2 Basin loading points. Both the overflows from the Cutoff Model and the Loading points from the C2 basin are summed in the downstream direction to produce conservative estimates of expected flows at the defined locations to size prospective detention facilities.

TABLE 4-2

West Valley Peak Flow Rates For Preliminary Sizing of Storage Facilities

	Peak Flow (cfs)				
Intersection Location	[1]Q_2 (cfs)	[1]Q_5 (cfs)	[2]Q_{100} (cfs)	[2]Q_{200} (cfs)	[2]Q_{500} (cfs)
W. Moorehead Cir and Viele Channel	120	190	810	810	810
Foothills Parkway and Baseline Road	120	180	1390	1810	2020
Tenino Drive and Oneida Street	280	370	1410	1970	2280
Arapahoe Avenue at Dry Creek No. 2 Ditch	690	890	4100	5360	6230
Dry Creek No. 2 Ditch South of Flatiron PKWY	790	1020	4170	5420	6300

[1] Values obtained from the 5-year storm event from the *City of Boulder Stormwater Master Plan* completed by HDR in June, 2007 and are summed with flow rates from the "Cut-Off Model". These produced conservative flow rates for detention facilities.

[2] Values obtained from the *Climatology and Hydrology Report*, Completed by HDR, February 6, 2007 and are summed with flow rates from the "Cut-Off Model." These produced conservative flow rates for detention facilities.

Each Alternative plan was evaluated for the potential benefits associate with the proposed improvements. The nature of flooding along South Boulder Creek, particularly in the West Valley, which was the focus of the mitigation efforts, is such that minimal damages occur throughout the West Valley during more frequent flood events. It is not until US-36 is overtopped that increased damages and flooding are experienced in the West Valley. Since this occurs around the 100-

year event, the sizing of infrastructure for control of events less than that resulted in very small facilities that provided little benefit during the larger storms. The resulting benefit to cost ratio was small and would render the improvements unattractive. As such, the Project Sponsors concluded that alternatives should be sized to control the 100-year flood and evaluate the benefits and effects on the larger 500-year storm, with the exception of the alternative specifically intended to provide the improvements identified in the Stormwater MP.

At this stage in the evaluation, the distinction between open channel conveyance and underground conveyance was not critical unless some other constraint drove the determination. Preliminary alignments were chosen based on available corridors using parcel data provided by the city and the County. Every effort was made to define alignments down public rights of way so that public impacts would be minimized.

The sizing of the flood storage facilities also relied on information derived from the Course Grid or Cut-Off MIKEFLOOD model results. Here, rather than merely determining the peak flow, it was also necessary to determine a hydrograph and total volume of flow to the area in question. This was specifically necessary when considering the alternatives that had storage upstream of US-36.

Best Alternative Plan Hydraulics

Best Alternative Plans were looked at more carefully than previous analysis of the alternatives described in the Alternative Development and Conceptual Alternative Analysis, both in terms of the refinement of system elements and in the hydraulic evaluations. The Best Alternative Plans utilize the MIKEFLOOD "Coarse Grid" model exclusively to model and optimize each plan. Using MIKEFLOOD analyses of the alternatives were more comprehensive and provided a more refined understanding of the system performance, flow rates expected for each flood mitigation system and the resulting floodplain extent. This proved to be particularly true for the detention alternatives where the MIKEFLOOD tool provided a much better understanding of the complex interaction between the South Boulder Creek channels, the floodplain, and the storage facilities. This more refined approach also provided data used to update and refine the size of facilities based on the routed flow rates from the model, refine the damage estimates, and allowed the team to refine and update the benefit cost analysis.

Storage facilities were simulated in MIKEFLOOD with a relatively high level of resolution. This was necessary because of the complex interaction of flows between the various sub-reaches of the system and because of the severe constraints that were identified around most of the storage options. While a conventional analysis of storage options would allow the simple development of stage, storage and discharge functions, MIKEFLOOD, and the site conditions around each of the storage elements made this typical evaluation process inadequate. Rather, a detailed grading plan was necessary at each site so that the facility could be adequately represented in the model. Grading plans for each site can be found in Appendix D

The storage facilities near Hwy-93 proved to be complex. These storage facilities capture overflows over Hwy-93 and delay their return to the mainstem. While these storage facilities are of considerable size, the value of the detention comes from the impacts on hydrograph routing and timing more so than the actual storage of water. The flow passing through the storage facility during the early stage of the hydrograph is returned to South Boulder Creek through a large weir un-detained. However, the storage facility near Hwy-93 begins to detain flow during the peak of the South Boulder Creek hydrograph. This detention prevents the overtopping of US-36 by reducing the peak flow at US-36. This storage area consists of two areas, which, in combination, provide the necessary control. The layout of these storage areas was based on some, but minimal, excavation and the construction of relatively high embankments. Concept Plans for this detention alternative can be found in Appendix D

Storage at US-36 was more straightforward but had some unique complexities. The layout was intended to maximize the storage and minimize impacts to CU property and to Open Space land. A combination of excavation and fill were incorporated into the storage footprint. The existing Viele Pond was incorporated into the refinements made at this stage of the evaluation to attempt to maximize the existing storage areas. The operation of this system proved to be very sensitive to outflow and several refinements were necessary to achieve the desired performance.

Lower basin storage such as the storage at Manhattan Middle School was incorporated into the MIKEFLOOD model with little difficulty. The outfall from these facilities was optimized to provide the maximum benefit and to minimize the need to replace existing downstream infrastructure.

The storage associated with the Distributed Regional Detention presented challenges similar to Hwy-93 storage. These facilities included a combination of mainstem and off channel storage that had complex interactions during flood events. A careful review of flood hydrographs from the Coarse Grid MIKEFLOOD model at key locations throughout the project area and a review of physical constraints allowed the modeling and optimization of the timing of capturing and releasing flows to downstream detention facilities. These facilities were used to mitigate and improve flooding conditions throughout the West Valley by preventing the overtopping of US-36 and controlling and reducing peak flows along the mainstem of South Boulder Creek.

The incorporation of underground pipes and large open channels into MIKEFLOOD is complex and time consuming. However, the benefits of these facilities needed to be characterized so that reasonable determinations of the reduction in flood threat could be conducted. The process for representing these facilities in the MIKEFLOOD model was to adjust the surface flow rate. This was done within MIKEFLOOD by creating a "sink" where flow leaves the system. A physical analogy for this would be that the "sinks" represent inlets that take flow from the surface of the model and into the pipe or large open channel. This simplification provided a realistic representation of the system and enabled the model to establish the character of residual overland flows that might cause flood damage.

The results of the more detailed hydraulic evaluations for the Best Alternative Plans resulted in considerable refinement of the storage areas but only nominal changes to the conveyance facilities. The model did provide a better understanding of the nature and extent of the residual floodplain, particularly in areas in the lower part of the watershed along the mainstem. Figures 7-1 through 7-9 include the results of the hydraulic evaluations conducted for each of the Best Alternate Plans using MIKEFLOOD.

Flood Hazards

Flood hazards in the South Boulder Creek watershed are clearly articulated in the reports prepared as part of the Mapping Study. These hazards were confirmed using the Coarse Grid model. Only very small storms stay confined to the channel, storm drain systems or within the street right of way. Other events quickly exceeded the capacity of the conveyance areas and spread into the overbank. The 2-D model effectively allowed the determination of how much water left the channel and where it went.

The existing conveyance infrastructure throughout the West Valley includes both open channel conveyance and closed conduit conveyance. As described earlier the west valley can be broken down into three major flow profiles and existing irrigation ditch channels. During the flood mapping study, 1-D channels were selected for modeling based on one or more of four criteria.

1. channels with significant hydraulic capacity; in excess of 1,000 cfs,
2. channels with hydraulic capacity that were wholly or partially outside of the 2D model domain
3. channels which the resolution of the 2D topography did not resolve adequately or
4. channels that had hydraulic structures on them, i.e., bridges, culverts, or diversion gates.

For additional information on how 1-D elements were selected for modeling for the South Boulder Creek Flood Mapping Study please see Appendix C of the *South Boulder Creek Hydraulic Modeling Report, HDR, December 30, 2008.*

Irrigation Ditches/Channels

Several irrigation ditches cross the South Boulder Creek floodplain. These irrigation ditches are hydraulically linked to the South Boulder Creek floodplain and are still in use delivering water to customers throughout the West Valley. Figure 4-1 displays the 1-D modeling domain in MIKEFLOOD and the modeled 1-D channels.

Anderson Extension Ditch

This ditch parallels Table Mesa Drive and South Boulder Road to the south. The ditch originates on Bear Canyon Creek at the intersection of Table Mesa Drive and Broadway west of the project area. This ditch is currently operated by the Baseline Reservoir stakeholders and has an active decree flow of 50 cfs. This channel intercepts overflows from South Boulder Creek near the Table Mesa – Foothills Parkway Interchange for flood ranging from the 25-year recurrence

interval through the 500-year recurrence interval and again north of the interchange from the overtopping of US-36 during flood greater than the 100-year flood. The capacity of the ditch is exceeded when the floodwaters enter the channel during the 100-year flood. This channel was not modeled in the 1-D model because it conveyed flow less than 1,000 cfs, However the culverts along the Anderson Extension Ditch were determined to be hydraulically significant and were added to the 1-D modeling domain for the Mapping Study MIKEFLOOD model. A loading point was used at the southeast corner of the Table Mesa Drive and US-36 and was included in the 2-D modeling domain.

Dry Creek No. 2 Ditch

This ditch runs south to north roughly parallel to 55th Street through the West Valley. This channel is a remnant of the South Boulder Creek alluvial fan channel system prior to development. Currently the ditch diverts water near Eldorado Springs south of the project area, runs north through Marshall and the South CU Campus. The ditch is conveyed through a 6' x 4' Reinforced Concrete Box Culvert (RCBC) under US-36 and then enters the West Valley. Currently this ditch has three remaining shareholders north of US-36 that include Manhattan Middle School, Flatirons Golf Course, and a private owner in the Flatirons Industrial Park. The active decree for the ditch is 69 cfs. This ditches' capacity is overwhelmed during the 25 year and 50 year recurrence intervals due to local basin inflows including C2 basin loadings at Manhattan Middle School and inflows from the Wellman Canal. The 100-year overflow of US-36 by South Boulder Creek enters Dry Creek No. 2 Ditch and overwhelms the entire capacity of the ditch for storms greater than the 100-year storm.

Wellman Canal

The Wellman Canal is owned by Xcel Energy and flows from west to east from Boulder Creek south of Arapahoe Road to Valmont Reservoir. This ditch delivers decreed flows to the Xcel operated Valmont Power plant for cooling processes. The Wellman Canal was not modeled in the 1-D, due to the general lack of hydraulic structures and the low flow rates normally conveyed by the channel. This canal was captured in the 2-D model domain.

This ditch is aligned perpendicular to Bear Canyon Creek, South Boulder Creek, and Dry Creek No. 2 Ditch and intercepts flood flows from all of these channels, which quickly overwhelm the channel capacity from storms as small as the 25-year storm. The total decreed flow for the Wellman Canal is 819.2 cfs, which is the sum of the decreed flows from South Boulder Creek, Skunk Creek, and Bear Canyon Creek. Much of this water does not enter into the Wellman Canal and is delivered to the Valmont Reservoir through flow exchanges with various water holders throughout the basin. The total decreed flow from all water sources would exceed the capacity of the existing channel, which has a current capacity of approximately 80 cfs maximum. Xcel energy would prefer that the existing capacity of the ditch be maintained in review of any alternatives that impact the Wellman Canal

Viele Channel

The Viele channel runs generally from west to east parallel to Table Mesa Drive, crosses through culverts through the Foothills Parkway interchange and then parallels South Boulder Road on its way to South Boulder Creek. This channel intercepts South Boulder Creek floodwaters near South Boulder Road but is also the source of local sub-basin flows that contribute to the flooding of South Boulder Creek. This channel is not an irrigation channel but a natural conveyance channel and has an approximate capacity of 500 cfs. This channel did not meet the 1,000 cfs criteria for modeling in the 1-D MIKEFLOOD modeling domain. However, the culvert structures did meet the criteria and the Viele Channel culverts were added in as 1-D elements for the MIKEFLOOD regulatory model.

Enterprise Ditch

The Enterprise ditch has its head gates at South Boulder Creek just downstream of South Boulder Road. This ditch carries water northeast north of Baseline Reservoir. This ditch Primarily crosses open space and is completely overwhelmed by the flood flows from South Boulder Creek. Flows that enter this ditch either spill from its banks back into South Boulder Creek or continue along the conveyance removing flow from the South Boulder Creek Floodplain. This ditch is primarily located in Boulder County and was not a focus of this current study.

Scherer Ditch

The Scherer Ditch runs generally northeast east of South Boulder Creek and crosses US-36 near Cherry Vale Road. The head gates of this ditch are located just north of HWY -93. Flows that enter this ditch are conveyed away from South Boulder Creek and do not have a chance to re-enter South Boulder Creek. Due to capacity-limited culverts near US-36 Land adjacent to the highway is expected to see shallow flooding during a 100-year event. This ditch is primarily located in Boulder County and was not a focus of this study.

Local Storm Drainage

Local storm drainage facilities through the West Valley generally flow from south to north and rely on existing irrigation ditches to help convey flood flows through the area. Below is a detailed description of the existing local storm drainage through each neighborhood within the Study Area as well as a reach-by-reach description of the local storm drainage infrastructure. For a detailed description of the local storm drainage infrastructure, please see the HDR Engineering, Inc. *Volume 1 - Final Report City of Boulder Stormwater Master Plan*. Boulder (2007).

Keewaydin Neighborhood

In this neighborhood east of Foothills Parkway and north of South Boulder Road, the existing storm sewer infrastructure generally takes water from the neighborhood west to the storm sewer trunk line that parallels Thunderbird Lane west of Foothills Parkway. Storm sewer in the area is generally less than 27" in diameter and conveys nuisance flows. This stormsewer infrastructure was not included in the MIKEFLOOD model that was completed for the flood mapping study. The flood conveyance is generally south to north through this neighborhood and the existing storm sewer has little impact on the 100-year flood.

Frasier Meadows Neighborhood

The Frasier Meadows Neighborhood lies just to the west of Foothills Parkway. This neighborhood is impacted by the overflow of US-36 by South Boulder Creek. Existing storm sewer infrastructure leads to a trunk line under Thunderbird Lane. This trunk line accepts flows from both the Frasier Meadows Neighborhood and the Keewaydin Neighborhood. The maximum pipe diameter is 48" and discharges into detention ponds at the corner of Foothills Parkway and Baseline Road. These systems are overwhelmed by the overtopping flows from South Boulder Creek. This pipeline was not included the 1-D MIKEFLOOD model due to the limit capacity of the pipe and the potential for debris blockage.

Park East Neighborhood

The Park East Neighborhood is north of Baseline Road and East of Foothills Parkway. This neighborhood is flooded by the West Valley flooding from Baseline Road. There is not any storm sewer through this neighborhood except along Pennsylvania Avenue on the north edge of the neighborhood. This storm sewer intercepts flow and takes it east to Dry Creek No. 2 Ditch and the Wellman Canal. The maximum size of the storm sewer is 36" in diameter and is overwhelmed by the 100-year flood flows. This pipeline was not included the 1-D MIKEFLOOD model due to the limit capacity of the pipe and the potential for debris blockage.

Arapahoe Ridge Neighborhood

The Arapahoe Ridge Neighborhood is located north of the Wellman Canal and East of Foothills Parkway. This neighborhood is flooded by the West Valley flooding from the Wellman Canal. Storm sewers in the area generally take flow north across Arapahoe Avenue and Boulder Creek or east to the Flatirons Golf Course and Dry Creek No. 2 Ditch Drainage. The maximum size of the storm sewer is 45" and is on average 24" in diameter. The storm sewer is overwhelmed by the 100-year flood flows. This pipeline was not included the 1-D MIKEFLOOD model due to the limit capacity of the pipe and the potential for debris blockage.

Flatirons Industrial Park

This is the final area prior to South Boulder Creek discharging to Boulder Creek. This area is north of Arapahoe Road and east of Foothills Parkway. Storm sewers in this area are generally small and drain most of the flow to Dry Creek No. 2 Ditch that is the main stormwater conveyance through the area. Storm sewer mains can reach a maximum size of 60" x 36" RCBC but are on average 24" in diameter. This system helps alleviate flooding through the Industrial Park but still is overwhelmed by flooding from South Boulder Creek. This pipeline was not included the 1-D MIKEFLOOD model due to the limit capacity of the pipe and the potential for debris blockage.

Flooding Problems

Flooding problems through the West Valley are generally caused by uncontrolled overtopping of US-36 into the West Valley as identified in the Flood Mapping Study. However, additional sources of flooding also occur within the West

Valley. A reach-by-reach description of flooding issues follows, and Figure 2-4, Reach Description, graphically displays each reach described below.

Reach 1

South Boulder Creek exceeds the conveyance capacity of its channel at the very upstream of this study reach near Hwy-93. Here, both the channel and the Hwy-93 crossing of the South Boulder Creek mainstem are undersized. Flood flows in excess of the 10-year flood spread to the west and north behind Hwy-93 and overtop the highway and inundate Marshall Road, eventually reaching the CU levee and being directed back toward the mainstem. The CU levee effectively protects the area of the South Campus and, in combination with the mainstem and Dry Creek No. 2 Ditch conveys flows toward US-36.

The channel upstream of US-36 is inadequate to convey the full flood flows under US-36. While the bridge is adequate to convey the full 100-year flood, only a small fraction of that flow remains in the channel. Flows in excess of the upstream channel capacity spill to the west and flow along the south side of the US-36 right of way toward the Viele Channel and the Foothills Parkway interchange. The water spreads out behind US-36, inundating portions of the CU property and spilling into the pond on the Viele Channel. For storms smaller than the 50-year event, the flood flows are generally confined to the upstream side of US-36. Storms in excess of the 50-year overtop US-36 and spill into the West Valley, flowing north along Foothills Parkway.

Reach 2

Flows from the local tributary sub-watershed contribute to the flood hazard along South Boulder Creek. The primary sub-watershed of concern (Sub-watershed C2) is to the west of the mainstem and consists of highly urbanized areas of South Boulder. During the Mapping Study, the C2 sub-watershed was further subdivided into five areas and the inflows were added into the hydraulic model at points that represent the natural drainage patterns as shown on Figure 4-3. Inflows from the Bear Canyon Creek watershed are also accounted in the model. These tributary inflows create a flood hazard that is independent of the mainstem flood issues. It was the intent of this study to mitigate the effects of flooding from the South Boulder Creek mainstem only and not address localized flooding caused by local basin inflow flooding. While smaller in nature than the large floods associated with the mainstem, these have the potential to create damages. As is expected, the extent of the flooding associated with these tributary inflows increases as the storm intensity increases. Most of the flooding within the areas west of the mainstem associated with these inflows is localized and the result of undersized street and drainage system capacity.

Reach WV2

The flood threat in the West Valley is greatest when US-36 overtops during events in excess of the 50-year flood. The overflows from US-36 generally follow the alignment of Foothills Parkway, initially concentrated on the west side of the Foothills Parkway roadway. These flows are significant and would cause extensive damage along Thunderbird Drive all the way to Baseline Road. In addition to the flooded areas, there are two structures located within the city's designated High Hazard Zone in this reach. Some buildings and facilities designated by the city as critical are also in the floodplain in this reach.

Reach DC2

The Dry Creek No. 2 Ditch corridor is the source of considerable flooding below US-36. This conveyance is part of the primary outlet for the ponded water above US-36. As the water from larger floods passes under the highway through Dry Creek No. 2 Ditch, the Anderson Extension, and Viele Channel, it exceeds the combined capacity of these systems at South Boulder Road. Water overtops South Boulder Road and flows through the neighborhoods west of Dry Creek No. 2 Ditch. Water generally follows the street corridors and causes some localized flooding when street and drainage system capacity are undersized.

Reach M2

Mainstem flows that make their way under the US-36 crossing continue to exceed the capacity of the South Boulder Creek channel. This water spreads out above South Boulder Road and overtops the road, creating two flow paths, one along the mainstem and another along the alignment of the New Anderson Extension and Enterprise Ditch. These two flow paths recombine at Baseline Road. There are additional overflow paths from the mainstem just north of the East Boulder Recreation Center that continues to the north across undeveloped land. A portion of the flood flows are diverted out of the basin and flow toward Baseline Reservoir. The details of that flow are provided in the Mapping Study *Hydraulic Modeling Report* (HDR, December 30, 2008)

Reach 3

Between Baseline Road and the Wellman Canal (approximately Colorado Avenue extended) the flood hazard continues to be most significant for properties located along roadways used as the primary conveyance and for areas adjacent to the mainstem.

Reach WV3

The flows from the upstream reaches of the West Valley are exacerbated by inflows from portions of the C2 basin joining at Baseline Road and Foothills Parkway. The combined flows overtop Baseline Road and flow through the neighborhood along McIntyre Street and Brooklawn Drive. Homes along these streets and the adjacent and interconnecting roadways are subject to flood threats as the capacity of the street and drainage system is exceeded. A portion of the flow remains west of Foothills Parkway and is diverted over to the Bear Canyon Creek watershed. These flows are generally confined to the road right of way and do not pose a significant hazard to residential or commercial properties.

Reach DC3

Dry Creek No. 2 Ditch in this reach is generally adequate to convey all but the most extreme flows. There are a few locations where the ditch capacity is exceeded and minor inundation occurs adjacent to the channel. The lower part of the reach, there is an inflow from the West Valley overflow that occurs near 55th Street and Pennsylvania Avenue that cause flooding of Dry Creek No.2 Ditch into the surrounding neighborhood and the Wellman Canal.

Reach M3

The mainstem floodplain is broad in this reach extending from Gaptor Road on the east across Open Space land, almost reaching Meadow Glen Drive. Fortunately, with the exception of homes along Gaptor Road, there is very little hazard to properties other than Open Space.

Reach 4

Below the Wellman Canal (approximately Colorado Avenue extended) the floodplain from the various tributaries begins to converge. At Arapahoe Avenue, the minor storms continue to have distinct areas of flooding but as the flood events become more extreme, the flood flows join and form one large area of ponding above Arapahoe Avenue.

Reach WV4

There is limited infrastructure along this reach and flows quickly exceed the capacity of the roadway and the minor drainage system. Residential flooding along the street is common and the properties adjacent to Arapahoe Avenue are subject to considerable hazard for all but the smallest events. The portion of the flow that remains west of Foothills Parkway and is diverted over to the Bear Canyon Creek watershed begins to spread outside the right of way to the west before reaching Boulder Creek. Flood flows near the confluence of Bear Canyon Creek and Boulder Creek do not pose a significant hazard to residential or commercial properties.

Reach DC4

Dry Creek No. 2 Ditch in this reach enters the Flatirons Golf Course where flood flows spread out over the golf course in shallow overland flooding. These flood flows have limited impact to the structures on the property. The Clubhouse is elevated above the 100-year flood. Minor damage and the resulting repair to the golf course would be expected during large floods. Flood flows spread out west of the channel and impact a few properties along Arapahoe Avenue. Once flows reach Arapahoe Avenue, they combine with flows from the West Valley and the mainstem to form a large pool upstream of the roadway.

Reach M4

The mainstem floodplain is broad in this reach extending from the back yards of homes along Gaptor Road across the Flatirons Golf Course to the west. Much of the flood flows are confined to the channel but also extend to the golf course and can begin doing damage to residences along Old Tale Road and Gaptor Road during the 10-year flooding event.

Damages across the golf course are negligible. Once flow reaches Arapahoe Avenue, the floodwaters combine with the flow from the West Valley and Dry Creek No. 2 Ditch to form a large pool upstream of Arapahoe Avenue.

Reach 5

South Boulder Creek below Arapahoe Avenue is characterized by large tracts of commercial and industrial properties with a broad floodplain but significant conveyance capacity. Nevertheless, there is considerable flood hazard as flood waters flow overland before reaching these large channels.

Reach WV5

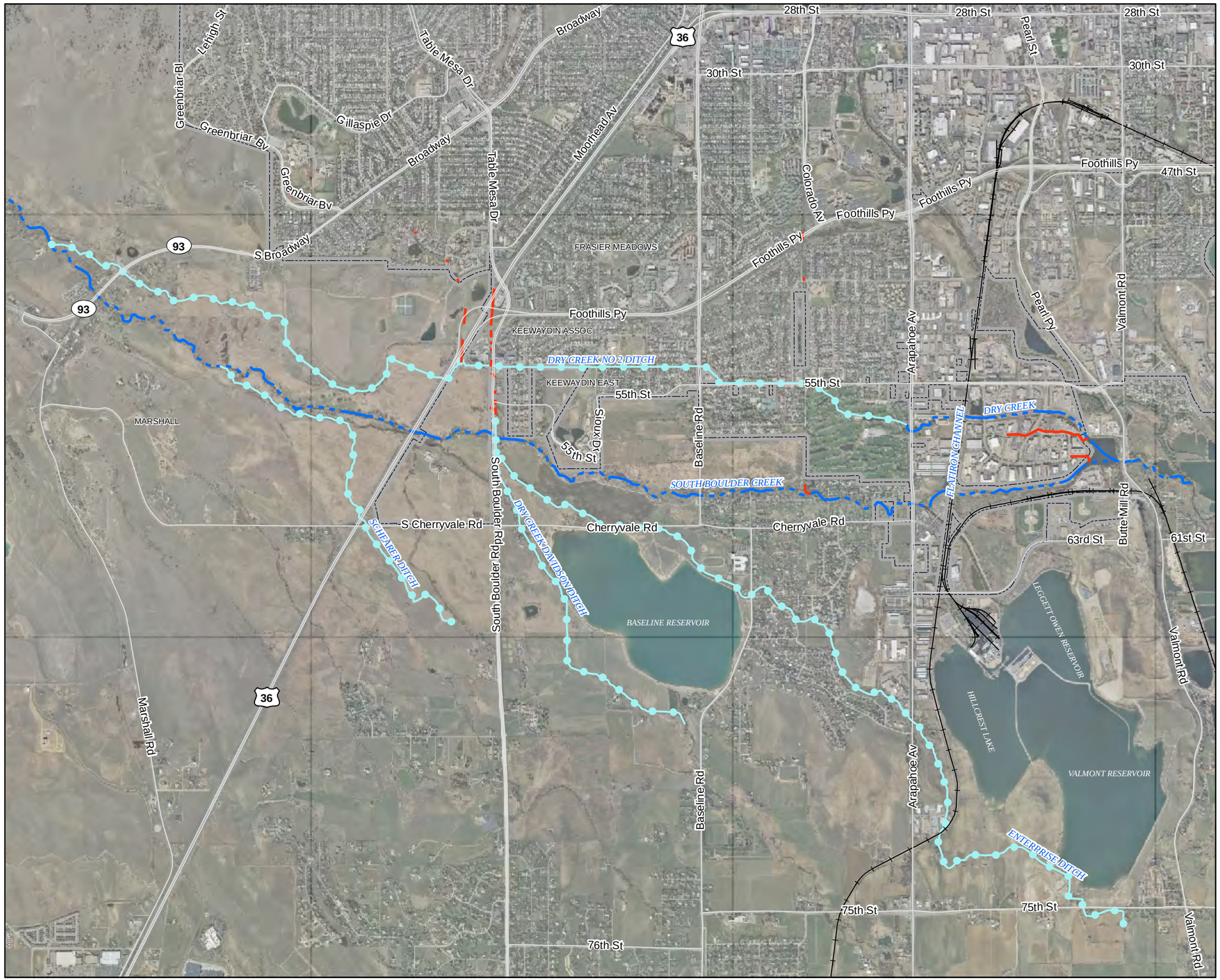
There is limited infrastructure along this reach and flows never return to South Boulder Creek. Rather, they flow north down roadways and through developed properties south of the railroad tracks. Once at the tracks, the flow diverts and flows directly to Boulder Creek west of the Roche property or along 55th before reaching Boulder Creek.

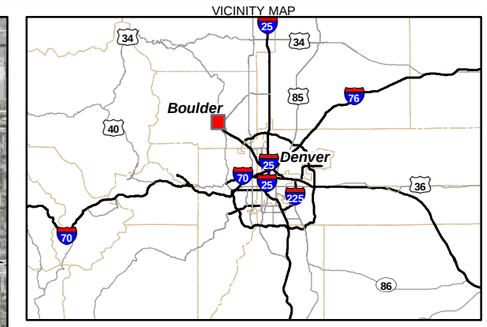
Reach DC5

Dry Creek No. 2 Ditch in this reach has a somewhat limited capacity between Arapahoe Avenue and the railroad. There is a relatively broad floodplain extending both east and west from the channel and inundating several properties. Once the Dry Creek Ditch No. 2 channel has crossed the Burlington Northern railroad, the channel capacity increases dramatically over upstream capacity and flood flows entering the channel are conveyed to Boulder Creek without exceeding the capacity of the channel. The railroad serves to concentrate and collect flow and the floodplain downstream is smaller. Areas within the Flatirons Industrial Park are subject to some elevated flood threat during events that exceed the capacity of the channel.

Reach M5

The mainstem of South Boulder Creek between Arapahoe Avenue and the railroad is similar to that of DC2 in that it has a limited capacity but there is limited impact because of undeveloped parcels. The overtopping of Arapahoe Avenue does create a broad flood threat to the business and industrial area to the north of Arapahoe Avenue. At the railroad, flow is once again concentrated and flows under the tracks and into the main channel. A cross channel between Dry Creek No. 2 Ditch and the mainstem is undersized and cannot effectively balance flows between the two conveyance channels. This results in flows during larger events flowing into the Flatirons Industrial Park. At Valmont Road, South Boulder Creek, flows join those in Boulder Creek.





LEGEND

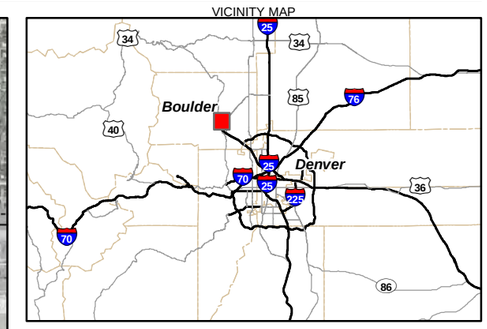
1-D Modeled Channels

- 1-D Modeled Streams
- 1-D Modeled Irrigation Ditches
- 1-D Modeled Culverts & Storm Sewers
- Boulder County

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 4-1
Graphic Extent of Flood Mapping Study 1-D Hydraulic Simulation Channels
South Boulder Creek Flood Mitigation Report



LEGEND

- 2-D Model Domain
- Streams, Creeks and Ditches
- Boulder County

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 4-2
Graphic Extent of Flood Mapping Study 2-D Hydraulic Simulation Area
South Boulder Creek Flood Mitigation Report

CH2MHILL

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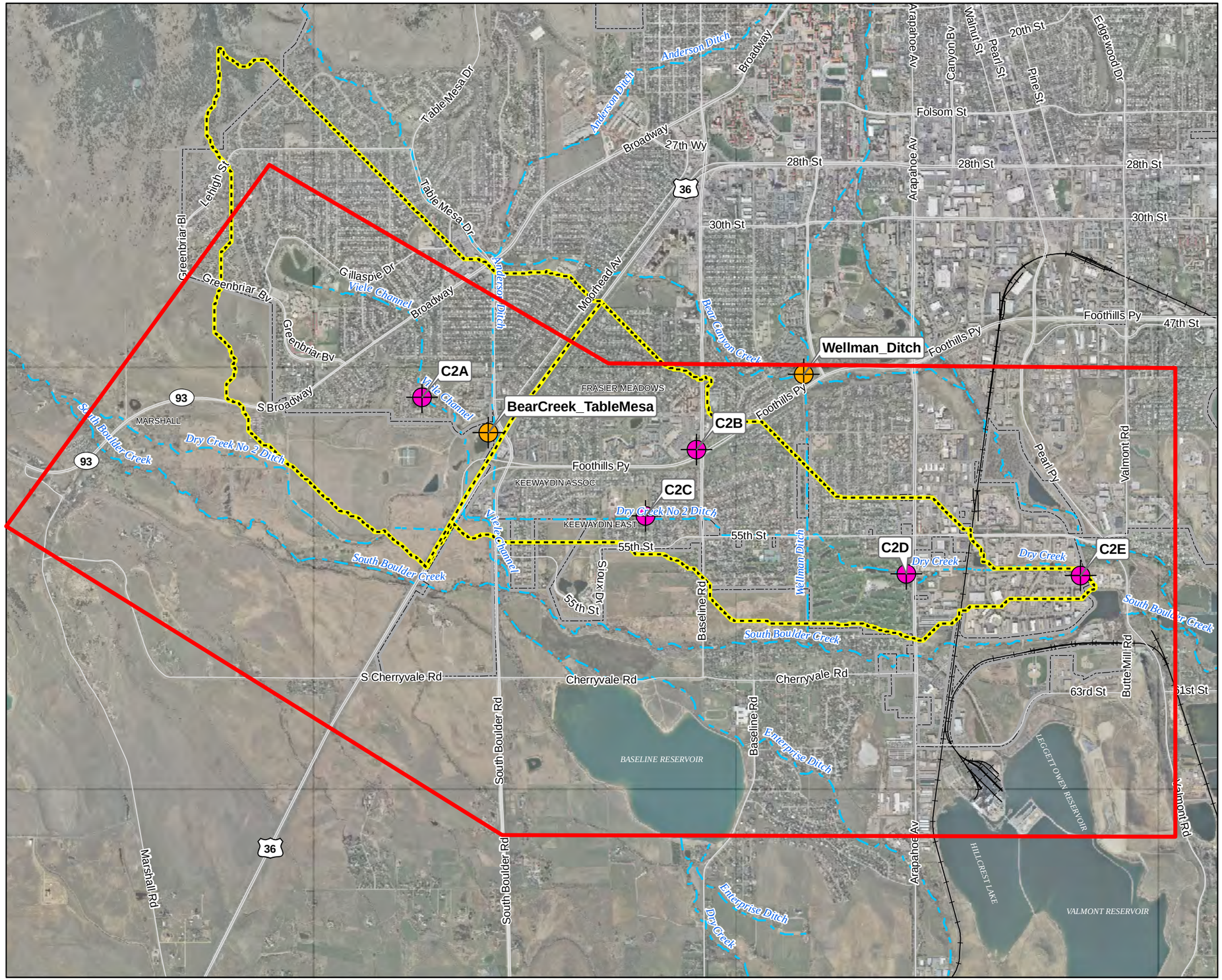

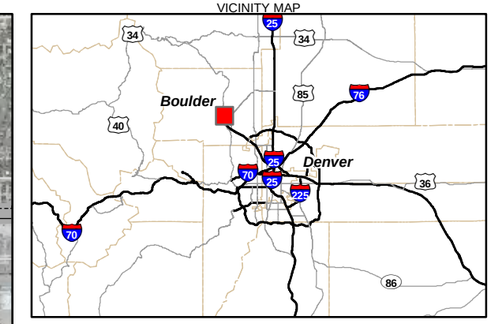

LEGEND

- Bear Canyon Creek Overflow Loading Points
- C2 Sub-Basin Hydrograph Loading points
- South Boulder Creek C2 Basin Boundary
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 4-3
Tributary Basin Loading Points
South Boulder Creek Flood Mitigation Report

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V. Alternative Development

Sections V, VI, VII, VIII and IX describe the process of developing alternatives to address flooding issues through the West Valley from South Boulder Creek from initial problem identification through the selected plan.

Section V presents the process for initial problem identification, identified problem solutions and screening of the initial identified problem solutions. This initial screening process was accomplished through interactive workshops with stakeholders, an initial public meeting, and with the use of basic hydrologic and hydraulic tools.

Section VI presents the formulation of the 15 Conceptual Plans and the method of evaluation. This secondary screening process was accomplished through interactive workshops with stakeholders and was further screened by utilizing MIKEFLOOD to optimize the concept design, develop the alternative benefits and cost, and to estimate the benefit cost analysis of each alternative.

Section VII presents the review and selection process for the 9 Best Alternative Plans from the 15 identified plans described in Section VI. These alternatives were further screened by utilizing MIKEFLOOD to optimize the concept design, develop the alternative benefits and cost, and to estimate the benefit cost analysis of each alternative. After presentation of the 9 Best Alternative Plans to WRAB on December 14, 2011, WRAB along with subsequent discussions with OSMP selected 5 Alternative Plans to be refined further. The 5 alternatives selected for further refinement were the:

- Status Quo Alternative
- High Hazard Zone Mitigation Alternative
- Regional Detention at US-36 Alternative
- Distributed Regional Detention Alternative
- Bear Canyon Creek Pipeline Alternative

Section VIII presents the refinements to the 5 plans selected by WRAB and discussions with OSMP. This section presents a more detailed evaluation so that the elements of the plans could be refined with greater resolution and the plans could be more clearly communicated to the public.

Section IX describes the process and reasoning behind the Engineers Recommended Plan that will be presented to city Staff for further review through public input, WRAB meetings and city Council meetings prior to ratification of the mitigation plan. This section includes the final benefit - cost ratio and final configurations, and sizes of all flood control facilities recommended by the engineer.

Alternative Development Process

The development and evaluation of alternatives is a sequential process that takes a broad range of options and systematically reduces them into a manageable number of alternatives. The process defined by the District and articulated in the approved Scope of Work follows this approach.

The initial screening of options builds on an understanding of the problems within the watershed and the identification of various types of improvements to address the identified problems. The general problem understanding builds on the insights gained in the Flood Mapping Study and Risk Assessment. In this, several broad issues that caused much of the flood threat within the West Valley were identified:

- **Overtopping of US-36** – Overtopping creates a number of flood hazards downstream, including overwhelming the existing conveyance system, which, in many cases, consists exclusively of surface conveyance via roadways, or small undersized storm sewer systems.
- **Overflows from existing pipe and channel conveyance systems** – The undersized systems often cause flooding along the channel banks or the pipe alignment due to overflows from the pipes and channels. However, in many cases, the undersized open channel conveyance systems often back up water behind existing structures and embankments causing additional flood damage because of upstream inundation and roadway overtopping.
- **Overflows from surcharged irrigation ditches** – Similar to the undersized channels, undersized ditches present a flood hazard as the result of potential overtopping. When undersized ditches exceed their flow capacity and convey additional flood flows from South Boulder Creek, adjacent properties may be subjected to flooding. Moreover, irrigation ditches provide a means for flows from the South Boulder Creek drainageway to reach areas that may be isolated from the direct flooding effects of South Boulder Creek. In the case of ditches conveying flood flows from South Boulder Creek and other surrounding watersheds, these ditches exacerbate the flood hazard by conveying flows to flood prone properties.
- **Overflows from the mainstem that worked their way into the West Valley** - In areas where the mainstem of South Boulder Creek is inadequate, flow leaves the mainstem and flows overland toward the West Valley. These flows reach areas where the existing infrastructure is not intended to capture and convey those flows and quickly becomes surcharged, increasing the flood risk.
- **Transbasin inflows from Bear Canyon Creek** – Flows from Bear Canyon Creek enter the South Boulder Creek watershed, in multiple locations, because of undersized drainage conveyance in the Bear Canyon Creek watershed. Control structures are subject to overtopping with the excess discharge flowing down streets or irrigation channels to South Boulder Creek.
- **Local C2 Basin Inflows** – Flows originating from the local C2 basin within the South Boulder Creek watershed, in multiple locations, result in additional local flooding issues. The flows from the C2 basin, which enter the West Valley North of US-36, fill the capacity of local drainage systems eventually overwhelming the local drainage systems prior to South Boulder Creek Flooding the West Valley. Excess discharge from the overwhelmed local drainage system ends up flowing down streets or irrigation channels to South Boulder Creek causing flooding damage through the West Valley.

Within each of the above-described identified flooding triggers, a number of more specific issues were identified within the various study reaches. Because of the preliminary nature of this evaluation, the study reaches were more generally defined into two reaches, one following the alignment through the West Valley and the other along the Dry Creek No. 2 Ditch. Since the focus of the evaluation was limited to addressing problems in the West Valley, issues of concern along the mainstem were not explicitly addressed. Similarly, a detailed evaluation of the specific problems within each of the previously described sub-reaches along both the West Valley and the Dry Creek No. 2 Ditch alignments was premature for screening purposes.

The project also defined a number of potential mitigation measures that were included in the evaluation process. These alternatives formed the suite of potential options that would be considered to address the identified problems. The alternatives ranged from large structural improvements such as pipes, channels or detention ponds to flood-proofing and non-structural floodplain management measures to maintaining the status quo. Specific measures to be considered include:

- **Installation of Major Underground Conduits** – Major underground conduits are those that have the capacity to convey large quantities of flow. For this analysis, they were assumed capable of conveying flows in excess of the 10-year flood. These conduits would generally follow existing street alignments but may, in some cases, follow other undeveloped corridors.
- **Limited Structural Improvements or Additions** – Limited improvements are generally identified to address a specific problem that stems from a very well defined and isolated source. These may include the culvert enhancements that relieve an obstruction caused by an undersized bridge or culvert. In other cases, these improvements may consist of an addition of another conveyance element that improves the hydraulic conditions at the identified location.
- **Improvements to Existing Channels** – These improvements generally consist of the expansion of existing channels to provide greater conveyance capacity. In many areas, this will require the widening of the existing channel because groundwater or grade constraints preclude the significant lowering of the channel bottom.
- **Regional Detention Facilities** – These are large flood storage facilities that capture significant portions of the flood flows and store them for later release when there is available capacity in the downstream facilities. These facilities often consist of earthen embankments or excavated areas that capture floodwaters and relatively small outlet pipes that meter the water slowly back into the natural drainage course.

- **Local Detention Facilities** – In contrast to large regional detention facilities, these local detention facilities are much smaller and are intended to address inflows from a much smaller drainage basin. In many cases, properly located and sized local facilities can significantly reduce the infrastructure required to handle inflows from the lower tributary areas along South Boulder Creek.
- **Flood Proofing of Critical Facilities** – In some cases, the nature of the flooding is so distributed that extensive stretches of the stream cannot be economically addressed. In these cases, it is sometimes advisable to focus on isolated structures to mitigate flood hazard. In the case of flood proofing, modifications to specific structures can be made to reduce the impacts of flood flows by preventing them from entering and damaging the structure or by reducing the expense to repair the structure after a flood.
- **Non-Structural Methods** – Non-structural methods have long been embraced in Boulder. These include measures such as flood warning or floodplain management to the preservation of the natural flood storage found on Open Space lands.
- **Flow Diversion** – Flow diversion takes advantage of the potential available capacity in adjacent waterways to convey flood flows out of the areas of greatest impact. Flow diversions allow the residual flow to be reduced and often significantly reduce the flood threat.

A screening matrix approach was used to evaluate the suite of identified problems and identified solutions. The more specific problems defined one axis of the Potential Solutions Screening Matrix while the suite of potential mitigation measures defined the other axis. This screening matrix provides a quick summary of the full suite of potential solutions and allows a quick assessment of the viability of any solution to address the identified problem area.

Alternative solution elements were screened by determining the viability of a particular option. In all cases, the options were generally assumed viable unless some particularly significant constraint was identified or the option was not applicable to the problem. Constraints were generally deemed significant if they would impose an extraordinary mitigation burden or that would require significant cost to address. These might include significant impacts to Open Space where the proposed uses were in direct conflict with known Open Space values. An example might be the construction of a large culvert that would drain an Open Space area acquired for its wetland habitat thereby changing the natural community, intended use of the land and ecological function. Similarly, an alternative that proposed the enlargement of a small, naturally vegetated open channel with a large, prismatic landscaped open channel might have unacceptable impacts to threatened and endangered species along the alignment. Alternative elements that were considered not applicable were ones, which would not address the identified flood hazard problem in any meaningful way. None of the evaluation standards were absolute and alternative elements were sometimes carried forward even in the face of substantial flaws if it was felt that they may be important elements of a future plan that would address the overall hazard in a meaningful way.

Two Potential Solutions Screening matrices were developed, one for each of the two study reaches. Within the screening matrix, each potential solution was assessed to determine if it could be part of a broader solution effort that resolved each of the identified issues. A high-level screening matrix was developed for each reach and is presented as Figure 5-1, Potential Solutions Matrix. In this matrix, large dots represent feasible options that received further attention.

The content of Figure 5-1, Potential Solutions Matrix was discussed and developed during the first of several workshops conducted during the study. Workshop Number 1 focused on the identification of significant constraints that would render a particular solution element infeasible. The workshop, conducted on January 27, 2010, was attended by most of the project stakeholders. A number of other major constraints were identified during the workshop including the consideration of past public objection and the lack of an existing defined drainageway that would preclude the construction of a new open channel.

Following Workshop Number 1, a second series of Potential Solutions Screening matrices were developed that looked more carefully at specific elements to address specific problem areas. In this matrix, presented as Figure 5-2, Refined Potential Solutions Matrix, more detail regarding the specific elements that could be used to address a problem area is provided.

The various elements presented in the refined matrix provide a better understanding of the type of improvements envisioned. For example, rather than merely identifying that channel improvements are reasonable, the refined matrix describes a general location and type of channel that will address the identified problem. All evaluations used to refine the matrix were qualitative and based on the input received during the Workshop and are located in Appendix A. In most cases, the capacity of the improvements, the specific alignment or the exact geometry was not specified. Sizing and specific alignments were defined in general terms. With this better understanding of potential elements that could address specific problems it was possible to begin a more detailed evaluation and then assemble the elements into viable plans.

Constraints and Criteria

In order to guide the evaluation of the various elements, several overlaying objectives were identified. These objectives provided some framework that would shape the formulation of plans.

The primary focus of the study remained the protection of properties in the West Valley. This previously articulated objective is consistent with direction received subsequent to the past planning efforts and during the Flood Mapping Study. The protection of these properties that were constructed prior to a clear understanding of the flood threat remains the primary focus of the study.

Constraints

Containment of the High Hazard Zone so that no structures are impacted by this floodplain zone designation is a broad objective established by city Council during past planning studies. This past direction was imposed on this study. Efforts would be made to contain the High Hazard Zone so that future determinations would not include these structures. The existing defined High Hazard Zone includes a large area of street flow. While these areas pose a significant hazard during large floods, the focus of the containment measures would be limited to the removal of structures.

During the course of discussion related to the High Hazard Zone, the city also indicated that it would be desirable to provide a greater level of protection to Critical Facilities within the 100- and 500-year floodplain. These facilities are more distributed and do not generally lend themselves to economical removal using conveyance improvements. However, the desire to provide an enhanced level of protection demanded that some action be taken. The option of flood proofing these Critical Facilities will be incorporated into the alternative plan development process.

In June of 2007, HDR published a Stormwater MP that described the types of improvements necessary to address localized flooding associated with minor floods (2- and 5-year) and to provide guidance on water quality enhancement measures. The systems defined in the Stormwater MP establish a base level of protection against nuisance flooding problems but does not materially affect the threat associated with major floods. However, the consideration of the Stormwater MP recommendations also reiterated the potential of flood hazard throughout the watershed resulting from storms that were more localized than the design storm used to define the 100-year flood theat. Therefore, additional objectives included the potential for any identified improvements to provide protection against the major flood threat associated with a localized storm falling over the lower watershed and to consider the value-identified facilities would have to support the objectives of the Stormwater MP.

The City of Boulder has a very well established system of Open Space lands. Many of these areas are within or adjacent to the delineated floodplain of South Boulder Creek. While many communities view flood control as a compatible use of Open Space land, the city has very specific guidelines that regulate the use of Open Space. In general, these regulations restrict the use of these lands to uses that are consistent with the intended function for that particular parcel. When looking at flood control options along South Boulder Creek, careful attention was given to assuring that any proposed actions would be compatible with the city's Open Space regulations.

The acquisition of land is frequently a necessity to successfully implement a particular alternative. Many of the elements identified in the screening matrix would require additional land to be effectively implemented. Past studies that looked at flood control raised the issue of land acquisition. During those earlier studies, the general direction was that only properties for which there are willing sellers should be considered as part of any specific alternative. When properties were identified, the fair market cost for that land, based on recent sales or assessments, should be the basis for the development of cost estimates. At the early stages of project, alternative formulation the availability of land was not yet

determined. Properties were all assumed available if fair market prices are paid. As the alternative plans become more refined, more site-specific assessments of individual properties will be conducted to determine if alternative plans using private parcels remain desirable alternatives.

Wetlands and habitat for threatened and endangered species are common along South Boulder Creek. Particular care needed to be exercised to assure that no unintended impacts to these areas resulted from any of the proposed improvements. Because of the abundance of wetlands and habitat areas along the corridor, it may not be possible to avoid all impacts. In cases where facilities cannot avoid impacts, mitigation measures, as defined by the City of Boulder's Stream, Wetland and Waterbody Protection Ordinance, to minimize the adverse impacts on wetlands need to be considered. The specific nature of the disturbance will determine the type and extent of the mitigation approach.

One of the most important constraints identified during the evaluation process was that of the public interest. This was qualitative at this stage of the evaluation and incorporated the past input gathered during public meetings on South Boulder Creek projects as well as other projects around the city. Much of what has been heard has already been incorporated into the other identified constraints, but several other issues were brought forward against which all alternatives would be measured. These included concerns related to construction impacts, aesthetics, use of eminent domain to secure land from unwilling sellers, and broader community development interests and policies. While too numerous to mention individually, whenever these constraints become the basis for an action related to a particular alternative, it will be identified and discussed in detail.

Criteria

The city has formally adopted a set of design standards for drainage related improvements. These include Chapter 7 of the *City of Boulder Design and Construction Standards* and Section 9-3-2 through 9-3-9 of the *Boulder Revised Code*. The city also relies on the requirements of the District as articulated in the *Urban Storm Drainage Criteria Manual, Volumes 1 – 3* for guidance in the layout and design of drainage and flood control facilities. The governing design criteria used in the design of the components making up the improvements in the alternative plans are summarized in Table 5-1, Design Standards. Together, these tools facilitated the evaluation of alternative systems and elements relatively quickly and efficiently. Using the evaluations of the various plan elements to better understand the floodplain impacts, the various components were assembled into Alternative Plans. These Alternative Plans were eventually incorporated into the Coarse Grid Model version of MIKEFLOOD to confirm performance consistent with earlier assumptions. In some cases, refinement of the alternatives was necessary to achieve the level of performance desired. This refined Coarse Grid MIKEFLOOD model became the basis for the determination of project benefits and the visual representation of the residual floodplain. The alternatives assembled and evaluated as part of this process are depicted in figures located in Appendix B, Alternative Development Figures and listed in Table 5-2.

TABLE 5-1

Design Standards

Regulation	Description
Culvert Sizing Criteria	Manning's n for CMP, n = 0.024
Culvert Sizing Criteria	Manning's n for concrete, n = 0.013
Open Channel Criteria	Maximum velocity in open channels = 7 ft/s
Open Channel Criteria	Maximum depth in open channels = 4 ft
Open Channel Criteria	Slope = 0.4%
Open Channel Criteria	Freeboard = 1 ft
State Engineers Office Dam Criteria	Reservoir with a capacity greater than 100 Acre-Feet
State Engineers Office Dam Criteria	Reservoir with a surface area greater than 20 Acres
State Engineers Office Dam Criteria	Reservoir with a berm higher than 10-feet measured from the lowest point of the natural surface to the spillway crest.
State Engineers Office Dam Criteria	Minor Dam, is a jurisdiction dam that does not exceed 20 feet in height and or 100 acre-feet in capacity
State Engineers Office Dam Criteria	Small Dam, is a jurisdiction height greater than 20 feet in height but less than 50 feet in height or a reservoir with greater than 100 acre-feet in capacity but less than 4,000 acre-feet in capacity.

TABLE 5-2

Appendix B: Alternative Development Figures

Figure Number	Title
5-3	Summary of Flow Rates
5-4	High Hazard/Critical Facility Alternative
5-5	High Hazard Purchase/Critical Facility Alternative
5-6	Upstream Storage Dry Creek Ditch No. 2 Alternative
5-7	Upstream Storage Bear Canyon Creek Alternative
5-8	Upstream Storage Bear Canyon Creek Alternative 2
5-9	Upstream Storage Bear New Conveyance Alternative
5-10	Upstream Storage Bear New Conveyance Alternative 2
5-11	100-Year Regulatory Dry Creek Ditch No. 2 Alternative
5-12	100-Year Regulatory Bear Canyon Creek Alternative
5-13	100-Year Regulatory Bear Canyon Creek Alternative 2
5-14	100-Year Regulatory New Conveyance Alternative
5-15	100-Year Regulatory New Conveyance Alternative 2

Identified Problem Areas		Potential Solutions									
		Routine Maintenance of Existing Configuration	Development of Naturalistic Historic Channel	Installation of Major Underground Conduits	Lined Flood Channels	Limited Structural Improvements Or Additions	Existing Channel Improvements	Detention Facilities	Acquisition of Flood Prone Properties	Non-Structural Methods	Relocation of Channel
1	S. Boulder Rd. Inundation from Viele Channel/Dry Creek No. 2 Ditch	●	×[4]	●	●	●	●	●	×	×	×
2	Businesses/Residences Inundated between US-36 and Baseline Road	●	×[4]	●	●	●	●[4]	●[4]	●	●	●[4]
3	Inundation of Baseline Road	●	×[4]	●	●	●	●[4]	●[4]	×	×	●[4]
4	Residences Inundated between Baseline Rd. & Wellman Ditch	●	×[4]	●	●[4]	●	●[4]	●[4]	●	●	●[4]
5	Bear Canyon Creek / Wellman Ditch Flow Inundating West Valley	●	×[4]	●	●[4]	●	●[4]	●[4]	×	×	●[4]
6	Residences Inundated between Wellman Ditch & Arapahoe Avenue	●	●[4]	●	●[4]	●	●[4]	●[4]	●	●	●[4]
7	Inundation of Arapahoe Avenue	●	×[4]	●	●	●	●[4]	●[4]	×	×	●[4]
8	Residences Inundated between Arapahoe Avenue & BNSF RR	●	×[4]	●	●	●	●[4]	●[4]	●	●	●[4]
9	Flooding associated with BNSF RR Inundation	●	×[4]	●	●	●	●[4]	●[4]	×	×	●[4]
10	Businesses Inundated Downstream of BNSF RR	●	×[4]	●	●	●	●[4]	●[4]	●	●	●[4]

Notes:
1 - Potential solution conflicts with known uses of City of Boulder Open Space
2 - Potential solution conflicts with a known habitat conservation area or endangered species habitat
3 - Potential solution has pas public opposition
4 - Potential solution has right of way constraints
5 - Channel or structure currently does not exist

FIGURE 5-1
Potential Solutions Matrix
Reach 1 – 55th Street/ Dry Creek No. 2 Ditch
South Boulder Creek Flood Mitigation Report

Identified Problem Areas		Potential Solutions									
		Routine Maintenance of Existing Configuration	Development of Naturalistic Historic Channel	Installation of Major Underground Conduits	Lined Flood Channels	Limited Structural Improvements Or Additions	Existing Channel Improvements	Detention Facilities	Acquisition of Flood Prone Properties	Non-Structural Methods	Relocation of Channel
1	Flooding Associated with US-36 Overflow	●	×[4]	●	●	●	●	●	●	●	●[4]
2	Businesses/Residences Inundated between US-36 and Baseline Road	●	×[4]	●	●[4]	●	×[5]	●[4]	●	●	●[4]
3	Inundation of Foothills Parkway and Baseline Road Intersection	●	×[4]	●	●[4]	●	●	●[4]	×	×	×[4]
4	Inundation of Foothills Parkway North of Baseline Road	●	×[4]	●	●[4]	●	●	●[4]	×	×	×[4]
5	Residences Inundated between Baseline Rd. & Wellman Ditch	●	×[4]	●	●[4]	●	×[5]	●[4]	●	●	●[4]
6	Bear Canyon Creek / Wellman Ditch Flow Inundating West Valley	●	×[4]	●	●[4]	●	●	●[4]	×	×	●[4]
7	Residences Inundated between Wellman Ditch & Arapahoe Avenue	●	×[4]	●	●[4]	●	×[5]	●[4]	●	●	●[4]
8	Inundation of Arapahoe Avenue	●	×[4]	●	×[5]	●	×[5]	●[4]	×	×	●[4]
9	Residences Inundated between Arapahoe Avenue & BNSF RR	●	×[4]	●	×[5]	●	×[5]	●[4]	×	●	●[4]
10	Flooding associated with BNSF RR Inundation	●	×[4]	●	×[5]	●	×[5]	●[4]	×	×	●[4]

Notes:
1 - Potential solution conflicts with known uses of City of Boulder Open Space
2 - Potential solution conflicts with a known habitat conservation area or endangered species habitat
3 - Potential solution has pas public opposition
4 - Potential solution has right of way constraints
5 - Channel or structure currently does not exist

FIGURE 5-1
Potential Solutions Matrix
Reach 2 – West Valley FIS Profile
South Boulder Creek Flood Mitigation Report

			Potential Solutions							
			Installation of Major Underground Conduits	Limited Structural Improvements Or Additions	Existing Channel Improvements	Regional Detention Facilities	Local Detention Facilities	Flood Proofing Critical Facilities	Non-Structural Methods	Flow Diversion
Identified Problem Areas	1	South Boulder Road inundation from Dry Creek No. 2 Ditch	Pipe all Dry Creek No. 2 Ditch	Enlarge Dry Creek No. 2 Ditch Culvert	Enlarge Dry Creek No. 2 Ditch / Crossing Structure	Storage Upstream of US-36 (Regional)	X - Habitat Impacts	NA	Flood Warning, Road Closure, Etc.	X - Habitat Impacts
			Pipe South to Regional Storage Pond	Waste way from Dry Creek No. 2 Ditch to Viele Channel	Raise South Boulder Road					
				Gate/SCADA at South Boulder Road to move water to Viele Channel / Anderson Ditch Extension						
	2	South Boulder Road Inundation from Viele Channel	X - Habitat Impacts	Enlarge Viele Culvert	X - Habitat Impacts	Storage Upstream of US-36 (Regional)	X - Habitat Impacts	NA	Flood Warning, Road Closure, Etc.	Divert Flow to South Boulder Creek
	3	South Boulder Road inundation from Anderson Ditch Extension	Pipe all of New Anderson Ditch to Viele Channel	Broadway & Table Mesa - Enlarged Culvert under Table Mesa	Enlarged New Anderson Ditch/ Crossing	Storage Upstream of US-36 (Regional)	Storage at Table Mesa & US-36	NA	Flood Warning, Road Closure, Etc.	Divert Flow to Viele Channel/ South Boulder Creek
	4	Structures inundated between US-36 and Baseline Road	Increase size of existing 42" RCP Dry Creek No. 2 Ditch at Tenino Avenue - Outfall at North of Aztec Drive	Improved conveyance structure at Baseline Road at South Boulder Creek to prevent back water flows	Replace Dry Creek No. 2 Ditch culvert at Manhattan Middle School & Oneida Street with enlarged open channel	Storage Upstream of US-36 (Regional)	Local Storage at Manhattan Middle School	Flood Proof Manhattan Middle School and Montessori School	Flood Warning, Road Closure, Etc.	Flow Diversion from Dry Creek No. 2 Ditch East to East Boulder Recreation Center ponds via existing irrigation ditch
			Place Dry Creek No. 2 Ditch in a conduit from South Boulder Road to Baseline Road		Channelization from South Boulder Road to Baseline Road just east of Foothills Parkway					Pipe from Manhattan Middle School to open space north of East Boulder Rec. Center
			Collect flow in a major conduit at SBR & Foothills Parkway to Baseline Road and Crescent Avenue							
	5	Structures inundated between Baseline Road & Wellman Ditch	Pipe Dry Creek No. 2 Ditch	Culvert improvements at 55th Street & Tennis Courts	Conveyance improvements / enlarge Wellman	Storage Upstream of US-36 (Regional)	X - Right of Way constraints	Flood proof / acquire school	Flood Warning, Road Closure, Etc.	Flow diversion from Dry Creek No. 2 Ditch to South Boulder Creek at Tennis Courts
			Pipe flow from Pennsylvania to Golf Course	Culvert improvements at Pennsylvania Avenue	Conveyance improvements / enlargement of Dry Creek No. 2 Ditch			Flood proof fire station		Flow diversion from 55th street to South Boulder Creek via Wellman
	6	Structures inundated between Wellman Ditch & Arapahoe Avenue	Large conduit along 55th street	Culvert improvements at Arapahoe Avenue	Conveyance improvements through golf course	Storage Upstream of US-36 (Regional)	Local storage in golf course	NA	Flood Warning, Road Closure, Etc.	Diversion to golf course
	7	Structures inundated between Arapahoe Avenue & BNSF RR	Large conduit along 55th street to Boulder Creek	NA	New channel along existing alignment behind buildings	Storage Upstream of US-36 (Regional)	Store flows in Leggett Reservoir	NA	Flood Warning, Road Closure, Etc.	Divert flows to Leggett Reservoir

Notes:
1. Routine maintenance of existing configuration will be a stand along alternative for all problems and will be analyzed as the "No Action" alternative moving forward. Maintenance will be a key component of all alternatives considered for this project.
2. Developing a naturalistic channel was not considered as a solution for problems in the planning study. Due to the developed nature of the West Valley profile and 55th Street/Dry Creek No. 2 Ditch profile, a naturalistic channel is infeasible.

FIGURE 5-2
Refined Potential Solutions Matrix
Reach 1 – 55th Street / Dry Creek No. 2 Ditch
South Boulder Creek Flood Mitigation Report

			Potential Solutions							
			Installation of Major Underground Conduits	Limited Structural Improvements Or Additions	Existing Channel Improvements	Regional Detention Facilities	Local Detention Facilities	Flood Proofing Critical Facilities	Non-Structural Methods	Flow Diversion
Identified Problem Areas	1	Flooding Associated with US-36 Overflow	Enlarge New Anderson Extension Crossing	Enlarge Dry Creek No. 2 Ditch Culvert	Levees to Force all flow through US-36 Bridge along Mainstem	Storage upstream of US-36 (Regional)	Store Table Mesa overflows from Bear Canyon Creek at Foothills Interchange and Drain to New Anderson Extension	NA	Flood Warning, Road Closures, Etc.	Divert overflows to South Boulder Creek via New Anderson Extension
	2	Structures Inundated between US-36 and Baseline Road	Large Pipe to carry over flows from US-36 to Foothills Parkway	X - Habitat Impacts	Create new open channel between Foothills Parkway and Thunderbird Drive	Storage upstream of US-36 (Regional)	X - Right of Way Impacts	Flood proof Frasier Meadows Manor	Flood Warning, Road Closures, Etc.	Divert flow to South Boulder Creek
					Extend noise barrier wall along Foothills Parkway					
	3	Inundation of Foothills Parkway and Baseline Road Intersection	Large underground pipe in the direction of the existing profile	Increase capacity of culverts through Baseline Road and Foothills Parkway	NA	Storage upstream of US-36 (Regional)	Localized storage at intersection of Foothills Parkway and Baseline Road	NA	Flood Warning, Road Closures, Etc.	Divert flow through underground pipe to Dry Creek
	4	Inundation of Foothills Parkway North of Baseline Road	Large underground pipe parallel to the existing flow path	Increase capacity of existing culverts through Baseline Road / Foothills Parkway so that overtopping does not occur	NA	Storage upstream of US-36 (Regional)	Localized storage at intersection of Foothills Parkway and Baseline Road	NA	Flood Warning, Road Closures, Etc.	Divert flows through underground pipe to South Boulder Creek
			Pipeline parallel to Foothills Parkway							
	5	Structures Inundated between Baseline Rd. & Wellman Ditch	Large underground pipe parallel to the existing flow path	X - Right of Way Impacts	Conveyance improvements / enlarge Wellman	Storage upstream of US-36 (Regional)	Localized storage at intersection of Foothills Parkway and Baseline Road	NA	Flood Warning, Road Closures, Etc.	Divert flows through underground pipe to South Boulder Creek
										Flow diversion from 55th Street to South Boulder Creek via Wellman
	6	Structures Inundated between Wellman Ditch & Arapahoe Avenue	Replace Wellman Ditch with underground pipe	SCADA system on the Wellman / Bear Canyon Creek diversion structure	Increase capacity of Wellman Ditch extending to South Boulder Creek	Storage upstream of US-36 (Regional)	Localized storage at intersection of Foothills Parkway and Baseline Road	Flood proofing of critical facilities	Flood Warning, Road Closures, Etc.	Diversion to Golf Course
			Large underground pipe parallel to the existing flow path	Culvert improvements through Arapahoe Avenue			Local storage at Eisenhower Elementary School			
				Limited structural improvements along the Wellman to improve capacity						
	7	Structures Inundated Below Arapahoe Avenue	Large conduit along 55th Street to Boulder Creek	Culvert Improvements at Arapahoe Avenue	New open channel along existing alignment behind buildings	Storage upstream of US-36 (Regional)	Store flows in Leggett Reservoir	NA	Flood Warning, Road Closures, Etc.	Large underground pipe to South Boulder Creek

Notes:
1. Routine maintenance of existing configuration will be a stand along alternative for all problems and will be analyzed as the "No Action" alternative moving forward. Maintenance will be a key component of all alternatives considered for this project.
2. Developing a naturalistic channel was not considered as a solution for problems in the planning study. Due to the developed nature of the West Valley profile and 55th Street/Dry Creek No. 2 Ditch profile, a naturalistic channel is infeasible.

FIGURE 5-2
Refined Potential Solutions Matrix
Reach 2 – West Valley FIS Profile
South Boulder Creek Flood Mitigation Report

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VI. Conceptual Alternative Plans

Conceptual Alternative Plan development came during the second workshop that was held on March 17, 2010 to present and discuss the Refined Potential Solutions Matrix. Based on the feedback from the first and second workshops and the Refined Potential Solutions Matrix, the plan elements were assembled into a series of Conceptual Alternative Plans.

The plans were built using various combinations of several common elements. Using this approach provided an appropriately broad range of alternatives and resulted in a reasonable assurance that the best alternatives were considered. Common elements that were assembled into the plans included:

- Regional Detention at US-36 – This element included off-channel storage along the upstream side of the embankment along US-36 and considered storage on Open Space land, private property and CU property.
- Regional Detention near Hwy-93 – This element included off-channel storage near Hwy-93 and considered storage on both Open Space land and private property in the area.
- Downstream conveyance along Dry Creek No. 2 Ditch – This element included a series of conveyance improvements along the Dry Creek No. 2 Ditch corridor and looked at both pipes and open channels for flow rates ranging from the 10-year flood through the 100-year flood.
- Downstream conveyance through the West Valley – This element included a series of conveyance improvements through the West Valley generally along Foothills Parkway and then through utility easements and roads through the East Foothills Neighborhood to Boulder Creek. This alternative included both pipes and open channels for flow rates ranging from the 10-year flood through the 100-year flood.
- Mainstem Containment – This element included measures to reduce the threat of overflows across US-36 by constructing a series of improvements to contain flow within the channel above the US-36 crossing. It also included various mitigation elements downstream of US-36 to mitigate the impacts of increased flows in the mainstem including using Baseline Reservoir to store flood flows.
- Diversion to Bear Canyon Creek/Boulder Creek – These elements convey excess flows from the West Valley to the adjacent watershed using a series of pipes and channels.
- Downstream Storage – These elements were investigated to try to control flooding during both the US-36 overtopping events and those of lesser frequency that generate flooding below US-36. Small-localized downstream storage locations included Manhattan Middle School and the Flatirons Golf Course.

These elements, in various combinations, were the basis for the formulation of alternative plans. The intent of the formulation process was to identify elements from the options above and combine them in ways that formed complete systems to address the identified problems. With this, it was possible to look at the lower basin holistically and determine if benefits were realized in areas beyond the specific issue the particular option addressed.

Alternative Plan Formulation

A total of 15 different alternative plans were developed for further consideration. These plans were intended to address the full suite of issues by defining a full system of improvements. For example, in this evaluation, the benefits of upstream detention configurations were seen in the required sizing of the downstream facilities.

Not only was the analysis conducted using combinations of the various elements but the level of protection was also evaluated. For each alternative, all of the infrastructure elements were looked at across a broad range of flow rates so that the relative impact on benefits and cost could be considered. The determination of flow rates in the analysis was complicated by the 2-D nature of the floodplain determination, the basin specific design storm and the impacts associated with the overtopping of US-36.

The 2-D analysis used a process by which the flood hydrograph was routed through the stream system and overbanks and takes into account floodplain storage throughout the basin. While this represents a realistic determination of the flood hazard along South Boulder Creek, the model is very sensitive to change due to changes in floodplain storage. Any physical changes to the system, using culverts, detention or improved channels, were likely to result in a change to flooding depths, flow rates and inundation elsewhere in the system. For the purposes of this analysis, a simplified approach that added flow rates in the downstream direction was employed. If the improvements such as detention at an upstream location reduced the discharge, it was assumed that reduction would apply from that point downstream. Similarly, if an improvement such as a culvert enlargement increased a flow rate downstream, the resulting increase in discharge was assumed to apply to every other point downstream. This provided a simple and conservative methodology to quickly review the effectiveness of individual alternatives in solving flooding problems throughout the basin without employing MIKEFLOOD.

The analysis conducted for this Study recognizes that the focus is on flooding generated from a flood that maximizes the flow along the mainstem of South Boulder Creek. During the Flood Mapping Study, it was noted that the potential for small-localized storms falling below the Basin Specific Design Storm location could result in higher flows along some of the areas tributary to the mainstem. The area of the West Valley, because it is hydraulically disconnected from the mainstem flood for smaller events, may be one area where this potential exists. However, after considerable deliberation, it was concluded that the focus of this study should remain to address the flood threat associated with the mainstem and that localized events would not be explicitly evaluated. However, the improvements incorporated into the various alternative plans are sized to convey the lower storm center hydrology or Stormwater MP hydrology if US-36 does not overtop, resulting in an increased level of protection for smaller localized storms.

Finally, the overtopping of US-36 dramatically influences the flood response in the West Valley. Unlike a typical riverine system where the flood threat increases in a general linear relationship with flow rates, the West Valley is generally free of a significant flood threat for all events until US-36 overtops at around the 100-year flood. At that time, a considerable hazard is created. While the benefit of the protection below the 100-year flood is considerable, the result is that improvements in the West Valley intended to address local floods more frequent than the 100-year event will be overwhelmed by the overtopping of US-36 and will not materially reduce the flooding impacts from the 100-year storm.

Alternative Plan Identification

The 15 specific alternatives identified are described as follows. Figures for each Conceptual Alternative Plans can be found in Appendix C.

- **Status Quo** – This option represents the existing condition. While the name suggests no additional actions are to be taken, the status quo actually reflects a considerable amount of attention to the control of flood hazards. The city has an extensive body of floodplain and floodway protections built into the zoning, land use and development regulations. Physical infrastructure to warn citizens of an impending flood threat exists through sirens and other warning mechanisms and an impressive body of master planning exists for many of the city's drainageways. Figure 6-1, Status Quo can be found in Appendix C.
- **High Hazard Zone containment with critical structure flood proofing** – This option focuses on the control of the flood hazard to the two existing structures located in the High Hazard Zone. It is expected that there will be minor improvements required to remove structures located in the High Hazard Zone. Measures to address the flood threat to Critical Structures will largely be limited to flood proofing the existing structures., Figure 6-2, High Hazard Zone Containment with Critical Structure Protection can be found in Appendix C.
- **US-36 detention with downstream conveyance along Dry Creek No. 2 Ditch** – Detention at US-36 eliminates the overflow of US-36 and provides a substantial benefit to downstream properties in the West Valley. The detention pond is configured to maximize the use of existing flood prone areas, to minimize the impacts to Open Space land and the University of Colorado South Campus and to minimize the potential visual impact by integrating into existing roadway improvements in the area. To address the flood threat downstream of US-36, improvements are proposed along the alignment of Dry Creek No. 2 Ditch. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 6-3, US-36 Detention with Downstream Conveyance along Dry Creek No. 2 can be found in Appendix C.
- **US-36 detention with downstream conveyance through West Valley** – This alternative includes the detention facility at US-36 described above and to address the flood threat downstream of US-36, improvements are proposed along a new conveyance alignment through the West Valley. These improvements will generally consist

of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 6-4, US-36 Detention with Downstream Conveyance through West Valley can be found in Appendix C.

- **US-36 detention with downstream storage and conveyance through West Valley and along Dry Creek No. 2 Ditch** –The cornerstone of this alternative is the detention at US-36. To address the flood threat downstream of US-36. This alternative differs from previous alternatives by handling downstream flood threats through both storage and conveyance improvements. The proposed improvements are located in the West Valley and along the alignment of Dry Creek No. 2 Ditch. The storage component of the downstream improvements allows for locally generate flood peaks to be attenuated and results in a decrease in the size of the required infrastructure downstream. The combination of conveyance improvements along both drainage corridors reduces the amount of overland flooding that poses a threat once floodwaters leave either corridor. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 6-5, US-36 Detention with Downstream Storage and Conveyance through West Valley can be found in Appendix C.
- **US-36 detention with downstream diversion to Bear Canyon/Boulder Creek** – This alternative again begins with the detention facility at US-36. This alternative differs in the approach to addressing the flood threat downstream of US-36. Improvements downstream of US-36 are proposed that divert flows from the West Valley out of the South Boulder Creek System and move them along Foothills Parkway into the Bear Canyon Creek channel where they eventually outfall to Boulder Creek. These improvements will generally consist of enlarged channel with culvert improvements at roadway crossings. No improvements are proposed along the Dry Creek No. 2 Ditch corridor so some residual impacts may still be seen. Figure 6-6, US-36 Detention with Downstream Diversion to Bear Canyon/Boulder Creek can be found in Appendix C.
- **US-36 detention with downstream diversion to mainstem** – The focus on this alternative is diversion of floodwaters from the West Valley to the mainstem coupled with Detention at US-36.. To address the flood threat downstream of US-36, improvements are proposed that divert the excess flows through the West Valley back to the mainstem of South Boulder Creek. These improvements will generally consist of enlarged channels or pipes that carry water from the West Valley and the Dry Creek No. 2 Ditch corridor, east back to the mainstem. Figure 6-7, US-36 Detention with Downstream Diversion Main Stem can be found in Appendix C.
- **Detention near Hwy-93 with downstream conveyance along Dry Creek No. 2 Ditch** – Detention near Hwy-93 provides an a similar benefit to that of detention closer to US-36 but avoids the challenges associated with coordination with CU, CDOT and other stakeholders in the vicinity of the US-36 corridor. The detention near Hwy-93 is an off-stream facility that captures overflows from Hwy-93 and releases them later during the flood. This delay allows the mainstem flows around US-36 to decrease and reduces the overflows from the main channel that fill the existing inadvertent detention near US-36 and Foothills Parkway. In doing so, overflows of US-36 can be avoided. The detention facility near Hwy-93 would require the purchase of two privately held properties from unwilling sellers. To address the flood threat downstream of US-36, improvements are proposed along the alignment of Dry Creek No. 2 Ditch. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 6-8, Detention near Hwy-93 with Downstream Conveyance along Dry Creek No. 2 Ditch can be found in Appendix C.
- **Detention near Hwy-93 with downstream conveyance through West Valley** – This alternative combines the detention near Hwy-93 with the conveyance improvements through the West Valley that will consist of enlarged pipes or to minimize the potential for residual flooding in the area. Figure 6-9, Detention near Hwy-93 with Downstream Conveyance through West Valley can be found in Appendix C.
- **Detention near Hwy-93 with downstream storage and conveyance through West Valley and along Dry Creek No. 2 Ditch** – This alternative combines the detention near Hwy-93 with, both storage and conveyance improvements that would include enlarged pipes or channels through the West Valley and along the alignment of Dry Creek No. 2 Ditch. The storage component allows for locally generate flood peaks to be attenuated and results in a decrease in the size of the required infrastructure downstream. The combination of conveyance improvements along both drainage corridors reduces the amount of overland flooding that poses a threat once floodwaters leave either corridor. Figure 6-10, Detention near Hwy-93 with Downstream Storage and Conveyance through West Valley can be found in Appendix C.
- **Detention near Hwy-93 with downstream diversion to Bear Canyon/Boulder Creek** – Detention near Hwy-93 becomes a cornerstone for this alternative and is combined with improvements that divert flows from the West Valley along Foothills Parkway over to the Bear Canyon Creek channel where they eventually outfall to Boulder Creek. These improvements will generally consist of enlarged channel with culvert improvements at roadway crossings. No improvements are proposed along the Dry Creek No. 2 Ditch corridor so some residual impacts may still be seen. Figure 6-11, Detention near Hwy-93 with Downstream Diversion to Bear Canyon/Boulder Creek can be found in Appendix C.
- **Detention near Hwy-93 with downstream diversion to mainstem** – This alternative combines detention near Hwy-93 with improvements that divert the excess flows back to the mainstem of South Boulder Creek. These improvements will generally consist of enlarged channels or pipes that carry water from the West Valley and the Dry Creek No. 2 Ditch corridor to the east back to the mainstem. Figure 6-12, Detention near Hwy-93 with Downstream Diversion Main Stem can be found in Appendix C.
- **No upstream detention with downstream conveyance along Dry Creek No. 2 Ditch –** This alternative does not control the overflow of US-36. The impacts upstream are relatively limited and the overflow of US-36 does little immediate damage downstream of US-36. However, as the flood wave progress to the north, considerable damage is seen. This alternative collects and captures the overflow downstream of US-36 and provides a large, stabilized conveyance to move those flows along the Dry Creek No. 2 Ditch corridor. The improvements are larger pipes or channels and the associated inlets. No improvements are proposed though the West Valley. As a result, some potential for damage during local floods remains. Figure 6-13, No Upstream Detention with Downstream Conveyance along Dry Creek No. 2 Ditch can be found in Appendix C.
- **No upstream detention with downstream conveyance through West Valley –** This alternative is similar to the alternative ***No upstream detention with downstream conveyance along Dry Creek No. 2 Ditch***, but capture the overflow in a large, stabilized conveyance to move those flows through the West Valley along Foothills Parkway, Thunderbird Land and eventually 55th Street. The improvements are larger pipes or channels and the associated inlets. No improvements are proposed along the Dry Creek No. 2 Ditch corridor so some residual damage is expected as overflows from the mainstem work their way to the west. Figure 6-14, No Upstream Detention with Downstream Conveyance along through West Valley can be found in Appendix C.
- **No upstream detention with downstream diversions** – This alternative does not control the overflow of US-36 but collects and captures the overflow and provides a large, stabilized conveyance to move those flows east to South Boulder Creek or the west toward channels that have adequate capacity. In general, overflows reaching the West Valley will be captured and diverted north and west to the Bear Canyon Creek system along Foothills Parkway downstream of Baseline. Flows that reach the Dry Creek No. 2 Ditch corridor will be captured and moved east back toward the mainstem where adequate capacity exists. The improvements are larger pipes or channels and the associated inlets. Figure 6-15, No Upstream Detention with Downstream Diversions can be found in Appendix C.

Conceptual Alternative Plan Evaluation

The evaluation process was a sequential effort that built on the earlier assessments by adding progressively more detail and filtering out projects or options that proved to be infeasible or otherwise flawed. The intent was to develop a common understanding of the different alternatives and compare them against one another. Subsequent evaluations built more detail into the alternative and allowed a more refined comparison.

The intent of the evaluation of the Conceptual Alternative Plans was to provide a clearer understanding of the costs, benefits and constraints of the alternatives and to identify the most workable alternatives for further evaluation. Each of these plans was developed at a conceptual level reflecting this step in the overall process.

Residual floodplains were not quantitatively determined during this phase of the evaluation. Rather, general estimates of the physical extent of the floodplain were determined using information from the earlier MIKEFLOOD Coarse Grid

simulations. Since the majority of the improvements were intended to provide protection from the 100-year flood, the elimination of the 100-year flood hazard was assumed. For those alternatives that had a different level of protection, the residual floodplain was estimated by determining the residual surface flow rate and correlating that to a modeled flood event from the *Risk Assessment Report* (HDR, May 2009). Figures depicting the residual floodplains are located in Appendix C. Table 6-1 describes the location of each figure.

TABLE 6-1

Summary of Conceptual Alternative Plans

Alternative	Description	Figure Location
1	Status Quo	Appendix C, Figure 6-16
2	High Hazard Zone containment with critical structure flood proofing	Appendix C, Figure 6-17
3	US-36 detention with downstream conveyance through West Valley	Appendix C, Figure 6-18
4	Detention near Hwy-93 with downstream storage and conveyance through West Valley	Appendix C, Figure 6-19
5	Mainstem Flow Containment With Distributed Regional Detention	Appendix C, Figure 6-20
6	Mainstem Flow Containment With Local West Valley Improvements	Appendix C, Figure 6-21
7	No upstream detention with Bear Canyon Creek Conveyance Improvements	Appendix C, Figure 6-22
8	No upstream detention with Dry Creek No. 2 Ditch Conveyance Improvements	Appendix C, Figure 6-23
9	Stormwater Master Plan Improvements	Appendix C, Figure 6-24

Flood Damages

Flood damage assessments for both the existing condition and post flood conditions are necessary to determine the economic benefits of a particular alternative. The District has published guidelines that were used in the evaluations conducted for the study. It is also the city's intention to look at alternative funding opportunities such as FEMA grants and all financial investigations were conducted in accordance with FEMA guidelines as described in FEMA's Benefit Cost Analysis (BCA) Version 4.5.5 tool. This is a software tool that performs project financial benefit-cost evaluations based on FEMA approved standards. Unfortunately, the tool was developed for more traditional riverine systems and did not lend itself to direct application to the information available using MIKEFLOOD. However, manual input methodologies embedded in the tool can be used to define flood damages based on the FEMA Hazards U.S. Multi Hazard (HAZUS-MH) methodology that are consistent with the methodologies used in the South Boulder Creek *Risk Assessment Report*.

A meeting was held with the Colorado Department of Emergency Management (CDEM) and FEMA. During this meeting, the FEMA representative accepted the proposal of calculating damages outside of the FEMA BCA tool by using the HAZUS-MH methodology for flood damage estimation and manually importing those results into the BCA tool for further analysis.

In addition to reviewing the BCA tool, the CDEM and FEMA representatives reviewed the Risk Assessment damage methodology, which utilized the HAZUS-MH depth damage curves similar to the BCA tool, to determine if it is appropriate and acceptable for the purposes of applying for FEMA grants. It was decided that the Risk Assessment methodology for damage estimates would be carried forward into this planning phase.

Most of the information necessary to determine the damages under existing conditions (baseline damages) was obtained using the information derived from the Risk Assessment. In that document, the damage for various recurrence interval storms was reported. The values were refined in this analysis to reflect updated assessed values and the depths reported in the Course Grid model. There were slight changes between the reported damages in the Risk Assessment and those computed as part of this analysis. These differences were investigated. The primary difference was attributed to a slight increase in the assessed value of the properties flooded since the Risk Assessment was completed. This difference was approximately 10%. A careful review of the damage spreadsheet in the Risk Assessment also identified duplication in the accounting of damages for some structures. This error was corrected and accounted for a decrease of approximately 5% in damage estimates from the Risk Assessment. Finally, the impact of the difference between the Regulatory 4 meter grid model and the Course Grid 8 meter model was investigated. It was found that the difference in computed water surface between the 4–meter grid model and the 8-meter grid model showed a slight increase in the depth of flooding in the 8-meter grid model. The difference in computed damages based on the increased water surface elevations increased the damage estimates by approximately 7.5%. Overall, the current damage analysis is slightly higher when compared to the Risk Assessment due to the changes made to the analysis to make it FEMA compliant.

The damages were also sub-divided to provide estimates of the damages along the various project reaches. Specific structures were assigned to a particular reach and the damages for each storm were aggregated. The estimated damages for each storm were then integrated over the full spectrum of probabilities to compute an average annual damage estimate. Average annual damages were converted using the FEMA approved discount rate of 7% into an equivalent capital cost. This discount rate is higher than the discount rate reported in the Risk Assessment. The Risk Assessment utilized a discount rate of 3.5% and the effect of the increased discount rate was to decrease the average annual damages compared to the Risk Assessment Damages. These updated damage estimates are summarized in Table 6-4, Baseline Damage Estimates.

Project Benefits

An estimation of conceptual alternate plan benefit calculations was necessary to allow a useful comparison between the alternatives. A relationship between flow rate and damages was established for each of the project study reaches reported in Table 6-4. An example of these curves is presented as Figure 6-1, Damage-Discharge Relationship for Dry Creek No. 2 Ditch from the Wellman Canal to Arapahoe Avenue. As this curve demonstrates, when the flow rates increase, the overall damages increase. This information proved valuable in the sizing of facilities and the evaluation of the relative benefit of those sizing strategies.

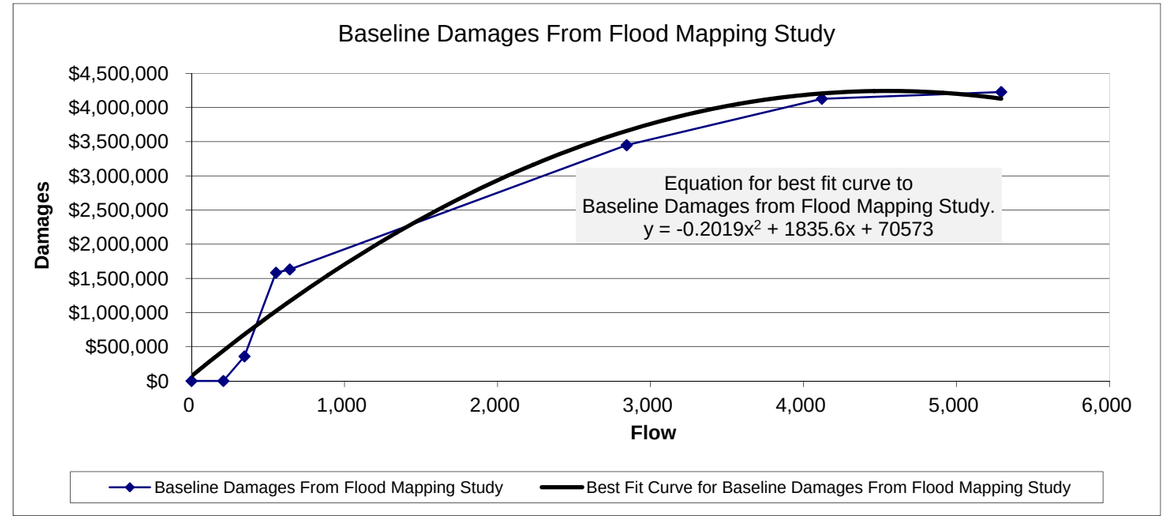

FIGURE 6-1: Damage Discharge Relationship for Dry Creek No. 2 Ditch, Wellman Canal to Arapahoe Avenue

These curves were used to estimate the residual damages for each of the specific alternatives studied. Residual damages were not explicitly computed for any of the alternatives. Rather, an estimate of the residual surface flow (original flow rate minus alternative improvement flow capacity) was computed. This residual flow rate was then used to enter the Damage-Discharge Relationship curve to determine the associated damage. A parallel curve was generated that represented the residual damages that would be expected with the incorporation of a specific alternative.

The estimated residual damage formed the basis for the determination of project benefits. Project benefits were estimated for each of the alternatives by developing a damage estimate with the improvements in place for each recurrence interval storm and subtracting them from pre-project damages. The reduction in damages was determined to be the project benefit. The estimated benefits for each storm return period were then integrated over the probability of recurrence for any given year, to compute an average annual project benefit. Average annual benefits were developed using the FEMA approved discount rate of 7% and converting the average annual benefits into an equivalent capital cost. Other potential project benefits such as the intangible benefit associated with peace of mind or the more tangible reduction in flood insurance premiums were not included at this stage of project formulation. This consistent estimate of the benefit of project implementation allowed for a direct comparison between the various alternatives. Table 6-2 reports the baseline damages reported in the Risk Assessment Report, the revised damage analysis based on the Flow Damage Curves and the estimated project benefit, which is the difference between the Baseline Damages (annual damages expected from the regulatory flood in today's dollars) and the residual damages.

