



CITY OF BOULDER
Facilities and Asset Management

Boulder Main Library

Structural Flood Assessment

April 22, 2013

COB P0 07004

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1.0 EXECUTIVE SUMMARY

We have assessed the ability of the Boulder Public Library's Main Branch to resist loading and water infiltration resulting from a 100-year flood event, and what improvements would be required to bring the structures into compliance with current structural codes. We have also investigated the impact of scour on the building foundations. The design criteria used in our analysis was based on the most stringent of the newly adopted 2012 Boulder Creek floodplain study, the preceding 1994 Boulder Creek floodplain study, and the 2010 Gregory Creek floodplain study. The resulting flood protection elevations are 3.33 feet above finished floor, 2.40 feet below finished floor, and 3.11 feet above finished floor for the South, Center, and North wings respectively. Scour against the building foundations is not expected to reach below the foundation elements at any of the three wings. In general, our solution involves installing new concrete flood walls and passive flood gates. Alternate solutions such as replacing the existing storefronts with structural glazing designed to resist flood loading have not been examined in depth. Our solutions are described in more detail within the body of this report.

After conducting our assessment, we have concluded that the buildings as constructed are not able to withstand the 100-year flood event. However, the measures that would be required to floodproof and reinforce the existing structure of the Boulder Public Library buildings are relatively straightforward and inexpensive. The estimated cost of the required structural improvements alone is \$366,930 for the three wings combined. Much of the work required lies in areas few restrictions on access. As mentioned elsewhere in the report, there would be costs incurred in addition to the required structural improvements.

2.0 INTRODUCTION

2.1 SCOPE OF SERVICES

The scope of structural services is to provide a report summarizing the results of our structural analysis of the Boulder Main Library wings and connecting bridge for flood loading as they exist, what improvements would need to be made to floodproof the buildings, and the approximate cost associated with improving the buildings. Floodproofing of architectural elements such as door gaskets and waterproof membranes are not included in this report. Site and utility improvements are also not included in this report.

2.2 ASSUMPTIONS AND BASIS OF ANALYSIS

Our assumptions for the analysis of the Boulder Main Library wings are as follows:

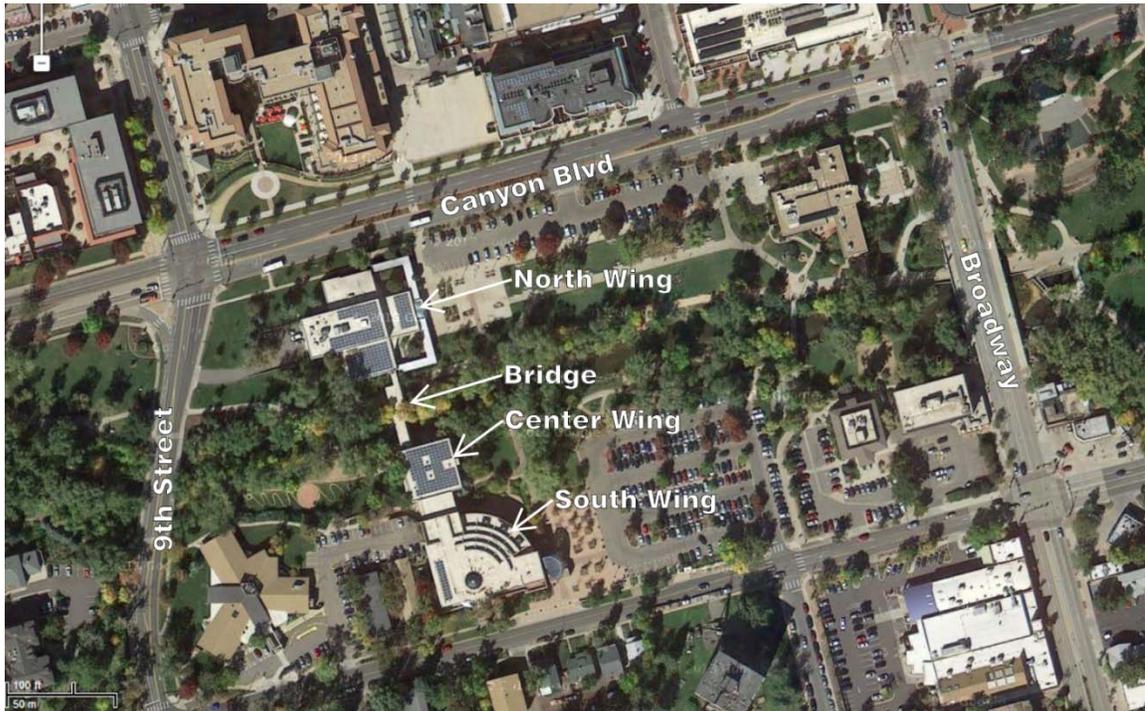
- The soils underlying each building are similar to those encountered in a test pit excavated by Anthem, LLC on the west side of the center wing
- The water surface elevations are linearly interpolated between cross-sections
- The non-observable elements each wing are as described in item 6.0

The analysis is based on the information provided by the City of Boulder indicated in Item 4.0, including drawings of the 1990 addition and remodel, floodplain data from both the newly adopted 2012 Boulder Creek floodplain study and the preceding 1994 Boulder Creek floodplain study, and floodplain data from the 2010 Gregory Creek floodplain study. Additionally, our analysis was based on our investigation of existing conditions outlined in Section 5.0.

2.3 LIMITATIONS AND EXCEPTIONS

Our analysis is limited to the information provided, and the observable elements of the structures. Alternate methods of addressing scour, such as armoring, have not been investigated.

3.0 SITE LOCATION AND CHARACTERISTICS



Site Location; accessed online 01/25/13 at <https://maps.google.com/maps?ll=40.0146,-105.280&z=18>

3.1 LOCATION AND LEGAL DESCRIPTION

The Boulder Public Library main facility is located between Canyon Blvd. and Arapahoe Ave. just east of 9th St at 1001 Arapahoe Ave. The building stretches across three distinct wings and a connecting bridge as illustrated above. A large public parking lot is provided west of the South Wing and city employee parking is provided west of the North Wing. Boulder Creek runs under the bridge, separating the North Wing from the remainder of the building. The City of Boulder Municipal Building lies at the opposite end of the employee parking lot. West of the site is the Senior Center. North across Canyon Blvd. is the St. Julien hotel.

The legal descriptions for the two properties are:

South and Center Wings: TRACTS 57 57A 58 58A 59 & 60 31-1N-70 & SUBLLOT J LOT 10 SMITHS & PT VACATED 10TH ST & RIVERSIDE ST PER ORDINANCE 5332

North Wing: BLKS 11 & 12 & TRACK ADJACENT TO BLK 11 ON THE WEST - BOULDER O T & PT LOT 9 SMITHS ADDITION TO BOULDER & VAC RIVERSIDE ST & 10TH ST & 11TH ST

3.2 SITE CHARACTERISTICS

The North Wing of the Main Library is located on fairly level ground that gently slopes towards the east. The south side slopes steeply to Boulder Creek. The South Wing is also located on fairly level ground gently sloping to the northeast. There is a large drop at the north side of the building to the terrace underneath the Center Wing. The terrace below the elevated Center Wing is generally level with a steep slope at the north edge down to Boulder Creek. Asphalt parking lots lie to the east of the North and South Wings. Open grass park areas extend east and west of the Center Wing and west of the North Wing.

The City of Boulder has recently adopted a new floodplain study for Boulder Creek, which will hereon be referred to as the 2012 Study. At this time, the study has not yet been approved by the Federal Emergency Management Agency (FEMA). Until the new study is adopted by FEMA, both the 2012 Study and the previous floodplain study, hereon referred to as the 1994 Study must be considered to determine the flooding conditions for the site. Both floodplain models indicate that the site is located within the 100-year floodplain. The Middle Wing and South Wing are located in the conveyance zone and the bridge and elevated part of the Middle Wing are located in high hazard flood zone. Additionally, the south wing lies in the Gregory Creek floodplain. The 100-year flood water depths around the buildings are generally around 5 feet, with velocities ranging from approximately 2 feet per second at the South Wing to 11 feet per second at the bridge. Floodplain maps and cross section information is included in Appendix A.

3.3 CURRENT USE OF PROPERTY

Owned and managed by the City of Boulder, the Boulder Public Library main facility houses approximately 75% of the library's collection. The North Wing contains studios for Channel 8 Boulder, a large auditorium, library technical services, tutoring spaces, and offices for cultural programs, volunteer coordination, graphics, and the Library Innovation & Technology Division. The Center Wing has fiction and nonfiction stacks, a teen area and a

plumbing core. The South Wing is the primary public space including a children's area, reference materials, staff offices and computers.

