BOULDER SLOUGH FLOODPLAIN MAPPING STUDY

Prepared for:

City of Boulder
Public Works Department
Utilities Division
1739 Broadway
Boulder, Colorado 80306

Prepared by:

Anderson Consulting Engineers, Inc.
375 E. Horsetooth Road, Bldg. 5
Fort Collins, Colorado 80525
(ACE Project No. COBLDR08)

September 2014

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Civil • Water Resources • Environmental

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I. INTRODUCTION

1.1 Background

Boulder Slough historically carried flood overflows from Boulder Creek. Many years ago improvements were made to Boulder Slough in order to promote the efficient conveyance of irrigation flows for Boulder & Whiterock Ditch, Boulder & Left Hand Ditch, and North Boulder Farmers Ditch. The Slough currently originates as a left bank diversion from Boulder Creek at an irrigation diversion structure located directly east of the Broadway Bridge. The Slough trends east-northeast terminating at its confluence with Goose Creek east of Foothills Parkway. Along its length, Boulder Slough collects stormwater runoff derived from the area west of the Slough. North of Canyon Boulevard, near 21st Street, a diversion structure on Boulder Slough serves to divert a portion of the irrigation flows from the Slough into the Boulder & Whiterock Ditch.

The City of Boulder is currently implementing a number of flood mitigation and recreation trail improvements along the lower portion of Boulder Slough which will significantly improve the flood flow conveyance function of the Slough. As these projects continue to be implemented, they will be reflected in a future floodplain study. Consequently, the current study reach for Boulder Slough begins roughly ½ mile upstream of Goose Creek, approximately 300 feet downstream of 30th Street. The upstream limit of the current study is approximately 100 feet downstream of 18th street, where the Boulder Slough floodplain ties in to the Boulder Creek 100-year floodplain.

The effective FIRM panel for this area (Panel No. 394J) indicates a Zone A flood hazard area along Boulder Slough for a portion of the current study reach; elsewhere along the study reach, the effective FIRM panel shows a Shaded Zone X flood hazard area. A vicinity map of the study reach along Boulder Slough is provided as Figure 1.1.

1.2 Previous Studies

Muller Engineering completed a floodplain study for Boulder Slough in 1981. This study defined 100-year discharges along the Slough, conducted hydraulic analyses to determine conveyance capacities of the Slough, and mapped a 100-year floodplain along the Slough. FEMA's effective FIRM panels define the flood hazard along Boulder Slough as an approximate (Zone A) flood zone that appears to reflect the information shown in the Muller report.

1.3 Purpose and Scope of the Current Study

The current study includes hydraulic modeling along Boulder Slough from approximately 300 feet downstream of 30th Street, upstream to the northern boundary of the Boulder Creek 100-year floodplain, approximately 100 feet downstream of 18th Street. This study included evaluation of 100-year floodplain, conveyance zone analysis (equivalent to a ½-foot rise floodway analysis), and high hazard zone analysis along Boulder Slough. No other return periods were evaluated due to lack of