TABLE 6-2

Baseline Damage Estimates

	Baseline Average Annual Damage[1]	100-Year Residual Average Annual Damage[2]	Average Annual Benefit[3]	Capital Equivalent[4]
West Valley US-36 to Baseline Road	$1,400,000	$400,000	$1,000,000	$14,000,000
West Valley Baseline Road to Wellman Canal	$300,000	$50,000	$300,000	$4,100,000
West Valley Wellman Canal to Arapahoe Avenue	$300,000	$40,000	$300,000	$4,100,000
West Valley Below Arapahoe Avenue	$1,600,000	$0	$1,600,000	$22,500,000
Dry Creek US-36 to Baseline Road	$300,000	$100,000	$200,000	$2,700,000
Dry Creek Baseline Road to Wellman Canal	$100,000	$10,000	$60,000	$900,000
Dry Creek Wellman Canal to Arapahoe Avenue	$100,000	$20,000	$10,000	$1,700,000
Dry Creek Below Arapahoe Avenue	$1,000,000	$70,000	$1,100,000	$14,900,000

1. Baseline Average Annual Damages – Annual damages expected from the regulatory flood in today's dollars.

2. 100-Year Residual Average Annual Damages – Annual damages expected from the proposed improvements in today's dollars

3. Average Annual Benefit – Difference between the Baseline and 100-Year Residual Average Annual Damages

4. Capital Equivalent – Estimated cost of the improvements justified by the reduction in annual average damages by implementing improvements

Alternative Costs

Once the alignments were established and general capacities for the elements understood, cost estimates were prepared. These estimates were developed based on general cost development information using cost estimating tools provided by the District and updated to reflect some critical site specific data such as Boulder area land costs. The various project elements were aggregated to develop an overall project implementation cost.

Planning level cost data was developed to allow a comparison between the various alternatives. The costs were developed using a general estimating spreadsheet that incorporated some uniquely developed unit costs along with costs embedded in the District's UD-Cost tool. The combination was deemed appropriate because of the indeterminate nature of the work elements. Rather than estimating specific type, size and grade of the improvements, more general costs per unit discharge or size were used. These were based on summaries of past projects. Table 6-3, Conceptual Unit Costs summarizes the major cost elements.

The unit costs were combined with estimated facility sizes and quantities to develop an approximate cost for each of the identified alternatives. These costs use the District's spreadsheet with the modifications described but also have some additional modifications that reflect the nature of this project. Of greatest significance is the incorporation of a higher contingency reflecting the uncertainties associated with the complex nature of flooding along South Boulder Creek. This complexity is likely to result in some additional refinement of project elements beyond what might ordinarily be expected on District projects. Other factors and standard allowances remain unchanged.

TABLE 6-3

Conceptual Unit Costs

Item	Unit Cost	Unit of Measurement
36 - 48" RCP	$126.81 - $169.08	LF
90 - 120" RCP	$459.79 - $865.20	LF
Flared End Sections for 36 - 48" RCP	$1,545 - $2,060	EA
Headwalls for 90 - 120" RCP	$2,853 - $3,777	EA
Wingwalls for 90 - 120" RCP	$19,294 - $28,633	EA
Manhole, 6' Diameter	$5,407.50	EA
Type B Manhole	$10,300.00	EA
Storm Inlet	$3,605	EA
Box Culvert	$473.58 - $1,443.57	LF
Headwalls and Toewalls for Box Culvert	$454.92 - $1,123.08	EA
Wingwalls for Box Culvert	$6,865.01 - $26,895.69	EA
Sloping Drop Structures	$116,000.00	EA
Detention Ponds	$46,968	AC-FT
Roadway Reconstruction	$50.00	SY
Open Channel Improvements	$0.20	LF/Q
Regional Detention Ponds	Cost ($M) = (1+0.00215*AC-FT)	AC-FT
Channel O&M	$27.60	LF
Pond O&M	$1,380.00	AC-FT
Utility Relocation Costs	0.32*Construction Total	LS
Acquisition of Open Space Property	$0.83	SF
Acquisition of Private Property in City of Boulder	$17	SF
Acquisition of Private Property in Boulder County	Assessed Value	LS
Mobilization	5% Capital Improvement Costs	
Stormwater Management/Erosion Control	5% Capital Improvement Costs	
Engineering	15% Capital Improvement Costs	
Legal/Administrative	5% Capital Improvement Costs	
Contract Administration/Construction Management	10% Capital Improvement Costs	
Contingency	50% Capital Improvement Costs	

Benefit-Cost Analysis

With both the costs for an alternative and the benefit expressed as a capital value, the benefit-cost ratio could be determined. The aggregated costs for each of the Conceptual Alternative Plans were compared to the computed benefits to determine a Benefit-Cost relationship for the alternative. This ratio provides a simple numeric measure of the approximate return on investment for a specific alternative. Ratios over one indicate the project benefits outweigh the necessary investment and are a financially justifiable use of public money. However, a ratio in excess of one does not necessarily suggest that the projects are the best use of public funds nor is a favorable ratio an indication that the project is not flawed in other ways.

Other Considerations

Other considerations such as environmental or community impacts, alignment with the city's defined objectives or general financial viability were also considered. The evaluation of the various alignments was initially conducted to determine if any constraints existed that would render the alternative infeasible. This included consideration of land uses (both existing and anticipated future uses) that might render the alternative extremely costly or incompatible. Political constraints were generally defined as issues or concerns presented during past studies, and identified during stakeholder and public meetings that would not be compatible with public concerns or Council direction. Environmental factors were also considered and qualitative assessments were made on the impacts that might result from project implementation. Avoidance or mitigation was factored into the evaluation of the alternative plans.

Field visits were conducted to validate the information and assumptions made during the screening and alternative development process. These visits were intended to define other considerations that may not be obvious from available data such as property owner improvements, mature vegetation or physical or topographic constraints.

Table 6-4, Summary of Conceptual Alternative Plans Evaluation presents the findings of the evaluation. In this table, each alternative cost, benefit, benefit-cost ratio and some of the other considerations are presented for easy comparison and evaluation. This table provides the foundation for the decisions that were made in selecting the Best Alternative Plans. The results of this evaluation were presented at a workshop to the Project Sponsors and Stakeholders on May 11, 2010. During this workshop, the stakeholders discussed the elements of the various alternative plans and focused on the broader considerations and impacts associated with each of the plans. At the meeting, the stakeholders and Project Sponsors identified eight alternatives that were to be taken forward for further evaluation. These alternatives are collectively known as the Best Alternative Plans.

During the evaluation and refinement of these alternatives it was determined that a ninth alternative should be considered among the Best Alternative Plans. This alternative was identified in late September 2010 and the project team was directed to conduct evaluations on this alternative in addition to the previously identified eight.

TABLE 6-4

Summary of Conceptual Alternative Plans

Alternative	Description	Estimated Construction Cost	Estimated Benefit	Benefit to Cost Ratio	Environmental Impacts	Social Impacts
1	Status Quo	$0	-	-	• No Impacts	• No reduction in flood risk
2	High Hazard Zone containment with critical structure flood proofing	$11,500,000	$1,150,000	0.10	• Limited Impacts	• No reduction in flood risk • Flood proofing reliability concerns
3	US-36 detention with downstream conveyance along Dry Creek No. 2 Ditch	$24,600,000	$46,700,000	1.90	• Habitat and wetland impacts • Periodic inundation of Open Space	• Requires formal agreement with CU • Provides 100-year protection in West Valley
4	US-36 detention with downstream conveyance through West Valley	$28,000,000	$46,700,000	1.67		
5	US-36 detention with downstream storage and conveyance through West Valley and along Dry Creek No. 2 Ditch	$24,200,000	$46,700,000	1.93		
6	US-36 detention with downstream diversion to Bear Canyon/Boulder Creek	$25,500,000	$46,700,000	1.83		
7	US-36 detention with downstream diversion to mainstem	$25,600,000	$46,700,000	1.82		
8	Detention near Hwy-93 with downstream conveyance along Dry Creek No. 2 Ditch	$24,100,000	$46,700,000	1.94	• Habitat and wetland impacts • Periodic inundation of Open Space	• Requires purchase of currently developed private property or OSMP • Provides 100-year protection in West Valley
9	Detention near Hwy-93 with downstream conveyance through West Valley	$27,500,000	$46,700,000	1.70		
10	Detention near Hwy-93 with downstream storage and conveyance through West Valley and along Dry Creek No. 2 Ditch	$23,700,000	$46,700,000	1.97		
11	Detention near Hwy-93 with downstream diversion to Bear Canyon/Boulder Creek	$25,000,000	$46,700,000	1.87		
12	Detention near Hwy-93 with downstream diversion to mainstem	$25,100,000	$46,700,000	1.86		
13	No upstream detention with downstream conveyance along Dry Creek No. 2 Ditch	$39,100,000	$46,700,000	1.19	• No water quality enhancement opportunities • Limited wetland impacts	• Construction traffic, road closures, and noise near homes • Traffic disruption on major roads including possible closures • Utility disruption during construction • Requires easement coordination with ditch companies • Provides 100-year protection in West Valley
14	No upstream detention with downstream conveyance through West Valley	$47,900,000	$46,700,000	0.97		
15	No upstream detention with downstream diversions	$38,900,000	$46,700,000	1.20		

VII. Best Alternative Plans

The Best Alternative Plans represent those that were felt to best achieve the project objectives while also having the most favorable return of the capital investment and the fewest undesirable community impacts. The alternatives spanned the range of the alternatives considered and included a Status Quo alternative, protection for high hazard and critical facilities, conveyance alternatives and storage alternatives.

The original 15 alternatives were reviewed based on benefit - cost analysis, staff and OSMP feedback and public meeting comments and feedback on alternatives. Based on this analysis, 6 of the 15 conceptual alternative plans from Section 6 were moved forward. The alternatives moved forward are reported in Table 7-1 and include Alternative 1 (Alternative 1 from Section 6), 2 (Alternative 2 from Section 6), 3 (Alternative 5 from Section 6), 4 (Alternative 10 from Section 6), 7 (Alternative 13 from Section 6), and 8 (Alternative 14 from Section 6).

Based on recommendations from staff and public feedback three additional alternatives were added. These included looking at Baseline Reservoir as a potential storage facility to mitigate increased flood flows through the US-36 bridge to avoid overtopping. In addition an alternative was added that looked at providing distributed detention storage at facilities near US-36 east of the CU South campus, at South Boulder Road, and at Baseline Road, and providing local flood improvements along Dry Creek No. 2 Ditch to address the remaining hazard. These alternative detention facilities eliminated the need for detention on private property at Hwy-93 or detention on the CU South Campus. Finally, a flood protection alternative to handle nuisance flows was added to address issues related with the flood threat generated by local runoff. This alternative was based on the recommendations included in the Stormwater MP completed by HDR. The nine alternatives selected as Best Alternative Plans are summarized in Table 7-1, Best Alternative Plans and are presented as Figures 7-1 through 7-9.

TABLE 7-1

Best Alternative Plans

Alternative	Description
1	Status Quo
2	High Hazard Zone containment with critical structure flood proofing
3	Regional Detention at US-36 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
4	Regional Detention near Hwy-93 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
5	Distributed Regional Detention with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch
6	Mainstem flow containment with local West Valley improvements
7	Dry Creek No. 2 Ditch pipeline
8	Bear Canyon Creek pipeline
9	Nuisance – Level Flood Improvement Protection

The alternatives are generally described as follows:

1. **Status Quo** –. This alternative remains unchanged from the Conceptual Alternative Plan. Figure 7-1 in Appendix D presents the existing floodplain conditions that would result from maintain the status quo.

   High Hazard Zone containment with critical structure flood proofing –25 structures are proposed to be flood proofed with this alternative and include hazardous materials facilities, schools, essential government offices, public safety and emergency medical facilities and at risk population facilities as outlined in the City of Boulder's Critical Facilities and Mobile Populations Ordinance. A facility was identified if it was within the 500- or 100-year floodplain. The structures identified for flood proofing and the structures in the High Hazard Area are shown on Figure 7-2, High Hazard Zone Containment with Critical Structure Flood Proofing in Appendix D. This alternative remains unchanged from the Conceptual Alternative Plan.

3. **Regional Detention at US-36 detention with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch** – The proposed 560 AC-FT Detention at US-36 prevents the overflow of US-36 and provides 100-year protection from the overtopping flows from South Boulder Creek to downstream properties in the West Valley. The detention pond combines excavation and fill to produce a configuration that minimizes the impacts to Open Space land and the University of Colorado South Campus and to minimize the potential visual impact by integrating into existing roadway improvements in the area. The Remainder f the alternative includes improvements along Dry Creek No. 2 as described in the Conceptual alternatives Plan.. Figure 7-3 US-36 Detention in Appendix D presents the proposed improvements.

4. **Regional Detention near Hwy-93 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch** – Detention near Hwy-93 provides detention on approximately 40 acres of land (420 acre-feet of storage). This alternative reduces impacts of city owned Open Space and isolates the detention onto two large privately owned parcels, avoiding the challenges associated with coordination with CU South Campus, CDOT and other stakeholders in the vicinity of the US-36 corridor but would require the purchase of currently developed private property from unwilling sellers.

   This alternative has other constraints that make its implementation difficult. This alternative relies on uncontrolled overflows of Hwy-93 to function. There is no guarantee that the specific natural conditions that currently cause this overflow to occur would continue in perpetuity. These conditions include the geometry of Hwy-93, which will likely change in the future, upstream conditions including irrigation diversions, changes to upstream vegetation and land use and the location of any specific design storm. If any of the above-mentioned conditions change, it could affect the overflow at Hwy-93 and the function of the proposed detention structure potentially changes the flow conditions and storage capacity of the alternative.

   The Remainder f the alternative includes improvements along Dry Creek No. 2 as described in the Conceptual alternatives Plan.. Figure 7-3 US-36 Detention in Appendix D presents the proposed improvements.. Figure 7-4, Detention near Hwy-93 in Appendix D presents the proposed improvements.

5. **Distributed Regional Detention with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch** – This alternative was developed in response to feedback opposing Alternative 4. The objective of this alternative is to provide 100-year flood protection within the West Valley area using lands owned by the city OSMP or through the purchase of currently undeveloped private land. This represents a derivative of the Mainstem Containment option but incorporates some of the features of the detention alternatives. The intention of this plan is to provide mainstem containment but to mitigate the impacts associated with the increased flows through the US-36 bridge by providing storage both upstream and downstream of US-36. Detention to mitigate the impacts of increased flows through the US-36 bridge were accomplished using the following detention locations:

   - Approximately 130 acre-feet of detention storage (38 acres surface area) at US-36. Floodwaters would be stored behind a berm constructed along the south side of US-36 on the west side to South Boulder Creek. The berm would begin at the bridge, reach a maximum height of 13 feet near the Foothills Parkway interchange and be constructed entirely on OSMP lands, avoiding construction on CU property.
   - Approximately 130 acre-feet of detention storage (49 acres surface area) at South Boulder Road. Flood waters would be stored behind a berm constructed along the south side of South Boulder Road, have a maximum height of six feet above South Boulder Road and be constructed entirely on OSMP lands.
   - Approximately 295 acre-feet of detention storage (38 acres of surface area) at Baseline Road. The water would be stored behind a berm constructed along the south side of Baseline Road that would have a maximum height of approximately 13 feet above Baseline Road. The berm would be constructed on OSMP land but would also require the purchase of privately owned parcel. Construction of this detention facility would require relocating

an OSMP trail head and access parking lot from the south side of Baseline Road likely to the west side of Cherryvale Road.

To address the flood threat downstream of US-36, both storage and conveyance improvements are proposed through the West Valley and along the alignment of Dry Creek No. 2 Ditch. The storage component of the downstream improvements allows for locally generate flood peaks to be attenuated and results in a decrease in the size of the required infrastructure downstream. The combination of conveyance improvements along both drainage corridors reduces the amount of overland flooding that poses a threat once floodwaters leave either corridor. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 7-5, Mainstem Containment with Storage in Appendix D presents the elements of this alternative.

6. **Mainstem flow containment with local West Valley improvements** – This alternative does not control the overflow of US-36 using storage. Rather, it provides a berm parallel to the existing CU South Campus Berm to contain the flow in the main channel and forces more water through the US-36 bridge. Localized improvements through the West Valley and along the Dry Creek No. 2 Ditch corridor are still required to manage locally generated flows. Both storage and conveyance improvements are proposed through the West Valley and along the alignment of Dry Creek No. 2 Ditch. The storage component of the downstream improvements allows for locally generate flood peaks to be attenuated and results in a decrease in the size of the required infrastructure downstream. The combination of conveyance improvements along both drainage corridors reduces the amount of overland flooding that poses a threat once floodwaters leave either corridor. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. The impacts associated with higher flows along the mainstem would be mitigated by providing additional storage capacity in Baseline Reservoir. Currently, some of the mainstem flows reach Baseline Reservoir. This alternative proposes to formalize this flow path and add additional flow capacity and storage in Baseline Reservoir to mitigate impacts to downstream properties. On July 30, 2010, the project team met with Staff from the Baseline Reservoir Company and City of Lafayette to discuss the use of Baseline Reservoir for storage of flood flows. From this meeting several issues regarding the alternative were brought to light.

   – Baseline Reservoir is a drinking water storage reservoir and Lafayette has concerns that adding additional flood flows to the reservoir could detrimentally affect the quality of the drinking water for Lafayette. The City of Lafayette would require water quality enhancements to mitigate the effect of the additional flood flows to the water quality in Baseline Reservoir.

   – There was concern that adding additional flood flows to the reservoir could affect the spillway and embankment of the reservoir requiring a lengthy and expensive retrofit or upgrade to the reservoir embankment and spillway to accept additional flood flow waters.

   These issues are significant factors to the successful implementation of this alternative and are reflected in the benefit cost ratio for the alternative.

   Figure 7-6, Mainstem Flow Containment in Appendix D shows the proposed improvements.

7. **Dry Creek No. 2 Ditch pipeline –**. This alternative remains the same as the alternative described in the Conceptual Alternative Plan. It should be noted however that no improvements are proposed though the West Valley. As a result, some potential for damage during local floods remains. Figure 7-8, Dry Creek No. 2 Ditch Conveyance in Appendix D presents the proposed improvements.

   This alternative has the potential to create significant disruption to both local neighborhoods and arterial roadways throughout Boulder. Potential impacts could include disruption or closure of both local residential streets and major arterials including Baseline Road and 55th Street to accommodate the construction of the Pipelines. In addition, there could be additional disruptions to utilities as utility conflicts with water, sewer gas, electricity and telecommunications are resolved during construction.

8. **Bear Canyon Creek pipeline** – This alternative remains the same as the alternative described in the Conceptual Alternative This alternative collects and captures the overflow and provides a large, conveyance to move those flows to the west toward channels that have adequate capacity. In general, overflows reaching the West Valley will be captured and diverted north and west to the Bear Canyon Creek system along Foothills Parkway downstream of Baseline Road. Remaining flows that reach the Dry Creek No. 2 Ditch corridor will be captured and moved east back toward the mainstem where adequate capacity exists. Improvements include larger pipes or channels and associated collection facilities and inlets. Figure 7-7, Diversion to Bear Canyon Creek in Appendix D presents the proposed improvements.

   This alternative has the potential to create significant disruption to both local neighborhoods and arterial roadways throughout Boulder. Potential impacts could include disruption or closure of both local residential streets and major arterials including Baseline Road and 55th Street to accommodate the construction of the Pipelines. In addition, there could be additional disruptions to utilities as utility conflicts with water, sewer gas, electricity and telecommunications are resolved during construction.

9. **Nuisance – Level Flood Improvement Protection** – This alternative considers the improvements proposed in the Stormwater MP. This alternative does not explicitly address the hazards of the 100-year flood but focuses on the minor floods that cause considerable nuisance but little major damage. The primary purpose of this alternative was to assess the potential flood damage reduction if these lower events were controlled. The facilities proposed in the Stormwater MP are the basis for this alternative and are generally smaller pipes that collect local runoff. This alternative does not significantly alter or reduce the 100-year floodplain as the proposed pipe systems will be surcharged during a 100-year event. However, during smaller local basin storms this alternative will address local basin and small flooding events helping to eliminate repetitive damages in the basin during small storms. Figure 7-9, Stormwater MP, in Appendix D shows the proposed facilities.

Project Benefits

Benefits associated with the various alternatives were derived directly from the results of MIKEFLOOD. Unlike the earlier evaluations that required an estimation of the damage to flooded structures, the MIKEFLOOD model results defined a depth of flooding at each structure in the floodplain for each recurrence interval event. Similar to the original estimate of the flood damages, it was possible to aggregate these damages estimates and determine the residual flood damage for each simulation.

The resulting flood damages, when subtracted from the baseline flood damage, provide an estimate of the project benefits. Residual damages for each event were computed and average annual residual flood damage was determined. The difference between the baseline average annual flood damage and the residual average annual flood damage was the computed project benefit. Average annual benefits were converted to an equivalent capital cost using the processes defined by the District and FEMA using the FEMA approved discount rate of 7%.

Alternative Costs

The planning level cost estimating tools developed during Conceptual Alternative Plan evaluations were generally applied to develop costs for the Best Alternative Plans. The higher level of resolution of the alternatives allowed for an improved cost estimate for each of the alternatives. In particular, the resolution used to define the storage facilities provided a better understanding of the earthwork and of the outlet control structures. This greater level of resolution was incorporated into the planning cost estimates.

Unit cost was not changed in the revised alternative evaluations. Land costs were reviewed and clarifications were added. Purchase or easements on property outside of the City of Boulder's corporate limits were valued based on the assessed value of both the land and structures as found in the Boulder County Assessors data. Land within the City of Boulder's Corporate Limits was conservatively valued based on zoning designations within the city's boundaries as shown in Table 7-2.

TABLE 7-2
Land Value Data for South Boulder Creek Flood Mitigation Project
Source: City of Boulder Utilities

Zoning Code	Description	Price per Square Foot ($)
AG	Agricultural	0.80
PU	Public	19.00
RB	Regional Business	180.00
CB	Community Business	39.00
HD	High Density Residential and Mobile Home	50.00
MD	Medium and Mixed Density Residential	36.00
LD	Low Density and Rural Residential	22.00
IND	Industrial	15.00

Benefit-Cost Analysis

The refined aggregated costs for each of the Best Alternative Plans were compared to the refined computed benefits to determine a Benefit-Cost relationship for the alternative. This ratio provides a simple numeric measure but does not necessarily suggest that the projects with the best ratios are the best use of public funds nor is a favorable ratio an indication that the project is the most favorable project without the consideration of social, political and environmental constraints. The results of this analysis are presented in Table 7-3.

Other Considerations

Decisions regarding which alternatives should be taken forward for additional investigation and consideration are not made solely based on the financial impacts. While these financial impacts are an important consideration that will profoundly affect the implementation potential, many financially viable projects are in other ways flawed. The consideration of these other issues often drives decisions on the real potential for a project to successfully address the flood control objectives while conforming to other community standards.

Water Quality

The city has a strong history of efforts that demonstrate a commitment to water quality enhancement. All of the alternatives will continue to incorporate the ongoing measures already in place within the city such as the National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge permit program. In this program, the city has identified and implemented measures that collectively will improve the quality of stormwater runoff within the city. While these control measures are generally focused on minor, first flush events that convey the majority of pollutants of interest, they provide broad benefit, and considerations for major floodwater quality were taken into account.

Water quality impacts and the measures necessary to address those impacts generally fall into two categories, temporary and permanent. Temporary impacts are often associated with construction activities and focus primarily on the disturbance to natural ground cover during construction activities. While the general extent of these impacts often varies with the nature of the construction, mitigation measures required by the NPDES Stormwater Discharge Permits held by the city and Boulder County will be imposed on any construction activities. As such, there is not likely to be any difference in the temporary water quality impacts associated with the various improvements.

Permanent impacts to water quality are likely to differ among the alternatives. In general, alternatives employing natural channels will provide greater water quality benefits than those, which include conveyance mechanisms such as pipes or lined channels that accelerate flow and eliminate the natural filtration provided by the natural systems. Similarly, detention storage has water quality benefits due to the water being detained allowing large particles to settle out of suspension. These particles are common carriers of many pollutants in stormwater and, after being removed from the flow, result in reduced concentrations of many of the most significant constituents impairing water quality.

Stormwater inherently conveys pollutants. Flood control improvements that convey this stormwater to areas not typically receiving these flows have the potential to create adverse impacts if not carefully considered. Efforts were made to understand the potential impact of water quality changes on receiving waters such as Baseline Reservoir.

Natural Environment

Boulder has a longstanding tradition of nurturing, protecting and integrating the natural environment into the community. Flood control projects are no exception. Whether greenways, Open Space lands, buffers, wetlands or other habitat areas; identification, protection and preservation of these areas must be incorporated into flood control projects.

The projects identified as Best Alternative Plans are mindful of the city's interest in the natural environment and have been laid out to minimize impacts. Areas containing high functioning wetlands have been avoided to the extent possible. In some cases, minor impacts to the fringes of these areas may have been unavoidable but the level of encroachment has been minimized.

While not an element directly incorporated at this level of study, enhancement of the natural environment is often an element of flood control improvements. These can be incorporated as trails that provide the public with better access to natural areas or in may be the enhancement of natural spaces. Ponds and open channels are frequently revegetated with native plant materials that provide aesthetic means of stabilization integrate into the surrounding environment and provide habitat and other functions often found in natural environments. As the alternatives identified for further study are refined, specific measures to enhance the natural environment will be incorporated.

The natural environment also includes the groundwater resource in the area. Drainage improvements often affect the natural flow of groundwater. In many cases, the construction of these drainage improvements lowers groundwater tables by providing improved and lowered drainage channels. That is likely to be the case where open channel improvements are proposed. However, a high groundwater table also constrains some alternatives. High groundwater complicates construction activities and may limit the effectiveness of facilities such as detention ponds by occupying some of the intended flood storage capacity. Along South Boulder Creek, there are numerous areas where the groundwater table supplies an important water source for wetlands. Every effort was made to understand the nature of the groundwater near the proposed improvements. Further investigations are likely to be required if specific alternatives move forward for additional consideration.

Threatened and Endangered Species

Numerous resources from Boulder County, OSMP and the City of Boulder were referenced that identify the locations of threatened and endangered species within the South Boulder Creek watershed. These consist primarily of *Spiranthes diluvialis* or Ute lady's tresses orchid and the Preble's Meadow Jumping Mouse (PMJM), which have been mapped as having habitat along the mainstem, primarily upstream of US-36. Figure 2-5 through Figure 2-8, presented earlier in this report provide a summary of the habitat areas along the study alignment.

The flood control measures proposed in the various Alternative Plans have been formulated to avoid these areas to the maximum extent possible. Any projects that move forward toward implementation will be required to look at these habitat areas more carefully and provide assurance that no adverse impacts to threatened and endangered species occur.

Open Space Lands

Numerous areas of designated Open Space land exist within the South Boulder Creek watershed. These areas serve many important functions, any of which may be unique to a given property. The alternatives identified in these plans were formulated to minimize the impacts to Open Space lands. However, since many of these lands fall in or near the conveyance areas of the channel, all impacts were unavoidable.

The Project Stakeholders group included representatives from city OSMP. Numerous discussions were held to understand the types of Open Space lands being impacted and to identify any possible measures that might be allowable on a particular Open Space parcel. In general, the layout of improvements associated with the Alternative Plans limited physical improvements on Open Space lands to the extent possible and required several iterations of concept designs.

Operation and Maintenance

The costs identified for the various alternatives include an allocation for the long-term maintenance of the component facilities. These costs are generally mowing and cleanup costs. For the purposes of comparing the various Alternative Plans, the maintenance costs have been converted to an equivalent capital cost and rolled into the total improvement cost for a specific plan.

The design criteria developed by the District and adopted by the city also include considerations that minimize the long-term cost of maintenance of drainage facilities. Measures have been incorporated into the layout of alternatives that assure there is adequate access for routine maintenance or for emergency repairs if required. Other design standards have been developed to limit future erosion and to provide stable slopes with appropriate vegetation.

Social Impacts

Impacts to the community pose a particular constraint on many types of improvement options. These impacts include disruptions during construction, visual or aesthetic impacts, and many other impacts that were expressed during the public involvement process on this project. These must be included in the final consideration of the various alternative plans.

Each of the projects, other than the Status Quo, will have associated construction impacts. While these are temporary, they have the potential to disrupt business activity, make travel from home to office and other destinations more difficult and create noise and dust. Typical construction specifications impose conditions on the contractor that require the mitigation of these impacts. It can be assumed that such conditions will be included in any improvements that are associated with the selected plan.

Much of the character of the community is defined by the maturing of the landscaping along many of the streets and parcels on which improvements have been identified. Considerable feedback was provided during the public meetings about the desirability to maintain the large mature trees that line many of the drainage corridors in the city. Any impact to this vegetation would create considerable disruption and would be looked upon with skepticism by the community. Efforts were made to minimize the potential disruption along the mature drainageways whenever possible.

Other visual impacts were also considered. In particular, the construction of embankments for flood control storage would obstruct existing sight lines. Moreover, the construction of an embankment often gives the appearance of creating an entirely new landscape that is very imposing. Efforts were made to understand the impact of these new facilities and to minimize the visual impact by aligning them with existing features of similar geometry.

The implementation of flood control improvements often requires new rights – of - way. The alignments identified for the various alternative plans were chosen to minimize the impact on private properties. Not all impacts to private property, however, could be avoided. The costs for each of the plans include provisions for the purchase of easements or outright purchase of the property. The estimates are based on costs derived from the City of Boulder assessor's data.

City Policies

During past studies of South Boulder Creek, the city identified priorities that could be used as guidance in the development and evaluation of alternatives for this study. Many of these reflect sound flood control principles while others reflect the collective interests of the community and its leadership. Among these were issues discussed earlier such as the avoidance of alteration to Open Space or the consultation and approval should any impacts be necessary and the preservation of habitat and riparian areas.

Other objectives include an interest in avoiding channelization of South Boulder Creek. Because the corridor had many areas of designated habitat and wetlands and because the corridor was home to long reaches of mature vegetation, these areas were generally avoided in the formulation of the alternative plans. Minor improvements were identified along the mature drainageways within South Boulder Creek but they were limited to the extent necessary to provide the necessary flood protection.

The city has expressed an interest in minimizing the impacts to the community and that includes the potential purchase of property for flood control facilities. The intention of the identification and selection of the alternatives was to minimize disruption to the community, including limiting the amount of private property necessary for the implementation of the alternatives. The facilities were located so that the number of private property impacts would be minimized. In the case of the Distributed Regional Detention, that meant aligning the alternative so that the impacts would be borne by a single property owner rather than several. While the impacts to that property owner were indisputably higher as a result, the position taken during alternative development and evaluation was that the impact would be mitigated by payment of fair market value for any impacts.

The city has expressed a strong interest in minimizing the use of large mainstem dams to control flooding along South Boulder Creek. That interest was reflected in the development of these alternatives. The alternatives selected generally try to provide storage off channel, although on-channel detention facilities were included to limit disturbances to private property. All Detention structures focused on minimizing excavation and minimizing the impacts to habitat areas and wetlands that are most commonly along the mainstem. In many cases, the storage areas that are proposed are in areas already impacted by flood flows so there is little additional impact to habitat areas.

In all cases, the city's commitment to floodplain management is maintained. Each of the alternatives continues the city's ongoing efforts to protect the community from the hazards of flooding along South Boulder Creek and from its tributaries. The practices such as flood warning systems, education and floodplain regulations provide a strong foundation that is complementary to the structural measures identified as part of most of these alternatives.

Best Alternative Plan Evaluation Summary

The evaluation of the Best Alternative Plans is summarized in Table 7-3, Best Alternative Plan Evaluation Summary.

TABLE 7-3

Best Alternative Plan Evaluation Summary

Alternative	Description	Estimated Construction Cost	Benefit-to-Cost Ratio	Environmental Impacts	Social Impacts
1	Status Quo	$0	0.00	• No impacts	• Flood risk still remains
2	High Hazard Zone containment with critical structure flood proofing	$10,700,000	2.20	• Flood proofing of critical facilities reduces the potential exposure of flood waves to toxins	• Flood limits do not change • Flood proofing reliability concerns • Provides emergency egress to homes within the high hazard zone
3	Regional Detention at US-36 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch	$28,800,000	2.68	• Impacts to Environmental Conservation Area Land • Impacts to wetland • Periodic inundation of Open Space lands • Groundwater impacts still to be determined	• Requires formal agreements with CU, Boulder Valley School District (BVSD), OSMP, CDOT, ditch companies, and city Parks • Provides 100-year protection in West Valley Area • Includes enhancements to Manhattan Middle School play fields and includes enhanced bike/pedestrian trail at Arapahoe Avenue
4	Regional Detention near Hwy-93 with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch	$31,100,000	2.49	• Habitat and wetland impacts • Periodic inundation of Open Space lands • Groundwater impacts still to be determined	• Requires purchase of currently developed private property • Requires formal agreement with CU, BVSD, OSMP ditch companies and city Parks • Provides 100-Year protection in West Valley Area • Includes enhancements to Manhattan Middle School play fields and includes enhanced bike/pedestrian trail at Arapahoe Avenue
5	Distributed Regional Detention with downstream storage and conveyance improvements through West Valley and along Dry Creek No. 2 Ditch	$29,200,000	2.60	• Habitat and wetland impacts • Periodic inundation of Open Space lands • Impacts Boulder county Critical Wildlife Area at Baseline Road • Groundwater impacts still to be determined	• Requires formal agreements with BVSD, OSMP, CDOT, ditch companies, and city Parks • Provides 100-year protection in West Valley Area • Includes enhancements to Manhattan Middle School play fields and includes enhanced bike/pedestrian trail at Arapahoe Avenue • Requires purchase of undeveloped private property
6	Mainstem flow containment with local West Valley improvements	$39,200,000	1.94	• Impacts to Open Space and Environmental Conservation lands downstream of South Boulder Road • Impacts Boulder County Critical Wildlife Area at Baseline Road • Groundwater impacts still to be determined	• Requires approval from State Engineers Office • Requires formal agreements with City of Lafayette, BVSD, CDOT, OSMP, ditch companies, and city Parks • Provides 100-year protection in West Valley Area • Includes enhancements to Manhattan Middle School play fields and includes enhanced bike/pedestrian trail at Arapahoe Avenue
7	Dry Creek No. 2 Ditch pipeline	$45,700,000	1.24	• No water quality enhancement opportunities • Wetland impacts at Baseline Road/ Foothills Parkway intersection	• Extensive disruption during construction • Requires easement coordination with ditch companies • Provides 100-year protection in West Valley Area • Significant utility relocation costs
8	Bear Canyon Creek pipeline	$46,300,000	1.25	• No water quality enhancement opportunities • Wetland impacts at Baseline Road/ Foothills Parkway intersection	• Extensive disruption during construction – Construction traffic, road closures, and noise near homes – Traffic disruption on major roads including possible closures – Utility disruption during construction • Requires easement coordination with ditch companies • Provides 100-year protection in West Valley Area • Significant utility relocation costs
9	Nuisance – Level Flood Improvement Protection	$14,000,000	0.10	• No impacts	• Limited reduction in flood risk

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VIII. Refinement of Best Alternative Plans

Introduction

The refinement of five of the Best Alternative Plans was authorized by an amendment dated May 18, 2011. The need for the refinements to these alternatives came because of City of Boulder staff's discussions with the Water Resources Advisory Board (WRAB) and Open Space and Mountain Parks (OSMP) staff. During those discussions, additional interests and issues were identified that were beyond the scope of the original planning study. The selected five alternatives were deemed the most viable and the only alternatives among the previous nine that warranted further consideration. All other alternatives were eliminated from further consideration.

The scope of the amendment called for a more detailed evaluation so that the elements of the plans could be refined with greater resolution and the plans could be more clearly communicated to the public. The five alternatives identified for further evaluation include:

- Status Quo Alternative
- High Hazard Zone Mitigation Alternative
- Regional Detention at US-36 Alternative
- Distributed Regional Detention Alternative
- Bear Canyon Creek Pipeline Alternative

The focus of the evaluations continued to be on cost effective ways to address the 100-year flood threat in the West Valley. The refinements continued to rely on the representation of the flood threat as defined by the 8-meter grid MIKEFLOOD model. The refinements included more detailed engineering evaluations to better define the characteristics of the plan elements including conceptual grading and layout, the associated costs, and proposals for the most logical implementation sequence. In addition, renderings of select components of the plans were developed to communicate the details to the public more clearly. These more refined evaluations provide the necessary information to allow the city to put forward a single recommendation for formal consideration and adoption.

Alignment Refinements

The refinements looked more carefully at identified environmental constraints and existing public easements and utilities. The alignment and geometry of the improvements were revised to reduce impacts and costs.

Costs Refinements

One of the key objectives was to better define the likely implementation costs for each of the Best Alternative Plans. In addition to the higher resolution of the various plan elements, other items affecting cost such as utility relocations, easement and right-of-way acquisition, and environmental mitigation were identified and incorporated. A more detailed summary of the cost estimate refinements is presented in Appendix F, Cost Summary.

Unit costs for the various work elements and estimating contingencies were also reviewed and updated as required. The unit costs used were generally based on the default values found in the Urban Drainage and Flood Control District's (District) program UD-MP COST Version 1.1. While this proved to be a useful starting point, the nature of some of the improvements proposed along South Boulder Creek necessitated the modification of some of these values. The refined analysis included a more detailed grading plan for each of the ponds proposed in the alternatives and resulted in a better estimate of the embankment fill, impervious core, and impervious key. The evaluation also concluded that a concrete spillway would probably be required by the State Dam Safety staff in order to assure the stability of the embankment during the spillway design flood.

The utility relocation costs continued to be handled using a factor applied to the capital cost of all infrastructure. During the refinement process, it was concluded that the proposed ponds would have very little impact on existing utilities; therefore, the utility relocation cost factor applied to these costs was removed. Facility locations were adjusted to avoid impacts to individual single-family residential properties in favor of the purchase of larger easements from undeveloped or commercial and industrial properties.

The earlier alternatives recognized that there would be impacts to environmentally sensitive areas and anticipated that the cost of mitigation could reasonably be included in the project contingency. After discussions with OSMP staff, it was concluded that environmental mitigation should be estimated separately. A per acre cost based on the market price for creation of comparable wetlands for wetland areas that are regulated by the city or USACE was the basis of environmental mitigation costs.

The early estimates of Best Alternative Plan costs used a 50 percent construction contingency instead of the District's default value of 25 percent. These contingencies are above the engineering, legal, administrative and management contingencies that add another 30 percent. The higher factor was deemed appropriate because the nine alternatives were schematic in nature. The refined plans looked at various elements in greater detail than the original nine alternatives but are still not at the level of conceptual design drawings, so a construction contingency value of 35 percent was utilized for the refined costs.

Refined Benefits

The refinements to the various plan elements did not result in any substantive changes to the estimated benefits. The refined benefit-cost ratios reflect changes to the cost estimates discussed above.

Other Considerations

The refinement of the Best Alternative Plans allowed the team to gain a better understanding of the various project impacts and to assess the proposed plans against a broad range of considerations. Details of many of the identified impacts are discussed in a memorandum that updated the earlier assessment conducted by the OSMP staff. The memorandum is included in Appendix G, OSMP Impact Memorandum Update. These considerations included:

- Water Quality
- Natural Environment
- Threatened and Endangered Species
- Open Space Lands
- Operations and Maintenance
- Social Impacts
- Other city Departments

The refinements did not create any substantive changes in expected water quality benefit from those identified during the earlier evaluations.

As a result of the refined analysis and discussions with OSMP staff, several environmental considerations and impacts were analyzed. Most of the improvements proposed reduce or avoid impacts to the main channel of South Boulder Creek that represents the majority of the natural areas.

Impacts to threatened and endangered species are expected as part of some of the alternative plans being considered. The two species noted are the PMJM and the Ute Ladies' Tresses Orchid. The Northern Leopard Frog is also a species of interest, and impacts to its habitat areas have been identified. While every effort was made to reduce the impact of construction footprints and permanent facilities, some impacts were unavoidable. The proposed plans include costs to mitigate the impacts through the development of compensatory mitigation or the purchase of land. In addition, all disturbed lands will be restored to the extent possible. Some impacted areas can be enhanced during the restoration process through the establishment of more suitable vegetation types or densities and grading changes to create more suitable habitat.

There are many impacts to both privately owned and city-owned Open Space lands, including permanent improvements such as embankments and temporary impacts that were not materially changed during the refinement. These areas will be restored.

All of the facilities will require routine maintenance to assure correct performance. Permanent access was incorporated during the refinement to facilitate operations and maintenance.

Social impacts were considered in the refinement process. This includes minimizing the visual impacts of any proposed improvements. This included concerns over the impacts to mature vegetation that currently serves as a visual barrier, as

well as impacts to unvegetated areas that provide unobstructed views. The proposed facilities generally avoid direct impact to the recreational corridor and do not preclude access to Open Space. There will inevitably be temporary impacts to residents along the areas of proposed construction, regardless of which alternative may be identified as the Selected Alternative. Final design and construction should include measures to assure that business and residential impacts are addressed.

Phasing Recommendations

The implementation of the Best Alternate Plans will require a capital investment of somewhere between $30 million and $50 million. It is quite likely that the city, even with a funding partner such as the District, will not be able to commit sufficient funds to construct the improvements for all elements of the plan concurrently. A more probable scenario is that the improvements will be phased to better align capital outlays with revenue streams.

In many drainageway improvement projects, facilities are implemented in an upstream direction. That is, the facilities farthest downstream are constructed first so that improvements will not increase the flood hazard to facilities further down in the system. This implementation strategy is often modified in the event of detention storage, which is commonly upstream in the system. Along South Boulder Creek, the definition of these implementation priorities is further complicated because of the unique flood threat that results from the overtopping of US-36. Many downstream improvements have little impact on the floodplain and are intended to capture and convey locally generated flows. Without detention to control the overtopping of US-36, the downstream improvements offer little flood threat reduction.

The challenge in providing phasing recommendations is that various considerations must be balanced in order to define the most reasonable order of implementation. This is a highly subjective process and one in which different people could reach different conclusions. In this case, the phasing recommendations are the product of interests expressed by the project team, the interested public during the various public meetings held on the project, and the direction and input received from WRAB and other city staff.

The process used to determine the recommended phasing for the various Best Alternative Plan elements is built upon several different criteria, including:

- Hydraulic Considerations
- Estimation of Residual Damage
- Capital Cost
- Element Benefit-cost Ratio
- Flood Control and Life Safety Issues
- Broader Public Interest Issues

For the phasing analysis, elements of the various plans that resulted in the lowest residual damages were determined to be more desirable than those with higher residual damages. Because the available funds to implement any of the identified plans are limited, the overall cost of the plan and the individual elements of the plan is an important consideration. In general, a higher benefit-cost ratio indicates a greater return on the community's investment and would suggest a higher priority. However, in some cases, the capital cost may be too high to warrant a high implementation priority. The comparison of the relative benefit-cost ratios assumes each phase might be implemented independently. By using this approach, the order of implementation can vary without the need to refine the benefit-cost ratio.

The primary objective of the Flood Mitigation Planning Study was to define a plan that would reduce the flood hazard in the West Valley. Alternative plan elements that helped to achieve this objective were accorded high priority when determining phasing recommendations.

Status Quo Alternative Refinements

This remains an important baseline against which all other alternatives will be measured and is unchanged from the earlier analysis. Figure 8-1, located in Appendix E, depicts the status Quo Alternative.

High Hazard Zone Mitigation Alternative Refinements

This alternative now focuses only on mitigation of High Hazard Zone conditions affecting two multi-family residential structures (Fig. 8-2, High Hazard Zone Mitigation Located in Appendix E) and no longer includes physical measures to floodproof Critical Facilities, as defined in the city's new Critical Facilities and Mobile Populations Ordinance. However, floodproofing schemes were identified and are discussed for informational purposes, but no specific floodproofing improvements are incorporated into the plan. More detailed suggestions of the possible floodproofing measures that could be employed for these structures are presented in Appendix H, Floodproofing.

The grading and structural improvements necessary to remove these two structures from the High Hazard Zone have been more clearly defined. A short structural floodwall adjacent to each structure and creation of a swale to improve conveyance along the emergency access lane and combined driveway north of Pima Court could be constructed. These improvements will prevent high-velocity flows from affecting the buildings and will effectively remove the structures from the designated High Hazard Zone. In addition to addressing the life safety threat, the elimination of the High Hazard Zone designation offers regulatory relief to property owners who seek to make modest improvements on the property that would have been disallowed in this zone. Figure 8-3, High Hazard Grading Improvements, located in Appendix E, shows the adopted concept for addressing the High Hazard Zone mitigation.

The High Hazard Mitigation Plan costs have been modified substantially. As part of the refinements to the High Hazard Plan the properties identified as critical facilities as part of the Cities Critical Facilities ordinance were further reviewed. The originally identified critical facilities were further filtered based on the following criteria:

- Remove facilities that are outside the 100-year floodplain
- Remove hazardous chemical facilities
- Identify city owned facilities

Based on the refined filtering of the critical facilities, three non-hazardous materials critical facilities located within the 100-year floodplain were identified and none of the facilities is city owned. The three remaining critical faculties identified are:

- RTD Parking Structure at Foothills parkway and US-36
- Frasier Meadows Manor
- The Friends School

Because the three remaining critical facilities are not city owned, the Project Sponsors concluded that the cost of floodproofing of these critical facilities, as well as any flooded residential structures, should be borne by the property owner. As a result, it was also concluded that any benefits from floodproofing activities should not be included in the Plan benefits. The High Hazard Mitigation Plan now has no identified benefits because the grading work described above would not produce any material reduction in flood damage.

The implementation of this alternative does not lend itself to phasing. The improvements are relatively low cost and must be done in aggregate to provide the necessary changes to the High Hazard Zone. As such, this alternative plan must be implemented in its entirety.

Regional Detention at US-36 Alternative Refinements

US-36 Detention Pond

The grading for the detention pond adjacent to US-36 was refined to make sure that there was sufficient room for the incorporation of future transportation corridor improvements identified in the US-36 Corridor Environmental Impact Statement (EIS). The improvements specified in the EIS were generally limited to the addition of acceleration lanes east of the Foothills Parkway /US-36 interchange and the addition of a regional recreational trail along the south side of the existing highway. The proposed grading for the US-36 Detention Pond embankment is presented in Figure 8-4, US-36 Detention located in Appendix E. To provide a buffer between the proposed flood control facilities, provide right-of-way for the regional trail and allow for potential alterations to the US-36 EIS as design proceeds, a 20-foot shift of the

embankment to the south and away from the existing roadway was incorporated. This created a slight increase in the amount of embankment material required to provide the necessary storage as well as slight additional impacts to OSMP property.

The public expressed considerable concern over the height and alignment of the embankment for the detention pond. The project team looked at this very carefully to minimize the footprint and the visual impact while maintaining the desired flood storage capacity of 560 acre-feet (AF). Some visual impacts, however, were unavoidable. A rendering was developed to depict the view of the embankment across its highest point, as shown in Figure 8-5, US-36 Detention Pond Embankment Rendering, located in Appendix E. To capture the perspective that featured the greatest obstruction, the rendering was produced looking from the Table Mesa Drive crossing of US-36 toward the southeast with and without the embankment in place.

The project team also looked very closely at the identified environmentally sensitive areas near the embankment. Impacts to areas of special environmental interest including the South Boulder Creek Natural Area, the PMJM Critical Habitat Area identified by the USFWS, the PMJM conservation area, and riparian and wetlands impacts were re-evaluated. The embankment was designed to minimize impacts to environmental resources and was successful in not affecting regulated wetlands. However, 1.0 acres of PMJM habitat would be impacted and the purchase of land and construction of compensatory mitigation would be required. The embankment would encroach onto property owned by CU for its future South Campus expansion. The CU-Boulder South Conceptual Framework Plan developed by the University was incorporated into the earlier investigations and was not updated during the refinement period.

The refinement also included a review of the various structural elements that are incorporated into the detention facilities at US-36. These include structures draining the pond, either at existing irrigation facilities or new outlet works, and the emergency spillway. The outlet facilities were found to be reasonable and were not modified. However, the emergency spillway erosion protection was expanded as a result of the refinement process. The extent of the riprap erosion protection was enlarged to provide a higher degree of assurance that flows in excess of the 100-year flood could be safely conveyed over the embankment and onto the US-36 right-of-way.

Arapahoe Avenue Detention

The pond, as originally conceived, was located adjacent to Arapahoe Avenue and took advantage of the Flatirons Golf Club golf course. The overall geometry of the facility and the infrastructure upstream of Arapahoe Avenue was largely unchanged during the refinement process, and the pond maintained a capacity of 58 AF.

The east outlet channel below Arapahoe Avenue has been realigned to minimize the impact on the existing development and to minimize future disruption to any new development. The realignment resulted in slightly more extensive downstream improvements and an increase in the associated right-of-way needs. The refinement to the outfall affected 0.14 acre of city-regulated wetlands that will require mitigation. The cost of mitigation for these impacts is now explicitly included in the cost estimate.

West Valley Improvements

Improvements along Dry Creek No. 2 Ditch are critical to the success of this alternative. The project team was asked to evaluate the potential of using a pipe to convey the 420 cfs flow down the Dry Creek No. 2 Ditch corridor in lieu of the open channel included in the original plan. The evaluation determined that a closed conduit pipeline 72 inches in diameter could be used instead of the previously identified open channel. The pipeline alignment was modified to take full advantage of existing publically owned lands, minimize the number of individual property owners impacted and minimize the conflicts with known utility lines.

Cost Refinements

The costs increased by approximately 20 percent over the earlier estimate but are generally within the range of anticipated variation. Proposed costs for the Regional Detention at US-36 have been updated to $36.2 million. Alternative costs are summarized in Table 8-1, Alternative Plan Summary, located in the Summary of Refined Alternatives section at the end of this Chapter.

The changes in the cost of the pond construction represent about 75 percent of the total overall change in cost of the Regional Detention at US-36 cost. The updated grading plan provided a much higher degree of resolution of the embankment materials necessary to provide desired flood storage. The updated geometry also allowed a better estimate of the amount of material necessary to construct the impervious core and fill the key trench.

The spillway costs have been refined to reflect the better understanding of the nature of flood flows when they exceed the 100-year event. Because this is not a mainstem pond, the spillway lining material is still assumed to be Type VH riprap, but the extent of the spillway protection on the downstream embankment face was expanded because the pond footprint was shifted away from US-36.

The capital cost of the West Valley improvements is largely unchanged, but the required footprint for the construction and long-term maintenance now reflects the adjustments made so that utility conflicts and single-family residential property acquisition costs are minimized. Annual operation and maintenance costs have been revised.

The environmental mitigation costs for the West Valley improvements have been included as a single line item. These costs were built into the project contingency in the earlier plans because specific impacts had not yet been quantified. The refined plan better describes the impacts to environmentally sensitive areas, and the cost of mitigation for those impacts is included in the estimated costs.

More right-of-way will need to be acquired to accommodate future channel construction downstream of the Arapahoe Avenue Detention pond. The new alignment also requires the enlargement of an existing channel that flows through city-designated wetland areas. The cost of mitigation for these impacts is now explicitly included in the cost estimate.

Refined Benefits

The refinements to the various plan elements did not result in any substantive changes to the estimated benefits. The average annual benefit expected to result from these improvements is estimated to be $77.3 million. Because the costs for this alternative have changed, the benefit-cost ratio has also changed. The revised value is now 2.14.

Other Considerations

Based on the plan refinements, there will be about 5.4 acres of impact to the South Boulder Creek State Natural Area because of the Regional Detention at US-36 alternative. This represents 0.5 percent of the total area of the State Natural Area.

Impacts to the PMJM habitat areas were determined based on a comparison of the project footprint and a 15-foot-wide access area to the USFWS Critical Habitat Area as well as the city's Conservation Zone. The Regional Detention at US-36 alternative affects about 1.6 acres of Critical Habitat Area and 7.1 acres of Conservation Zone. A majority of this impact is on Open Space lands, but some falls on the US-36 right-of-way. The Regional Detention at US-36 embankment will affect approximately 5.5 acres of Open Space lands.

An Operations and Maintenance (O&M) Plan may be required for areas designated as compensatory mitigation. In most cases, constructing new wetlands and habitat areas for compensatory mitigation will require a long-term commitment to operations to assure the facilities actually reestablish lost function and are sustainable. An operations plan should be developed and included in the design of any compensatory mitigation areas.

Phasing

This alternative is made up of three broad elements: US-36 detention, West Valley improvements, and Arapahoe Avenue detention. The overall plan implementation cost is about $36.2 million, making implementation of the full alternative at one time improbable. The following presents an alternative implementation strategy. The computed benefit-cost ratio for each element described below, reflects damage reductions that are associated with those improvements only and do not reflect the additional benefits that accrue as a result of the implementation other flood mitigation elements.

Priority 1 – US-36 Detention

US-36 detention is the recommended first element to be implemented. In addition to having an element benefit-cost ratio of approximately 2.0, the capital cost of $13.3 million may be low enough to be funded as a single project. The relatively high benefit-cost of this alternative makes it an attractive candidate for funding from other sources. Because

this is a stand-alone element that provides significant flood control benefit, it may be possible to secure funding from other sources such as the Federal Emergency Management Agency (FEMA) or the USACE.

In the event that the US-36 detention is built prior to other improvements downstream, there would need to be several minor temporary improvements to existing culverts that drain the US-36 detention facility at Dry Creek No. 2 Ditch, the Viele Channel, and the New Anderson Ditch. These culverts, in the absence of the interim controls will be under higher head and will convey more water. As such, they will require gates or structures to reduce the flow exiting from these culverts after the construction of this pond to pre -construction flow rates until the downstream improvements are in place. This will help to reduce potential flooding impacts through the West Valley. They may be a slight reduction in the capacity of the detention pond that could slightly increase the potential for overtopping of US 36 in comparison to the performance when the entire system is in place.

This project element fulfills the defined purpose of the project (reduce the flood hazard due to US-36 overtopping in the West Valley) without the need for further investment. In doing so, the flood insurance burden associated with the South Boulder Creek 100-year flood for those properties in the West Valley is eliminated and the real flood threat reduced to that of locally generated runoff flooding. The elimination of the overtopping of US-36 means this important transportation corridor remains open.

Priority 2 – Local West Valley Improvements

The proposed improvements in the West Valley address a number of different issues and comprise several smaller elements, including local detention at Manhattan Middle School, Dry Creek No. 2 Ditch pipeline improvements, local detention at Baseline Road and Foothills Parkway, floodwall improvements along Baseline Road, improvements to the New Anderson Ditch, and improvements to the Wellman Canal. In aggregate, these improvements are expected to cost $11.0 million to implement and result in a benefit-cost ratio of 3.2. While this is a high benefit-cost ratio, the benefits are largely seen at lower frequency events when smaller flood flows are handled by the smaller capacity local improvements. There is limited benefit during the 100-year flood and higher events.

The localized detention storage should be implemented early in the process to fully exploit the flow reduction realized through these facilities. Then the flood control measures such as the pipeline improvements along Dry Creek No. 2 Ditch and along Baseline Road should be implemented to provide adequate conveyance of the remaining flows. The improvements to the other irrigation ditches are intended to prevent overflows and contain those flows in the original system. These can often be done independently of any other improvements and can be implemented as needed or as opportunities arise.

Priority 3 – Arapahoe Avenue Detention

The Arapahoe Avenue detention pond and associated downstream improvements provide considerable flood relief to those properties below Arapahoe Avenue. The improvements are estimated to cost $11.9 million and will result in a benefit-cost ratio of 1.3. The majority of the benefits accrue to the commercial and industrial properties below Arapahoe Avenue. This element has been ranked as the last priority in part because the improvements benefit only commercial and industrial properties.

Distributed Regional Detention Alternative Refinements

The three regional detention pond embankments were refined to reduce impacts to Open Space lands, environmental resources, right-of-way and utilities. In addition, grading refinements, outlets, control structures, and emergency spillways were all reviewed and refined if necessary. Refinements to proposed facilities within the West Valley and at Arapahoe Avenue were similar to those considered for the other alternatives. Figure 8-6 presents the Distributed Regional Detention option, located in Appendix E.

US-36 Detention Facility

The alignment of the detention pond embankment along US-36 was reviewed to better understand impacts to Open Space lands and other properties in the area. The revised alignment is shown on Figure 8-7, Distributed Regional Detention – US-36 Pond, located in Appendix E. The western arm of the embankment has been relocated to avoid any contact with the existing levee protecting the CU South Campus property while still maintaining the desired 130 AF of storage. It was determined that a free-standing structure provided greater flexibility in future implementation and minimized the coordination issues with both the University and Federal regulators that may arise as a result of modifications to the levee system.

The northern and eastern portions of the embankment were moved slightly to minimize impacts to Open Space lands and to the riparian corridor along the South Boulder Creek mainstem. While these refinements helped to reduce the impacts, including the elimination of impacts to city-regulated wetlands, some encroachment into Open Space areas, PMJM Critical Habitat Area, and other habitat areas were unavoidable. Mitigation would be required to compensate for these 9.6 acres of unavoidable impacts.

The control structure that controls the flow of water from the South Boulder Creek mainstem into the detention pond at US-36 was modified during the refinement process. The earlier control strategy was to prevent overtopping of the US-36 embankment during the 100-year flood by pushing more of the flood flows through the US-36 Bridge using a berm and box culverts across the mainstem of the creek. This control strategy created unacceptable impacts to the riparian corridor upstream of US-36.

A revised strategy was developed that uses a more passive control structure that splits higher flows off and leaves low flows in the main channel, separating them from those in the overbank. The mainstem would continue to convey flows up to about 1,000 cfs without any water being directed to the detention pond. The structure would capture flows in excess of the first 1,000 cfs and convey them through the pond by creating a physical barrier across the section that captures and separates the overbank flows. A schematic of the cross section modifications that are proposed to create this control structure is presented in Figure 8-8, Distributed Regional Detention – US-36 Pond Control Structure, located in Appendix E. As the image shows, the overbank will need to be modified slightly to force more flow into the overbank during higher flow events.

Once the flows in excess of the 1,000 cfs threshold are separated from the channel flows, they flow into the pond. The storage-discharge relationship can be controlled by varying the shape and size of the outlet structure. The refinements allowed the performance of the outfall structure to be similar to that of earlier evaluations and helped minimize the storage in the overbank during flows less than the 100-year peak. Only during very large floods would the storage pool above the top of the pond outlet structure be used.

South Boulder Road Detention Facility

This 130 AF pond is an important element in controlling the impacts associated with the increased flow through the US-36 Bridge. The embankment alignment was modified to avoid encroachment into the South Boulder Road right-of-way and to minimize impacts to Open Space lands (Figure 8-9, Distributed Regional Detention - South Boulder Road Embankment, located in Appendix E). The shift of the embankment to the south would require reconstruction of portions of the Viele Channel. The portion of the channel flowing along the west side of the pond embankment was not changed because a concrete wall was used in lieu of an earthen embankment for this part of the pond. However, as the channel and embankment parallels South Boulder Road, the toe of the refined embankment encroaches into the existing channel, requiring realignment of the channel. This area may contain Ute Ladies' Tresses Orchids. A more exhaustive investigation may be required to determine if it is possible to mitigate these impacts. Regardless, at a minimum it is estimated that a total of 3.6 acres of regulated wetlands will need to be mitigated.

The pond has a mainstem embankment requiring the full flood hydrograph to pass through the pond. As a result, the emergency spillway required some refinements not considered in the earlier layout. The full spillway design flood must pass over the embankment because the topography at the site does not lend itself to a spillway over one of the overbank areas. To assure the long-term integrity of the embankment, it was decided the spillway should be constructed of concrete with the concrete extending down the full face of the embankment and all the way to South Boulder Road.

Baseline Road Detention Facility

The proposed detention facility at Baseline Road was modified to avoid encroachment into the road right-of-way and to minimize impacts to Open Space lands. (Figure 8-10, Distributed Regional Detention - Baseline Road Pond Embankment, Located in Appendix E). The southern embankment has been moved to the south resulting in some minor additional impacts to the Open Space lands. The east end of the embankment covers the existing trailhead and parking area. This

impact has been mitigated through the proposed relocation of the trailhead parking off Cherryvale Road rather than from Baseline Road. A trail connection back to the regional trail system is proposed as part of the plan. In addition to the relocation of the trailhead, 3.4 acres of city-regulated wetlands were impacted by berm refinements that would need to be mitigated. This pond also has a mainstem embankment. The emergency spillway here has been modified to consist of a concrete overflow spillway as described for the South Boulder Road pond. Based on the refinements to the berm and continued modeling of the alternatives through the 8-Meter MIKEFLOOD model, the volume of the pond was increased from 295 AC-FT to 375 AC-FT to accommodate additional flood flows and to ensure that there was not an increase in existing flood discharges downstream from the facility.

The proximity of the pond embankment to local roadways created some concern about the aesthetic impacts during the public meetings. As a result, an architectural rendering of the embankment as seen from the corner of Baseline Road and Cherryvale Road (Figure 8-11, Baseline Road Detention Pond Embankment Rendering, Located in Appendix E) was prepared. This image shows that the embankment has a relatively minor impact on the view of the Open Space lands to the south and west.

Arapahoe Avenue Detention Facility

The refinements at Arapahoe Avenue are similar to those identified during the evaluation of the Regional Detention at US-36 alternative plan. The primary difference between the earlier proposed plan details and those subsequent to refinement are downstream of Arapahoe Avenue.

West Valley Improvements

The facilities in the West Valley associated with this alternative are very similar to those identified for the Regional Detention at US-36 alternative. The most substantial refinement was the change from open channel to pipe for the improvements along Dry Creek No. 2 Ditch and the realignment of those improvements to minimize right-of-way acquisition costs. Improvements to the New Anderson Ditch are no longer required in the West Valley because the detention above US-36 no longer extends across to the New Anderson Ditch culverts passing under US-36.

The evaluation determined that the flows being conveyed in open reaches of Dry Creek No. 2 Ditch could effectively be conveyed in a closed conduit.

Cost Refinement

The refinement of the Distributed Regional Detention alternative resulted in a much better understanding of the plan elements and an increase in the estimated plan implementation cost of approximately 40 percent to $48.1 million. This cost variability is at the upper end of the anticipated range of expected costs at this level of resolution, but the refinements are expected to result in less variability for future refinements.

The refinements in the pond spillway structure accounted for almost 40 percent of the change in estimated cost. The mainstem ponds at South Boulder Road and Baseline Road now have concrete emergency spillways to address potential concerns from the State's Dam Safety Officer. The US-36 pond inlet control structure refinements resulted in some additional right-of-way acquisition, as well as earthwork and protection not originally included in the estimate. These modifications resulted in an additional 10 percent increase in cost.

A better definition of the environmental mitigation costs was possible during the refinement process. The refined design built upon the OSMP evaluations and incorporated refinements to address many of the concerns. However, it was not possible to completely avoid compensatory environmental mitigation. The estimated costs for property acquisition, largely to address the mitigation needs at the three ponds and the other improvements proposed as part of this alternative, account for about 30 percent of the change in the estimated implementation cost.

Refined Benefits

The refinements to the various plan elements did not result in any substantive changes to the estimated benefits. The average annual benefit expected to result from these improvements is estimated to be $75.9 million. Because the costs for this alternative have changed, the benefit-cost ratio is also changed. The revised value is now 1.58.

Other Considerations

The refinement of the alternatives allowed the team to better understand the various project impacts and to assess the proposed plans against a broad range of considerations.

Impacts to city-regulated wetlands and PMJM Critical Habitat will need to be mitigated at a ratio of two to one. It is expected that acceptable mitigation will replace the type and function of the lost areas. There will be over 30 acres impacted by the Distributed Regional Detention plan, representing 2.5 percent of the total area of the State Natural Area. Impacts to PMJM and Ute Ladies' Tresses Orchid habitats are expected, as are impacts to Northern Leopard Frog habitat areas. These impacts were generally in the vicinity of mainstem embankments and along the improvements to the Viele Channel. The Distributed Regional Detention alternative plan has 16.9 acres and 29.7 acres of impact to the Critical Habitat Areas and Conservation Zone, respectively. A total of 17.3 acres of Northern Leopard Frog habitat are impacted. The project costs include the purchase of the Granite property or a similar parcel with the hope that this land can be used as mitigation for impacts to the Conservation Zone. It is believed that this area is already suitable for habitat and that, with minor enhancements; it could serve to replace any potential loss due to the implementation of the project.

Impacts to Open Space lands will include permanent improvements such as embankments, as well as temporary impacts that will be restored. The Distributed Regional Detention plan embankments will affect approximately 34.8 acres of Open Space lands.

Phasing Strategies

This alternative is also made up of three broad elements: Arapahoe Avenue detention; detention at US-36, South Boulder Road, and Baseline Road; and improvements within the West Valley. The overall plan implementation cost is about $48.1 million, making the implementation of the full alternative at one time improbable. The following presents an alternative implementation strategy.

Priority 1 – Local West Valley Improvements

The proposed improvements in the West Valley address a number of different issues and comprise several smaller elements, including local detention at Manhattan Middle School, Dry Creek No. 2 Ditch pipeline improvements, local detention at Baseline Road and Foothills Parkway, floodwall improvements along Baseline Road, and improvements to the Wellman Canal. These improvements in aggregate are expected to cost $9.6 million to implement and result in a benefit-cost ratio of 3.6. While this is a high benefit-cost ratio, the benefits are largely seen at lower frequency events when smaller flood flows are handled by the smaller-capacity local improvements. There is limited benefit during the 100-year flood and higher events.

Detention should be implemented early in the process to fully exploit the flow reduction realized through these facilities. Then, the flood control measures such as the pipeline improvements along Dry Creek No. 2 Ditch and along Baseline Road should be implemented to provide adequate conveyance of the remaining flows. The improvements to the other irrigation ditches are intended to prevent overflows and contain those flows in the original system. These can often be done independently of any other improvements and can be implemented as need or opportunities arise.

Priority 2 – Arapahoe Avenue Detention

The Arapahoe Avenue detention pond and associated downstream improvements provide considerable flood relief to those properties below Arapahoe Avenue. The improvements are estimated to cost $11.9 million and will result in a benefit-cost ratio of 1.3.

The floodplain reduction associated with these improvements remains relatively localized. The detention facility ponds water above Arapahoe Avenue onto Flatirons Golf Club property, controlling the discharge across Arapahoe Avenue and reducing widespread flooding downstream. The less frequent overtopping of Arapahoe Avenue reduces the threat to life and minimizes the disruption to traffic along Arapahoe Avenue.

Priority 3 – Detention at US-36, Baseline Road, and South Boulder Road

These three detention ponds, in combination, address the overtopping of US-36 but only have a benefit-cost ratio of 0.9, meaning that the $26.6 million investment does not provide a reduction in average annual flood damages by an equal amount. Moreover, these three ponds need to be constructed in unison to assure that the flood control benefits are realized and that no adverse impacts occur within the system.

This project element fulfills the defined purpose of the project (reduce the flood hazard due to US-36 overtopping in the West Valley) without the need for further investment. In doing so, the flood insurance burden associated with the South Boulder Creek 100-year flood for those properties in the West Valley is eliminated, and the real flood threat is reduced to that of locally generated runoff flooding. The elimination of the overtopping of US-36 means this important transportation corridor remains open.

The construction of three ponds, two of which have mainstem embankments, does require properly sized and constructed emergency spillways to assure that the potential of embankment failure is properly mitigated. The use of the distributed detention creates a greater impact to Open Space lands. These impacts are related to both the embankment and the upstream flow control structure. While alignments were adjusted to the extent possible, the site topography required encroachment. Mitigation would be required for this phase. .

Bear Canyon Creek Pipeline Alternative Refinements

The refinements to the Bear Canyon Creek Pipeline alternative focused primarily on the development of a more detailed strategy to capture overflows from US-36 and identification of areas where the proposed pipeline could be aligned to minimize impacts to properties and utilities.

Pipeline Alignment Refinement

A careful review of the proposed alignment of the Bear Canyon Creek Pipeline indicated that an alternative route would result in fewer right-of-way acquisition issues and would reduce the number of potential utility conflicts. The earlier alignment had followed the alignment for upgraded storm sewer lines identified in the Stormwater Master Plan. That alignment generally followed the lowest point of the floodplain from Apache Drive downstream to Baseline Road. The revised alignment takes the 114-inch-diameter line east to Thunderbird Road and then north (Figure 8-12, Bear Canyon Creek Pipeline, located in Appendix E). The revised alignment rejoins the original alignment at Baseline Road and follows that alignment to the outfall into Bear Canyon Creek just below Foothills Parkway and Colorado Avenue.

The mainstem pipeline and the lateral lines were sized based on the computed inlet capacity. In this way, the size of the pipelines was more closely aligned with the likely flow rates, rather than relying on the earlier assumption that all flow needed to be conveyed along the entire pipeline length. Pipeline sizes are also reported on Figure 8-13, Bear Canyon Creek Pipeline – Thunderbird Pipeline Alignment, located in Appendix E.

Inlet Location and Layout Refinement

The layout of the inlets necessary to capture the overflow of US-36 was refined. City of Boulder Type R inlets were selected rather than the combination inlets because of their smaller encroachment into the street surface. The chosen inlets have a slightly lower capacity but were deemed to be less disruptive to pedestrian and bicycle traffic through these residential areas. The inlet location was limited by the spread of the overtopping flows. The hydraulic capacity of the inlets also was limited by the depth of flow and the gradient of the streets.

The inlet layout intercepts the maximum amount of water possible before the overflows reach structures. Much of the frontage of Apache Drive west of Pima Court (approximately 300 feet) was committed to inlets to collect as much of the 1,250 cfs of overflow as possible (Figure 8-14, Bear Canyon Creek Pipeline Collection System, located in Appendix E). These are in areas where flooding is expected to be well in excess of 1 foot at the gutter flow line. As such, a simplified sizing methodology was employed that assumed the hydraulic performance would be similar to a sump inlet, with a single foot of head and a capacity of approximately 1.67 cfs per linear foot of opening. The estimated capacity included the City of Boulder required blockage. East of Pima Court along Apache Drive, the 130 feet of Type R inlets are assumed to have a capacity of approximately 0.80 cfs per linear foot of opening because the depth of flooding was slightly lower. These inlets capture about 100 cfs.

Another 380 feet of Type R inlets are proposed along both the east and west sides of Pima Court to capture additional flow not captured at Apache Drive. The street gradient down Pima Court is relatively flat, and the street section is not capable of conveying the full flow without considerable depth at the flow line. Once again, to simplify sizing, a capacity of 0.80 cfs per linear foot was assumed. The result is an assumed capture of an additional 300 cfs.

A final bank of Type 13 inlets (36 square feet) is located in the sump at the mouth of the drainage swale just off the driveway off Pima Court to capture an additional 40 cfs. These pick up a majority of the overflow, but additional inlets are required farther downstream near the intersections of Osage Drive and Qualla Drive with Thunderbird Drive. A review of the topography in the area suggests flows are likely to split. As such, it was concluded that approximately 300 feet of inlets would be provided along both roadways to capture the remaining overflows. The gradient along both streets as they approached Thunderbird Drive was approximately 0.6 percent resulting in an approximate capacity of 0.5 cfs per linear foot of opening.

The location and extent of these inlets is based on early estimates of the overflow and are likely to be refined if this alternative moves forward. During final design, other options to collect the overflow that reflect a more thorough understanding of the overflow characteristics can be explored.

The lateral pipelines conveying water from the inlets to the Bear Canyon Creek Pipeline were laid out to minimize potential utility impacts. The upstream end of the mainstem pipe at the overflow location of US-36 and Apache Drive provides a conveyance for the uppermost inlets, and the remaining inlets along Apache Drive can be discharged directly into the 114-inch-diameter pipeline. The inlets along Pima Court require the construction of a 72-inch-diameter lateral line. While a pipeline that follows the surface gradient would be preferable, the utility conflicts would have presented considerable challenges. It was therefore concluded that a pipeline from the inlets at the northeast end of Pima Court and from the Type 13 inlets to the Apache Drive pipeline would minimize utility conflicts. The length of the pipeline draining against the surface gradient is relatively short, approximately 200 feet, and does not create an abnormally deep pipeline.

West Valley Refinement

The facilities in the West Valley associated with this alternative differ from those in the other alternatives because of the US-36 overflow. The flow that crosses US-36 near the Park-n-Ride facility influences the New Anderson Ditch. The improvements proposed to convey the 720 cfs overflow were realigned to avoid utility corridors and to minimize easement acquisition costs (Figure 8-15, Bear Canyon Creek Pipeline - Dry Creek No. 2 Ditch Pipeline Alignment, Located in Appendix E). The increased flows captured by the pipeline discharge into the 90-inch-diameter pipeline along Dry Creek No. 2 Ditch. This pipeline alignment has been modified slightly to avoid known utilities and to minimize easement acquisition costs to the extent possible.

Arapahoe Avenue Detention Refinement

The refinements at Arapahoe Avenue are similar to those identified during the evaluation of the Regional Detention at US-36 alternative plan and are focused on one of the two outlet channels downstream of Arapahoe Avenue.

Cost Refinements

The refinement of the Bear Canyon Creek Pipeline alternative provided a much better understanding of the plan elements but resulted in a nominal change in the estimated plan implementation cost of approximately 1 percent to $46.8 million. The improvements proposed through the West Valley resulted in changes to the required property acquisition and operation and maintenance costs. The costs now reflect a pipeline rather than the originally proposed open channel. The capital cost of this facility is largely unchanged, but the required footprint for the construction and long-term maintenance now reflects the adjustments so that utility conflicts and single-family residential property acquisition costs are minimized. Annual operation and maintenance costs were updated.

The refined plan better describes the impacts to environmentally sensitive areas, and the cost of mitigation for those impacts is included in the estimated costs.

More right-of-way will be needed to accommodate future Arapahoe Avenue outfall channel construction. The new alignment also requires the enlargement of an existing channel that flows through city-designated wetland areas. The cost of mitigation for these impacts is now explicitly included in the cost estimate.

The estimated costs of this plan are summarized in Table 8-1 located in the Summary of Refined Alternatives section at the end of this Chapter.

Refined Benefits

The average annual benefit resulting from the refined improvements is estimated to be $58.0 million with a revised benefit-cost ratio of 1.24.

Other Considerations

The refinement of the alternatives allowed the team to better understand the various project impacts and to assess the proposed plans against a broad range of considerations.

The proposed alternatives were refined to minimize the impact to mature vegetation so that the long-standing character of the watershed was minimally impacted. The construction of the proposed improvements will have a significant local disruption. Large areas of residential neighborhoods will be disturbed during the construction of the inlets and pipelines. Final design and construction should include measures to assure that business and residential impacts are addressed. This may require temporary access, traffic control, or other measures.

Underground facilities like pipelines and culverts are generally designed with an expected service life in excess of 50 years. However, periodic inspections are necessary to confirm that there are not unexpected failures and that no debris or sediment has been deposited that might affect hydraulic capacity. Surface facilities such as curb opening inlets require more frequent cleaning and debris clearing so that their full capacity remains consistent with the design assumptions. Some debris clogging has been incorporated into the hydraulic assumptions in accordance with the city's drainage guidelines. A schedule of routine maintenance should be developed and enforced to assure correct function of these important hydraulic features.

Phasing Strategies

This alternative is also made up of three broad elements: the Arapahoe Avenue detention, inlets and pipeline improvements to capture US-36 overflows, and the improvements within the West Valley. The overall plan implementation cost of $46.8 million makes the implementation of the full alternative at one time improbable. The following presents an alternative implementation strategy.

Priority 1 – Local West Valley Improvements

The proposed improvements in the West Valley address a number of different issues and comprise several smaller elements, including Dry Creek No. 2 Ditch pipeline improvements and improvements to the New Anderson Ditch and the Wellman Canals. These improvements in aggregate are expected to cost $12.8 million to implement and result in a benefit-cost ratio of 1.2. In contrast to the improvements for the other alternative plans, these will be a necessary element to address the 100-year floodplain as they capture and collect some of the overflow of US-36 but, without the proposed pipeline improvements, do not fully address the 100-year floodplain threat.

The improvements to the Wellman Canal can be done independently as funds and interest permits. These improvements address the potential overflow of water in the ditch and do not rely on improvements in the systems above or below.

The improvements to the New Anderson Ditch and to Dry Creek No. 2 Ditch are intended to be complementary. The New Anderson Ditch improvements collect overflows of US-36 and convey them to Dry Creek No. 2 Ditch, which must be enlarged to convey the increased flow safely. Pipeline improvements should be implemented by first providing downstream conveyance capacity before proceeding upstream to increase collection capacity.

Priority 2 – Arapahoe Avenue Detention

The Arapahoe Avenue detention pond and associated downstream improvements are recommended as the next highest priority. The improvements are estimated to cost $11.9 million and will result in a benefit-cost ratio of 1.3. The implementation of this alternative has a direct benefit to the 100-year floodplain at a lower cost than the other elements that reduce the floodplain footprint and it has the added benefit of reducing the frequency of overtopping of Arapahoe Avenue.

Priority 3 – Bear Canyon Creek Pipeline

Construction of the pipeline and inlet systems has an estimated implementation cost of $22.2 million and a 1.2 benefit-cost ratio. The benefits are considerable but the cost is too high to be considered a top priority. However, it does meet the primary project objective of addressing the 100-year flood threat in the West Valley by capturing and controlling the overflow of US-36.

Summary of the Refined Alternatives

The five alternatives that were evaluated more carefully during the refinement process present a range of different approaches to address the flood threat along South Boulder Creek. They vary in cost and, in some cases, the level of protection provided, but they offer city staff, the various stakeholders, and city Boards and Council an array of options from which to choose. Table 8-1, Alternative Plan Summary, presents the costs, benefits, and a brief description of the plan.

TABLE 8-1

Alternative Plan Summary

Alternative	Total Implementation Cost ($millions)	Present Worth of Benefits ($millions)	Benefit-to-Cost Ratio	Plan Elements	Significant Issues
Status Quo	$0.0	$0.0	0.00	Maintains systems and processes as they are today.	Provides no enhanced flood protection anywhere in the system.
High Hazard Mitigation	$0.14	$0.0	0.00	Includes grading changes to eliminate structures from the designated High Hazard Zone.	Provides no substantive enhancement to level of flood protection anywhere in the system.
Regional Detention at US-36	$36.2	$77.3	2.14	Detention pond at US-36 reduces US-36 overtopping threat and eliminates 100-year floodplain within West Valley. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Meets defined objective of eliminating 100-year floodplain in West Valley. Some encroachment of facilities onto city-owned Open Space lands.
Distributed Regional Detention	$48.1	$75.9	1.58	Three detention ponds reduce US-36 overtopping threat to eliminate 100-year floodplain within West Valley and mitigate increased mainstem flows in channel downstream of US-36. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Meets defined objective of eliminating 100-year floodplain in West Valley. Significant encroachment of facilities onto Open Space lands and into identified habitat areas.
Bear Canyon Creek Pipeline	$46.8	$58.0	1.24	Inlets and pipelines to capture and convey overflows from US-36. Local improvements in West Valley and at Arapahoe Avenue address local flood issues.	Generally addresses the objective of eliminating 100-year floodplain in West Valley with the exception of Apache Drive. Nominal impact to Open Space lands and identified habitat areas. Significant disruption to residential properties is expected during construction.

IX. Engineers Recommended Plan

Introduction

The Engineer's Recommended Plan to address the identified flooding issues within the South Boulder Creek study area is the Regional Detention at US 36 Plan (Recommended Plan). This Recommended Plan is offered for consideration based on feedback from public meetings, project stakeholders, staff input and preliminary discussions with WRAB and OSMP staff.

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

The Engineer's Recommended Plan has been presented to city staff and the active stakeholder's group. Earlier comments by the group have been addressed and refinements incorporated into the Recommended Plan as necessary. The Recommended Plan, once reviewed and approved by city Staff, is now ready to be presented to WRAB. It is also expected that a presentation will be made to the public and the OSMP Board that describes the planning process and the elements of the Recommended Plan. In addition to these presentations, the team intends to present the Recommended Plan to city Council for formal consideration and adoption. Once the plan has been adopted, city Public Works Utilities staff will incorporate the recommendations into a long term Capital Improvements Program.

Plan Description

The recommended plan prevents the overtopping of US-36 and provides 100-year protection from the overtopping flows of South Boulder Creek to downstream properties in the West Valley. The detention pond combines excavation and fill to produce a configuration that minimizes the impacts to Open Space land and the University of Colorado (CU) South Campus and to minimize the potential visual impact by integrating the detention berm into existing roadway improvements in the area. To address the flood threat downstream of US-36, both storage and conveyance improvements are proposed through the West Valley and along the alignment of Dry Creek No. 2 Ditch. The storage components of the downstream improvements allow for locally generated flood peaks to be attenuated and results in a decrease in the size of the required infrastructure downstream. The combination of conveyance improvements along both drainage corridors reduces the amount of overland flooding that poses a threat once floodwaters leave either corridor. These improvements will generally consist of enlarged channels or pipes to minimize the potential for residual flooding in the area. Figure 9-1, Regional Detention at US-36 presents the proposed improvements. The elements of the plan and their respective costs are presented in tabular form in Table 9-1, Regional Detention at US-36.

The Recommended Plan does create some unavoidable impacts to areas defined by the city as environmentally sensitive. This includes city regulated wetlands and some areas that may include critical habitat. These impacts have not been addressed explicitly; however plan costs include compensatory mitigation at a ratio of two to one for every impacted acre.

US-36 Detention Pond

This storage area is the cornerstone of this alternative. This pond captures water from South Boulder Creek's west overbank and stores it, thereby eliminating the overtopping of US 36 during the 100-year event. The pond provides 560 AF of storage. The layout of the pond does create some impacts to city Open Space lands and requires the inundation of a portion of the property owned by CU for their future South Campus expansion. The plan alignment and layout of the embankment minimizes the impacts to these areas to the extent possible. Figure 9-2, US-36 Detention, presents a more detailed view of this facility.

Arapahoe Avenue Detention

The improvements at Arapahoe Avenue take advantage of the Flatirons Golf Club golf course to provide 58 AF of storage that reduces the impact to downstream industrial and commercial properties. Two outlet channels below Arapahoe Avenue are proposed to convey attenuated flows downstream to outfalls of adequate capacity. There are some unavoidable impacts to city-regulated wetlands that will require mitigation and the alternative requires the acquisition of some private property. Figure 9-3, Arapahoe Avenue Detention, shows the details of this element.

Improvements in the West Valley

The facilities in the West Valley associated with this alternative are intended to capture and convey locally generated inflows. The 25 AF detention at Manhattan Middle School is a key element of the plan capturing locally generated flows that can be controlled and discharged to the existing downstream infrastructure to help minimize or eliminate additional downstream system improvements. Figure 9-4, Manhattan Middle School Detention presents a conceptual alayout of this detention facility. Similarly, the existing detention at the intersection of Baseline Road and Foothills Parkway will be required to be enlarged to 9 AF to take full advantage of the capacity of the downstream system. Infrastructure enhancements to the channel and an increase to the concrete retaining wall along Baseline Road east of Foothills Parkway are included in the plan. Improvements are identified to the New Anderson Ditch to accommodate the additional flow that results from the increased head generated by the storage above US-36. A wasteway structure for the Wellman Canal, east of Foothills Parkway, will be required to discharge flood flows from Bear Canyon Creek back into the Bear Canyon Creek historic channel. This improvement is required to help eliminate flood flows exceeding the capacity of the Wellman Canal from causing additional flood hazards through the West Valley. Improvements along Dry Creek No. 2 Ditch include a 72-inch diameter pipe to convey the 420 cfs that flows down the Dry Creek No. 2 Ditch corridor. Alignments of all the facilities take full advantage of existing publically owned lands and minimize the number of individual property owners impacted and impacts to known utility lines. Figure 9-5, West Valley Improvements, summarizes the layout of the improvements proposed in the West Valley.

Other Features of the Recommended Plan

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

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

Basis for Selection

The primary objective defined at the outset of the study was to reduce the impact on properties within the West Valley that were within the designated 100-year floodplain. The Recommended Plan does that effectively, removing approximately 700 structures from the floodplain. Moreover, the Recommended Plan addresses important life safety concerns by eliminating the high hazard zone from many areas of the West Valley and reducing the threat of overtopping of many major city and state arterials, including US-36, South Boulder Road, Baseline Road and Arapahoe Avenue. This reduced hazard provides much better access for emergency vehicles during flood events.

The Recommended Plan has the highest benefit-cost ratio among the plans evaluated. This means that the city's investment in infrastructure to address flooding generates a favorable return by reducing the average annual flood damages by a factor of 2 over the investment cost.

The Recommended Plan does create some unavoidable impacts to areas designated by the city as having important environmental value. However, the elements of the Recommended Plan have been laid out to minimize these impacts and costs have been included in implementation estimates to provide compensatory mitigation for those impacts that were unavoidable. Similarly, the Recommended Plan requires the acquisition of some property so that the identified facilities can be constructed. The implementation estimate includes costs for the purchase of the necessary right-of-way and easements at fair market prices.

TABLE 9-1

Regional Detention at US-36

Element	Construction Cost ($Millions)	Mobilization ($Millions)	Stormwater Management / Erosion Control ($Millions)	Utility Relocation ($Millions)	Subtotal ($Millions)	Easement / Right of Way ($Millions)	Engineering ($Millions)	Legal / Administration ($Millions)	Contract Admin / Construction Management ($Millions)	Contingency ($Millions)	Total Capital Cost ($Millions)	Present Worth of O & M Cost ($Millions)	Total Implementation Cost ($Millions)
US-36 Detention Pond	$5.55	$0.28	$0.28	$0.03	$6.14	$1.80	$0.92	$0.31	$0.61	$2.78	$12.56	$0.77	$13.34
Improvements to the New Anderson Ditch	$0.66	$0.03	$0.03	$0.12	$0.85	$0.00	$0.13	$0.04	$0.09	$0.30	$1.40	$0.01	$1.41
Dry Creek Ditch No. 2 Pipeline Improvements	$1.25	$0.06	$0.06	$0.37	$1.75	$1.06	$0.26	$0.09	$0.18	$0.98	$4.32	$0.00	$4.32
Local Detention at Manhattan Middle School	$1.21	$0.06	$0.06	$0.01	$1.34	$0.31	$0.20	$0.07	$0.13	$0.58	$2.63	$0.03	$2.67
Local Detention at Baseline Road/Foothills Parkway	$1.10	$0.06	$0.06	$0.02	$1.23	$0.00	$0.19	$0.06	$0.12	$0.43	$2.04	$0.01	$2.05
Wall Enhancements at Baseline Road	$0.04	$0.002	$0.002	$0.00	$0.04	$0.22	$0.01	$0.002	$0.004	$0.09	$0.37	$0.00	$0.37
Improvements to Wellman Canal	$0.04	$0.002	$0.002	$0.00	$0.05	$0.00	$0.01	$0.002	$0.005	$0.02	$0.08	$0.08	$0.16
Arapahoe Avenue Detention Pond	$3.87	$0.19	$0.19	$0.14	$4.39	$3.37	$0.66	$0.22	$0.44	$2.72	$11.80	$0.10	$11.90
Total	**$13.73**	**$0.69**	**$0.69**	**$0.70**	**$15.81**	**$6.76**	**$2.37**	**$0.79**	**$1.58**	**$7.90**	**$35.21**	**$1.00**	**$36.21**

Implementation Strategies

Implementation of the Recommended Plan will require the resolution of some issues that were outside the scope of the current Mitigation Planning Study. The study team believes these issues are not insurmountable and did not impose any fatal flaws on the Recommended Plan. Coordination with the University on the layout of the facilities associated with the US-36 Detention should continue. The proposed layout reflects early discussions but some further refinement may be desirable to optimize the use of the area while minimizing impacts from the berm. Similar refinements may be possible to further reduce the impact to Open Space lands. Working in concert with both CU and OSMP may provide further refinements that further optimize the use of the space.