4.0 INFORMATION PROVIDED BY THE CITY OF BOULDER

4.1 DRAWINGS

- Structural and civil drawings of the Boulder Public Library dated August 28th, 1990

4.2 FLOOD INFORMATION

- 1994 Boulder Creek Flood Study maps and data
- 2012 Boulder Creek Flood Study maps and data
- 2010 Gregory Creek Flood Study maps and data

5.0 INVESTIGATION OF EXISTING CONDITIONS

5.1 METHODOLOGY AND LIMITING CONDITIONS

The original construction drawings that were provided by the City of Boulder were reviewed to determine the existing structural configuration of the South Wing of the Main Library building. Original construction drawings were not available for either the North or Center Wings; however, limited structural information was available in the renovation drawings provided by the City of Boulder. Additionally, a test pit was excavated west of the Center Wing to determine soil properties at the site. Observations were limited to visible components. No destructive investigation was performed. There were no available soils reports for the site.

6.0 BUILDING DESCRIPTIONS

6.1 DESCRIPTION OF SOUTH LIBRARY WING (1990 ADDITION)

The south wing of the Main Library is a 2-story structure designed in 1990 and completed in



1992. Drawings provided by the City of Boulder indicate the structure consists of 9” post-tensioned concrete floors supported on cast-in-place concrete columns at 17’-0” to 24’-0” centers founded on drilled piers. The children’s area consists of a 5” concrete slab on grade while the basement level is a 10” thick structural concrete slab. The roof

structure is a mix of steel bar joists and custom tube steel trusses supported on tube steel columns.

6.2 DESCRIPTION OF CENTER LIBRARY WING AND BRIDGE (1974 ADDITION)

The Center Wing is a two story steel and concrete structure over a one story open terrace originally constructed in 1974 with minor renovations designed in 1990. Drawings from the

1990 renovation indicate the structure consists of concrete slab on metal deck floor and roof surfaces supported by steel bar joists spanning 25’-3”. The bar joists bear on steel wide flange beams supported by cast-in-place concrete columns on spread footings. Based on the drawings, the footings bear approximately 3’-0” below the surface of the



terrace. Constructed at the same time as the Center Wing, the Bridge connecting it to the north wing uses the same system of steel joists, steel beams, and cast-in-place concrete columns.

6.3 DESCRIPTION OF NORTH LIBRARY WING (1961)



The North Wing is a two story concrete structure originally constructed in 1961 with minor renovations designed in 1990. Drawings from the 1990 renovation indicate the structure consists of slab on grade main floor with a perimeter grade beam on spread footings. The second floor and roof are one

way concrete slabs supported on concrete beams, columns, and spread footings. Bottom of footing elevation is 4'-0" below the main floor elevation based on the renovation drawings.

7.0 FINDINGS AND REQUIRED IMPROVEMENTS

7.1 FINDINGS

The flood studies were reviewed to determine flood water elevations and velocities. This information was used to determine the flood loads for the buildings. A preliminary scour analysis based on the available soils information was performed in order to determine the impacts of scouring on the existing foundation systems. The existing structures were then analyzed for flood conditions and improvements to the buildings were designed that would resist the flood conditions. Complete structural calculations are contained in Appendix B. The following are summaries of our analysis results:

TABLE 7.1 - SUMMARY OF RELEVANT ELEVATIONS

Building	FFE	WSE	FPE	Δ	BOF	DOS	Δ Ftg
	[Ft]	[Ft]	[Ft]	[Ft]	[Ft]	[Ft]	[Ft]
Library (N.E.)	5356.07	5356.33	5358.33	2.26	5352.07	5353.9	+1.83
Library (N.W.)	5358.07	5359.18	5361.18	3.11	5354.07	5357.59	+3.52
Library (Center)	5363.22	5358.82	5360.82	-2.40	5349.67	5350.29	+0.62
Library (South)	5358.57	5359.90	5361.90	3.33	5351.97	-	-

Elevations are expressed in NAVD88 Datum. Abbreviations: FFE = Finished Floor Elevation, WSE = Water Surface Elevation (aka Base Flood Elevation), FPE = Flood Protection Elevation, BOF = Bottom of Footing Elevation, DOS = Depth of Scour elevation.

The forces used for our analysis are based on the 2012 Boulder Creek floodplain study and the 2010 Gregory Creek floodplain study. Calculations used to determine these forces are contained in Appendix B. The following is a summary of the forces to the structure:

TABLE 7.2 - SUMMARY OF FORCES TO STRUCTURE

Building	Hydrostatic	Buoyant	Hydrodynamic	Debris Impact	Special Impact
	[PLF]	[PSF]	[PLF]	[#]	[#]
Library (N)	302	194	106	1643	100
Library (C)	N/A	N/A	N/A	2006	100
Library (S)	346	208	8	447	100

7.2 NORTH WING

7.2.1. Foundation Improvements

As indicated in Table 7.1, during a 100-year flood event, the scour would not undermine the existing foundations; therefore, no improvements are recommended.

7.2.2. Superstructure Improvements

As indicated in table 7.1, the flood protection elevation varies from 3.33 feet above the first floor elevation at the west end of the North Wing to 2.26 feet above the first floor elevation at the east end of the North Wing. The 1990 modifications and improvements to the North Wing are adequate to resist the new flood loads with the exception of the courtyard areas at the east end of the building. An 8” concrete flood wall would need to be constructed to above the flood protection elevation around the two courtyard areas at the east end of the building where there is presently a concrete lattice and flood doors. Based on the 1990 drawings, flood walls were indicated to be installed at these locations – see Figure 7.1. The top elevation of the existing flood gate is above the flood protection elevation, and is therefore adequate. The existing flood gate should be tested for mechanical functionality and water-tightness since it is approximately 20 years old.

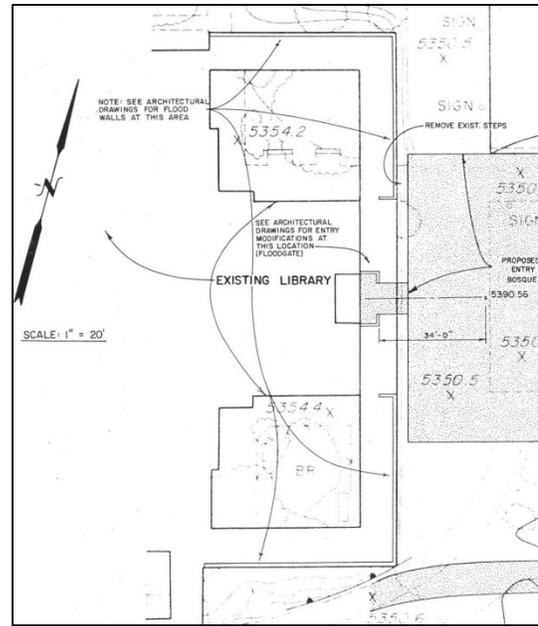
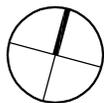
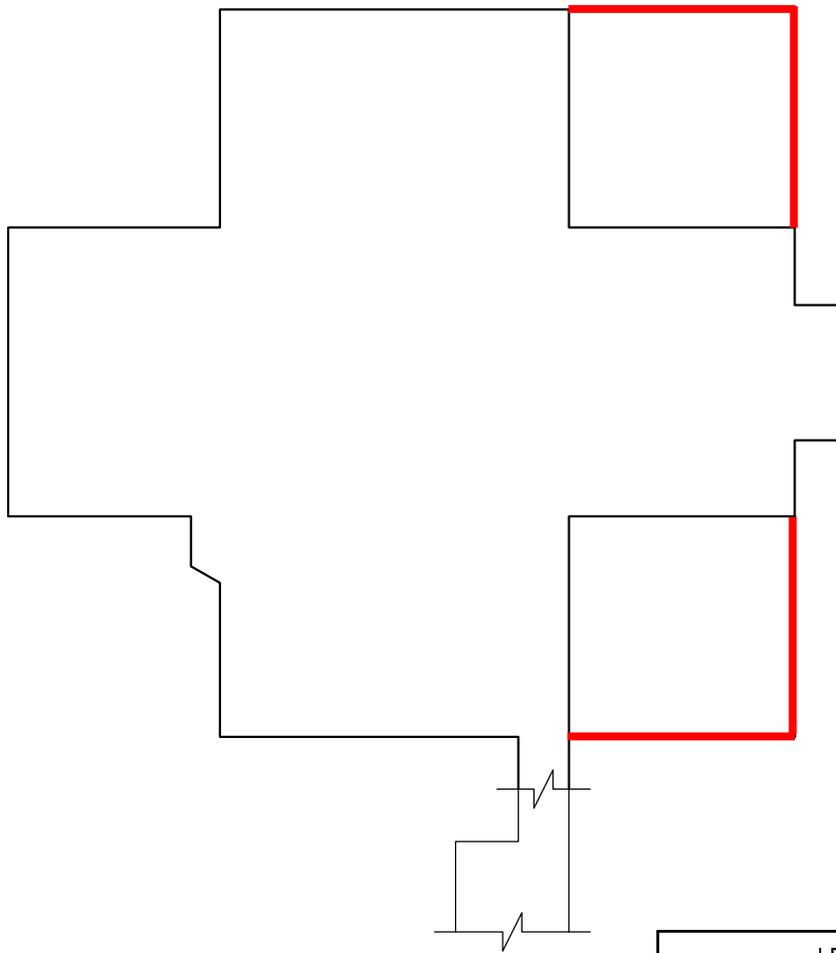
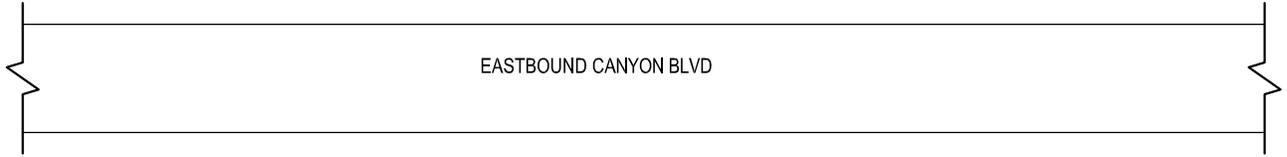