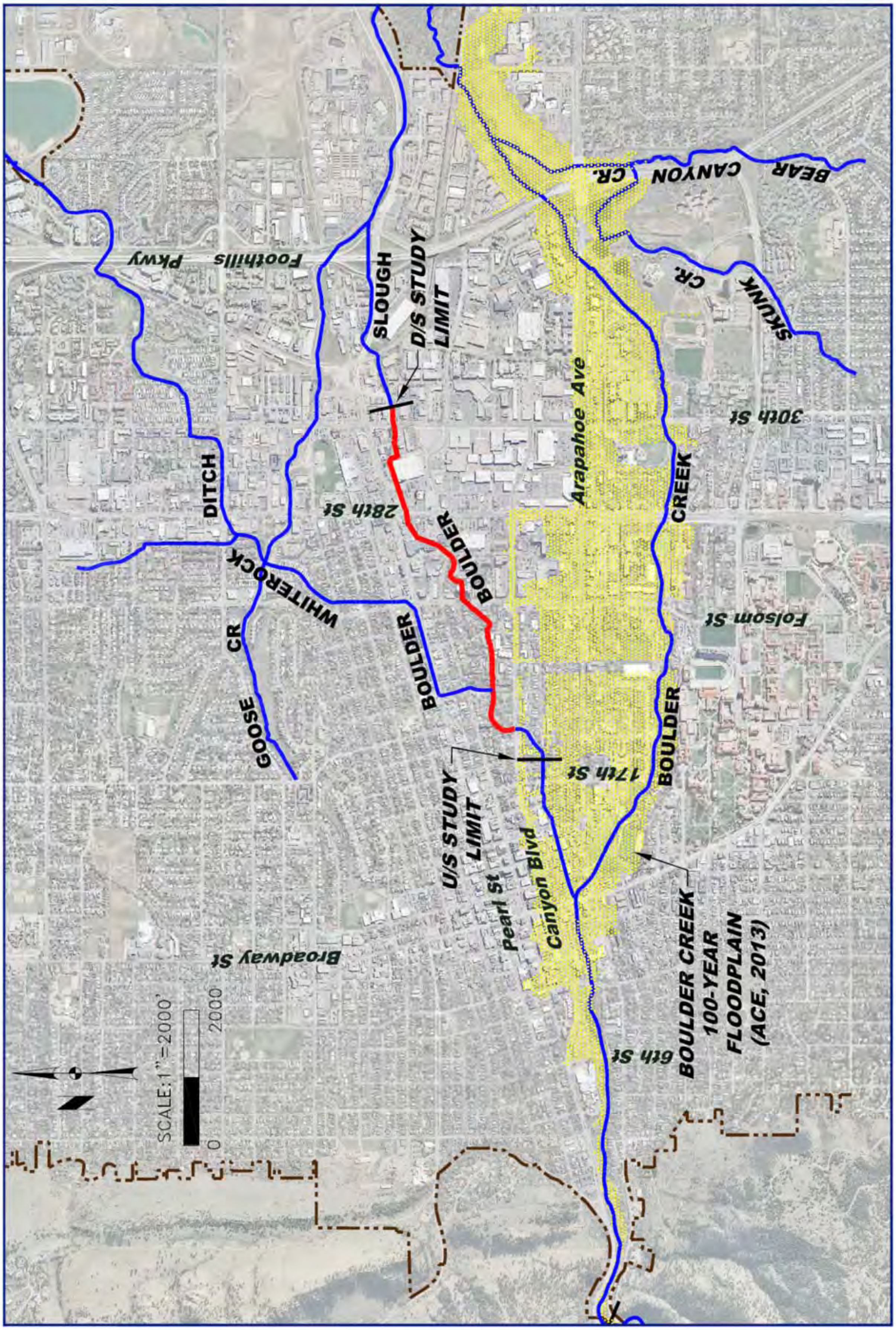

Figure 1.1 Vicinity Map for the Boulder Slough Floodplain Study.

hydrologic data. It is the intention of the City to adopt this new 100-year floodplain, conveyance zone (floodway), and high hazard zone mapping along Boulder Slough, and to attain adoption of the floodplain and floodway by FEMA.

1.4 Topographic Mapping

The primary base topography for Boulder Slough was provided by the City of Boulder and consists of a LiDAR based Digital Elevation Model (DEM) and 1-foot contours, produced in 2013. Base topography throughout the study reach was supplemented by field survey data collected at all bridge and culvert crossings, including channel cross sections associated with these structures. In addition, field survey data were collected to supplement the base topography in areas where the original topography on which this study was founded (1-foot contours from 2004) did not accurately reflect local topography, or in areas where it was necessary to more closely define specific topographic features.

