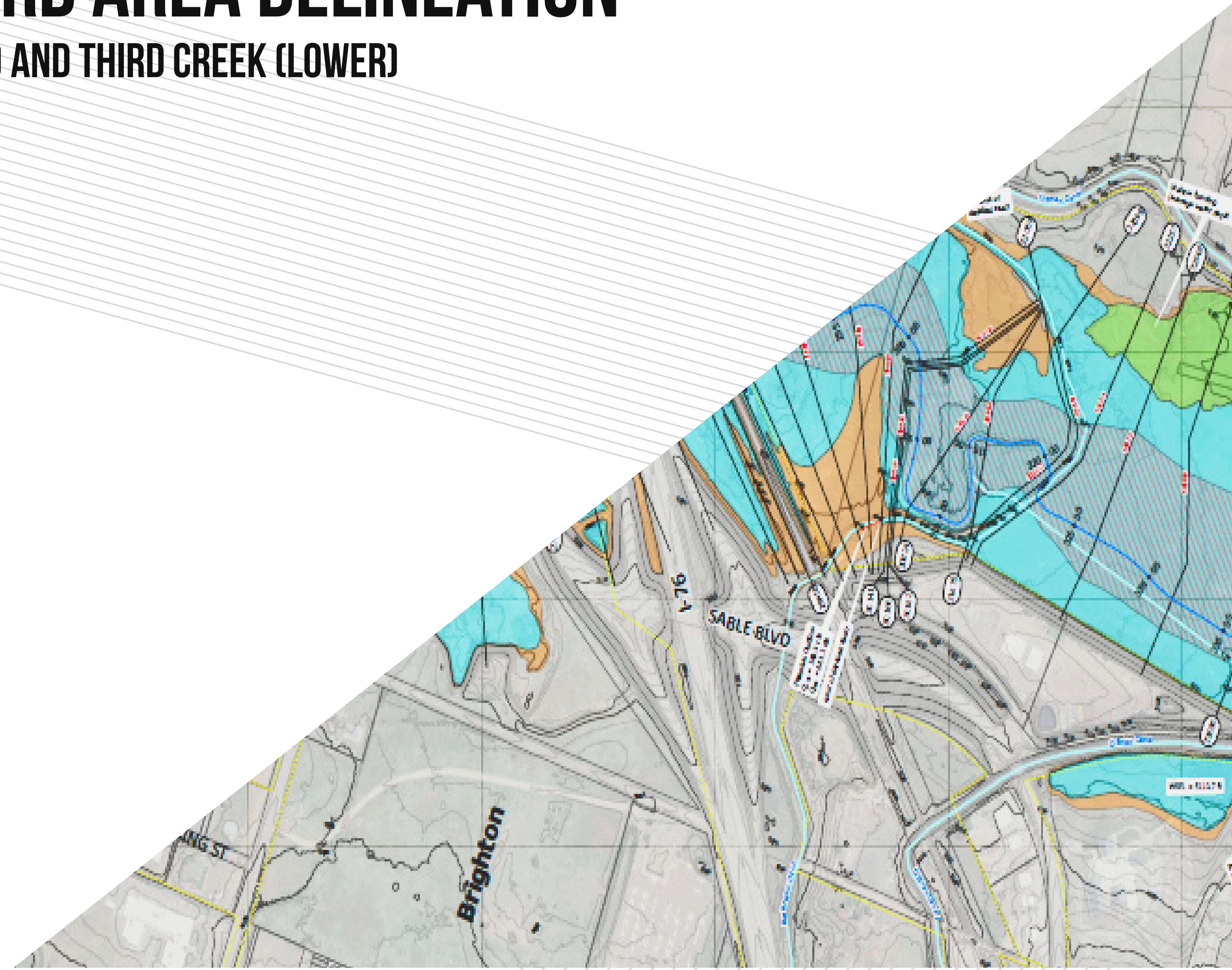
FLOOD HAZARD AREA DELINEATION

SECOND CREEK (LOWER) AND THIRD CREEK (LOWER)



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RESPEC

September 2022

Ms. Teresa Patterson
Watershed Manager
Mile High Flood District
2480 West 26th Avenue, Suite 156-B
Denver, CO 80211

Subject: Lower Second Creek and Lower Third Creek
Flood Hazard Area Delineation
MHFD Agreement No. 16-10.08

Dear Ms. Patterson:

RESPEC Consulting & Services is pleased to submit this report titled *Lower Second Creek and Lower Third Creek Flood Hazard Area Delineation*, dated May 24, 2022. We would like to acknowledge the help and support in the preparation of this report that was furnished by Unincorporated Adams County, the City of Brighton, and the City of Commerce City.