Figure 7.1 – Above: Existing Flood Door and garden wall
Right: Plan showing proposed flood walls

7.2.3. Opinion of Probable Cost for Structural Improvements

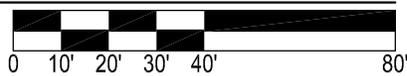
We estimate that the cost to floodproof the structural elements of the North Wing to be approximately **\$60,590**. This cost does not include architectural elements (such as door gaskets, membranes, elevator float switches), utility relocation, parking slabs, relocation of employees during construction, etc.

The market value of the North Wing is \$3,943,100 based on the current Boulder County Assessment Report for the property and insurance valuation provided by the City of Boulder. Since the costs for the required structural improvements are less than 50% of the market value of the structure, the improvements are not considered to be ‘substantial improvements’ as defined in 9-16-1 of the City of Boulder Revised Code. Additionally, the wing is located outside of the high hazard zone based on both the 1994 study and the 2012 study, and are therefore may be improved in accordance with 9-3-5(d)(2) of the City of Boulder Revised Code.



MAIN LIBRARY NORTH WING

1" = 40'



7.3 CENTER WING AND BRIDGE

7.3.1. Foundation Improvements

As indicated in Table 6.1, during a 100-year flood event, the scour at the Center Wing foundations directly adjacent to the South Wing would not be scoured below the bottom of footing elevation. The depth of the bridge foundations is assumed to be 32” below grade directly adjacent to the main channel. It was observed that the foundations are protected from scour upstream and downstream along the north and south banks with rip rap.

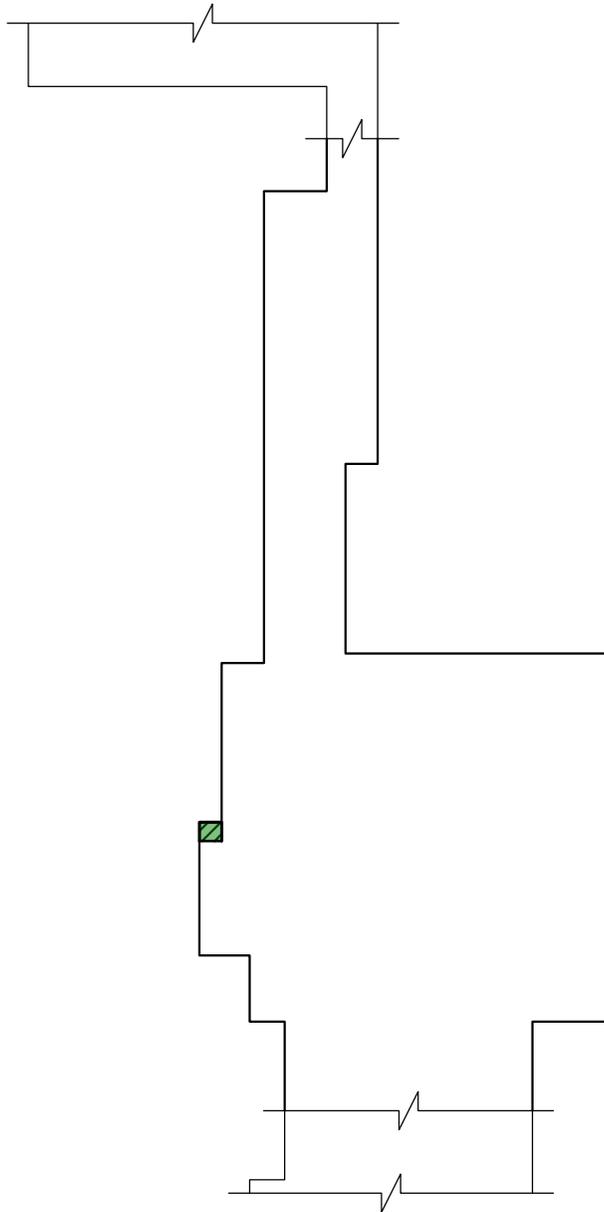
7.3.2. Superstructure Improvements

As indicated in Table 7.1, the flood protection elevation is below the main floor elevation. However, two mechanical cores extend down to grade and must be protected by adding a new areaway for the mechanical louver. Additionally, the doors should be floodproofed if they are not already. The existing columns were checked for debris impact of approximately 1,600 pounds, based on a 5,000# truck impacting the column for a duration of ½ second at the flood protection elevation, and are capable of resisting the impact load. This criterion is more stringent than is what is required by the City of Boulder floodplain regulations, which is a 1,000# object impacting for a duration of 1 second.

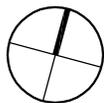
7.3.3. Opinion of Probable Cost for Structural Improvements

We estimate that the cost to floodproof the structural elements of the Center Wing and Bridge to be approximately **\$8,680**. This cost does not include architectural elements (such as door gaskets, membranes, elevator float switches), utility relocation or retrofitting, parking slabs, relocation of employees during construction, etc.

The market value of the Center Wing and Bridge is \$2,074,900 based on the current Boulder County Assessment Report for the property and insurance valuation provided by the City of Boulder. Since the costs for the required structural improvements are less than 50% of the market value of the structure, the improvements are not considered to be ‘substantial improvements’ as defined in 9-16-1 of the City of Boulder Revised Code.



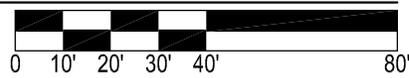
LEGEND	
	NEW AREAWAY



PLAN NORTH

MAIN LIBRARY CENTRAL WING

1" = 40'



7.4 SOUTH WING

7.4.1. Foundation Improvements

As indicated in Table 7.1, during a 100-year flood event, the scour would not undermine the existing foundations; therefore, no improvements are recommended.