Implementation of the full plan will be costly. Projects of this nature are typically funded by a combination of sources, including Stormwater Utility fees, city general funds, UDFCD funds and available local and Federal grants. Once adopted, the elements of the Recommended Plan can be integrated into the city's broader storm drainage improvements capital improvement plans and strategies defined to fund implementation. While developing funding and prioritization strategies for the implementation of the Recommended Plan, other potential funding sources such as FEMA and CWCB Pre-Disaster Mitigation Grants can be explored.

Phasing of the elements of the Recommended Plan provides an opportunity to distribute the cost of implementation over a longer time and allows the community to reap benefits from the individual aspects of the improvements without full plan implementation. The elements of the Recommended Plan do allow for a phased implementation. The discussion below summarizes a possible Recommended Plan phased implementation recommendation.

Priority 1 – US-36 detention:

US-36 Detention is the recommended first element to be implemented. This project element fulfils the defined purpose of the project (reduce the flood hazard due to US-36 overtopping in the West Valley) without the need for further investment. In doing so, the flood insurance burden associated with the South Boulder Creek 100-year flood for those properties in the West Valley is eliminated and the real flood threat reduced to that of locally generated runoff flooding. . The proposed US-36 Detention facility has an element benefit-cost ratio of approximately 2.0 and an approximate capital cost of $13.3 million.

Priority 2 – Local West Valley Improvements

The proposed improvements in the West Valley address a number of different issues and are comprised of several smaller elements, including: local detention at Manhattan Middle School, Dry Creek No. 2 Ditch pipeline improvements, local detention at Baseline Road and Foothills Parkway, floodwall improvements along Baseline Road, improvements to the New Anderson Ditch and improvements to the Wellman Canal. Implementation of these elements should generally follow broad drainage facility implementation guidance. That is, detention can and should be implemented early in the process to fully exploit the flow reduction realized through these facilities. Then the flood control measures such as the pipeline improvements along Dry Creek No. 2 Ditch and along Baseline Road should be implemented to provide adequate conveyance of the remaining flows. The improvements to the other irrigation ditches are intended to prevent overflows and contain those flows in the original system. These can often be done independently of any other improvements and can be implemented as need or opportunities arise. In aggregate, these improvements are expected to cost $11.0 million to implement and result in a benefit-cost ratio of 3.2.

Priority 3 – Arapahoe Avenue Detention

The Arapahoe Avenue detention pond and associated downstream improvements provide considerable flood relief to those properties below Arapahoe Avenue however; the floodplain reduction associated with these improvements is relatively localized making this the last of the suggested implementation priorities. The improvements are estimated to cost $11.9 million and will result in a benefit-cost ratio of 1.3.

Water Quality Impacts

In general terms, detention pond storage will have beneficial water quality impacts by providing an opportunity for pollutant carrying sediments to drop out of suspension. These improvements are likely to be realized by the inclusion of stormwater quality outlet facilities in the design of the ponds. While not explicitly addressed during this planning level, these improvements are part of local community regulations and are implicit in any proposed plans.

Any other improvements that capture and collect stormwater before they reach areas of potential contamination are also likely to have a beneficial water quality impact. Such is the case for improvements that reduce the floodplain and the potential exposure of Critical Facilities housing hazardous chemicals to flood flows.

The mitigation of impacts to wetlands and other environmentally sensitive areas at a ratio in excess of one to one will have a beneficial impact on water quality. These mitigation areas, provided they are within the South Boulder Creek watershed, will promote infiltration and filtration of floodwaters and will store and attenuate flood flows while helping to expand and reestablish wetlands throughout the corridor. All these functions tend to reduce the generation and transport of contaminants.

The Recommended Plan incorporates by reference all of the existing city programs that support the enhancement of stormwater quality. These include the various elements required by the city's NPDES Stormwater Discharge Permit. These measures assure control of erosion from construction sites, provide public education and outreach programs and address other sources of pollution that may enter stormwater.

Operations and Maintenance

Most of the facilities proposed in the Recommended Plan are passive and will not require manual operation during flood events. All control structures, spillways, inlets and outlets function without any external user control. Operations during a flood will be limited to observations and inspections to monitor system performance. All of the facilities have been laid out so that permanent access is included to facilitate operations and maintenance. These access paths are typically located above the level of frequent flooding but may not be useable during periods of extreme flooding. This is not the case with the detention pond embankments, each of which has some access, generally from an adjacent roadway, that can be used for access during extreme events.

All of the facilities will require routine maintenance to assure correct performance and longevity. For earthen embankments and open channels, this means periodic inspections, routine mowing of grasses, removal of trees and shrubs, and debris pickup. By performing this maintenance, conformance with design assumptions can be expected. It is expected that a majority of the facilities will be re-vegetated with native grasses not requiring supplemental irrigation.

Underground facilities like pipelines and culverts are generally designed with an expected service life in excess of 50 years. However, periodic inspections are necessary to confirm that there are no unexpected failures and that no debris or sediment has been deposited that might affect hydraulic capacity.

Surface facilities such as curb opening inlets require more frequent cleaning and debris clearing so that their full capacity remains consistent with the design assumptions. Some debris clogging has been incorporated into the hydraulic assumptions in accordance with the city's drainage guidelines. A schedule of routine maintenance should be developed and enforced to assure correct function of these important hydraulic features.

An operations and maintenance plan may be required for areas designated as compensatory wetlands or environmental mitigation. In most cases, the use of newly constructed wetlands and habitat areas for compensatory mitigation requires a long-term commitment to operations to assure that facilities actually reestablish lost function and are sustainable. An operations plan should be developed and included in the design of any compensatory mitigation areas.

Environmental and Safety Assessment

Environmental Impacts

The impacts to environmentally sensitive areas were evaluated and refined to avoid impacts to the extent practicable but in some cases impacts are unavoidable. Most of the improvements proposed avoid the main channel of South Boulder Creek that represents the majority of the South Boulder Creek State natural area, OSMP owned property, PMJM Habitat and riparian and wetlands vegetation . A summary of environmental impacts from the Engineers Recommended alternative can be found in Table 9-2, Recommended Plan Environmental Impact.

The location of facilities onto Open Space lands was the topic of considerable debate. During the public meetings, opinions were expressed favoring placement of facilities on Open Space lands rather than on private properties but others suggested that any activities on Open Space would be contradictory to the expressed purpose for those lands. During these discussions representatives from OSMP also indicated that a majority of OSMP lands also reside in the South Boulder Creek State Natural Area that was identified as area of potential impact.

The impacts to Open Space lands will include permanent improvements such as embankments as well as temporary impacts that will be restored. The embankment footprint will result in a loss of function for that area. In general, the remaining areas of impact will not result in a loss of function for Open Space lands near the proposed facilities. These are largely floodplain lands that are subject to periodic inundation. The use of these lands for flood storage is a compatible use and the nature of the storage will be similar to the current periodic inundation that exists for relatively short durations on the Open Space lands. The nature of inundation is likely to be slightly longer and deeper but the improvements will not result in any permanent pools or standing water. The Recommended Plan will affect approximately 5.5 acres of Open Space land. In addition, the South Boulder Creek State Natural Area will have 5.4 acres of this area are impacted much of which is located on OSMP lands. The costs presented for the alternatives assume the purchase of these lands or compensation to OSMP through the purchase of comparable land.

Impacts to threatened and endangered species are expected as part of the Recommended Plan. The two species noted are the Preble's Meadow Jumping Mouse and the Ute Ladies' Tresses Orchid. The Northern Leopard Frog is also a species of interest and impacts to those habitat areas have been identified. While every effort was made to reduce the impact of construction footprints and of permanent facilities, some impacts were unavoidable. Impacts to the Preble's Meadows Jumping Mouse habitat areas were determined based on a comparison of the berm footprint including a 15-foot wide maintenance access area to the U.S. Fish and Wildlife Service Critical Habitat Area as well as the city's Conservation Zone. The proposed improvements affect about 1.6 acres of Critical Habitat Area and 7.1 acres of Conservation Zone. A majority of this impact is on Open Space land but some falls on the US-36 right of way. For the purpose of defining the impacts to the Northern Leopard Frog, it was assumed their habitat is coincident with the OSMP defined wetland areas. This impact totals 3.6 acres for the Recommended Plan. The habitat area for the Ute Ladies' Tresses Orchid is known to extend throughout the area. However, the sensitivity of this plant precluded OSMP from sharing a precise definition of the habitat area. Because of this, assumptions regarding the extent of impact needed to be made. It was concluded that the impact would be defined as the full extent of the permanent impact to Open Space land (5.5 acres).

The Recommended Plan includes costs to mitigate the impacts through the development of compensatory mitigation or the purchase of land. Compensatory mitigation is proposed based on the impact of the permanent improvements to defined wetland areas and Critical Habitat areas. Purchase of land to replace lost areas within the Conservation Zone is also included in the project costs. The project costs include the purchase of the Granite property or a similar parcel with the hope that this land can be used as mitigation for impacts to the Conservation Zone. It is believed that this area is already suitable for habitat and that with minor enhancements could serve to replace any potential loss due to the implementation of the project.

In addition, all disturbed lands will be restored to the extent possible. It is also hoped that some impacted areas can be enhanced during the restoration process. This may include the establishment of more suitable vegetation types or densities, grading changes to create more suitable habitat and the inclusion of other features that may promote wetland enhancements.

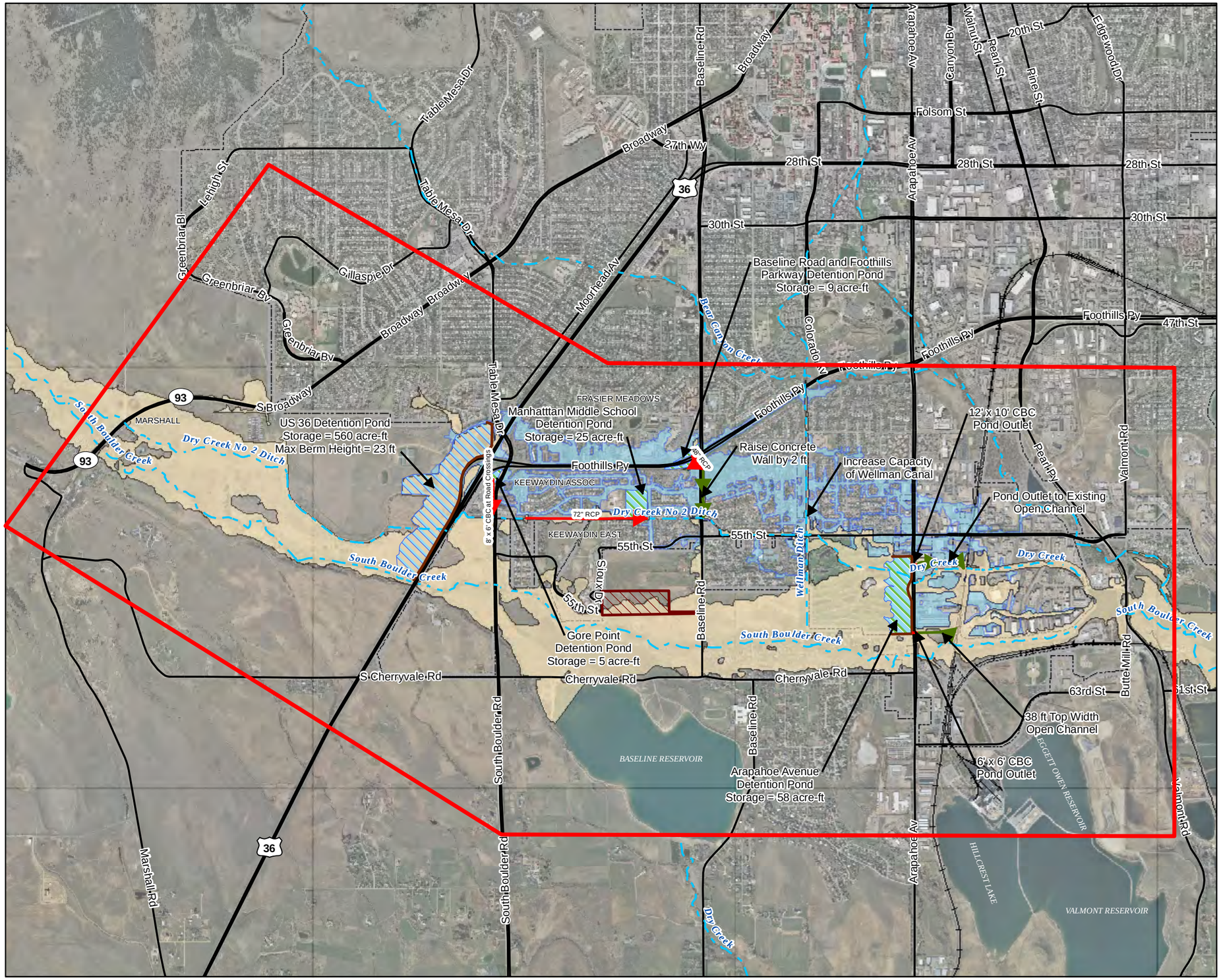
TABLE 9-2
Recommended Plan Environmental Impacts

Category	Impacted Area (Acres)
OSMP Lands	5.5
South Boulder Creek Natural Area Lands	5.4
PMJM Critical Habitat Area	1.6
PMJM Conservation Area	7.1
Northern Leopard Frog Habitat	3.6
Ute Ladies Tresses Orchid Habitat	5.5
Regulatory Wetlands	0.0
Riparian Vegetation	3.6
Agricultural Lands	5.2 (Grazing Lands Only)

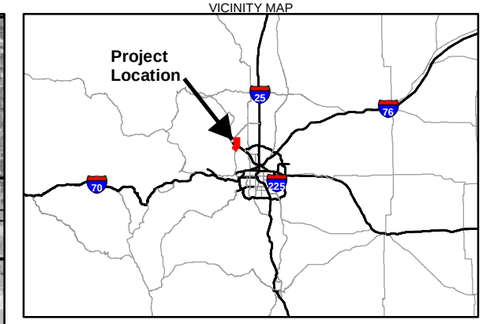
Safety

Reducing the potential overtopping of US-36 provides a significant safety benefit to the city of Boulder by maintaining corridors for emergency vehicle access and avenues for safe egress from flooded areas. The broader safety benefit of the regional storage at US-36 is the reduction or elimination of the floodplain through the West Valley, and eliminating or minimizing those areas of the High Hazard Zone that encroach onto residential properties.

In addition to controlling the 100-year flood, the proposed improvements also reduce the threat of flooding from more frequent events. The West Valley improvements and those proposed near Arapahoe Avenue capture preventing the uncontrolled overtopping of Arapahoe Avenue and discharge flow through two outfalls to the Dry Creek No. 2 flood channel reducing the frequency and extent of nuisance flooding.



VICINITY MAP



LEGEND

Conveyance Alignment

Category

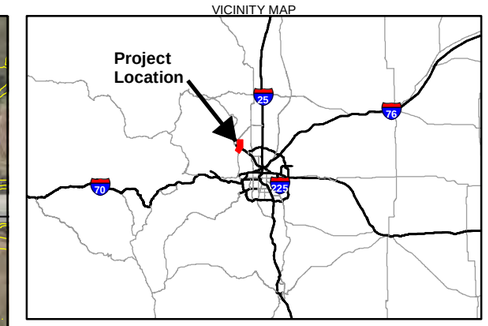
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Embankment
- Streams, Creeks and Ditches
- Detention at US 36
- Local Detention
- Granite Property
- Post Project Floodplain
- Existing Floodplain

Notes:
1. Study Area

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 9-1
Regional Detention at US-36
South Boulder Creek Flood Mitigation Report

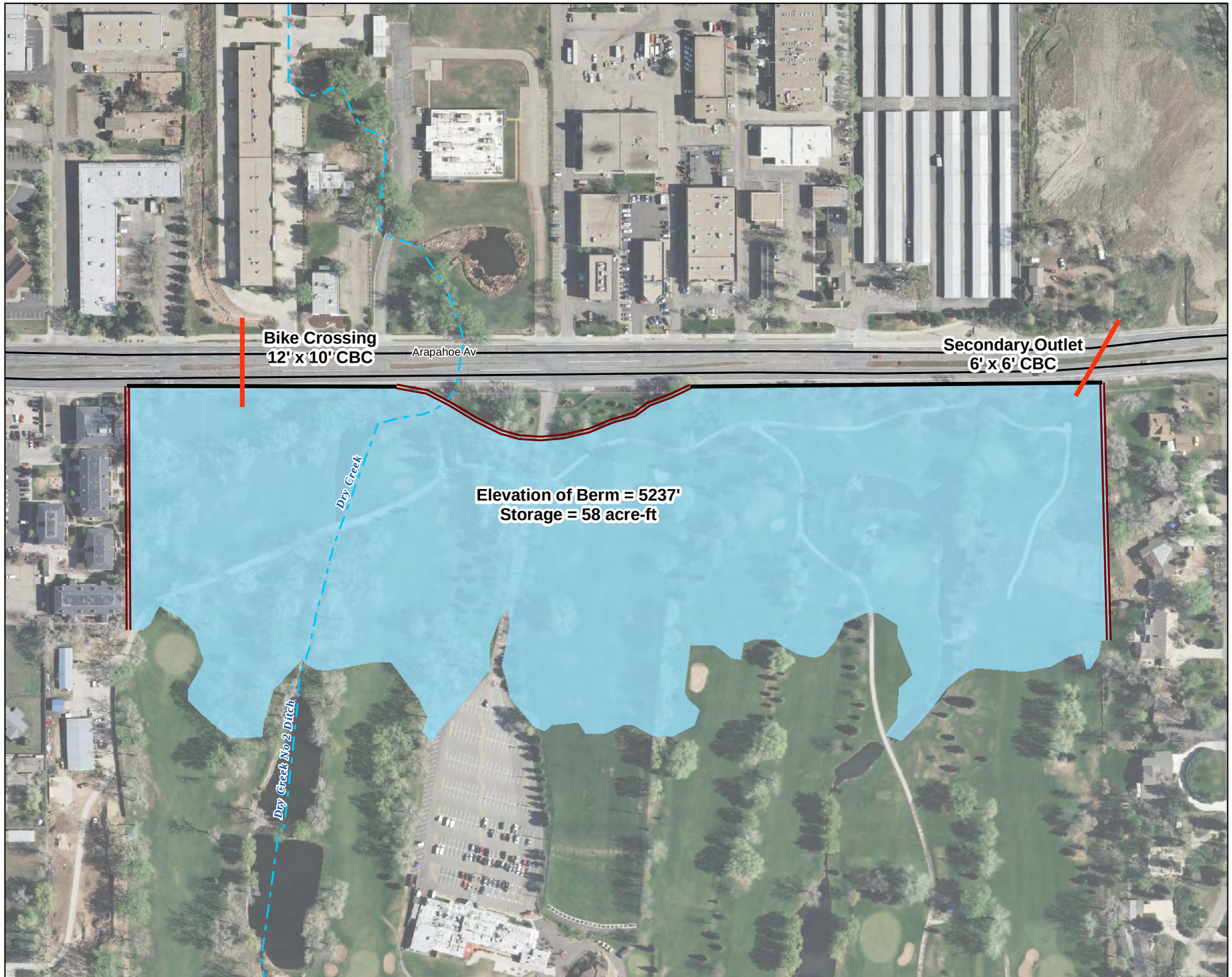


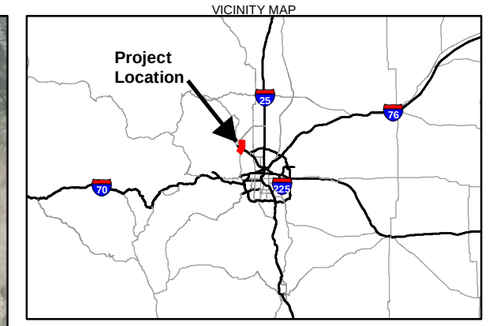
LEGEND
- Streams, Creeks and Ditches
- Main Road
- Proposed Grading at US-36
- Existing 5' Contours
- Detention Pond Limits
- Fill by Others

N

0 400 800 1,200
Feet

FIGURE 9-2
US-36 Detention
South Boulder Creek Flood Mitigation Report





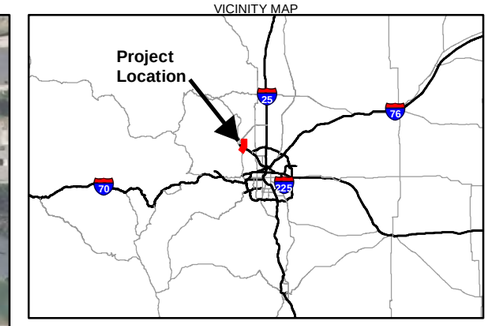
LEGEND
- Detention Pond Limits
- Culvert Outlet
- Berm
- Wall
- Streams, Creeks and Ditches

N

0 100 200 400 Feet

FIGURE 9-3
Arapahoe Avenue Detention
South Boulder Creek Flood Mitigation Report

VICINITY MAP



LEGEND

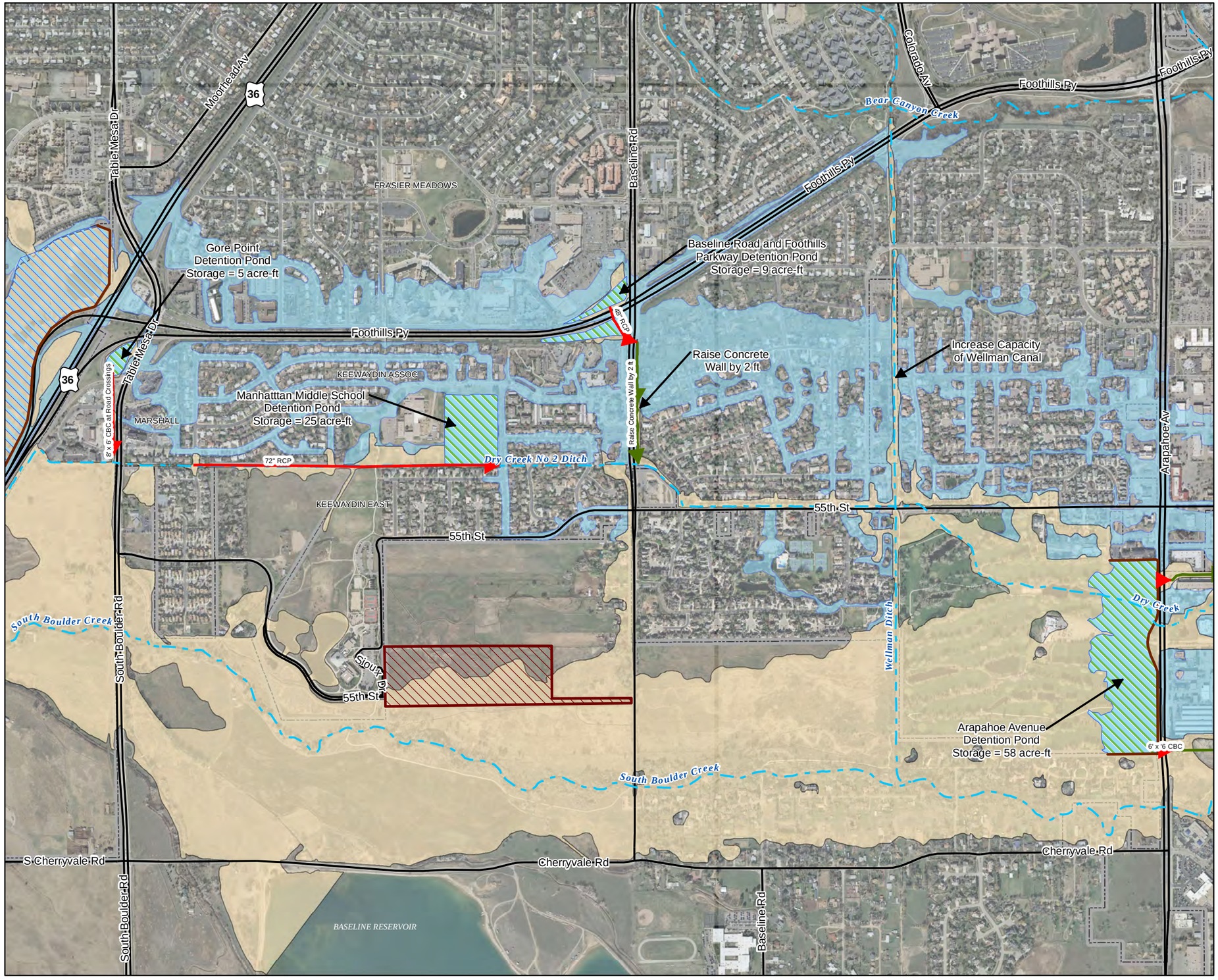
Depth (ft)

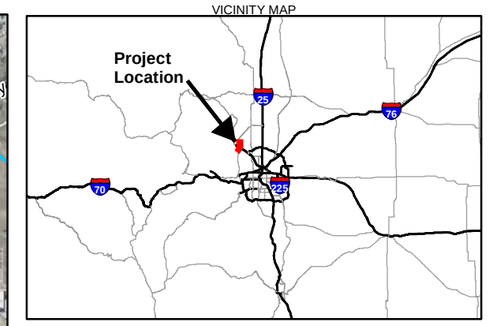
- 6 - 7
- 5 - 6
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1
- Pond Outlet
- Streams, Creeks and Ditches

N

0 50 100 200 300 Feet

FIGURE 9-4
Manhattan Middle School Detention
South Boulder Creek Flood Mitigation Report





LEGEND

Conveyance Alignment

Category

- Open Channel Improvement
- Pipeline/Culvert Improvement
- Embankment
- Streams, Creeks and Ditches
- Detention at US 36
- Local Detention
- Granite Property
- Post Project Floodplain
- Existing Floodplain

N

0 500 1,000 1,500
Feet

FIGURE 9-5
West Valley Improvements
South Boulder Creek Flood Mitigation Report

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X. References

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APPENDIX A TABLE OF CONTENTS

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Appendix A
Project Correspondence

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Appendix A-1
Project Meeting Minutes

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South Boulder Creek Progress Teleconference Meeting No. 1 Notes

ATTENDEES: Kurt Bauer/City of Boulder, Bob Harberg/City of Boulder, Shea Thomas/UDFCD, Mark Glidden/CH2M HILL, Alan Turner/CH2M HILL, Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: February 11, 2010

Status of the Model

The 8-meter model did not accurately portray the median barrier at US Highway 36. The median barrier is important to the flooding characteristics so the bathymetry file is being updated to include the median barrier. The 8-meter and cutoff model will be re-run with the new bathymetry.

Alan Taylor's Involvement

During the meeting, it was reiterated that Alan Taylor's involvement will be most beneficial to the project early in the process of the alternatives development to utilize his knowledge of the study area and problem areas. The project team will include Alan on all email correspondence and get him involved in the bi-weekly calls.

Review and Discussion of Preliminary Screening Matrix

As a result of the initial project workshop, the matrix was modified in the following ways:

- The lined flood channels solution was combined with the existing channel improvements.
- Detention as a possible solution was divided into local and regional detention.
- Acquisition of flood prone properties was determined to be limited to high hazard zones.
- Flood proofing of critical facilities was separated from non-structural methods.

Reach 1:

- Development of a naturalistic channel was removed due to right-of-way constraints.
- Installation of underground conduits is mostly viable except at the Viele Ditch where there are T&E species.
- Limited structural improvements are generally viable except where the floodplain is broad.
- Existing channel improvements are generally feasible except at the business park where there are regulated wetlands and at the Viele Ditch where there are T&E species.
    - The city is required to mitigate wetlands at a 2:1 ratio making it very hard to mitigate more than 1 acre of wetlands. Any wetland categorized as highly functioning is

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essentially untouchable. Kurt Bauer will send CH2M HILL the GIS layer of highly functioning wetlands.

- Regional detention considers detention upstream of US Highway 36.
- Local (Sub-Regional) detention considers detention downstream of US Highway 36 which is only possible in a few locations. Local detention may or may not be online and is designed to address specific flooding issues such as the C-2 loading points.
- Acquisition of flood prone properties will not be considered within this reach because no structures are within the high hazard zone.
- Non structural methods include not allowing owners to re-build in the floodplain, education, and a warning system. For non-critical facilities, it will be up to the owner to perform flood proofing. This solution will be included as part of the baseline alternative.
- Flow diversion is defined as redirecting the flow, probably towards the mainstem of South Boulder Creek. This solution was previously called relocation of channels. Flow diversion can be open channel or an underground conduit.

Reach 2:

The discussion of the matrix for Reach 2 was similar to the discussion of the matrix for Reach 1.

In an email, Chuck Howe suggested raising the berm at Foothills Parkway to reduce the flooding in the West Valley. CH2M HILL will respond to Chuck saying that this possible solution will be evaluated as part of the potential solutions matrix. Other possible solutions will only be added to the matrix if they do not fit specifically into a category on the existing matrix.

Comments on the Matrix

The project team must be sure to include all the potential solutions presented in the Taggart study as potential solutions in the matrix. An on-stream reservoir would be included in the regional detention solution. By not going into specifics in defining the potential solutions at this time, it allows the project team to look at a variety of different alternatives within each potential solution. CH2M HILL will use the MIKE FLOOD cutoff model to determine the maximum volume of water that must be stored to eliminate the overtopping of US Highway 36 and flooding in the West Valley from the mainstem of South Boulder Creek.

Initial Public Meeting/ Open House

The preliminary plan is to hold the first public meeting on Wednesday, March 3rd 2010 from 5:30 – 7:30 PM in the East Boulder Recreation Center. The public meeting will begin with a short presentation (~1/2 hour) followed by an open house style setting with three or four stations.

Presentation of Costing Information for Preliminary Screening of Alternatives

The screening process will be used to determine how potential alternative elements compare to each other. The project team will use general cost approaches such as assigning detention ponds a cost per acre-ft or assigning culverts a cost per square foot per linear foot. A cost benefit analysis will be performed for each included in the screening process.

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For Fourmile Canyon Creek, Love and Associates and Icon Engineering produced vastly different benefit-cost ratios. For South Boulder Creek, the FEMA BCA model will be used. CH2M HILL will look into the depth-damage curves from the FEMA BCA model and compare to the depth-damage curves used damage estimates from the risk assessment. If the depth-damage curves are substantially different, an adjustment factor may be used.

Flood Threat from Lower Basin Storm

During the kick off meeting, there were questions as to whether the peak flow and maximum flooding extents seen in the West Valley come from a thunderstorm upstream over the mainstem of South Boulder Creek (South Boulder Creek floodplain study) or from a similar thunderstorm placed directly over the C-2 Basin (HDR XPSWMM Analysis). The results of the cutoff model will be compared with the HDR XPSWMM Analysis to determine the differences in the flooding extents in the West Valley between the two approaches. CH2M HILL will also compare the hydrographs at the C-2 loading points from the two approaches.

Discount Rate

FEMA requires a discount rate of 7% for flood mitigation projects to receive FEMA grant money. UDFCD typically uses a discount rate of around 3.5%. It was agreed upon that a discount rate of 7% would be used for this project.

Action Items

- Kurt Bauer will provide CH2M HILL with the highly functional wetlands GIS layer and a map of the siren coverage in the study area.
- The first public meeting will be scheduled for Wednesday, March 3rd from 5:30 – 7:30 PM in the East Boulder Recreation Center.
- Kurt Bauer will send CH2M HILL the correspondence between Icon Engineering and Love and Associates regarding the FEMA BCA model.
- CH2M HILL will look into the depth-damage curves from the FEMA BCA model and compare to the depth-damage curves used damage estimates from the risk assessment.
- CH2M HILL will compare the hydrographs at the C-2 loading points from the cutoff model with the hydrographs from the HDR XPSWMM Model.
- The project team will include a regional detention alternative that does not utilize the CU property in the alternatives analysis.
- Shea Thomas will send the project team the UDFCD Master Plan Cost Spreadsheet.
- CH2M HILL will continue working with Eric Fontenot at DHI to complete the cutoff model.

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SBC Flood Mitigation Study - Progress Teleconference #2 Meeting Notes

ATTENDEES:

Bob Harberg / City of Boulder	Consulting
Kurt Bauer / City of Boulder	Mark Glidden / CH2M HILL
Shea Thomas / UDFCD	Alan Taylor / CH2M HILL
Alan Taylor / Alan Taylor	Aaron Cook / CH2M HILL

FROM: CH2M HILL

DATE: February 23, 2010

Review of Past Meetings Actions Items

- CH2M HILL received the functional wetlands and siren coverage GIS layers form the City of Boulder
- The first public meeting has been scheduled for March 3, 2010 in the Flagstaff Room of the East Senior Center from 5:00 PM – 8:00 PM
- Kurt Bauer sent CH2M HILL correspondence between Icon Engineering and Love and Associates regarding the FEMA BCA model.
- CH2M HILL will look into the depth-damage curves from the FEMA BCA model and compare to the depth-damage curves used damage estimates from the risk assessment.
- CH2M HILL has reviewed the hydrology for the C2 basin loading between the SBC Study and the lower basin thunderstorm.
- The project team is looking into regional detention sites that do not utilize the CU property.
- Shea Thomas sent the project team the UDFCD Master Plan Cost Spreadsheet.
- The MikeFlood cutoff model is complete.

Review of Lower Basin Hydrology vs. SBC Hydrology for C2 Basin Loading

CH2M HILL presented a spreadsheet to the team showing the C2 sub-basin loadings from the MikeFlood Floodplain Study, the MikeFlood Lower Storm Center Analysis, and the HDR XPSWMM Analysis. For the MikeFlood Analysis, the sub-basin loading was extracted from the MikeFlood regulatory model. Only the peak flows in the C2 basin were available for the Lower Storm Center Analysis and the XPSWMM Model. The peak flow from the C2 basin was apportioned using the same ratio as in the MikeFlood Regulatory Model to determine the peak flow at each C2 sub-basin.

The project team is still looking for the 5-year peak flow rates from the City of Boulder Stormwater Master Plan for comparison.

After looking at the spreadsheet, the team decided infrastructure in the West Valley will be sized according to the peak flows from the MikeFlood Lower Storm Center Analysis. All

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damage estimates from the floodplain study are based on the results of the regulatory model so there may not be a direct comparison between the damage estimates from the floodplain study and the damage estimates for the flood mitigation study. The 500-year damage estimates from the floodplain study may approximate the 100-year peak flows in the lower storm center analysis.

Review of Cutoff Model Results

The cutoff model was presented to the project team as depth of flow versus time step. The sinks in the model were set up downstream of US Highway 36 to collect any overtopping flows. The cutoff model was set up to contain flows overtopping US Highway 36 and flows from the Viele Ditch and New Anderson Ditch. This model is mean to replicate storage upstream of US Highway 36 which would also store flows in the Viele Ditch and New Anderson Ditch.

The cutoff model shows that there are some localized flooding issues in the West Valley but storage upstream would control most of the damages in the West Valley. CH2M HILL will determine the volume of water that is being cutoff which will represent the volume of detention required upstream of US Highway 36 to prevent overtopping. This will be done by cutting transects in the MikeFlood model. It should be noted that the cutoff model includes the median barrier and additional storage will be required if the east bound lane of US Highway 36 cannot overtop.

For the public meeting, one or two screenshots from the cutoff model will be presented to show the maximum extents of flooding in the West Valley with no flow overtopping US Highway 36.

Updated Alternatives Matrix

CH2M HILL refined the previous matrix with additional details. The routine maintenance alternative was removed from the matrix as it will be included in all alternatives. The naturalistic channels alternative was also removed because it is not possible to place a naturalistic channel in the West Valley due to right-of-way constraints. CH2M HILL will send the updated matrix to the project team for review.

The project team looked specifically at the West Valley between US Highway 36 and Baseline Road. In this area, the Stormwater Master Plan recommends increasing the capacity of storm sewers and the City of Boulder would like the project team to include these recommendations. CH2M HILL will look into the Stormwater Master Plan to determine if a BCA was performed or if damage estimates are presented.

Public Meetings

For the public meeting, four GIS figures will be presented; Above US Highway 36, from US Highway 36 to Baseline Road, from Baseline Road to Arapahoe Avenue, and North of Arapahoe Avenue. During the public meeting, Alan Taylor, Mark Glidden, Alan Turner, and a representative from the City of Boulder will each be stationed at one board to answer questions from the public.

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Next Steps

Action Items

- CH2M HILL will review the correspondence between Icon Engineering and Love and Associates regarding the FEMA BCA model.
- CH2M HILL will look into the depth-damage curves from the FEMA BCA model and compare to the depth-damage curves used damage estimates from the risk assessment.
- The project team is looking for the 5-year peak flow rates from the City of Boulder Stormwater Master Plan for comparison.
- All infrastructure in the West Valley will be sized according to the results of the MikeFlood Lower Storm Center Analysis (Q_{peak} = 1100 cfs).
- CH2M HILL will determine the volume of water that is being cutoff which will represent the volume of detention required upstream of US Highway 36 to prevent overtopping. This will be done by cutting transects in the MikeFlood model.
- CH2M HILL will send the updated matrix to the project team for review.
- CH2M HILL will look into the City of Boulder Stormwater Master Plan to determine if a BCA was performed or if damage estimates are presented.
- CH2M HILL will send the four GIS figures to the project team for review.

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SBC Progress Meeting March 26, 2010

ATTENDEES: City of Boulder

FROM: CH2M HILL

DATE: April 7, 2010

Presentation of Alternatives

This meeting was conducted with Kurt Bauer from the City of Boulder and Alan Turner, Mark Glidden and Aaron Cook from CH2M HILL to discuss proposed South Boulder Creek Mitigation Plans, design hydrology and progress forward with the project. Four alternative drainage corridors were presented which were assembled from the element-screening matrix and generally followed the recommendations from the City of Boulders *Stormwater Master* Plan. The four corridors are described below.

1. Dry Creek No. 2 Ditch Alternative – This alternative uses Dry Creek No. 2 Ditch as the primary conveyance corridor for the drainage of flood waters from the West Valley (See Attached Figure **Upstream Storage Dry Creek No 2 Ditch Alternative**)
2. New Conveyance Alternative – This alternative adds additional major conveyance through the West Valley South of Baseline Road to Boulder Creek (See Attached Figure **Upstream Storage New Conveyance Alternative**)
3. Bear Canyon Creek Alternative – This alternative allows diversions of Wellman Ditch overflow as and overflows along Foothills Parkway to be diverted to Bear Canyon Creek (See Attached Figure **Upstream Storage Bear Canyon Creek Alternative**)
4. High Hazard Alternative – This alternative removes the two structures identified in the high hazard zone and utilizes pipes to remove these structures from the High Hazard Zone (See Attached Figure **High Hazard Alternative**)

These four general alternatives will be assessed for two separate conditions:

1. Detention Upstream of US-36
2. No Detention Upstream of US-36

and for the most conservative flow conditions between the following:

1. 10-year to the 500-year regulatory flows
2. 5-year to 100-year *Lower Storm Center Flow Analysis*

In addition to the above Kurt emphasized the need to locate a detention alternative outside of the CU property. Review of the topography and floodplain boundaries indicated that there could be a potential site for off line detention downstream of SH-93 and up stream of the CU Property on the left bank of South Boulder Creek. This detention site will utilize overflows and existing culverts under SH-93 to funnel overflows to the detention site until

the flows could be released back to South Boulder Creek. The project team is continuing to determine the feasibility of this option.

In addition to additional detention sites, a review of options along the mainstem were requested to be reviewed. To begin this process CH2M HILL will create a levee MIKE FLOOD model to determine the downstream effects of channelizing flow through US-36 downstream along the mainstem of South Boulder Creek. To accomplish this it will be assumed that the Existing CU Levee will be extended to US-36 to prevent overflows to the west. Currently this model is being reviewed by DHI for correctness.

Review of Future Progress

In order to understand how current work will be used in conjunction with future MIKE FLOOD runs a review of preferred alternatives to be reviewed was completed. The Best Alternatives to be modeled in MIKE FLOOD and included in detailed cost benefit analysis will include:

1. High Hazard Alternative that includes conveyance to remove homes from the High Hazard Zone
2. High Hazard Alternative that includes acquisition of the High Hazard Zone properties
3. Detention at the CU property with conveyance improvements through the West Valley
4. Detention at the outside the CU property with conveyance improvements through the West Valley
5. Conveyance through the West Valley assuming no detention and designed for the full South Boulder Creek overflows.
6. An alternative that includes conveyance through the West Valley for 10 – year to 100-year flow rates obtained fort the City of Boulder *Stormwater Masterplan.*
7. An alternative that includes improvements to the mainstem of South Boulder Creek to eliminate or minimize flooding through the West Valley.

The conveyance improvements will include the best plan chosen after an analysis of the alternatives from above.

Design Hydrology

A review of the memorandum of understanding regarding design flow rates. The discussion has lead to a review of the flowrates and an update of the memorandum of understanding. The memorandum will be revised and presented during the next progress meeting.

SBC Flood Mitigation Study - Progress Meeting #5 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M HILL

DATE: April 14, 2010

Presentation of Preliminary Alternatives and Drainage Corridors

High Hazard Alternative: Two options were considered for the high hazard alternative; (1) removing structures from the high hazard zone with improved conveyance and (2) purchasing structures in the high hazard zone. In the West Valley there are only two structures in the high hazard zone, both near the overflow of US-36 into the West Valley.

The goals of the high hazard alternative will not include removing all high hazard zones from the study area. The City of Boulder plans to use a flood warning system in place of removing all high hazard zones.

Critical Facilities: critical facilities are to include any facilities that have hazardous material on site, such as the chemical facility or gas stations, in addition the critical facilities already included in the alternative plans (schools, daycares, assisted living centers, etc.). Kurt Bauer will provide CH2M HILL with the City of Boulder GIS layer of critical facilities.

Alternative Alignments: Three possible alternative alignments for conveyance improvements within the West Valley have been established.

1) Dry Creek Ditch #2 Alignment – drive all flows to Dry Creek Ditch #2. Includes improvements at Arapahoe Avenue.

2) Bear Canyon Creek Alignment – divert flows along Foothills Parkway to Bear Canyon Creek. Removes some pressure from Dry Creek Ditch #2. Improvements at Arapahoe Avenue are still needed. May be some issues with trans-basin diversion.

3) New Conveyance Alignment – divert flow through a new conveyance between Foothills Parkway and 55th Street. Removes some pressure from Dry Creek Ditch #2. Improvements at Arapahoe Avenue are still needed. Possible impacts to private property.

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Review of Field Visit with Kurt Bauer and Alan Taylor on April 8, 2010

Kurt Bauer is interested in storage within the West Valley. Possible locations for storage include Manhattan Middle School and other parks. Kurt also expressed interest in preventing overflows of South Boulder Road, Baseline Road, and Arapahoe Avenue by creating a 3′ to 4′ structural barrier that would allow water to pond upstream of the road. The structural barrier could be used to separate bike trails from vehicle traffic. At Arapahoe Avenue, an underpass could be constructed for bike traffic and flood conveyance.

Constraints determined during the field visit:

- Due to right of way constraints, the pipe north of Manhattan Middle School from Tenino Avenue to Baseline Road cannot be modified.
- Dry Creek Ditch #2 between Baseline Road and the Wellman Canal cannot be modified due to the number of trees around the ditch.

Report of Design Hydrology and Hydrology Memorandum

The hydrology Technical Memorandum has been finalized and includes peak flows at C2 loading points. The peak flows that will be used to size infrastructure are a combination of flows loaded directly at the C2 loading point plus the flows loaded at loading points upstream. This approach is similar to a typical master planning approach where a one-dimensional model is used.

Report on Alternate Detention Sites

Two alternatives were evaluated for detention upstream of US-36 without impacting the CU South Property.

Option 1

- Between CU property and US 93
- Excavate South Boulder Creek overbank to allow overflows to reach detention pond
- Dry Creek Ditch #2 would also contribute to storage in detention pond
- Approximately 320 acre-ft
- Downstream depth is approximately 15 feet, embankment depth is approximately 18 feet
- Positives to option 1; no water rights issues
- Negatives to option 1; impacts to open space and private property

Option 2

- Between CU property and US 93, similar to option 1
- Excavate South Boulder Creek overbank to allow overflows to reach detention pond
- Dry Creek Ditch #2 would also contribute to storage in detention pond
- Approximately 320 acre-ft
- Downstream depth is approximately 8 feet, embankment depth is approximately 11 feet
- More extensive berm on the west side
- Positives to option 1; lower embankment height, no impacts to private property

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- Negatives to option 1; impacts to open space, would need low flow channel for decreed flows in Dry Creek Ditch #2.

Both options are off-channel detention alternatives and do not require a Probable Maximum Flood (PMF) spillway. It was suggested during the meeting that the west berm be along Marshall Road and that the north berm could be aligned with an existing trail to minimize the disturbance to open space.

Schedule

The Best Alternative Workshop was tentatively scheduled for April 26th, but has been moved to the afternoon of May 11th at the 13th Street Conference Room in Boulder. Over the next two weeks, CH2M HILL will size facilities to create the best alternative plans based on the three alignments presented above. CH2M HILL will then evaluate each plan using a benefit-cost analysis. The seven best alternative plans are tentatively as follows:

1. High Hazard Alternative that includes conveyance to remove homes from the High Hazard Zone
2. High Hazard Alternative that includes acquisition of properties within the High Hazard Zone
3. Detention at the CU property with conveyance improvements through the West Valley
4. Detention outside of the CU property with conveyance improvements through the West Valley
5. Conveyance through the West Valley assuming no detention and designed for full South Boulder Creek overflows
6. An alternative that includes conveyance through the West Valley for 10- year to 100-year flow rates obtained from the City of Boulder *Stormwater Master Plan*
7. An alternative that includes improvements to the mainstem of South Boulder Creek to eliminate or minimize flooding through the West Valley.

The project team is still evaluating alternatives and each alternative can include a number of different options. For example, alternative 4 may include multiple storage options, multiple storage volumes, and different alignments for improvements through the West Valley.

This best alternative plan information will be presented at the next bi-weekly teleconference. This will allow the project team to have a discussion and provide input on the best alternative plans. The information will then be presented to stakeholders at the workshop on May 11th.

Damage Estimates

The BCA uses a discharge/damage relationship. The South Boulder Creek Risk Analysis used a depth/damage relationship at each structure. CH2M HILL is still working on the damage estimates.

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SBC Flood Mitigation Study - Progress Meeting #6 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M HILL

DATE: April 28, 2010

Action Items from the Progress Meeting

- CH2M Hill will send out a packet of information to the project team and stakeholders prior to Workshop #3. This packet will include an agenda for the meeting, alternatives figures, and a summary of work to date.
- CH2M Hill will modify the figure showing detention south of the CU property to include City of Boulder open space and an outlet to the pond.
- The City of Boulder will meet with Don D'Amico, Open Space, to discuss the detention pond south of the CU property on City of Boulder open space.
- CH2M Hill will run a MIKE FLOOD Model to see if the detention pond south of the CU property prevents overtopping of US 36.
- CH2M Hill will size an outlet to the detention pond at Arapahoe Avenue if the culvert outlet does not include a bike path crossing.
- The City of Boulder will engage a representative from Manhattan Middle School to discuss the possibility of a local detention pond at the school.

Water Resources Advisory Board (WRAB) Meeting

CH2M Hill is scoped to attend an initial and final WRAB meeting and will assist Kurt Bauer in creating figures and providing the advisory board with the necessary information.

Review Outline for Workshop #3

After reviewing the draft outline, it was suggested that some of the information be sent to the stakeholders and project team prior to the workshop. Items to be sent out prior to the workshop include figures and a summary of work to date. Some attendees at the workshop such as representatives from WRAB, City of Boulder Open Space, and CU may not be interested in the technical aspects of how the project team arrived at the best plans. The project team will determine the best way to package the information so it isn't too technical and the package will be sent around May 5th to give the stakeholders a few days to review.

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Review highlights of preferred plans

Storage south of CU property:

In the current configuration, the detention pond south of the CU property is approximately 300 acre-ft, has a 12' berm, and is mostly on City of Boulder Open Space. Some excavation would be required. CH2M Hill will run a MIKE FLOOD model to determine if this detention pond would prevent the US 36 overtopping during the 100-year flood. Kurt Bauer suggested that an outlet to the pond and open space be added to the figure showing the detention pond. Representatives from the City of Boulder will discuss this alternative with Don D'Amico, City of Boulder Open Space.

Storage at Arapahoe Avenue:

The City of Boulder Parks department is ok with the concept of storage at Arapahoe Avenue on the golf course. CH2M Hill will determine the size required for the outlet culvert if it is not used as a bike path crossing. Kurt Bauer will coordinate with the Parks department regarding the underpass outlet to the pond. The channel north of Arapahoe is private property and would require a drainage easement.

Local Storage in the West Valley:

The maximum storage available at Manhattan Middle School is approximately 60 acre-ft. The City of Boulder will involve a representative from the school to discuss this alternative. CH2M Hill will create a figure showing detention at Manhattan Middle School similar to the figure showing the detention pond south of the CU property. At the middle school, there is the possibility to have different levels of inundation where different fields are inundated at different flood levels.

The maximum storage available at the Foothills Parkway and Baseline Road intersection is approximately 9 acre-ft. The maximum storage available at Baseline Road is approximately 37 acre-ft but a berm would have to be constructed on open space to make this alternative work.

In an alternative that include storage upstream of US 36 to prevent overtopping and local storage in the West Valley, most of the infrastructure along Dry Creek and in the West Valley does not need to be improved.

Status of Cost Benefit Analysis

CH2M Hill has replicated HRD's damage estimate and reviewed UDFCD's criteria for cost benefit analysis. CH2M Hill will present the results of the cost benefit analysis at the workshop.

Hydrology

Hydrology will be discussed with Kurt Bauer in greater detail outside of this progress meeting. Below is a summary of flows that will be evaluated for improvements in the West Valley:

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- Regulatory Model Flows – determined from the MIKE FLOOD model in which overtopping of US 36 occurs. Large pipes through the West Valley are required to convey the 100-year Regulatory Model Flows.
- Lower Storm Center Flows – the 100-year peak flows from the Lower Storm Center analysis are greater than the 10-, 25-, and 50-year peak flows from the Regulatory Model.
- Stormwater Master Plan Flows – the 5-year peak flows from the Stormwater Master Plan are larger than the 10-year peak flows from the Regulatory Model because the Stormwater Master Plan thunderstorm was centered over the West Valley where as the thunderstorm for the Regulatory Model was centered upstream over the South Boulder Creek mainstem. The 5-year peak flows from the Stormwater Master Plan represent the lowest values that will be evaluated.

Levee Model

CH2M Hill successfully ran a levee model in MIKE Flood. The levee to prevent overtopping of US 36 causes an increase in depth of approximately 0.1 meters for most of the South Boulder Creek mainstem north of US 36, although larger increases in depth are seen at some locations such as downstream of Arapahoe Avenue. The outlet to Leggett Reservoir overflows in the levee model. It was pointed out during the meeting that an increase in high hazard zones is likely for this alternative.

Next Steps

CH2M Hill and Kurt Bauer will meet on April 30 to discuss the hydrology, alternatives, cost benefit analysis, and workshop #3 agenda in more detail. Workshop #3 is schedule for May 11. The project team may decide to cancel the progress meeting schedule for May 12.

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SBC Flood Mitigation Study - Progress Meeting #7 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M HILL

DATE: May 26, 2010

Action Items from the Progress Meeting

- CH2M Hill will develop a conceptual sketch showing a revised detention pond at Marshall Road. This pond will not require excavating more than 5 feet and will not require a berm greater than 10 feet.
- Alan Turner will send an updated schedule to the project team.

Review of Detention Alternatives Upstream of US-36

The City of Boulder asked CH2M Hill to evaluate two alternatives for regional detention upstream of US-36. Specifically, CH2M Hill was asked to evaluate storage at the gravel pits south of the CU property and at a property adjacent to Marshall Road. Neither of these parcels is located on the City of Boulder open space land.

Storage at Gravel Pits

To prevent overtopping of US-36 with storage upstream of US-36, approximately 500 acre-feet of storage is required. The gravel pit parcel is approximately 25 acres in area and is located south of the CU property. Because the total area of the parcel is relatively small, the depth of storage required is approximately 30 feet. This pond would be filled from Dry Creek Ditch No. 2 and outlet via a gravity pipe to South Boulder Creek. Due to high groundwater in the area, the pond would most likely be constructed by excavating between 5 and 10 feet and constructing a berm between 20 and 25 feet.

Storage at Marshall Road

The parcel at Marshall Road is approximately 23 acres and requires a storage depth of between 30 and 35 feet to store the 500 acre-feet required to prevent overtopping of US-36. This pond would be filled from Dry Creek Ditch No. 2 and overflows from South Boulder Creek. The pond could outlet to Dry Creek Ditch No. 2 or South Boulder Creek. Similar to the pond alternative at the gravel pits, this pond would most likely be constructed by excavating between 5 and 10 feet and constructing a berm between 25 and 30 feet to prevent groundwater issues and allow it to drain via gravity flow.

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The City of Boulder requested that CH2M Hill evaluate a variation of the storage at Marshall Road that extends partially onto City of Boulder open space. The project team agreed that it would not be possible to construct a 500 acre-foot detention pond with either excavating or constructing a berm on City of Boulder open space, although representatives from open space have stated that excavation or construction of a berm on open space would not be permitted. The City of Boulder suggested that the maximum excavation for this variation be 5 feet and the maximum berm height be 10 feet. This pond would be approximately double the area of the parcel adjacent to Marshall Road. CH2M Hill will develop a conceptual sketch showing the revised location of the storage pond at Marshall Road. Expanding the Marshall Road detention pond may also protect the trailer park located just east of Marshall Road.

The project team agreed that the Marshall Road and gravel pit detention alternatives are not feasible in the current configurations. These alternatives will no longer be considered in the alternatives analysis.

CU Detention

Kurt Bauer, Mark Glidden, and Alan Turner met with Jeff Lipton from CU to discuss the CU detention option. Jeff stated that CU is willing to be flexible with the design of their property but any plan must maintain the developable footprint and the access road to the property is a constraint. CH2M Hill has identified a new alternative for CU storage which moves the storage to the east side of the property and builds up the rest of the land on the property to remove it from the floodplain. The existing levee would be removed and an embankment would be built up along the west side of the detention pond to match the elevation of the access road.

In the MIKE FLOOD Model, the Table Mesa Pond stores flow from the Table Mesa loading points as well as overflows from the Viele Channel. This pond is still inundated in the new CU detention alternative. The Table Mesa Pond can't be drained via gravity flow to the New Anderson Ditch because the pond is at a lower elevation than the ditch resulting in dead storage in the pond. It may be possible to drain the pond to Viele Channel near South Boulder Creek via gravity flow.

FEMA BCA Benefit Cost Analysis Update

Alan Turner and Kurt Bauer met with representatives from FEMA and determined that we can use the FEMA BCA software without flow rates. The HAZUS model will be used and the approach will be similar to the approach taken by HDR.

Modeling 7 Best Alternatives

CH2M Hill is in the process of modeling the 7 best alternatives in MIKE FLOOD. CH2M Hill is running the detention alternatives and only experiencing a few minor issues. Eric Fontenot/DHI is helping to solve some of these minor issues. By looking at the intermediate results files, it is apparent within a day or so whether a detention pond model will work or not, saving some time from the 3 days it takes to run the full regulatory model.

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Next Steps

- Alan Turner will send an updated schedule to the project team.
- Kurt Bauer will set up a meeting with FEMA either the first or second week of June.
- The City of Boulder will meet with the representatives from open space to discuss the new pond configurations.
- The City of Boulder will schedule a meeting with Jeff Lipton/CU to discuss outstanding issues.
- The City of Boulder is scheduled to present the South Boulder Creek Master Plan progress to the Water Resources Advisory Board (WRAB) on June 21, 2010. The materials to be presented are due to the WRAB on June 11, 2010 and to Bob Harberg and Annie Noble for review prior to June 11, 2010.
- CH2M Hill will continue to run MIKE FLOOD models including the south of CU detention model.
- Kurt Bauer will attempt to contact a representative from Manhattan Middle School to discuss detention at the school.

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SBC Flood Mitigation Study - Progress Meeting #8 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M HILL

DATE: June 9, 2010

Review of Storage Options above CU

The newest option for storage for storage south of CU uses as much private property as possible with as limited impact to open space as possible. The maximum berm height is 10 feet and the maximum excavation in the pond is 5 feet. The 10 foot berm height does not include the 3 feet required for the spillway. This detention pond alternative provides approximately 420 acre-ft of storage and covers approximately 38 acres, 11.5 of which are located on City of Boulder open space. The pond outlets to Dry Creek through a 6′ x 4′ concrete box culvert and to South Boulder Creek through 5 – 7′ x 5′ concrete box culverts. This pond is a peak shaving pond which is why the outlet to South Boulder Creek is so large. The pond fills from Highway 93 overflows and the pond is placed at a location that is already in the floodplain. This detention pond has limited impact to wetlands, does not impact Boulder County Critical habitat, but does impact three private parcels which would have to be purchased to construct the pond.

Kurt Bauer will meet with Don D'Amico to discuss this concept for storage south of CU. In this meeting, Kurt will reiterate that we can include additional wetland areas within the pond and that the City of Boulder will gain approximately 25 acres of open space if this pond is constructed.

Modeling 7 Best Alternatives

The MIKE FLOOD modeling is working as expected with a few minor modifications to the plans presented at the last workshop. CH2M Hill has successfully modeled the detention pond at Arapahoe Avenue alternative, the CU storage alternative, the high hazard alternative, the and is working on the other alternatives. The number of MIKE FLOOD models that can be modeled concurrently limits the modeling effort. CH2M Hill will meet with Kurt Bauer and Alan Taylor next week to discuss the results of the modeling effort.

FEMA BCA Benefit Cost Analysis Update

Kurt Bauer and Alan Turner met with FEMA and the Colorado Department of Emergency Management (CDEM) to discuss the benefit cost analysis used by HDR for the floodplain

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mapping study. Both FEMA and CDEM agreed that the project team can proceed with the same procedure as was used by HDR. Alan Turner will document the benefit cost analysis procedure in a technical memorandum and send to the project team.

PDM Grant

The CDEM is interested in the City of Boulder submitting for a PDM grant this year, specifically for the detention pond at Flatirons Golf Course/ Arapahoe Avenue. CDEM has agreed to split the cost to check the first floor elevations throughout the West Valley. The first floor elevations were originally surveyed via a window survey by HDR. CDEM did not specify how many structures need to be surveyed to confirm that the window survey is accurate.

Schedule

The recommended plan workshop will be moved back by approximately one month to around July 28, 2010. This will allow CH2M Hill to complete the modeling and BCA analysis prior to the workshop. The City of Boulder agrees that this is a good idea.

CH2M Hill will not be attending the WRAB meeting. This WRAB meeting is an internal update for WRAB members and CH2M Hill will attend the first of two WRAB meetings in late August or early September.

Next Steps

- CH2M Hill will coordinate a meeting with Jeff Lipton (CU) to discuss the CU detention alternative.
- Kurt Bauer will meet with Don D'Amico (City of Boulder Open Space) to discuss the south of CU detention alternative.
- Kurt Bauer will meet with representatives from Boulder Valley School District to discuss the detention pond at Manhattan Middle School.
- Kurt Bauer, Alan Taylor, and CH2M Hill will meet next week to discuss the results of the modeling effort.

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SBC Flood Mitigation Study - Progress Meeting #9 Notes

ATTENDEES: Kurt Bauer/City of Boulder, Bob Harberg/City of Boulder, Shea Thomas/UDFCD, Alan Taylor/Alan Taylor Consulting, Mark Glidden/CH2M HILL, Alan Turner/CH2M HILL, Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: June 23, 2010

Land Acquisition Costs

The project team agreed that the land acquisition costs are as follows:

- Detention Ponds - $36,000/ acre
- Drainage Easements for Pipelines – 0.5 * Land Cost/SF
- Drainage Easements for Open Channels – 0.9 * Land Cost/SF

The land acquisition costs for detention ponds may be modified when more information is gathered from stakeholders such as CU and Boulder Valley School District.

The following table shows approximate land values in Boulder. This information was provided by the City of Boulder.

TABLE 1
Approximate Land Value Costs for Boulder

Zone Code	Description	$/SF
AG	Agricultural	0.8
PU	Public	19
RB	Regional Business	180
CB	Community Business	39
HD	High Density Residential and Mobile Home	50
MD	Medium and Mixed Density Residential	36
LD	Low Density and Rural Residential	22
IND	Industrial	15

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Review of BCA

CH2M Hill has reviewed both the United States Army Corps of Engineers (USACE) and HAZUS curves. The curves are similar and CH2M Hill will proceed with using the HAZUS curves for damage estimates to be consistent with the work performed by HDR.

The assessed structure values are currently approximately 15% higher than the assessed structure value presented by HDR in 2007. CH2M Hill will use the same procedure as HDR with the new assessed structure values.

Modeling Progress

CH2M Hill is currently approximately 85% complete with the MIKE FLOOD Modeling and running 3 models concurrently. CH2M Hill will create a PDF of the resulting floodplain for the CU detention pond with local detention in the West Valley alternative to share with the project team. Some of the alternatives have included minor modifications from the plans presented in the last workshop but nothing significant.

WRAB Meeting

Kurt Bauer presented to WRAB last week and did not receive a lot of direction from the WRAB representatives. Representatives from WRAB wanted a list of the critical facilities proposed for flood proofing in the high hazard/critical facilities alternative and this list was provided by CH2M Hill. Only three members of WRAB were present at the meeting.

Flow Rates

In the West Valley, the only known local basin peak flows are the 5-year peak flow from the stormwater master plan and the 100-year peak flow at the confluence of Dry Creek Ditch No. 2 with South Boulder Creek. In order to recommend improvements for local basin peak flows, the project team needs to have a better idea of the peak flows caused by the local basin storm. In addition, the FEMA BCA only applies to the regulatory peak flow rates and damages for the local basin peak flows are unknown. The project team agrees that the scope of this project is to address the regulatory peak flows but that the project team as well as the City of Boulder must acknowledge the peak flows from the local basin storm.

The project team may agree to evaluate the local basin peak flows using either the standard UDFCD procedure or by moving the South Boulder Creek storm over the C2 B basin.

The project team will develop a phasing plan for the final recommended plan and CH2M Hill will evaluate the cost to benefit ratio for single elements such as the CU detention pond and the detention pond at Arapahoe Avenue for phasing purposes.

Next Steps

Kurt Bauer, Mark Glidden, and Alan Turner will meet with Jeff Lipton (CU) to discuss the CU detention alternative on June 24th at 9:00 AM.

Kurt Bauer left two messages for Don D'Amico (City of Boulder Open Space) to discuss the south of CU detention alternative. Kurt will try to contact Don again.

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Kurt Bauer met with representative from Boulder Valley School District to discuss the Manhattan Middle School detention pond. Boulder Valley School District gave the go ahead to continue with this part of the plan.

Alan Turner and Alan Taylor will meet to discuss the best way to contact the ditch companies regarding additional storage at Baseline Reservoir.

The next workshop is scheduled for July 28th, 2010. CH2M Hill will discuss whether or not all the information needed for the next workshop will be ready by this date.

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SBC Flood Mitigation Study - Progress Meeting #10 Notes

ATTENDEES: Kurt Bauer/City of Boulder, Annie Noble/City of Boulder, Shea Thomas/UDFCD, Alan Turner/CH2M HILL, Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: July 7, 2010

Review of Meetings

Meeting with CU

Kurt Bauer, Mark Glidden, and Alan Turner met with Jeff Lipton from CU. Jeff is generally ok with the CU detention pond alternative but would like the project team to look into a few items. Jeff would like the project team to look into a pond which includes a berm along the northern edge of the Table Mesa Pond. Jeff also wants to know the total area of the pond on CU property, the total area of the Table Mesa Pond, and a proposed layout for the recreational fields' configuration within the pond area.

Jeff thought that the $36,000 per acre for land acquisition costs was too low for the CU South Campus property. It was agreed upon that the project team would assume the cost for land acquisition would match the undeveloped agricultural cost provided by the City of Boulder for all areas that are not proposed building sites. For proposed building sites, the project team should assume $19 per square foot for land acquisition costs.

Meeting with Open Space

Kurt Bauer met with Don D'Amico from City of Boulder Open Space Department to discuss the latest version of the detention pond south of CU. Don made the following recommendations:

1. Minimize the impact of the berm on Open Space Property.
2. Look into using the properties adjacent to the detention pond between Marshall Road and South Foothills Parkway.
3. Look into using weirs/spillways as the outlet to the pond instead of culverts outlets.

Update on Detention Alternatives for Open Space

CH2M HILL created a revised pond that minimizes the impact to open space and utilizes the adjacent properties between Marshall Road and South Foothills Parkway. The revised pond layout also includes a weir/spillway outfall to South Boulder Creek but the culvert outfalls at Dry Creek Ditch No. 2 and the other irrigation ditch through the pond must

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remain as culverts to convey the decreed flows in the ditches. Grading is necessary at the culvert outfalls.

The main section of the pond has approximately at 350 acre-foot capacity and the pond section between Marshall Road and South Foothills Parkway has approximately a 70 acre-ft capacity. The main pond has a berm height of 12 feet which becomes 15 feet with the spillway. The berm height includes a combination of cut and fill. The small pond invert is 3 feet higher than the main pond so that the small pond drains to the main pond. Approximately 15 feet of excavation is needed in the southern most section of the small pond.

This revised alternative for detention south of CU has not been input into the MIKE FLOOD model but it is expected that limited improvements to the CU property are necessary with this alternative. A small berm along the Viele Channel is still required to prevent flows from reaching the Table Mesa pond. When water reaches the Table Mesa Pond, overtopping of US 36 occurs almost immediately.

Review of Progress on Recommended Plan Workshop

CH2M Hill is running four MIKE FLOOD models concurrently. The results from the MIKE FLOOD models are being evaluated to determine the benefit-cost analysis for each alternative. It is expected that the MIKE FLOOD models and the benefit cost analysis will be complete within the next couple of weeks.

The Levee/ Mainstem Flow Containment alternative is currently being run in MIKE FLOOD. Two alternatives are being evaluated for the Levee/ Mainstem Flow Containment alternative designed to prevent overtopping of US 36 by forcing more flow to the South Boulder Creek mainstem and eventually into Baseline Reservoir. The first alternative is to lower Cherryvale Road which should allow more water to overtop the road into Baseline Reservoir. The second alternative is to increase the capacity of the New Anderson Ditch which conveys flow to Baseline Reservoir. This section of the New Anderson Ditch is located on City of Boulder Open Space so the City of Boulder Open Space Department may have issues with this alternative. The ditch company will also have to be consulted to discuss this alternative. At least one diversion structure along the New Anderson Ditch would have to be modified if the capacity of the New Anderson Ditch is increased.

For the public meeting process, the project team will have to be careful when discussing the Levee/ Mainstem Flow Containment alternative. The project team should not present this alternative as a levee which protects the CU South Campus property, which may cause issues the public.

Hogan/Pancost Property

The Hogan/Pancost Property, located south and east of the East Boulder Community Park, is scheduled for development. At the first public meeting, a number of questions or comments were directly related to the Hogan/Pancost property. It is expected that this property will be topic of discussion with the public at the next public meeting. The public recommended regional detention for this property but the City of Boulder Development Review Team said that regional detention would not work in this area. The recommended plan for this flood mitigation study may include local detention at Manhattan Middle

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School, located just north of the Hogan/Pancost property. The recommended improvements along Dry Creek Ditch No. 2 for the Hogan/Pancost development are not the same as the recommended plan for any of the best alternative plans for the flood mitigation study but the project team will continue along the same path independent of the recommendations from the development plan.

Next Steps

Alan Taylor and Alan Turner will set up a meeting with Baseline Reservoir to discuss the possibility of storing more water in the reservoir in the Levee/ Mainstem Flow Containment alternative.

Alan Taylor and Alan Turner will set up a meeting with the ditch companies to discuss the possibility of enlarging the New Anderson Ditch to carry more water to Baseline Reservoir.

The Recommended Plan Workshop is scheduled for August 11, 2010. The project team may have an intermediate meeting to discuss what information will be presented at this workshop and how to best present this information.

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SBC Flood Mitigation Study - Progress Meeting #11 Notes

ATTENDEES: Kurt Bauer/City of Boulder, Bob Harberg/City of Boulder, Shea Thomas/UDFCD, Alan Taylor/Alan Taylor Cons, Alan Turner/CH2M HILL, Mark Glidden/CH2M HILL

FROM: CH2M HILL

DATE: July 21, 2010

Review of Revised Regional Pond Design

CU Alternatives

Alan Turner described the two concepts and reviewed the summary TM. Concept 1 excludes the Viele Pond from the main channel flow storage. When costs were computed, the cost of the land occupied by the Viele Pond was included. Bob noted this is already a committed ponding area and the land costs should not be assigned to this project. The memo will be revised to eliminate the land cost for this area and to describe the assumptions used in developing the cost estimate.

Concept 2 includes the area of the Viele Pond to help control main channel overflows. The elevation of the embankment is lower, but the berm height is greater because of the revised alignment. The note identifying the spillway location misrepresents the actual spillway location. The spillway will be located along the east end of the embankment to allow overflows to go back to the main channel and not across the west valley. The embankment may also be somewhat exaggerated since improvements to the interchange with Table Mesa Drive could result in a new ramp that could also function as a part of the embankment.

A few comments were offered related to the memo. Figure 3 should include a note that mentions that the ball fields would be subject to flooding and that refinements would probably be necessary during final design. Also, Bob requested an estimate of the volume of cut and fill that would be required to create the developable areas. If this had a significant impact on the cost of the alternatives, these should be understood.

South Regional Park

The concept developed earlier has been refined to reflect feedback from Open Space. The new layout provides about 420 AF of storage using the two areas identified. There is still a need for pipes to allow ditch flows to pass without interruption but the large box culverts have been replaced with a weir to control flows. The embankment is still 10′ high with an additional 5′ of excavation. While this alternative does not impact the CU South Campus site, it does still require the purchase of some land from the University. This is the antenna site that CU described. Bob asked that the county wetland areas be removed from the drawing. These may not be accurate and could misrepresent actual impacted areas.

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Review of Progress on Recommended Plan Workshop

BCA

CH2M HILL has developed a draft memo describing the results of the work to date. The memo is being reviewed and will be finalized shortly. The evaluation showed a slight increase in the estimated damages. This is attributed to an increase in the assessed values of the properties and a slight change in the flood elevations as a result of the 8M grid. Differences are generally less than 10%. Cost estimates are also being refined to allow the BC analyses to be finalized.

Modeling

The 8M grid models of 10-, 25- and 50-year floods for the various alternatives are being run. We have asked Eric to do a QC review of the models and are incorporating his comments. There continue to be surprises when the model results are reviewed but the significance of these is generally pretty small.

Recommended Plan Workshop

The plan will be to conduct the workshop following an agenda similar to the last workshop. We will review work to date and develop a matrix of the Best Alternative Plan Evaluation. This will allow a simple comparison of the alternatives. More detail of the evaluations will then be provided. The intention of the workshop will be to identify the stakeholders' interests so that a recommended plan reflects the group's collective desires. The agenda will be updated to reflect more discussion regarding what should be taken forward to the public. It should also be clear that this will not be the recommended plan until public input has been gathered.

Next Steps/Meetings

The workshop is scheduled for August 11. Information needs to be distributed to the stakeholders the week prior.

Meetings with the ditch companies and the Baseline Reservoir representatives need to be conducted prior to the workshop. Alan Taylor is trying to put together a short memo describing the issues related to Baseline Reservoir before the meeting to lay a foundation for discussion. At the meeting with both the ditch company and the reservoir representatives, impacts and mitigation measures need to be discussed.

It was concluded that someone familiar with the ditch companies should be invited to the next workshop. The City staff representative would be a good person to participate.

The public meeting should be scheduled around the last week in August but certainly before Labor Day. The WRAB meeting is scheduled for September 20 and there needs to be time to incorporate any public comment. Kurt was going to find a suitable date.

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SBC Flood Mitigation Study - Progress Meeting #12Notes

ATTENDEES: Kurt Bauer/City of Boulder, Alan Taylor/Alan Taylor Consulting, Alan Turner/CH2M HILL, Mark Glidden/CH2M HILL, Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: August 4, 2010

Review of Meeting with Baseline Reservoir Representatives

The meeting with the Baseline Reservoir representatives was not discussed because all meeting attendees were either at the meeting or are aware of what was discussed at the meeting.

Recommended Plan Workshop

Review Handout

CH2M Hill is planning on sending out a handout before the recommend plan workshop. This handout will include the best alternative figures with the aerial image behind the improvements, a best alternatives decision matrix, and a short narrative describing the best alternatives decision matrix. For the Best Alternatives Workshop, scheduled for August 11, 2010, additional information will be presented, including residual floodplain images.

The best alternatives decision matrix will present the project implementation cost, the average annual benefit, the present worth of project benefits, the benefit to cost ratio, water quality impacts, environmental factors, social factors, and other factors. The damage and benefit estimates were been broken down by reach but this will not be presented in the matrix but will be available for discussion at the workshop.

The Stormwater Master Plan alternative will be presented as was presented by HDR although there are a few discrepancies when comparing the recommended storm sewer pipe improvements with existing storm sewer pipes. The MIKE FLOOD Models for the Stormwater Master Plan alternative may not be done by the workshop but CH2M HILL will be able to present a cost/benefit analysis based on some of the other MIKE FLOOD Models that have been completed.

Recommended Plan Workshop Outline

The recommended plan workshop will begin with a short (5 – 10 minutes) discussion of work to date followed by a discussion of the matrix. A large portion of the meeting will be the discussion of the best alternative plans and possible selection of the best plan. One of the goals of this workshop is to get City of Boulder staff to agree on what the best alternative plan is. It is important that the project team come to a consensus on the best plan before the

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public meeting. Some of the alternatives, including the mainstem flow containment alternative, will get screened out due to factors discussed in the matrix.

It was suggested that phasing may need to be discussed during the recommended plan workshop in case it comes up during the public meeting. The project team will not bring up phasing during the public meeting but must be prepared for any questions regarding the total cost of each alternative and where the money will come from.

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SBC Flood Mitigation Study - Progress Meeting #13 Notes

ATTENDEES: Kurt Bauer/City of Boulder, Shea Thomas/UDFCD, Alan Taylor/Alan Taylor Consulting, Alan Turner/CH2M HILL, Mark Glidden/CH2M HILL, Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: August 18, 2010

Action Items

- CH2M HILL will provide a projector and laptop for the public meeting.
- Kurt Bauer will develop a draft of the sign in sheets and comment sheets for the public meeting.
- Kurt Bauer will provide refreshments and snacks for the public meeting.
- CH2M HILL will provide a rough draft of the public meeting PowerPoint Presentation to Kurt Bauer by Friday, August 20th.
- CH2M HILL will prepare a list of questions which are expected to be asked at the public meeting and prepare answers to these questions.
- CH2M Hill will prepare the information to be posted on the website prior to the public meeting.
- Kurt Bauer will meet with one of the private property owners impacted by the south regional detention pond.
- Alan Turner will contact Randy Rhodes – Xcel/Wellman
- Alan Turner will contact Brad Dallum – New Anderson Ditch
- Alan Turner will contact the US Fish and Wildlife Service to determine the Preble's Meadow Jumping Mouse habitat boundary

Review of Meeting with Dry Creek Ditch No. 2 Stakeholders

The ditch company is concerned about the liability associated with accepting flood flows although they might be willing to abandon the ditch to the City of Boulder below South Boulder Road. The ditch still must deliver water to Manhattan Middle School and Flatirons Golf Course. The ditch company agreed that the concept proposed as part of the alternative evaluation is sound and there are no major issues at this time although an agreement will need to be worked out in the future.

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Public Meeting

The public meeting will begin with a 35-40 minute presentation followed by question and answer sessions at various stations. The project team agreed that there will be three stations; one for the two detention alternatives, one for the high hazard/critical facilities alternative, and one for the conveyance alternatives (diversion to Bear Canyon Creek, Dry Creek Pipeline, and mainstem flow containment). There will be four boards for the detention alternatives; one to show the CU detention pond, one to show the south regional pond, and two showing the improvements through the West Valley. There will be one board for the high hazard alternative and possibly two boards for the conveyance alternatives. There will also be a board showing the matrix with pros and cons for each alternative. The matrix may also be left on the screen after the PowerPoint presentation is finished. The preliminary plan is to have Alan Turner and Kurt Bauer at the detention station, Aaron Cook at the high hazard/critical facilities station, and Mark Glidden and Alan Taylor at the conveyance stations. Bob Harberg, Shea Thomas, and Annie Noble will float around wherever they are needed.

The presentation will be structured as follows:

1. Bob – Introduction/meeting agenda/meeting intentions (2 slides, 2 minutes)
2. Kurt – Introduce project team/overview of process (3 slides, 4 minutes)
3. Mark – Concept development/alternative development/costs/benefits (4 slides, 6 minutes)
4. Alan – Alternative description/residual floodplains (7 slides, 10 minutes)
5. Kurt – Costs/benefits/pros and cons/ alternatives that dropped out (8 slides, 10 minutes)
6. Kurt – Next steps (2 slides, 2 minutes)

The project team decided that we will not discuss phasing or where the funding will come from during the public meeting unless specifically asked. The project team expects to be asked this question so we should be prepared to answer this question. At this time, the project team must have a better idea of what the preferred alternative is before determining phasing or funding.

The project team will not discuss funding for flood proofing of critical facilities unless specifically asked during the public meeting. Right now, it is unknown whether the funding for flood proofing of critical facilities will be public or private.

The project team will prepare a list of questions which are expected to be asked at the public meeting and prepare answers to these questions. These questions may be related to CU, open space, the Hogan Pancost property, Dry Creek Ditch No. 2, or the Preble's Meadow Jumping Mouse habitat among others.

During a discussion of the questions that are expected to be asked during the public meeting, the project team tried to address the response if the question of "Which alternative do you like best?" was raised. The team consensus was that the CU detention with West Valley improvements alternative made the most sense. Everyone agreed that this response

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needed to be carefully presented and CH2M HILL agreed to try and include this in the draft Q&A being developed.

Next Steps/Meetings

This public meeting on September 2, 2010 will be the last public meeting. The public meeting will be followed by a presentation to the Water Resources Advisory Board (WRAB). The project team will make a recommendation to WRAB at this meeting. WRAB will have some time to think about the recommendation before the second WRAB meeting.

Other next steps:

- Kurt Bauer will meet with one of the private property owners impacted by the south regional detention pond.
- Alan Turner will contact Randy Rhodes – Xcel/Wellman
- Alan Turner will contact Brad Dallum – New Anderson Ditch
- Alan Turner will contact the US Fish and Wildlife Service to determine the Preble's Meadow Jumping Mouse habitat boundary

CH2M Hill will prepare the following information to be posted on the website prior to the Public Meeting:

- Simplified agenda/outline
- Alternative figures
- Matrix
- Glossary of terms

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SBC Flood Mitigation Study - Progress Meeting #14Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Mark Glidden/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: September 1, 2010

Action Items

Review of Meeting Agenda, Rules, and Flow

- Kon Damas will introduce the meeting and will introduce each presenter.
- Alan Turner and Kurt Bauer will be stationed at the detention alternatives.
- Aaron Cook will be stationed at the High Hazard/Critical Facilities alternative.
- Mark Glidden and Alan Taylor will be stationed at the conveyance alternatives (pipelines, SWMP, mainstem flow containment).
- Bob Harberg, Annie Noble, Shea Thomas, and Ken MacKenzie will be floaters who can help out at any station.

Review of PowerPoint Presentation

- Kon will present slide 3.
- Kurt would like to delete slide 7.
- On slide 6, the text should say that the initial presentation to WRAB will occur in November or December.
- Bob prefers to keep the next steps vague.
- A "Do Nothing" alternative will be added to the presentation to show the existing non-structural methods for flood control that the City of Boulder has implemented.
- The presentation will refer to the two detention alternatives as "Regional Detention at US 36" and "Regional Detention near Highway 93". The project team agreed with this idea but the public meeting boards were already printed and won't be changed for the public meeting.

Dress Code

Dress code for the public meeting is business casual.

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Speaker Information

Each member of the project team will have a packet of information that includes the following:

- Glossary of Terms
- Preble's Mouse Habitat Figure
- Small Prints of the Public Meeting Boards (11" x 17")
- PDF of the Public Meeting Presentation
- List of Assignments for the Public Meeting

Glossary Handout

Alan Turner developed a list of terms with definitions (i.e. critical facilities, open space, flood proofing, benefit to cost ratio, WRAB, detention, etc.). The project will have this list during the meeting but it the list will not be presented at the public meeting. Presenting this list at the public meeting may distract from the purpose of the meeting. This list will be put on the South Boulder Creek website later.

List of Probable Questions with Answers

The list of probable questions with answers was developed by CH2M HILL for internal project team use. Each member of the South Boulder Creek project team will have this document at the public meeting. Kurt will go through the City of Boulder Communications staff to see if this information can be put on the South Boulder Creek website.

From a technical perspective, regional detention at US 36 or near Highway 93 is still the best alternatives. The project team agreed that an on-line reservoir would not be feasible due to the large dam that would be required to store the entire flood.

The Marshall Road property owners are questioning the detention near Highway 93 alternative due to the presence of high groundwater. Groundwater will have to be considered throughout the study area, not just at the detention pond near Highway 93.

South Boulder Creek cannot be channelized because of critical habitat, open space issues, and the high costs associated with channelization.

Comment Sheets

Kurt sent comment sheets to the project team. The project team agreed that they were a nice, simple, clean design.

Preble's Mouse Habitat

Each member of the project team will have a figure showing the Preble's Mouse habitat in the study area. Some proposed improvements would require mitigation of the Preble's Mouse Habitat.

Arrival Time

The room will be ready at 4:00 PM. The project team agreed to arrive between 4:00 PM and 4:30 PM to have some time to set up.

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The projector screen in the room is small and both the City of Boulder and CH2M HILL will bring a screen. The larger screen will be used for the presentation.

Next Steps/Meetings

- Public Meeting – 9/2/2010
- A report summarizing the work to date will be completed and submitted to the City of Boulder by October 1st.
- The alternatives will be presented to WRAB in November or December.

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SBC Flood Mitigation Study - Progress Meeting #16 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Dave Webster/Boulder County
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Mark Glidden/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: September 15, 2010

Public Meeting – Review of Meeting and Comments

From the comment sheets collected at the public meeting, the favorite alternative is detention at US 36 and the least favorite alternative is detention near HWY 93, although this may only represent a small cross section of the community. Kurt Bauer has recorded all of the comments from the comments sheets, grouped the comments, and removed the duplicate comments. The meeting summary should be posted to the South Boulder Creek Flood Mitigation Study website soon. The City of Boulder Communication group may review the meeting summary before it is posted to the website.

Bob Harberg will meet with the director of the City of Boulder Open Space department and the Public Works director to discuss the possibility of a detention pond on open space near HWY 93. The open space near HWY 93 has been designated as sensitive habitat for some species including the Preble's Meadow Jumping Mouse.

Ned Williams, City of Boulder Public Works, suggested looking into the possibility of detention west of HWY 93 and that open space away from South Boulder Creek may not have the same sensitivity as open space directly adjacent to South Boulder Creek.

Dave Webster will meet with the County Commissioners next week. Some of the County Commissioners are concerned about the path forward. Dave asked if WRAB had been involved in the project, and the City responded by saying that Chuck Howe, a WRAB member, has been involved and that the project had been presented at a WRAB meeting. The WRAB has advisory status within the City.

The citizens' advisory group, brought up by the public during the public meeting, was initially formed during the Taggart Study. Typically, UDFCD has not had advisory groups for Master Planning Studies but has had them for design projects. The City of Boulder has had advisory groups for past City of Boulder projects.

Flood Mitigation Report Progress to Date

The South Boulder Creek Flood Mitigation Report generally follows the typical UDFCD template. The first four sections (Introduction, Study Area Description, Hydrologic

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Analysis, and Hydraulic Analysis) of the South Boulder Creek Flood Mitigation Report are nearly complete and CH2M Hill is in the process of writing section 5 (Alternative Development), and will begin working on section 6 (Alternative Evaluation). The draft of the first four sections will be sent to the project team by the end of this week. The draft of the first six sections will be complete and sent to the project team for review by the first couple of weeks of October.

Because the floodplain mapping study was very detailed, it has been difficult to pull information from the Floodplain Mapping Study without being too detailed. The goal is to provide enough information within this report to understand each section but not be too detailed with all the information presented in the Floodplain Mapping Study. The Floodplain Mapping Study will be referenced for those who want additional information.

Next Steps

- CH2M Hill and Alan Taylor will review the City Council Information Packet for questions they receive regarding the public meeting.
- CH2M Hill will provide summary information regarding the land value costs for the detention at US 36 alternative and the other alternatives involving land acquisition.
- Bob Harberg will meet with the director of the City of Boulder Open Space department and the Public Works director to discuss the possibility of a detention pond on open space.
- CH2M Hill will attend the next WRAB Meeting, tentatively scheduled for December.

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SBC Flood Mitigation Study - Progress Meeting #16 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Dave Webster/Boulder County
Kon Damas
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Mark Glidden/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: September 29, 2010

Public Meeting Debriefing

Detention near HWY 93 Alternative

The progress meeting began with Kon Damas asking if we received comments on alternatives other than Detention at HWY 93. Although there were a number of people other than those from Marshall, it appeared that they were intimidated to speak up at the public meeting. Although the Detention at HWY 93 alternative was unpopular at the public meeting, it is still an option. At this stage of the project, we are only presenting alternatives and are not to the point where the decisions are made. The City typically prefers to negotiate with land owners or modify the preferred alternative but condemnation has been used a couple of times over the last decade for flood mitigation purposes.

Dave Webster stated that the Marshall residents would prefer to be left along, with no flood mitigation improvements. Dave also stated that the County would get involved if this alternative was selected as a viable alternative. This alternative may include other issues such as the 1041 process and land use issues. Dave expects a public letter from the County within two to three weeks discussing this alternative. Bob Harberg would like the County to wait to issue a public letter because the alternative evaluation report is not complete and the county still has the opportunity to give input over the next couple of months. Dave stated that the County Commissioners want to issue to public letter soon.

Public Meeting Format

The format of the public meeting was discussed at length at this progress meeting. Using an open house format likely would have resulted in less of a mob mentality, although some members of the public specifically requested to skip the public meeting format and continue with the questions/comments/ answers format. It was suggested that the public meeting format could follow City Council format which includes two-hours for public comment. Other options include small discussion groups and a "self guided tour" detailing the process behind selecting the best alternative plans. Dave Webster stated that Boulder County typically uses an open house format for public meetings.

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For any subsequent public meetings, we need to figure out a way to tell the public; "We've heard you, let's move on". This would allow others, such as those from the West Valley, to comment and ask questions. Any subsequent meeting may begin with the results of voting from the previous public meeting as a starting point.