Enclosed is the Digital Flood Hazard Area Delineation (DFHAD) Report for the Second Creek Drainageway downstream of the Denver International Airport and the Third Creek Drainageway downstream of E 132nd Ave. This report documents the DFHAD study process from initiation through completion of the final floodplain and floodway delineations. A summary of the project history, description of the study area, field inventory of hydraulic structures, summary of hydrologic and hydraulic analyses, HEC-RAS water surface modeling results for the 10-, 50-, 100-, and 500-year storm events, and determination of the 0.5-foot rise floodways are provided in this report.

The floodplain and floodway information provided herein should assist the Mile High Flood District and other project sponsors in administration of new and existing development in the areas prone to flooding.

Thank you for the opportunity to complete this phase of the project.

Best Regards,
RESPEC Consulting & Services

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LIST OF ABBREVIATIONS

ALP	Airport Layout Plan
BNSF	Burlington Northern Santa Fe Railroad
CDOT	Colorado Department of Transportation
CFS	Cubic Feet per Second
CUHP	Colorado Urban Hydrograph Procedure
DEM	Digital Elevation Model
DIA	Denver International Airport
DFA	Direct Flow Area
DFHAD	Digital Flood Hazard Area Delineation
DP	Design Point
DRF	Depth Reduction Factor
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIS	Geographic Information System
MDP	Major Drainageway Plan
MHFD	Mile High Flood District
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NAIP	National Agriculture Imagery Program
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OSP	Outfall Systems Plan
SWMM	Stormwater Management Model
UPR	Union Pacific Railroad
USDA	United States Department of Agriculture
USDCM	Urban Storm Drainage Criteria Manual
USGS	United States Geological Survey
WSS	Web Soil Survey

1 INTRODUCTION

1.1 AUTHORIZATION

On November 8, 2016, the Mile High Flood District (MHFD) (then known as the Urban Drainage and Flood Control District) contracted with RESPEC Consulting & Services (RESPEC) for the provision of engineering services for a Major Drainageway Planning (MDP) and Digital Flood Hazard Area Delineation (DFHAD) Study for the Second Creek watershed (Agreement No. 16-10.08). The study is co-sponsored by MHFD, Unincorporated Adams County (Adams County), the City of Brighton (Brighton), and the City of Commerce City (Commerce City) (Project Sponsors).

Lower Third Creek was added to the scope in February 2019 to address combined flows from Second and Third Creeks.

1.2 PURPOSE AND SCOPE

The purpose of this Flood Hazard Area Delineation (FHAD) is to provide updated hydraulic information for the Second Creek watershed using the updated hydrology from the MDP. The FHAD encompasses Lower Second Creek (downstream of Denver International Airport (DIA)) and Lower Third Creek (downstream of E 132nd Ave). The upstream study limits for Second Creek is at its intersection with DIA, approximately 1700 ft to the west of E-470 and 4000 ft north of Pena Blvd. Its downstream study limit is at its confluence with the South Platte River. The study limits begin upstream for Third Creek at E 132nd Ave and ends at its confluence with the South Platte River.

The scope of this FHAD study is as follows:

1. Gather and assemble information on the existing drainage system including hydraulic structures (bridges and culverts), channel characteristics, and topographic information.
2. Define the water surface profiles for the 10-, 50-, 100-, and 500-year flood events.
3. Define the flood boundaries for the 100- and 500-year flood events and the 0.5 ft floodway.
4. Prepare flood maps and flood profile drawings of Second Creek and Third Creek showing the limits of the 0.5 ft floodway, 100-year and 500-year floodplains, and the 10-year, 50-year, 100-year, and 500-year flood profiles.
5. Document the study results in the FHAD report.

The FHAD project scope was amended on February 27, 2019, by agreement No. 16-10.08A. The amendment increased the size of the study and added additional tasks as follows:

- The addition of Third Creek to the HEC-RAS model where flooding sources from Second and Third Creeks merge.