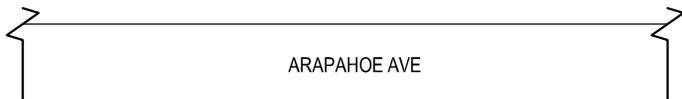
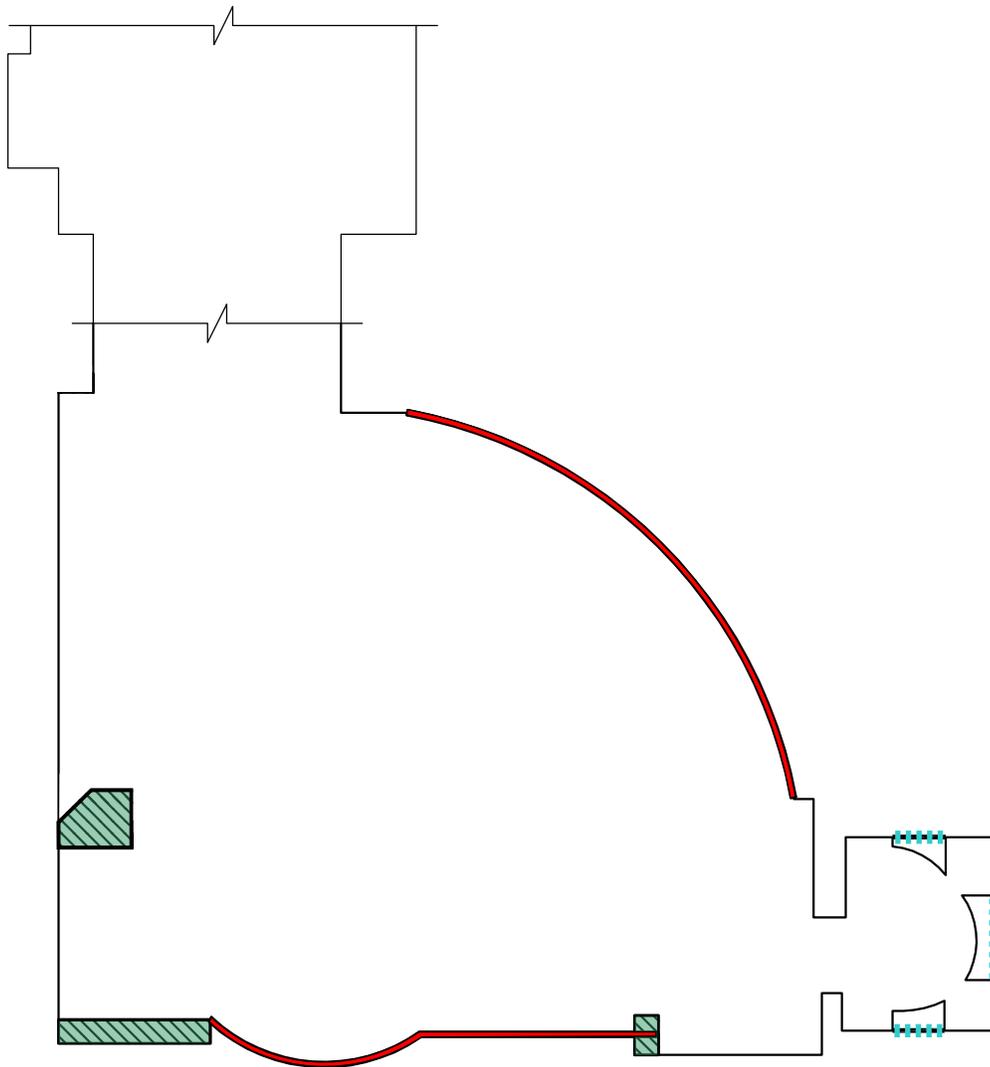
7.4.2. Superstructure Improvements

As indicated in table 7.1, the flood protection elevation is 3.33 feet above the first floor elevation. Much of the perimeter of the South Wing is flood resistant – however, there are some areas which would need to be floodproofed. There are two mechanical areaways at the south end and one areaway on the west end which would need to have the walls raised above the flood protection elevation. There is a storefront system at the south end and one at the east end, as well as the entrance vestibule, which would need to be protected by a flood wall. In addition to the flood wall at the entrance vestibule, a flood gate would need to be installed similar to the gate at the North Wing. There is a large louver at the north end of the structure that extends below the flood protection elevation. This opening would need to be infilled to the flood protection elevation.

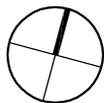
7.4.3. Opinion of Probable Cost for Structural Improvements

We estimate that the cost to floodproof the structural elements of the South Wing to be approximately **\$297,660**. This cost does not include architectural elements (such as door gaskets, membranes, elevator float switches), utility relocation or retrofitting, parking slabs, relocation of employees during construction, etc.

The market value of the South Wing is \$10,458,000 based on the current Boulder County Assessment Report for the property and insurance valuation provided by the City of Boulder. Since the costs for the required structural improvements are less than 50% of the market value of the structure, the improvements are not considered to be ‘substantial improvements’ as defined in 9-16-1 of the City of Boulder Revised Code.



LEGEND	
	FLOODWALL/STOREFRONT REPLACEMENT
	NEW PASSIVE FLOODGATE
	NEW AREAWAY/AREAWAY EXTENSION



MAIN LIBRARY SOUTH WING

1" = 40'



8.0 CONCLUSIONS

After conducting our assessment, we have concluded that the buildings as constructed are not able to withstand the 100-year flood event. We have also investigated the impact of scour on the building foundations. The design criteria used in our analysis was based on the most stringent of the newly adopted 2012 Boulder Creek floodplain study, the preceding 1994 Boulder Creek floodplain study, and the 2010 Gregory Creek floodplain study. The resulting flood protection elevations are 3.33 feet above finished floor, 2.40 feet below finished floor, and 3.11 feet above finished floor for the South, Center, and North wings respectively. Scour against the building foundations is not expected to reach below the foundation elements at any of the three wings.

After conducting our assessment, we have concluded that the buildings as constructed are not able to withstand the 100-year flood event. However, the measures that would be required to floodproof and reinforce the existing structure of the Boulder Public Library buildings are relatively straightforward and inexpensive. The estimated cost of the required structural improvements alone is \$366,930 for the three wings combined. Much of the work required lies in areas few restrictions on access. As mentioned elsewhere in the report, there would be costs incurred in addition to the required structural improvements.

9.0 REFERENCES

The following published references were used in the preparation of this report:

Federal Emergency Management Agency: *Technical Bulletin 3: Non-Residential Floodproofing-Requirements and Certification for Buildings Located in Special Flood Hazard Area*, 1993

Federal Emergency Management Agency: *FEMA-102: Floodproofing Non-Residential Structures*, May 1986.

Federal Emergency Management Agency: *FEMA-114: Design Manual for Retrofitting Flood-Prone Residential Structures*, September 1986.

Federal Emergency Management Agency: *FIA-TB-4: Elevator Installation for Buildings Located in Special Flood Hazard Areas*

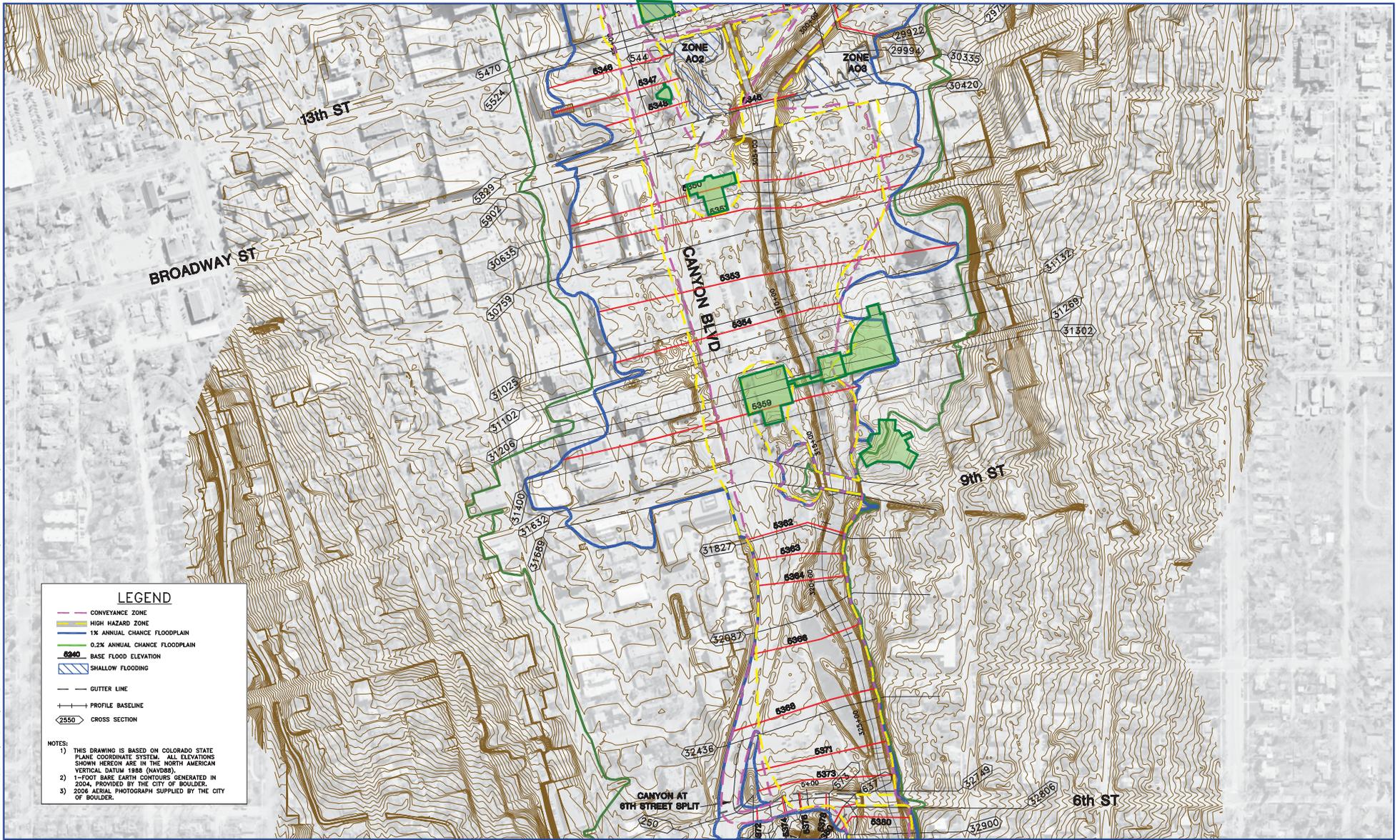
Colorado State University: *Colorado State University Pier Scour Equation (modified from Richardson and others)*, 1993.