Within the current Boulder Slough study reach, additional field survey data were collected by either King Surveyors or Boulder Land Consultants at the following locations:

(a) King Surveyors provided in-channel field survey data – points for all structures, as well as points and 1-foot contours in select areas along the main channel of Boulder Slough from 18th Street to 26th Street;

(b) King Surveyors surveyed pipe invert elevations for the closed conduit reach starting at 26th Street and extending downstream to east of 28th Street;

(c) King Surveyors provided field survey data (points and 1-foot contours) from the outlet of the closed conduit reach east of 28th Street to approximately 50 feet west of 30th Street; and

(d) Boulder Land Consultants provided as-built survey data (points and 1-foot contours) from the upstream face of the pedestrian bridge just west of 30th Street to the downstream study limit.

Certified drawings showing all of the field survey data collected by King Surveyors for this project are provided in Appendix A.1. Certified drawings showing all of the field survey data collected by Boulder Land Consultants for this project are provided in Appendix A.2. These data are also included in the AutoCAD drawing of the flood hazard work maps.

All topographic mapping and field survey data utilized for this study were based on the North American Vertical Datum of 1988 (NAVD88), and provided in the Colorado State Plane North coordinate system based on the North American Datum of 1983 (NAD83).

II. HYDROLOGY

The 1981 study of Boulder Slough by Muller Engineering Company defined local 100-year inflows to the Slough between Canyon Boulevard and 47th Street, essentially spanning the entire reach of Boulder Slough from the northern limit of the Boulder Creek 100-year floodplain to Goose Creek. In addition, the 1981 study defined the portion of the 100-year flow along Boulder Creek that would be intercepted by the Slough at 18th Street, a stream distance of approximately 600 feet upstream of Canyon Boulevard. A copy of the 1981 Muller report is provided in Appendix B of the current report.

Based on ACE's recent Boulder Creek modeling results, an evaluation was conducted to verify the Muller flows at the upstream end of Boulder Slough by estimating the 100-year discharge intercepted by Boulder Slough between Canyon Boulevard and 18th Street. The limiting conveyance capacity of the Slough through this reach was determined to be nearly equivalent to the 225 cfs cited in the Muller study at 18th Street.

The Muller study hydrologic calculations included several "diverted outflows" due to irrigation diversions and a street overflow. At the hydrologic design points for 22nd Street, Folsom Street, and 26th Street, Muller cited diverted outflows that would reduce the total flow by 50 cfs, 30 cfs, and 17 cfs, respectively. In order to maintain consistency across flood studies, whereby it is generally assumed that irrigation ditches and canals are running full when the peak discharge arrives, the City of Boulder requested that these otherwise diverted outflows be included in the hydraulic model. This assumption also provides the City with flexibility with respect to floodplain administration if changes are made to diversion structures or roads such that these outflows are eliminated in the future.

The Muller 1981 report documents a 100-year discharge in Boulder Slough at 18th Street of 225 cfs, as well as surface inflow values at Canyon Boulevard, 22nd Street, 24th Street (Folsom), 26th Street, 28th Street and 30th Street. Storm sewer inflows are also identified at 26th Street, 28th Street and 30th Street. Utilizing these discharges (taken from the Muller report provided in Appendix B) and assuming concurrent peaks of all inflows to the Slough, while ignoring the irrigation diversions and street overflow identified in the Muller report, the 100-year discharge profile (presented in Table 2.1) was derived for Boulder Slough.

Table 2.1 Boulder Slough 100-Year Discharge Profile.

Cross Section ID (Current Study)	100-Year (1% Annual Chance) Peak Discharge (cfs)	Location
9552	225	Upstream End of Study
8955	234	Canyon Blvd
7585	261	22nd Street
6595	267	Folsom
5691	325	26th Street
4710 (Closed Conduit Reach)	488	28th Street
3256	712	30th Street

III. HYDRAULIC MODELING AND FLOOD HAZARD MAPPING

Hydraulic modeling for the 1.3-mile study reach along Boulder Slough was conducted using HEC-RAS Version 4.1.0 for open channel reaches and StormCAD Version 5.5 for the closed conduit reach. Hydraulic modeling included analysis of the 100-year event, as well as analyses to support delineation of the conveyance zone (equivalent to the ½-foot rise floodway) and the high hazard zone. In addition to the main Boulder Slough channel corridor, a 0.4-mile long split flow path starting just upstream of 22nd Street was identified; this split flow largely reconnects with the main channel just west of 26th Street. Spills between the main channel and the 22nd Street Split Flow Path were modeled using the lateral weir functionality of HEC-RAS. The starting water surface elevation at the downstream end of Boulder Slough was based on normal depth using a computed bed slope at Cross Section 2850 of 0.0125 ft/ft.