Review of Progress on South Boulder Creek Flood Mitigation Report

The first four chapters (Introduction, Study Area Description Hydrologic Analysis, and Hydraulic Analysis) of the South Boulder Creek Flood Mitigation Report have been completed in draft format and sent to the project team for review. The fifth chapter (Alternative Development) of the report is nearly complete and will be sent out for review soon. Chapter six (Alternative Evaluation) is in progress.

Field Visit with OSMP

The meeting with the City of Boulder OSMP is scheduled for September 30 at 2:00 PM. Kurt Bauer suggested using MapQuest instead of Google Maps to get the correct directions to the meeting spot. Alan Turner will bring a packet of information to the meeting which will include an aerial photograph, topography, land owners, and open space information.

Review of Out of Scope Work and Approximate Cost

The majority of the out of scope work to date includes work on detention pond alternatives or independent stakeholder meetings. The out of scope work to date adds up to approximately $39,000. Alan provided a letter to Kurt Bauer prior to this meeting detailing the out of scope items and will forward it to Shea Thomas.

Other Detention Pond Alternatives

Alan Taylor suggested evaluating a series of attenuators, at US 36, South Boulder Road, Baseline Road, and the Golf Course. With this alternative, the flow would be forced to the mainstem upstream of US 36, similar to the Mainstem Flow Containment Alternative with storage at Baseline Reservoir, although in this alternative, the series of smaller ponds would be used to offset the additional peak flow and flow volume being forced to the South Boulder Creek Mainstem instead of forcing the flow to Baseline Reservoir.

Kurt Bauer noted that City of Boulder staff have suggested looking into using the East Boulder Recreation Center land for a detention pond.

Alan Taylor suggested that the parcel to the north of the East Boulder Recreation Center could also be used for a detention pond. This parcel is not open space but open space has looked into acquiring it in the past. According to Alan Taylor, this parcel includes heavy wetlands and does not have a lot of development potential. The City of Boulder Staff will discuss with OSMP staff to see if the owner(s) of this parcel is a willing seller because OSMP staff have had previous discussions with the owner.

Bob Harberg suggested evaluating a combination of a pond near HWY 93 with a pond at US 36. Using a combination approach may reduce the berm height and amount of excavation required to store enough water to prevent overtopping of US 36. For both ponds, the location of excavation and the berm should be off of or near the edge of open space property.

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Next Steps

- CH2M Hill will have the South Boulder Creek Flood Mitigation Report through chapter six complete and sent for review by the second week of October.
- Kurt Bauer will go on an informal field trip with WRAB members to the project site to receive informal direction about the project. The field trip is preliminarily scheduled for October 7th. Shea Thomas stated that she won't be able to make it on October 7th.
- The South Boulder Creek Flood Mitigation Report will be presented at the December WRAB meeting.
- CH2M Hill will look into the hydraulic feasibility of the new open space detention pond alternative. This alternative is supported by Dave Webster when compared to the Detention at HWY 93 alternative presented at the public meeting.
- The schedule has been updated with a final delivery date of May, 2011. Alan Turner will send the new email to the project team.

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SBC Flood Mitigation Study - Progress Meeting #17 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Ned Williams/City of Boulder
Shea Thomas/UDFCD
Dave Webster/Boulder County
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Mark Glidden/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: November 3, 2010

Review Progress on South Boulder Creek Flood Mitigation Report

CH2M Hill has incorporated comments from Kurt Bauer and Shea Thomas on sections one through five of the South Boulder Creek Flood Mitigation Report. Alan Turner will contact Kurt Bauer regarding a few questions on Kurt's comments. CH2M Hill is finished with section six of the South Boulder Creek Flood Mitigation Report with the exception of Alternative 9. The project team determined that CH2M Hill will submit section six once Alternative 9 is complete and incorporated into the report. CH2M Hill will submit section 6 by Thanksgiving.

Review and Discuss Alternative 9 Feasibility

Alternative 9 is a derivative of the mainstem flow containment alternative which forces all the flow from upstream of US 36 through the US 36 bridge over South Boulder Creek. The mainstem flow containment alternative forces approximately 210 acre-feet of additional water to the mainstem of South Boulder Creek which must be mitigated downstream. Kurt Bauer questioned why the project team was evaluating detention pond alternatives upstream of US 36. The project team is evaluating options upstream of US 36 because it is likely that more than 210 acre-ft of storage will be needed because the ponds are in series and storage upstream of US 36 lessens the impacts at US 36. The alternatives will be evaluated in Mike Flood to determine if storage upstream of US 36 is necessary to help mitigate the additional volume of water being forced to the mainstem.

Storage at US 36

Detention immediately upstream of US 36 provides approximately 131 acre-feet of additional storage when compared to the regulatory model. Because storage upstream of US 36 was included in the mainstem flow containment alternative, this storage cannot be counted towards the 210 acre-feet of water being forced to the mainstem of South Boulder Creek. For this alternative, the berm ties into the US 36 Bridge over South Boulder Creek and wraps around parallel to the CU berm.

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Storage at South Boulder Road

The detention pond at South Boulder Creek is created by either raising South Boulder Road or constructing upstream of South Boulder Road. The current plan includes a berm with a height of 5 feet above the existing elevation of South Boulder Road. Flood storage would be up to a height of 3 feet above the existing elevation of South Boulder Road with the remaining 2 feet left for a spillway and freeboard. This detention pond provides an additional 130 acre-feet of storage. To protect the private property to the west, the berm must wrap around between Dry Creek Ditch #2 and the Viele Ditch. The berm on the west side is approximately 2 – 3 feet high.

The South Boulder Road detention pond figure included in the Technical Memorandum *South Boulder Creek – Alternative 9 Detention Ponds* shows a ponded depth up to 14 feet because there is already storage at South Boulder Road in the existing conditions. The proposed detention pond is created by raising South Boulder Road to provide additional storage. The project team recommended that the figure also show the areas that will be flooded in the proposed conditions that are not flooded in the existing conditions.

Storage at the Granite Property

There are two alternatives for storage on the Granite Property. The first option is an 18 foot berm with 15 feet of flood storage and 3 feet for a spillway and freeboard. The total storage for this alternative is 93 acre-feet. The problems with this alternative are the large berm and the length of the horseshoe shaped berm. The second alternative includes two detention ponds in series, each with a maximum berm height of 11 feet with 8 feet of flood storage. The total storage for the second alternative is approximately 54 acre-feet. Both of the alternatives assume no excavation on the Granite Property.

Flood waters would enter detention ponds on the Granite Property via a channel from the mainstem of South Boulder Creek. Outflows from the detention ponds would be conveyed via a new open channel back to South Boulder Creek.

Storage on Open Space between US 36 and Highway 93

The proposed detention pond on open space between US 36 and Highway 93 has no impact to private property, property owned by the University of Colorado, or high quality wetland areas and includes no excavation on open space property. With a 17 foot berm height, 14 feet for flood storage and 3 feet for a spillway and freeboard, the total storage is approximately 146 acre-feet. The discharge from this detention pond is through the existing ditch systems and a spillway back to South Boulder Creek.

Storage between Highway 93 and Marshall Road

The wedge shaped detention pond between Highway 93 and Marshall Road has a 12 foot maximum berm height and 35 acre-feet of storage. This pond is identical to the small part of the two stage detention pond presented at the second public meeting. This detention pond includes excavation.

Summary

The total storage within the project area ranges from 365 to 404 acre-feet depending on which detention pond alternative is selected at the granite property. Because the total storage is greater than the 210 acre-feet being forced to the mainstem of South Boulder

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Creek, this alternative is feasible to mitigate the additional volume. Alternative 9 will have to be evaluated in Mike Flood to confirm that mitigation of 210 acre-feet of water is possible.

Questions on Detention Pond Alternatives

Bob Harberg questioned why the berm at US 36 doesn't extend to the bridge deck at South Boulder Creek. In the mainstem flow containment alternative, the berm does extend to the bridge deck elevation but the water surface elevation never reaches that elevation so a berm to that height is not necessary.

Alan Taylor suggested a berm at Baseline Road similar to the berm at South Boulder Road. This detention pond could include low head culverts to direct the outflow to open space and away from private properties. Bob Harberg questioned why this alternative was not previously considered. One of the reasons this site was not considered for a detention pond was that City of Boulder Open Space has been trying to acquire the Granite Property and suggested a detention pond on that property. A berm/detention pond at Baseline Road may be more favorable than a pond on the Granite Property due to the height and length of the berm required on the Granite Property.

CH2M Hill will evaluate the feasibility of a detention pond at Baseline Road and report back to the project team. This option would likely keep Baseline Road open to traffic during the 100-year storm event.

The question was asked whether it would beneficial to move the detention pond on open space between US 36 and Highway 93 further to the North. The project team agreed that a 17 foot berm is too large and that a 10 – 12 foot berm would be more realistic. Kurt Bauer suggested CH2M Hill evaluate the detention ponds downstream of US 36 in Mike Flood to determine if storage upstream of US 36 is necessary. CH2M Hill will complete the Mike Flood analysis of Alternative 9 prior to showing the preferred Alternative 9 to City of Boulder Open Space representatives.

Staff Recommendations on Next Steps with SBC Flood Mitigation Report

Next Steps

- CH2M Hill will submit section six of the South Boulder Creek Flood Mitigation Report by Thanksgiving. Section six will include Alternative 9.
- CH2M Hill will evaluate the feasibility of a detention pond at Baseline Road and report back to the project team.
- CH2M Hill will evaluate Alternative 9 in Mike Flood.
- A progress meeting is scheduled for November 10, 2010. Kurt suggested moving this progress meeting until after the Mike Flood analysis is complete. Additional progress meetings will be scheduled for November 12, 2010 and November 17, 2010 for flexibility depending on when the Mike Flood analysis is complete.

WRAB Schedule:

- The WRAB meeting is scheduled for December 14, 2010.

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- The final packet of information must be submitted to WRAB members by December 6, 2010 to give them one week to review the information submitted.
- The draft packet of information should be submitted to the City of Boulder by November 30, 2010 for City review and the City would prefer to get this information prior to Thanksgiving (11/25/2010).

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SBC Flood Mitigation Study - Progress Meeting #19 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Ned Williams/City of Boulder
Shea Thomas/UDFCD
Dave Webster/Boulder County
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Mark Glidden/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: November 3, 2010

Review Alternative 9

The total cost for Alternative 9 is approximately $29,500,000. This cost includes land acquisition for the Granite Property and purchase of open space equal to the berm bottom width plus 15 feet. This cost does not include land acquisition for additional inundated areas. The City of Boulder will discuss the land acquisition for inundated areas with the City of Boulder Open Space Department. The total cost also includes all West Valley improvements. The residual floodplain shown is approximate and may change.

Detention near Highway 93

With the limitations of the pond on open space near Highway 93, including no excavation and a berm height of less than or equal to ten feet, it was determined that a detention pond near Highway 93 had little impact on reducing the peak flow or volume along the mainstem as is not included in this alternative.

Detention at US 36

The maximum berm height is 13 feet with a maximum pool depth of 17 feet and an approximate additional storage of 130 acre-feet. The berm is completely separate from CU berm.

This detention pond requires a control structure to reduce the flow through the US 36 Bridge and allow for more storage upstream of US 36. This control structure could be combined with the CDOT bike path which is tentatively planned to be placed directly upstream of US 36. At this time, CH2M Hill does not have additional information about this structure.

Ned Williams is concerned about the public policy of choking the flow at the US 36 Bridge. If the control structure is placed upstream of US 36, the flow wouldn't be choked at US 36, it would be choked upstream. Bob Harberg would like more information about this structure before a final decision can be made.

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Due to the sensitivity of the Table Mesa Pond, the Viele Channel on the CU South Campus must still be improved to collect and convey flows. The City of Boulder can perform channel improvements without having to negotiate with CU.

Detention South Boulder Road

The berm height is 6 feet above South Boulder Road with a maximum pool height of 4 feet above South Boulder Road. The maximum depth of storage is approximately 13 feet and the total additional storage is approximately 130 acre-ft. The spillway for this detention pond is to the east of the mainstem of South Boulder Creek. Downstream of the detention pond at South Boulder Road, the Viele Channel must be improved to collect and force flows towards the mainstem of South Boulder Creek. Flows overtopping the Viele Channel flow towards the East Boulder Recreation Center.

Detention at Baseline Road

The berm height is 10 feet above Baseline Road with a maximum pool height of 7 feet above Baseline Road. The maximum pool depth is approximately 13 feet with an approximate additional storage of 295 acre-feet. This detention pond may require the purchase of the Granite Property due to additional inundation caused by the berm. With the detention ponds at US 36, South Boulder Road, and Baseline Road, approximately 70% of the structures on Gaptor Road are seeing an increase of less than 2 inches in flood depth from the regulatory model. This alternative may also reduce the frequency at which these structures along Gaptor Road are flooded.

The detention pond at Baseline Road impacts a parking lot and trail head. The City of Boulder stated that a cost to relocate the parking lot and trailhead should be included in the cost estimate for the distributed regional detention alternative.

WRAB Meeting Preparation

The alternatives that will be suggested at the WRAB Meeting for further investigation are as follows:

- No Action
- High Hazard/Critical Facilities Protection
- US 36 Detention
- Alternative 9 (Distributed Regional Detention)

The other alternatives will not be evaluated in further detail.

Additional Public Outreach

The Open Space Board Presentation is scheduled for January, 2011. This presentation will be similar to the presentation at the WRAB meeting. Don D'Amico/City of Boulder Open Space will present a 5 minute presentation regarding the South Boulder Creek Flood Mitigation Study on December 10, 2010.

Next Steps

CH2M Hill will the following items to the City of Boulder:

- Draft figures to be used in the WRAB Presentation
- Cost/benefit analysis for Alternative 9 by Thanksgiving
- Alan Taylor will look into the pros and cons for Alternative 9

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- Chapters 1 – 6 of the report in draft format
- The additional flow forced to Baseline Reservoir in the distributed regional detention alternative
- The assessed value of the Granite Property to be used in the distributed regional detention alternative
- CH2M Hill will summarize the cost spreadsheets into major elements

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SBC Flood Mitigation Study - Progress Meeting #20 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Don D'Amico/City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: December 8, 2010

Review Report Status

The following list shows the progress on the South Boulder Creek Major Drainageway Plan – Alternative Analysis Report:

- The draft report has been reviewed by the City of Boulder and UDFCD.
- Alan Turner proposed to remove Appendices B and C and reference previous reports in the flood mapping study for hydrologic and hydraulic information. The City of Boulder and UDFCD agree that Appendices B and C can be removed.
- Appendix F will include the grading plans for the detention pond alternatives.
- Kurt Bauer stated that the figures in Chapter 7 are difficult to read. The figures were presented in this format to be consistent throughout the report. Both UDFCD and the City of Boulder agreed that the figures in Chapter 7 can be left as is.
- Kurt Bauer likes the updated executive summary.
- CH2M HILL will include the list of critical facilities in the appendices.
- CH2M HILL will make the necessary changes to the report and send to Kurt Bauer. Kurt will put the report of the project website and others can download the report there. Kurt wants the report on the website by the end of the week.

WRAB Meeting Preparation

The memo from Kurt Bauer to WRAB is going on the website today. The memo was reviewed by CH2M Hill. Kurt is going to call the Swanstroms and Militzers to let them know of the recommendations to WRAB.

Kurt Bauer will go through a dry run of the presentation on Friday with City of Boulder staff. The presentation will be approximately 20 minutes long. Kurt Bauer will present at the WRAB meeting and CH2M HILL will be available for a question and answer session.

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Kurt will send the PowerPoint presentation to CH2M HILL before the WRAB meeting for reference. CH2M HILL will bring figures for each alternative to the WRAB meeting.

Shea Thomas will not attend the WRAB meeting. Don D'Amico and Annie Noble will attend the public meeting. Annie will arrive late as she has another public meeting that day.

The WRAB meeting starts at 7:00 PM. Kurt Bauer and CH2M HILL will arrive around 6:00 PM. The dress code for the meeting is business casual.

Additional Public Outreach

The presentation to the City of Boulder Open Space Board will occur in January. The presentation will be similar to the one that will be presented at the WRAB meeting, with additional specific information focused on impacts to open space. Kurt and Don will work together to determine the specific information to present to the Open Space Board. Don stated the agenda for the January Open Space Board is full and isn't sure how much time will be dedicated to the South Boulder Creek flood mitigation project. Don will pass this information on to the project team once the agenda becomes available.

Next Steps

The WRAB meeting presentation and presentation to the Open Space Board in January are the next major milestones. The project team will wait for feedback from these two presentations to move on with further analysis of the selected alternatives. Alan Turner will update the schedule to include the WRAB meeting and the Open Space Board presentation.

Kurt Bauer needs the out of scope items amendment from CH2M HILL. CH2M HILL is almost ready to send this information to Kurt.

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SBC Phase II Kickoff Meeting

ATTENDEES: Kurt Bauer / City of Boulder
Shea Thomas / UDFCD
Mark Glidden / CH2M HILL

COPIES: Bob Harberg / City of Boulder
Annie Noble / City of Boulder
Aaron Cook / CH2M HILL
Alan Taylor / Alan Taylor Consulting
Mark Taylor / Architerra

FROM: Alan Turner / CH2M HILL

DATE: June 9, 2011

PROJECT NUMBER: 400168

Introduction

This meeting was to discuss schedule and to set up milestones and goals for the second phase of the South Boulder Creek Flood Mitigation Project.

1. Accepted Work Plan
    a. Complete review and analysis of OSMP Memorandum compared to proposed alternatives – ***CH2M HILL***
    b. Refine easement analysis based on existing alternatives – ***Alan Taylor Consulting***
    c. Identify utility conflicts and proposed solutions – ***CH2M HILL***
    d. Collect existing information regarding irrigation flows to ensure alternatives are sized correctly for decreed flows. – ***Alan Taylor Consulting***
    e. Identify proposed flood proofing alternatives– ***Alan Taylor Consulting***
    f. Create a preliminary rendering of a berm for review - ***Architerra***
    g. Progress meeting Wednesday, June 20, 2011 10:30 am
        i. Review results of task a – f above

    h. Begin refinement of alternatives based on above information
        i. Collection system for Bear Canyon Creek Pipeline
        ii. Refined conveyance facilities for Dry Creek #2 Ditch
            1. Pipeline
            2. Open Channel
        iii. Refined control structure for US 36 flow split
    i. Workshop meeting July 20, 2011
        i. Will include Architerra to review landscape perspectives
        ii. Review refinements to date and make changes based on City and UDFCD Comments
    j. Final Refinement of alignments based on updated easement information
    k. Final Refinement of utility conflicts and preparation of conceptual relocation plans
    l. Phasing analysis and incremental benefits evaluation
    m. Update of Cost Benefit analysis based on refinements
    n. Final workshop meeting August 17, 2011
        i. Review final alternatives
    o. Prepare final report text
    p. Tentative OSMP Meeting September, 2011
2. Action Items
    a. CH2M HILL will work with Architerra and Alan Taylor to begin initial work on South Boulder Creek Refinements.
    b. CH2M HILL will call Xcel Energy and QWEST to attempt to recover atlas sheets for phone, gas and electricity in the vicinity of the improvements.
3. Schedule
    a. Begin Work June 6, 2011
    b. Progress Meeting Jun 20, 2011
    c. Workshop Meeting July 20, 2011
    d. Progress Meeting August 3, 2011
    e. Workshop Meeting August 17, 2011
    f. OSMP Meeting September 2011

SBC Flood Mitigation Study - Progress Meeting #23 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL

FROM: CH2M HILL

DATE: August 3, 2011

Distributed Detention Changes and Update

The detention pond upstream of US-36 in the distributed regional detention alternative has been modified. The revised detention pond provides off-line storage that allows the detention ponds at South Boulder Road and Baseline Road to function without overtopping. The detention pond was previously modeled, in MIKE FLOOD, as a culvert along the mainstem of South Boulder Creek, but it was agreed upon that a structure along the mainstem would not be possible.

The new control structure is between the mainstem of South Boulder Creek and the west overbank. The detention pond is designed such that approximately 1,000 cfs will remain in the mainstem of South Boulder Creek with any flows exceeding 1,000 cfs allowed to flow into a lowered west overbank and into the detention pond. The berm, which previously tied into the US-36 bridge over South Boulder Creek, now extends to the south keeping the flow in the mainstem separate from the flow in the lowered overbank. The first 1,000 to 2,000 cfs reaching the pond would flow directly through the culvert outlet structures, back to the mainstem of South Boulder Creek. The detention pond begins to store water only at higher flows.

The additional length of the berm increases the impact to open space property and critical habitat. The additional berm does not impact the trail system adjacent to South Boulder Creek but may provide a visual barrier to trail users looking to the west, especially near US-36 where the height from the trail to the top of the berm is at a maximum.

Review of Open Space Memorandum

The open space memorandum made a few key assumptions that are not consistent with the assumptions made by the South Boulder Creek Flood Mitigation Study project team. A few of the key difference in assumptions are:

- Open space assumed the berms were entirely on open space land. The Flood Mitigation project assumed the berms would be placed partially on City or State Right of Way.

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- For the Distributed Regional Detention alternative, the open space memorandum stated the maximum berm height at US-36 is 18 feet. The actual maximum berm height is 12 feet.
- For the Distributed Regional Detention Alternative, the open space memorandum stated the maximum berm height at Baseline Road is 18 feet. The actual maximum berm height is 18 feet but only if measured from the South Boulder Creek invert to the top of the berm.
- In general, the estimated impacts to open space and critical habitats are less than what was reported in the open space memorandum, although the impacts to open space and critical habitat are greater than what was reported for the detention pond at US-36 for the Distributed Regional Detention alternative where the berm was extended to the south.

Alan Turner/CH2M HILL will finalize the memorandum detailing the inconsistencies between the South Boulder Creek Flood Mitigation Project and what was presented in the open space memorandum.

Review of Renderings and Rendering Locations

The Architerra Group has prepared two renderings showing the impacts of the proposed berms. The renderings they've prepared are:

- Distributed Regional Detention Alternative – Looking southwest from the corner of Baseline Road and Cherryvale Road
- Storage at US-36 Alternative – Looking south from Table Mesa Drive overpass to University of Colorado south property

The Architerra Group will prepare two additional renderings:

- Distributed Regional Detention Alternative – From trail adjacent to South Boulder Creek (upstream of US-36) looking northwest
- Storage at US-36 Alternative – From trail adjacent to South Boulder Creek (upstream of US-36) looking northwest

Bob Harberg requested that the view of each of the renderings be expanded to 180° to show a better representation of the proposed improvements. Alan Turner will coordinate with Kurt Bauer if the two additional renderings to not fit within the existing budget for Architerra.

Utilities Conflict Updates

CH2M HIILL has not been able to contact Qwest or Xcel for utility line locations but will include a contingency for utility conflicts. Actual locations and utility conflicts can be pursued at a later date such as conceptual design.

Alternative Phasing Strategy

The goal is to develop a phasing plan that the city can implement and identify ways to get the projects funded. A preliminary phasing plan was presented to the project team for each

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alternative but CH2M HILL will have to evaluate the final costs and benefits before recommending a final phasing strategy. In general, the phasing considerations are:

- Benefit/cost analysis
- Capital cost
- Relationship to other improvements
- Traditional downstream to upstream approach

The benefits are mostly clear for the larger improvements but become less clear for the smaller improvements. When the benefit/cost analysis becomes difficult, a traditional downstream to upstream approach should be used.

Updated Cost Estimates

The cost for the Bear Canyon Creek pipeline alternative has been updated to include the cost for the inlets and lateral pipelines where flow overtops US-36. The updated cost estimate is approximately $4,000,000 higher than the previous estimate.

CH2M HILL would like to include a more detailed cost estimate for the construction of detention pond berms and is currently working on this. One idea is to determine a cost per linear foot of jurisdictional berm based on estimates from CWCB or other consultants.

Discussion of Current City of Boulder Terrain Files

The terrain data that the project team has been using for the South Boulder Creek Flood Mitigation Project is not the most current terrain data from the City of Boulder. At the onset of the project, the City loaded the old terrain data to the City of Boulder FTP site, which is the data that the project team has been using.

In the 2003 survey, vegetated cover prevented gathering proper topography in some stream areas. Merrick & Company was hired to correct the topography in stream areas using LIDAR. The topography corrected in stream areas was never loaded to the City of Boulder FTP site.

The City just recognized this issue and both the Floodplain Mapping Study and Flood Mitigation Project have used the old terrain data. The difference between the corrected and not corrected topography is generally less than 0.5 feet but can be as much as 2 – 4 feet in isolated areas.

CH2M HILL is in the process of contacting Eric Fontenot/DHI to determine which topography was used for the Floodplain Mapping Study in the MIKE FLOOD Model. CH2M HILL has continued to use the same topography in MIKE FLOOD for each alternative that was modeled. CH2M HILL will also perform an analysis to determine the difference between the corrected and not corrected topography for the South Boulder Creek project area.

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SBC Flood Mitigation Study –Progress Meeting #24 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/ City of Boulder
Annie Noble/ City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Mark Taylor/Architerra

FROM: CH2M HILL

DATE: August 31, 2011

This meeting summary documents the discussion and major decision made during Progress Meeting 24.

Review of Refined Costs and Comparison of Plan Costs

The costs for each alternative were refined by evaluating each element within each alternative plan. Unit costs, construction costs, land acquisition, wetland mitigation, etc. were refined for each alternative. The major changes to the cost estimates include:

- Included environmental mitigation
- More detail and a better understanding of the detention ponds footprints
- Better understanding of required land acquisition
- Contingency decreased from 50% to 35%

High Hazard and Critical Facilities Alternative: CH2M HILL and Alan Taylor are still working on the refined costs for this alternative. Alan Taylor is working on the unit costs for floodproofing Frasier Meadows Manor, schools, and gas stations. The project team determined that only the cost for mitigating the high hazard zone should be included in this alternative. The costs for floodproofing of critical facilities will be noted but it will not be a cost to the City of Boulder.

Storage at US-36 with Downstream Improvements Alternative: This alternative was divided into three elements for consideration in the phasing recommendation; detention pond at US-36, improvements in the West Valley, and detention at Arapahoe Avenue. The increase in cost for this alternative is due to a better understanding of the detention pond footprint at US-36 (with 4:1 side slopes and an impervious core key trench), additional riprap for the US-36 detention pond spillway, and a better understanding of the environmental mitigation required for the channels downstream of the Arapahoe Avenue detention pond. Environmental mitigation, which was not included in the previous cost estimate, was included in the refined costs.

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Distributed Regional Detention with Downstream Improvements Alternative: This alternative was divided into three elements for consideration in the phasing recommendation; regional detention ponds, improvements in the West Valley, and detention at Arapahoe Avenue. The increase in cost for this alternative is due to the following:

- Computational problems in previous spreadsheet (contingency not applied correctly, mistake in applying detention pond equation) (approximately $4 million)
- Added environmental mitigation (approximately $4 million)
- Increase in property acquisition cost (approximately $4 million)
- Increase in spillway and earthwork cost for detention ponds (approximately $5 million)

Bear Canyon Creek Pipeline Alternative: The property acquisition and wetland mitigation costs increased but the overall pipeline refinement decreased the overall cost for this alternative.

Cost Benefit / Phasing

The goal of the phasing plan is to offer direction as to how the facilities, as part of the overall alternative, should be implemented. The phasing considers benefit to cost ratio, capital cost, and other intangibles such as life safety, flood control, and public interests. The final phasing will require input from the City of Boulder and UDFCD.

Storage at US-36 with Downstream Improvements Alternative: For this alternative, the recommended phasing is as follows:

1. Detention pond at US-36 (favorable benefit to cost ratio, capital cost not too much higher than other improvements, prevents overtopping of US-36)
2. West Valley Improvements (high benefit to cost ratio, doesn't eliminate 100-year floodplain)
3. Detention pond at Arapahoe Avenue (favorable benefit to cost ratio)

Distributed Regional Detention with Downstream Improvements Alternative: For this alternative, the recommended phasing is as follows:

1. Detention pond at Arapahoe Avenue (favorable benefit to cost ratio, downstream to upstream improvements)
2. Distributed regional detention ponds (benefit to cost ratio less than one, prevents overtopping of US-36)
3. West Valley Improvements (high benefit to cost ratio, doesn't eliminate 100-year floodplain)

Bear Canyon Creek Pipeline Alternative: For this alternative, the recommended phasing is as follows:

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1. Detention pond at Arapahoe Avenue (favorable benefit to cost ratio, downstream to upstream improvements)
2. Bear Canyon Creek Pipeline/Inlets (favorable benefit to cost ratio, captures flow overtopping US-36, eliminates 100-year floodplain)
3. West Valley Improvements (favorable benefit to cost ratio, eliminates 100-year floodplain)

The costs for each of the three alternatives, Storage at US-36 with Downstream Improvements, Distributed Regional Detention with Downstream Improvements, and Bear Canyon Creek Pipeline Alternative, have a favorable benefit to cost ratio with the refined costs but not every element within each alternative has a favorable benefit to cost ratio.

Renderings

Mark Taylor presented three photos showing the view from the trail upstream of US 36. These photos were taken with the intent of showing the berms for the detention ponds upstream of US-36 for both the Storage at US-36 alternative and the Distributed Regional Detention Alternative. From the vantage points that the three photos were taken, it would be very difficult to show either of the berms. The berms are either blocked by vegetation or are too far away. For now, Architerra will leave the photos as is without creating a rendering of the berms.

Mark Taylor also presented the rendering of the US-36 berm at the CU South Campus (taken from Table Mesa Drive) with a widened view.

Terrain

Report Chapters and Outlines

Schedule

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Appendix A-2

Workshop Meeting Minutes

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South Boulder Creek Flood Mitigation Study Preliminary Plan Element Identification Workshop Meeting Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Don D'Amico/City of Boulder Open Space
Ned Williams/City of Boulder Public Works
Ken MacKenzie/UDFCD
Jeffrey Lipton/CU-Boulder
Chuck Howe/Boulder Water Resources Ad. Board
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting
Kaia Anderson/Anderson & Co., Inc.
Steven Griffin/CDOT
Bob Hays/CDOT
Mark Nelson/USACE
Chris Fassero/USACE
Kayla Eckert Uptmor/USACE

FROM: Aaron Cook

DATE: February 3, 2010

PROJECT NUMBER: 400168

Welcome/ Introductions/ and Background Information

The 2008 floodplain delineated with MIKE FLOOD is expected to be adopted by FEMA in 2011. A risk assessment was performed along with the floodplain delineation. There is a substantial difference between the 2008 floodplain and the regulatory floodplain in terms of flooding in the West Valley. The existing regulatory floodplain is only along the mainstem of South Boulder Creek. The 2008 floodplain study also includes a high hazard zone (extreme depth, extreme velocity, or a combination); defined as where the product of velocity and depth is greater than 4 ft^2/s or the depth is greater than 4 feet, and a conveyance zone, which is a 0.5-foot floodway.

The City of Boulder has contracted with CH2M HILL for a Flood Mitigation Study in the West Valley. Representatives from the City of Boulder stated that full 100-year containment is only a possibility when substantial money comes in from an outside source. Instead of mitigating the 100-year floodplain, the City mitigates the high hazard zone. Previously, the City would contain the 100-year flow and remove the 100-year floodplain from development, but recent City Council direction has shifted the focus to the high hazard zone. At this stage, floodplain mitigation in the West Valley will remain an objective in addition to high hazard zone mitigation.

The United States Army Corps of Engineers (USACE) is also performing a reconnaissance study along South Boulder Creek. The USACE wants to develop a one dimensional HEC-RAS model calibrated to the results of the MIKE FLOOD model. The City of Boulder has

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attempted to develop a calibrated HEC-RAS model with multiple flow paths in the past with little success. CDOT expressed concerns about using MIKE FLOOD to model hydraulics within the study area. It was noted that in MIKE FLOOD, the channels are represented as one dimensional elements (MIKE 11) which may help in developing HEC-RAS models or real-time models.

CDOT performed an Environmental Impact Statement in the study area, which assumed all flows were conveyed through US Highway 36 instead of breaking out of the main channel as is shown in the MIKE FLOOD model.

Summary and Goals of South Boulder Creek Flood Mitigation Project

The project team has a good idea of where the problems are within the study area. The scope of work for CH2M HILL is to mitigate the flood threats by blending the typical UDFCD approaches with refinements made possible by the tools being used and the knowledge of the study area.

The goal of this meeting was to review known flood hazards, to understand issues and constraints for mitigation alternatives, to get input from stakeholders, to understand ongoing projects (USACE, CDOT) within or near the study area, and to develop a suite of potential elements to address the flood hazards. The project team will then begin to look at potential alternative elements in more detail.

A second workshop will be held in the future to discuss possible alternative elements in more detail and reduce the number of alternatives. A series of alternative plans will then be developed to address flood hazards in the West Valley. The combined benefits of each plan will be evaluated and a few plans will be selected as the Best Alternative Plans for analysis in MIKE FLOOD. A cost-benefit analysis will be performed on the Best Alternative Plans to select the Recommended Plan.

The public will be involved in the alternative selection process. Two public meetings will be held throughout the project, one during the alternative plan development stage and one during the process to define the recommended plan.

Review of Study Area Limits

The study limits for this flood mitigation project are limited to the West Valley. This project will not necessarily address issues with the South Boulder Creek mainstem, but the mainstem cannot be completely disregarded due to the interactions between the mainstem and the West Valley downstream of US Highway 36. The majority of the mainstem of South Boulder Creek is outside the City of Boulder limits, within Boulder County. To date, Boulder County has not expressed interest in improvements along the mainstem. The USACE project has a broader view than the West Valley.

There are two centerlines for flow in the West Valley, one along the Dry Creek drainage and 55th street (East of Foothills Parkway), and one West of Foothills Parkway. Each centerline represents a reach in the development of alternatives. A third reach has been defined as the mainstem upstream of US Highway 36 where improvements could reduce the flood hazard in the West Valley.

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The study area includes the C-2 basin. The C-2 basin is a tributary basin to South Boulder Creek and was included in the MIKE FLOOD model as a series of distributed loading points throughout the West Valley. In the hydrology stage, the C-2 basin was subdivided into five basins so there are five loading points in the West Valley.

Within the West Valley, there is little open space although there are city owned properties such as East Boulder Community Center and The Flatirons Golf Course within the West Valley. Considerations will also have to be made for the Preble's Meadow Jumping Mouse habitat upstream of US Highway 36.

Identification of Flooding Problems

Based on the South Boulder Creek Floodplain/Flooding animation, the first flooding issues in the West Valley come from the C-2 loading points, flows from the Wellman Ditch/Bear Canyon Creek, and the New Anderson Ditch. Later in the simulation, the C-2 loading points start to overtop infrastructure and the mainstem starts to break out upstream of US Highway 36. At this time, there are also breakouts from the mainstem towards the West Valley. There are flooding issues in the West Valley before the West Valley flooding is associated with the flows overtopping US Highway 36. Later in the simulation, there is a breakout from Dry Creek Ditch No. 2 into the West Valley and US Highway 36 overtops. The flows overtopping US Highway 36 (approximately the 50-year flow overtops US Highway 36) become the second wave of flooding in the West Valley. At this time, the interaction between the West Valley and the mainstem begins. The final flooding problem identified in the West Valley is a flow split at the Baseline Road and Foothills Parkway intersection and flooding down Foothills Parkway.

Most of the damage estimated during the risk assessment was to properties within the West Valley, specifically those properties with basements. For the 100-year storm, there is $180 million in damages to the West Valley and $35 million in damages along the mainstem. For the 10-year storm, there is $18 million in damages to the West Valley and $11 million in damages along the mainstem. The majority of the damages associated with the mainstem are along Gaptor Road. The high hazard zone within the West Valley is mostly limited to streets.

Discussion of Known Constraints from Project Stakeholders

CDOT – US Highway 36

There is a number of potential CDOT wetland mitigation sites located within the project area. The potential CDOT wetland mitigation sites were provided to CDOT by the City of Boulder and include but are not limited to the following:

- Near the confluence of South Boulder Creek with Boulder Creek
- South of Baseline Road, west of South Boulder Creek
- North of Recreation Center
- South of CU Property

The City of Boulder is not locked into any of these wetland mitigation sites, but CDOT needs 13 acres of wetland mitigation within the area. According to Don D'Amico, a representative from City of Boulder Open Space, the City cannot construct detention on

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high quality open space lands. City of Boulder Open Space also acknowledged that more frequent inundation of open space lands would likely be an ecological benefit, as it would replicate historic flooding conditions. The project team will look into a combination of uses within the study area such as improving the channel and providing a wetland habitat area. Danielle Yearsley/CH2M HILL is a good resource regarding the improvements to US Highway 36.

USACE Reconnaissance Study

The USACE has performed a Reconnaissance Study on South Boulder Creek and is preparing to move forward with the Feasibility phase. To finalize the Reconnaissance Study phase, the USACE needs a Letter of Intent from the City of Boulder. The cost of the Feasibility Phase to the City of Boulder would be approximately $2.5 Million, which is a 50/50 cost share with Federal Funds. The advantage to the City of Boulder collaborating with the USACE for the Feasibility Study is the potential cost savings during construction of recommended improvements.

CU Property

The CU property is 308 acres and was a former gravel mine. A Conceptual Land Use Assessment was created for the CU property but the development of the property is still in the conceptual phase and there is a lot of flexibility in the plan. The conceptual plan includes areas for buildings, wetlands, natural area, flood storage, and ponds. The wetland areas located within the South CU campus can be moved as this site is still considered a reclamation site. CU is willing to cooperate with the flood mitigation project. If a portion of the CU property is used for flood storage, CU would like the City to consider providing CU with connections to water and sewer lines.

Identification of Potential Solutions

A matrix of identified problem areas versus potential solutions was presented for each reach. Reach 1, South Boulder Creek above US Highway 36, was eliminated as a reach, and the potential solutions above US Highway 36 will be included in Reach 2 or Reach 3.

The 55th Street/Dry Creek Ditch #2 FIS Profile was defined as Reach #2. In the initial presentation of the matrices, a number of potential solutions were removed due to:

- Potential solution conflicts with City of Boulder Open Space
- Potential solution conflicts with known habitat conservation area of endangered species habitat
- Potential solution has past public opposition
- Potential solution has right of way constraints
- Channel or structure does not exist

For the public meeting, a designation "N/A" will be added to each alternative solution that is not applicable for a given identified problem area.

During the discussion of feasible alternatives, it was determined that the project team will not look into improvements for the 2- and 5-year events but will include consideration of improvements for the 500-year event. Some critical facilities will require protection up to the 500-year event.

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The following is a list of conclusions from the Alternatives Development workshop for Reach 2:

- The Routine Maintenance of Existing Configuration Alternative will be used as the baseline to compare to all other alternatives and cannot be eliminated from consideration.
- Acquisition of flood prone properties will only be considered for properties within the high hazard zone. Industrial and commercial properties will not be considered for acquisition of flood prone properties.
- The only practical locations for major detention facilities are upstream of US-36 or on the school grounds.
- The Lined Flood Channels Alternative will be combined with the Existing Channel Improvements Alternative. It was also determined that lining flood channels would have significant public opposition and significant environmental impacts.
- It is not practical to realign the channel for most locations within this reach.
- It was not determined who would pay for flood proofing. Would flood proofing be paid for by the City or private owners?
- Improvements upstream of South Boulder Road will be limited by the presence of Threatened and Endangered Species (Orchid and Preble's Mouse). Raising South Boulder Road to store more water was discussed as a possible alternative because excavation behind South Boulder Road would not be possible due to the presence of T&E species.
- Between US-36 and Baseline Road, there are potential Easement and Right-of-Way issues.
- There are possible Right-of-Way constraints between Baseline Road and the Wellman Ditch.

It was determined that the natural state of the area upstream of US Highway 36 floods during storm events. To provide additional storage in this location, the storage would have to mimic the current depth/duration/frequency, etc. of flooding. For open space designated as high quality, further research must be conducted to determine the possibility of constructing a large detention facility.

Possible alternatives for Reach 3 were not discussed during the workshop.

Next Steeps

Schedule:

- A standing meeting will be set up for every other Wednesday at 10:30 AM. Alan Turner and Kurt Bauer will also coordinate via phone call as necessary.
- The initial public meeting will be held within the next month.
- Draft Alternative Plans/Recommendations - complete by August/September 2009
- Engage stakeholders when the alternatives are a more developed than they currently are
- USACE Reconnaissance Study is complete, ready to move forward with Feasibility Study
- CDOT improvements to US Highway 36 are not in the near future (possibly 2035)
- RTD Plans will not be a constraint on the recommended plan

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Initial Public Involvement Meeting

The public meeting will include a more detailed agenda broken down by reach with refined alternatives matrices. The public meeting may be set up as a 30 minute detailed presentation followed by an open house session. The alternatives development process will be explained to the public at this meeting and the public will be asked if there are additional problem areas within the study area that the project team should consider.

Action Items

- CH2M HILL will provide the project team with the Technical Memorandum produced by HDR that addresses the flood threat from a lower basin storm.
- CH2M HILL will revise the screening matrices for the two reaches within the West Valley.

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South Boulder Creek Flood Mitigation Study Conceptual Alternative Plan Identification Meeting Notes

ATTENDEES:
Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Don D'Amico/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Jeffrey Lipton/CU-Boulder
Chuck Howe/Boulder Water Resources Ad. Board
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: Aaron Cook

DATE: March 17, 2010

PROJECT NUMBER: 400168

Introduction

CH2M HILL and Alan Taylor have been looking over the possible alternative elements and alternative elements. The goal of this meeting is to eliminate some of the alternatives and end up with few alternative alignments with elements.

Every improvement recommended in a given alternative plan will have ramifications downstream. For example, if a culvert capable of conveying the 100-year regulatory flow is installed, the storage upstream will be removed, and the peak flow will increase downstream. The alternatives are in a preliminary stage right now and details such as impacts downstream will be evaluated for only the best alternative plans.

Public Meeting Review

Everyone in attendance agreed that the public meeting went well. The community impacted by the West Valley flooding was in attendance. The community was interested in the impacts to their houses and gave a few recommendations. A number of people in attendance at the public meeting suggested that open space be used for flood mitigation.

Schedule

The project is on schedule. Although the kickoff meeting was a few weeks behind schedule, the Conceptual Alternative Plan Identification Workshop was originally schedule for March 17 so the project team has made up time. The next workshop, to evaluate the best alternative plans, is schedule for the end of April.

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Development of Screening Elements

The Alternative Element Matrix was updated to include specific options rather than a dot to show which alternatives are feasible. A narrative summary was also provided. The main categories of improvements are storage and conveyance (pipes or channels).

Upstream of US-36, the options include a levee to direct flows to South Boulder Creek and storage. Storage directly upstream of US-36 would be off-line detention while any other storage location would probably be on-line storage with a large embankment and a large spillway to convey the probable maximum flood. Approximately 2,000 – 3,000 acre feet of storage would be needed for an on-line detention pond. The Town of Boulder would like an alternative for storage upstream of US-36 that does not impact the CU South Campus property. One alternative to not impact the CU property is to have a smaller detention pond upstream of US-36 combined with increased flows through the South Boulder Creek/US-36 Bridge. The US-36 Bridge over South Boulder Creek can convey the 100-year regulatory flow. Storage upstream of US-36 alone does not fix all the West Valley flooding issue but is one key element. Other improvements upstream of US-36 could include improvements to the Viele Channel and the New Anderson Ditch.

From US-36 to Baseline Road, alternatives include storage upstream of South Boulder Road, additional storage in Baseline Reservoir, improved conveyance of Dry Creek Ditch No. 2, diversions to open space, and storage at Manhattan Middle School or the Baseline Road/ Foothills Parkway Intersection. The approximate available storage at Manhattan Middle School is 35 acre-feet, not nearly enough for the 100-year regulatory peak flows.

From Baseline Road to Arapahoe Avenue, alternatives include a pipeline along Foothills Parkway, a new conveyance through the neighborhood, storage at the golf course, and conveyance improvements to the Wellman Canal and Dry Creek Ditch No. 2.

North of Arapahoe Avenue is the location of much of the damages. Possible alternatives North of Arapahoe Avenue include a new conveyance behind buildings and a splitting some of the flow to South Boulder Creek.

Bob Harburg from the City of Boulder would like to conclude that the only reasonable solution is off-line storage upstream of US-36 but the project team concluded that we should instead eliminate the options of a large pipeline from US-36 to the confluence with Boulder Creek.

According to Don D'Amico, not all open space is equal. Above Baseline road along South Boulder Creek is high quality open space which is valuable to the City. Below Arapahoe Avenue along South Boulder Creek, the open space is not as valuable to the City. Don also reiterated that excavation in open space is unlikely.

Hydrology

The 10-year regulatory hydrology for the West Valley is being used because there is no 10-year hydrology for the lower storm center analysis and the stormwater master plan only evaluated the 2- and 5-year events. The regulatory hydrology will also be used for the 100-year event for alternatives with and without storage upstream of US-36. For alternatives with storage upstream of US-36, the lower storm center analysis with a peak flow of 1100 cfs will also be considered.

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Costs of Screening Elements

A spreadsheet with alternative elements for the 100-year regulatory, 100-year cutoff, and 10-year events was provided to those in attendance. The project total on the spreadsheet includes 5% for Mobilization, 5% for Stormwater Management/Erosion Control, 15% for Engineering, 1% for Legal/Administrative, 5% for Contract Admin/Construction Management, and 50% for Contingency. Unit costs were taken from the Urban Drainage and Flood Control District (UDFCD) Master Planning Cost Estimate spreadsheet. The costs provided help to compare alternatives and individual elements to determine the most cost effective alternative. Open channels are based on a flow rate per linear foot.

Screening Level Benefits

Spreadsheets showing the average annual benefit and justifiable capital investment for four reaches within the project area were presented at the meeting. For each reach, a damage ($) versus flow rate (cfs) was created as the baseline and offset for 10-year and 100-year improvements. From the damage versus flow rate curve, a damage ($) versus probability curve was created for the 10- and 100-year improvements and average annual damage, average annual benefit, and justifiable capital investment was determined for each reach. A capital cost factor of 7% for 50 years was used in this analysis. This process will be used to determine which alternative provides the best benefit to cost ratio.

During the meeting, it was brought up that City Council will evaluate other factors besides benefit to cost ratio. Council will evaluate the types of buildings flooded, life safety, or may only look at the high hazard zone.

Discussion of Possible Alternative Plans

The following items will be considered during the alternatives evaluation:

- **Off-line detention upstream of US-36 -** The off-line detention upstream of US-36 could have the capacity to store the theoretical maximum storage (~1100 acre-feet), could match the existing storage capacity (~300 acre-feet), or could be have a storage capacity in between the existing and theoretical maximum storage. If the CU property becomes part of the detention pond, Jeff Lipton from CU would like to use the storage areas for other uses such as playing fields.
- **Drain detention under US-36 using New Anderson and Viele -** Push water through the New Anderson and Viele crossings of US-36 to the open space between US-36 and South Boulder Road and eventually back to South Boulder Creek.
- **Extend CU berm (combined storage/levee option)** - The alternative would not provide the necessary storage upstream of US-36 but would act as a levee in forcing more water through the US-36 bridge at South Boulder Creek. A large embankment would not work according to open space requirements but this options will be evaluated further. With this alternative, the project team will need to evaluate the increased hazard downstream as a result of forcing more water back to South Boulder Creek.
- **High Hazard Alternative -** One alternative will include only those improvements necessary to remove buildings from the high hazard zone.

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- **Local detention in West Valley -** The project team will continue to evaluate local detention in the West Valley
- **Diversion to South Boulder Creek –** The project team will continue to evaluate diversions to South Boulder Creek and diversion to Bear Canyon Creek.
- **Gaptor Road –** The City may annex this area with regulations concerning the types of improvements which can be made to South Boulder Creek. Possible alternatives for improvements include improved/enlarged channel or an overflow channel. It was noted that this area is within the high quality open space area.
- **Improvements to Baseline Road –** One possible alternative is to increase the capacity through Baseline Road and spreading out the flow downstream of Baseline Road.
- **Concrete channel –** Probably not a viable option but will still be considered.
- **Grass-lined channel –** Grass-lined channels would be much wider than concrete lined channels and would come with increased Right-of-Way costs and possibility of needing to purchase residential properties. The City is willing to purchase portions of properties but not an entire residential property unless it is within the high hazard zone.
- **Underground pipes –** Underground pipes will still be considered unless the costs become too expensive.
- **Diversion to Baseline Reservoir –** Baseline Reservoir is owned by Lafayette but it is believed that there is additional storage available. The diversion to Baseline Reservoir may not be formalized but may be a consequence of forcing more water to South Boulder Creek.
- **Diversion to Leggett Reservoir –** Legget Reservoir doesn't have much additional capacity. This alternative will not be removed at this time.
- **Conveyance to Boulder Creek via Bear Canyon Creek –** This alternative will be evaluated but includes trans-basin flows which may alert the Colorado Water Conservation Board (CWCB).
- **Improvements to Ditches –** Improvements to ditches will be considered but any improvement must be approved by the ditch companies.
- **Improvements at Arapahoe Avenue –** Improvements at Arapahoe Avenue will include mitigation of commercial properties. Any improvement at Arapahoe will include collecting the flow and moving it to South Boulder Creek and Dry Creek Ditch No. 2 which are believed to have enough capacity.

Next Steps

- The City of Boulder will provide CH2M HILL with a land acquisition cost.
- CH2M HILL will finalize a Technical Memorandum regarding the hydrology in the West Valley.
- CH2M HILL and Alan Taylor will assemble possible alternatives.

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- The project team will schedule a meeting with Jeff Lipton to discuss the CU south property.
- The project team will schedule a meeting with Don D'Amico to discuss open space uses once some alternative plans have been created.

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South Boulder Creek Flood Mitigation Study Workshop #3 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Shea Thomas/UDFCD
Chuck Howe/Boulder Water Resources Ad. Board
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M Hill

DATE: May 11, 2010

PROJECT NUMBER: 400168

Review Progress to Date

Mark Glidden from CH2M Hill presented a brief overview of the progress to date. Work to date includes identification of the sources of the problems, development of a suite of potential solutions, development of alternative plans, determination of design discharge, alignment refinement, cost determination, and benefit estimation.

See the Workshop No 3 Review Packet for a complete summary of progress to date.

Recommended Best Alternative Plans

High Hazard/Critical Facilities Protection

The High Hazard and Critical Facilities Protection alternative includes flood proofing of all critical facilities within the West Valley and re-grading two properties to remove two structures from the high hazard zone. The two structures in the high hazard zone are located at the location where flow overtops US 36 into the West Valley, west of Foothills Parkway. The project team evaluated using conveyance improvements and purchasing the two structures to remove them from the high hazard zone but re-grading the properties was the least costly alternative. Critical facilities include schools, senior housing, and any building with hazardous materials. The majority of the critical facilities in the West Valley are located north of Arapahoe Avenue.

No structures along Gaptor Road will be flood proofed or removed from the high hazard zone because Gaptor Road is not included in the study area or scope of work. The majority of the residents along Gaptor Road are going to be annexed into the City of Boulder but do not want improvements to the South Boulder Creek mainstem adjacent to their properties. The residents of Gaptor Road are aware of the risks associated with South Boulder Creek flooding and do not want any changes made.

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The cost of the High Hazard/ Critical Facilities Protection alternative is approximately $10,682,000 but does not include any costs for non-structural improvements such as a flood warning system.

CU Storage with Local West Valley Improvements

The detention pond located directly south of US 36 is located partially on CU property and partially on City of Boulder open space. The pond is approximately 750 acre-ft and prevents overtopping of US 36 into the West Valley. Without any grading to the pond area, the surface area of the pond is approximately 115 acres. A berm approximately 8 feet high is required constructed along the west and north edges of the pond to make this detention pond configuration work.

The pond must be 750 acre-ft due to the timing of the hydrology and the dead storage at US 36. In the regulatory MIKE FLOOD model, 300 acre-ft overtops US 36 into the West Valley, so 300 acre-ft, in addition to the dead storage at US 36, must be stored. The 750 acre-ft also represents the existing conditions without adding or removing any culverts through US 36. If all of the flow is forced back into the South Boulder Creek mainstem bridge at US 36, a total of 1150 acre-ft of storage is required to prevent overtopping of US 36. . If an additional 6′ x 4′ concrete box culvert (CBC) is placed adjacent to the existing 6′ x 4′ CBC at Dry Creek Ditch No. 2, a total of 300 acre-ft of storage is required to prevent overtopping of US 36.

The project team discussed the possibility of this detention pond configuration with Jeff Lipton from CU. Jeff Lipton suggested that excavation and a tiered approach be used to reduce the surface area of the pond and reduce the impact to the CU property. CH2M Hill will look into re-grading the detention pond to include excavation of the CU property. Re-grading the detention pond will allow CU the same building footprint as what is shown in their Master Plan for this property. The Master Plan currently shows 82 acres dedicated to flood storage. The downside to re-grading the detention pond to include excavation is that the pond at Table Mesa does not have a lot of capacity and flow reaching this pond will quickly overtop US 36. Representatives from the City of Boulder will be in contact with CU to determine what concessions will be required in exchange for this detention pond.

The local West Valley Improvements will be common among many of the alternatives in which overtopping of US 36 is prevented. The best alternative for local improvements in the West Valley is improving the Dry Creek Ditch No. 2 alignment with local storage. The diversion to Bear Canyon Creek and the diversion down the West Valley profile were much more costly alternatives, due to extra pipe costs, and were removed from consideration. The first element is a 48″ RCP to collect local inflows from US 36 to Baseline Road, west of Foothills Parkway followed by 9 acre-ft detention pond at the Baseline Road – Foothills Parkway Intersection. The 9 acre-ft detention pond reduces the peak flow from 150 cfs to 50 cfs and eliminates the need to modify the existing concrete lined channel parallel to Baseline Road which has a capacity of approximately 50 cfs.

Along Dry Creek Ditch No. 2, a 78″ RCP from South Boulder Road to Illini Way and an upsized open channel from Illini Way to Tenino Avenue are required to convey flows in Dry Creek Ditch No. 2. Improvements along Dry Creek Ditch No. 2 from South Boulder Road to Tenino Ave are not recommended as part of the City of Boulder Stormwater Master Plan. The local West Valley Improvements also include a 25 acre-ft detention pond at

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Manhattan Middle School. The detention pond at Manhattan Middle School discharges to the existing 48" RCP at along Dry Creek Ditch No. 2 and eliminates the need to upsize that pipe. With the two detention ponds upstream of Baseline Road, no improvements are required along Dry Creek Ditch No. 2 from Baseline Road to Arapahoe Avenue.

At Arapahoe Avenue, a 58 acre-ft detention pond/collection system is recommended to collect and store flows from along Dry Creek Ditch No. 2 and flows spilling across Flatirons Golf Course from South Boulder Creek. To create the storage at Arapahoe Avenue, a 3' barrier will be constructed along Arapahoe Avenue to separate vehicle traffic from bike traffic while also providing additional storage capacity. The outlet to the detention pond is a 12' x 10' CBC to an existing channel downstream of Arapahoe Avenue. The CBC also serves as a bike crossing. Currently, the City of Boulder Parks Department is updating the Master Plan for the Flatirons Golf Course and are on board with this improvement. This detention pond is included in all alternatives because each alternative has a need to collect flows at Arapahoe Avenue and it removes structures below Arapahoe Avenue from the floodplain, providing a large damage reduction, and protects critical facilities.

A drainage easement must be purchased for the existing open channel directly downstream of Arapahoe Avenue but no other improvements are necessary downstream.

Improvements to the Wellman Canal are recommended for all alternatives. These improvements allow the Wellman Canal to convey the decreed flows. A 36" RCP is recommended along the Wellman Canal through Foothills Parkway to prevent additional flows from Bear Canyon Creek to be conveyed through the Wellman Canal during flooding events.

The total cost for this alternative is $30,058,000 although the costs of the concessions to CU are unknown at this point.

Storage South of CU with Local West Valley Improvements

The detention pond south of CU is located entirely on City of Boulder Open Space. The detention pond is 400 acre-ft and has large outlet pipes so that low flows are conveyed through the pond and only the peak flows are stored within the pond. This pond has to be greater than the 300 acre-ft that overtop US 36 into the West Valley because it is located higher in the watershed.

Kurt Bauer and Annie Noble met with Don D'Amico from City of Boulder Open Space to discuss this detention pond alternative. Don said that no excavation can occur and that a berm cannot be constructed on this site. The site is a wetland mitigation site and is being purchased by CDOT. During the meeting, Don suggested an alternative detention site located adjacent to Marshall Road. The site adjacent to Marshall Road is not on City of Boulder Open Space but is a smaller site than the open space site. There would be no limits to excavation or building a berm on this site although the site would have to be purchased.

If this alternative continues forward, wetlands can be incorporated into the detention pond. Representatives from the City of Boulder are planning on meeting with Don again next week and will report to the rest of the project team.

The local improvements in the West Valley are the same as the improvements recommended in the CU storage plan. The total cost for this alternative is $28,220,000. The

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total cost assumes the cost to purchase the open space land to construct a detention pond is $36,000 per acre as was given in the Urban Drainage and Flood Control District Master Planning cost estimating spreadsheet.

Mainstem Flow Containment with Local West Valley Improvements

This alternative forces all flow above US 36 back to the South Boulder Creek mainstem by making improvements to the CU levee and extending the levee along US 36. It is likely that this levee will become a jurisdictional levee due to the height, volume stored upstream of the levee, or surface area of the storage upstream. From a comparison of the regulatory MIKE FLOOD model and the levee MIKE FLOOD model, the levee forces approximately an additional 200 acre-ft of volume and an increase in peak flow of approximately 500 cfs to the mainstem. Without any improvements along the mainstem, the levee increases the depth of flow along the mainstem by less than 0.5 meters in most locations.

Other improvements along the South Boulder Creek mainstem are also required to mitigate the additional flow that is being forced to the mainstem. The first improvement is additional storage in Baseline Reservoir. It is unknown at this time what the additional capacity of the reservoir is, the price of storage in the reservoir, or what other concessions would have to be made to store stormwater flows in the reservoir. For comparison, Pine Brook Hills paid $50,000 per acre-ft of permanent storage. The other improvement recommended along the mainstem is 2 – 8' x 5' CBCs through Baseline Road to allow some of the water ponding behind Baseline Road into open space land downstream of Baseline Road, reducing the flow in the mainstem.

The improvements in the West Valley are the same as those recommended in the detention alternatives with one exception. The detention pond at Arapahoe Avenue would need a secondary outlet, an 8' x 8' CBC with a new open channel back to South Boulder Creek. This secondary outlet is required because, unlike the detention alternatives where flow was being stored upstream, this alternative forces additional flow to the detention pond at Arapahoe Avenue.

This alternative was mentioned as a possible alternative at the first public meeting. According to UDFCD, levees are acceptable as long as the prevent flooding, but detention above US 36 would be better. The total cost for this alternative is likely greater than either detention option but does provide a possible alternative should the upstream detention options be eliminated due to constraints.

No Storage above US 36, Diversion to Bear Canyon Creek

This alternative includes no detention upstream of US 36 and large pipelines in the West Valley. In the West Valley there are two primary flow paths, one to Bear Canyon Creek and the other along Dry Creek Ditch No. 2. No local detention is recommended because the cost for local detention is greater than the decrease in cost due to decreasing the pipe size with local detention in place. Both the diversion to Bear Canyon Creek and improvements to Dry Creek Ditch No. 2 are still being considered because the cost of each alternative is similar.

The first element of this alternative is a 114" RCP extending from US 36 to Baseline Road, west of Foothills Parkway. The 114" RCP crossing the Foothills Parkway – Baseline Road intersection and continues parallel to Foothills Parkway to Bear Canyon Creek.

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An 8′ x 5′ CBC is required along the New Anderson Ditch to prevent overtopping into the West Valley and Dry Creek Ditch No. 2. Along Dry Creek Ditch No. 2, all pipes must be upsized to 90″ RCPs, and open channels must have their capacity increased to convey the 100-year regulatory flow. With large pipes, right-of-way constraints may become an issue. The section of open channel through the golf course will not be upgraded. This alternative also includes improvements to the Wellman Canal.

Similar to the other alternatives, detention/collection at Arapahoe Avenue must occur and the detention pond must have two outlets. The first outlet is a 12′ x 10′ CBC to an existing open channel downstream of Arapahoe Avenue and the second, an 8′ x 8′ CBC, to a new open channel back to South Boulder Creek. A drainage easement must be purchased for the existing open channel downstream of Arapahoe Avenue. No other improvements are necessary downstream of Arapahoe Avenue.

The total cost for this alternative is $36,533,000, higher than the detention alternatives but a low enough number to still provide a positive benefit to cost ratio.

No Storage above US 36, Improvements to Dry Creek Ditch No. 2

This alternative does not include any detention upstream of US 36 and conveyance in the West Valley must convey the 100-year regulatory flows. Similar to the previous alternative, this alternative does not include local detention in the West Valley. This alternative includes a 114″ RCP from US 36 to Baseline Road in the West Valley and a 132″ RCP to replace the existing concrete lined channel parallel to Baseline Road. Along Dry Creek Ditch No. 2, pipes are to be replaced with 90″ RCPs upstream of Baseline Road and with a 132″ RCP from Baseline Road to the Golf Course. There are no improvements recommended to Dry Creek Ditch No. 2 in the Golf Course.

Similar to the other alternatives, a detention pond/collection at Arapahoe Avenue is required to reduce the peak flow and collect flows. Two outlets to the pond are required. The first is a 12′ x 10′ CBC to the existing channel north of Arapahoe Avenue. The 12′ x 10′ CBC also serves as a bike crossing. The second outlet to the pond is an 8′ x 8′ CBC to a new open channel to convey flows back to South Boulder Creek. A drainage easement is required for the new open channel north of Arapahoe Avenue. This alternative also includes improvements to the Wellman Canal.

The total cost for this alternative is $36,092,000.

No Storage above US 36, Stormwater Master Plan Improvements

This alternative does not convey the 100-year peak flows from the regulatory model but does solve the flooding issues associated with the 5-year peak flows from the City of Boulder Stormwater Master Plan. There is no detention associated with the alternative, upstream of US 36 or local detention in the West Valley.

For local inflows, a 48″ RCP is recommended from US 36 to Baseline Road in the West Valley. No improvements are necessary for the existing concrete lined channel parallel to Baseline Road or along Dry Creek Ditch No. 2 from South Boulder Road to Arapahoe Avenue. For local inflows from Baseline Road to the Wellman, a 36″ RCP is necessary along Foothills Parkway. A 36″ RCP is recommended along 55th Street from approximately Tenino Avenue to Baseline Road and another 36″ RCP is recommended west of 55th Street

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connecting to the Wellman Canal. Downstream of Arapahoe Avenue, a 48″ x 30″ RCP is needed along Dry Creek Ditch No. 2 to the railroad and a 54″ x 36″ RCP is needed from Arapahoe Avenue to South Boulder Creek west of 55th Street.

The total cost for this alternative is $13,004,000.

Damage Estimates

CH2M Hill has reproduced the damage estimates from HDR with a few modifications. It appears that HDR double counted approximately 30 properties in the West Valley so the CH2M Hill damage estimates in the West Valley are less than those produced by HDR.

The following is a summary of the HDR approach to damage estimates and the FEMA BCA.

HDR Approach

- Used Hazus Curves
- Depth/damage relationship
- Stepwise function
- Assessed values

FEMA BCA

- Possible change to Hazus Curves
- Uses curve rather than stepwise function
- Uses flow rate versus damage relationship
- Replacement values rather than assess values

Because of the difference in approach, the FEMA BCA and the approach used by HDR may lead to differing results. CH2M Hill suggests the HDR approach with a few modifications.

- Use updated Hazus Curves
- Use replacement value

The project team must speak with representatives from the State to determine if this approach will work because the State has stated previously that, in order to get grant money, the City of Boulder must use the FEMA BCA approach.

Next Steps

- Water Resources Advisory Board Meeting – June 21, 2010
- Second Public Meeting – July, 2010
- No conference call on Wednesday, May 12, 2010

Action Items

- CH2M Hill will run the best alternative plans in MIKE FLOOD on the 8 meter grid.

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- CH2M Hill will determine the residual floodplain for each alternative input into MIKE FLOOD using the 8 meter grid. Using the results of the residual floodplain, the damage associated with each property will be determined and a benefit to cost ratio for each alternative can be established.
- CH2M Hill will evaluate excavation at the CU detention site
- CH2M Hill will evaluate the possibility of additional storage in Baseline Reservoir
- CH2M Hill will evaluate how the stormwater master plan improvements impact critical facilities and facilities within the high hazard zone
- CH2M Hill will provide the City of Boulder with a figure for detention at Manhattan Middle School. The City of Boulder will discuss this alternative with representatives from Manhattan Middle School.
- CH2M Hill will send a copy of the PowerPoint presentation to the project team
- CH2M Hill will send a link to the FEMA BCA software
- CH2M Hill is working on sections of the report

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South Boulder Creek Flood Mitigation Study Recommended Plan Selection Workshop Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Bob Harberg/City of Boulder
Annie Noble/City of Boulder
Don D'Amico/City of Boulder
Bob Crifasi/Dry Creek Ditch #2
Shea Thomas/UDFCD
Jeffrey Lipton/CU-Boulder
Chuck Howe/Boulder Water Resources Ad. Board
Christina Martinez/CWCB
Steve Griffin/CDOT
Bob Hayes/CDOT
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Alan Taylor/Alan Taylor Consulting

FROM: CH2M HILL

DATE: August 11, 2010

PROJECT NUMBER: 400168

Action Items

- Kurt Bauer will contact property owners impacted by the South of CU Detention Alternative.
- Kurt Bauer and Alan Turner will meet with Bob Crifasi on August 12, 2010 to discuss impacts to Dry Creek Ditch #2.
- CH2M HILL will coordinate with Danielle Yearsley/CH2M HILL about the improvements to US 36.
- For each alternative, CH2M HILL will evaluate the impact to critical facilities.
- CH2M HILL will prepare an outline/shell of the public meeting PowerPoint presentation and send to the project team for review prior to the public meeting.
- Christina will send the USACE document on flood proofing to the project team.

Introduction

The goals of this workshop are to present the work done to date and the seven best alternatives, to discuss the seven best alternatives, and to come to a conclusion about the recommended plan(s). The project team and stakeholders will also discuss what will be presented to the public at the next public meeting. Chuck Howe is concerned that each alternative is mutually exclusive. The alternatives being mutually exclusive is fine for presentation to the public. It is still possible that alternatives could be combined, phased, or both.

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Review of Work to Date

The project team has developed alternatives, sized elements for each alternative, and determined the cost and benefit for each alternative. The seven best alternatives are as follows:

- High Hazard/Critical Facilities Protection
- CU Detention with West Valley Improvements
- South of CU Detention with West Valley Improvements
- Mainstem Flow Containment with West Valley Improvements
- Pipeline Diversion to Bear Canyon Creek
- Dry Creek Pipeline
- Stormwater Master Plan

Each alternative was evaluated on the following criteria.

- Cost
- Average annual benefit/Present worth of project benefits
- Benefit to cost ratio
- Water Quality Impacts
- Environmental Impacts
- Social Impacts
- Other Factors

Best Alternative Plan Discussion

Alternative 1 – High Hazard/Critical Facilities Protection

The High Hazard/Critical Facilities Protection alternative focuses on public health and safety. There are two structure within the high hazard zone near the US 36 overtopping into the West Valley. These structures will be removed from the high hazard zone with localized grading improvements, but will not be removed from the 100-year floodplain. The goal of removing these structures from the high hazard zone is to reduce imminent danger of structural damage or potential loss of life.

The critical facilities protection portion of this alternative focuses on flood proofing all critical facilities within the study area. There are 25 critical facilities within the West Valley, most of which are commercial properties north of Arapahoe Avenue. Critical facilities include schools, facilities with at-risk populations, and facilities containing hazardous materials. The list of critical facilities was provided by the City of Boulder and only those facilities identified as critical facilities are included in this alternative.

Flood proofing can be problematic and is not always a reliable alternative. For purposes of evaluating the benefit of flood proofing, the project team should assume that flood proofing is only 50% reliable.

The City will not be paying for flood proofing of commercial critical facilities.

Alternative 2 – CU Detention with West Valley Improvements

The CU Detention with West Valley Improvements alternative focuses on preventing the 100-year flood from overtopping US 36 with a 560 acre-ft detention pond at US 36, partially on CU property and partially on City of Boulder Open Space property. The detention pond

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berm begins at the US 36 bridge over South Boulder Creek, continues west along US 36 and the ramp from Foothills Parkway to US 36, and wraps around the Table Mesa Pond. The maximum berm height is 18 feet near the Table Mesa Pond and the maximum berm height along US 36 is 6 feet. There are no water rights issues associated with this alternative because water is stored in the detention pond for less than 48 hours.

According to the Colorado Department of Transportation (CDOT), the Regional Transportation District (RTD) is in the process of designing a pedestrian bridge and on ramp near the Table Mesa Pond. The Environmental Impact Statement (EIS) also changes the Foothills Parkway to US 36 ramp which could impact the design of the detention pond. It was determined that the alternatives are only in the conceptual design phase and any design changes could be made at a later time.

CDOT was asked whether or not they would allow an embankment to be built adjacent to US 36 or if they would allow US 36 to function as the embankment for the pond. CDOT would probably accept an embankment adjacent to the ramp as long as it doesn't impact the EIS area and would prefer to have US 36 and the detention pond embankment separate. CDOT also suggested that a maintenance agreement would have to be agreed upon so CDOT would not be responsible for maintenance of the detention pond.

The spillway to the detention pond would be across US 36 towards open space and back to South Boulder Creek. CDOT stated that they could reinforce US 36 at the spillway location. The existing outlets along Viele Channel and the New Anderson Ditch do not have to be improved with this alternative. There is some question if the spillway can be directed back to South Boulder Creek since the existing flow path is towards the West Valley.

Don D'Amico noted that some of the embankment is still on City of Boulder Open Space property and in a natural area with endangered species. The project team noted that the detention pond may provide a more reliable habitat for wetland species. Don stated that detention is typically to infrequent to provide a reliable source of water for wetland species and wetland species are already present meaning there is already a reliable source of water in this area.

West Valley Improvements

The West Valley improvements are common among the detention and mainstem flow containment alternatives. The West Valley Improvements include a 9 acre-ft detention pond at the Foothills Parkway and Baseline Road intersection with improvements (raise downstream concrete wall by 1 – 2′) to the channel parallel to Baseline Road to prevent overtopping.

Also included in this alternative are 8′ x 6′ concrete box culverts at four road crossings along the New Anderson Ditch parallel to South Boulder Road. Additional storage in the US 36 gore point is also recommended. This improvement does not impact Dry Creek Ditch #2.

Improvements to Dry Creek Ditch #2 include an increased ditch capacity from Illini Way to Tenino Avenue to prevent overtopping into the adjacent neighborhoods. At Tenino Avenue, all excess flows would be routed to a detention pond at Manhattan Middle School and no additional flows would be routed to Dry Creek Ditch #2 downstream of the Manhattan Middle School detention pond. Bob Crifasi, representing Dry Creek Ditch #2, stated that the ditch cannot accept additional flood flows due to liability issues. If the ditch

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company were to allow flood flows into the ditch, they would ask for a complete waiver of liability. The project team should consider a pipeline parallel to Dry Creek Ditch #2 from Illini Way to Tenino Avenue. The ditch company has a 25′ easement along Dry Creek Ditch #2 so coordination with the ditch company would still be necessary. These same topics should be considered when recommending improvements to the New Anderson Ditch or the Wellman Canal. Both the City of Boulder and the ditch company prefer to separate drainage facilities from ditches so this alternative should include a separate facility for drainage conveyance.

The detention pond at Manhattan Middle School has a capacity of 25 acre-ft and is tiered to allow the fields to be inundated under different flows. The northeast corner of the field becomes the deepest portion of the pond. The pond outlets from the northeast corner back to Dry Creek Ditch #2. This pond eliminates the need for improvements to Dry Creek Ditch #2 downstream.

Along the Wellman Canal, a waste away structure is recommended near Foothills Parkway to allow flood flows back into Bear Canyon Creek. The Wellman Canal company does not want to reduce the capacity of the canal.

A 58 acre-ft detention pond is recommended at Flatirons Golf Course along Arapahoe Avenue. This pond has two outlets; the first is a 12′ x 10′ concrete box culvert to an existing drainage channel and the second is a 6′ x 6′ concrete box culvert in the northeast corner back to South Boulder Creek. Two pond outlets are needed because there are two low points in the pond. No other improvements are recommended downstream of Arapahoe Avenue.

The residual floodplain for the CU Detention with West Valley Improvements alternative shows that much of the damage in the West Valley is eliminated. There is still a residual floodplain north of Arapahoe Avenue but that is caused by flood flows from South Boulder Creek, not through the West Valley. Although there is still a residual floodplain, there is a significant reduction in damage due to a reduction in the depth of flooding. The benefit to cost ratio for this alternative is 2.15 which includes a lot of reduction of residential property damage.

It was suggested that the project team be better prepared to discuss the benefit/cost information at the public meeting by including slide(s) in the PowerPoint presentation. The slide(s) can discuss critical information such as the 7% discount rate over 50 years recommended by FEMA and the process by which the average annual damage for each alternative was calculated. Some of this information may be posted to the website prior to the public meeting.

Alternative 3 – South of CU Detention with West Valley Improvements

This alternative includes a 420 acre-ft detention pond south of the CU property. The pond is a two-stage pond with upper stage being located between Marshall Road and Highway 93 and the lower stage located east of Marshall Road. The lower stage will require the purchase of three parcels, one of which is owned by CU. There is a large antenna on the parcel owned by CU making negotiations with CU for this parcel potentially difficult. All parcels contained in the detention pond are inundated in the existing 100-year flood. Other property owners impacted by this detention pond will be notified of the upcoming public meeting.

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The inflow into this detention pond is from flows overtopping Highway 93 and from South Boulder Creek overflows. The pond releases decreed flows to Dry Creek Ditch #2 and the main release from the pond is through a weir back to South Boulder Creek. According to Bob Crifasi, this pond cannot impact Dry Creek Ditch #2. The maximum berm height is 13′ with a maximum excavation of 5′. This pond was designed to minimize impacts to City of Boulder Open Space property but still impacts approximately 4 acres and a portion of the berm must be constructed on Open Space property.

According to Don D'Amico, City of Boulder Staff would not be in favor of this alternative. The parcel between Highway 93 and Marshall Road is owned by open space (approximately 10 acres) so the impact to Open Space property is actually 14 acres. There is also a conservation easement on the large parcel to be occupied by the lower pond, there would be visual impacts to the area, and there would be a disposition of open space. The US Fish and Wildlife Service is also trying to get this area designated as a Preble's Meadow Jumping Mouse habitat.

This alternative also includes improvements at the Viele Channel near US 36 to prevent overtopping of US 36 and the same West Valley improvements presented in the previous alternative. The residual floodplain is also similar to residual floodplain for the previous alternative. The benefit to cost ratio for this alternative is 2.51, higher than the previous alternative due to less land acquisition costs for the pond.

Alternative 4 – Mainstem Flow Containment with West Valley Improvements

The goal of this alternative is to force flows to the South Boulder Creek mainstem and through the bridge at US 36. To mitigate the impacts of forcing flow back to South Boulder Creek, approximately 210 acre-ft of water would have to be stored at Baseline Reservoir. The project team discussed this alternative with representatives from Baseline Reservoir and it was concluded that this is not a viable alternative due to uncertainty about the requirements the State Engineer may impose if additional water is stored in the reservoir.

The other elements of this alternative are improvements through Baseline Road along the mainstem of South Boulder Creek and West Valley improvements similar to the detention alternatives.

Alternative 5 – Pipeline Diversion to Bear Canyon Creek

This alternative includes a large (114") pipeline diversion from the West Valley to Bear Canyon Creek as well as pipeline additional pipelines parallel to Dry Creek Ditch #2 for flows which cannot be diverted to Bear Canyon Creek. This alternative would be considered a trans basin diversion and may cause water rights issues.

The other elements of this alternative are improvements to the Wellman Canal and a 58 acre-ft detention pond at Flatirons Golf Course similar to the West Valley improvements alternative.

The residual floodplain shows a reduction in damage through the West Valley. The residual floodplain is significantly larger at Bear Canyon Creek than the previous alternatives but does not cause an increase in damage. The residual floodplain is also larger downstream of Arapahoe Avenue because no limited water is being stored upstream. The benefit to cost ratio for this alternative is 1.25. The cost for this alternative is significantly higher than the detention alternatives due in part to significant utility relocation costs.

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Alternative 6 – Dry Creek Pipeline

The Dry Creek Pipeline alternative forces all flows to a large pipeline parallel to Dry Creek Ditch #2. The other elements of this alternative are improvements to the Wellman Canal and a 58 acre-ft detention pond at Flatirons Golf Course similar to the West Valley improvements alternative.

The large pipeline alternative forces more flows towards the Industrial Park North of Arapahoe Avenue, increasing the depth of flooding, increasing the damage to the high value commercial properties meaning the average annual benefit for this alternative is not as great as in the Diversion to Bear Canyon Creek Alternative. The costs for this alternative are lower than in the Bear Canyon Creek Alternative because only one pipeline is constructed. The benefit to cost ratio is 1.24.

Alternative 7 – Stormwater Master Plan

The Stormwater Master Plan includes only minor improvements to the existing stormwater infrastructure in the West Valley. This alternative has a low benefit to cost ratio (0.10) because the storm sewers are surcharged during the 100-year event and there is limited reduction in floodplain area or flooding depth. The Stormwater Master Plan alternative is designed to address nuisance flows, not large flood events.

Discussion and Selection of Recommended Plan

The public meeting will be held on September 2, 2010. It was determined that some of the alternatives will not be presented in detail at the public meeting. The public meeting presentation and stations will focus on the two detention alternatives and the high hazard/critical facilities protection alternative. The large pipeline alternatives will not be presented in detail and there will not be a station for either pipeline alternative. The mainstem flow containment alternative will be presented but will not have a station. The stormwater master plan will not be presented.

The project team will be prepared to discuss the following issues which are expected to be brought up by the public:

- Hogan Pankost Property
- Costs/Benefits
- Ditch Company Issues
- CU Detention
- South of CU Detention

Prior to the public meeting, CH2M HILL will prepare an outline/shell of the PowerPoint presentation and send to the project team for input. It was determined that information will be posted to the website prior to the public meeting and no printouts will be brought to the meeting. Public meeting figures should include the 100-year residual floodplain.

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SBC Flood Mitigation Study – Alternative Refinement Workshop #1 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Mark Taylor/Architerra

FROM: CH2M HILL

DATE: July 20, 2011

This meeting summary documents the major decision made during Workshop #1.

Review of Alternative Refinements

Bear Canyon Creek Pipeline Alternative

Bear Canyon Creek pipeline alternative alignment refined by Alan Taylor to avoid utility conflicts. The previous alignment followed the Stormwater Master Plan alignment. The new alignment follows Thunderbird Drive, crosses Foothills Parkway, then runs along the east side of Foothills Parkway before tying into the previous alignment. Additional excavation would be required along the east side of Foothills Parkway because of the existing noise berm but no right of way purchase is required. The new alignment eliminates all water and sewer crossings except major lines.

The alignment for the improvements along Dry Creek Ditch #2 was also refined by Alan Taylor to take advantage of existing easements. There are no existing easements between Tenino Avenue and Baseline Road along Dry Creek Ditch #2.

CH2M HILL is attempting to contact Qwest and Xcel to additional utility line information. If CH2M HILL cannot get this information from Qwest and Xcel, the City of Boulder has atlas sheets which have this information.

The inlet structure for collecting the flow overtopping US 36 was determined using the floodplain map, existing topography, aerial imagery, and Google Earth Street View. The inlet structure includes Type R inlets along Thunderbird Drive, Type R, Type 13 inlets and a lateral pipe along Pima Court, Type R inlets and a lateral pipe along Osage Drive, and Type R Inlets and a lateral pipe along Qualla Drive.

Regional Detention at US 36

The US 36 Environmental Impact Statement (EIS) includes widening US 36 to the north. To be conservative, the berm was shifted 20 feet off the edge of payment which allows CDOT room for an extra lane or a bike path. The new grading results in some fill between the berm and the roadway.

The berm for the Regional Detention at US 36 alternative impacts less open space and critical habitat than what OSMP assumed.

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Distributed Regional Detention

The berm for the detention pond at US 36 for the Distributed Regional Detention alternative is lower than that for the Regional Detention at US 36 alternative. The berm is 20 feet off the edge of US 36 and 15 feet off the edge of CU property.

The Distributed Regional Detention alternative was originally modeled, in MIKE FLOOD, with on-line control structures at the bridges (US 36, South Boulder Road, and Baseline Road). The control structure at US 36 cannot be an on-line structure but must replicate the hydraulics of the on-line structure. To replicate the hydraulics of the on-line control structure, approximately 1,000 cfs must remain in the main channel with the remaining 6,000 cfs being conveyed in a lowered overbank. The lowered overbank requires approximately 4 feet of excavation. A berm extending from the US 36 bridge to the lowered overbanks keeps the flow in the main channel from interacting with the flow in the overbank. The flow in the overbank is stored in a pond with an outlet structure discharging back to the South Boulder Creek main channel upstream of US 36. This alternative increases the impacts to open space and critical habitat.

The detention pond/berm at South Boulder Road includes the following:

- Conspan Structure
- Realign Viele Channel 10 feet east
- Maintain existing Dry Creek Ditch #2
- Berm to protect homes from Viele Channel overflows
- Pipe New Anderson Ditch under berm
- Extend Viele Channel culvert through South Boulder Road
- Possible bike trail along top of berm
- Spillway points away from West Valley for flows greater than 100-year
- Berm is 10 feet of edge of pavement
- Maximum berm height is 7 feet above South Boulder Road
- Concrete wall instead of berm to separate Dry Creek Ditch #2 from Viele Channel

The detention pond/berm at Baseline Road includes the following:

- Conspan structure
- Offset of property lines to maintain access, easements, etc.
- Maximum berm height is 9 feet above Baseline Road
- Equalizing culverts to spread flow into open space and away from South Boulder Creek mainstem
- Irrigation ditches need to be reconnected (ditches in this area are return flows)

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- Trail head to be relocated
- Trail connections to be reestablished

Review of Conceptual Renderings

Two renderings were presented at this workshop:

- Looking southwest from the intersection of Baseline Road and Cherryvale Road (Distributed Regional Detention alternative)
- Looking south from the Table Mesa Drive overpass to University of Colorado property (Regional Detention at US 36 alternative)

Both renderings are based on grading provided by CH2M HILL to show the actual visual impacts of the berms. Neither rendering shows plantings, other than grasses, on the berms. Because of the process used in creating the renderings, if the viewpoint changes, the renderings must be redone.

Review of Required Easements

Dry Creek Ditch #2 has a 10′ existing easement on the east side, but there are no easements between Tenino Avenue and Baseline Road. The required easement width along Dry Creek Ditch #2 can be reduced if the preferred alternative is a 72″ RCP instead of a 34 foot top width open channel.

An easement is needed downstream of Baseline Road to raise the concrete wall.

An easement is needed downstream of Arapahoe Avenue for the secondary channel from the detention pond at Arapahoe Avenue to the South Boulder Creek mainstem. This property is in plans for development. To reduce the easement cost, the open channel could become a pipe. To be conservative, the open channel will remain the preferred alternative.

Review of Utility Conflicts

Conflicts of water, sewer, and sanitary lines were evaluated using GIS. The review of utility lines led to the adjustment of some pipeline alignments.

South Boulder Creek Restoration Project

The OSMP project from South Boulder Road to Marshall Road along the mainstem of South Boulder Creek should no impact on this project.

Review of Budget and Progress to Date

Schedule

Next progress meeting – August 3, 2011

Next workshop – August 17, 2011

Presentation to WRAB – Fall 2011

Presentation to OSMP – Winter 2011

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SBC Flood Mitigation Study – Alternative Refinement Workshop #2 Notes

ATTENDEES:

Kurt Bauer/City of Boulder
Shea Thomas/UDFCD
Alan Taylor/Alan Taylor Consulting
Mark Glidden/CH2M HILL
Alan Turner/CH2M HILL
Aaron Cook/CH2M HILL
Mark Taylor/Architerra

FROM: CH2M HILL

DATE: August 17, 2011

This meeting summary documents the major decision made during Workshop #2.

Update on Design Elements

The improvement to Dry Creek Ditch #2 between Illini Way and Tenino Avenue has been changed from a 34 foot top width open channel to a 72 inch diameter RCP. The pipeline includes a 25 foot easement which is less than the 40 foot easement required for the open channel.

The grading diversion structure for the detention pond at US 36 in the distributed regional detention alternative has been updated. The updated structure increases the impacts to open space and critical habitat but the function of the structure hasn't changed.

The berm at South Boulder Road for the distributed regional detention alternative has been revised to include a small wall between the Viele Channel and Dry Creek Ditch #2. The revised berm reduces the impacts to open space.

Update on Open Space Memorandum

The impacts to open space and critical habitat increased for the detention pond at US 36 for the distributed regional detention alternative. The impacts to open space have increased by approximately 8 acres. The lowered overbank area could be returned to open space after construction but this area would still need to be purchased.

According to the City of Boulder's GIS layers, there are no wetlands upstream of US 36. It was determined that the City has identified wetlands in this area but they aren't included in the GIS layer.

The impacts to open space and critical habitat for the South Boulder Road berm are slightly less than what the City of Boulder Open Space and Mountain Parks has previously presented.

No changes at Baseline Road

Update on Revised Cost Estimates

The revised cost estimates for the US 36 detention alternative and the distributed regional detention alternative increased while the cost estimate for the Bear Canyon Creek Pipeline

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alternative remained relatively unchanged. The largest changes in the detention alternative is due to increases in the cost of the berms, easements, and wetland mitigation.

Detention Ponds

CH2M HILL had previously used and equation based on the volume of storage to determine the total cost for the regional detention ponds. The unit costs from the UDFCD spreadsheet are based on local detention and result in costs that are too high for large detention ponds. In the refined analysis, actual quantities (earthwork, imported core material, riprap, concrete, and re-vegetation) were used to estimate the total cost of the detention ponds. As a result of the refined analysis, the total cost for each detention pond increased substantially. CH2M HILL will evaluate the assumptions used to develop the refined cost estimate for the detention pond and update the project team.

Easements

Easements costs were based on existing zoning code and City of Boulder prices per square foot for land acquisition. A land acquisition cost of $0.83 per square foot was used for open space lands and for acquisition from CU. The detention pond on CU property does not impact any developable land.

The zoning for Manhattan Middle School is Public ($19 per square foot). In the refined cost estimate, it is assumed that the cost for land acquisition at Manhattan Middle School is $0.83 per square foot, the same as open space, because the pond area will be reconstructed the match the underlying function of the land.

An additional 12 to 13 foot easement is required along Dry Creek Ditch #2 for the 72 inch diameter RCP. The easement is substantially less than the easement required for the 34 foot top width open channel.

Contingency

It contingency is currently set at 50%. The default for the UDFCD cost estimation spreadsheet is 25%. Because the alternatives have been evaluated in more detail, it was determined that the contingency can be reduced to 30 or 35%.

Wetlands Mitigation

Wetlands mitigation has been included in the refined cost estimate at $100,000 per acre at an assumed 2:1 mitigation rate. The cost per acre includes purchasing the land and construction and design of the wetlands. The cost per acre is similar to the cost CH2M HILL has estimated for other projects.

Utilities Contingency

A contingency of 32% has been added to all pipeline costs to account for utility relocation. A CH2M HILL internal cost estimating tool was used to determine the contingency for an urban area with no other information. The cost for utility relocation will be evaluated in further detail during conceptual design.