Appendix A

Flood Study Information

K:\COBLDR02\Boulder Creek FP 2\Upstream Topo July0711\Local\BOULDER CREEK FP WORKMAPS August 2012\Altwater.dwg 10/31/2012 8:00 AM



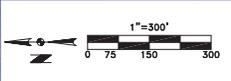
LEGEND

- CONVEYANCE ZONE
- HIGH HAZARD ZONE
- 1% ANNUAL CHANCE FLOODPLAIN
- 0.2% ANNUAL CHANCE FLOODPLAIN
- BASE FLOOD ELEVATION
- SHALLOW FLOODING
- GUTTER LINE
- PROFILE BASELINE
- 2550 CROSS SECTION

NOTES:

- 1) THIS DRAWING IS BASED ON COLORADO STATE PLANE COORDINATE SYSTEM. ALL ELEVATIONS SHOWN HEREON ARE IN THE NORTH AMERICAN VERTICAL DATUM 1985 (NAVD83).
- 2) 1-FOOT BARE EARTH CONTOURS GENERATED IN 2004, PROVIDED BY THE CITY OF BOULDER.
- 3) 2008 AERIAL PHOTOGRAPH SUPPLIED BY THE CITY OF BOULDER.

REVISIONS
REV1
REV2
REV3
REV4
REV5
REV6



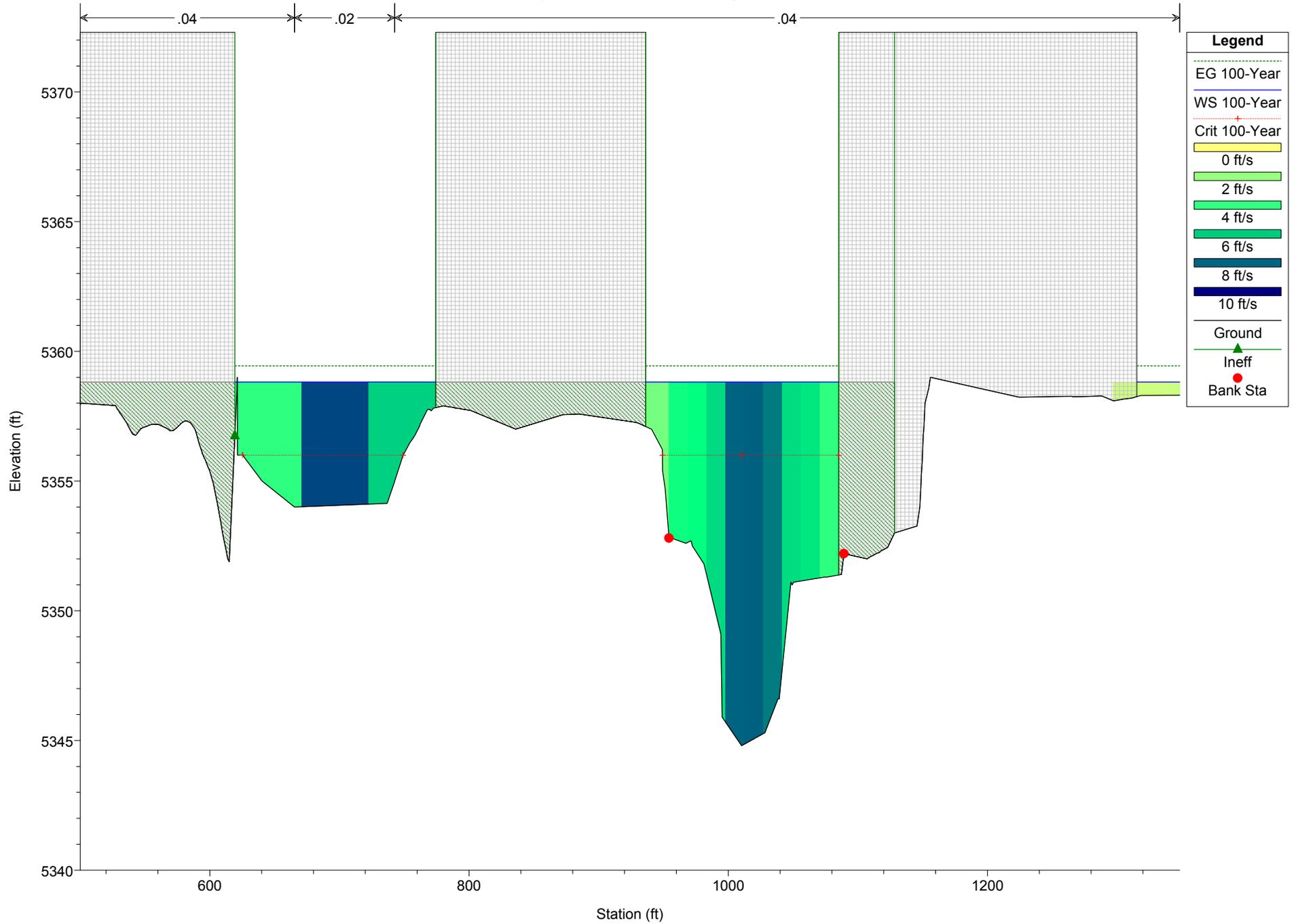
PROJECT NUMBER: COBLDR02	DRAWN BY: MRC
ACAD FILE: BlDr Ck FP Alt	DESIGNED BY: JMA
DATE: 10/31/2012	CHECKED BY: GJK

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CITY OF BOULDER
BOULDER CREEK FLOODPLAIN STUDY

BOULDER CREEK
FLOOD HAZARD WORKMAP

COBLDR02 Plan: 100-yr w/o Roche (Oct 2012) 10/25/2012
 US side of Library. Overbanks of xsec cut using HecGeoRAS from 1