3.1 Boulder Slough Roughness Coefficients and Photographic Documentation

A detailed field reconnaissance program for Boulder Slough was conducted by ACE staff as part of the current study. This effort included walking the entire reach of Boulder Slough, making visual observations of stream corridor conditions and all stream crossings. This field reconnaissance work was completed in addition to the detail field observations of all stream crossing structures collected by King Surveyors whose notes and sketches are provided in Appendix C.1.

Manning's *n* roughness coefficients for Boulder Slough were estimated using Cowen's Method and the "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains," [USGS, 1989]. Roughness coefficients for urbanized overbank areas within the floodplain were assigned based on generally accepted values presented in "Open-Channel Hydraulics," [Chow, 1959]. For the Boulder Slough channel, Manning's *n* values range from 0.015 to 0.150. For the few overbank areas within the Boulder Slough floodplain, Manning's *n* values range from 0.015 to 0.200. The concrete pipe system extending from 26th Street to east of 28th Street was modeled using a Manning's *n* value of 0.013. For the streets that serve as distributary flow paths, the curb-to-curb Manning's *n* value was defined as 0.025. Roughness coefficients for overbank areas along streets range from 0.025 to 0.050. Worksheets showing the Cowen's Method and USGS procedure calculations for defining Manning's *n* values along Boulder Slough are included in Appendix C.2.

Photographic documentation of the stream corridor was also completed as part of the field reconnaissance work. Photographs taken along Boulder Slough are provided in Appendix C.3. These photographs were taken in April 2009 just prior to leaves setting on the trees and shrubs, as well as the emergence of other vegetation along the channel. The effort to define roughness coefficients for the hydraulic model included adjustments to account for the vegetative cover that would be present during flood season.

3.2 Modeling Considerations for Boulder Slough Channel Crossings

A total of 23 bridges and/or culverts are included in the HEC-RAS model of the current study reach. Twelve of these bridges and culverts carry vehicular traffic, while eleven are fixed bridges that primarily serve pedestrians and bicycles. One of these pedestrian bridges (located approximately

300 feet downstream of Canyon Boulevard) is attached to a building which also spans the channel, essentially serving as a bridge. A second building (the Horizons West Building located directly east of Folsom) also spans Boulder Slough but does not function as a bridge. In this case, Boulder Slough passes through a large breezeway under the center of the building, with the breezeway completely encompassing the 100-year floodplain and also containing a pedestrian bridge over the Slough. Field survey notes for each of these bridges and/or culverts, prepared by King Surveyors as part of this study, are provided in Appendix C.1.

In addition to the bridges and culverts, the Slough is contained within an 1,800-foot pipe system extending from 26th Street to east of 28th Street. This system was modeled using StormCAD® Version 5.5. The StormCAD® model was developed using design plans for various sections of the pipe network, as well as surveyed pipe inverts at all located manholes. The 100-year tailwater elevation at the downstream end of the pipe system set based on the water surface elevation computed at the upstream end of the lower HEC-RAS reach (Cross Section 3827). An internal boundary condition was defined in HEC-RAS at Cross Section 5691, specifying the 100-year water surface elevation at the upstream end of the pipe system based on the results of the StormCAD® model. The StormCAD® model utilized to analyze this intermediate reach of Boulder Slough is included on the DVD provided with this report.