Update on Benefits and Phasing

To determine the benefit for individual elements included in each alternative plan without running additional MIKE FLOOD models, the results of the benefit/cost analysis for each

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alternative were manipulated to isolate the individual element. The benefits were estimated using an results adjusted to account for the fact that the 8 meter grid overtops US 36 during the 25-year event while the 4 meter grid overtops US 36 during the 100-year event.

The phasing of each alternative is based on the benefit to cost ratio, capital costs, flood control, life safety, and public interest.

For the detention alternatives, all local west valley improvements will be lumped together such that the benefits become easier to quantity. The local west valley improvements included improvements to the New Anderson Ditch, Dry Creek Ditch #2, Manhattan Middle School, the Wellman Canal, and the detention ponds at Baseline Road and Foothills Parkway.

For the Bear Canyon Creek Pipeline alternative, the lateral pipes and inlets will be included with the main pipeline and inlets along Thunderbird Drive.

Update on Flood Proofing

Frasier Meadows Manor

The flood proofing for Frasier Meadows Manor includes a 3 foot tall barrier wall around the perimeter. The garden level units at Frasier Meadows Manor make it impossible to flood proof at the building. With the 3 foot barrier wall, the entries/exits from Frasier Meadows Manor become problematic. Alan Taylor suggests using a floating gate that raises when there is flooding, similar to other gates used in the City of Boulder. During a flood, emergency access to Frasier Meadows Manor would be via access points on the north and west sides of the building. Alan Taylor will look into the cost of flood proofing Frasier Meadows Manor.

Friend's School

The flood proofing for Friend's School, located at the corner of Baseline Road and 55th street, will at the building. The 100-year depth at Friend's School is approximately 1 foot, so the entire perimeter of the building would be flood proofed to a 3 foot depth. Flood proofing this facility results in no change to the floodplain.

Gas Stations

Flood proofing of gas stations include ensuring underground structures are water tight and buoyancy resistant. Gas stations must all have automatic shutoff valves. Additional minor flood proofing around the structure itself can also be done.

Update on Renderings

Update on Terrain for Flood Mapping Study

Update on Report Outline

Schedule and Next Steps

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Appendix A-3

Public Meeting Minutes

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South Boulder Creek Flood Mitigation Project

Public Meeting #1 - March 3, 2010

The public meeting began at 5:30 PM and was finished at 7:45 PM. A 30-minute presentation by the project team that outlined the project, past studies and goals of the flood mitigation project started the meeting. At the conclusion of the presentation, general questions were entertained from the public and then the attendees gathered around four stations to ask questions and discuss potential problems and mitigation solutions related to specific project reaches

General Questions and Answers

Q1. How will the changes from the mitigation project be incorporated into FEMA Floodplain Mapping?

A1. The City of Boulder, after completing a mitigation project, will revise the FEMA floodplain maps through a Letter of Map Revision (LOMR). This process is currently occurring on the Elmer's 2-Mile project.

Q2. How will the construction portion of the flood mitigation project be funded?

A2. The City of Boulder has earmarked $4 Million Dollars in 2012 for potential construction of the mitigation project. Other Sources for funding could come through the Federal Emergency Management Agency (FEMA) Grant Programs, the United States Army Corps of Engineers (USACE), and cost sharing projects with the Urban Drainage and Flood Control District (UDFCD).

Q3. How will current construction and development projects be incorporated into the flood mitigation study?

A3. As the flood mitigation project proceeds, current construction and development in the floodplain will be reviewed to ensure the mitigation solution incorporates these changes to the floodplain.

Q4. How was the initial South Boulder Creek Flood Mitigation Project Public Meeting publicized?

A4. The public meeting was advertised on the City's web site, 2,200 postcards were sent out to properties impacted by the South Boulder Creek 100-year floodplain, notices were sent to the newspaper, and an E-newsletter was sent. The project website address is **www.southbouldercreek.com**

Q5. What is the existing warning system that is in place if flooding occurred on South Boulder Creek?

A5. The City of Boulder has collaborated with UDFCD to implement a flood warning system in Boulder. This flood warning system consists of a network of rain gages, stream gages and radar systems to track rainfall, stream flow and storm events. If it

appears that South Boulder Creek would flood, flood sirens along South Boulder Creek would be sounded to evacuate residents and reverse 911 calls and text messages can be sent to warn residents.

Q6. How often are sirens tested?

A6. During April - October (flood season in Boulder) they are tested the first Monday of every month at 10:00 AM.

Q7. Have you looked at what other communities are doing to address flooding?

A7. The City is a member of UDFCD has hired a consultant and individual team members have professional project experience so the project team is aware of what is working and being adopted in other municipalities.

Q8. Have you looked at potential development and taken into consideration future development for the flood mapping and flood mitigation study?

A8. The flood mapping study was completed using future land use conditions. Boulder is almost completely built out and does not have large areas of land that can be developed. Development and redevelopment can occur in the watershed however; the hydrology for the flood mapping study took into account development and will move forward, unaltered, for the flood mitigation study. While the new floodplain has not yet been adopted, the City is already regulating to the revised 100-year floodplain. In fact, City Council has directed City Development Services to regulate to the most conservative flood elevation from either the effective FEMA study or the revised floodplain study.

Q9. Does this plan take into account Denver Water's Plan to increase the size of Gross Reservoir?

A9. The flood mapping study did consider this. However, during the hydrology study the most severe flood threat was the result of a storm centered below Gross Reservoir, so the reservoir had limited impact on the flooding on South Boulder Creek.

Q10. Are the public meeting exhibits available for the public to review?

A10. The maps and matrices are available on the project website at www.southbouldercreek.com. The presentations and other comment forms will be posted on the website shortly after the meeting.

Q11. How much cash is available for implementing the study?

A11. The City's Utility Capital Improvement Budgets has identified $4 million in 2012 to account for the study, land acquisition and design. $3 million of that total will be secured through bonds, the repayment of which is factored into the existing rate structure. Currently $1 million dollars in cash is available.

Q12. How will the selected plan construction be phased?

A12. It will depend on the selected alternative project and what makes sense physically and hydraulically.

Q13. The 100-year flood does not mean much to folks was the 1969 flood a 100-year flood?

A13. The 1969 flood was estimated to be smaller, about a 25-year flood. The 100-year flood is the flood that has a 1% chance of occurring in any given year. However, the 100-year storm can occur back to back.

Q14. What is the definition of the 100-year flood and how much rainfall that is?

A14. The 100-year storm was a six-hour storm with a peak rainfall of 3.89". (During the meeting the depth of this storm was mistakenly reported as around 5 inches)

Q15. What causes the flooding?

A15. Rainfall across the basin overwhelms the stream system. Four major causes.

1. Rain over West Valley causes initial West Valley flooding before South Boulder Creek Floods
2. As the flood peak approaches US-36, South Boulder Creek does not have capacity to contain the flow so flood waters flow out onto the shallow floodplain
3. As the South Boulder Creek Flood peak reaches US-36, the roadway is overtopped causing significant flooding of the West Valley
4. Culverts downstream of US-36 are undersize and contribute flows to the west valley

Q16. What is the depth of the flooding?

A16. Flooding depth varies across the floodplain from 6" deep to more than 8 feet deep depending on location. Floodplain maps can be found on www.southbouldercreek.com.

Q17. What is the duration of the flooding?

A17. The storm duration is six hours and the flood will subside substantially within 12 – 24 hours.

Q18. What are the worst types of damage?

A18. The risk assessment describes in detail the damage and risk from flooding and can be found on the website at www.southbouldercreek.com.

Q19. Will the sewer systems function during a flood?

A19. It is anticipated that the sewer system will be overwhelmed during a flood.

Comments Received on the Boards and Flip Charts

South of US-36

1. Consider proper natural channelization of South Boulder Creek to prevent floodwaters from leaving the channel.

US-36 to Baseline Road

1. Hogan/Pancost - City has built up and is building soccer fields above natural grade in the area. Previous development raised the natural grade as well. This raised grade is causing groundwater to rise and is flooding basements south of Manhattan Middle School.
2. Groundwater is about 1' below ground between US-36 and Baseline Road and needs to be taken into consideration.
3. Dry Creek No. 2 Ditch should be piped from South Boulder Road to the existing pipeline at Tenino Avenue to prevent flooding along the ditch.

Baseline Road to Arapahoe Avenue

1. The Wellman Ditch has not been maintained in several years and should be maintained.
2. The Wellman Ditch should be placed in a storm sewer pipe.
3. Stormsewer should be added to Merritt Drive diverting flood flows north to Arapahoe Avenue.

North of Arapahoe Avenue

1. South Boulder Creek should be channelized along its entire length similar to Boulder Creek to prevent flood flows from leaving the main channel, particularly at roadways.

Comments Received on Comment Sheets and Email

Additional Problem Areas

1. Manhattan Drive – Runoff from South Boulder Road flows out, down Manhattan Drive, and along the ditch easement. Flow overwhelms gutters along Manhattan Drive and inundates lawns and driveways. Water freezes in the wintertime with ice 4 – 6" deep in the gutter.
2. The Intersection of Kewanee Dr. and Cimarron Way floods with minor rainstorms. In the winter, melted snow does not drain away leading to a skating rink.
3. Dry Creek No. 2 Ditch should be piped from South Boulder Road to the existing pipeline at Tenino Avenue to prevent flooding along the ditch.
4. City soccer fields west of East Community Center were raised 4' in 1979 (?) and are again being raised by the City's recreation deptartment. Website does not contain any information on new soccer fields. Soccer fields are currently creating a dam by being raised.

5. Dry Creek No. 2 Ditch functions as a storm drain for Cimarron Street, Kewanee Street and part of Manhattan.
6. Iroquois and Manhattan floods and has inadequate storm drainage to handle minor storms
7. Keep high groundwater in mind when evaluating solutions
8. Look at the impact of raising soccer fields 4 – 5 feet.
9. There is an overflow identified along the berm west of Foothills Parkway. This berm is high above the ground and seems unlikely to be overtopped. This area should be reviewed.
10. How will the changes to the soccer fields including artificial turf west of the EBRC effect flood drainage to neighborhoods west of the fields. Will flood mitigation be included in the soccer fields? Is the Land going to be raised at the soccer fields?
11. How will the development of the Hogan-Pancost parcel affect storm and flood drainage due to the increased imperviousness. How will this affect the neighborhood west of the parcel?

Additional Solutions to Carry Forward

1. Provide containment for South Boulder Road overflow entering Manhattan Drive.
2. Pipe Dry Creek Ditch No. 2 behind homes on Oneida Street to the existing culvert on Tenino Avenue.
3. Improve drainage from Kewanee Drive and Cimarron Way to drain water to Dry Creek Ditch No. 2.
4. Do not allow development of Hogan/Pancost parcel and use it as a drainage easement to drain floodwaters to the east and open space. (Between US-36 and Baseline Road)
5. Re-grade soccer fields to 1970 grades west of East Community Center to prevent ponding and water flow to Kewanee Area
6. Enlarge Dry Creek No. 2 Ditch to prevent flooding in the Kewanee area.
7. Detention south of US-36 appears to provide the biggest benefit.

Additional Comments

1. Maps do not show names. Great Meeting
2. Good meeting but should be held in a larger hall. You are wrong in saying the newspaper was used to publicize the meeting. Do a better job of publicizing meetings because many people are interested.
3. Good Informative Meeting
4. Do not talk so fast in the presentations.

Email Comments

1. Pipe Dry Creek Ditch No. 2 behind homes on Oneida Street to the existing culvert on Tenino Avenue.
2. Provide a direct link to the flooding animation on the South Boulder Creek Web Site
3. Most logical and cost effective alternative would be a directional levee to direct the flood back to and through the bridge under US Highway 36, together with enough flood storage above the highway to knock down the flood peak to a manageable level.

South Boulder Creek Flood Mitigation Planning Public Meeting #2 Meeting Notes

TO: City of Boulder

FROM: CH2M HILL

MEETING DATE: September 2, 2010

Introduction

This document summarizes the public feedback and input received at the second public meeting for the South Boulder Creek Flood Mitigation study held September 2nd, 2010. Comments and questions were organized in subtopics based on alternative or general comments or questions.

Introductory Presentation

Kon Damas, the meeting facilitator, introduced the project team and the meeting format that was to include a short presentation, answers to general questions and breakouts into a series of stations around the room where more detailed questions related to specific alternatives could be answered.

Kurt Bauer, the City's Project Manager, gave a brief overview of the project status to date and reiterated the objective of the meeting was to solicit public input on the alternatives being presented.

Mark Glidden, the consultant Project Manager, described the approach to the technical analysis of the various alternatives starting with the alternative screening and then discussing the improvement cost estimates and benefits.

Alan Turner, the consultant Project Engineer, described each of the alternatives evaluated in anticipation of this meeting. They included:

Alternative 1 – Status Quo
This is the do nothing but actually continues the current floodplain management programs within the City.

Alternative 2 – High Hazard Mitigation and Floodproofing of Critical Facilities
This alternative has limited structural improvements but does modify grading to remove two properties in the High Hazard Zone. It also includes the floodproofing of structures designated by the City as Critical Facilities.

Alternative 3 – Regional Detention at US 36 with Downstream Improvements
This alternative provides a large regional stormwater facility immediately upstream of US 36, inundating portions of CU and open space property, to reduce the potential for overflow of US 36. Improvements are included

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downstream within the West Valley to capture and collect tributary inflows and eliminate the 10-year floodplain from the area.

Alternative 4 – Regional Detention near Hwy 93 with Downstream Improvements
This alternative provides a large regional stormwater facility immediately downstream of Hwy 93, inundating two large privately owned parcels as well as small portions of open space property, to reduce the potential for overflow of US 36. Improvements are included downstream within the West Valley to capture and collect tributary inflows and eliminate the 10-year floodplain from the area.

Alternative 5 – Conveyance Upgrades to Bear Canyon Creek and Dry Creek no 2
This alternative includes large pipes and other conveyance infrastructure to capture and convey overflows from US 36 and carry them away from flood prone properties. Once captured and collected, a portion of the flow is diverted to the adjacent Bear Canyon Creek drainageway where existing conveyance capacity exists. Improvements are required along Dry Creek No 2 to minimize the flood potential downstream.

Alternative 6 – Conveyance Upgrades to Dry Creek no 2
This alternative includes large pipes and other conveyance infrastructure to capture and convey overflows from US 36 and carry them away from flood prone properties. Once flows are captured and collected, improvements are required along Dry Creek No 2 to minimize the flood potential downstream.

Alternative 7 – Mainstem Containment
This alternative builds infrastructure above US 36 to prevent the overflows along US 36 to the west, thereby preventing the overtopping of US 36. A diversion into Baseline Reservoir of some of the additional flood water passing under US 36 is required to mitigate the increased discharge. Conveyance improvements along the mainstem are required to provide further mitigation.

Alternative 8 – Nuisance Flooding Upgrades Only
This alternative provides a storm sewer system that addresses nuisance flows but does little to control major floods.

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Kurt Bauer then returned to review the relative cost and benefit of the various alternatives. He presented the following table (the table alternatives have been rearranged to be consistent with the presentation numbering):

Alternative	Estimate Cost	Benefit to Cost Ratio	Pros / Cons / Issues
1 Status Quo	$0	0	• Flood risk still remains
2 High Hazard and Critical Facility Protection	$10,700,000	2.2	• Does not reduce floodplain limits • Questions regarding reliability of floodproofing
3 Regional Detention at US36	$35,900,000	2.15	• Some impacts to Open Space and habitat • Requires formal agreements with several entities
4 Regional Detention near Hwy 93	$30,700,000	2.51	• Requires purchase of private property • Habitat issues • Requires formal agreements with several entities
5 Bear Canyon Creek Pipeline	$46,286,000	1.25	• Significant disruption during construction
6 Dry Creek No. 2 Pipeline	$45,661,000	1.24	• Significant disruption during construction
7 Mainstem Flow Containment	$39,245,000	0.6	• State Engineers and water quality issues with Baseline Reservoir
8 Nuisance Flood Improvements Only	$13,976,000	0.1	• Does not substantially reduce floodplain limits

General Comments and Questions

- Label and number all figures and alternatives clearly.
- Figures and alternatives numbers need to track and correspond to comment sheet and handouts.
- How many homes will be lost in a 100-year and 500-year flood?
    a. 700 homes will be removed from the 100-year floodplain
- Why was the floodplain remapped?

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- Where operation and maintenance (O&M) costs included in all cost estimates for detention basins, pipes and other facilities?
- What neighborhoods are affected by the flooding and the proposed alternatives?
- How long will construction of the alternatives take?
- Can flood insurance be bought even if you do not live in the 100 year floodplain?
    a. yes
- How deep are the flood waters throughout the West Valley?
    a. It varies by location
- In general the attendees wanted more frequent opportunities for public comment.
- Attendees at the meeting would like future email notifications on public hearings including the citizen groups that were a part of the original flood mapping study.
- Too much budget has been spent with too little public input.
- It would be helpful is benefits were shown on the maps.
- How do other proposals/alternatives affect other neighborhoods?
- What is the length of time of disruption with these plans?
- What is the flood danger in the City? Is it solely related to the high hazard zone or only 100-year flood plain?
- During the 100 year flood – because roads and buildings are built better – there is a question as to whether or not water would be going over roads based on experience.
- Why does the effective FEMA County/City floodplain map not match the floodplain shown on the new mapping?
    a. The new floodplain mapping has not yet been adopted by FEMA. This should happen around January 2011.
- Are properties being added to the 100-year revise floodplain?
- How has the floodplain changed?
    a. A large floodplain has been identified in the West Valley
- How much water is going down the streets in the West Valley Neighborhoods?
    a. Floodwaters in the West Valley are relatively shallow but widespread.
- Benefits were estimated based on flood reduction. How did you get a dollar number from the benefits?
    a. Based on quantitative result by looking at assessed values and reduced flooding
- Is the City open to additional alternatives?
- Arizona has a unique model for flood control that includes detention on individual properties.
    – Dispersed detention
    – Contains tax incentives for individual property owners to build detention
    – Can be implements over many years
- Who will ultimately make the decision as to what alternative is selected?
    a. City council
- Why was the SBC mapping study initiated?
    a. The City knew the floodplain was wrong
- When will we know what alternatives have been selected or removed from further review?
    a. The City Staff will not form an opinion on which alternative is preferred until they get public feedback.

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a. Formal agreements would be required before any alternative moved forward. These formal agreements would include but is not exhaustive:
    - Individual property owners
    - University of Colorado
    - Independent ditch companies
    - City of Boulder Park and Recreation
    - City of Boulder Open Space and Mountain Parks
    - Boulder School District

- How do we (the public) know you are using correct models?
- Does benefit/cost ratio include or recognize the future potential change in zoning, structures and types of structures that may be built as the buildings in the West Valley age?
- The new flood mapping study has significant implications to property value based on the new 100-year floodplain. In the new floodplain property owners can't make improvements or remodel which affects resale value of the homes. For residents in the West Valley this flood mapping study and flood mitigation project is not just an issue of getting flood insurance.
- How many homes are projected to be removed by each alternative?
- Private property and homes should not be taken to implement solutions.
- The South Boulder Creek website is difficult to navigate and understand. On line mapping tool does not seem to work.
- The CU levee has to be certified.
    a. CU qualifies as public entity that can certify and maintain a levee according to FEMA.
- Does CU have any liability with flooding due to the berm/levee?
- South Boulder Creek big issue. 10 years ago the City spent money looking at flood mitigation through the West Valley. This was rejected by the public. It seems like the City has let public opinion die down and are now raising the issue again.
- The 500 year flood event needs to be analyzed with each alternative.
- Why are there no costs associated with Environmental/Social impacts?
- There is no trust for City officials.
- Attendee confirmed that the 1938 Flood resulted from a storm originating downstream of Gross Reservoir and the floodplain matches stories from what his grandfather told him.
- City of Boulder Open Space has restrictions on land use and habitat limitations that can constrain what improvements can be made in these areas.
- Action items need to be posted on the web site.
- Consultants should not charge extra to analyze new alternatives presented by the public.
- How many of the plans will have a positive impact on the West Valley?
- What is the benefit to insurance companies of completing a mitigation project?
- No one at the meeting was against flood mitigation just against certain alternatives.
- The public should be considered a stakeholder.

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Stakeholder Comments

Urban Drainage and Flood Control made a short statement that included the following points:

- UDFCD does not believe in condemnation.
- UDFCD believes flood control and open space go together to create or enhance habitat/recreation values.
- UDFCD does not like pipes; and would rather see open channels.

Dave Webster, from Boulder County Transportation, was not notified and the Boulder County commissioners were not notified. Dave Webster will update Boulder County commissioners on the content of this public meeting.

Alternative Specific Comments

Alternative #1 – No Action

- Attendees agreed that something should be done to minimize the flood hazard in the West Valley that does not impact private property.

Alternative #2 – High Hazard / Critical Facilities Protection

- How many structures are in the high hazard zone?
    a. 2 structures are in the high hazard zone.
- Why is the East Boulder Recreation Center not considered a High Hazard facility considering it stores chlorine and other chemicals?
- High hazard zone is not based on a Gross Reservoir failure.
    a. Only the 100 year storm event was used in estimating the high hazard zone.
- It would be helpful to clarify what a "Life and Limb" issue is.
- What is the High Hazard Zone? How deep or fast is the water?
    a. High hazard zone definition is a product of velocity (feet per second) and depth (feet) greater than 4.

Alternative #3 – Regional Detention at US-36

- How was the CU property valued for the cost estimates?
    a. The project used fair market values for the cost of the property
- CU has offer to donate land for flood storage in the past– why is there a cost now?
- Why can't the CU South Campus gravel pits that exist across the property be used for flood storage?
- The Wellman Canal from Bear Canyon Creek in the 1960's caused flooding through the West Valley Area. How will the Wellman Canal flooding be addressed?
    a. Improvements to avoid overflows from Bear Canyon Creek are a part of each alternative that involves conveyance improvements
- Manhattan Middle School – use lot for detention (ball fields).
- Would like to see a comparison of the number of structures damaged depending on alternative.
- CU Berm may be protecting West Valley from experience with previous floods.

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Alternative #4 – Regional Detention near SH-93

- What happens if a property owner is not willing to sell so that an alternative can be constructed?
- Saving Marshall – 80% of attendees support saving Marshall and oppose Alternative 4.
- Property owner Gary Swanstrom has established a website, www.rescuemarshall.com and read a statement during the meeting. The following points were included in a letter provided to the City:
    - He is not a willing seller.
    - "My house is not in the floodplain". The house and related structures are not in the floodplain.
    - Would like to see the pond placed in open space.
- Mr. Swanstrom's neighbors, Pat and Jon Militzer, made the following statement and provided a copy of their comments to the City:
    - They are not willing sellers.
    - They noted photographs of the high groundwater in the area of their residence.
    - Would like to see the pond placed on open space
- There is a high water table through the Marshall area.
- City will have to augment flows with water rights if the groundwater is exposed by the Marshall pond. The City does not own the water.
- Water table high in the area of the Marshall Pond. Pond will be full of groundwater and will not be able to hold full flood detention flows.
- City doesn't own water rights to the irrigation ditches and could have a legal issue with modifying the flow in those ditches by impounding water.
- Marshall Residents and landowners only had 2 weeks' notice of the alternative and public meeting.
- Marshall Residents and landowners had inadequate notification and would like email notice in the future of all meetings.
- The City open space behind Gary Swanstrom's Property is more suitable for detention.
- Open Space behind the Swanstrom property is damaged by gravel pits and could be restored to a more beneficial function through the flood control pond.
- The pond would destroy natural features and habitat. This habitat is currently undisturbed and has been historically undisturbed and should be left in that condition.
- Why can't take 41 acres of open space be used for flood storage?
- Move detention to open space.
- Flood detention upstream on south Boulder Creek should be reviewed. This includes a dam in Eldorado Canyon, west, of Eldorado State Park.
- The Rolling Rock area should be used for detention (Open Space north of Swanstrom/Militzer Properties).
- Would the City consider Condemnation?
- Marshal residents not part of the City and do not have representation in City Council. Stay out of Marshal.

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- Can the City condemn land outside of the City limits?
- CU South Campus should be bought and detention pond built there.
- Why not mitigate flood hazard upstream with Gross reservoir or sites upstream?
    a. Storm center and worst flood hazard are below Eldorado Canyon.
- Attendees do not believe the 2.51 Benefit/Cost ratio of alternative #4 because of high groundwater issues.
- There is distrust in the analysis and the model. Decisions are vulnerable to how the model was created. Results should be ground truthed by talking to people on ground.
- Is flood detention most effective at SH-93? Should it be lower in case a storm center moves further north in the basin?
- City should be looking at flood protection for Marshall.
- If the storm is centered differently Hwy-93 pond may not capture flood flows.

Alternative #5 – Mainstem Flow Containment

- No comments were registered for this alternative

Alternative #6 – Dry Creek Ditch No. 2 Pipeline Improvements

- The Southeast Boulder Neighbor Association should be involved during construction/after to understand and mitigate impacts from alternatives #6/#7 to adjacent properties.
- Try to stay within ditch easement / park property to minimize impacts to adjacent properties.
    a. Large Pipelines would replace Dry Creek Ditch No. 2.
    a. Detention would reduce pipe size diameters.
- Big pipes mean big excavation it is desirable to minimize impacts to tree and do not want to see trees taken down.
- What is percentage blockage assumed for the large pipeline alternatives? Pipelines generally will block and may provide limited flood protection due to debris.

Alternative #7 – Large Pipeline Diversion to Bear Canyon Creek

- The Southeast Boulder Neighbor Association should be involved during construction/after to understand and mitigate impacts from alternatives #6/#7 to adjacent properties.

Alternative #8 – Nuisance Flow Alternative

- No comments were registered for this alternative

Breakout Sessions

The public requested that the public comment period be extended in lieu of having breakouts at the previously described stations. No breakout session was conducted although team members provided responses to individual questions posed after the meeting was adjourned.

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South Boulder Creek Flood Mitigation Study
2nd Public Meeting Municipal Service Center
Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
1	Cathy Kowalski	28238 Richmond Hill	303838-2830	ckowalsk@jeffco.k12.co.us
2	Anna Hall	1493 Marshall rd	303-494-4632	annahall@rams.colostate.edu
3	Marcy Gallamore	6491 McIntyre Ct	303-456-6150	gmg1974@q.com
4	MARY CRUZ	7710 W 87th Dr #C	303 420-3504	
5	Sarah Rogers	1351 Marshall	303 250 1749	Sarah.Rogers@colorado.edu
6	Erin Moran	834 Marshall Rd	720 304 8610	maranep@yahoo.com
7	Richard Beran			
8	Kyle Bohnenstiehl	1351 Marshall Rd	720-320-7501	kyle@NAGI.com

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
9	Joyce Takamine	5449 Omaha Pl Boulder 80303	303 554-9785	jabira55@msn.com
10	Peter Ornstein	556 Aztec Dr Boulder 80305	303-499-2310	pno@mediaticnal.com
11	Andrea Larson	1588 Marshall Rd Boulder 80305	303-494-6013	andrealarson@q.com
12	Kelly DiNATALE	4833 VALHALLA DR BOULDER 80301	303-349 3668	Kelly@dinatalewater.com
13	KAREN LEWINN	PO Box 18238 B 80308-1238	3 494 5854	KLEWINN@yahoo.com
		LIVE on MANHATTAN DRIVE 80303		
14	Beverly Seeds	4721 McKinley Dr 80303	31447-0453	bevboulder@hotmail.com
15	Charles Demarest	1568 Marshall Rd.	303-931-3330	kryptoc@ix.netcom.com

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
16	RON CRAIG	260 CIMMARON WAY	303-494-2147	roncraig boulder@msn.com
17	William P.S. Breeden Jr	30 S. Bella Cir #3017	303-444-3669	
18	Jane Grotluschen	5887 S. Vale Rd	3-499 4510	jbgrotluschen@hotmail.com
19 20	WILL + SARAH PITTENGER	1524 MARSHALL RD.	303-494-8113	
21	Gary Myre	3175 11th St	3-587-8629	myre31@msn.com
22	Ruth Nielsen representing my parents Lloyd & Mary Vickery	127 Glen Mawr Dr. Rollinsville CO 80422	303-258-7337	Paschat11@aol.com
		5445 Marshall Rd		Ruth@Sparkmix.us

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
23	Olivia L. Carstensen	160 Manhattan Dr	303-494-4695	—
24	Gabriele Sattler	62 Huron Ct	303.554.6308	
25	Jeannette Armbrustmacher	33 So Holman Way Golden 80401	303-279-0418	Own 5431 White Place
26	FERN BOWMAN	5444 WHITE PL	3-817-9702	
27 28	ROBERT + LOUISA MATHIAS	980 CRESCENT	720-287 8162	
29	Ed Stroud	5215 Illini Way Boulder	303 499 7305	
30	Jim Broaddus	112 Mineola Ct	303-819-8895	jim@jimbroaddus.com

South Boulder Creek Flood Mitigation Study
2nd Public Meeting Municipal Service Center
Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
31	William Hall	1493 Marshall Rd	303-494-4132	hallb@ucar.edu
32	JOHN MILITZER	1190 MARSHALL RD	494-8219	MILITZER@UCAR.EDU
33	PAT "	"	"	FRIGAHOAGIE@COMCAST.NET
34	GARY SWANSTROM	1422 MARSHALL ROAD	303 494-7608	gjswanstrom@netzero.net
35	Carol Hall	1493 MARSHALL	303 494 4632	hallcik@hotmail.com
36	Pam Rice	1251 Marshall Rd	303 810 1468	plr@indra.com
37	Diana and			bobdianagabe2@msn.com
38	Bob Gehnicke	5420 Marshall Rd	970-240-0054	
39	JOE REA	5501 MARSHALL RD	303-499-5534	—

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
40	Kim Opler	1498 MARSALL Rd	303-494-1110	Kimopler@
41	Carly Carpenter	Boulder CO 80305	c) 720-838-7084	comcast.net
42	Riley Carpenter			
43	Scott Sober	1303 Marshall Rd Boulder, CO 80305	303-817-7501	scott@soberopa.com
44	CAROL ATKINSON	255 CIMMARON WAY 80303		abwlabu@yahoo.com
45	Marjorie Maague	3545 ARTHUR CT 80304		mpmaag@e.a yahoo.com
46	Judith Moore	1527 MARSHALL RD BLDR, CO 80305		JudithMoore@ Colorado.edu
47	PATRICK CLOWES	1613 MARSHALL RD.	3.447-0147	patrick.clowes
48	+ DOREEN CLOWES			@gmail.com

South Boulder Creek Flood Mitigation Study
2nd Public Meeting Municipal Service Center
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51 52	Jim + Jean Johnson	130 Manhattan Dr.	303-494-6710	jjbridges@msn.com
53	Ed McDowell	PO Box 229 Boulder, Co 80306	303-588 7727	ecmcdjr@aol.com
54	Clancy Philipsborn	5316 Pennsylvania Ave Boulder - 80303	3/884-8887	clancyph@aol.com
55 56	Robert + Yvonne Pickerwell	1591 Marshall Rd 1575 Marshall Rd	303-499-3416 303-499-5811	
57	Stacy Zander	3082 E. 143rd Pl Thornton Co 80602	303-424-8803	stacy_zander@juno.com
58	SARAH COWEN	1524 MARSHALL RD. BOULDER, CO	303.494.8113	sarahecowen@ gmail.com sarahecowen@ gmail.com

South Boulder Creek Flood Mitigation Study
2nd Public Meeting Municipal Service Center
Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
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61	Gene Peterson	5496 Seneca Pl Boulder	303 494-0621	jfpeterson@juno.com
62	DAVE WEBSTER	BOULDER COUNTY TRANSPORTATION DEPT P.O. BOX 471 BOULDER, CO 80306		
63	Tim Jacks	1453 Marshall Rd Boulder, co 80305	720 308 6675	Timjacks2@comcast.net
64	Don Chambers, AIA	1525 Marshall Rd.	303-554-5591	don@chambersarchitecture.com
65	Ruth Blackmore	705 S 41st Street 80305	3/494-3009	ruthelb@hotmail.com
66	John Stevens	~~[illegible]~~ 6420 Gunpark Dr Ste B Boulder CO 80301	3 210 3333	J.Stevens@ Sports Development.com

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	Name	Address	Phone	Email
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68	Lyle Rosbotham	1190 ALBION BOULDER, CO 80305	303-554-0797	Lyle@HIS.COM
69	Luis Martinez	10586 W. 107th Ave Broomfield	303-469-2488	
70	Robert Sharpe	5995 marshall Dr 80301		RSharp4802@AOL
71	Linda Gerstle	1521 Marshall Rd 81305	303-494-9169	lindagerstle@comcast.net
72	Shelley Schlender	751 Crescent Drive	3/494-2545	shelleyschlender@yahoo.com
73	TIM ENE	1506 S. FOOTHILLS HWY BOULDER, 80305	303-601-3654	T-ENE@NORTHAMSOFTWARE.COM

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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

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74	Loretta Hempstead	3315 Dover Dr 80305	303 4949325	llhemp2001@comcast.com
75	DON BARSHAY	705 S. 41st St. 80305	303-494 3009	
76	Jo Martinez	10556 W 107th Ave Broom	303 469-2488	
77	Gordon McCurry	1200 Albion Rd Boulder 80305	303-494-8771	gmccurry@comcast.net
78	Beth Ornstein	556 Aztec Dr	303-499-2317	beth@mediationnow.com
79	Mary Nelson	4800 QUALLA DR	303-499-0571	Please mail notices. Thx
80	Les Nelson	"	303-499-0571	

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

	Name	Address	Phone	Email
81	FRED CACCESE	1065-D FAIRWAY CT BOULDER, 80303	3/494-9134	fcaccese@hotmail.com
82	GLENDA LAINIS	375 MANHATTAN DR BOULDER 80303	720 8873524	aglainis@aol.com
83	BEN BINDER	720 So. 41ST BOULDER 80305	303-499-2568	BDINDER@DDGINC.COM
84	Jim Fulton	4995 Ricaire Dr Boulder 80303	303-494-3549	Jagfulton@aol.com
85	Chris Jessen	4900 RICARA DR	307-287-3546	Cjessen8@yahoo.com
86 87	Les Botham Leonard Rice Engrs.	2000 Clay St Denver CO 80211	303 455 9589	Les.Botham@LREwater.com
88	TAYLOR FREY	630 CREE CIR. & 5540 CENTRAL AVE	(303) 442-6995	taylor@flatironpark.com

South Boulder Creek Flood Mitigation Study
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	Name	Address	Phone	Email
89 90	Anne & Bob Fink	5432 whiteflower Boulder (Co) 80303	(303) 494-8958	robert_fink@colorado.edu
91	JOHN JASEK	19328 HILL DR. Morrison Colo	303 697 1868	JRJASEK@AOL.COM
92	Julie Leonard	1534 Marshall Rd Boulder, CO 80305	303-499-4811	j.a.leonard@mindspring.com
93 94	Jim & Helena Knox	5322 Pennsyl. Boulder 80303	303-499-9345	
95 96	Lynn & Sandi Spradlin	1019 S Foothills Hwy 80305	303-444-0542	sanlyn1@mail.com
97 98	Priscilla Robb Larry Trilling	1275 Marshall Rd Boulder 80305	303-494-2165	ltrillin@hotmail.com priscillarobb@hotmail.com
99	Letty Perkins	1423 Marshall Rd Bldr. 80305	303 499 0177	

South Boulder Creek Flood Mitigation Study
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Thursday Sept. 2, 2010 5:00 – 8:30 P.M.

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101	Bryce Kowalski	4305 W Kenyon Ave	720.934.7382	bryce983@yahoo.com
102	[illegible]	186 CARRS	303-237-6324	—
103	Marci Gasek	19328 Hill Dr.	3/697-1668	mjasek@jeffco.k12.co.us
104	David Shomper	3170 Kittrell	303 494 0629	dshomper@mac.com
105 106	Michael + Mary Craven	1475 Marshall Rd	720-299-9206	mmcraven@peoplepc.com
107	Keagan Rowley	1455 5th 74th Street	505 153 1077	Krodwalley@gmail.com

Appendix A-4
Stakeholder Meeting Minutes

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SBC Flood Mitigation Study – CU Meeting 5-6-10

ATTENDEES: Kurt Bauer/City of Boulder, Jeff Lipton/ University of CO, Mark Glidden/CH2M HILL, Alan Turner/CH2M HILL

FROM: CH2M HILL

DATE: May 6, 2010

The Taggert study indicated that considerable value accrues from storage in the South Boulder Creek watershed. This study has reached the same conclusion. Several different storage, size and geometries are being considered. Jeff indicated he wanted to know how much the current study proposals differ from those in the Taggert study so that he can approach his boss and the Board of Regents.

The current study looks at three different storage concepts, ranging from 300 acre feet (AF) to over 1200 AF. Each of these has some impact on the CU South Campus and may impact the use of the land for some of the identified purposes. Jeff recognized this would probably be the case. He wanted to make sure the impacts were limited and that full advantage was taken of the designated areas, including the lower pond.

Jeff described some of the basic constraints Cu would like to impose. First, they want to try and minimize the impact to the plan they formulated and presented to us at the first workshop. This describes areas they anticipate will be inundated as well as those areas they wish to preserve for development. He also described the access road and the challenges they faced when developing that alignment. They need to maintain the proposed configuration as closely as possible. There may be some potential to modify grades but not the alignment.

The team described the 750 AF alternative. This has an 18′ maximum berm height and minimizes excavation. However, it does have a pretty big impact to the identified building sites. Jeff asked if it would be possible to minimize that impact by doing some excavation and increasing the storage volume on areas not designated for development. He also expressed concerns about the extent of ponding at the current tennis court site. He encouraged the team to look at more excavation and any other means to reduce the footprint of the ponded area. He reiterated his interest in using the low area and pond to the north to the fullest extent possible. The team indicated we would look at ways to use more of the designated flooding area and reduce the impact on the sites designated for development.

Jeff did note that the fact the site has a reclamation permit means there are no designated wetlands on the site.

The team asked that Jeff provide some insights on the cost and political implications of the proposed plans. In particular, it was hoped that there would be a better understanding of the cost associated with land acquisition and any other necessary infrastructure improvements. Any other issues such as annexation or utility service needs could impact the feasibility of the alternatives and would need to be identified as early as possible.

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The team mentioned that the cost of land required by other entities was getting clearer. Parks would not require any direct payment of land used. Boulder Valley Schools would require the purchase of an easement at prevailing land rates. Open space was not likely to charge for the use of their lands but were likely to require other concessions.

The schedule was discussed. The interest in having the first presentation to WRAB on June 21 and then a public meeting in July make the determination of some of the details of the CU storage site critical. It is hoped that CU can provide feedback as soon as possible.

Jeff offered that the current alternatives that show ponding at a depth of 20′ at the tennis courts is unworkable and unacceptable. The team should look at excavation to minimize the depth and footprint of flooding in those areas designated for development.

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SBC Flood Mitigation Study – CU Meeting 6-24-10

ATTENDEES: Kurt Bauer/City of Boulder, Bob Harberg/ City of Boulder, Jeff Lipton/ University of CO, Mark Glidden/CH2M HILL, Alan Turner/CH2M HILL

FROM: CH2M HILL

DATE: June 24, 2010

Alan provided an overview of the current proposed pond configuration and the way the system works. (Proposed CU Detention Figure attached) The pond proposed in 520 acre feet (AF), smaller than the probable size discussed at the previous meeting. The pond volume was developed by using the natural topography and excavating to minimize the footprint. The excess excavated material is proposed as fill to elevate key areas of the CU property.

Alan also described the function of the lower pond. This pond controls the Viele channel and isn't really an element in the mainstem flooding from South Boulder Creek. The pond controls the tributary area draining along the Viele Channel and prevents that from surcharging the system and overflowing across US 36. However, the size is quickly overwhelmed if uncontrolled flow from the mainstem is allowed to reach the pond. The team concluded the lower pond needs to be isolated from uncontrolled mainstem flows. However, the timing and volume are such that the new storage pond can be drained into the Viele channel and then under US 36. Using this outfall avoids the need to construct another crossing under the highway.

Both Jeff and Bob identified that he proposed configuration should explore the expansion of the storage area to include the Table Mesa Pond by wrapping the embankment around that site. Alan would look at this to determine what the embankment configuration might look like.

Bob noted that the schedule for the project was to have the alternative evaluation done by the end of the year and then work with the City's Boards and Council to finalize the plan. He noted that the costs now are in the $30-40M range and it wasn't likely the City could come up with that kind of money in the short term. The team is looking at alternative funding sources such as the state through a Pre- Disaster Mitigation Grant or from the feds by working with the Corps of Engineers.

One key element is the cost of the land. The team is looking at costs ranging from $36k/acre to $19/SF depending on land use type. The selection of the cost has a profound effect on the viability of an alternative. Jeff suggested we look at recent open space land purchases to find a cost that could serve as a precedent.

Jeff asked if we have been coordinating with CDOT. Bob indicated that discussions have been held. During those discussions, they indicated that improvements to US 36 are very low on the list of priorities and that it may be 20 or 30 years before anything is done to the highway. There is some work ongoing related to a pedestrian overpass and other improvements outside the highway. Jeff mentioned that he was aware of some

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improvements to the configuration of the Table Mesa interchange. His contact is Mike Sweeney.

Jeff indicated he needed the following information before he could take the alternatives to his bosses:

- Estimate the acreage that would be undevelopable including the area within the Table Mesa pond.
- Compare the current configuration with the original plan and determine the impact on the developable footprint.
- Use the cost of recent open space acquisitions for agricultural lands as the basis for land costs that were designated as open or flood storage. Use developed costs for those areas designated for development.
- An updated version of the plan showing the impacts to the CU plan

Jeff noted that it would be desirable to be able to co-locate their detention storage within the bigger pond area. This probably would not material impact pond sizing and could be incorporated during final analysis and design. He also indicated that if grading was going to be done, it would be good if it could be done in such a way as to accommodate the future construction of recreation fields. He provided a plan with the desired recreation field layout. The team agreed to incorporate this in future modifications.

The City and CU need to figure out the terms of any development agreement or utility concessions. CU is ready to begin these negotiations. It isn't unreasonable to assume that process would lead to other issues.

The issue of groundwater levels was raised. Not only can that impact the potential effectiveness of the ponds, but exposed groundwater can have water rights implications. The team assured him that we have tried to avoid any impacts to extent data was available.

The site is still under a reclamation plan and any modifications would need the approval of the Mined Land Reclamation Board.

Jeff asked to look at the lower pond configuration again. Alan explained that we did look at the possibility of storage in the lower pond and simulated the hydraulics. The result was that a workable pond had to be about 30′ deep and might have some groundwater issues.

The team did consider a storage options above the CU property. This project includes a berm near Marshall Road that would control downstream flooding. This pond is also being revised based on feedback from Open Space. It would continue to result in some inundation of the CU property but no physical improvements would be required.

When developing costs for the CU pond, it is only necessary to consider rough grading costs in addition to land and pond infrastructure. CU would not expect any of the recreation fields to be built using these project funds.

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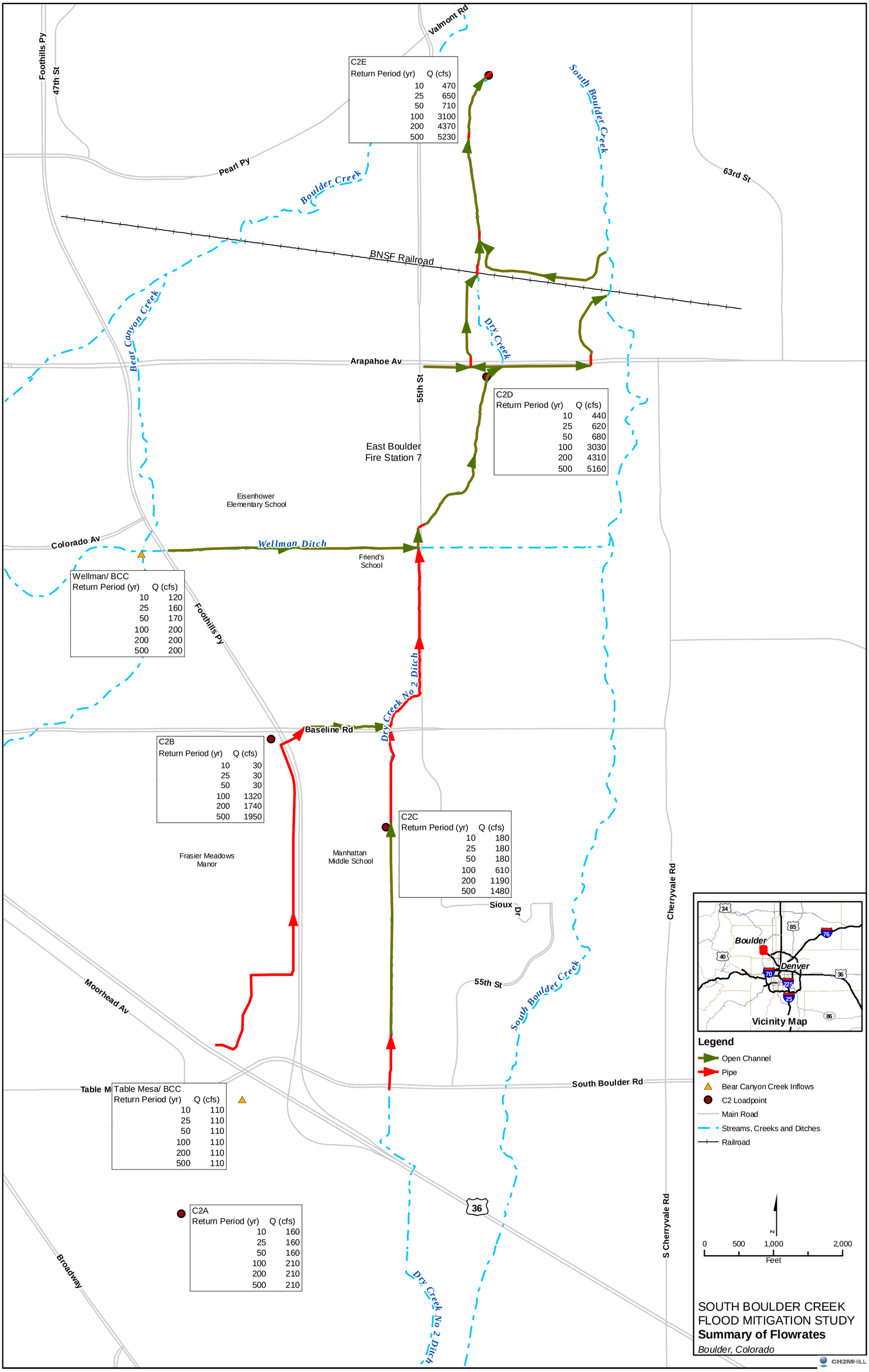
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Elementary School
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500 1480
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C2A
Return Period (yr) Q (cfs)
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Vicinity Map
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Main Road
Streams, Creeks and Ditches
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FLOOD MITIGATION STUDY
Summary of Flowrates
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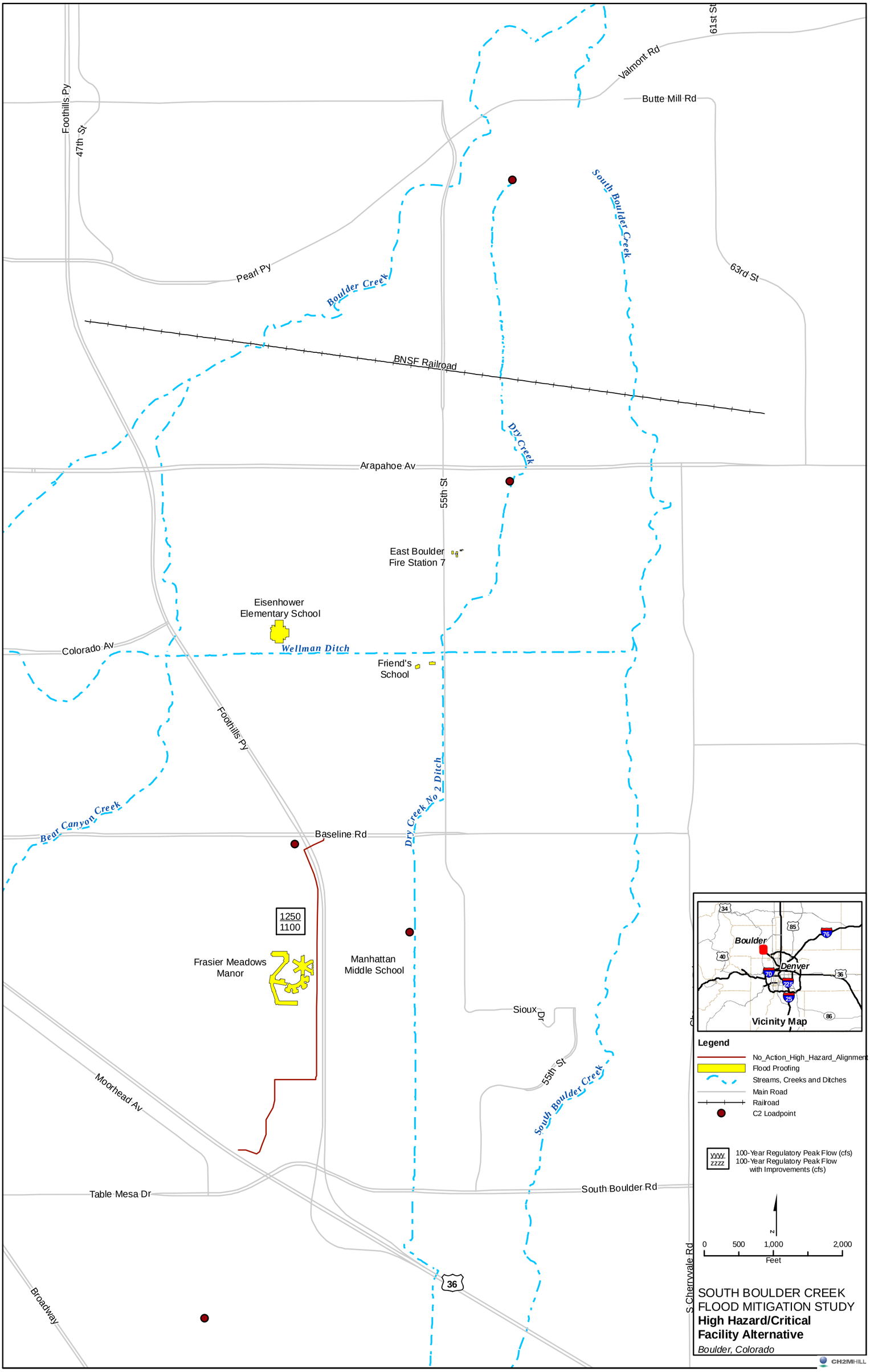
CH2MHILL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Main Road
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100-Year Regulatory Peak Flow
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High Hazard/Critical
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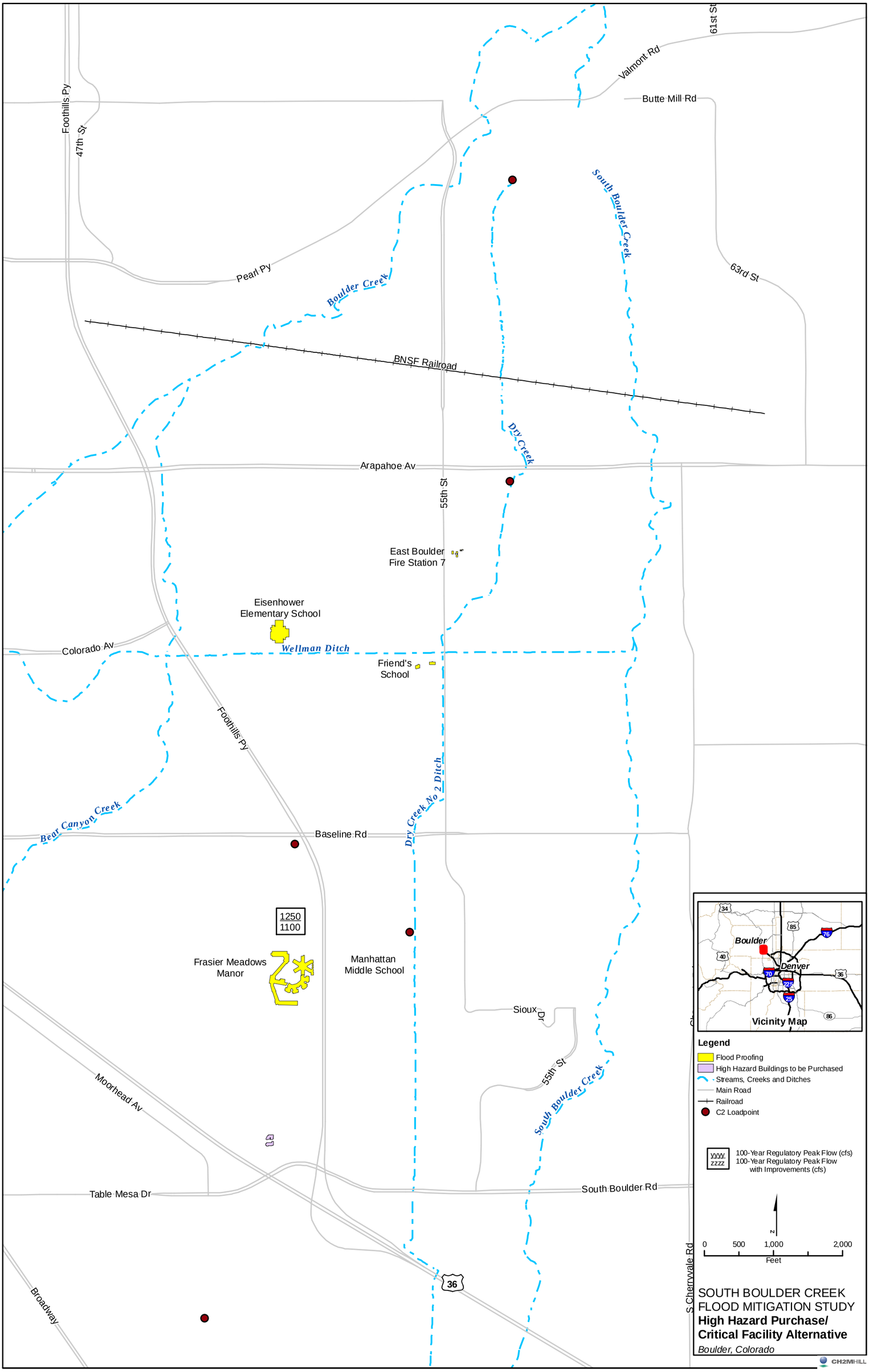
CH2MHILL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Legend
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Main Road
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100-Year Regulatory Peak Flow
with Improvements (cfs)
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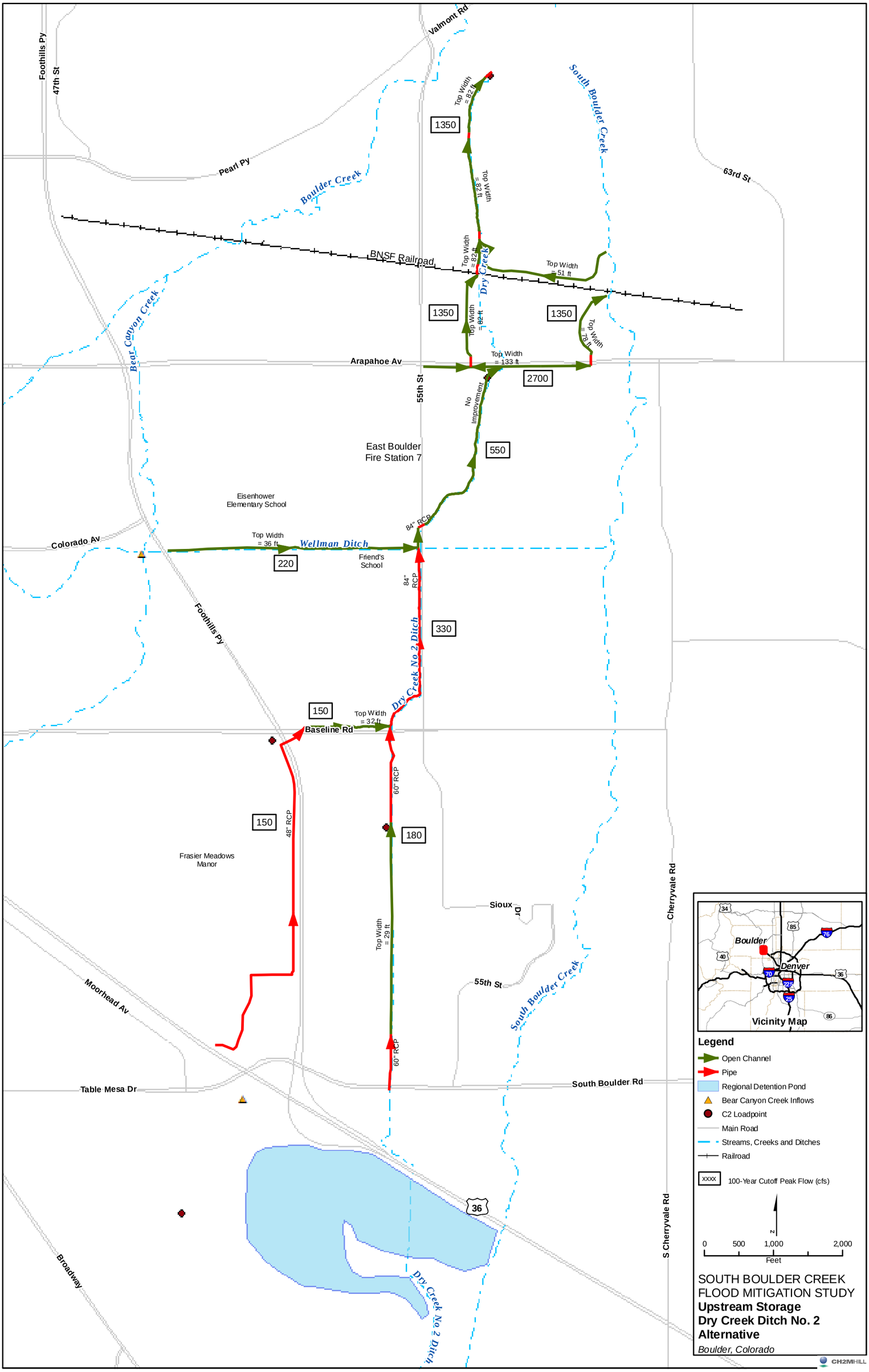
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Bear Canyon Creek Inflows
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Main Road
Streams, Creeks and Ditches
Railroad
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Dry Creek Ditch No. 2
Alternative
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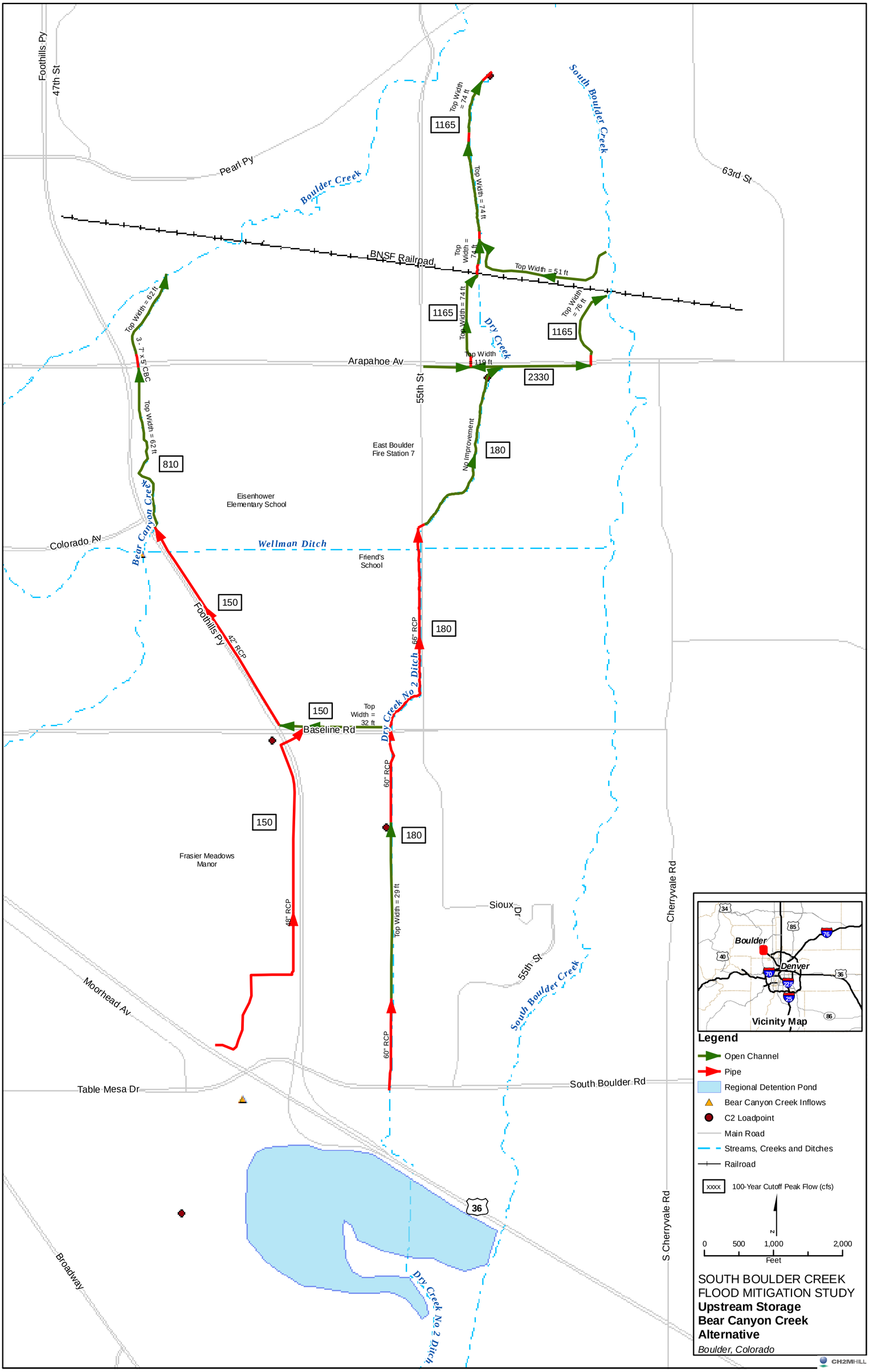
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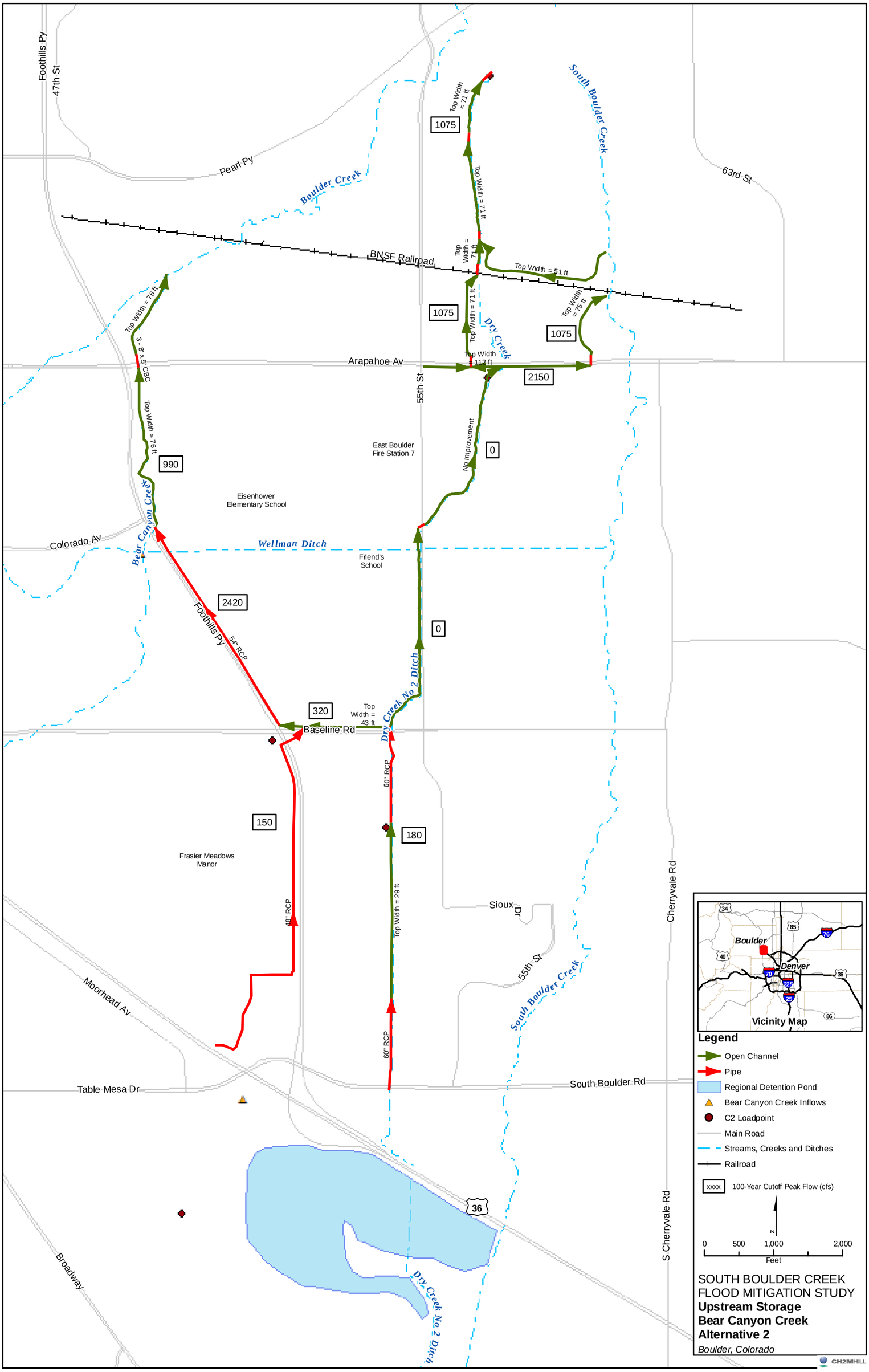
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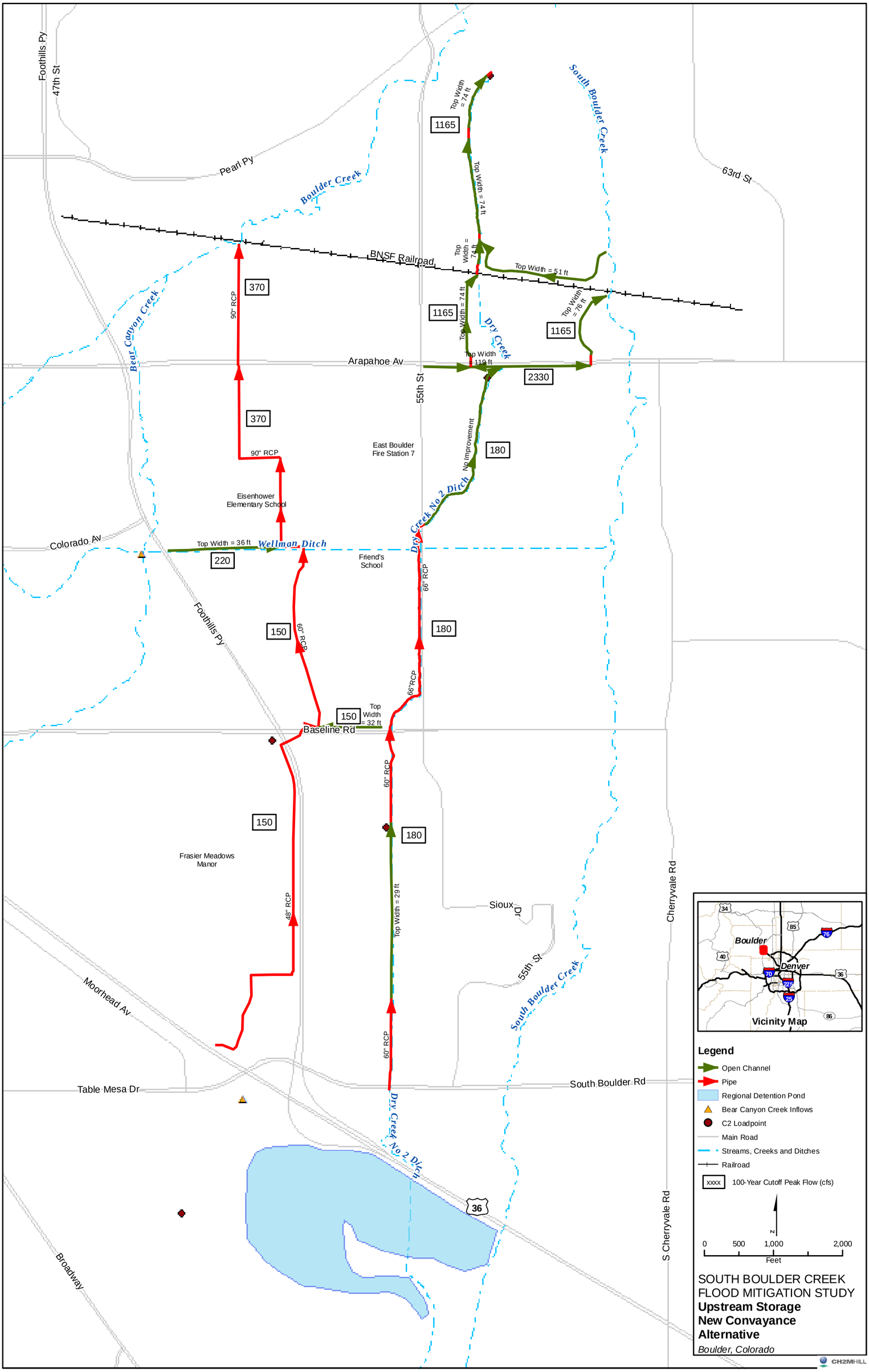
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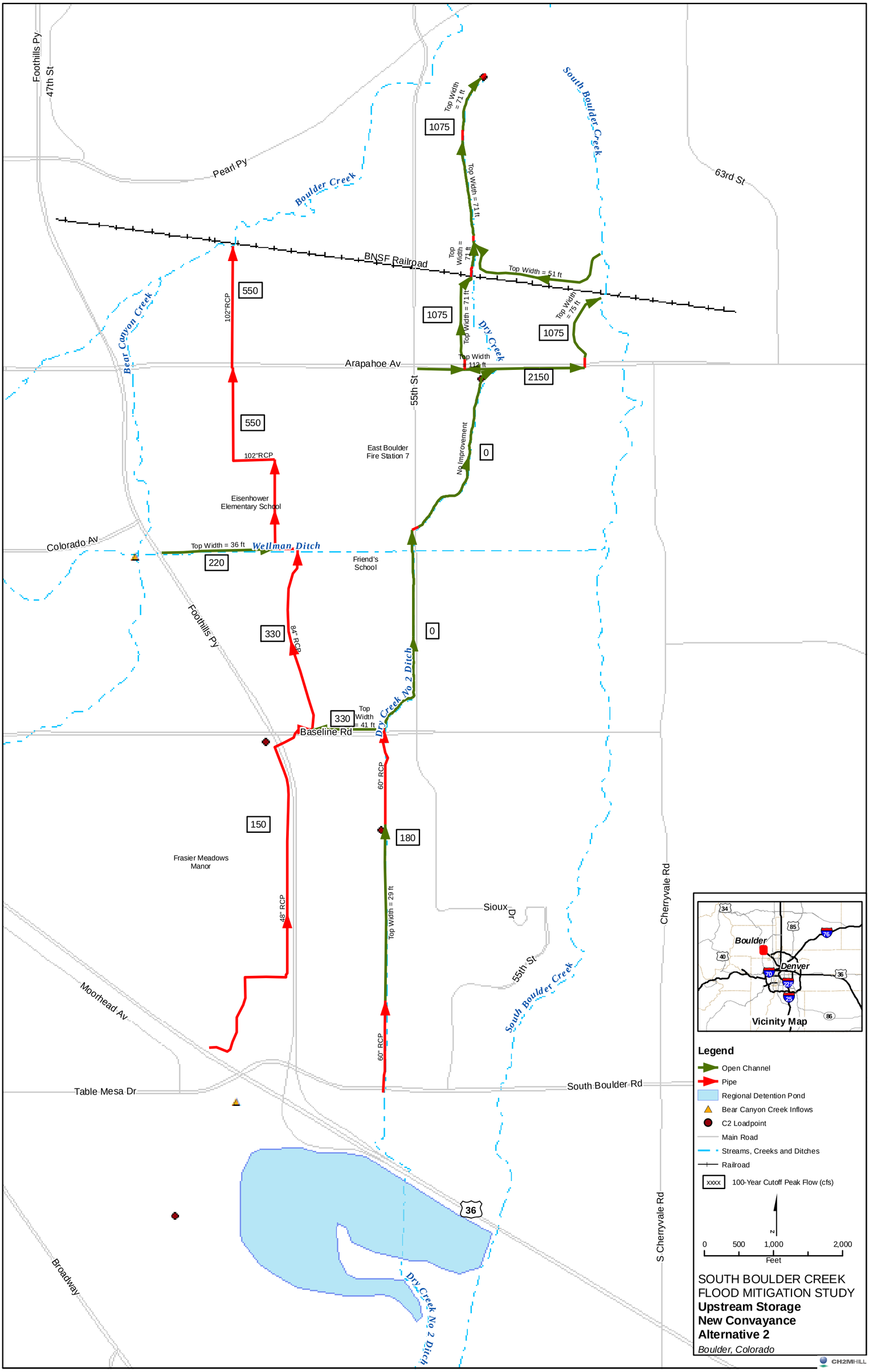
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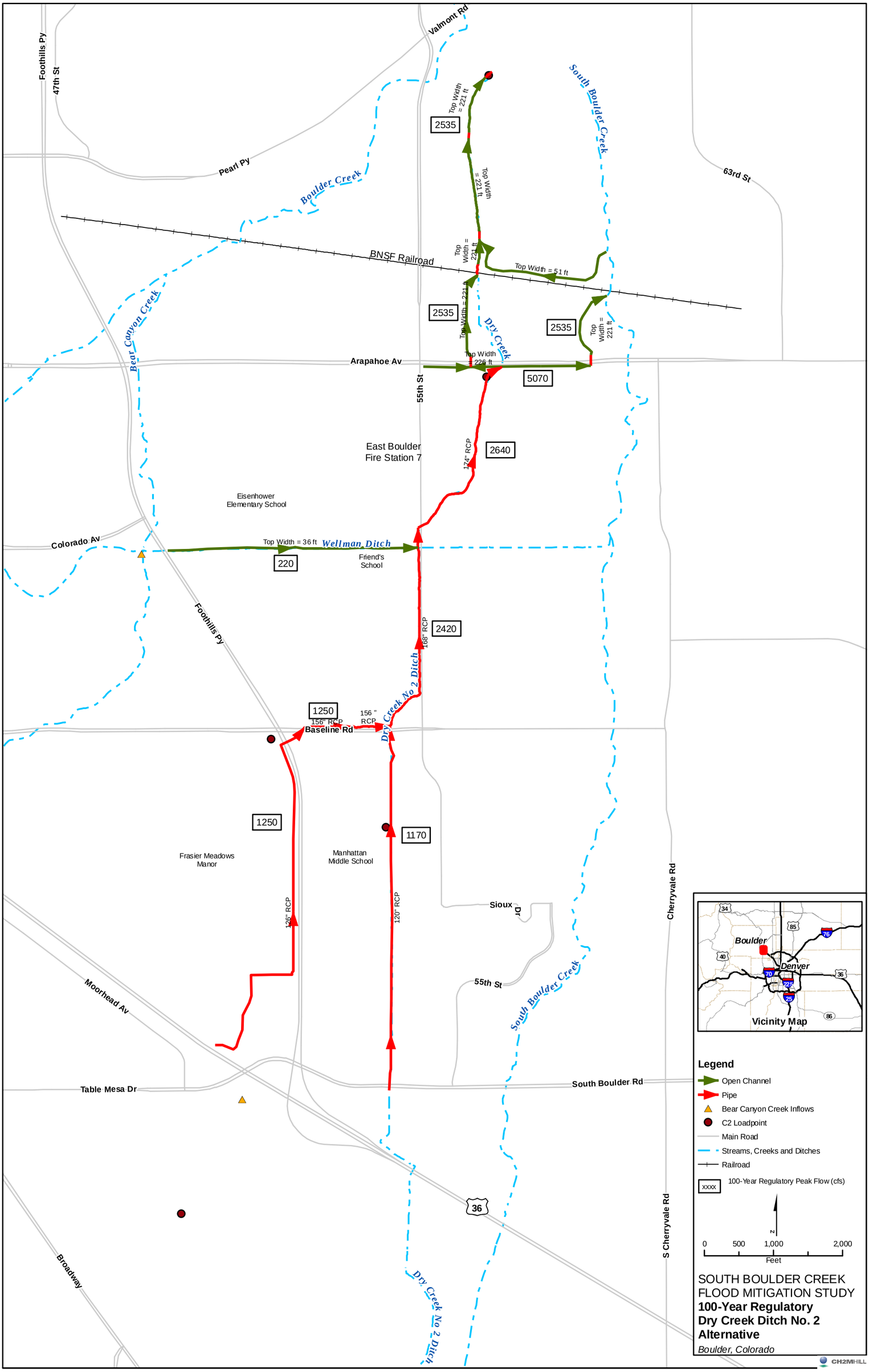
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Open Channel
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Bear Canyon Creek Inflows
C2 Loadpoint
Main Road
Streams, Creeks and Ditches
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Dry Creek Ditch No. 2
Alternative
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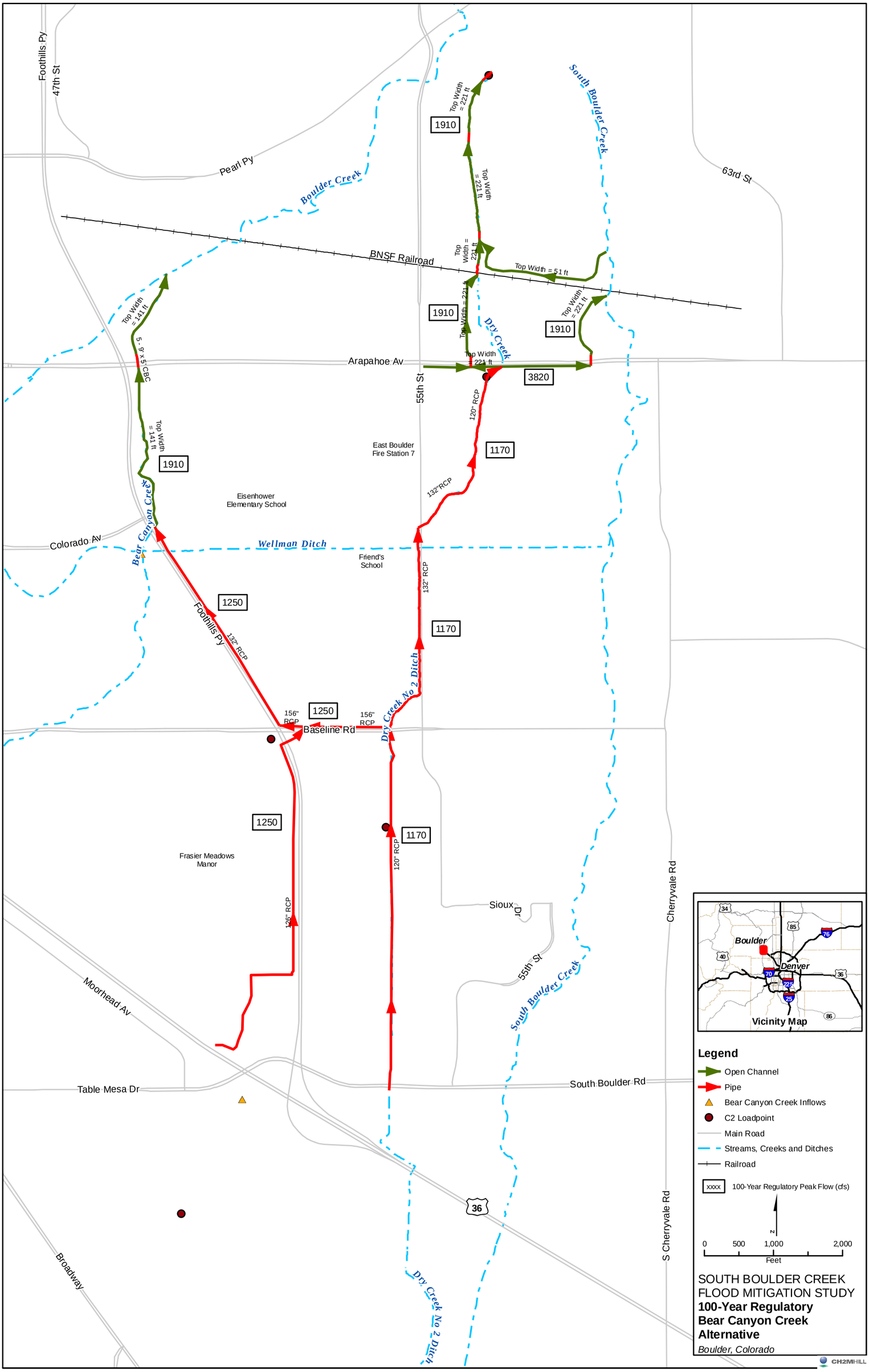
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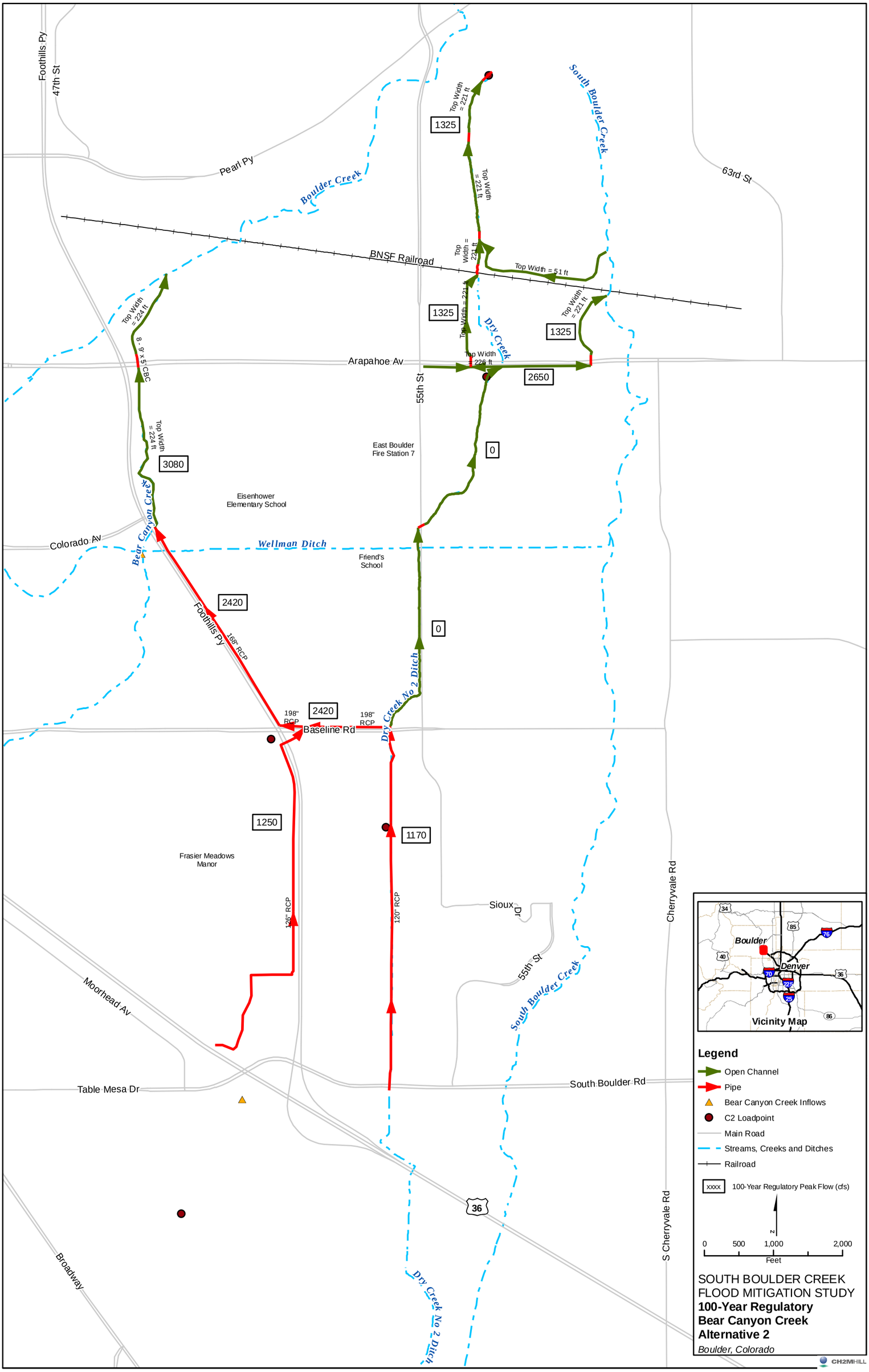
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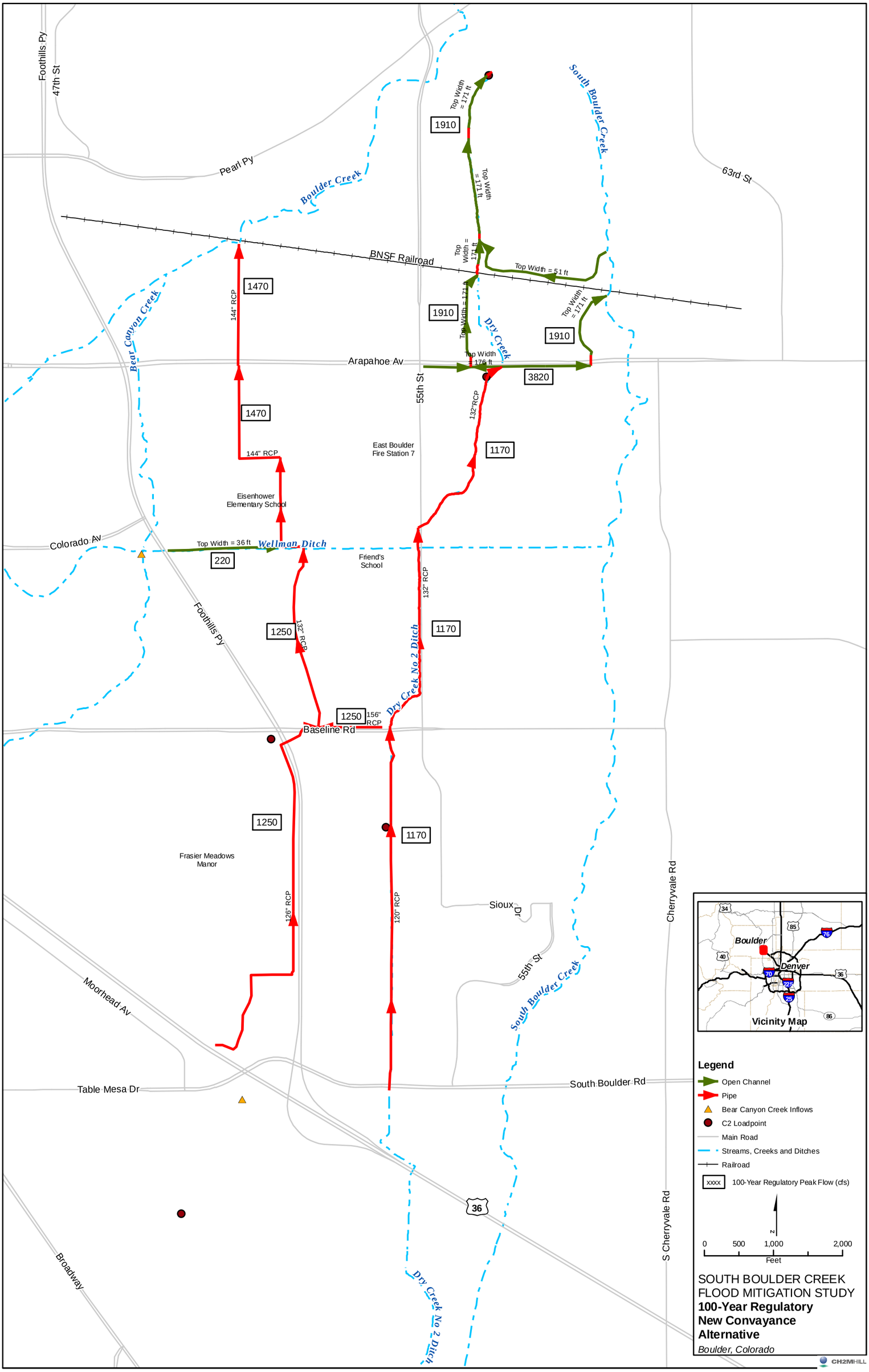
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Legend
Open Channel
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Bear Canyon Creek Inflows
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Main Road
Streams, Creeks and Ditches
Railroad
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SOUTH BOULDER CREEK
FLOOD MITIGATION STUDY
100-Year Regulatory
New Convayance
Alternative
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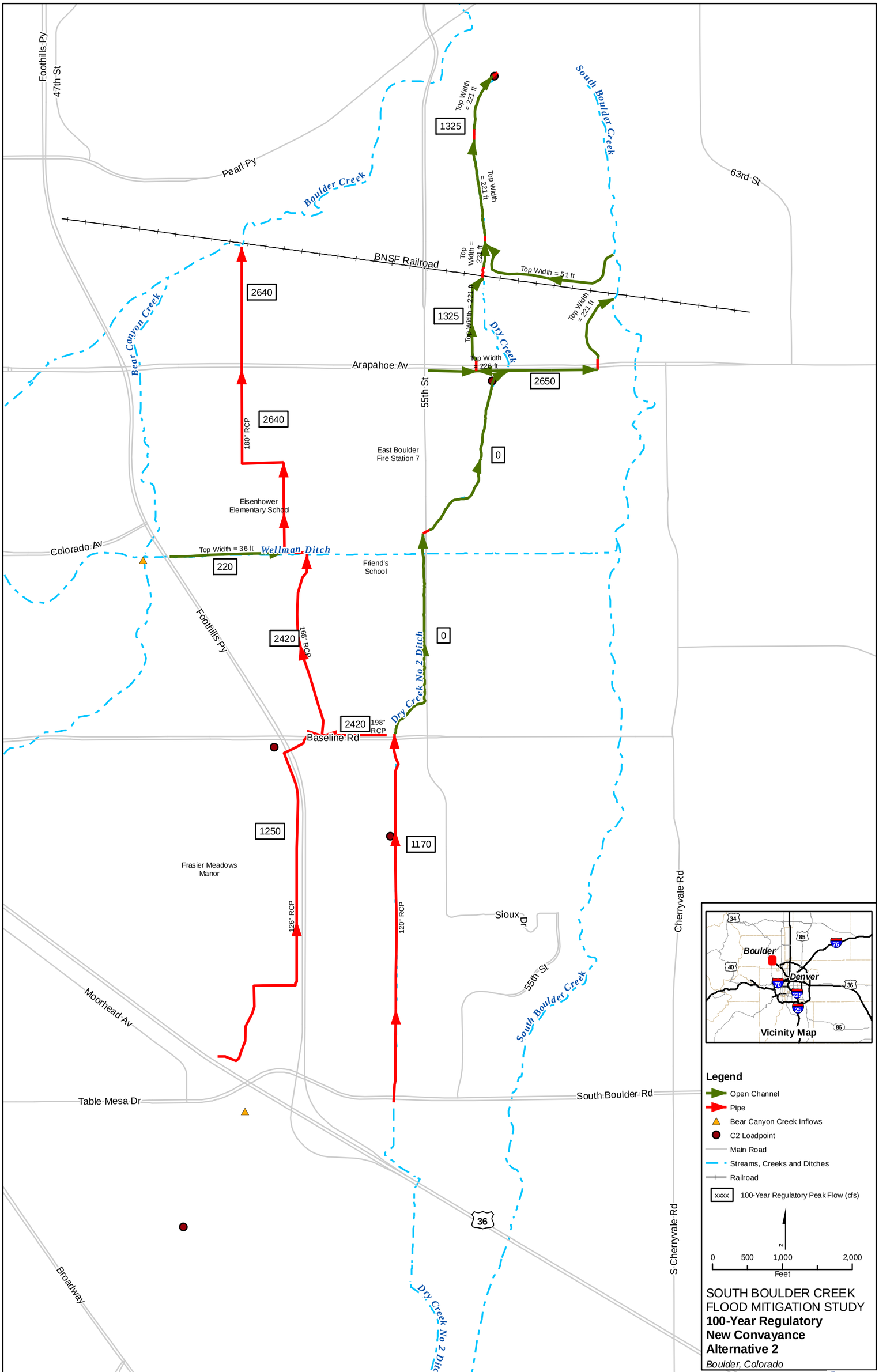
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Bear Canyon Creek
Dry Creek
Arapahoe Av
55th St
180" RCP
East Boulder Fire Station 7
Eisenhower Elementary School
Colorado Av
Top Width = 36 ft
Wellman Ditch
220
Friend's School
Foothills Py
2420
168" RCP
Dry Creek No 2 Ditch
198" RCP
Baseline Rd
1250
1170
Frasier Meadows Manor
126" RCP
120" RCP
Sioux Dr
Cherryvale Rd
Moorhead Av
Table Mesa Dr
South Boulder Rd
36
Broadway
S Cherryvale Rd
Boulder
Denver
Vicinity Map
Legend
Open Channel
Pipe
Bear Canyon Creek Inflows
C2 Loadpoint
Main Road
Streams, Creeks and Ditches
Railroad
xxxx 100-Year Regulatory Peak Flow (cfs)
0 500 1,000 2,000
Feet
SOUTH BOULDER CREEK
FLOOD MITIGATION STUDY
100-Year Regulatory
New Convayance
Alternative 2
Boulder, Colorado
CH2MHILL