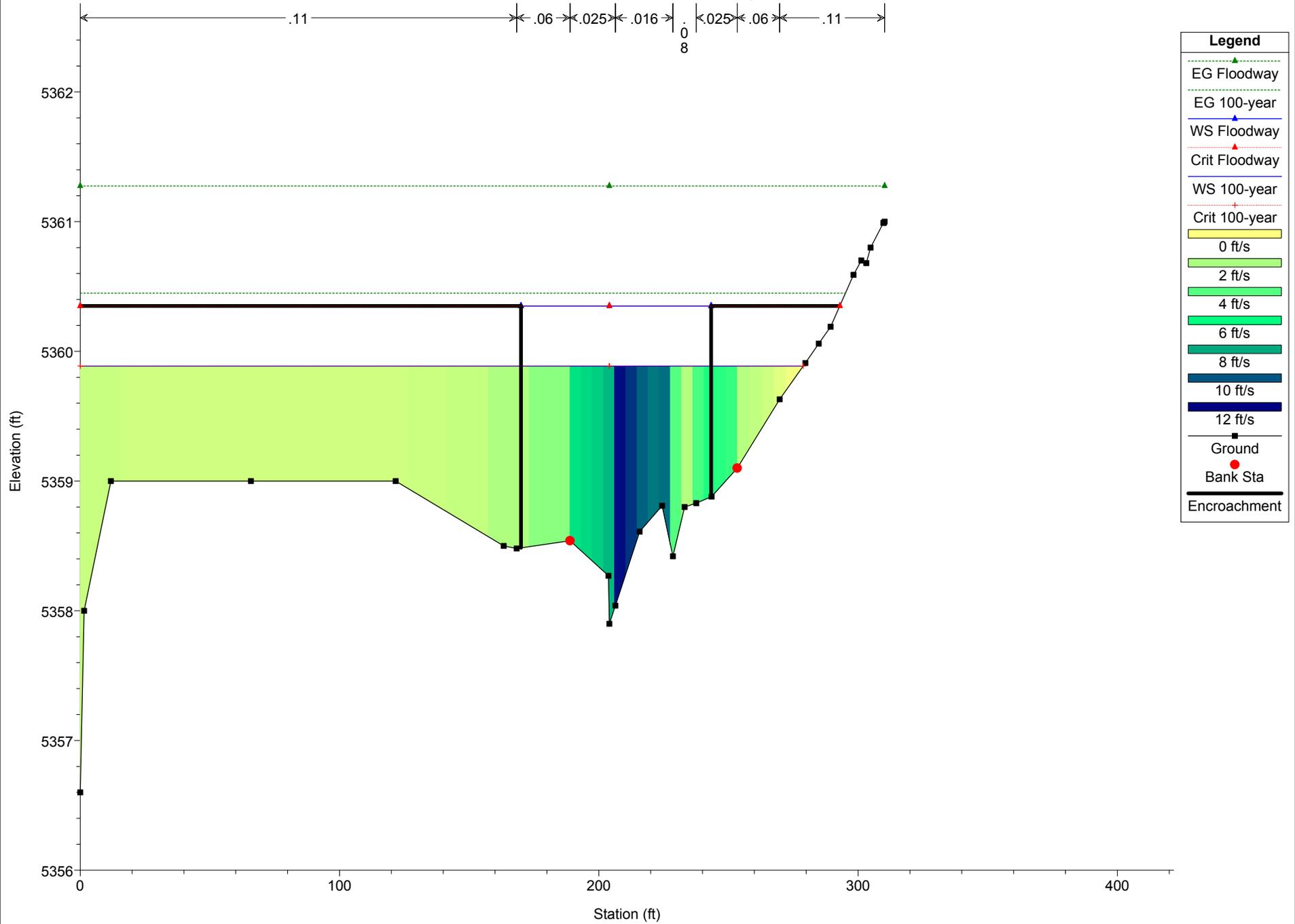
1 in Horiz. = 100 ft 1 in Vert. = 5 ft

Plan: 100-yr Boulder Creek 6th-Broadway RS: 31302 Profile: 100-Year

E.G. Elev (ft)	5359.44	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.63	Wt. n-Val.	0.024	0.040	0.036
W.S. Elev (ft)	5358.82	Reach Len. (ft)	6.00	6.00	6.00
Crit W.S. (ft)	5356.00	Flow Area (sq ft)	649.82	1251.30	21.60
E.G. Slope (ft/ft)	0.001666	Area (sq ft)	794.17	1251.30	21.60
Q Total (cfs)	12100.00	Flow (cfs)	3995.32	8083.28	21.41
Top Width (ft)	451.69	Top Width (ft)	268.63	131.00	52.06
Vel Total (ft/s)	6.29	Avg. Vel. (ft/s)	6.15	6.46	0.99
Max Chl Dpth (ft)	14.02	Hydr. Depth (ft)	3.76	9.55	0.41
Conv. Total (cfs)	296409.7	Conv. (cfs)	97871.9	198013.3	524.5
Length Wtd. (ft)	6.00	Wetted Per. (ft)	183.01	142.32	52.63
Min Ch El (ft)	5344.80	Shear (lb/sq ft)	0.37	0.91	0.04
Alpha	1.02	Stream Power (lb/ft s)	2.27	5.91	0.04
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	8.91	17.05	6.60
C & E Loss (ft)	0.41	Cum SA (acres)	4.76	2.01	3.03

GREGORY CANYON CREEK SPILL FLOODWAY Plan: FINAL-Spill Floodway-Rev-051810 6/16/2010

River = RIVER-1 Reach = Reach-1 RS = 905 manning's n channel/street updated



Legend	
EG Floodway	▲
EG 100-year	—
WS Floodway	▲
Crit Floodway	▲
WS 100-year	—
Crit 100-year	+
0 ft/s	□
2 ft/s	□
4 ft/s	□
6 ft/s	□
8 ft/s	□
10 ft/s	□
12 ft/s	□
Ground	■
Bank Sta	●
Encroachment	—

1 in Horiz. = 50 ft 1 in Vert. = 1 ft

Plan: 051810fw RIVER-1 Reach-1 RS: 905 Profile: 100-year

E.G. Elev (ft)	5360.45	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.56	Wt. n-Val.	0.096	0.022	0.061
W.S. Elev (ft)	5359.89	Reach Len. (ft)	301.23	303.70	299.30
Crit W.S. (ft)	5359.89	Flow Area (sq ft)	198.37	82.68	9.71
E.G. Slope (ft/ft)	0.008248	Area (sq ft)	198.37	82.68	9.71
Q Total (cfs)	900.73	Flow (cfs)	285.77	602.14	12.81
Top Width (ft)	278.85	Top Width (ft)	188.93	64.48	25.44
Vel Total (ft/s)	3.10	Avg. Vel. (ft/s)	1.44	7.28	1.32
Max Chl Dpth (ft)	3.29	Hydr. Depth (ft)	1.05	1.28	0.38
Conv. Total (cfs)	9917.7	Conv. (cfs)	3146.6	6630.0	141.1
Length Wtd. (ft)	302.64	Wetted Per. (ft)	192.83	64.70	25.45
Min Ch El (ft)	5357.90	Shear (lb/sq ft)	0.53	0.66	0.20
Alpha	3.77	Stream Power (lb/ft s)	0.76	4.79	0.26
Frctn Loss (ft)	2.83	Cum Volume (acre-ft)	0.69	0.51	0.23
C & E Loss (ft)	0.13	Cum SA (acres)	0.65	0.64	1.09

GROUND CONTROL SURVEY BY MERRICK & COMPANY
 AERIAL PHOTOGRAPHY BY MERRICK & COMPANY
 CONTOUR INTERVAL ONE FEET MERRICK & COMPANY
 DATE: FLOWMAY 2003
 PLANE COORD. — NORTH, VERTICAL. — NAD83