Based on historical hydraulic modeling precedent in the City of Boulder, the City of Boulder prescribed the use of the following assumptions and methodology to specify debris blockage for each bridge and culvert within the study reach. As directed by City Staff, bridges/culverts were assigned a percentage of debris obstruction of 15 percent or higher, except in a limited number of special cases where local conditions would support a lesser degree of obstruction. The relative degree of potential debris obstruction was assigned based on field reconnaissance efforts which identified debris obstruction categories for each bridge/culvert. Each bridge/culvert was placed in one of four debris obstruction potential categories based on the following: (a) debris production potential upstream of the subject structure; (b) bank erosion potential upstream of the structure; (c) shielding of the structure from debris due to the presence of nearby upstream structures; and (d) pier nose shape. The debris obstruction category defined for each bridge/culvert and the percentage of obstruction assigned to each structure are both identified in Table 3.1.

With the percentage of debris obstruction defined, the hydraulic model was modified as follows. The actual open area below the bridge deck or the open area of the culvert was determined, as shown in Table 3.1.

Since only two of the bridges within the current study reach features a pier, and obstructions were applied at only one of these two bridges, all debris obstructions at structures along the current study reach were applied at the bridge abutments, or at the sides of culverts. Full height flow obstructions were defined at the abutments to the width necessary to achieve the assigned percent obstruction of the actual open area below the bridge deck or the open area of the culvert. Collection of debris at bridges and culverts tends to occur primarily at the upstream end of the structures. This is particularly the case where a trash rack has been installed. Consequently, along the current study reach, debris obstructions were applied only at the upstream ends of the bridges/culverts.

Table 3.1 Debris Obstruction Data for Bridges and Culverts within the Boulder Slough Study Reach.

Location	Station	Total Open Area Below Bridge Low Chord or Within Culvert (sq. ft.)	Number of Piers	Debris Obstruction Category	Assumed Debris Obstruction (%)	Net Open Area Below Bridge Low Chord (sq. ft.)
19th Street Bridge	9259	30.1	0	3	20	24.1
Pedestrian Bridge (u/s of Canyon)	8989	62.1	0	4	25	46.6
Canyon Boulevard Bridge	8917	54.2	0	4	25	40.7
Pedestrian Bridge (d/s of Canyon)	8770	96.0	0	2	15	82.0
Pedestrian Bridge	8564	92.5	0	2	15	78.7
Building/Pedestrian Bridge	8505	114.8	0	2	15	97.6
22nd Street Culvert (3 - 3.75'Wx2.4'H HERCPs)	7551	22.3	n/a	4	33[a]	14.9
Pedestrian Bridge	7270	28.4	0	3	20	22.9
23rd Street Culvert (12'Wx3.55'H RCB)	7150	42.6	n/a	3	20	34.1
Private Bridge	7050	32.3	0	3	20	25.9
Pedestrian Bridge	7007	34.5	0	3	20	28.0
Pedestrian Bridge	6914	27.1	0	3	20	21.8
Folsom Bridge	6535	18.3	0	3	20	15.0
Pedestrian Bridge (Horizon West)	6321	55.1	0	2	15	46.7
Private Bridge (Horizon West)	6235	29.9	0	4	25	22.4
Private Bridge (Dairy)	5993	28.0	0	3	20	22.8
Pedestrian Bridge (Dairy)	5956	93.3	0	2	15	79.3
Closed Conduit System (26th Street to Target)	5690	varies	n/a	4	0[b]	varies
Culvert East of Target (2 - 8'Wx4'H RCBs)	3600	64	n/a	4	50[c]	32
Bike Path Bridge (west of 30th Street)	3265	80.0	1	4	50[d]	40.0
30th Street Bridge	3200	478.0	2	0	0	478.0
Pedestrian Bridge	3050	136.1	0	0	0	136.1
Private Bridge	2966	165.9	0	0	0	165.9
Private Bridge	2914	129.4	0	0	0	129.4

[a] Normal value of 25% increased to 33%; one of three elliptical pipes obstructed.

[b] Normal value of 25% increased to 50% due to trash rack. However, the trash rack obstructed at 50% still has a larger open area than the actual closed conduit system. Therefore, no obstruction assumed for the closed conduit system.