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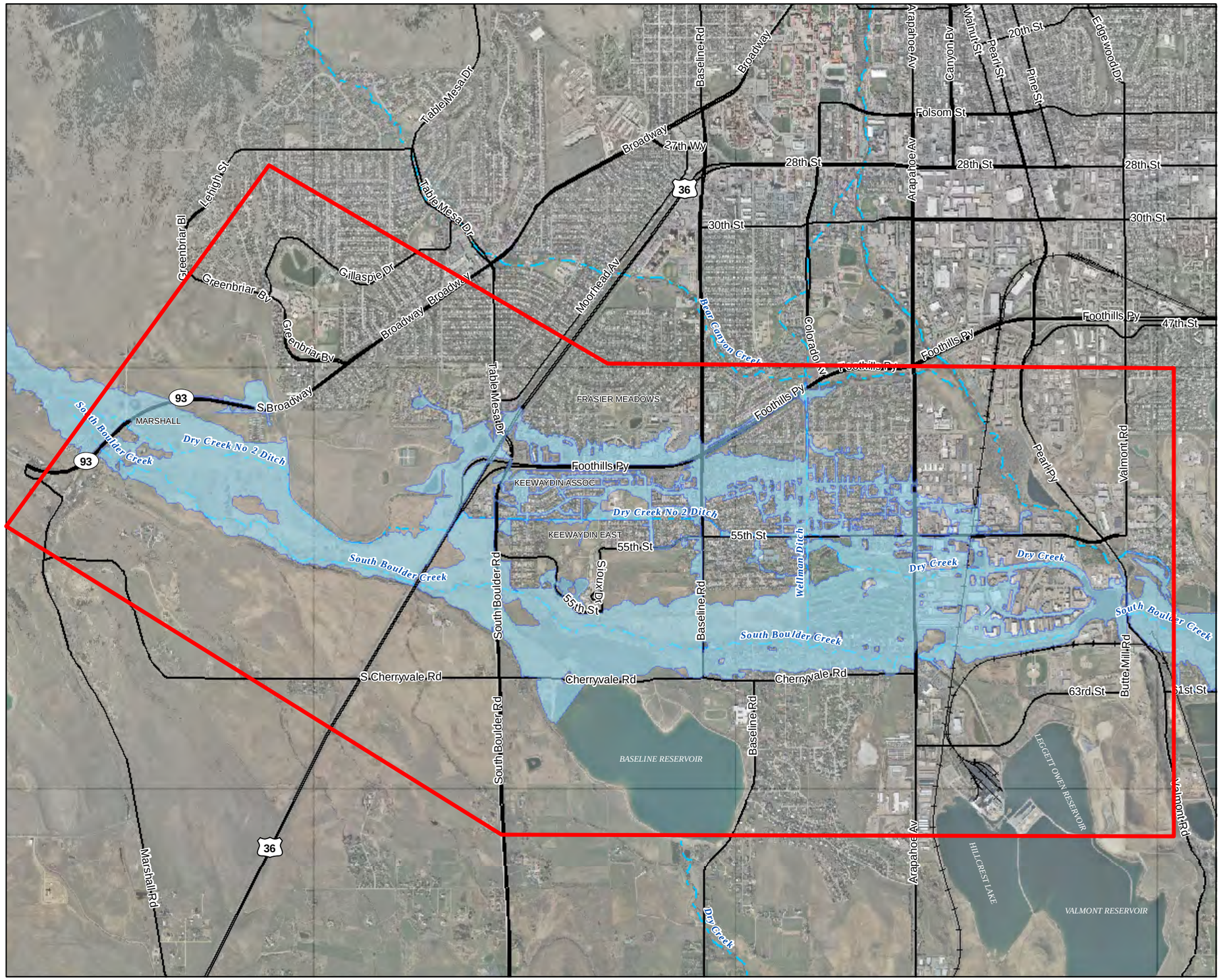
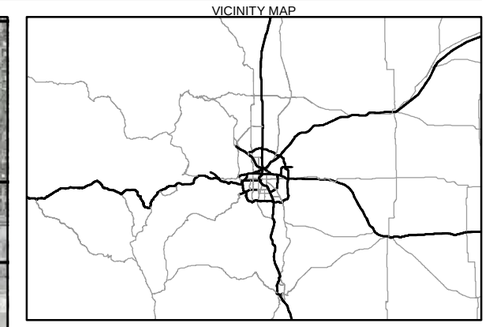




LEGEND

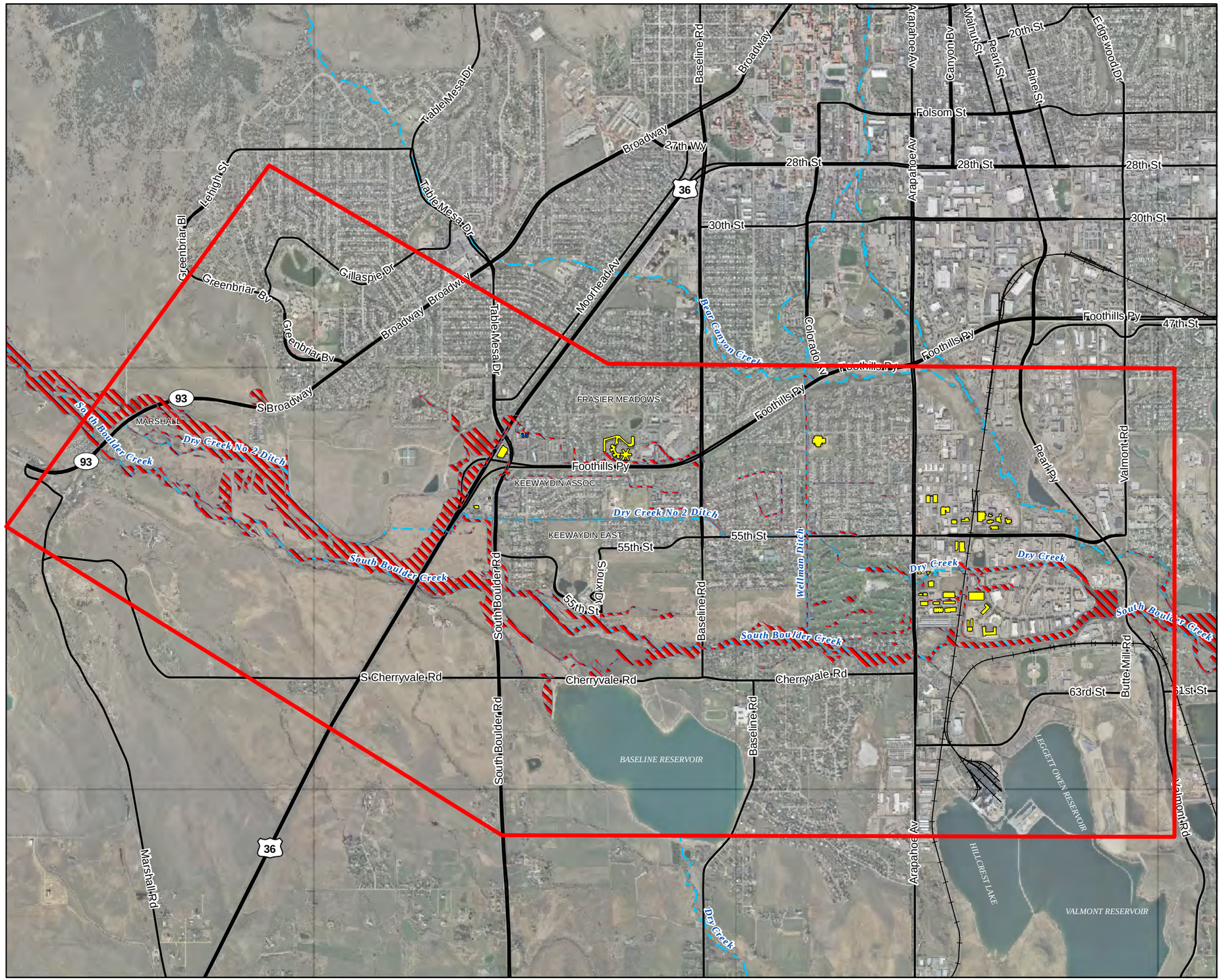
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

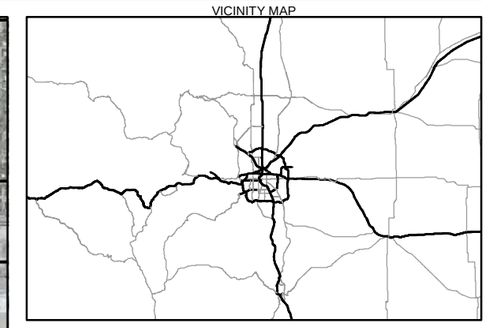
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-1
Status Quo
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

- Remove Buildings from High Hazard Zone
- Floodproof Critical Facilities
- High Hazard Zone
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-2
High Hazard Zone Containment with Critical Structure Protection
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

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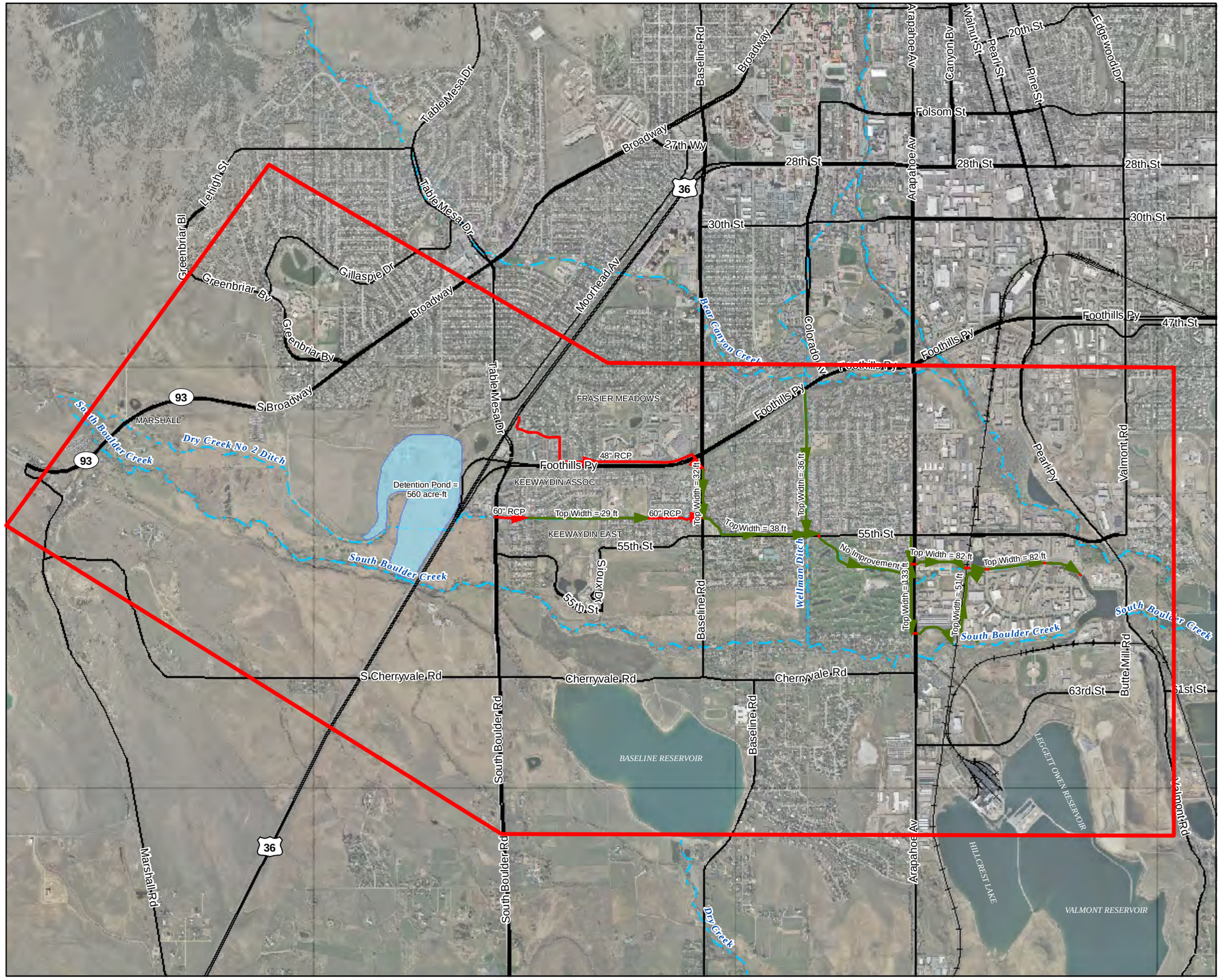
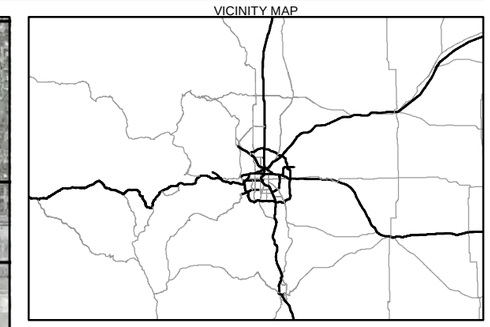
\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Figure 6-2 High Hazard Zone Containment with Critical Structure Protection.mxd





LEGEND

Conveyance Alignment

Category

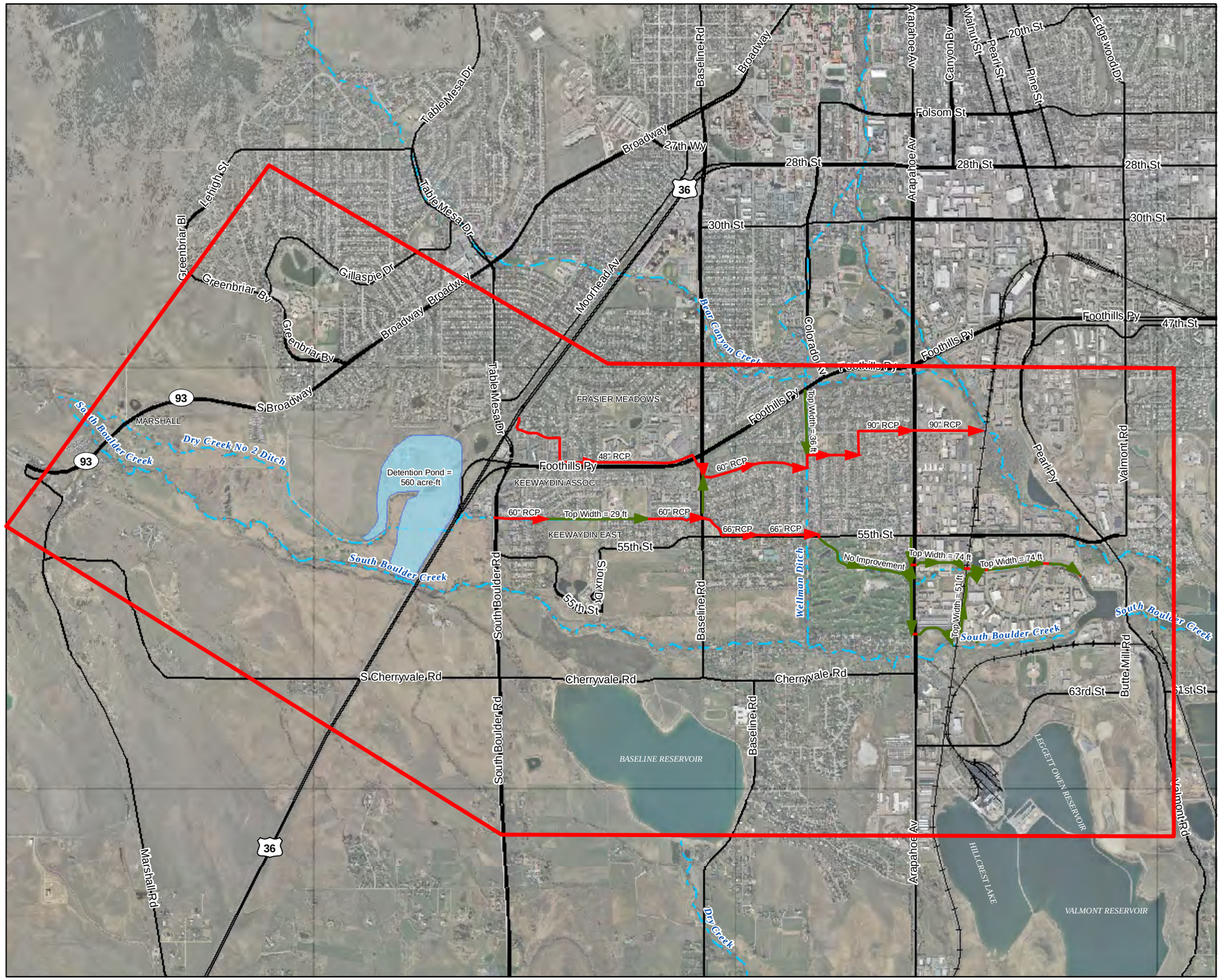
- Open Channel
- Pipe
- Regional Detention Pond
- Streams, Creeks and Ditches
- Boulder County

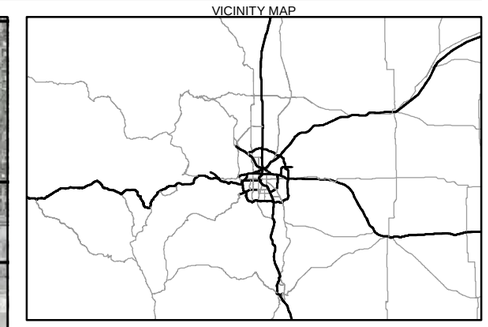
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-3
Us 36 Detention with Downstream Conveyance along Dry Creek No. 2 Ditch
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

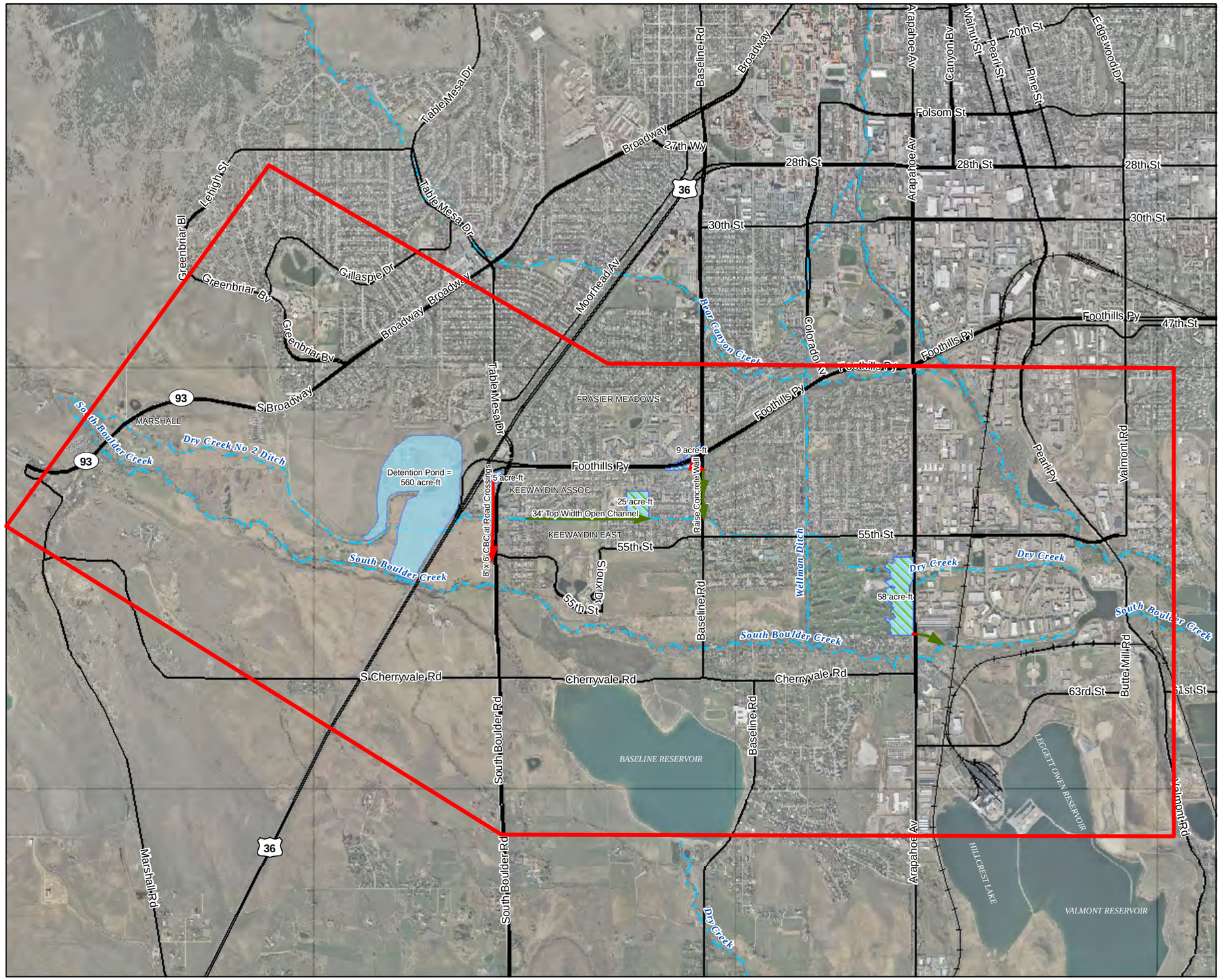
- Open Channel
- Pipe
- Regional Detention Pond
- Streams, Creeks and Ditches
- Boulder County

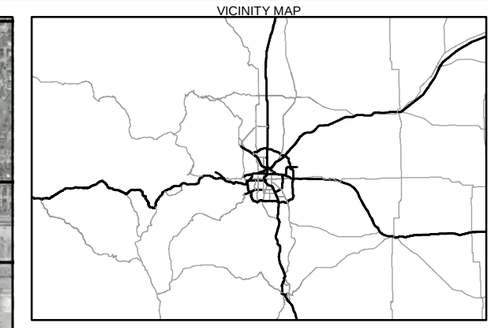
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-4
US 36 Detention with Downstream Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyane Alignment

Category

- Open Channel Improvement
- Pipeline/Culvert Improvement
- Regional Detention Pond
- Local Detention
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

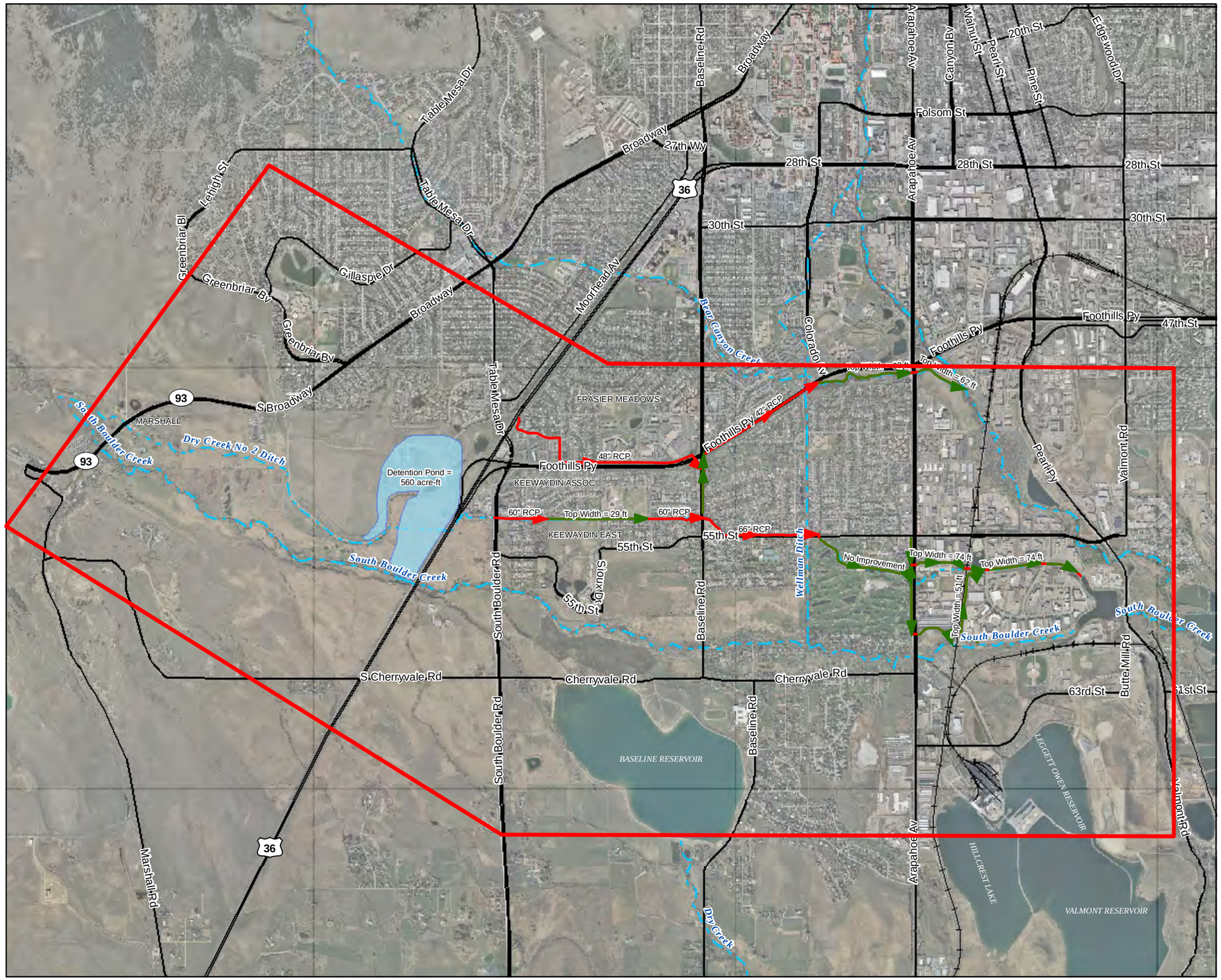
N

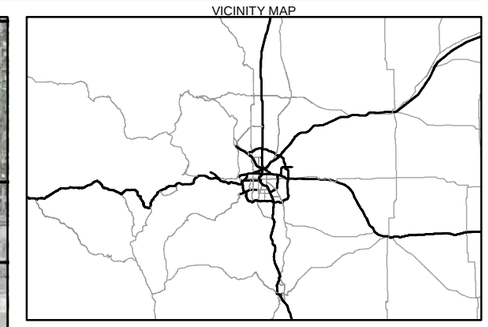
0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-5
US 36 Detention with Downstream Storage and Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Figure 6-5 US 36 Detention with Downstream Storage.mxd





LEGEND

Conveyance Alignment

Category

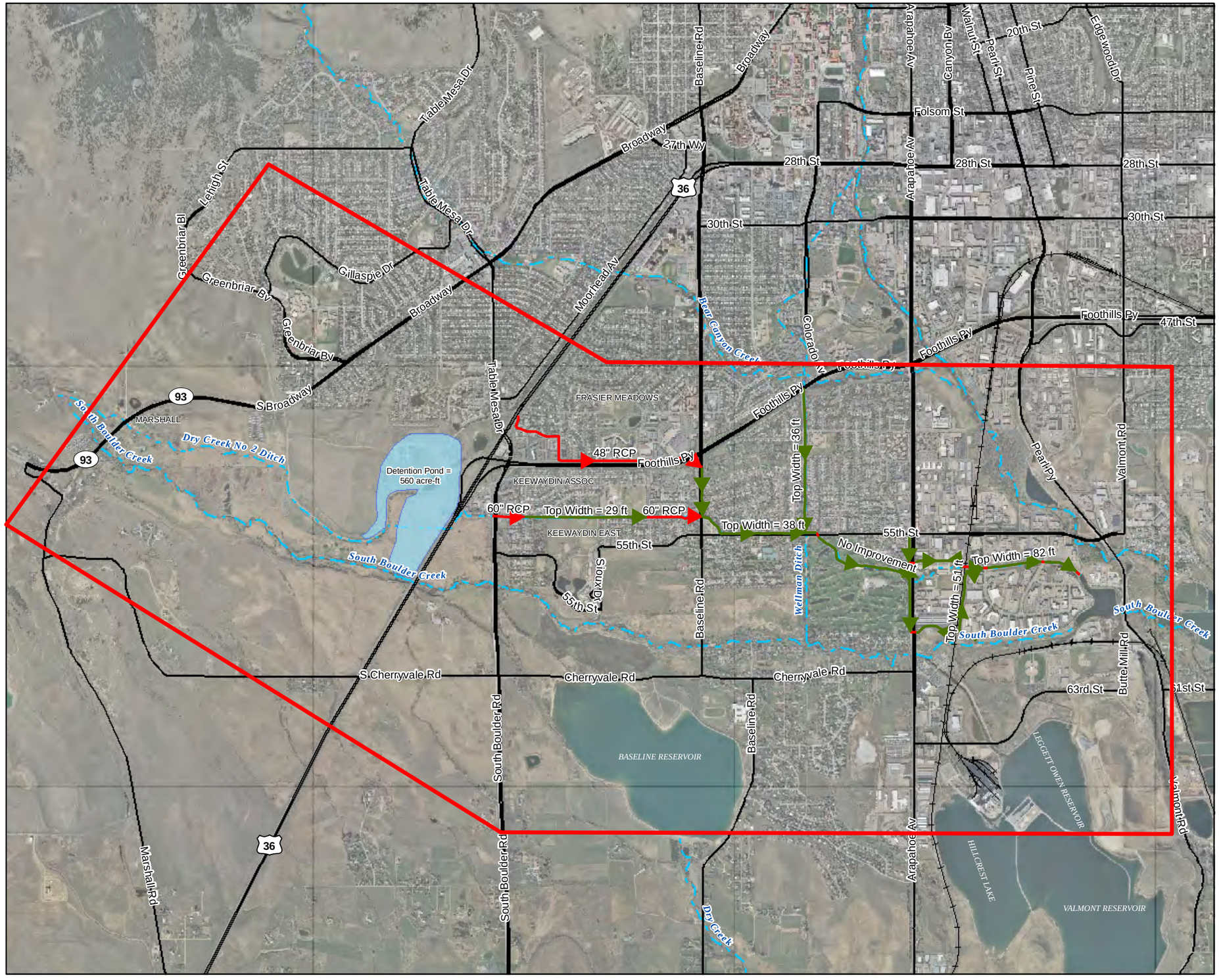
- Open Channel
- Pipe
- Regional Detention Pond
- Streams, Creeks and Ditches
- Boulder County

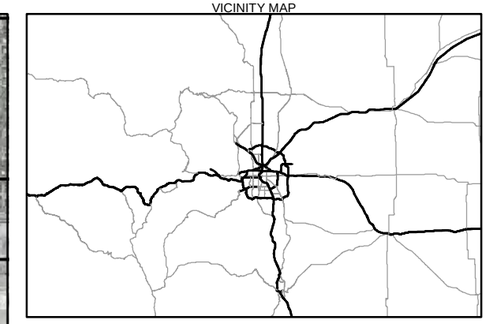
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-6
US 36 Detention with Downstream Diversion to Bear Canyon/Boulder Creek
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

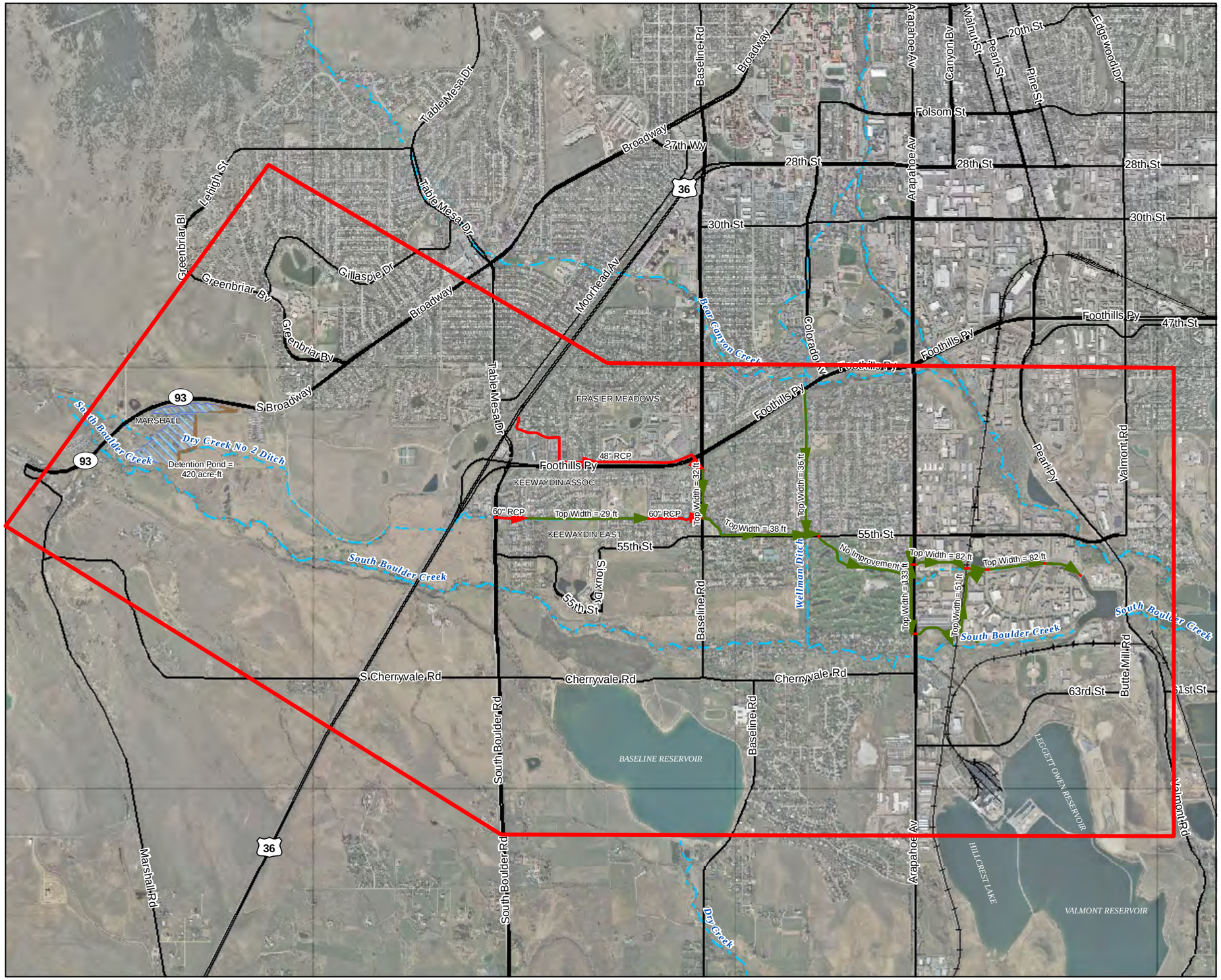
- Open Channel
- Pipe
- Regional Detention Pond
- Streams, Creeks and Ditches
- Boulder County

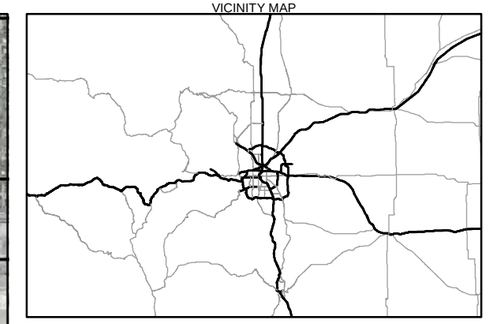
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-7
US 36 Detention with Downstream Diversion to Mainstem
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

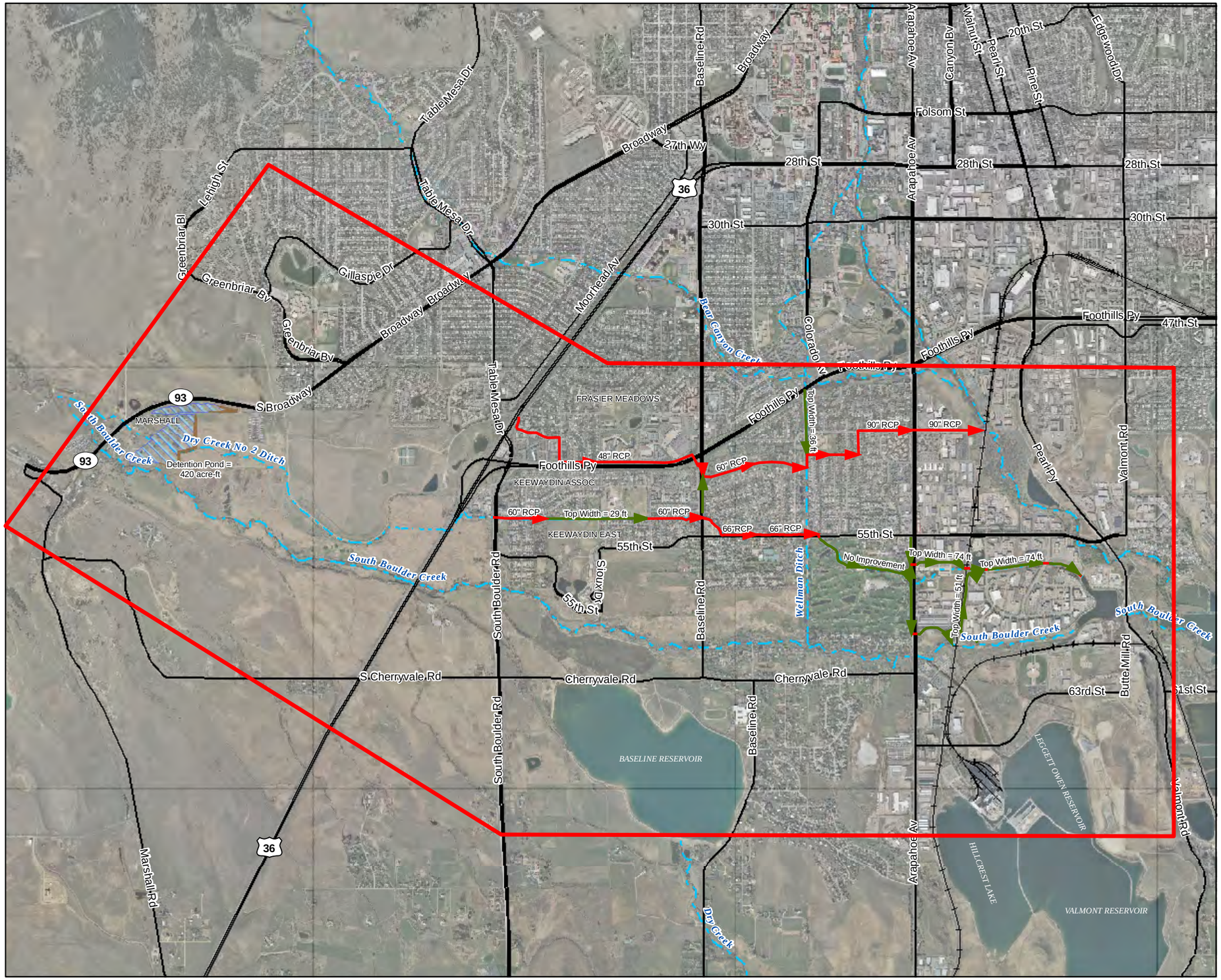
- Open Channel
- Pipe
- AREA OF EXCAVATION
- EMBANKMENT
- Streams, Creeks and Ditches
- Boulder County

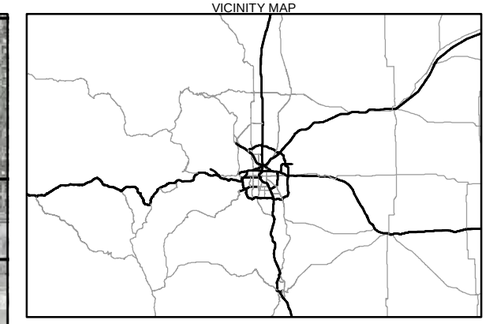
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-8
Detention near HWY 93 with Downstream Conveyance along Dry Creek No. 2 Ditch
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

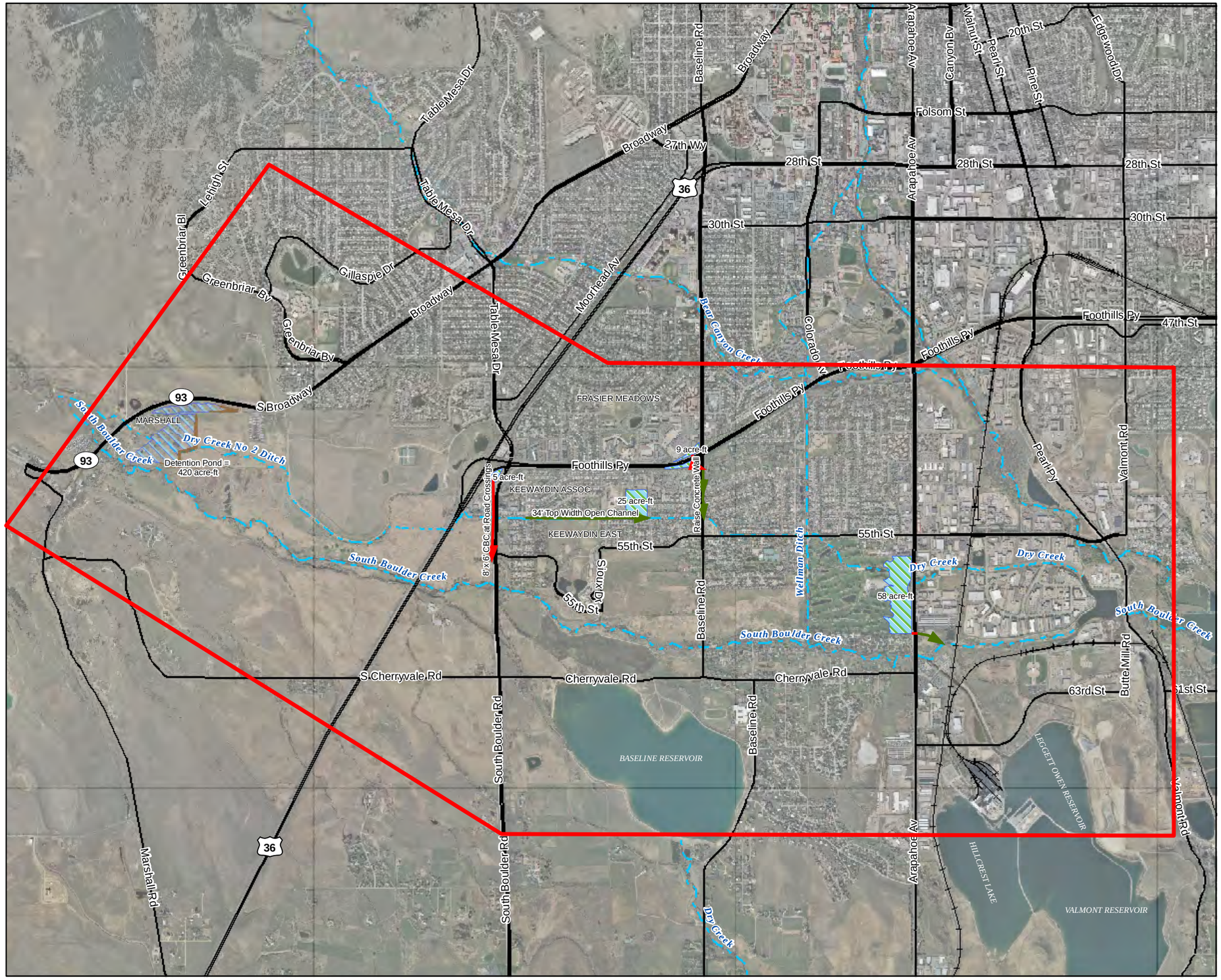
- Open Channel
- Pipe
- AREA OF EXCAVATION
- EMBANKMENT
- Streams, Creeks and Ditches
- Boulder County

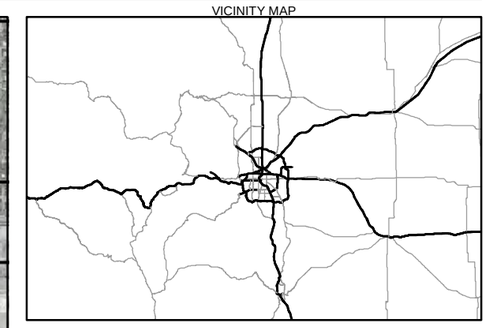
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-9
Detention near HWY 93 with Downstream Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyane Alignment

Category

- Open Channel Improvement
- Pipeline/Culvert Improvement
- Local Detention
- AREA OF EXCAVATION
- EMBANKMENT
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

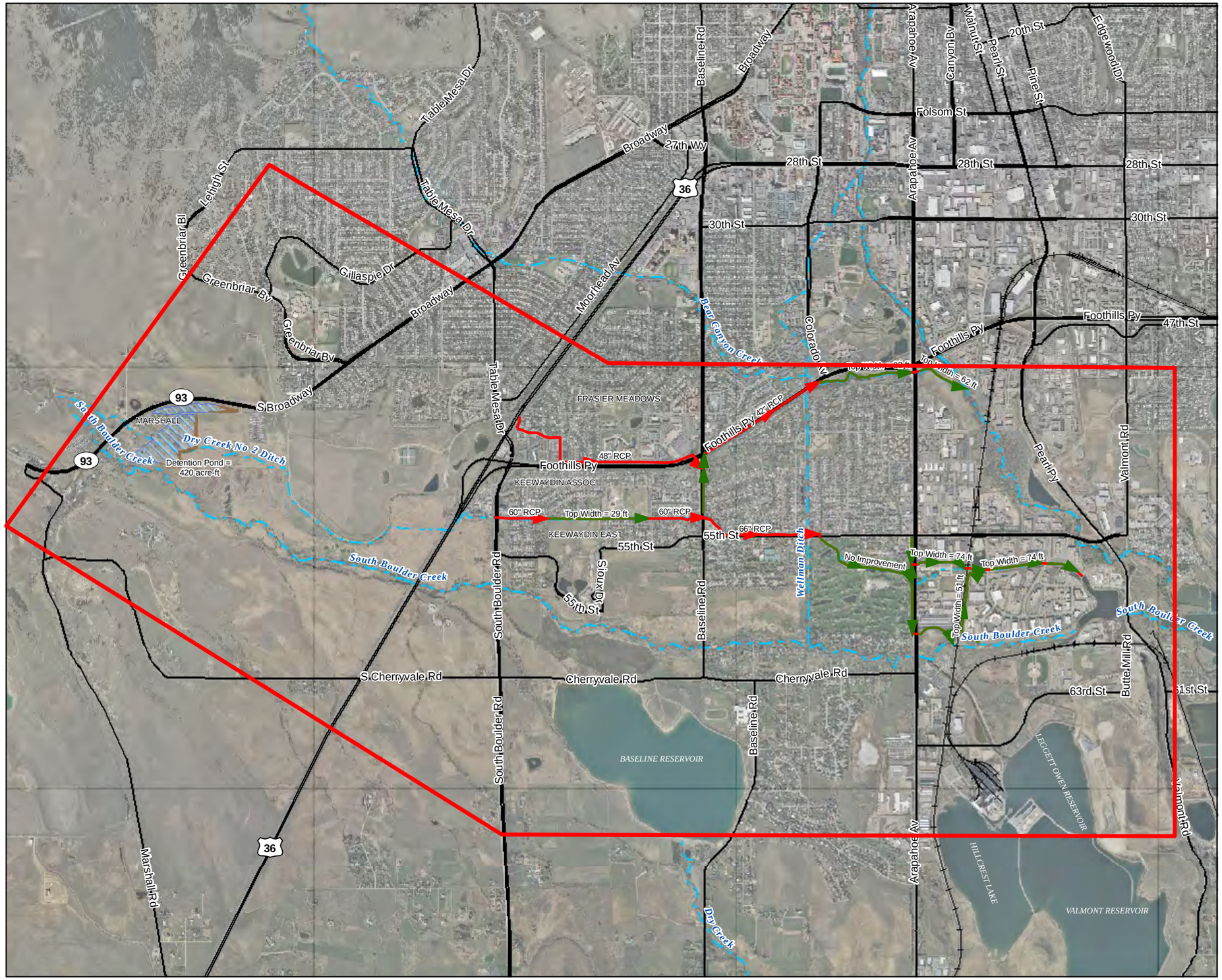
N

0 1,000 2,000 3,000 4,000 5,000
Feet

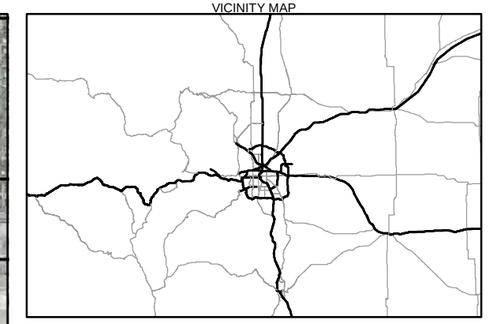
FIGURE 6-10
Detention near Highway 93 with Downstream Storage and Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Figure 6-10 Detention near Highway 93 with Downstream Storage.mxd



VICINITY MAP



LEGEND

Conveyance Alignment

Category

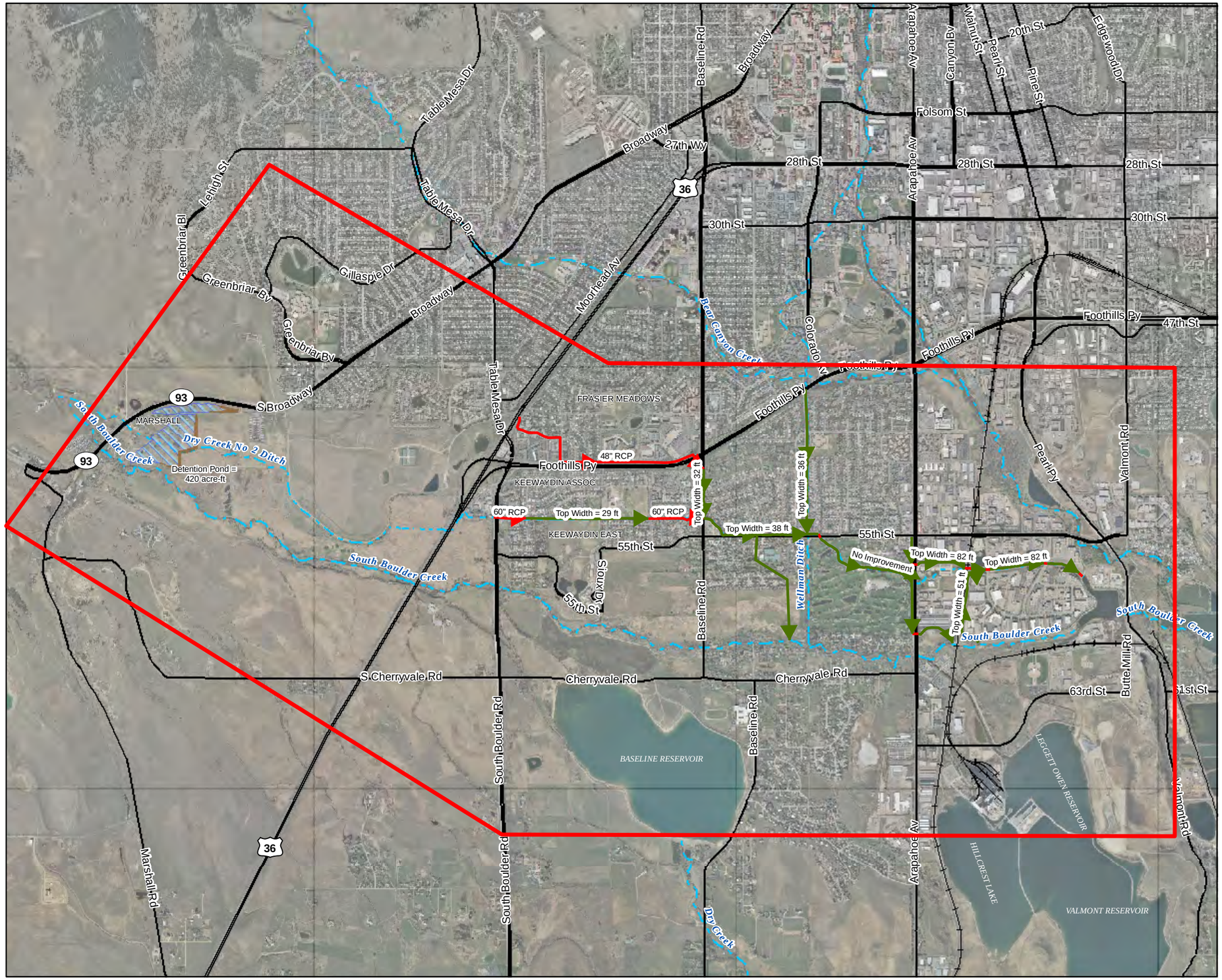
- Open Channel
- Pipe
- AREA OF EXCAVATION
- EMBANKMENT
- Streams, Creeks and Ditches
- Boulder County

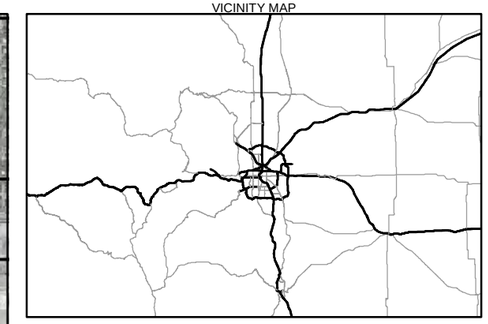
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-11
Detention Near HWY 93 with Downstream Diversion to Bear Canyon/Boulder Creek
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

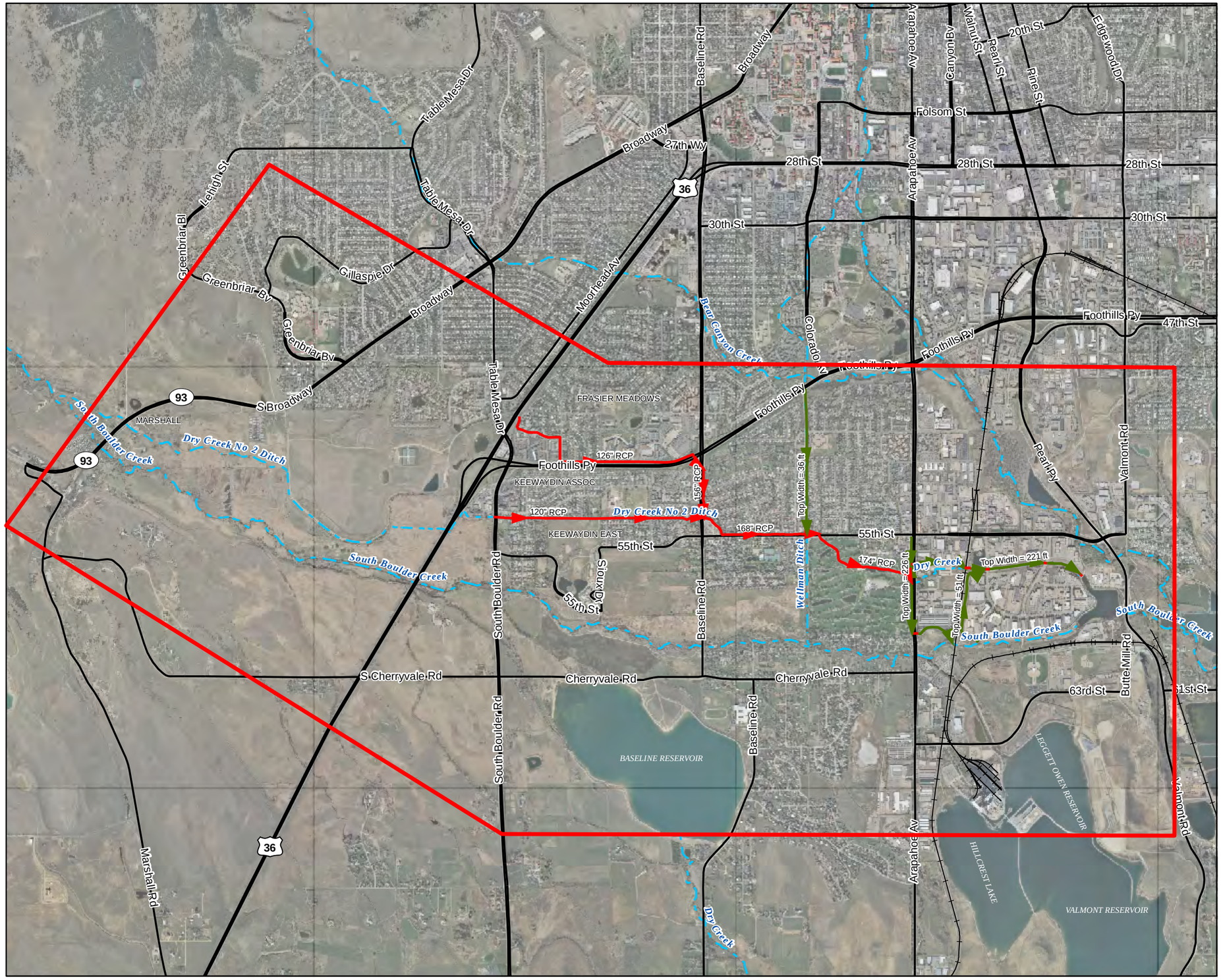
- Open Channel
- Pipe
- AREA OF EXCAVATION
- EMBANKMENT
- Streams, Creeks and Ditches
- Boulder County

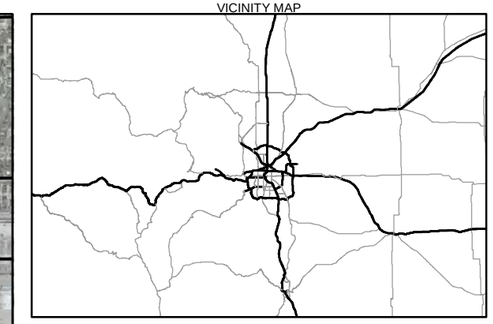
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-12
Detention near HWY 93 with Downstream Diversion to Mainstem
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

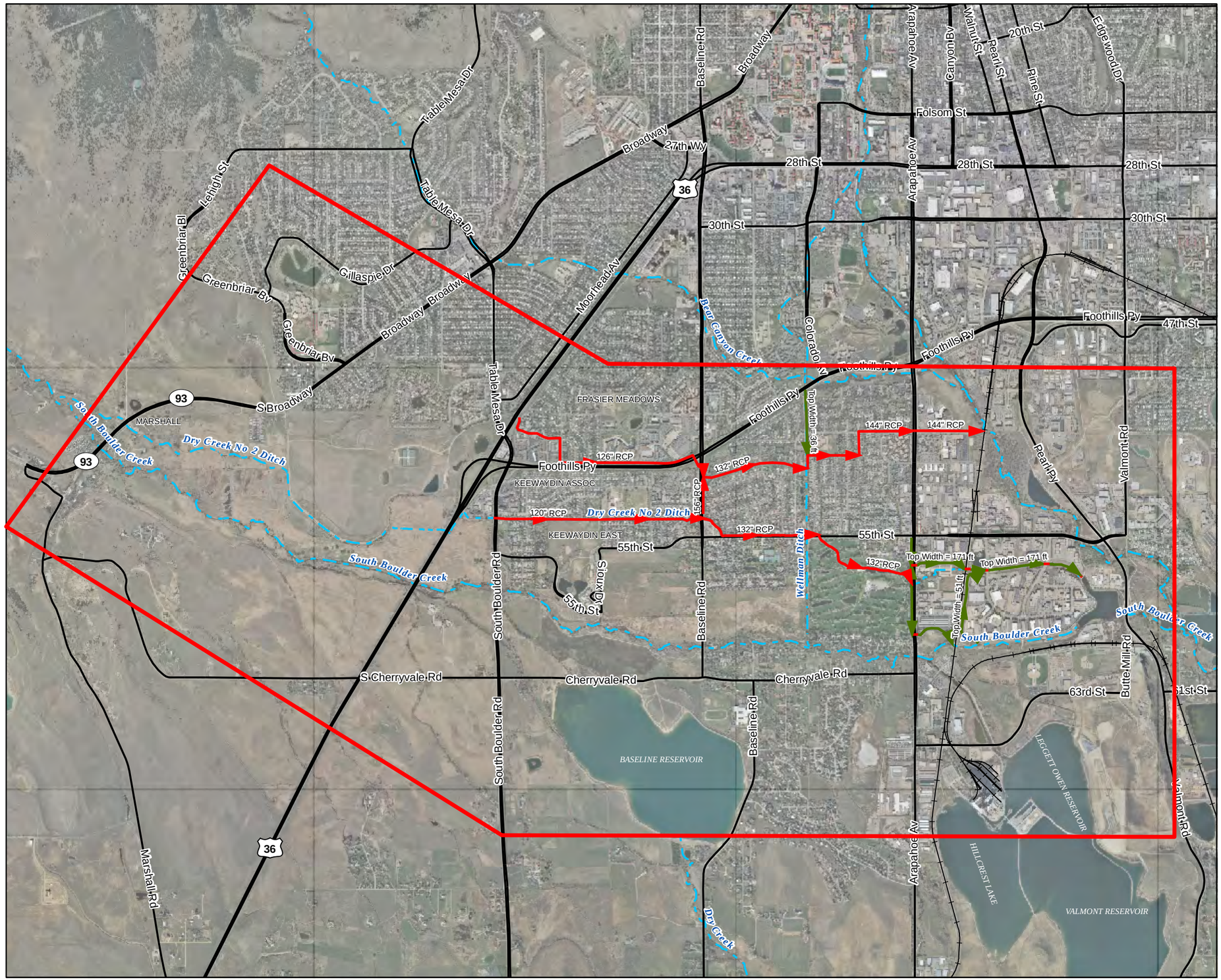
- Open Channel
- Pipe
- Streams, Creeks and Ditches
- Boulder County

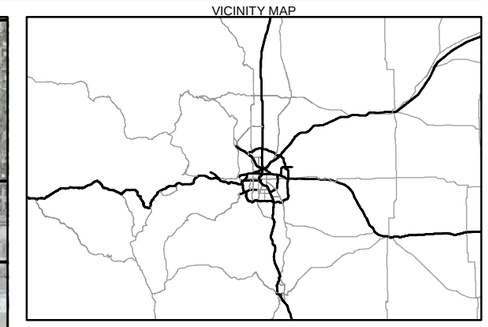
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-13
No Upstream Detention with Downstream Conveyance along Dry Creek No. 2 Ditch
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

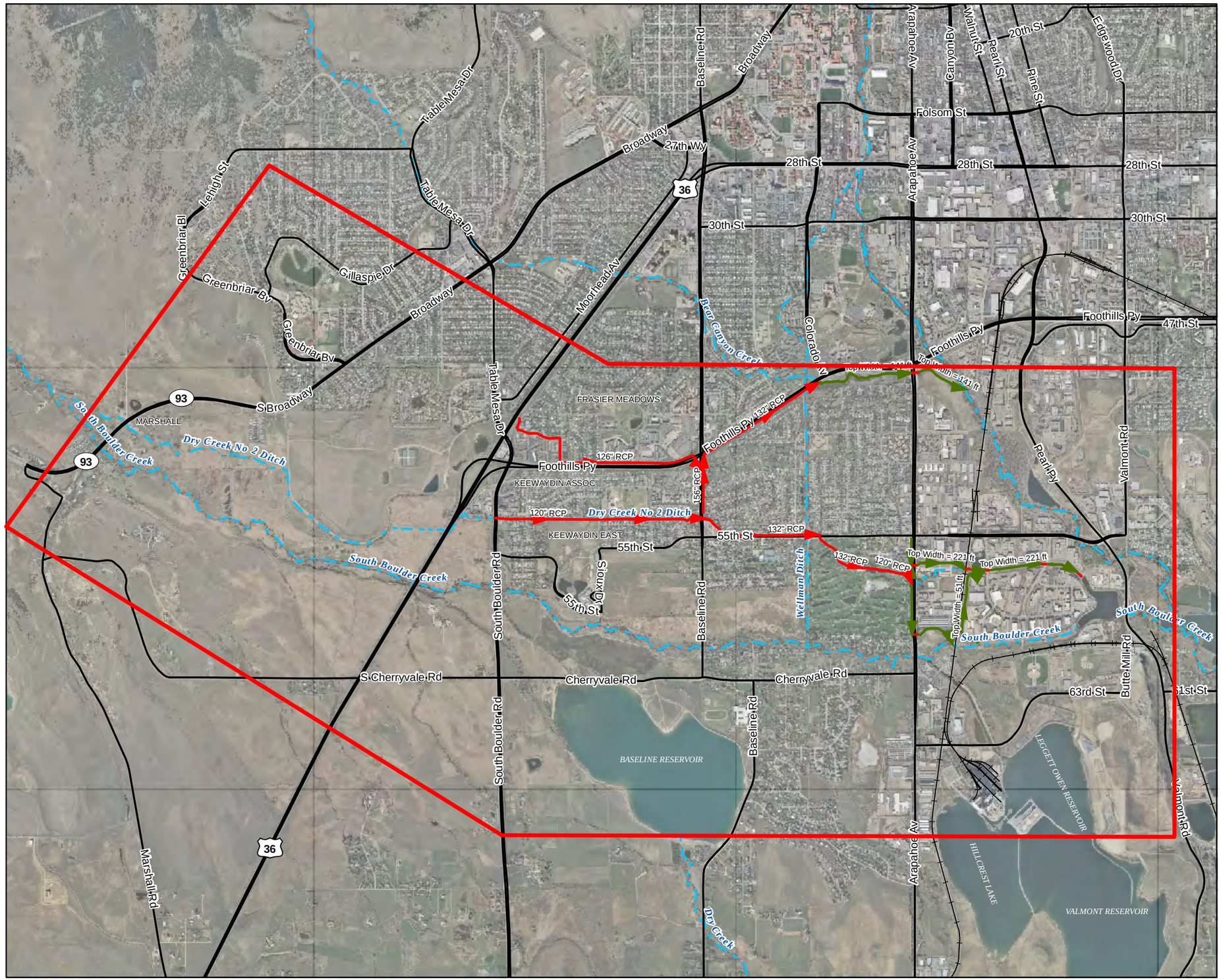
- Open Channel
- Pipe
- Streams, Creeks and Ditches
- Boulder County

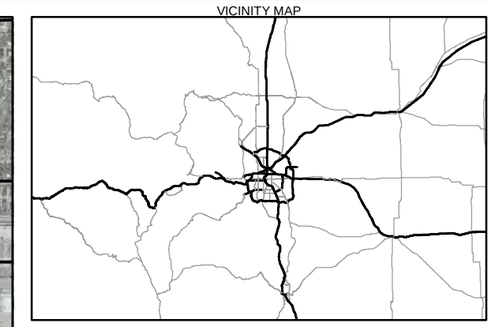
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-14
No Upstream Detention with Downstream Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyance Alignment

Category

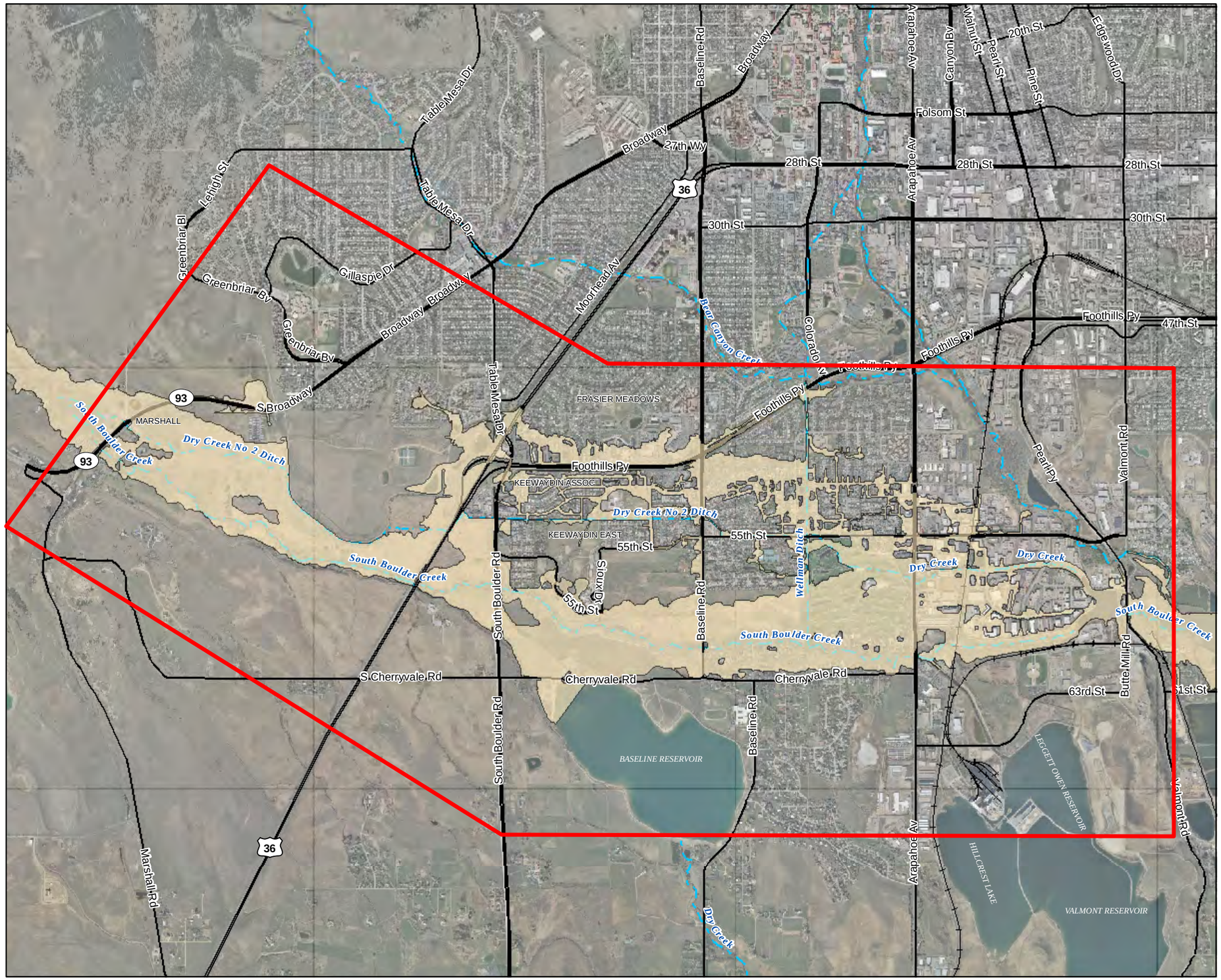
- Open Channel
- Pipe
- Streams, Creeks and Ditches
- Boulder County

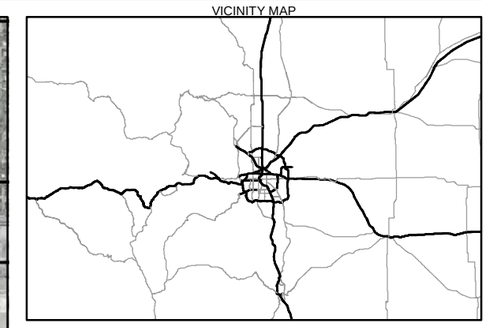
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-15
US 36 Detention with Downstream Diversions
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

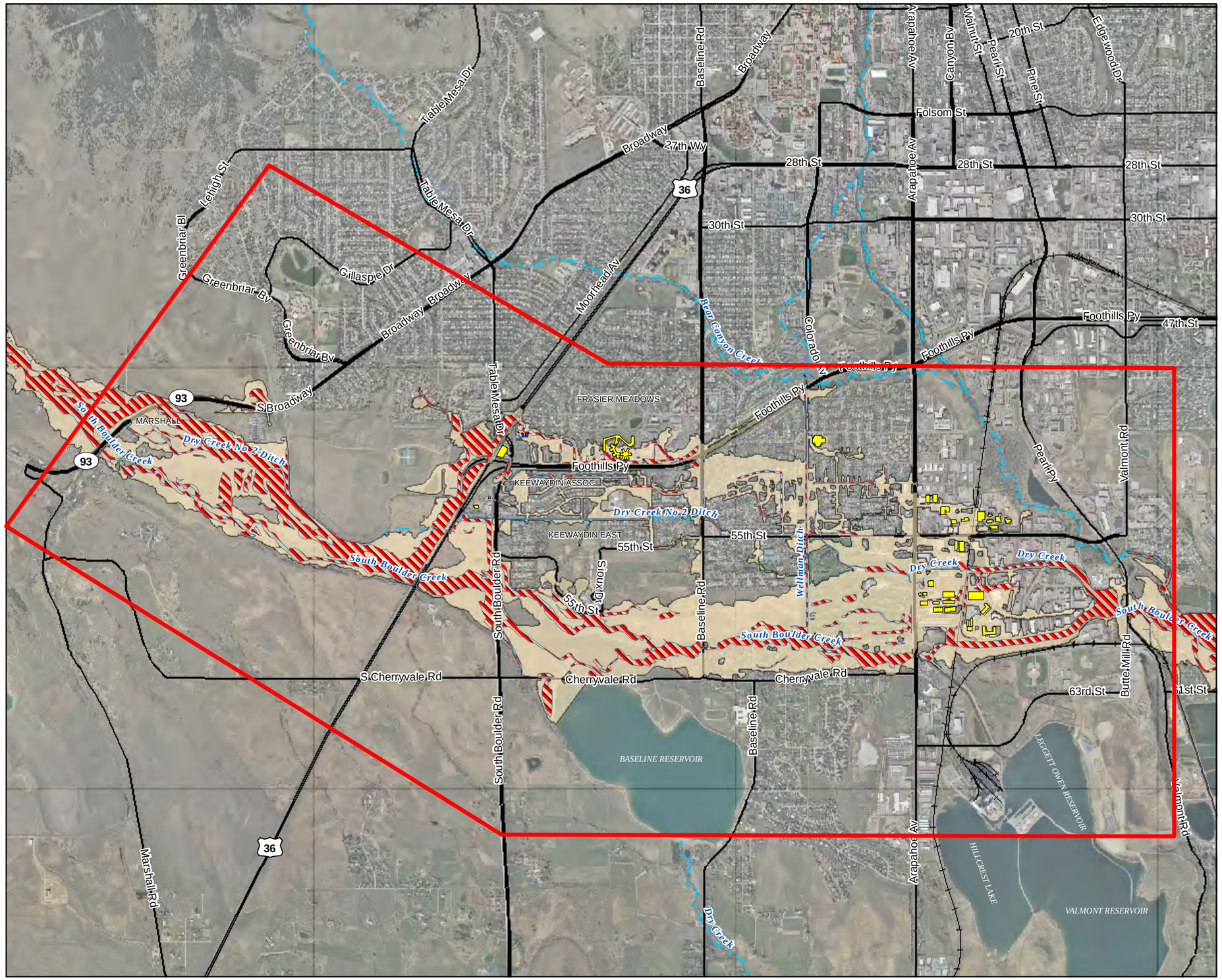
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

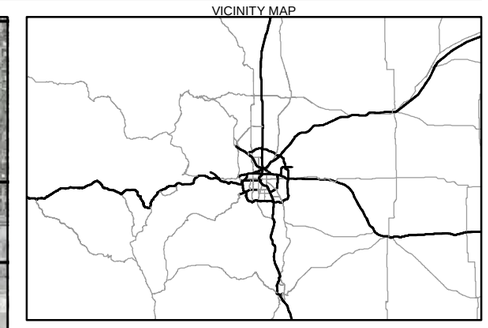
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-16
Status Quo
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

- Remove Buildings from High Hazard Zone
- Floodproof Critical Facilities
- High Hazard Zone
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-17
High Hazard Zone Containment with Critical Structure Protection
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

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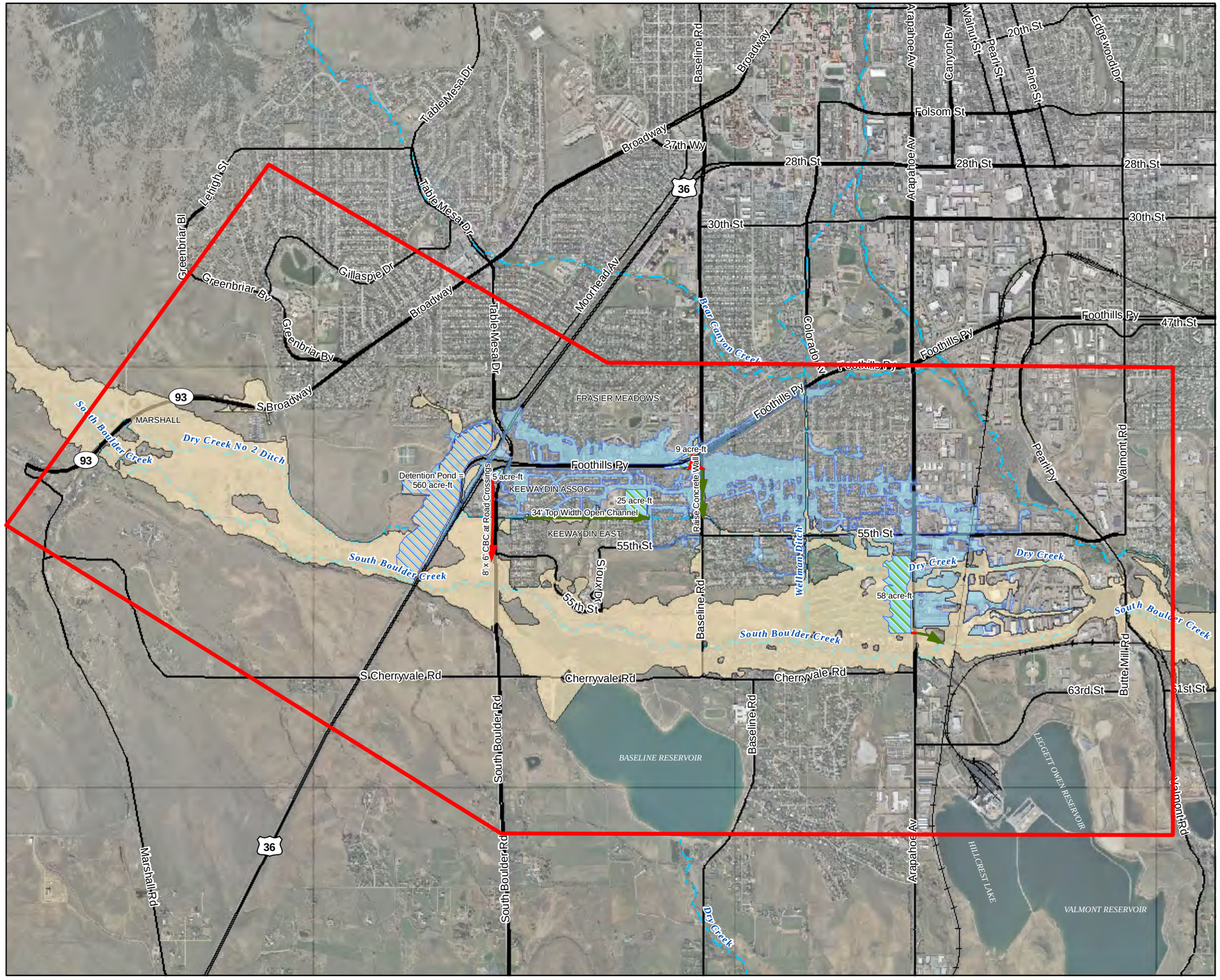
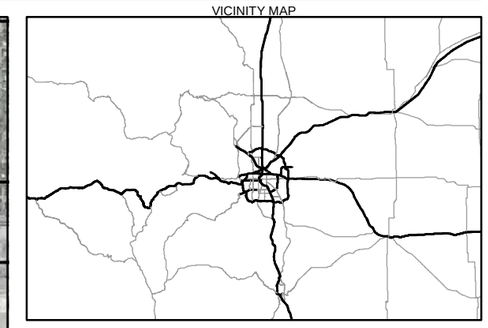
\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Chapter 6\Figure 6-17 High Hazard Zone Containment with Critical Structure Protection.mxd





LEGEND

Conveyane Alignment

Category

- Open Channel Improvement
- Pipeline/Culvert Improvement
- Detention at US 36
- Local Detention
- Post Project Conditions Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