CITY OF BOULDER, COLORADO

REVISIONS
 NO. DATE BY
 1 MAR 2010

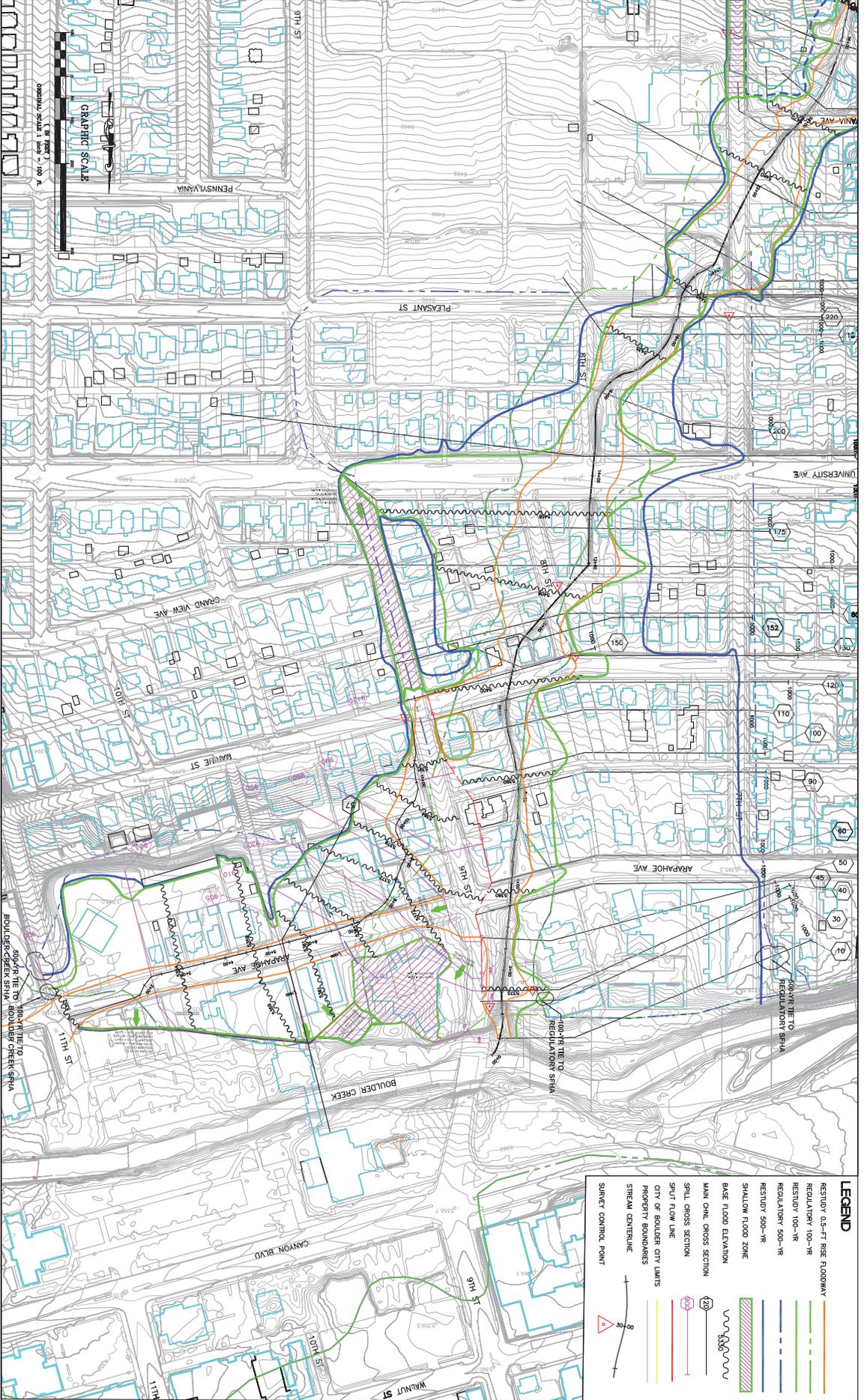
PREPARED BY
 BELT COLLINS WEST (No. 1)
 1000 17TH ST. BOULDER, CO 80502
 TEL: 303.440.1000 FAX: 303.440.1001



DATE	REVISIONS	BY

**GREGORY CANYON CREEK FLOODPLAIN
 WORK MAP STA. 0+00 TO STA. 24+00**

SHEET 1
 3



LEGEND

- REGULATORY 0.5-FT. RISE FLOODWAY
- REGULATORY 100-YR
- REGULATORY 100-YR
- REGULATORY 500-YR
- REGULATORY 500-YR
- SHALLOW FLOOD ZONE
- BASE FLOOD ELEVATION
- MAIN CHNL. CROSS SECTION
- SPILL CROSS SECTION
- SPILL FLOW LINE
- CITY OF BOULDER CITY LIMITS
- PROPERTY BOUNDARIES
- STREAM CENTERLINE
- SINKHOLE CONTROL POINT

Appendix B

Structural Calculations

Main Library (North) - Scour Analysis

Based on Cross Section 31206

Maryland Abutment Scour Equation:

$$d_{sc} = d - y$$

$d_{sc} =$	2.66	Feet	Depth of Scour
$y_1 =$	3.83	Feet	Upstream Flow Depth
$V_e =$	6.28	Ft/sec	Average Velocity of Flow
$D_{50} =$	0.013	Feet	Diameter of Particles for which 50% are Smaller in the Bed Material
$q =$	24.05	cfs/ft	Unit-Width Flow
$V_{c50} =$	3.29	Ft/sec	Critical Velocity for D_{50} Bed Material Size
$K_u =$	11.17		
$d =$	5.73	Feet	Total Flow Depth in Contraction
$x =$	0.77		Exponent in Computing d
$FS =$	1.4		Factor of Safety (Between 1.2 & 1.4)

Main Library (North) - Scour Analysis

Based on Cross Section 31206

Maryland Abutment Scour Equation:

$$d_{sc} = d - y$$

$d_{sc} =$	1.66	Feet	Depth of Scour
$y_1 =$	3.68	Feet	Upstream Flow Depth
$V_e =$	5.29	Ft/sec	Average Velocity of Flow
$D_{50} =$	0.013	Feet	Diameter of Particles for which 50% are Smaller in the Bed Material
$q =$	19.47	cfs/ft	Unit-Width Flow
$V_{c50} =$	3.26	Ft/sec	Critical Velocity for D_{50} Bed Material Size
$K_u =$	11.17		
$d =$	4.87	Feet	Total Flow Depth in Contraction
$x =$	0.77		Exponent in Computing d
$FS =$	1.4		Factor of Safety (Between 1.2 & 1.4)

Main Library (North) - Scour Analysis

Based on Cross Section 31206

Maryland Abutment Scour Equation:

$$d_{sc} = d - y$$

$d_{sc} =$	3.28	Feet	Depth of Scour
$y_1 =$	8.82	Feet	Upstream Flow Depth
$V_e =$	6.46	Ft/sec	Average Velocity of Flow
$D_{50} =$	0.013	Feet	Diameter of Particles for which 50% are Smaller in the Bed Material
$q =$	56.98	cfs/ft	Unit-Width Flow
$V_{c50} =$	3.78	Ft/sec	Critical Velocity for D_{50} Bed Material Size
$K_u =$	11.17		
$d =$	11.17	Feet	Total Flow Depth in Contraction
$x =$	0.77		Exponent in Computing d
$FS =$	1.4		Factor of Safety (Between 1.2 & 1.4)

South Library Building - Flood Analysis

Design Criteria (FEMA FIA-TB-3):

General:

Velocity of Water (V) =	1.44	ft/s
Specific Weight of Water (w) =	62.4	pcf
Mass Density of Water (m) =	1.94	slugs/ft ³
Equiv. Fluid Weight of Saturated Soil (S) =	0	pcf
Acceleration Due to Gravity (g) =	32.2	ft/s ²

Resultant Lateral Force Due to Hydrostatic Pressure From Freestanding Water:

Height of Freestanding Water (H) =	3.33	ft
Depth of Saturated Soil (D) =	0.0	ft

$$F_h = 1/2wH^2 = \underline{346} \#$$

$$F_{sat} = 1/2SD^2 + F_h = \underline{346} \#$$

Buoyancy Force:

Area of Horizontal Surface (A _h) =	1.00	ft ²
Depth of Building Below Flood Protection Elevation (H) =	3.33	ft

$$F_h = wA_hH = \underline{208} \#$$

Hydrodynamic Force:

Drag Coefficient (C _d) =	1.25	
Area of Vertical Surface (A _v) =	3.33	ft ²

$$F_d = C_d m 1/2V^2 A_v = \underline{8} \#$$

Debris (Normal) Impact Force:

Weight of Object (W) =	5000	#
Duration of Impact (t) =	0.5	sec

$$F_i = WV/(gt) = \underline{447} \#$$

Special Impact Force:

$$F_{is} = \underline{100} \text{ plf}$$

North Library Building - Flood Analysis

Design Criteria (FEMA FIA-TB-3):

General:	
Velocity of Water (V) =	5.29 ft/s
Specific Weight of Water (w) =	62.4 pcf
Mass Density of Water (m) =	1.94 slugs/ft ³
Equiv. Fluid Weight of Saturated Soil (S) =	0 pcf
Acceleration Due to Gravity (g) =	32.2 ft/s ²
Resultant Lateral Force Due to Hydrostatic Pressure From Freestanding Water:	
Height of Freestanding Water (H) =	3.11 ft
Depth of Saturated Soil (D) =	0.0 ft
$F_h = 1/2wH^2 =$	<u>302</u> #
$F_{sat} = 1/2SD^2 + F_h =$	<u>302</u> #
Buoyancy Force:	
Area of Horizontal Surface (A _h) =	1.00 ft ²
Depth of Building Below Flood Protection Elevation (H) =	3.11 ft
$F_h = wA_hH =$	<u>194</u> #
Hydrodynamic Force:	
Drag Coefficient (C _d) =	1.25
Area of Vertical Surface (A _v) =	3.11 ft ²
$F_d = C_d m 1/2V^2 A_v =$	<u>106</u> #
Debris (Normal) Impact Force:	
Weight of Object (W) =	5000 #
Duration of Impact (t) =	0.5 sec
$F_i = WV/(gt) =$	<u>1643</u> #
Special Impact Force:	
$F_{is} =$	<u>100</u> plf