[c] Normal value of 25% increased to 50% due to confined 90-degree bend at upstream end of culvert.

[d] Normal value of 25% increased to 50% due to trash rack.

In addition to the debris obstruction parameters applied to each bridge/culvert based on the information provided in the table, all handrails and guardrails associated with each structure were assumed to be completely obstructed by debris.

Standard bridge contraction and expansion coefficients of 0.3 and 0.5, respectively, were used at all stream crossings, with only two exceptions. Contraction and expansion coefficients of 0.6 and 0.8 were used for the elliptical culverts at 22nd Street, and for the twin 8'Wx4'H box culvert east of Target. The relatively small culverts at 22nd Street and the confined 90-degree bend upstream of the culverts east of Target indicated the need for the higher contraction and expansion coefficients. The size of the culvert at 23rd Street allows that structure to function similar to a bridge, thereby allowing for the lower contraction and expansion coefficients. General contraction and expansion coefficients of 0.1 and 0.3 were used elsewhere in the hydraulic model, except when two or more bridges were situated in close succession (wherein values of 0.3 and 0.5 were used for the intervening one or two cross sections).

3.3 Modeling Considerations for 30th Street Improvements

Subsequent to ACE's field reconnaissance efforts on Boulder Slough in April 2009, The City of Boulder made substantial improvements at the 30th Street crossing of the Slough. The 30th Street Bridge was enlarged substantially, and two trail crossings of the Slough were constructed, one each upstream and downstream of 30th Street. Photographs of these improvements taken by ACE staff in April 2012 are included in Appendix D. As-built survey data of these improvements were collected and compiled by Boulder Land Consultants; these data are part of the field survey data included previously in Appendix A.

Subsequent evaluation of these improvements identified the need to reduce the obstruction represented by the concrete wall along the west side of the upstream trail crossing; a portion of this wall serves as the headwall for the small bridge which carries Boulder Slough flows under the upstream trail crossing. Based on design parameters identified by ACE, a design was prepared by others to modify this wall and the railings attached to it. This modification of the wall and railings has subsequently been completed, and as-built drawings are included in Appendix D.

3.4 Boulder Slough Floodplain Modeling

Due to the break in surface conveyance of Boulder Slough flows by the closed conduit system between 26th Street and the Target store east of 28th Street, the geometry used to model the 100-year event along Boulder Slough is defined in two plans within the HEC-RAS model, one each representing the reach east and west of the closed conduit system. Three lateral weirs are utilized to determine potential flow splits from the Slough through the current study reach. A fourth lateral weir is included in the model, but this weir does not functionally transfer flow.

The first (upstream-most) lateral weir, located just east of 19th Street, is actually a set of three continuous weirs which allows flows to spill from the right (southeast) bank of the Slough to the Goss Alley Split Flow Path (SFP). During the 100-year event, a total of 14 cfs would spill to the Goss Alley SFP at this location. Due to the small size of the split, which does not require definition of a conveyance zone along the Goss Alley SFP, and the possibility of eliminating the split entirely with future improvements; the City of Boulder requested the conservative approach of mapping the Goss Alley SFP with the anticipated 14 cfs spill, while still leaving the full 225 cfs in the main channel of Boulder Slough.

The second lateral weir is located directly west of 22nd Street is actually a set of three continuous weirs which allow flows to spill from the left (north) bank of the Slough to the 22nd Street Split Flow Path (SFP). During the 100-year event, a total of 181 cfs would spill to the 22nd Street SFP at this location, leaving approximately 80 cfs in the Boulder Slough channel. Flows in the 22nd Street SPF travel northeast, both overland and along several streets, eventually ending up at the intersection of Walnut Street and 26th Street.

A third lateral weir is located between 22nd and 23rd Streets at a location where flows along Boulder Slough and the 22nd Street SPF would commingle. However, it was determined that less than 1 cfs would transfer between the two flow paths at this location and this lateral weir was disabled to improve the model's stability.