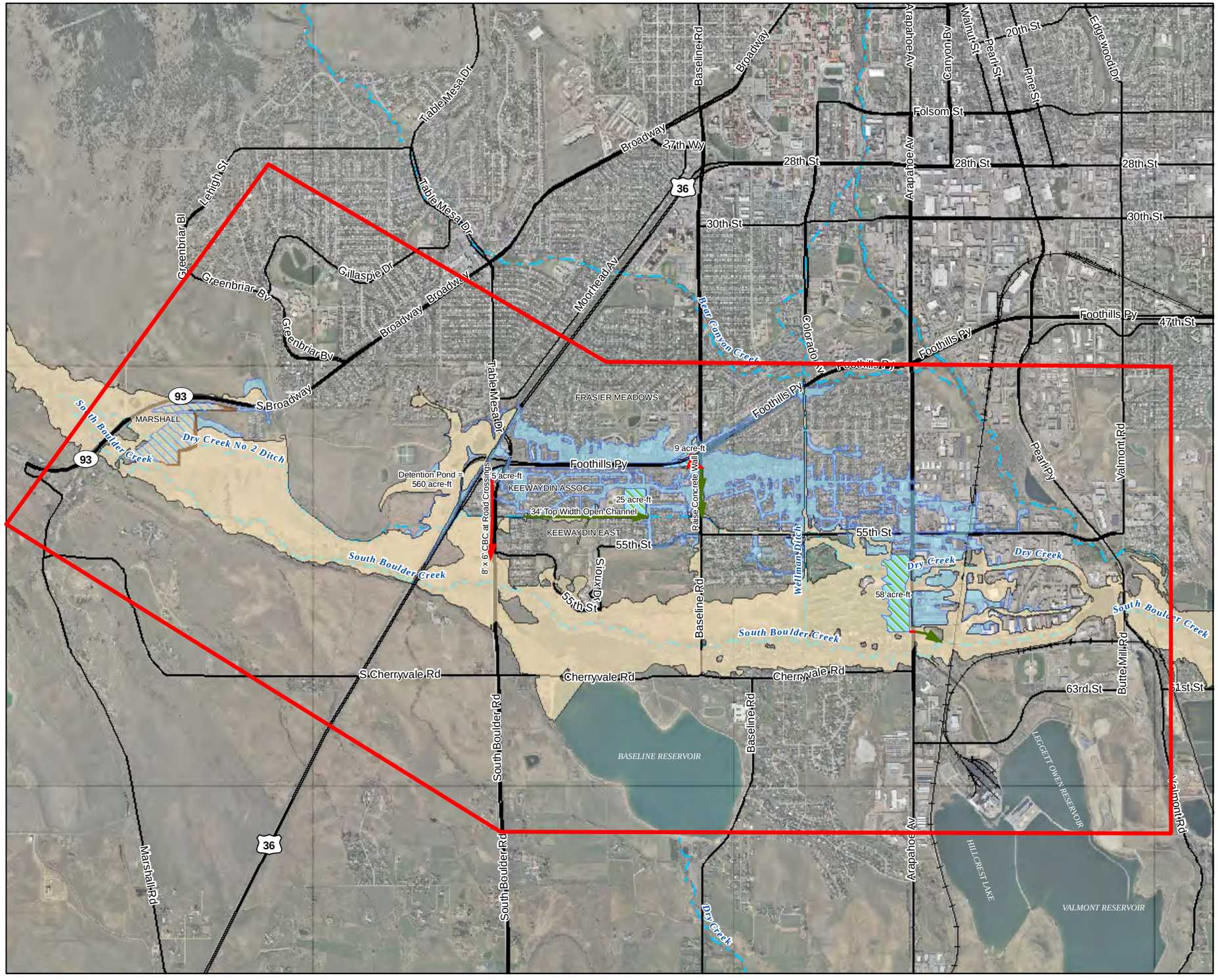
N

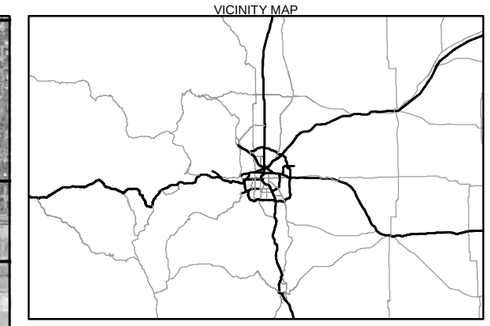
0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-18
US 36 Detention with Downstream Storage and Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Figure 6-18 US 36 Detention with Downstream Storage.mxd





LEGEND

Conveyane Alignment

Category

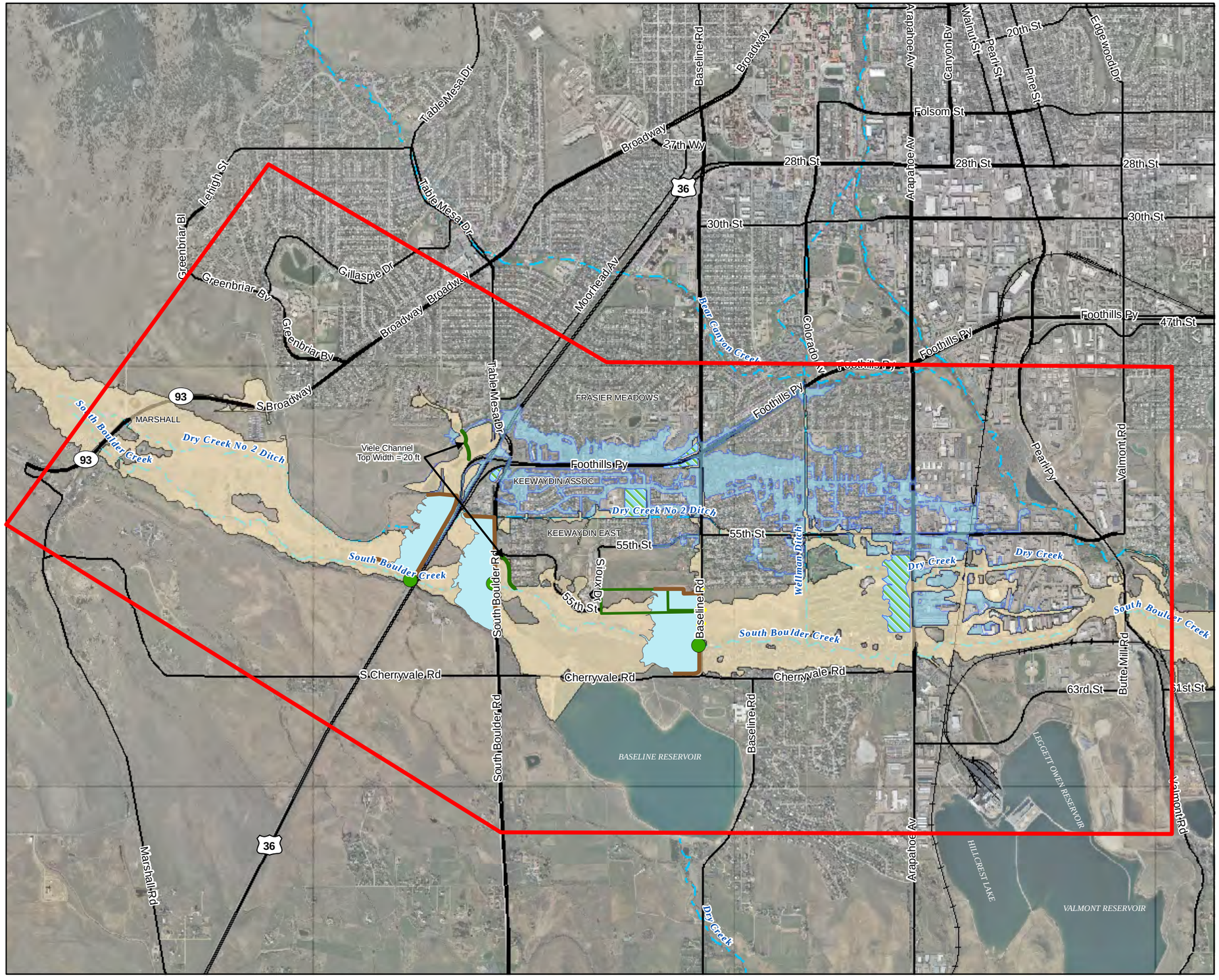
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Local Detention
- AREA OF EXCAVATION
- EMBANKMENT
- Post Project Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-19
Detention near HWY 93 with Downstream Storage and Conveyance through West Valley
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project



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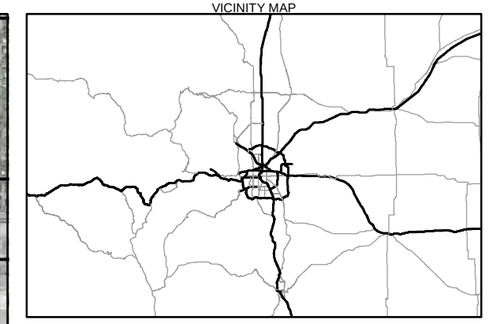


LEGEND

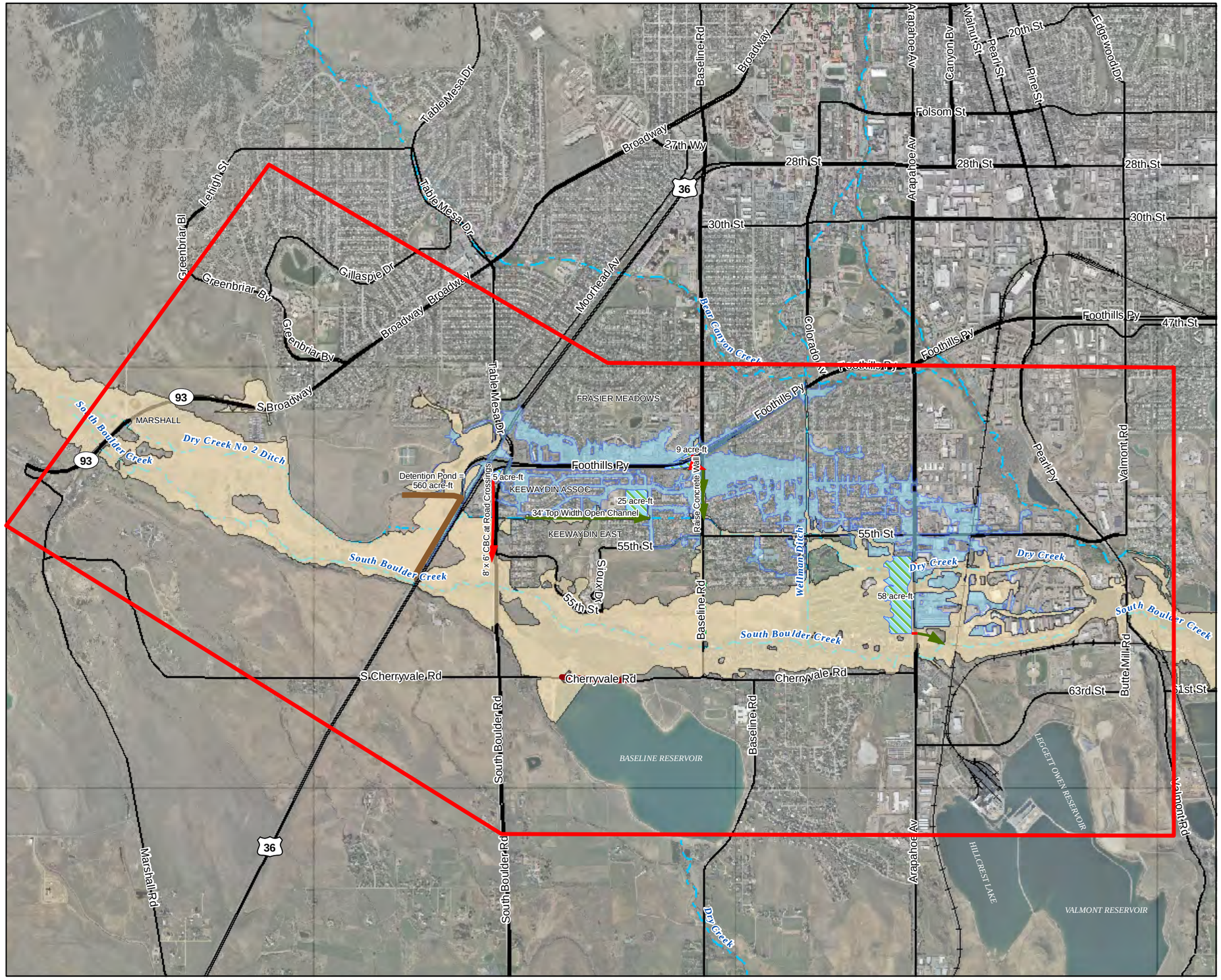
- Hydraulic Control Structures
- Berm
- Baseline Road Culverts
- Viele Channel Improvements
- Granite_Property
- Local Detention
- Distributed Regional Detention
- Post Project Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

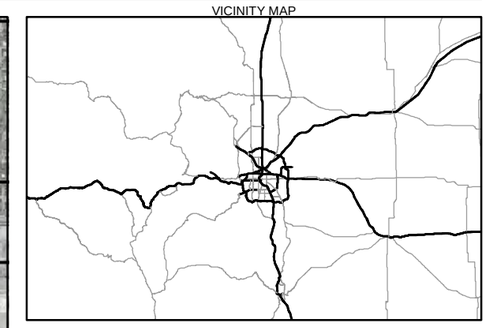
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-20
Mainstem Flow Containment with Distributed Regional Detention
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Conveyane Alignment

Category

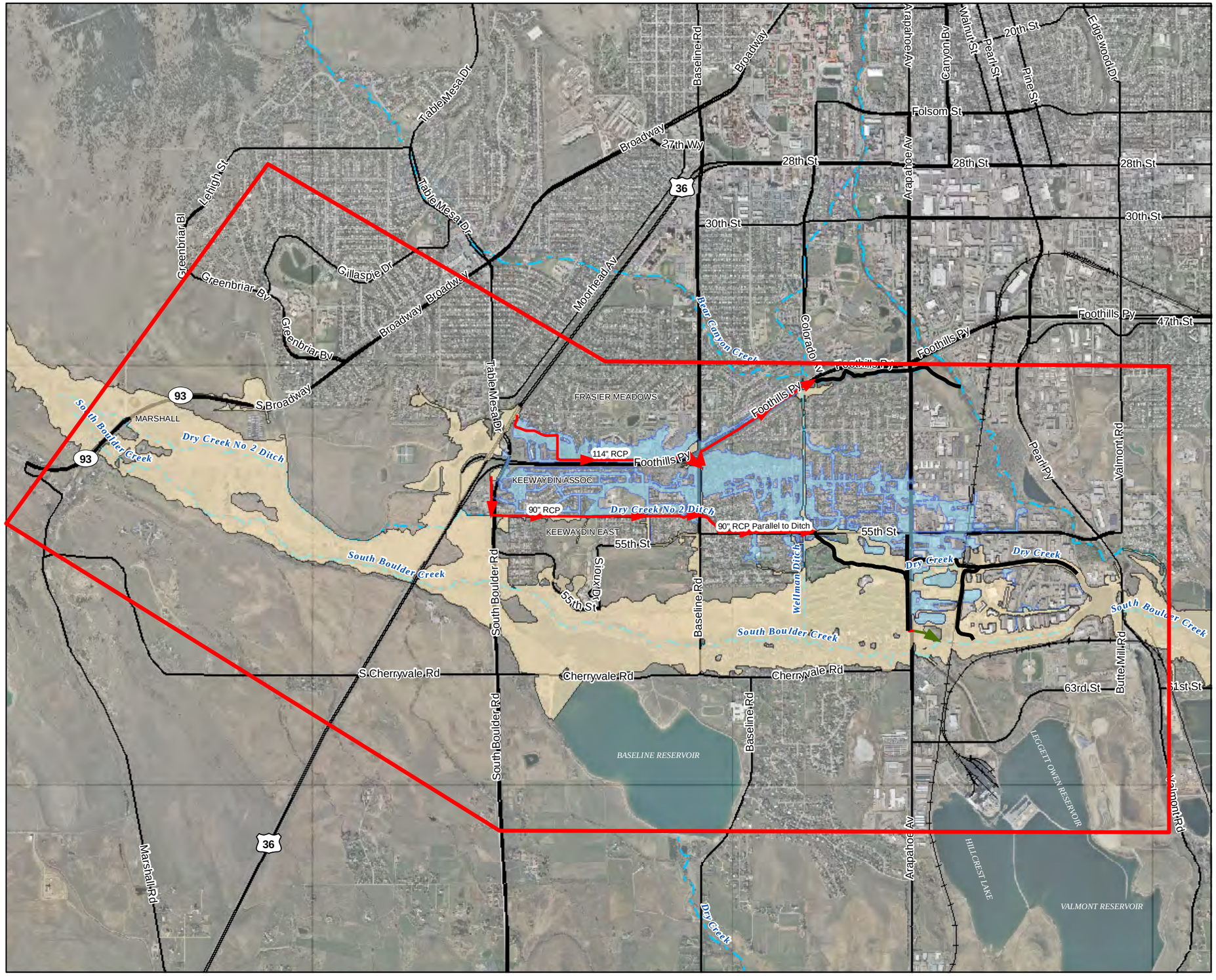
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Directional Berm
- Lower Cherryvale Road
- Culverts through Baseline Road
- Local Detention
- Post Project Conditions Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

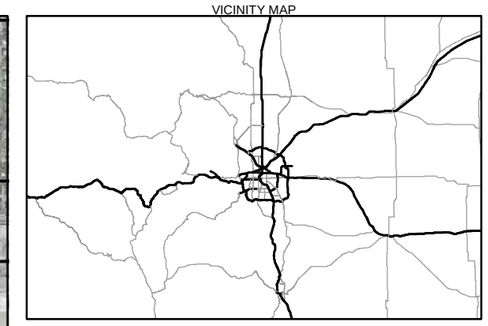
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-21
Mainstem Flow Containment with Local West Valley Improvements
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

Bear Canyon Creek Alignment Improvement

- No Improvement
- Open Channel Improvements
- Piipeline/Culvert Improvement
- Post Project Conditions Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

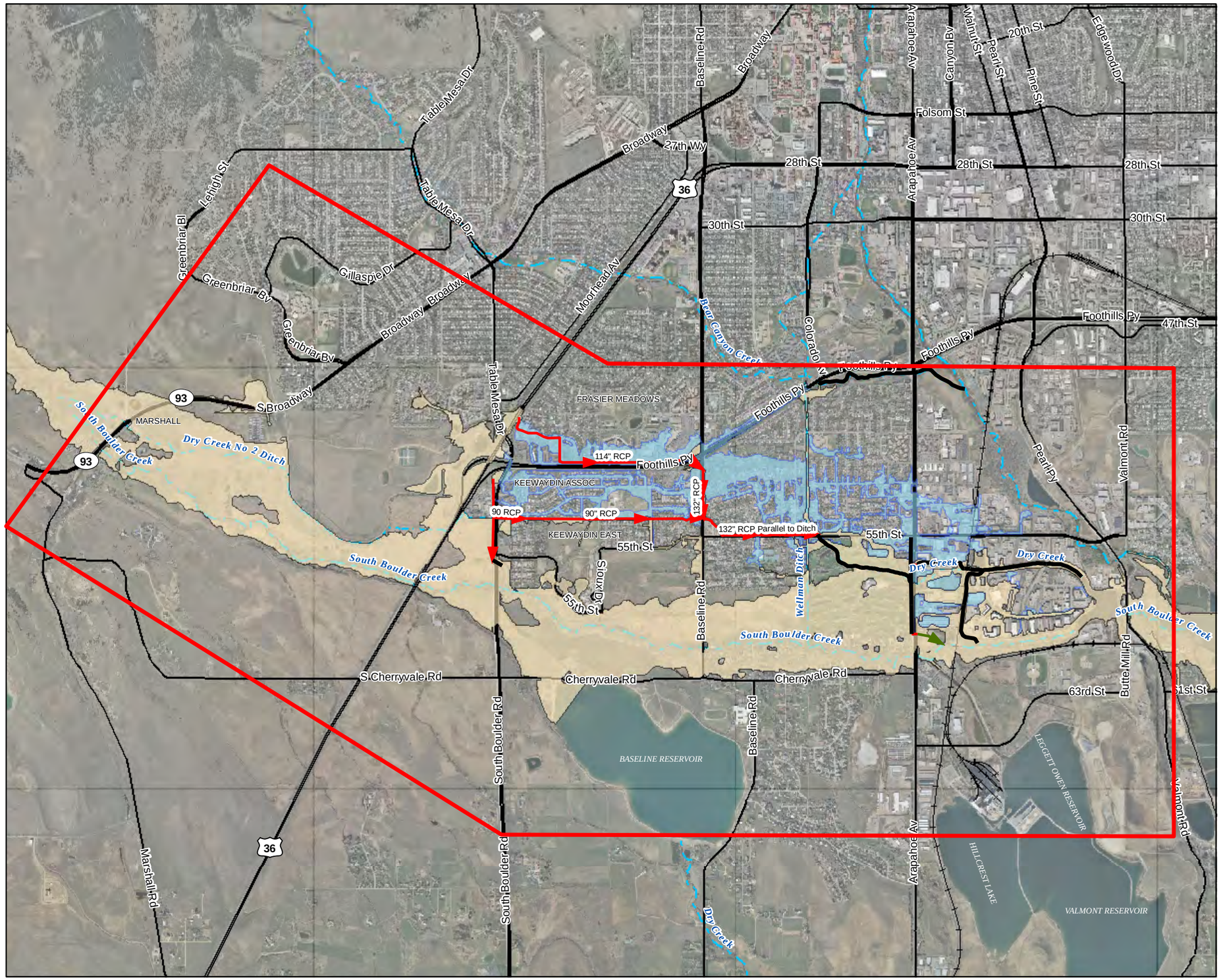
N

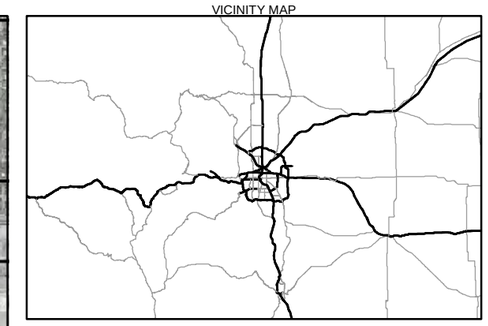
0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-22
No Upstream Detention with Bear Canyon Creek Conveyance Improvements
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Chapter 6\Figure 6-22 No Upstream Detention with Bear Canyon Creek Conveyance Improvements.mxd





LEGEND

Dry Creek Alignment

Improvement

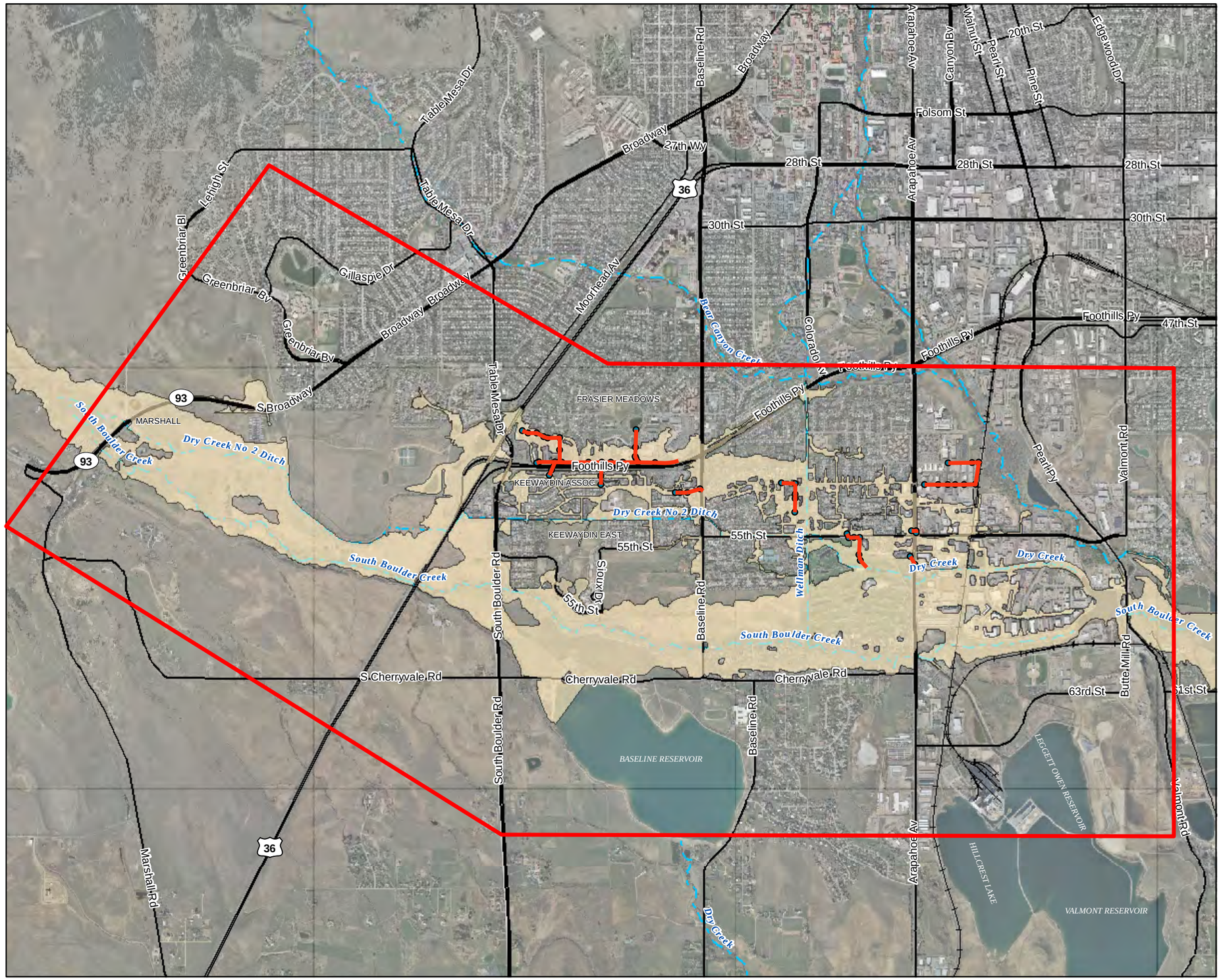
- No Improvement Required
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Post Project Conditions Floodplain
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

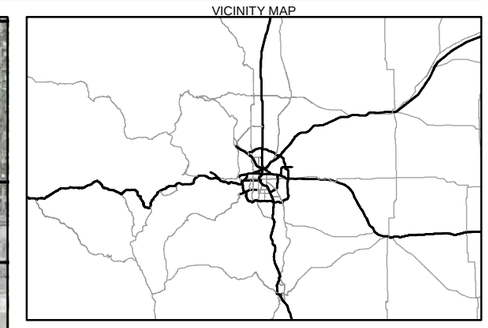
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-23
No Upstream Detention with Dry Creek No. 2 Ditch Conveyance Improvements
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project





LEGEND

- New Stormwater Facilities
- New Manholes
- Post Project Condtions Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 6-24
Stormwater Master Plan Improvements
South Boulder Creek Flood Mitigation Report
South Boulder Creek Flood Mitigation Project

Appendix D
Best Alternative Plan Figures

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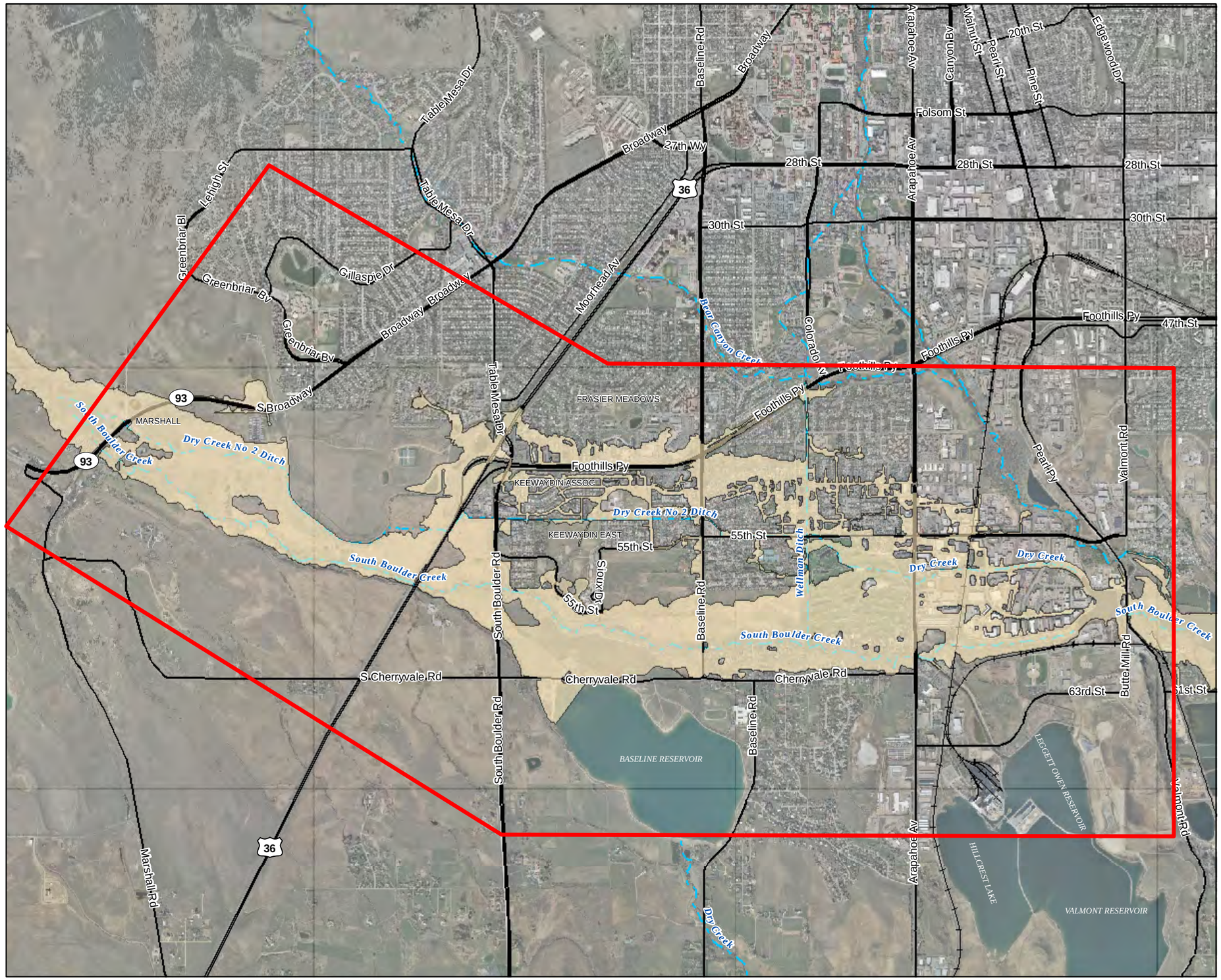
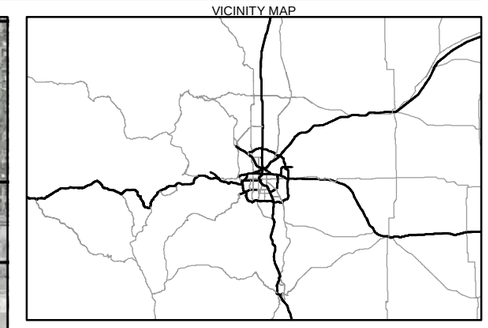




LEGEND

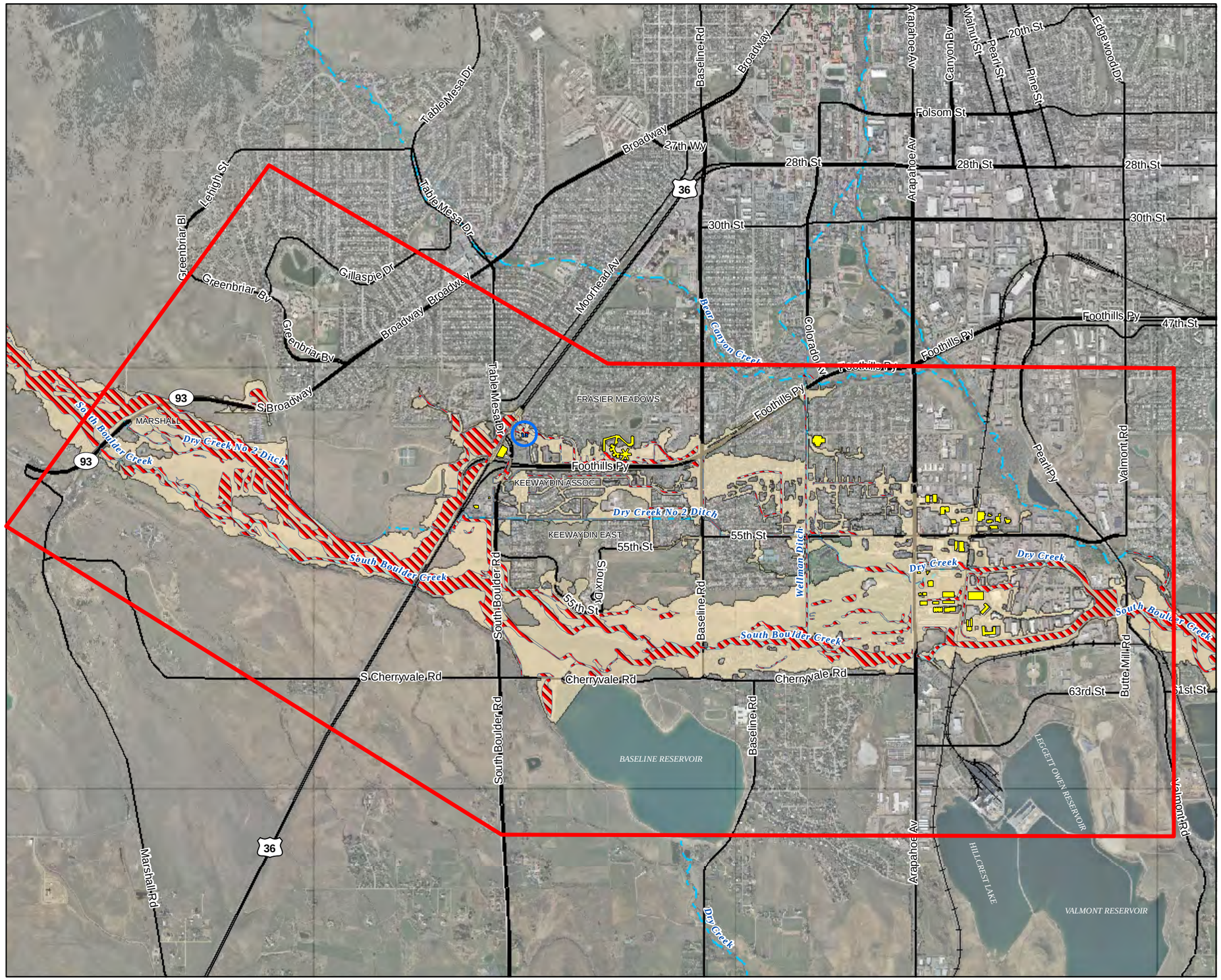
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

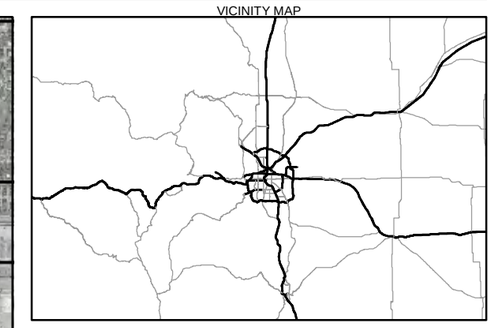
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-1
Status Quo
South Boulder Creek Flood Mitigation Report





LEGEND

- Remove Buildings from High Hazard Zone
- Floodproof Critical Facilities
- High Hazard Zone
- 100-Year Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

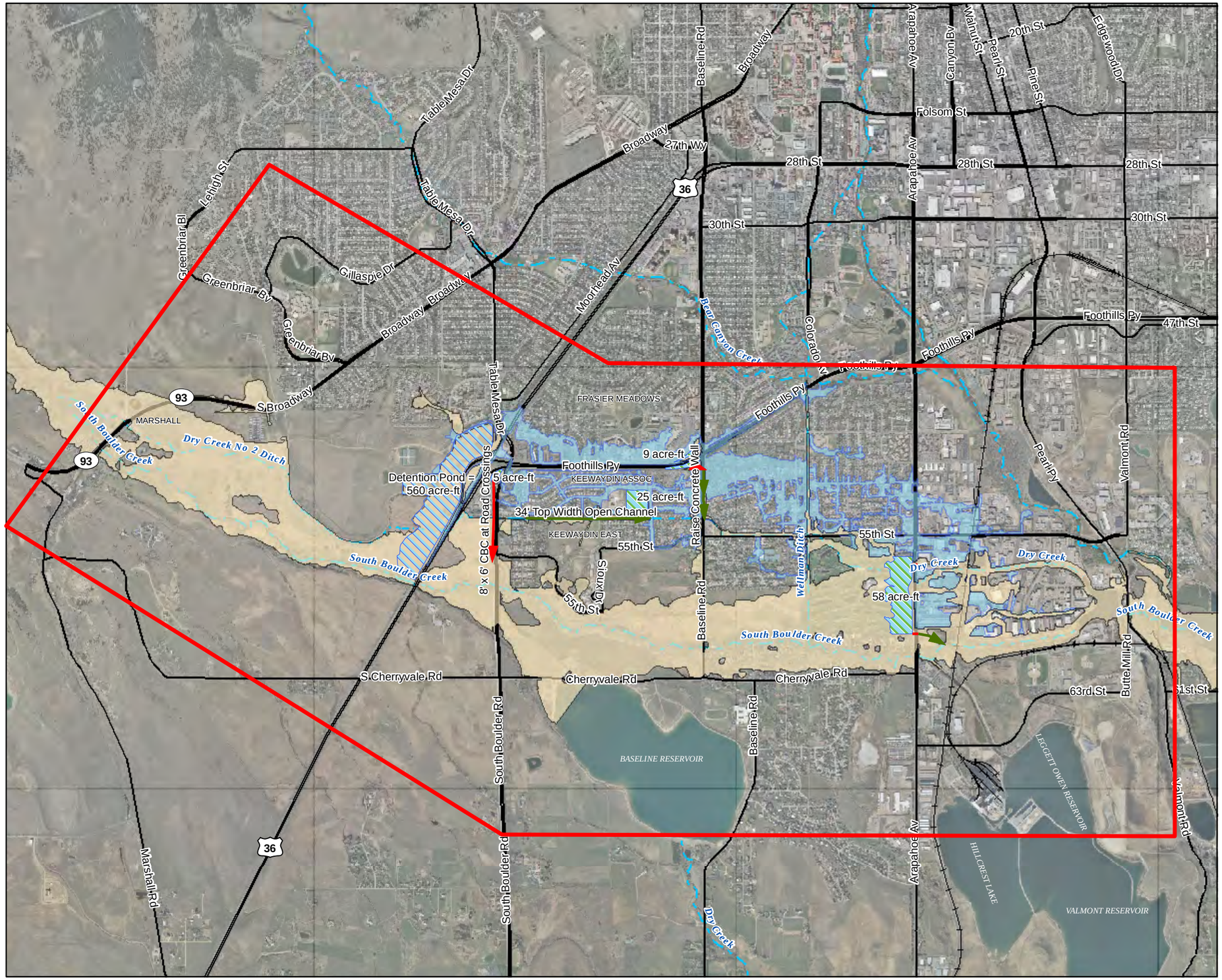
N

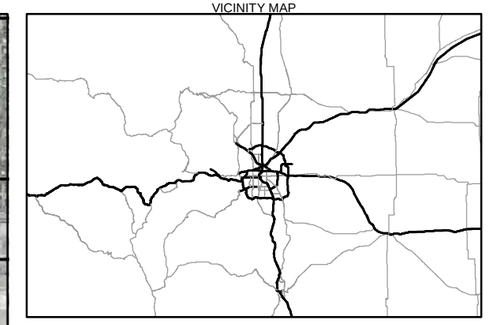
0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-2
High Hazard Zone Containment with Critical Structure Flood Proofing
South Boulder Creek Flood Mitigation Report

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Chapter 7\Figure 7-2 High Hazard Zone Containment with Critical Structure Protection.mxd





LEGEND

Conveyane Alignment

Category

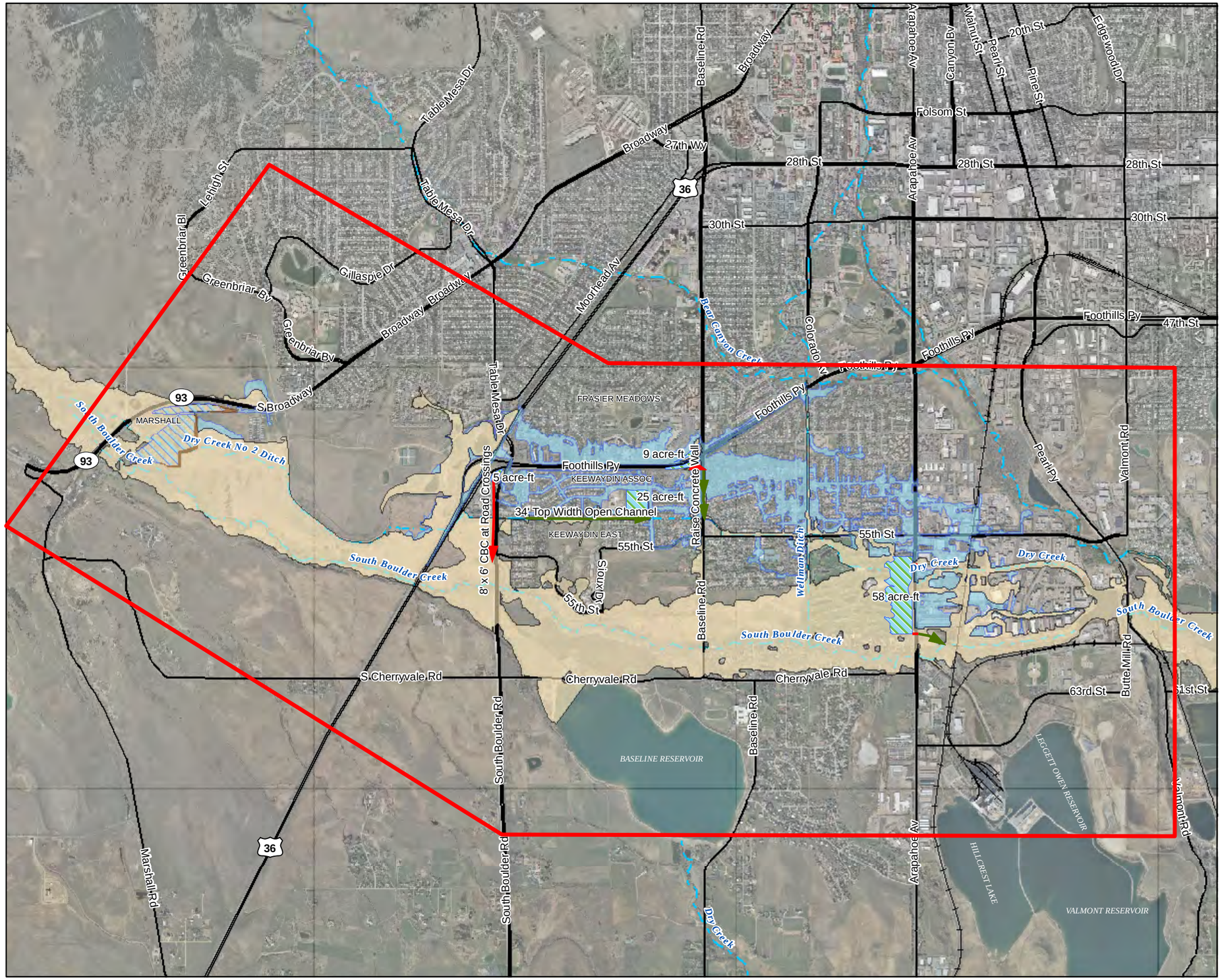
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Detention at US 36
- Local Detention
- Post Project Conditions Floodplain
- Existing Floodplain
- Streams, Creeks and Ditches
- Boulder County

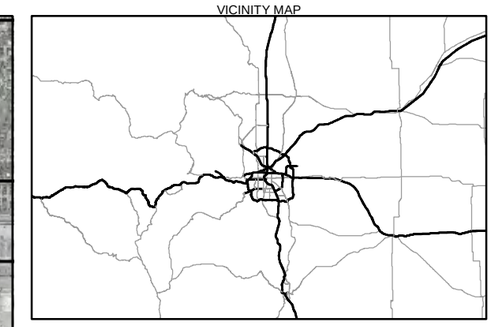
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-3
Regional Detention at US-36
South Boulder Creek Flood Mitigation Report





LEGEND

Conveyane Alignment

Category

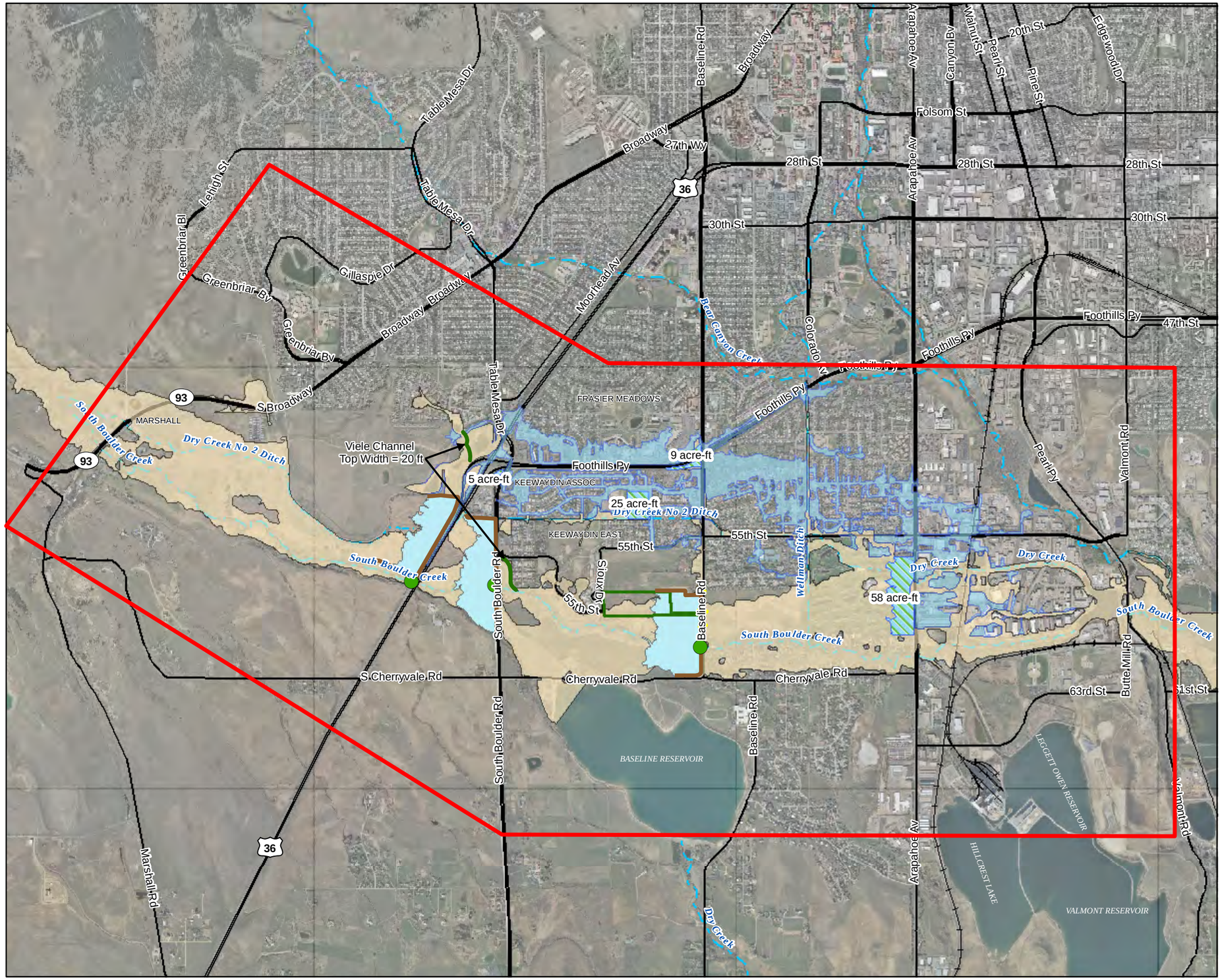
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Local Detention
- AREA OF EXCAVATION
- EMBANKMENT
- Post Project Floodplain
- Existing Floodplain
- Streams, Creeks and Ditches
- Boulder County

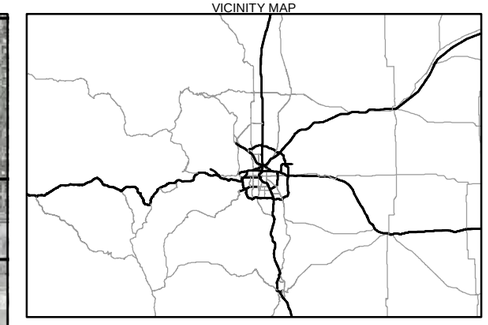
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-4
Regional Detention near HWY-93
South Boulder Creek Flood Mitigation Report





LEGEND

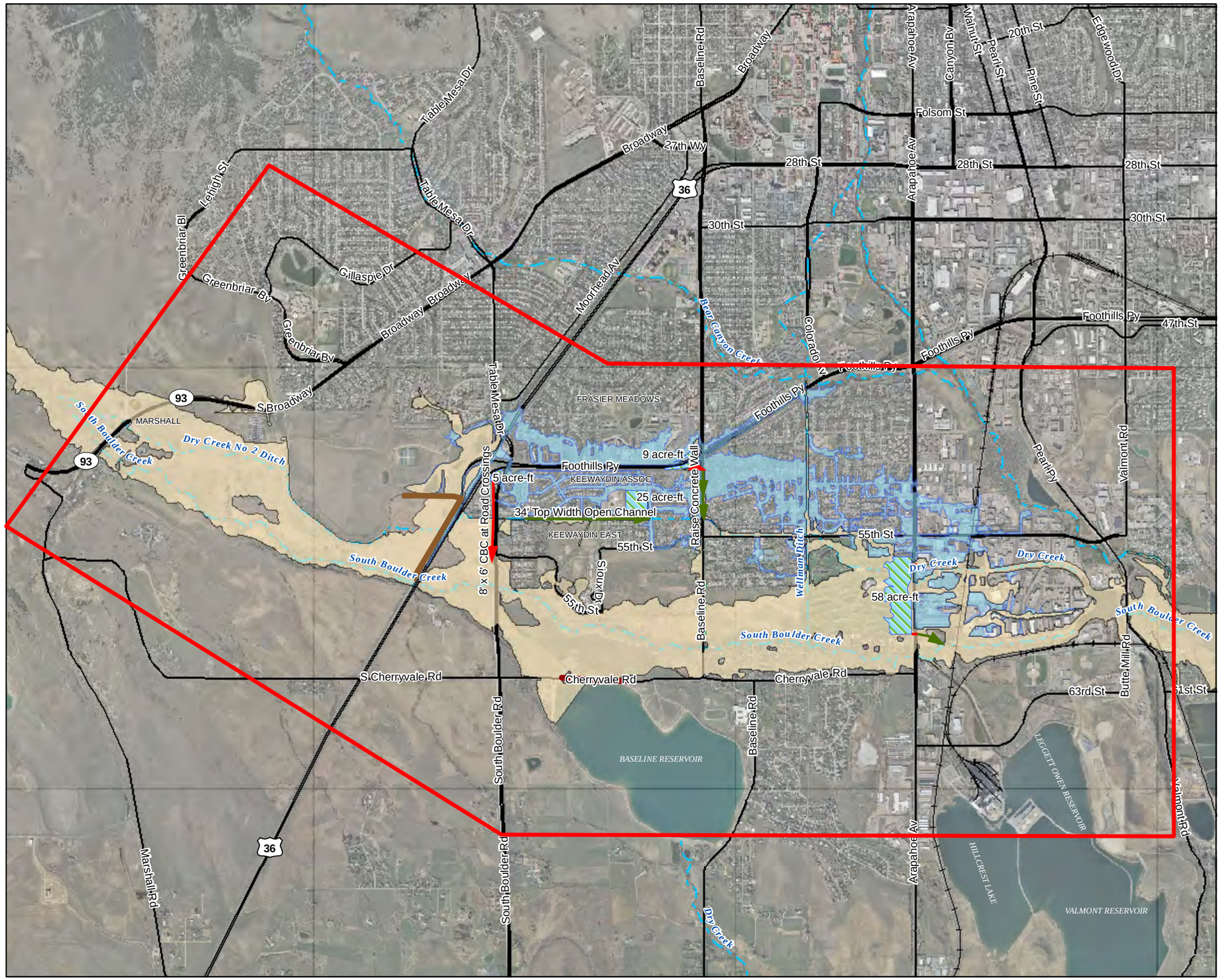
- Hydraulic Control Structures
- Berm
- Baseline Road Culverts
- Viele Channel Improvements
- Existing Floodplain
- Granite_Property
- Local Detention
- Distributed Regional Detention
- Post Project Floodplain
- Streams, Creeks and Ditches
- Boulder County

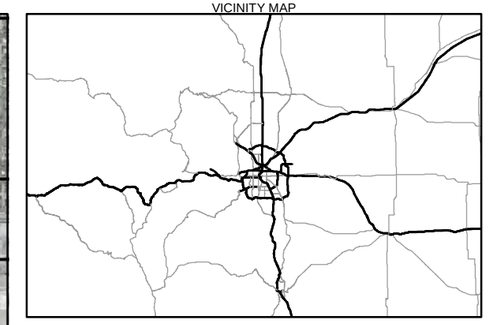
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-5
Distributed Regional Detention
South Boulder Creek Flood Mitigation Report





LEGEND

Conveyane Alignment

Category

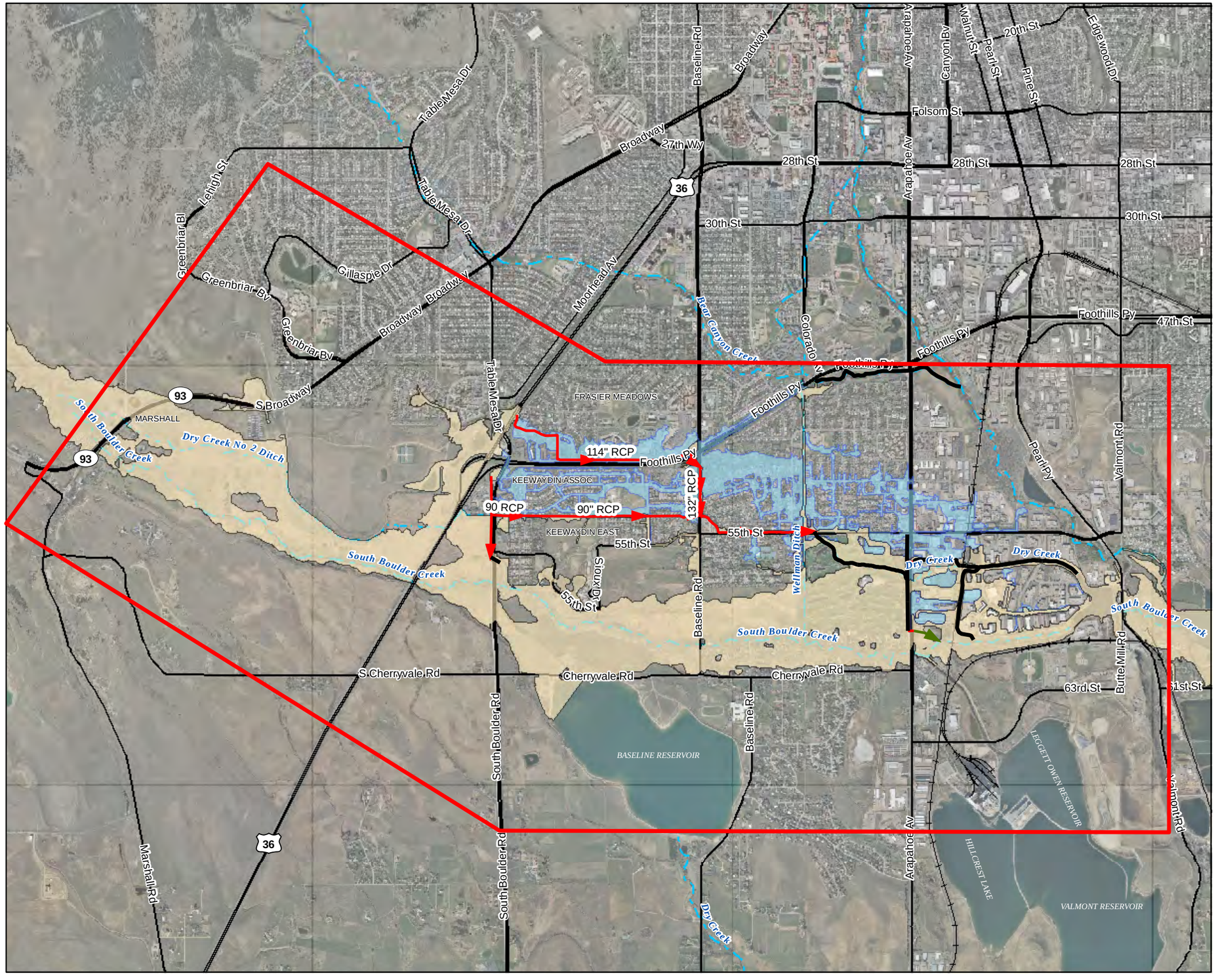
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Directional Berm
- Lower Cherryvale Road
- Culverts through Baseline Road
- Local Detention
- Post Project Conditions Floodplain
- Existing Floodplain
- Streams, Creeks and Ditches
- Boulder County

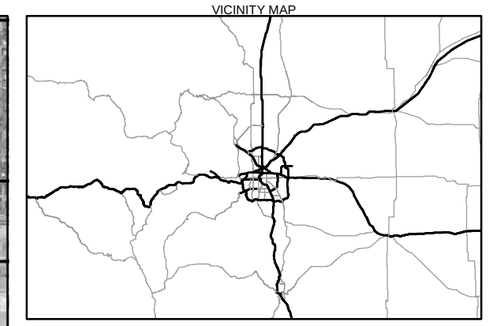
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-6
Mainstem Flow Containment
South Boulder Creek Flood Mitigation Report





LEGEND

Dry Creek Alignment

Improvement

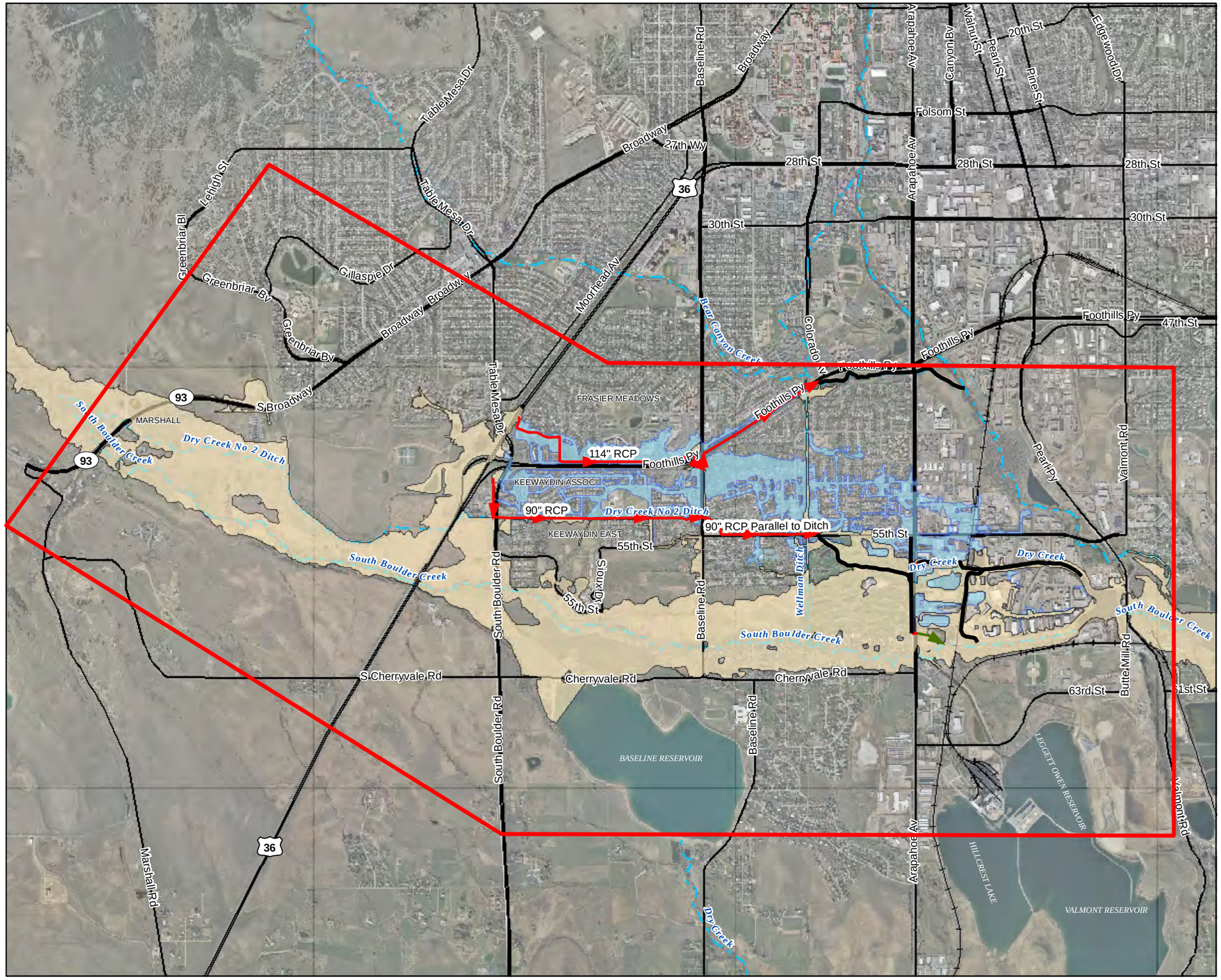
- No Improvement Required
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Post Project Conditions Floodplain
- Existing Floodplain
- Streams, Creeks and Ditches
- Boulder County

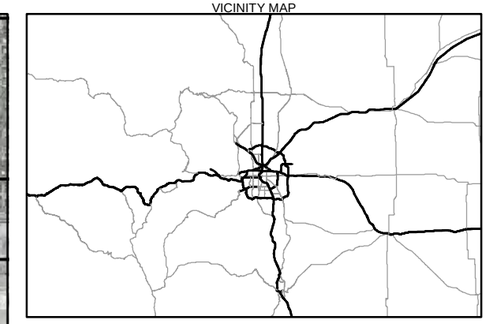
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-7
Dry Creek No. 2 Ditch Pipeline
South Boulder Creek Flood Mitigation Report





LEGEND

Bear Canyon Creek Alignment Improvement

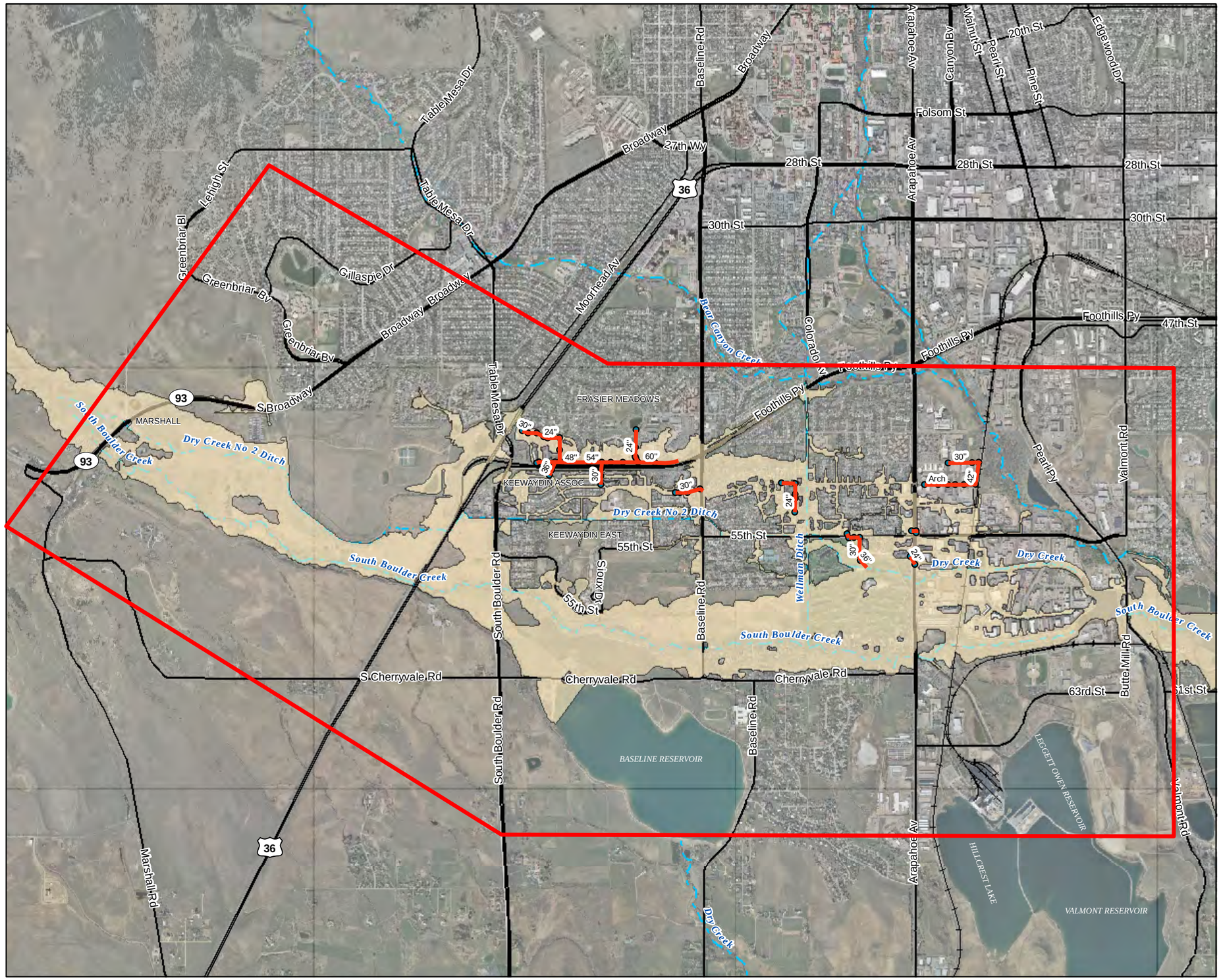
- No Improvement
- Open Channel Improvements
- Piipeline/Culvert Improvement
- Post Project Conditions Floodplain
- Existing Floodplain
- Streams, Creeks and Ditches
- Boulder County

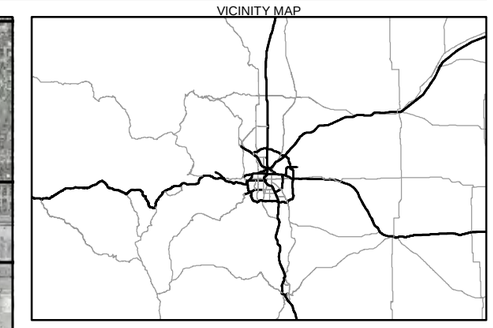
Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-8
Bear Canyon Creek Pipeline
South Boulder Creek Flood Mitigation Report





LEGEND

- New Stormwater Facilities
- New Manholes
- Post Project Condtions Floodplain
- Streams, Creeks and Ditches
- Boulder County

Notes:
1. Area of Interest

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 7-9
Nuisance-Level Flood Improvement Protection
South Boulder Creek Flood Mitigation Report

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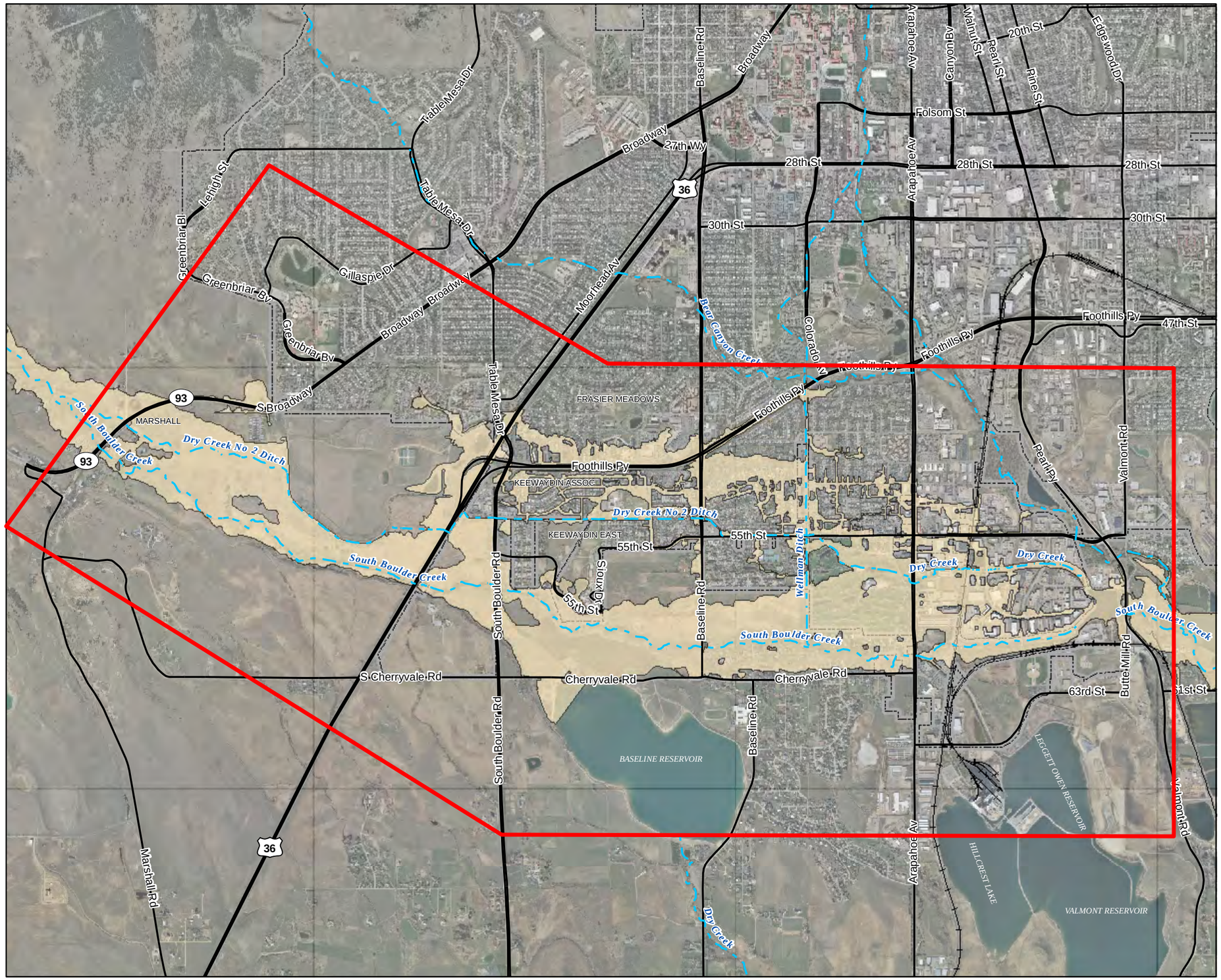
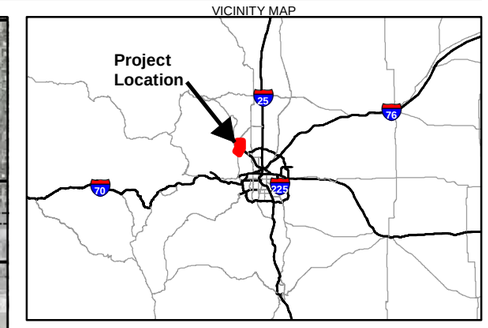




LEGEND

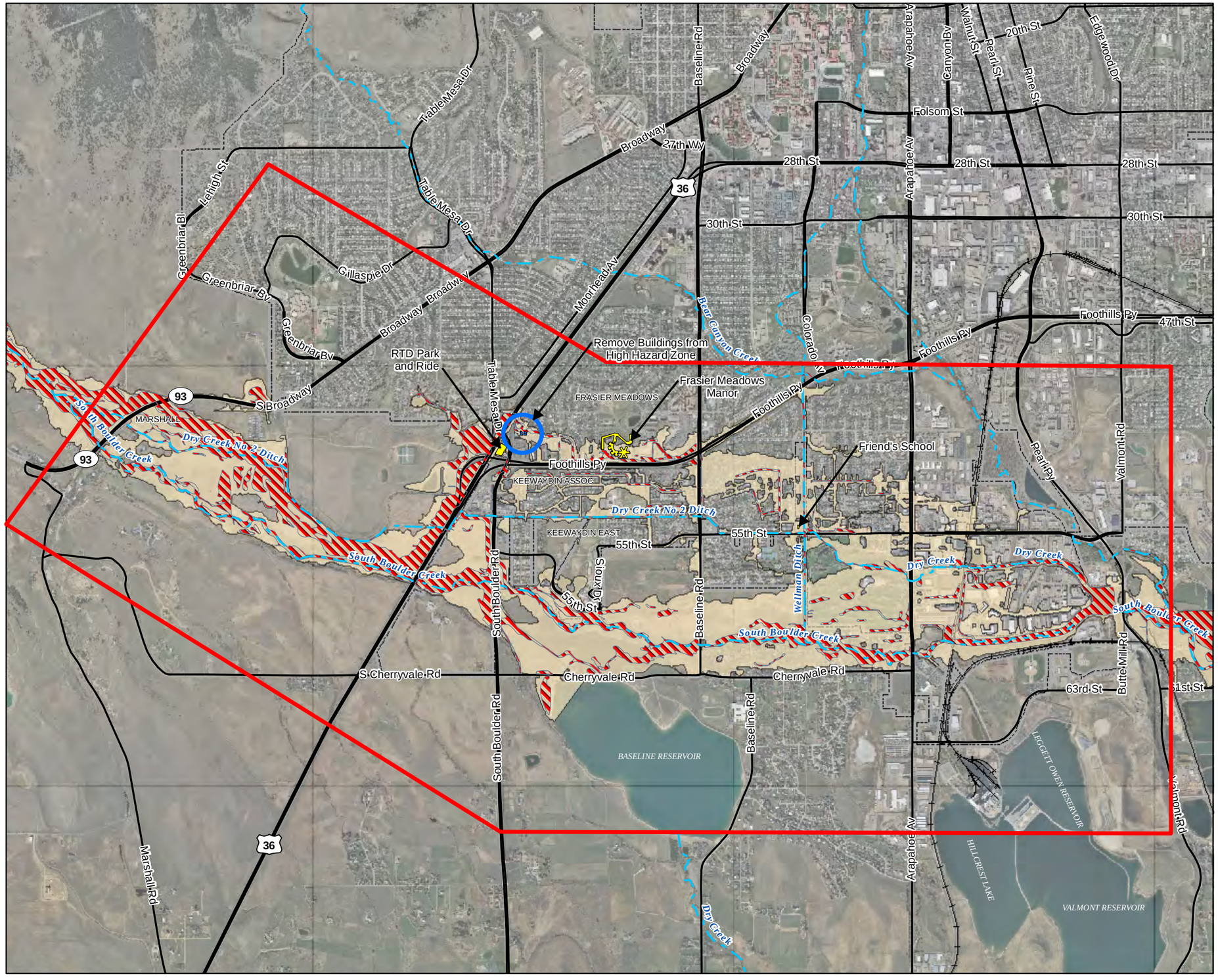
- Streams, Creeks and Ditches
- 100-Year Floodplain

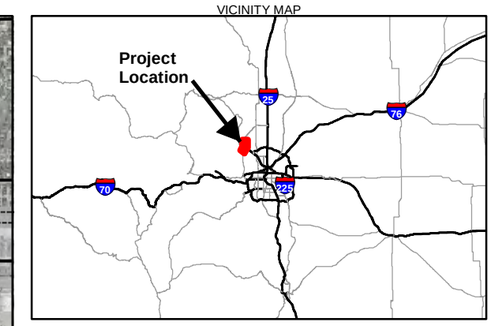
Notes:
1. Study Area

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 8-1
Status Quo-Existing Floodplain
South Boulder Creek Flood Mitigation Report





LEGEND

- Streams, Creeks and Ditches
- Remove Buildings from High Hazard Zone
- 100-Year Critical Facilities
- High Hazard Zone
- 100-Year Floodplain

Notes:
1. Study Area

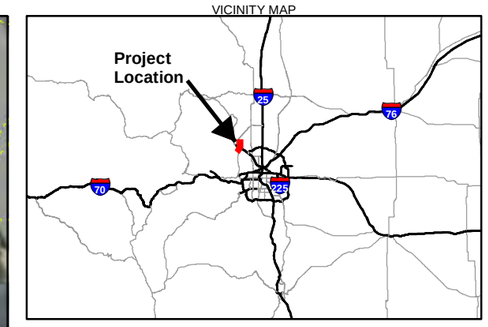
N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 8-2
100-Year High Hazard Zone Mitigation without Hazardous Materials Facilities
South Boulder Creek Flood Mitigation Report

CH2MHILL

\\gecko\wbg\400168_South_Boulder_Creek_Phase_A\08_GIS\MapFiles\Report\Chapter 8\Figure 8-2 High Hazard Zone Mitigation.mxd



LEGEND

- High Hazard Protection Wall
- High Hazard Protection Grading
- Buildings in High Hazard Zone
- High Hazard Zone

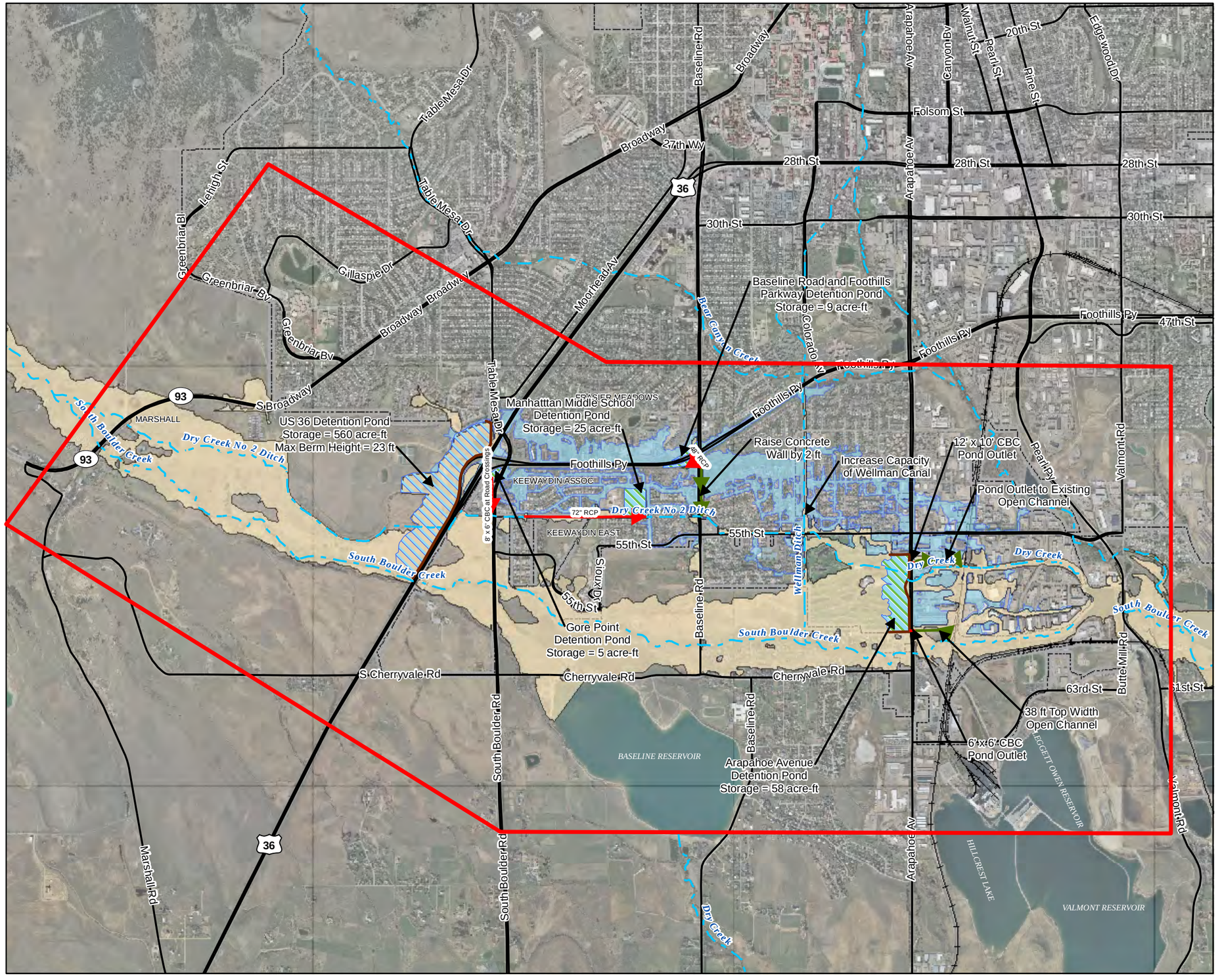
SBC 1' Topo

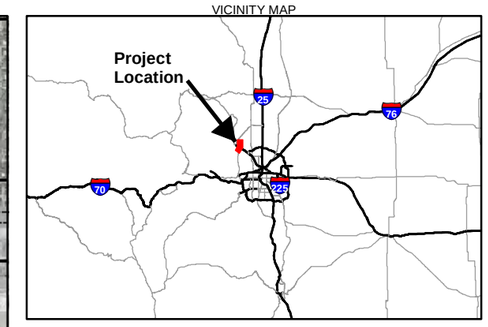
- Index Contour
- Interval Contour

N

0 40 80
Feet

FIGURE 8-3
High Hazard Grading Improvements
South Boulder Creek Flood Mitigation Report





LEGEND

Conveyance Alignment

Category

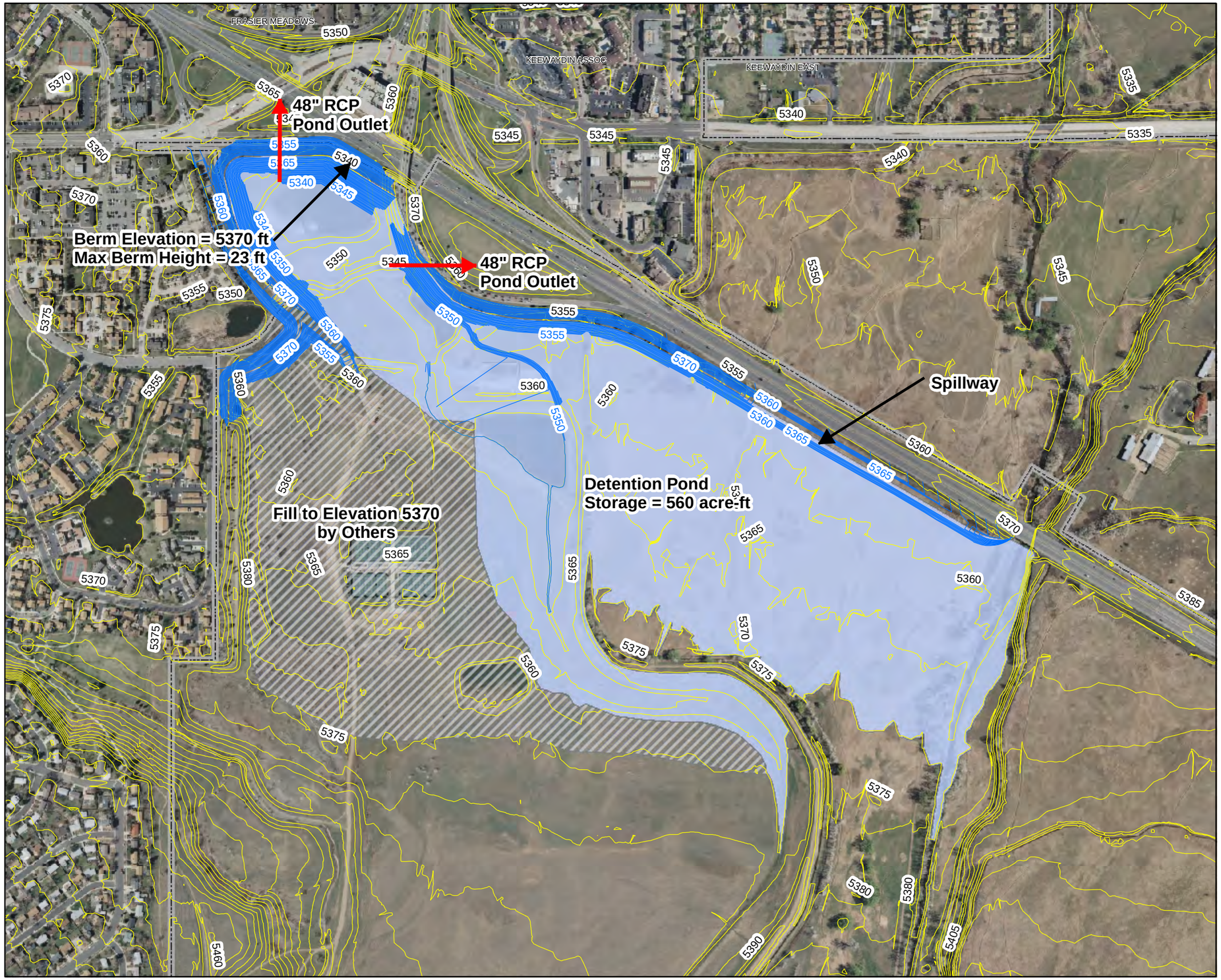
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Embankment
- Streams, Creeks and Ditches
- Detention at US 36
- Local Detention
- Post Project Floodplain
- Existing Floodplain

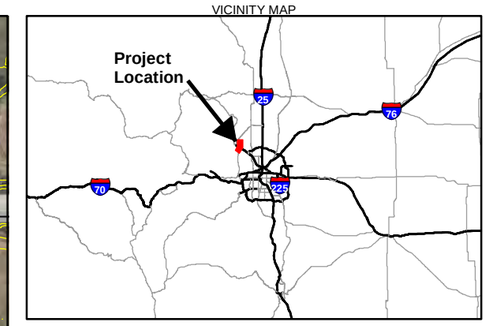
Notes:
1. Study Area

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 8-4
Regional Detention at US-36
South Boulder Creek Flood Mitigation Report





LEGEND

- Proposed Grading at US-36
- Detention Pond Limits
- Fill by Others
- Streams, Creeks and Ditches
- Main Road
- Existing 5' Contours