South Library Building - Flood Analysis

Design Criteria (FEMA FIA-TB-3):

General:		
Velocity of Water (V) =	6.46	ft/s
Specific Weight of Water (w) =	62.4	pcf
Mass Density of Water (m) =	1.94	slugs/ft ³
Equiv. Fluid Weight of Saturated Soil (S) =	0	pcf
Acceleration Due to Gravity (g) =	32.2	ft/s ²
Resultant Lateral Force Due to Hydrostatic Pressure From Freestanding Water:		
Height of Freestanding Water (H) =	0.00	ft
Depth of Saturated Soil (D) =	0.0	ft
$F_h = 1/2wH^2 =$	<u>0</u>	#
$F_{sat} = 1/2SD^2 + F_h =$	<u>0</u>	#
Buoyancy Force:		
Area of Horizontal Surface (A _h) =	1.00	ft ²
Depth of Building Below Flood Protection Elevation (H) =	0.00	ft
$F_h = wA_hH =$	<u>0</u>	#
Hydrodynamic Force:		
Drag Coefficient (C _d) =	1.25	
Area of Vertical Surface (A _v) =	0.00	ft ²
$F_d = C_d m 1/2V^2 A_v =$	<u>0</u>	#
Debris (Normal) Impact Force:		
Weight of Object (W) =	5000	#
Duration of Impact (t) =	0.5	sec
$F_i = WV/(gt) =$	<u>2006</u>	#
Special Impact Force:		
$F_{is} =$	<u>100</u>	plf

Appendix C

Opinion of Probable Cost

City of Boulder
 1001 Arapahoe Ave
 Boulder, Colorado, 80302
 Date: 01-Feb-13

Library Center Wing & Bridge
 Year 2013
 Unit Summary Report

Prepared By:
 Daniel Knapp
 Anthem, LLC

Division Description	Total
Division 03 Concrete	\$6,236.25
Subtotal	\$6,236.25
General Contractor's Markup on Subs	10.00% \$623.62
Subtotal	\$6,859.87
General Conditions	10.00% \$685.99
Subtotal	\$7,545.86
General Contractor's Overhead and Profit	15.00% \$1,131.88
Grand Total	\$8,677.74

City of Boulder
1001 Arapahoe Ave
Boulder, Colorado, 80302
Date: 01-Feb-13

Library Center Wing & Bridge
Year 2013
Unit Detail Report

Prepared By:
Daniel Knapp
Anthem, LLC

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113500020		<input checked="" type="checkbox"/>	C.I.P. concrete forms, grade beam, plywood, 1 use, includes erecting, bracing, stripping and cleaning	384.00	SFCA	\$7.25	\$2,784.00
032110600700	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Reinforcing Steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.57	Ton	\$1,696.13	\$2,662.92
032110600700		<input checked="" type="checkbox"/>	Reinforcing Steel, in place, 10 - 50 ton job, #3 to #7, add	1.00		\$114.95	\$180.47
033105350150		<input checked="" type="checkbox"/>	Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement (Type I) and water, delivered, excludes all additives and treatments	4.75	C.Y.	\$109.46	\$519.94
033105703250		<input checked="" type="checkbox"/>	Structural concrete, placing, grade beam, pumped, includes leveling (strike off) & consolidation, excludes material	4.75	C.Y.	\$18.72	\$88.92
Division 03 Concrete Subtotal							\$6,236.25

City of Boulder
 1001 Arapahoe
 Boulder, CO, 80302
 Date: 01-Feb-13

Library North Wing - Garden Walls
Year 2013
Unit Summary Report

Prepared By:
Daniel Knapp
Anthem, LLC

Division Description		Total
Division 03	Concrete	\$41,304.08
Division 31	Earthwork	\$2,239.20
Subtotal		\$43,543.28
General Contractor's Markup on Subs	10.00%	\$4,354.33
Subtotal		\$47,897.61
General Conditions	10.00%	\$4,789.76
Subtotal		\$52,687.37
General Contractor's Overhead and Profit	15.00%	\$7,903.11
Grand Total		\$60,590.48

City of Boulder

1001 Arapahoe
Boulder, CO, 80302

Date: 01-Feb-13

Library North Wing - Garden Walls
Year 2013
Unit Detail Report

Prepared By:
Daniel Knapp
Anthem, LLC

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113500020		✘	C.I.P. concrete forms, grade beam, plywood, 1 use, includes erecting, bracing, stripping and cleaning	2,544.00	SFCA	\$7.25	\$18,444.00
032110600700	🍃	✘	Reinforcing Steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	10.40	Ton	\$1,696.13	\$17,639.75
032110600700	🍃	✘	Reinforcing Steel, in place, 10 - 50 ton job, #3 to #7, add	1.00		\$114.95	\$1,195.48
033105350150		✘	Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement (Type I) and water, delivered, excludes all additives and treatments	31.40	C.Y.	\$109.46	\$3,437.04
033105703250		✘	Structural concrete, placing, grade beam, pumped, includes leveling (strike off) & consolidation, excludes material	31.40	C.Y.	\$18.72	\$587.81
Division 03 Concrete Subtotal							\$41,304.08
Division 31 Earthwork							
312316130060		✘	Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	60.00	B.C.Y.	\$6.13	\$367.80
312323130015		✘	Backfill, light soil, by hand, no compaction	60.00	L.C.Y.	\$24.78	\$1,486.80
312323130600		✘	Backfill and compact, by hand, 6" layers, compaction in layers, vibrating plate, add to above	60.00	E.C.Y.	\$6.41	\$384.60
Division 31 Earthwork Subtotal							\$2,239.20

City of Boulder
1001 Arapahoe Ave
Boulder, Colorado, 80302
Date: 01-Feb-13

Library South Wing
Year 2013
Unit Summary Report

Prepared By:
Daniel Knapp
Anthem, LLC

Division Description		Total
Division 03	Concrete	\$48,037.58
Division 08	Openings	\$180,000.00
Division 31	Earthwork	\$2,239.20
Subtotal		\$230,276.78
General Contractor's Markup on Subs		10.00% \$5,027.68
Subtotal		\$235,304.45
General Conditions		10.00% \$23,530.45
Subtotal		\$258,834.90
General Contractor's Overhead and Profit		15.00% \$38,825.23
Grand Total		\$297,660.13

City of Boulder
1001 Arapahoe Ave
Boulder, Colorado, 80302
Date: 01-Feb-13

Library South Wing
Year 2013
Unit Detail Report

Prepared By:
Daniel Knapp
Anthem, LLC

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113500020		<input checked="" type="checkbox"/>	C.I.P. concrete forms, grade beam, plywood, 1 use, includes erecting, bracing, stripping and cleaning	2,858.00	SFCA	\$7.25	\$20,720.50
032110600700		<input checked="" type="checkbox"/>	Reinforcing Steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	12.50	Ton	\$1,696.13	\$21,201.63
032110600700		<input checked="" type="checkbox"/>	Reinforcing Steel, in place, 10 - 50 ton job, #3 to #7, add	1.00		\$114.95	\$1,436.88
033105350150		<input checked="" type="checkbox"/>	Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement (Type I) and water, delivered, excludes all additives and treatments	36.50	C.Y.	\$109.46	\$3,995.29
033105703250		<input checked="" type="checkbox"/>	Structural concrete, placing, grade beam, pumped, includes leveling (strike off) & consolidation, excludes material	36.50	C.Y.	\$18.72	\$683.28
Division 03 Concrete Subtotal							\$48,037.58
Division 08 Openings							
083456100010		<input type="checkbox"/>	Floodgate 4' wide, 4' High	2.00	Ea.	\$40,000.00	\$80,000.00
083456100010		<input type="checkbox"/>	Floodgate, 8' wide, 4' high	2.00	Ea.	\$50,000.00	\$100,000.00
Division 08 Openings Subtotal							\$180,000.00
Division 31 Earthwork							
312316130060		<input checked="" type="checkbox"/>	Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	60.00	B.C.Y.	\$6.13	\$367.80
312323130015		<input checked="" type="checkbox"/>	Backfill, light soil, by hand, no compaction	60.00	L.C.Y.	\$24.78	\$1,486.80
312323130600		<input checked="" type="checkbox"/>	Backfill and compact, by hand, 6" layers, compaction in layers, vibrating plate, add to above	60.00	E.C.Y.	\$6.41	\$384.60
Division 31 Earthwork Subtotal							\$2,239.20