A fourth lateral weir is located on the east side of Folsom, at the intersection with South Street, where 80 cfs would spill back into Boulder Slough from the 22nd Street SFP, leaving 101 cfs in the 22nd Street SFP traveling north on Folsom, then east along Walnut Street.

A fifth and final lateral weir is located between Boulder Slough and Walnut Street at the north entrance to The Dairy Center for the Arts. At this location, 12 cfs would spill from Boulder Slough to the 22nd Street SPF along Walnut Street, resulting in a total street flow of 113 cfs. It appears that most of this flow would not likely rejoin Boulder Slough at 26th Street, but rather would divide between continuing east on Walnut Street and turning south on 26th Street. It appears that a significant portion of this flow would likely rejoin the Slough east of 28th Street. For modeling purposes, it was conservatively assumed that all flows recombine at 26th Street and that the entire 488 cfs would be conveyed through the closed conduit system.

While flows could split from Boulder Slough at the Boulder & Whiterock Ditch, consistent with typical floodplain modeling practice, it was assumed that the Boulder & Whiterock Ditch would be full at the time of the 100-year flood peak and flows are not diverted from the Slough at that location.

Flow obstructions are defined at appropriate locations along all cross sections that intersect buildings. Ineffective flows are utilized to represent boundaries between active flow corridors and flooded areas that would not convey flows to a significant degree due to their location in flow shadows of roadway embankments/bridge abutments, buildings, high ground, or other physical features. During the course of this study direction was provided by FEMA review staff dictating that, although some lateral weirs along Boulder Slough are obstructed by existing buildings, lateral weirs are to be left unobstructed in order to represent a bare earth condition. Consequently, no obstructions are included in the definition of lateral weirs in the Boulder Slough hydraulic model.

Cross sections were defined for all events using bare earth topography from the sources identified previously in Section 1.4. HEC-RAS Version 4.1 was used to analyze the 100-year event in the subcritical flow regime mode. The HEC-RAS floodplain model is provided on the DVD included with this report. A graphical water surface profile for the 100-year has been prepared for Boulder Slough in typical Flood Insurance Study format; these profile sheets are included in Appendix E.

3.5 Boulder Slough Conveyance Zone Modeling

Hydraulic modeling was conducted (using the 100-year floodplain model as a basis) to define the City of Boulder conveyance zone, a flood hazard designation equivalent to a ½-foot rise floodway. In an effort to avoid computing differing discharges for split flow reaches in the unencroached and encroached analyses, the floodway analysis was conducted using a modified version of the 100-year floodplain model wherein discharges along all flow paths were hardwired into the floodway model and all lateral weirs were disabled. However, these discharges were based on the floodplain modeling results after computation of the lateral spills.

The HEC-RAS function that determines floodway encroachments based on equal conveyance change was utilized to define the conveyance zone. Adjustments were made to the encroachments generated by HEC-RAS to ensure that the ½-foot rise criterion was met at all locations, and to optimize the floodway where possible. In addition, at the request of the City of Boulder, adjustments were made to the floodway where possible in an effort to contain the floodway to public right-of-way, thereby minimizing impacts to private property. Due to the significant discharge carried along the 22nd Street SFP, relative to the total flow along Boulder Slough, it was necessary to define a conveyance zone along the 22nd Street SFP. It was not necessary to define a conveyance zone along the Goss Alley SFP, as the spill was small enough to be contained within the Boulder Slough main channel without exceeding the ½-foot rise criterion.

The Boulder Slough HEC-RAS conveyance zone analysis is included in the floodplain model as two additional plans, one each upstream and downstream of the closed conduit system; the HEC-RAS model is provided on the DVD included with this report. Results of the Boulder Slough conveyance zone analysis are summarized in the Floodway Data Tables, produced in FIS format, included in Appendix F.