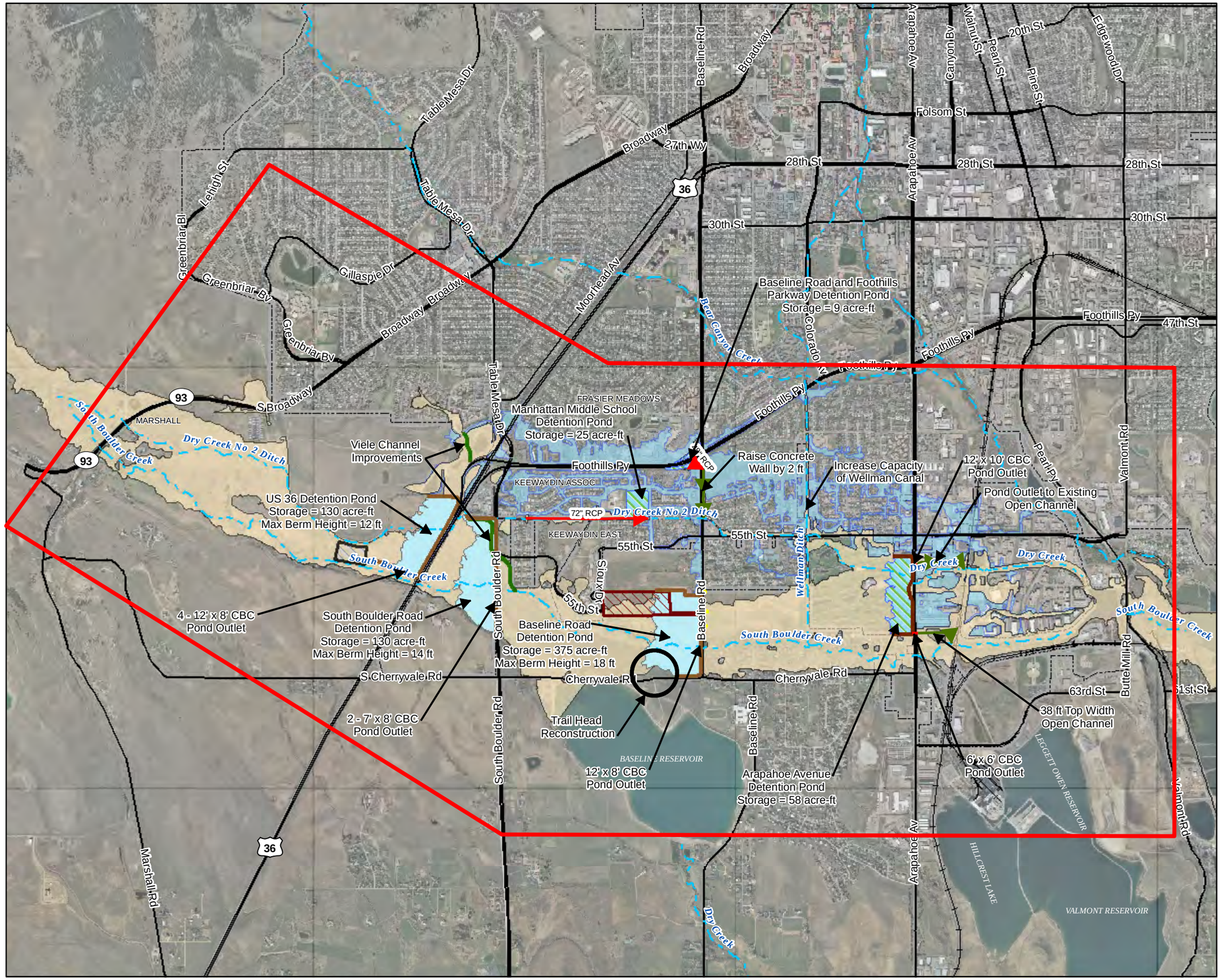
N

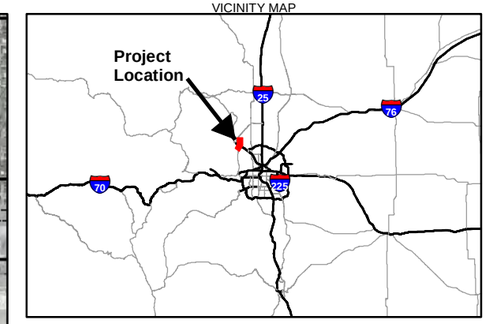
0 400 800 1,200
Feet

FIGURE 8-5
US-36 Detention
South Boulder Creek Flood Mitigation Report

Figure 8-6

US 36 Detention Pond Embankment Rendering





LEGEND

Conveyance Alignment Category

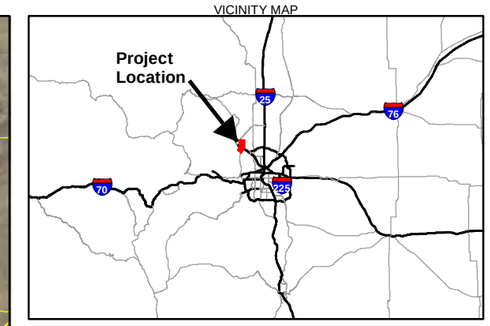
- Open Channel Improvement
- Pipeline/Culvert Improvement
- Control Structure
- Embankment
- Baseline Road Culverts
- Viele Channel Improvements
- Streams, Creeks and Ditches
- Granite Property
- Local Detention
- Distributed Regional Detention
- Post Project Floodplain
- Existing Floodplain

Notes:
1. Study Area

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 8-7
Distributed Regional Detention
South Boulder Creek Flood Mitigation Report



LEGEND
- Proposed Grading at US 36
- Detention Pond Limits
- Main Road
- Streams, Creeks and Ditches
- Existing 5' Contours

N

0 400 800
Feet

FIGURE 8-8
Distributed Regional Detention
US 36 Pond
South Boulder Creek Flood Mitigation Report

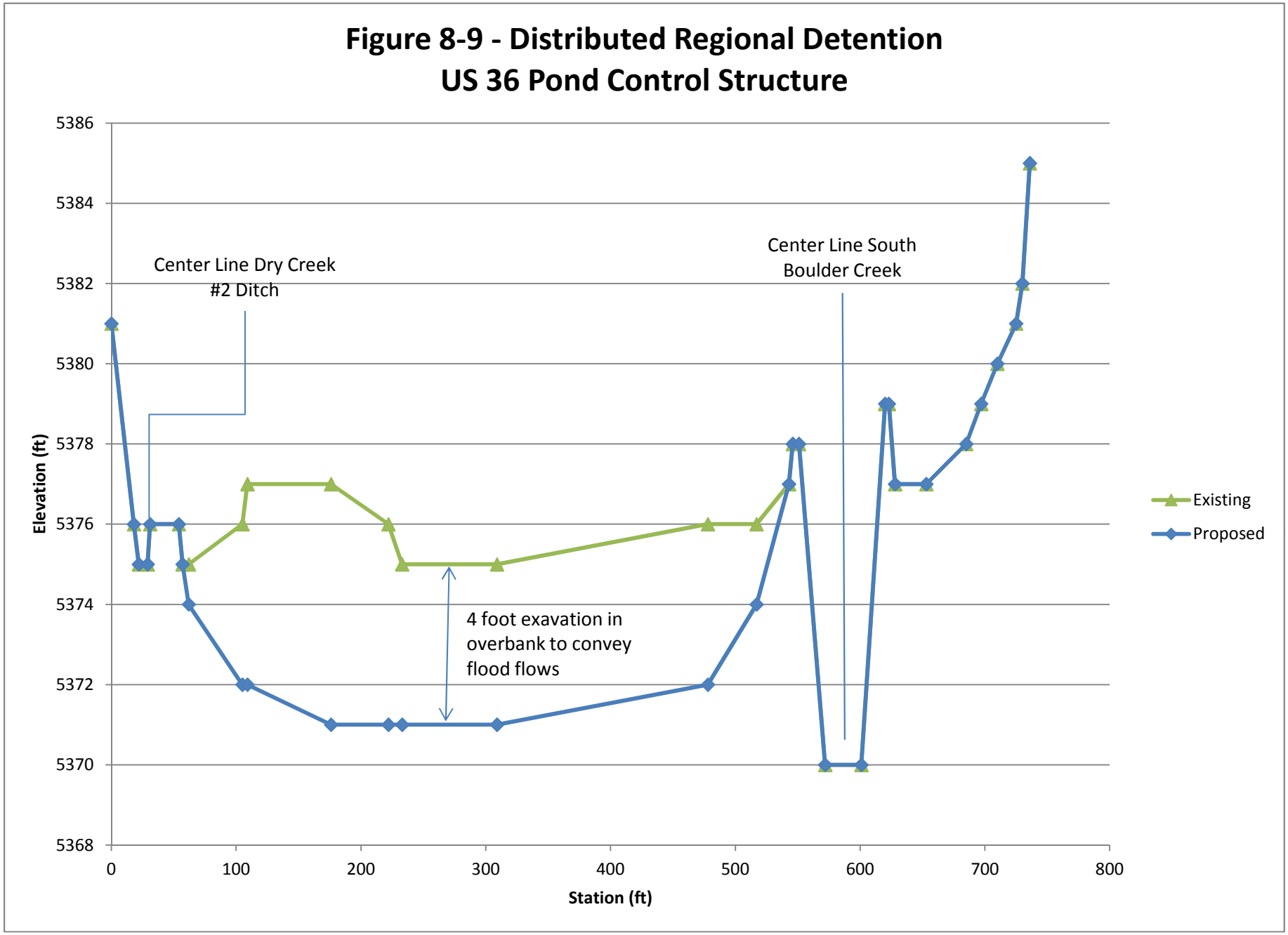
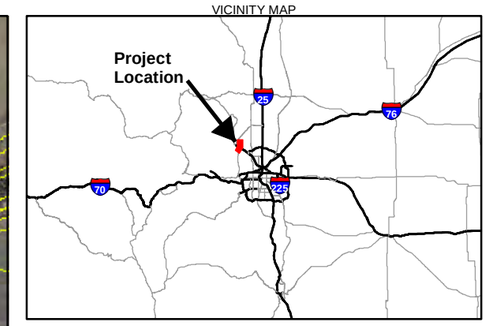


Figure 8-9 - Distributed Regional Detention
US 36 Pond Control Structure
Elevation (ft)
5386
5384
5382
5380
5378
5376
5374
5372
5370
5368
0
100
200
300
400
500
600
700
800
Station (ft)
Center Line Dry Creek
#2 Ditch
Center Line South
Boulder Creek
4 foot exavation in
overbank to convey
flood flows
Existing
Proposed



LEGEND

- Streams, Creeks and Ditches
- Main Road
- Proposed Grading at South Boulder Road
- Detention Pond Limits
- Existing 5' Contour

N

0
Feet

FIGURE 8-10
Distributed Regional Detention
South Boulder Road Pond Embankment
South Boulder Creek Flood Mitigation Report

CH2MHILL

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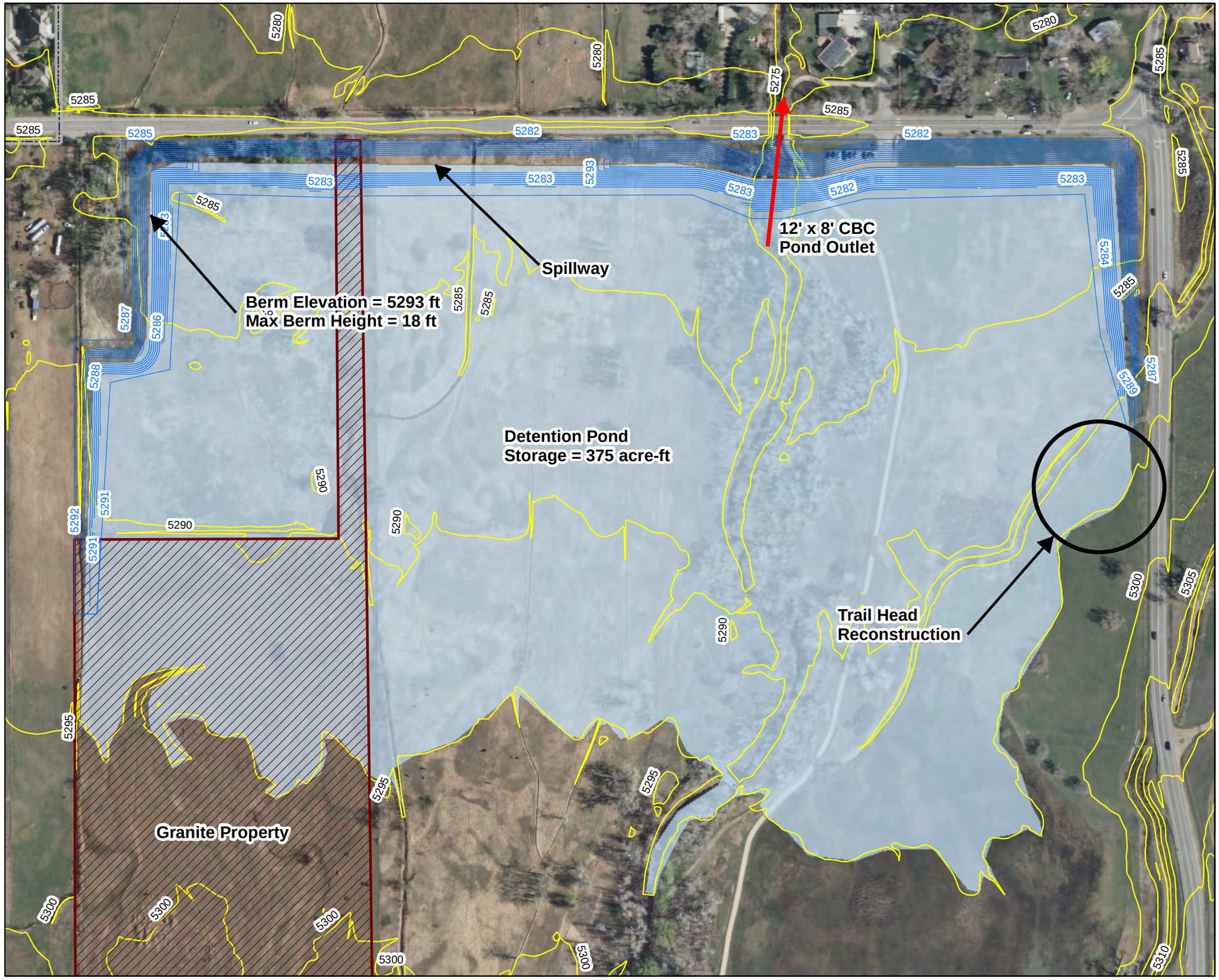
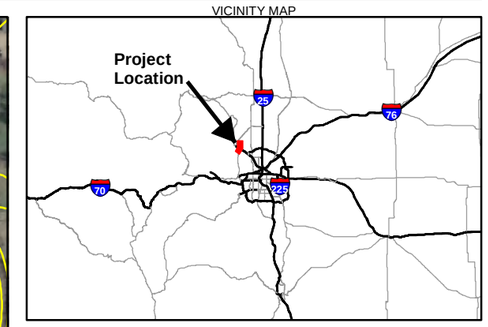




LEGEND
- Proposed Grading at Baseline Road
- Detention Pond Limits
- Streams, Creeks and Ditches
- Main Road
- Granite_Property
- Existing 5' Contours

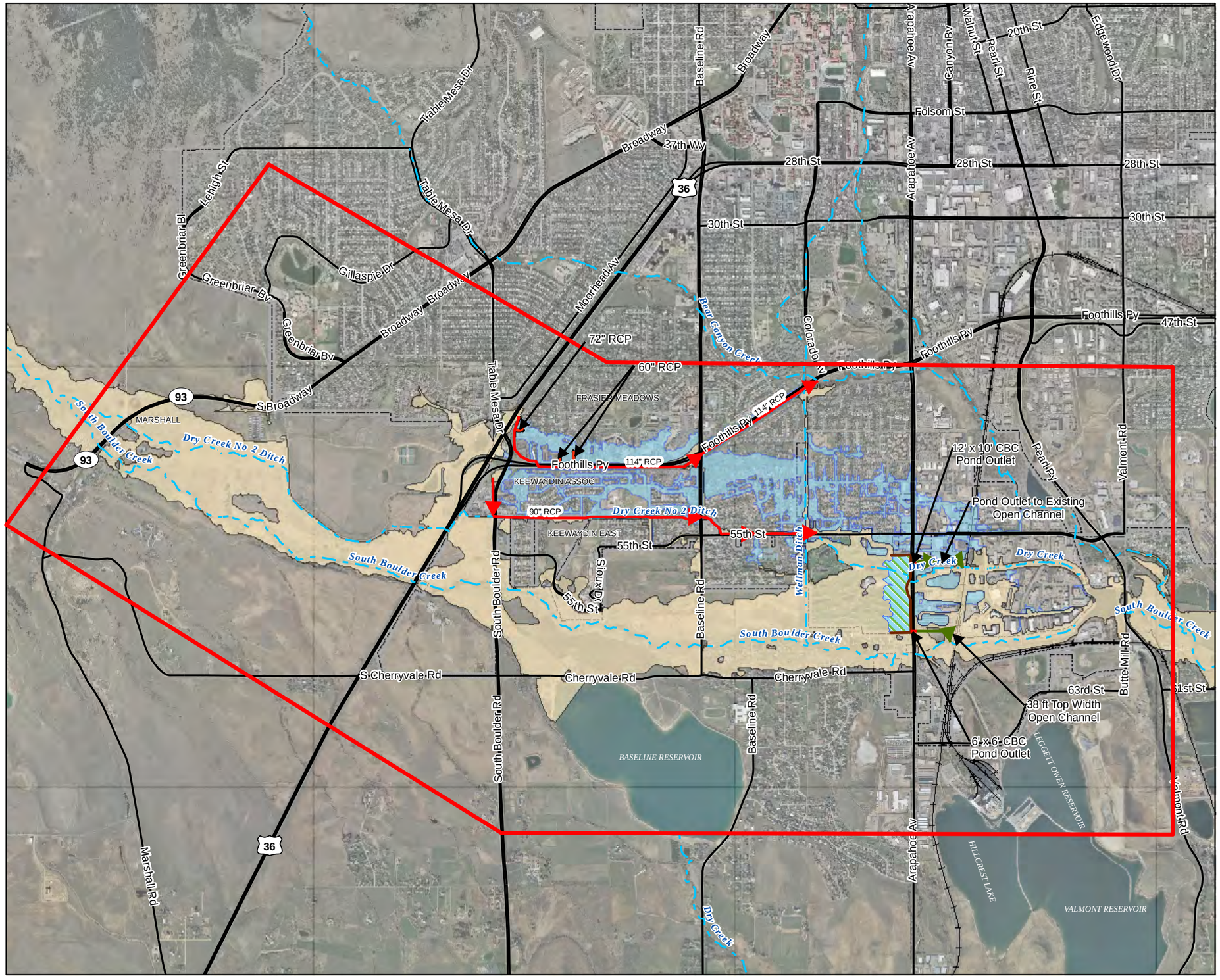
N

0 300 600
Feet

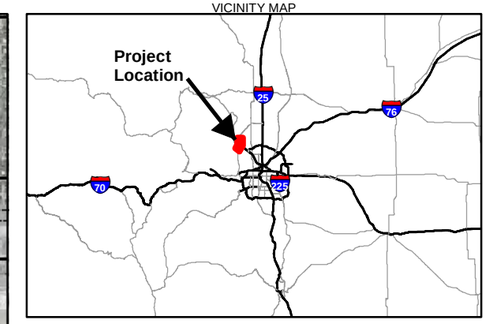
FIGURE 8-11
Distributed Regional Detention
Baseline Road Pond Embankment
South Boulder Creek Flood Mitigation Report

Figure 8-12

Baseline Road Detention Pond Embankment Rendering



VICINITY MAP



LEGEND

Bear Canyon Creek Alignment Improvement

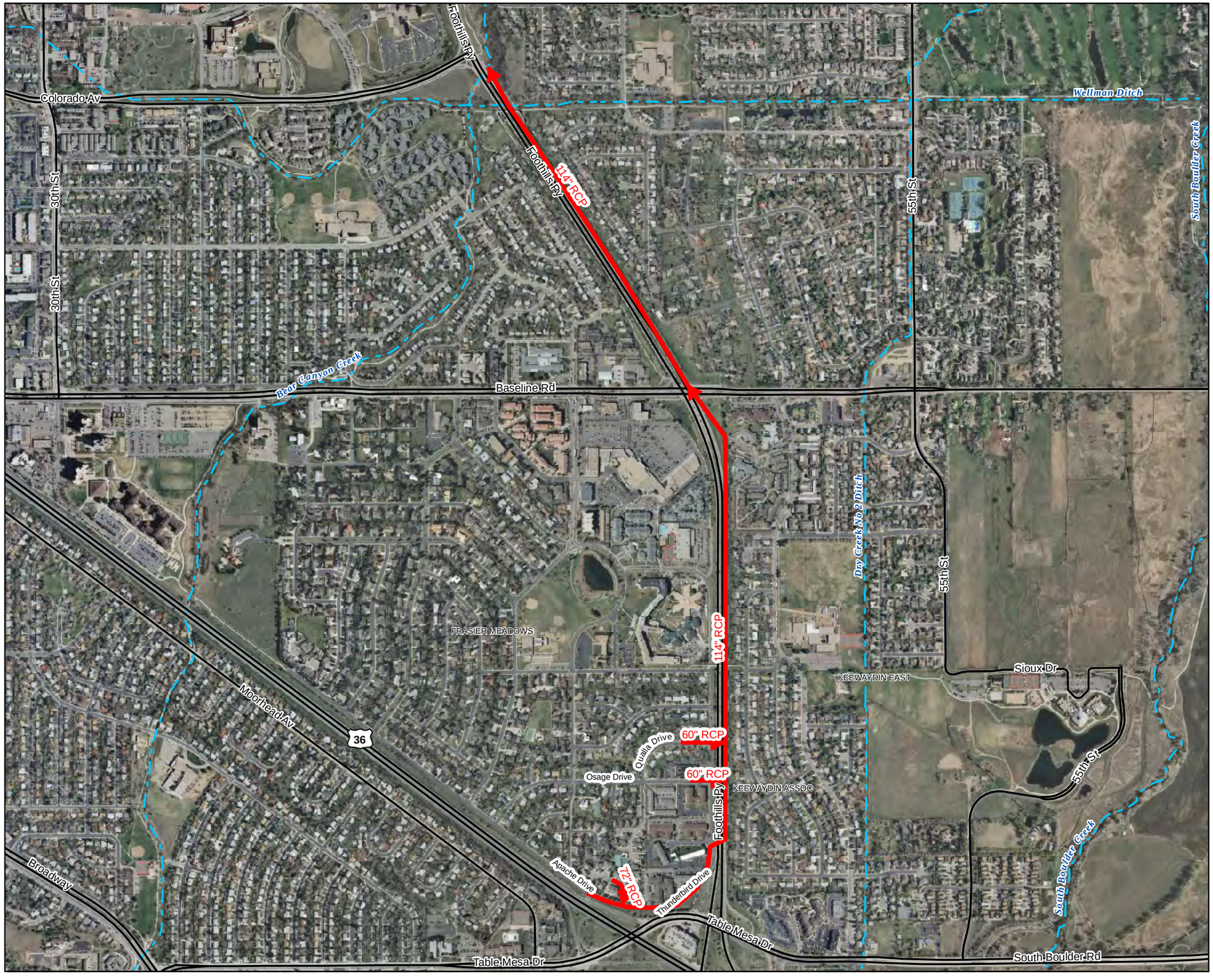
- Open Channel Improvements
- Piipeline/Culvert Improvement
- Lateral Pipes
- Inlets
- Arapahoe Avenue Berm
- Streams, Creeks and Ditches
- Arapahoe Detention Pond
- Post Project Conditions Floodplain
- Existing Floodplain

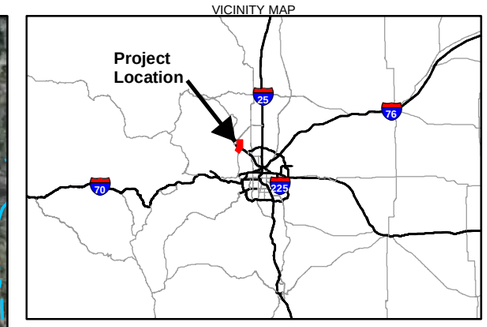
Notes:
1. Study Area

N

0 1,000 2,000 3,000 4,000 5,000
Feet

FIGURE 8-13
Bear Canyon Creek Pipeline
South Boulder Creek Flood Mitigation Report





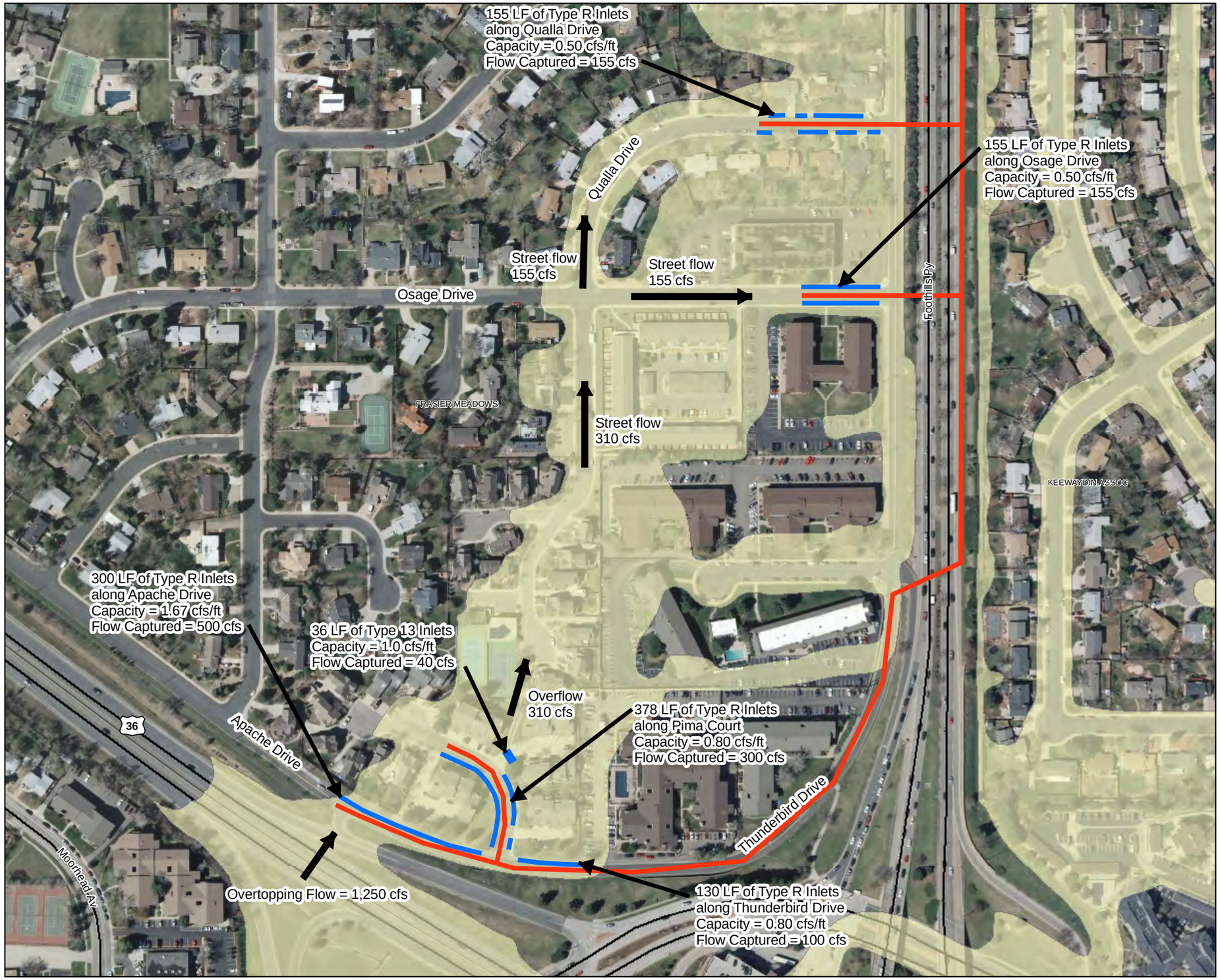
LEGEND

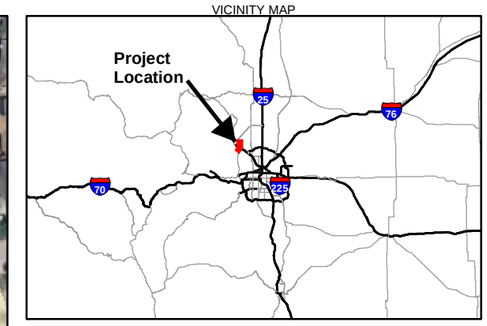
- Thunderbird Pipeline Alignment
- Streams, Creeks and Ditches
- Main Road

N

0 1,000 2,000
Feet

FIGURE 8-14
Bear Canyon Creek Pipeline
Thunderbird Pipeline Alignment
South Boulder Creek Flood Mitigation Report





LEGEND

BCC_Collection_Minor_Roads

Collection System

Thunderbird Pipeline Alignment

100-Year Floodplain

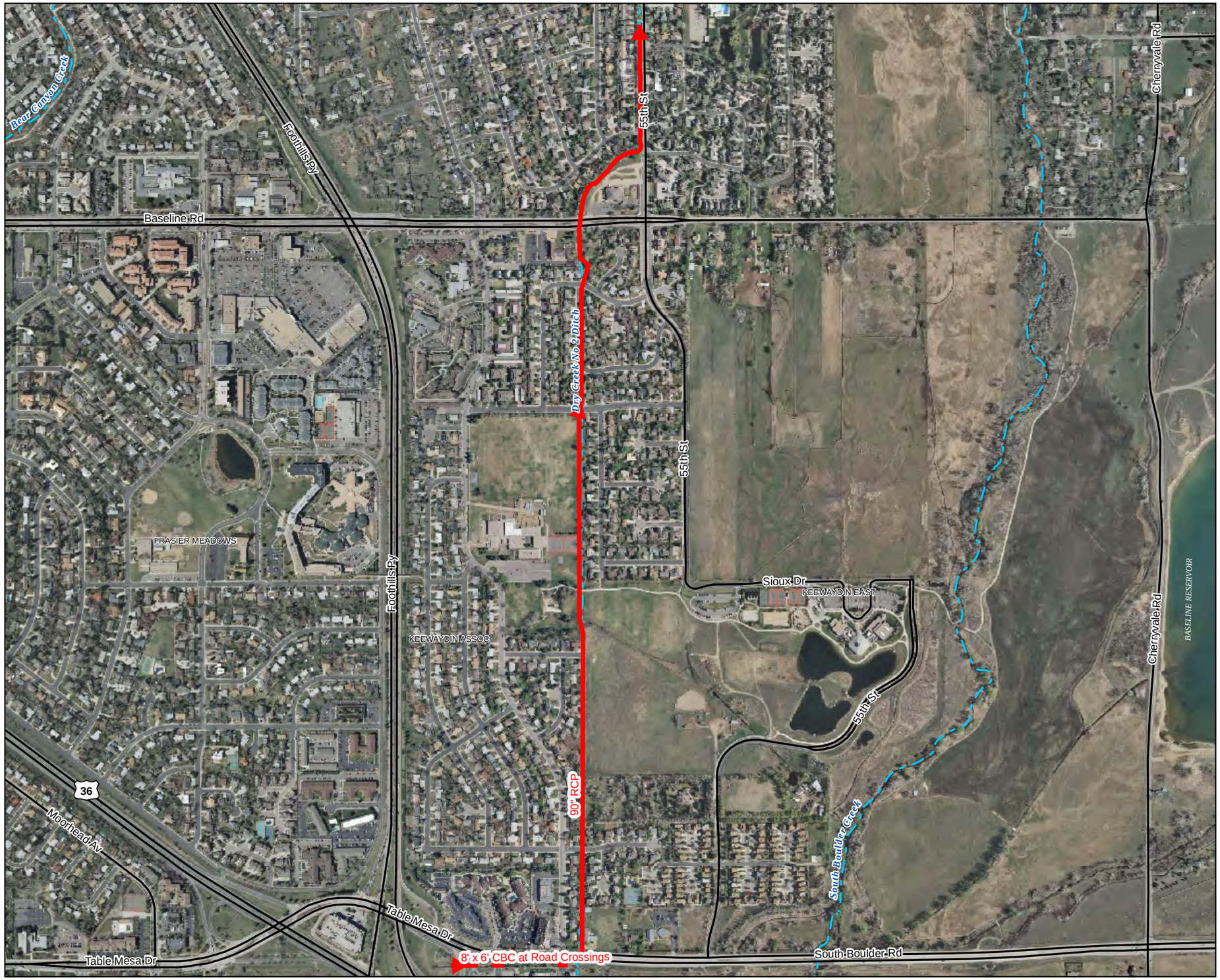
Streams, Creeks and Ditches

Main Road

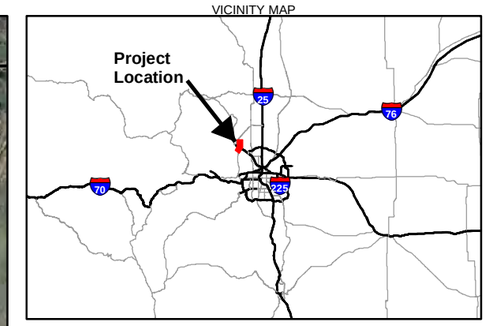
N

0 200 400
Feet

FIGURE 8-15
Bear Canyon Creek Pipeline Collection System
South Boulder Creek Flood Mitigation Report



VICINITY MAP



LEGEND

- Dry Creek Ditch #2 Pipeline Alignment
- Streams, Creeks and Ditches
- Main Road

N

0 1,000 2,000
Feet

FIGURE 8-16
Bear Canyon Creek Pipeline
Dry Creek Ditch #2 Alignment
South Boulder Creek Flood Mitigation Report

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Appendix F – Cost Summary

Refined Costs

One of the key objectives for updating the evaluations of the Best Alternative Plans was to better define the likely implementation costs for the various alternatives. In addition to the higher resolution of the various plan elements, other items impacting cost such as utility relocations, easement and right-of-way acquisition, and environmental mitigation were identified and incorporated. Unit costs for the various work elements and estimating contingencies were also reviewed and updated as required.

Unit Cost Values

The unit costs used in the development of the cost estimates were generally based on the default values found in the Urban Drainage and Flood Control District's (District) program, *UD-MP COST Version 1.1*. While this proved to be a useful starting point, the nature of some of the improvements proposed along South Boulder Creek necessitated the modification of some of these values. For example, the cost of property acquisition for various land use types is well defined in Boulder, and the values typically differ from those found in other parts of the District. These values were adjusted based on information provided by the City. Table F-1, Updated Unit Cost Values, presents the values used to estimate overall plan costs in the refined analysis.

Detention Pond Costs

The refined analysis provided a much better understanding of the elements of each of the detention ponds proposed as part of the alternatives. The most significant refinement of the ponds was the development of a more detailed grading plan for each of the ponds proposed in the various alternatives. This improvement provided a much better understanding of the actual amount of material that would be necessary for construction of the ponds. In addition to the overall quantity of material necessary for the pond construction, each of the ponds is assumed to have an impervious core and an impervious key. These were incorporated into the original estimate, but the volumes changed considerably as the actual geometry of the pond embankment became better defined.

Emergency spillways are an important part of the pond design. The earlier layout assumed a fairly consistent geometry for the spillway and that all spillways could be lined with Type VH riprap. However, upon further consideration, it was determined that those embankments that crossed the mainstem of South Boulder Creek would need to have a more substantial spillway due to the site topographic constraints that precluded a side channel spillway cut through native ground. A concrete spillway would probably be required by the State Dam Safety staff in order to assure the stability of the embankment during the spillway design flood.

Other elements necessary to implement the storage options were unchanged from the earlier analysis. Table F-2, Detention Pond Cost Elements, summarizes the various elements that were included in the estimation of the detention pond costs.

TABLE F-1
Updated Unit Cost Values

Item	Unit Cost	Unit of Measurement
Construction Cost		
Earthwork	$5.00	CY
Imported Impervious Core	$25.75	CY
Concrete, Cast-in-Place	$400.00	CY
Type M Riprap	$56.65	CY
Type VH Riprap	$82.40	CY
Revegetation	$1,030.00	Acre
Detention, Complete-in-Place	$46,968.00	AF
Lateral Pipe (36 to 60-inch RCP)	$126.81 - $211.36	LF
Main Pipe (72 to 114-inch RCP)	$367.83 - $865.20	LF
Type B Manhole	$10,300.00	Each
Storm Inlet, Type 13, 3-foot	$3,000.00	Each
Storm Inlet, Type R/Type 14, 4-foot	$3,605.00	Each
Concrete Box Culverts	$473.58 - $5,276.45	LF
Sloping Drop Structure	$142,790.74	Each
Wetland Mitigation	$100,000.00	Acre
Roadway Reconstruction	$50.00	SY
Open Channel Improvements	$0.20	LF/Q
Relocation of Trailhead	$500,000.00	LS
Property Acquisition Cost		
Agricultural	$0.80	SF
Public	$19.00	SF
Regional Business	$180.00	SF
Community Business	$39.00	SF
High Density Residential and Mobile Home	$50.00	SF
Medium and Mixed Density Residential	$36.00	SF
Low Density and Rural Residential	$22.00	SF
Industrial	$15.00	SF
Operation and Maintenance (O&M)		
Channel O&M	$27.60	LF
Detention Pond O&M	$1,380.00	AF

Note: CY = cubic yard, AF = acre-foot, LF = linear foot, SY = square yard, LF/Q = ?, LS = lump sum, SF = square foot

TABLE F-2

Detention Pond Cost Elements

Item	Unit Cost	Unit of Measurement
Construction Cost		
Earthwork	$5.00	CY
Imported Impervious Core	$25.75	CY
Concrete, Cast-in-Place	$400.00	CY
Type M Riprap	$56.65	CY
Type VH Riprap	$82.40	CY
Revegetation	$1,030.00	Acre
Outlet Structure	$169.08 - $5276.45	LF
Property Acquisition Cost		
Acquisition of Open Space Property	$0.83	SF
Acquisition of CU Property designated for flood control	$0.83	SF

Note: CY = cubic yard, LF = linear foot, SF = square foot

Utility Relocation Costs

The utility relocation costs were handled using a factor applied to the capital cost of all infrastructure. This value was updated slightly as a result of the plan refinements. Locations of City-owned utility infrastructure (e.g., water, sanitary sewer, storm sewer), as well as local phone, cable television, and gas services were obtained or inferred from general development patterns. Unfortunately, the alignment and extent of large natural gas transmission lines and fiber optic cable locations were not provided by the utility owners. However, no major lines denoted by utility delineators were noted during field visits to proposed flood control facility sites for review of possible improvement corridors.

During the refinement process, the alignments of the existing underground utilities were compared to the proposed improvements. It was concluded that the proposed ponds would have very little impact on existing utilities. As such, the utility relocation cost factor applied to these costs was removed. Other major underground infrastructure such as box culverts and outlet pipes associated with the detention ponds continued to have the utility relocation factor applied.

The pipeline improvements impacting City-owned lines were adjusted to minimize potential conflicts. Whenever possible, alignments were moved within the street corridor to avoid large conduits. However, the factor continued to be applied to the proposed improvement costs to reflect the need to deal with utility service lines and small lateral lines along many of the corridors.

Easement Acquisition Costs

As noted earlier, the unit cost of the various easements necessary for the implementation of the refined alternative plans remained unchanged. The extent of the necessary easement and right-of-way acquisition did change as a result of the refinement. In particular, the refined grading of the detention ponds better defined the footprint and therefore the necessary property acquisition. These values have been incorporated into the plan costs.

The alignments of the pipeline elements within the various alternatives were adjusted to try to minimize the impact on properties. In some cases, it was possible to slightly shift the pipeline alignments to better coincide with existing public easements and significantly reduce the property acquisition costs. More commonly, realignment of pipeline corridors was done to avoid impacts to individual single family residential properties. Based on feedback received during the public involvement process, it was determined that the public would prefer to minimize these impacts to individual property owners in favor of the purchase of larger easements from undeveloped or commercial and industrial properties. Pipeline alignments were shifted as necessary and as possible to achieve these objectives.

Environmental Mitigation Costs

The earlier alternatives recognized that there would be impacts to environmentally sensitive areas and anticipated that the cost of this mitigation could reasonably be included in the project contingency. The information provided by OSMP staff gave a far more refined picture of the environmental impacts. After review of this information and discussions with OSMP staff, it was concluded that environmental mitigation should be estimated separately.

The majority of the impacts to environmentally sensitive lands such as City-designated wetlands and habitat areas for endangered species and other species of interest are associated with the detention ponds. These impacts are much better understood, and estimates of the necessary mitigation cost can be better developed. The approach to mitigation is assumed to be compensatory mitigation at a ratio of two to one. That is, for every acre impacted, it is assumed that two acres of comparable area will need to be acquired and established with wetland habitat.

Two costing approaches were investigated: (1) looking at existing banks for similar wetland or habitat areas, and (2) purchasing and recreating a similar type of habitat. Because the cost of acquisition of property and reestablishment of habitat type is generally nested into the cost of credits from a bank, it was concluded that either approach would result in generally the same cost. The team chose to use a per-acre cost based on the purchase of credits from a wetland bank as the basis of environmental mitigation costs.

Administrative and Contingency Cost Estimates

The costs of various project elements common to all projects are embedded into the District's cost-estimating spreadsheet as factors. These are generally used without modification in this study. However, the overall project contingency applied to all Capital Costs and Property Acquisition Costs has been adjusted. The District's program uses a contingency factor of 25 percent based on a preliminary design level of detail generally found in their Planning Study Phase "B" reports. The early estimates of Best Alternative Plan cost used a 50 percent contingency instead of the District's default value of 25 percent. The higher factor was deemed appropriate because these plans were developed at a level of resolution generally consistent with District Planning Study Phase "A" reports. The refined plans looked at various elements in greater detail, but still lack the resolution of most District Planning Study Phase "B" reports. As such, the project team concluded a value of 35 percent was most appropriate for this study.

This 35 percent contingency has been included as a provision for unforeseeable, additional costs within the general bounds of the project scope, particularly where previous experience has shown that unforeseeable events that will increase costs are likely to occur. The contingency is used as a means to reduce the risk of possible cost overruns. The contingency in these estimates consists of two components: Bid Contingency and Scope Contingency. Bid Contingency covers the unknown costs associated with constructing a given project scope, such as adverse weather conditions, strikes by material suppliers, geotechnical unknowns,

and unfavorable market conditions for a particular project scope. Scope Contingency covers scope changes that invariably occur during final design and implementation.

The cost estimates presented in this study are "order-of-magnitude" (Level 4) estimates, as defined by the American National Standards Institute (ANSI) and the Association for the Advancement of Cost Engineering (AACE) International as "approximate estimates made without detailed engineering data. It is normally expected that estimates of this type will be accurate within plus 50 percent or minus 30 percent." This range implies that there is a high probability that the final project cost will fall within the range.

Table F-3, Administrative and Contingency Factors, presents the various factors that were applied in the development of the cost estimates.

TABLE F-3
Administrative and Contingency Factors

Item	Cost
Mobilization	5 percent of Subtotal Capital Improvement Costs
Stormwater Management/Erosion Control	5 percent of Subtotal Capital Improvement Costs
Utility Coordination/Relocation	32 percent of Pipe and Culvert Costs
Engineering	15 percent of Capital Improvement Costs
Legal/Administrative	5 percent of Capital Improvement Costs
Contract Admin/Construction Management	10 percent of Capital Improvement Costs
Contingency	35 percent of Capital Improvement Costs + Land Acquisition Costs

Refined Cost Summary by Plan

Each of the alternative cost estimates are summarized to include not only the overall cost of the implementation but also some of the major components of the alternative. These are summarized and presented in Table F-4, High Hazard Mitigation Plan Cost Summary; Table F-5, Regional Detention at US-36 Cost Summary; Table F-6 Distributed Regional Detention Cost Summary; and Table F-7, Bear Canyon Creek Pipeline Cost Summary.

Refined Cost Summary

The cost estimates have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimates and are summarized in Table F-8, Refined Alternative Plans Cost Estimate Summary. The final cost for the project will depend on such criteria as actual labor and material costs, competitive market conditions, actual site conditions, final project scope, and other variables. As a result, the final project cost will vary from this estimate. The proximity to actual costs will depend on how closely the assumptions of this estimate match final project conditions. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help assure proper project evaluation and adequate funding.

TABLE F-4
High Hazard Mitigation Plan Cost Summary ($ million)

Element	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
Grading	$0.02	$0.001	$0.001	$0.00	$0.02	$0.00	$0.003	$0.001	$0.002	$0.01	$0.04	$0.000	$0.04
Concrete	$0.06	$0.003	$0.003	$0.00	$0.06	$0.00	$0.009	$0.003	$0.006	$0.02	$0.10	$0.000	$0.10
TOTAL	$0.08	$0.004	$0.004	$0.00	$0.08	$0.00	$0.013	$0.004	$0.008	$0.03	$0.14	$0.000	$0.14

TABLE F-5
Regional Detention at US-36 Cost Summary ($ million)

Element	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
US-36 Detention Pond	$5.55	$0.28	$0.28	$0.03	$6.14	$1.80	$0.92	$0.31	$0.61	$2.78	$12.56	$0.77	$13.34
Improvements to the New Anderson Ditch	$0.66	$0.03	$0.03	$0.12	$0.85	$0.00	$0.13	$0.04	$0.09	$0.30	$1.40	$0.01	$1.41
Dry Creek Ditch No. 2 Pipeline Improvements	$1.25	$0.06	$0.06	$0.37	$1.75	$1.06	$0.26	$0.09	$0.18	$0.98	$4.32	$0.00	$4.32
Local Detention at Manhattan Middle School	$1.21	$0.06	$0.06	$0.01	$1.34	$0.31	$0.20	$0.07	$0.13	$0.58	$2.63	$0.03	$2.67
Local Detention at Baseline Road/Foothills Parkway	$1.10	$0.06	$0.06	$0.02	$1.23	$0.00	$0.19	$0.06	$0.12	$0.43	$2.04	$0.01	$2.05
Wall Enhancements at Baseline Road	$0.04	$0.002	$0.002	$0.00	$0.04	$0.22	$0.01	$0.002	$0.004	$0.09	$0.37	$0.00	$0.37
Improvements to Wellman Canal	$0.04	$0.002	$0.002	$0.00	$0.05	$0.00	$0.01	$0.002	$0.005	$0.02	$0.08	$0.08	$0.16
Arapahoe Avenue Detention Pond	$3.87	$0.19	$0.19	$0.14	$4.39	$3.37	$0.66	$0.22	$0.44	$2.72	$11.80	$0.10	$11.90
TOTAL	$13.29	$0.66	$0.66	$0.70	$15.32	$6.76	$2.30	$0.77	$1.53	$7.73	$34.40	$1.00	$36.21

TABLE F-6
Distributed Regional Detention Cost Summary ($ million)

Element	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
US-36 Detention Pond	$3.21	$0.16	$0.16	$0.00	$3.54	$0.61	$0.53	$0.18	$0.35	$1.45	$6.66	$0.18	$6.84
South Boulder Road Detention Pond	$4.84	$0.24	$0.24	$0.05	$5.38	$0.41	$0.81	$0.27	$0.54	$2.02	$9.42	$0.18	$9.60
Baseline Road Detention Pond	$4.83	$0.24	$0.24	$0.10	$5.42	$0.56	$0.81	$0.27	$0.54	$2.09	$9.69	$0.52	$10.20
Dry Creek Ditch No. 2 Pipeline Improvements	$1.25	$0.06	$0.06	$0.37	$1.75	$1.06	$0.26	$0.09	$0.18	$0.98	$4.32	$0.00	$4.32
Local Detention at Manhattan Middle School	$1.21	$0.06	$0.06	$0.01	$1.34	$0.31	$0.20	$0.07	$0.13	$0.58	$2.63	$0.03	$2.67
Local Detention at	$1.10	$0.06	$0.06	$0.02	$1.23	$0.00	$0.19	$0.06	$0.12	$0.43	$2.04	$0.01	$2.05

TABLE F-6
Distributed Regional Detention Cost Summary ($ million)

Element	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
Baseline Road/Foothills Parkway													
Wall Enhancements at Baseline Road	$0.04	$0.002	$0.002	$0.00	$0.04	$0.22	$0.01	$0.002	$0.00	$0.09	$0.37	$0.00	$0.37
Improvements to Wellman Canal	$0.04	$0.002	$0.002	$0.00	$0.05	$0.00	$0.01	$0.002	$0.00	$0.02	$0.08	$0.08	$0.16
Arapahoe Avenue Detention Pond	$3.87	$0.19	$0.19	$0.14	$4.39	$3.37	$0.66	$0.22	$0.44	$2.72	$11.80	$0.10	$11.90
TOTAL	$20.42	$1.02	$1.02	$0.69	$23.14	$6.54	$3.47	$1.16	$2.31	$10.39	$47.01	$1.10	$48.11

TABLE F-7
Bear Canyon Creek Pipeline Cost Summary ($ million)

Element	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
Bear Canyon Creek Pipeline and Inlets	$9.79	$0.49	$0.49	$2.68	$13.45	$0.00	$2.02	$0.67	$1.34	$4.71	$22.19	$0.00	$22.19
Dry Creek Ditch No. 2 Pipeline Improvements	$4.17	$0.21	$0.21	$1.25	$5.84	$1.16	$0.88	$0.29	$0.58	$2.45	$11.19	$0.00	$11.19
Improvements to New Anderson Ditch	$0.66	$0.03	$0.03	$0.12	$0.85	$0.00	$0.13	$0.04	$0.09	$0.30	$1.40	$0.01	$1.41
Improvements to Wellman Canal	$0.04	$0.002	$0.002	$0.00	$0.05	$0.00	$0.01	$0.002	$0.005	$0.02	$0.08	$0.08	$0.16
Arapahoe Avenue Detention Pond	$3.87	$0.19	$0.19	$0.14	$4.39	$3.37	$0.66	$0.22	$0.44	$2.72	$11.80	$0.10	$11.90
TOTAL	$18.54	$0.93	$0.93	$4.18	$24.57	$4.53	$3.69	$1.23	$2.46	$10.19	$46.66	$0.18	$46.84

TABLE F-8
Refined Alternative Plans Cost Summary ($ million)

Plan	Construction Cost	Mobilization	Stormwater Management/ Erosion Control	Utility Relocation	Subtotal	Easement/ Right-of-Way	Engineering	Legal/Admin	Contract Admin/ Construction Management	Contingency	Total Capital Cost	O&M Cost	Total Implementation Cost
Status Quo	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
High Hazard Mitigation	$0.08	$0.004	$0.004	$0.00	$0.08	$0.00	$0.01	$0.004	$0.01	$0.03	$0.14	$0.00	$0.14
Regional Detention at US-36	$13.73	$0.69	$0.69	$0.70	$15.81	$6.76	$2.37	$0.79	$1.58	$7.90	$35.21	$1.00	$36.21
Distributed Regional Detention	$20.42	$1.02	$1.02	$0.69	$23.14	$6.54	$3.47	$1.16	$2.31	$10.39	$47.01	$1.10	$48.11
Bear Canyon Creek Pipeline	$18.54	$0.93	$0.93	$4.18	$24.57	$4.53	$3.69	$1.23	$2.46	$10.19	$46.66	$0.18	$46.84

Refinements to Benefit-Cost Analysis

The project benefits and costs were updated as described. The benefits were largely unchanged except for the High Hazard Zone Mitigation alternative, which no longer includes benefits associated with the floodproofing activities. The estimated benefits for the other alternative plans were not changed and continue to be based on the 8-meter grid MIKE FLOOD model results.

Costs for the alternative plans reflect the refinements in both the design and the cost-estimating process. The costs have changed for all the alternative plans. The resulting benefit-cost summary is presented in Table F-9, Refined Alternative Plans Benefit-Cost Summary.

TABLE F-9
Refined Alternative Plans Benefit-Cost Summary ($ million)

Alternative	Total Implementation Cost	Present Worth of Benefits	Benefit-to-Cost Ratio
Status Quo	$0.0	$0.0	0.00
High Hazard Mitigation	$0.14	$0.0	0.00
Regional Detention at US-36	$36.2	$77.3	2.14
Distributed Regional Detention	$48.1	$75.9	1.58
Bear Canyon Creek Pipeline	$46.8	$58.0	1.24

Potential Funding Sources

Projects of this nature are generally funded by local communities using a variety of resources such as a Stormwater Utility Fee, General Funds, or bond sales. In addition, cities such as Boulder lie within the District, which collects tax revenues that are used to fund the study, design, and implementation of drainage improvements along major drainageways within its constituent communities. It is quite likely the District would be a financial participant in any forthcoming improvement projects along South Boulder Creek.

Because many of the indentified projects have benefit-cost ratios in excess of 1.0, it may be possible to secure additional funds from other sources such as the Federal Emergency Management Agency's Pre-Disaster Flood Mitigation Grant program or USACE's 905b Program. While application for these grants is beyond the current scope, much of the information provided in this study can be used to support application if the Selected Alternative meets program objectives.

Appendix G
OSMP Memorandum

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MEMORANDUM CH2MHILL

Evaluation of OSMP Memorandum Dated April 13, 2011

TO: Kurt Bauer / City of Boulder
Annie Noble / City of Boulder
Bob Harberg / City of Boulder
Shea Thomas / UDFCD

COPIES: Mark Taylor / Architerra

Alan Taylor / Alan Taylor Consultants

FROM: CH2M HILL

DATE: July 18, 2011, Revised August 3, 2011

Introduction

This memorandum will document the evaluation of the Open Space and Mountain Parks evaluations of the South Boulder Creek Alternatives, specifically the Regional Detention Alternatives evaluated by Open Space and Mountain Parks (OSMP) staff in a memorandum dated April 13, 2011. The OSMP staff reviewed the impact of the Proposed Berms for two of the alternatives

1. Regional Detention at US-36 – Alternative 2
2. Distributed Regional Detention – Alternative 5

OSMP evaluated the berms based on the potential environmental, irrigation, and agriculture impacts to Open Space Lands. Specifically the evaluation looked at impacts to the following specific items:

1. Wetlands
2. Riparian Vegetation
3. Preble's Meadow Jumping Mouse U. S. Fish and Wildlife Service (USFWS) Critical Habitat Area
4. Preble's Meadow Jumping Mouse (PMJM) Conservation Zone
5. Ute Ladies' Tresses Orchid
6. Northern Leopard Frog
7. Agricultural Resources
8. Irrigation Resources
9. The Plains Topminnow

10. Bobolink

Assumptions made by the OSMP staff to assess the impacts of the various detention alternatives include placing the entire berm footprint on OSMP lands, would have a 12′ foot top width for trail access and maintenance access and would have 4:1 side slopes.

This memorandum provides a more detailed evaluation of the proposed berms and potential impacts to OSMP resources as defined in their memorandum dated April 13, 2011.

Refined Alternative Design

The berms for the two alternatives outlined above were refined based on the concepts provided to WRAB in November 2010. Berms were contoured at a 1′ contour interval based on the City of Boulder's 2003 1′ Contour information. Contouring included reestablishing links to existing trails, a 20′ offset from the existing US36 edge of pavement to accommodate future traffic lanes on US-36, and accommodation for the proposed regional bike trail along US-36. Berms had the following geometrical constraints.

1. 4:1 side slopes typical for all berms
2. 12 foot top of berm width for maintenance and trails access
3. 15 foot construction, access and maintenance easement beyond the toe of all berms and offset from any property lines.

To complete the impact analysis GIS shapefiles were obtained from OSMP staff for the various resources of interest noted in the introduction. Table 1 below lists the shapefiles provided by OSMP and a description of use for estimating impacts to Open Space, critical habitat, or threatened or endangered species.

TABLE 1
Shapefiles from OSMP to estimate impacts to resources due to regional detention berms

Shapefile	Description	Use for Impact Evaluation by OSMP
WetlandsRiparian_VegMap.shp	This shapefile provides an evaluation of the groupings and species of vegetation on OSMP lands including riparian and wetland species.	Impacts to Wetlands/Riparian areas; Northern Leopard Frog Habitat
SouthBldrCrStateNatArea.shp	This shapefile Identifies lands that belong in the South Boulder Creek Natural Area.	Impacts to the South Boulder Creek Natural Area
PreblesCriticalHabitat.shp	This shape identifies the PMJM Critical habitat area defined by the USFWS as a corridor 460 feet adjacent to the South Boulder Creek Channel.	Impacts to the PMJM Critical Habitat Corridor
PreblesConsZones.shp	This shape identifies the PMJM Conservation Zones for the City of Boulder	Impacts to the PMJM Conservation Zones

Impacts to the Ute Ladies' Tresses Orchid were estimated to be the footprint of the berm and 15-wide access easement. Due to the sensitive nature of the species, OSMP declined to provide a GIS shapefile to identify the habitat areas of the Ute Ladies' Tresses Orchid.

The remainder of the impacts to:

1. Agricultural Resources;
2. Irrigation Resources;
3. The Plains Topminnow;
4. and Bobolink;

were qualitatively assessed by the OSMP staff as to the potential impacts to the various resources.

To complete the Refined Alternative Design on the potential berm impacts, the same shapefiles and assumptions made by OSMP staff were applied to identify impacts to the resources of concern. To further help quantify the impacts of the berms additional shapefiles, identified in Table 2, were used to quantify the impacts to:

1. Agricultural Resources;
2. Irrigation Resources including irrigation ditches, laterals and head gates;
3. And City of Boulder Regulatory Wetlands;

TABLE 2
Additional shapefiles provided by the City of Boulder to asses impacts of regional detention berms.

Shapefile	Description	Use for Impact Evaluation by OSMP
OSMP_Headgates.shp	This shapefile identifies head gates on OSMP lands	Impacts to head gates that will need to be rebuilt and reconnected
OSMP_Wells.shp	This shapefile identifies wells on OSMP lands	Impacts to wells on OSMP property
creek_ditch.shp	This shape identifies all irrigation ditches and laterals across the Open Space system.	Impacts to the irrigation ditches and laterals that would require mitigation
Wetalnds_regulatory_area.shp	This shapefile identifies the regulatory wetlands identified by the City of Boulder	Impacts to regulatory wetlands that would require mitigation
OSMP_Ag_Fields.shp	This shapefile identifies designated agricultural areas on the OSMP lands	Assess impacts to agricultural lands on OSMP property

Due to the qualitative assessment completed by OSMP staff on the Plains Topminnow and Bobolink and in absence of more defined information on the habitat and potential impacts on these species, the Plains Topminnow and Bobolink were not included in the Refined Alternative Design.

Results

All berms for the two alternatives that contain regional detention facilities were evaluated as part of this review. The tables that follow include a review and comparison of each item of interest described within the OSMP memorandum. All impacts presented in this memorandum would be permanent; construction-related impacts are not included herein.

TABLE 3
Comparison of Maximum Berm Height

Berm ID	Maximum Berm Height (feet) (OSMP Memorandum)	Maximum Berm Height (feet) (Refined Alternative Design)	
		Maximum Berm Height	Maximum Berm Height on OSMP Property
US-36 Regional Detention (Alt 2)	18	23[1]	15
US-36 Distributed Detention (Alt 5)	18	12[2]	12
South Boulder Road Distributed Detention (Alt 5)	14	14[3]	13
Baseline Road Distributed Detention (Alt 5)	18	18[4]	11[5]

1. Maximum berm height occurs at the Table Mesa Drive on-ramp to US-36 between Table Mesa Drive and Foothills Parkway.
2. Maximum berm height occurs at the Foothills Parkway on-ramp to US-36 between east of the Foothills Parkway Overpass.
3. Maximum berm height occurs east of South Boulder Creek and as observed from South Boulder Road.
4. Maximum berm height occurs at the South Boulder Creek channel. Due to the incised nature of the channel in this location the maximum berm height only occurs for a maximum distance of 300' while it transitions to the maximum of height of the majority of the berm of 9'
5. Maximum berm height from OSMP property occurs near the existing Bobolink Trailhead. The localized maximum can be found at the South Boulder Creek channel, which is 16 feet tall.

TABLE 4
Comparison of Total Berm Area

Berm ID	Total Berm Area (Acres) (OSMP Memorandum)	Total Berm Area (Acres) (Refined Alternative Design)	Total Berm Area on OSMP Land (Acres) (Refined Alternative Design)
US-36 Regional Detention (Alt 3)	9.09	27.60	5.50
US-36 Distributed Detention (Alt 5)	9.09	19.72	17.01
South Boulder Road Distributed Detention (Alt 5)	10.44	11.0	10.36
Baseline Road Distributed Detention (Alt 5)	10.74	7.72	7.42
Totals for Alt 5	30.3	38.44	34.79

TABLE 5
Comparison of Ute Ladies' Tresses Orchid affected Area

Berm ID	Total Ute Ladies' Tresses Orchid affected Area (Acres) (OSMP Memorandum)	Total Ute Ladies' Tresses Orchid affected Area[1] (Acres) (Refined Alternative Design)
US-36 Regional Detention (Alt 3)	9.09	5.50
US-36 Distributed Detention (Alt 5)	9.09	17.01
South Boulder Road Distributed Detention (Alt 5)	10.44	10.36
Baseline Road Distributed Detention (Alt 5)	10.74	7.42
Totals for Alt 5	30.3	34.79

1. Affected area assumed to be on OSMP land only. It was assumed the roadway right of way and privately held parcels did not contain habitat suitable to the Ute Ladies' Tresses Orchid.

TABLE 6
Comparison of affected Riparian/Wetlands Area

Berm ID	Total Riparian/Wetlands Area (Acres)[1] (OSMP Memorandum)	Total Riparian/Wetlands Area (Acres)[1] (Refined Alternative Design)	Total City of Boulder Regulatory Wetlands (Acres)[2] (Refined Alternative Design)	
			Class A Inner	Class A Outer
US-36 Regional Detention (Alt 3)	4.88	3.6	0	0
US-36 Distributed Detention (Alt 5)	4.88	11.2	0	0
South Boulder Road Distributed Detention (Alt 5)	4.33	2.3	2.76	0.80
Baseline Road Distributed Detention (Alt 5)	5.05	3.8	2.65	0.70
Totals for Alt 5	14.3	17.3	5.41	1.50

1. Affected area calculated using the WetlandsRiparian_VegMap.shp provided by OSMP.
2. Affected area calculated using the shapefile Wetlands.shp provide by the City of Boulder.

TABLE 7
Comparison of Northern Leopard Frog affected Area

Berm ID	Total Northern Leopard Frog Affected Area (Acres) (OSMP Memorandum)	Total Northern Leopard Frog Affected Area (Acres) (Refined Alternative Design)
US-36 Regional Detention (Alt 3)	4.88	3.6
US-36 Distributed Detention (Alt 5)	4.88	11.2
South Boulder Road Distributed Detention (Alt 5)	4.33	2.3
Baseline Road Distributed Detention (Alt 5)	5.05	3.8
Totals for Alt 5	14.3	17.3

TABLE 8
Comparison of affected PMJM Critical Habitat Area

Berm ID	Total PMJM Critical Habitat (Acres)[1] (OSMP Memorandum)	Total PMJM Critical Habitat (Acres) (Refined Alternative Design)	
		OSMP Property	Other Property[1]
US-36 Regional Detention (Alt 3)	1.27	1.0	0.6
US-36 Distributed Detention (Alt 5)	1.27	9.6	0.6
South Boulder Road Distributed Detention (Alt 5)	3.24	4.0	0
Baseline Road Distributed Detention (Alt 5)	3.34	2.7	0
Totals for Alt 5	7.9	16.3	0.6

1. Other Property includes roadway right of way and private property

TABLE 9
Comparison of affected PMJM Conservation Area

Berm ID	Total PMJM Conservation Area (Acres)[1] (OSMP Memorandum)	Total PMJM Conservation Area (Acres) (Refined Alternative Design)	
		OSMP Property	Other Property[1]
US-36 Regional Detention (Alt 3)	7.68	4.9	2.2
US-36 Distributed Detention (Alt 5)	7.68	16.0	2.2
South Boulder Road Distributed Detention (Alt 5)	6.4	7.1	0
Baseline Road Distributed Detention (Alt 5)	6.15	4.4	0
Totals for Alt 5	20.2	27.5	2.2

1. Other Property includes roadway right of way and private property

TABLE 10
Comparison of South Boulder Creek State Natural Area

Berm ID	Total South Boulder Creek State Natural Area (Acres) (OSMP Memorandum)	Total South Boulder Creek State Natural Area (Acres) (Refined Alternative Design)
US-36 Regional Detention (Alt 3)	8.17	5.4
US-36 Distributed Detention (Alt 5)	8.17	16,1
South Boulder Road Distributed Detention (Alt 5)	10.32	10.4
Baseline Road Distributed Detention (Alt 5)	6.7	4.8
Totals	25.2	31.3

In addition to those items quantified in the OSMP memorandum dated April 13, 2011, several additional impacts to resources were quantified by this Refined Alternative Design. These items included impacts to irrigation infrastructure and impacts to agricultural lands.

TABLE 11
Impacts to Irrigation Infrastructure

Berm ID	Head Gates	Irrigation Ditches (lf)							
		Howard Ditch		Anderson Ditch		Dry Creek No. 2 Ditch		Shearer Ditch	
		Main Ditch	Laterals	Main Ditch	Laterals	Main Ditch	Laterals	Main Ditch	Laterals
US-36 Regional Detention (Alt 3)	0	0	0	58	0	559	726	0	0
US-36 Distributed Detention (Alt 5)	0	0	0	0	0	458	3,199	0	0
South Boulder Road Distributed Detention (Alt 5)	1	0	0	221	0	728	1,198	0	1,365
Baseline Road Distributed Detention (Alt 5)	2	210	600	0	0	0	0	0	0
Totals for Alt 5	3	210	600	221	0	1,186	4,397	0	1,365

TABLE 12
Impacts to Agricultural Lands

Berm ID	Agricultural Fields (Acres)		
	Hay Production[1]	Grazing	Hay Production and Grazing[1]
US-36 Regional Detention (Alt 3)	0	5.2	0
US-36 Distributed Detention (Alt 5)	0	15.8	0
South Boulder Road Distributed Detention (Alt 5)	0	0	3.2
Baseline Road Distributed Detention (Alt 5)	0	3.5	0
Totals for Alt 5	0	19.3	3.2

1. Based on OSMP GIS layer files defining agricultural land use areas where only hay is produced and where hay and grazing occurs together.

Summary and Conclusions

The Refined Alternative Design for Alternative 5 – Distributed Regional Detention indicate that the impacts to Open Space lands are likely less than those reported in the OSMP memorandum dated April 13, 2011. The exception to this is the berm located at South Boulder Road. Due to the berm, the Viele Channel will need to be modified slightly which increases the impacts of this alternative to the metrics on Open Space lands. The draft OSMP memorandum did not specifically analyze impacts associated with the US-36 Regional Detention Alternative. As a result, only a comparison between CH2M HILL and OSMP impact estimates on resources are presented for the Distributed Regional Detention Alternative.

Distributed Regional Detention

– **Maximum Berm Height**

- **US-36 –** 12 feet on OSMP property, 6 feet less than the 18-foot value reported in the Memorandum.
- **South Boulder Road –** 14 feet located only within the South Boulder Creek channel. For the remainder of the berm a maximum height 13 feet tall, 1 foot less than the 14-foot value reported in the Memorandum is reached just east of South Boulder Creek.
- **Baseline Road –** 18 feet located only within the South Boulder Creek channel. For the remainder of the berm reaches a maximum height 11 feet tall, 7 feet less than the 18-foot value reported in the Memorandum.

– **Total Berm Area and impact to Ute Ladies' Tresses Orchid Habitat–**

- **US-36 –** 17.0 acres on OSMP property, 8 acres more than the 9.09 acres reported in the Memorandum. The total footprint area of 19.7 acres includes CDOT Right of way and includes all required maintenance easements.
- **South Boulder Road –** 10.36 acres on OSMP property, 0.8 acres less than the 10.44 acres reported in the Memorandum. The total footprint area of 11.0 acres includes roadway right of way and includes all required maintenance easements on private property for Dry Creek Ditch No. 2.
- **Baseline Road –** 7.42 acres on OSMP property, 3.32 acres less than the 10.74 acres reported in the Memorandum. The total footprint area of 7.72 acres includes roadway right of way and includes all required maintenance easements on private property (Granite Property).

– **Total Disturbance to Riparian/ Wetlands Vegetation and Northern Leopard Frog Habitat**

- **US-36 –** 11.2 acres on OSMP property, 6.3 acres more than the 4.88 acres reported in the Memorandum.
- **South Boulder Road –** 2.3 acres on OSMP property, 2.0 acres less than the 4.3 acres reported in the Memorandum.
- **Baseline Road –** 3.75 acres on OSMP property, 1.3 acres less than the 5.05 acres reported in the Memorandum.

– **Total Disturbance to PMJM Critical Habitat**

- **US-36 –** 9.6 acres on OSMP property, 8.3 acres more than the 1.27 acres reported in the Memorandum. There is a total impact of 10.2 acres of impact to the PMJM Critical Habitat area including property on CDOT right of way for this alternative.
- **South Boulder Road –** 4.0 acres on OSMP property, 0.76 acres greater than the 3.24 acres reported in the Memorandum.
- **Baseline Road –** 2.7 acres on OSMP property, 0.64 acres less than the 3.34 acres reported in the Memorandum.

– **Total Disturbance to PMJM Conservation Zones**

- **US-36 –** 16.0 acres on OSMP property, 8.32 acres less than the 7.68 acres reported in the Memorandum. There is a total impact of 18.2 acres of impact to the PMJM Conservation area including property on CDOT right of way for this alternative.
- **South Boulder Road –** 7.1 acres on OSMP property, 0.7 acres greater than the 6.4 acres reported in the Memorandum.
- **Baseline Road –** 4.4 acres on OSMP property, 1.72 acres less than the 6.15 acres reported in the Memorandum.

– **Total Disturbance to the South Boulder Creek Natural Area**

- **US-36 –** 16.1 acres on OSMP property, 7.93 acres more than the 8.17 acres reported in the Memorandum.
- **South Boulder Road –** 10.4 acres on OSMP property, 0.1 acres greater than the 10.32 acres reported in the Memorandum.
- **Baseline Road –** 4.8 acres on OSMP property, 1.9 acres less than the 6.7 acres reported in the Memorandum.

Appendix H - Floodproofing Critical Facilities

Introduction

Floodproofing critical facilities as defined in the City of Boulder's new *Critical Facility and Mobile Populations Ordinance*" was an element considered in the High Hazard Zone Mitigation Alternative. Issues of public/private ownership, varying facility type, community welfare and financial responsibility led to the conclusion that floodproofing of existing critical facilities should not be included as a component of the High Hazard Mitigation Alternative. However, basic floodproofing measures for critical facilities or government owned facilities located in the 100-year flood zone were developed as part of the mitigation plan for information purposes only.

Protection of critical facilities remains an important element in the City's overall floodplain management program. In order to provide basic information for future decision-making, measures to floodproof critical facilities or government owned facilities located in the 100-year flood zone were evaluated. Estimated costs to implement the floodproofing measures and mitigate the flood threat from South Boulder Creek were identified and are included in the mitigation master plan report for future reference. Many of these flood proofing measure could be applied across a broad spectrum of properties that are impacted by the South Boulder Creek Floodplain.

City Geographical Information System (GIS) records indicate that as many as 35 critical facilities may exist in the South Boulder Creek floodplain. These include a range of facility types, including essential services facilities, hazardous material facilities, and at-risk populations facilities. Most of the identified critical facilities are privately owned commercial/industrial operations that involve the use of hazardous materials. Under the City's recently adopted critical facilities ordinance these operations will be independently responsible for mitigating their flood threat by 2022. There is at least one essential service facility (the RTD Park 'N' Ride at US 36) and two at-risk population facilities (Friends School, and Frasier Meadows Manor) in the 100-year floodplain that don't fall into the privately owned commercial/industrial operations category.

This appendix focuses on possible options for the protection of these critical facilities and provides some definition of what infrastructure and costs may be required to floodproof these existing critical facilities. There are several primary approaches to floodproofing critical facilities that include:

1. Elevating the Structure, so that the facility is located above floodwaters and away from damage. This is not particularly practical for facilities already constructed.
2. Constructing Barriers between the Structure and Flooding, so that floodwaters cannot inundate the area around the facility. This minimizes required modifications to the structure.
3. Dry Floodproofing the Structure, so that the building's walls, floors and openings are watertight to prevent floodwaters from entering and damaging the facility. This often requires extensive modifications to the structure and may limit function during flood events.
4. Wet Floodproofing the Structure, using flood resistant construction materials and water repellant design measures, so that floodwaters that do enter the building will cause little or no damage.

Multiple references were used to analyze, recommend potential floodproofing measures, and determine reasonable cost estimates for several critical facilities in the South Boulder Creek floodplain. Primary references included:

- Local Flood Proofing Programs, US Army Corps of Engineers and the National Nonstructural/Flood Proofing Committee, February 2005
- Floodproofing Non-Residential Structures, FEMA 102, May 1986
- Selecting Floodproofing Techniques - Financial Considerations, Floodproofing Info #10, Southern Tier Central Regional Planning and Development Board
- FEMA Technical Bulletin 2, Flood Damage-Resistant Materials Requirements, August 2008
- FEMA Technical Bulletin 3-93, Non-Residential Floodproofing - Requirements and Certification
- FEMA Technical Bulleting 7-93, Wet Floodproofing Requirements
- Flood-proofing, ClimateTech Wiki, climatetechwiki.org
- Flood Proofing, UDFCD Drainage Criteria Manual, Volume 2
- UDFCD Cost Estimator for Master Planning (UD-MP Cost)
- Appendix C, Critical Facilities Flood Protection Analysis Calculations, City of Boulder Critical Facilities and Mobile Populations Ordinance Cost Analysis, The Sanitas Group, March 15, 2011

As part of the effort to evaluate floodproofing measures as an element of any proposed improvements identified in the South Boulder Creek mitigation planning study, the analysis was expanded to include an assessment and cost estimate of possible single-family residential structure floodproofing measures for dwellings with and without basements. Single-family residential structures are not defined as critical facilities and there is no regulatory requirement to protect them. These measures were not included in any of the plans.

Floodproofing of residential structures is not recognized by FEMA as an alternative to the purchase of flood insurance or as a measure to reduce required flood insurance premiums. However, floodproofing can provide a greater level of flood protection for the structure in the event of flooding. Some homeowners may want to consider these options for protecting their homes in the event of a flood.

The following pages include possible site floodproofing elements and costs analyses for the following existing critical facilities in the South Boulder Creek floodplain and for typical single-family residential structures:

- RTD Park 'N' Ride
- Frasier Meadows Manor
- Friends School
- Gasoline Service Stations at 55th and Arapahoe
- Single-family Residential Dwelling without a Basement
- Single-family Residential Dwelling with a Basement

South Boulder Creek Floodproofing Option-RTD Park & Ride Perimeter Floodwall

TABLE H-1
RTD Park and Ride Site Floodproofing Elements and Costs

Flood Proofing Element	Estimated 2011 Unit Cost	No. of Units	Element Costs
Increase Lower Parking Level Perimeter Wall 18"	$45.00 per square foot	1,700	$76,500
Automatic Driveway Flood Gates	$90,000	2	$180,000
Storm Sewer Check Valve	$20,000 per unit	1	$20,000
Flood Proof Concrete Walls and Seal All Field Joints	$50,000	1	$50,000
Incidentals	20% of Element Costs		$65,300
		Floodproofing Construction Sub-Total	**$391,800**
		Structural Analysis	$6,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$408,300**
		Contingency (20%)	$81,660
		Total Cost for Parking Structure	**$489,960**

Floodproofing Cost for this (50,300 square foot) Building is **$9.74 per square foot**

Assumptions:

- Max 500-year flooding depth around structure is 2.65 feet (Assuming 3 feet in depth for calculation purposes)
- Floodproofing to four feet above grade to provide 1 foot of free board
- Existing lower level of parking structure wall is approximately 30" tall
- There will need to be 1.5 feet of additional concrete added to lower parking structure wall to prevent floodwaters from entering
- Automated Flood Gates will be required at driveway entries
- It is assumed that the structure is a prefabricated concrete structure and is currently not watertight. Existing structure envelope will need to be sealed to be watertight.
- It is assumed the existing Interior Drainage System is adequately sized for areas inside the parking structure

South Boulder Creek Floodproofing Option-Frasier Meadows Manor Perimeter Floodwall

TABLE H-2
RTD Park and Ride Site Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Concrete Perimeter Floodwall	$45.00 per square foot	10,000	$450,000
Automatic Driveway Flood Gates	$90,000	4	$360,000
Sewer Main Check Valve	$20,000 per unit	1	$20,000
Site Interior Pumped Drainage System (with backup generation)	$150,000 per system	1	$150,000
Incidentals	20% of Element Costs		$196,000
		Floodproofing Construction Sub-Total	**$391,800**
		Structural Analysis	$6,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$408,300**
		Contingency (20%)	$81,660
		Total Cost for Parking Structure	**$489,960**

Floodproofing Cost for this (420,000 square foot) Building is **$3.41 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Floodproofing Involves Concrete Perimeter Floodwall Around East Property with Automated Flood Gates at Driveway Entries
- Total Height of Floodwall (to Footing) is Six Feet
- An Interior Drainage System Sized for Areas Protected by Levees is Required

South Boulder Creek Dry Floodproofing Options-Friends School

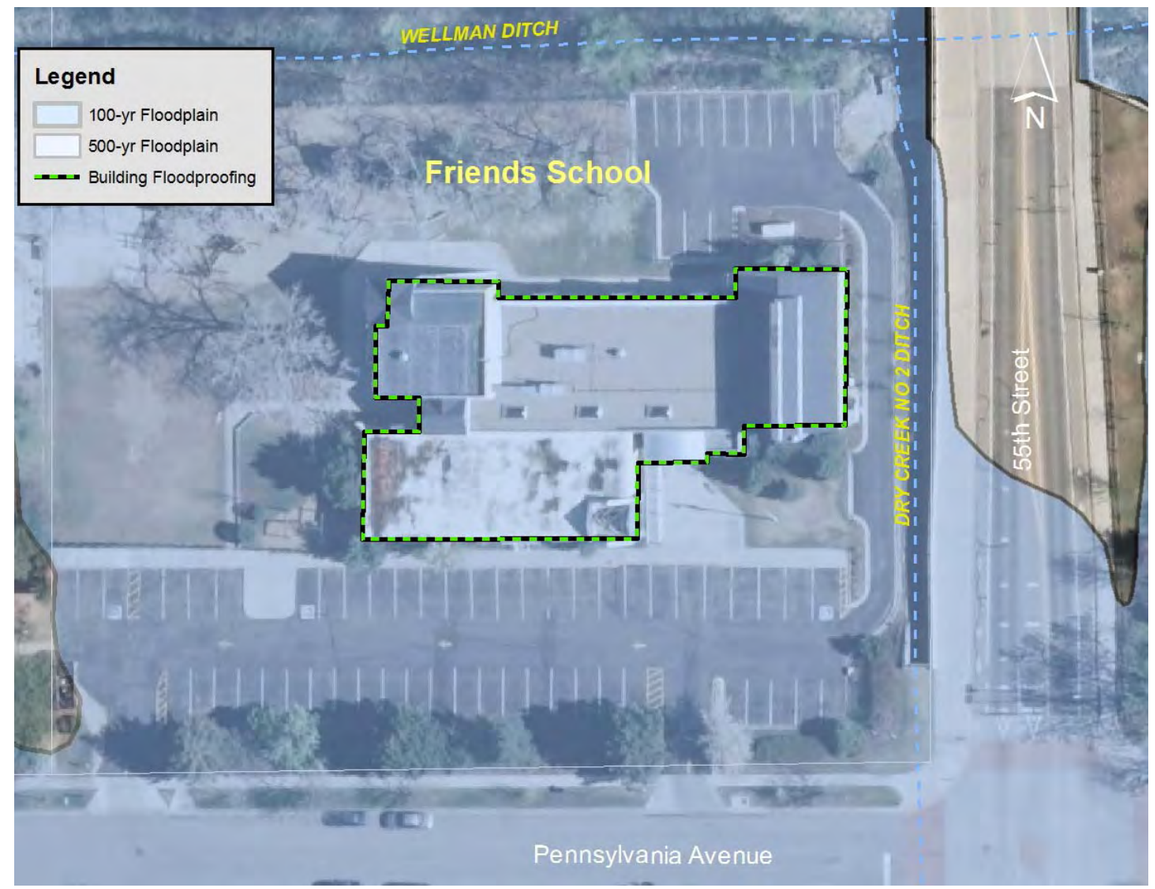
TABLE H-3
RTD Park and Ride Site Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Exterior Waterproofing and Refinish	$4.50 per square foot	1,722	$7,749
Floodproof Entry Doors	$4,000 each unit	4	$16,000
Main Entry Floodproofing	$7,000 each unit	1	$7,000
Sewer Line Check Valve	$1,200 per unit	1	$1,200
Sump Pump (w/battery backup)	$1,500 per unit	1	$1,500
Incidentals	20% of Element Costs		$6,630
		Floodproofing Construction Sub-Total	**$39,779**
		Structural Analysis	$3,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$53,279**
		Contingency (20%)	$10,656
		Total Cost for Parking Structure	**$63,935**

Floodproofing Cost for this Building is **$5.06 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Building Area = 12,634 square feet, Perimeter = 574 feet
- Three Entry Doors per Building
- Building Structurally Withstands Up to Three Feet of Flooding



South Boulder Creek Dry Floodproofing Options-Gas Station Retail Building

TABLE H-4
Gas Station Retail Building (1595 55th Street) Dry Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Exterior Waterproofing and Refinish	$4.50 per square foot	405	$1,823
Floodproof Entry Doors	$4,000 each unit	2	$8000
Sewer Line Check Valve	$1,200 per unit	1	$1,200
Sump Pump (w/battery backup)	$1,500 per unit	1	$1,500
Incidentals	20% of Element Costs		$2,505
		Floodproofing Construction Sub-Total	**$39,779**
		Structural Analysis	$3,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$28,528**
		Contingency (20%)	$5,706
		Total Cost for Parking Structure	**$34,234**

Floodproofing Cost for this Building is **$30.43 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Building Area = 1,125 square feet, Perimeter = 135 feet
- Three Entry Doors per Building
- Building Structurally Withstands Up to Three Feet of Flooding

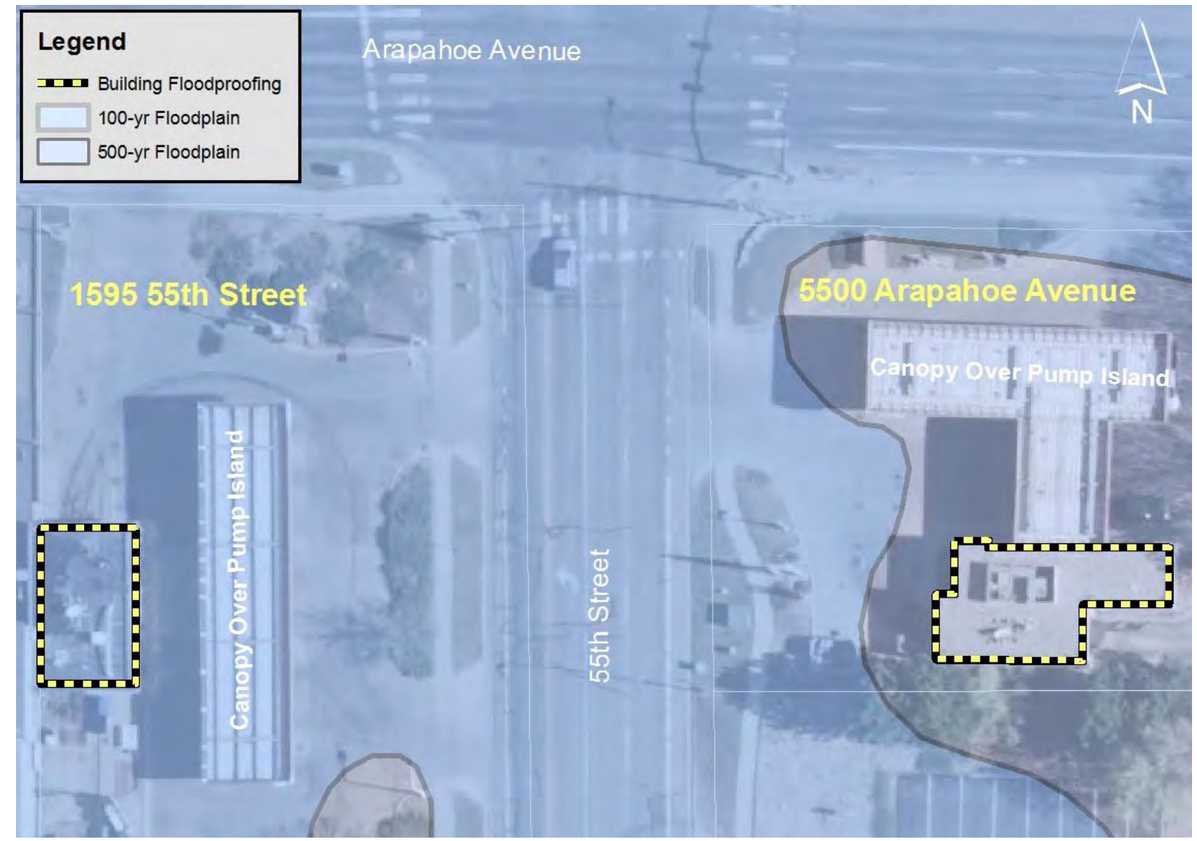
TABLE H-5
Gas Station Retail Building (5500 Arapahoe Avenue) Dry Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Exterior Waterproofing and Refinish	$4.50 per square foot	465	$2,093
Floodproof Entry Doors	$4,000 each unit	2	$8000
Sewer Line Check Valve	$1,200 per unit	1	$1,200
Sump Pump (w/battery backup)	$1,500 per unit	1	$1,500
Incidentals	20% of Element Costs		$2,559
		Floodproofing Construction Sub-Total	**$39,779**
		Structural Analysis	$3,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$28,528**
		Contingency (20%)	$5,706
		Total Cost for Parking Structure	**$34,234**

Floodproofing Cost for this Building is **$22.34 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Building Area = 1,550 square feet, Perimeter = 189 feet
- Three Entry Doors per Building
- Building Structurally Withstands Up to Three Feet of Flooding



South Boulder Creek Dry Floodproofing Options-Single Family Building - no Basement

TABLE H-6
Single-Family Residential Building - no Basement Dry Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Exterior Waterproofing and Refinish	$4.50 per square foot	480	$2,160
Floodproof Door Entry	$3,500 each unit	3	$10,500
Sewer Line Check Valve	$1,200 per unit	1	$1,200
Sump Pump (w/battery backup)	$1,500 per unit	1	$1,500
Incidentals	20% of Element Costs		$3,072
		Floodproofing Construction Sub-Total	**$18,432**
		Structural Analysis	$3,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$31,932**
		Contingency (20%)	$6,386
		Total Cost for Parking Structure	**$38,318**

Floodproofing Cost for this Building is **$25.55 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Building Area = 1,500 square feet, 50ft x 30ft, Perimeter = 160 feet
- Three Entry Doors per Building
- Building Structurally Withstands Up to Three Feet of Flooding

South Boulder Creek Dry Floodproofing Options-Single Family Building - with Basement

TABLE H-7
Gas Station Retail Building (5500 Arapahoe Avenue) Dry Floodproofing Elements and Costs

Floodproofing Element	Estimated 2011 Unit Cost	No. Units	Element Cost
Exterior Floodproof Concrete Ring wall	$45.00 per square foot	960	$43,200
Floodproof Door Entry	$3,500 each unit	3	$10,500
Sewer Line Check Valve	$1,200 per unit	1	$1,200
High Capacity Sump Pump (w/generator backup)	$4,500 per unit	1	$4,500
Incidentals	20% of Element Costs		$11,880
		Floodproofing Construction Sub-Total	**$71,280**
		Structural Analysis	$6,000
		Civil & Architectural	$4,000
		Permit Costs	$6,500
		Overall Sub-Total	**$87,780**
		Contingency (20%)	$17,556
		Total Cost for Parking Structure	**$105,336**

Floodproofing Cost for this Building is **$70.22 per square foot**

Assumptions:

- Floodproofing to Three Feet Above Grade
- Floodproofing Involves Exterior Concrete Floodwall Wrap Around Foundation
- Total Height of Floodwall (to Footing) is Six Feet
- Building Area = 1,500 square feet, 50ft x 30ft, Perimeter = 160 feet
- Three Entry Doors per Building
- Building and Basement Foundation Walls are Verified to Structurally Withstand Up to Three Feet of Flooding Above Grade