3.6 Boulder Slough High Hazard Zone Analysis

In support of the high hazard zone determination for Boulder Slough, the 100-year floodplain model was utilized to determine the velocity distribution for each cross section along Boulder Slough and the 22nd Street SFP. Working with the limitation in HEC-RAS of 45 slices per cross section, 21 slices were specified within the channel banks, while 12 slices were requested for each of the left and right overbanks. The HEC-RAS High Hazard Zone Tool developed by Anderson Consulting Engineers (ACE) was utilized to evaluate the results of the velocity distribution analysis in order to define the areas within each cross section where the product of velocity and flow depth equals or exceeds 4 ft^2/s. The results generated by the ACE High Hazard Tool are provided in the spreadsheets included on the DVD enclosed with this report.

The high hazard zone boundaries were delineated based on the results of the ACE High Hazard Zone Tool. Adjustments to these boundaries were made in a number of locations to: (a) match either the adjacent 100-year floodplain boundary or ineffective flow boundary; (b) encompass ponded areas; (c) encompass areas where the flow depth equals or exceeds 4 feet; and (d) provide generally smooth transitions where topography and site conditions allow. Finally, one area that could have been designated as high hazard zone is not included on the flood hazard map. This would have been a small, isolated area located on the 22nd Street SFP at Cross Section 1583. Finally, for any building not entirely surrounded by the high hazard zone, in accordance with directions provided by City Staff during the recent Boulder Creek Floodplain Study, the high hazard zone boundary was moved off of the face of the building a distance of one-half foot.

3.7 Boulder Slough Flood Hazard Mapping

Flood hazard work maps for Boulder Slough were prepared based on the floodplain and conveyance zone modeling, as well as the high hazard zone analysis, conducted for the current study. These work maps show boundaries for the 100-year floodplain, the conveyance zone (½-foot rise floodway), and high hazard zone. Selected base flood elevations are also shown, along with cross sections used to define geometry for the hydraulic model. Hard copy flood hazard work maps are provided in Appendix G. The AutoCAD® file containing the flood hazard work maps, including all lateral weir line work and other background data, such as field survey point data and the City of Boulder building footprints, is included on the enclosed DVD.

At the upstream end of the current study reach, the Boulder Slough 100-year floodplain abuts the adjacent 100-year floodplain for Boulder Creek. At the downstream end of the current study reach, the Boulder Slough 100-year floodplain simply ends at the downstream-most cross section in the current hydraulic model. FEMA's effective floodplain mapping at the downstream end of the current study reach shows only an encompassing Shaded Zone X. (An annotated copy of the effective FIRM panel that covers the Boulder Slough study reach is provided at the end of Appendix G.) This is consistent with the recent Boulder Creek 500-year floodplain mapping prepared by ACE which encompasses the entire Boulder Slough study area.

Although the entire Boulder Slough study area is contained within the Boulder Creek 500-year floodplain, three areas of Shaded Zone X are shown on the enclosed flood hazard work maps. These areas represent shallow flooding (generally less than 1-foot deep) during the 100-year event, where the hydraulic model does not indicate flooding. However, upstream overbank flows would likely need to pass through these areas in order to rejoin the 100-year floodplain at a downstream location.

Finally, as discussed previously in Section 3.4, at the downstream end of the 22nd Street SFP (on Walnut Street at 26th Street), 113 cfs remains in Walnut Street. This flow does not appear to rejoin flows along Boulder Slough at this location, but rather appears to divide between continuing east on Walnut Street and turning south on 26th Street. With the dispersal of this street flow as it travels both east and south, it becomes a nuisance flooding issue rather than a riverine flooding situation, with flooding depths generally less than 1 foot. Consequently, the areas impacted by this street flow would appropriately be designated as Shaded Zone X flood hazard zones. Since the entire Boulder Slough study area is contained with the Boulder Creek 500-year floodplain, the areas where this street flow would travel prior to rejoining Boulder Slough east of 28th Street are already contained within a Shaded Zone X flood hazard zone. Due to the considerable extent of the Boulder Creek 500-year floodplain, the limits of this Shaded Zone X area are not duplicated on the enclosed flood hazard work maps for Boulder Slough.

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