This amendment was deemed necessary because the Second Creek and Third Creek floodplains comingle between and including the Fulton Ditch and US 85. This comingling necessitated studying the lower portions of both creeks together rather than as individual reaches that do not affect one another. Third Creek downstream of E 132nd Ave was therefore added to the HEC-RAS model. The models were then amended to reflect their comingling and the addition of flow from Second Creek to Third Creek at the Fulton Ditch and US 85. This increased the 100-year flow by 550 cfs and 3250 cfs respectively.

Because of the complexity of combining Second and Third Creeks, additional reviews and meetings were necessitated, as well as time. This engendered two additional amendments to continue the project: No. 16-10.08B (December 6, 2020) and No. 16-10.08C (November 4, 2021).

1.3 PLANNING PROCESS

A kickoff meeting and 22 additional progress meetings were held for this study. These meetings included major Project Sponsors and were held on December 7, 2016, March 6, 2017, August 30, 2017, October 5, 2017, October 19, 2017, December 6, 2017, April 26, 2018, June 25, 2018, July 2, 2018, July 26, 2018, December 10, 2018, January 10, 2019, February 5, 2019, March 14, 2019, April 30, 2020, June 1, 2020, June 8, 2021, June 16, 2021, August 17, 2021, October 18, 2021, April 11, 2022, and May 3, 2022.

A public meeting was held to on May 19, 2021. Because of the COVID 19 pandemic, the meeting was held virtually from 7:00 – 8:00 pm. The purpose of the meeting was to present an overview of master planning, present an overview of the National Flood Insurance Program, discuss the Second Creek FHAD, talk about next steps, and answer questions that may have arisen from the audience.

Project Sponsor representatives involved with this study are listed in Section 1.6 – Acknowledgments. Meeting minutes , memos, and review comments and responses are included in Appendix A – Project Correspondence.

1.4 MAPPING AND SURVEYS

Color aerial photography provided by Esri served as background/base mapping for the study maps. The topography for the watershed was developed from the post-2013 flood digital elevation model (DEM) created by the Federal Emergency Management Agency (FEMA) October 16, 2013. FEMA, the United States Geological Survey (USGS), and the Denver Regional Council of Governments (DRCOG) partnered to create LiDAR data after the 2013 floods. The DEM was derived from this data and was obtained from the USGS for this project. The DEM and the contours used in this project were revised four times:

1. Tower Rd from E 80th Ave to 103rd Ave. The road was widened as part of a Colorado Department of Transportation (CDOT) project. The updated surface information was gleaned from a LOMR (case No. 15-08-1339R).
2. Buffalo Highlands. A bridge was installed at the E 96th Ave crossing of Second Creek, the channel was improved at the crossing, and two water quality ponds were constructed. The updated surface information was gleaned from a LOMR (case No. 18-08-0619P).
3. An additional survey in Second Creek near the Buffalo Highlands area provided by MHFD August 19, 2021.
4. An additional survey in Third Creek downstream of Brighton Rd near old gravel mines, provided by MHFD March 18, 2021.

Contours were developed from the DEM and the above three sources at 1-ft intervals. All mapping is in the Colorado State Plane North Zone projection, horizontal North American Datum of 1983 (NAD83) and North American Vertical Datum of 1988 (NAVD88). Ground survey was performed for 28 crossing structures for Second Creek; five surveyed crossing structures from the Third Creek FHAD were used in this project. See Section 5 – References for a complete list of digital data obtained for this study.

1.5 DATA COLLECTION

Multiple MDP and FHAD studies have been completed for different portions of the Second Creek and Third Creek watersheds. Below is a list of former studies that were consulted as part of this study:

- The entire Second Creek watershed was originally studied in the report titled *Second and Third Creek Flood Hazard Area Delineation,* prepared by Gingery Associates Inc., dated February 1976. The effective FEMA Flood Insurance Study (FIS) report utilizes peak flow values presented in the 1976 FHAD. Specifically, the 1976 FHAD was the basis for the FIS discharges for the downstream section of Second Creek between Tower Rd and the South Platte River.
- The entire watershed was restudied in the report titled *Second Creek and Direct Flow Area 0053 Outfall Planning Study,* prepared by Kiowa Engineering Corporation, dated May 1990.
- The portion of lower Second Creek between the South Platte River and the DIA boundary was restudied in the report titled *Second Creek (Downstream of DIA) and Direction Flow Area (DFA) 0053 Watersheds Outfall Systems Planning Study Update*, prepared by Kiowa Engineering Corporation, dated August 2004.
- Second Creek upstream of DIA was restudied in the report titled *Second Creek (Upstream of Denver International Airport) Flood Hazard Area Delineation and Major Drainageway Plan,* prepared by Olsson Associates and Matrix Design Group Inc., dated September 2011. The 2011 MDP/FHAD is the basis for FEMA effective discharges upstream of DIA.
- Second Creek between Tower Rd and 72nd Ave within DIA was restudied in the report titled *Denver International Airport Drainage Masterplan Baseline Hydrology Report*, prepared by RESPEC, dated August 2014.
- The entire Third Creek watershed was studied in the *Third Creek Flood Hazard Area Delineation*, dated November 2018. It was prepared by Matrix Design Group. The 2018 FHAD is the basis for the Third Creek hydrology used in this study.

In addition to the above MDP and FHAD studies, the following reports were also consulted when preparing this study:

- The report titled *Final Drainage Report for Tower Road Widening*, prepared by Huitt-Zollars Inc., dated May 2017, identifies the impacts of the proposed City of Commerce City road widening project. The proposed project consists of widening the existing two-lane road to a six-lane divided urban thoroughfare from the Denver/ City of Commerce City border to E 104th Ave.
  - As part of the above project, the *T-88 Bid Alternative System Drainage Report,* prepared by Huitt-Zollars Inc., dated May 2016, proposes roadway and drainage improvements that were under construction as of September 2017. These improvements diverted runoff that was once tributary to the neighboring Third Creek watershed to Second Creek via Gramma Gulch.
- Ballot measure 1A, approved in November 2015, ended restrictions that prohibited development at DIA unrelated to airport operation. In May 2016, the Colorado Department of Transportation (CDOT) released the *Colorado Aerotropolis Visioning Study* identifying a collaborative vision for a Colorado Aerotropolis and identifying 25,000 acres of planned developments near DIA.
- The *Porteos Master Drainage Report: Harvest Road and 56th Avenue,* dated June 20, 2012, and *Amendment Letter No. 1*, dated September 30, 2013, both prepared by Martin/ Martin Consulting Engineers, outlined the master drainage plan for the Porteos Property in the City of Aurora. The Porteos property was proposed to be developed as a mixture of commercial/retail zones, office/mixed-use zones and industrial zones.
- A large development called the Aurora Highlands was proposed at the upstream end of the watershed. The development proposed mixed uses, primarily single-family residential.

In addition to the above reports, data from several other sources was utilized during this study. Below is a brief list of the types of information collected. A complete list of references is provided in Section 5 – References.

- Digital mapping files
- Digital geographic information systems (GIS) and computer-aided design (CAD) files that include storm sewer, drainageways, streets, zoning, and land use

- Effective Flood Insurance Rate Map (FIRM) and FIS data from FEMA
- Planning study PDF files from the Project Sponsors
- Various maps provided by the Project Sponsors

1.6 ACKNOWLEDGEMENTS

RESPEC wishes to acknowledge the valuable contributions made by the following individuals in conducting this study:

Teresa Patterson	Mile High Flood District
Shea Thomas	Mile High Flood District
Terri Fead	Mile High Flood District
Hung-Teng Ho	Mile High Flood District
Melanie Poole	Mile High Flood District
Russell Nelson	Adams County
Scott Olsen	City of Brighton
Brent Soderlin	City of Commerce City
Chris Hodyl	City of Commerce City

The following individuals from RESPEC contributed to this study:

Alan Leak	Principal
Jennifer Winters	Project Manager
Mike Bannister	Project Engineer
Haley Heinemann	Staff Engineer
Jacob Brown	Staff Scientist
John Costello, PhD	Staff Engineer
Christopher Archuleta	Staff Engineer
Katie Bryant	Staff Engineer
Jon Orozco	Staff Scientist

Refer to Appendix A – Project Correspondence for more detailed information on meetings, attendance, and comment letters.

2 STUDY AREA

2.1 PROJECT AREA

2.1.1 Second Creek

The Second Creek watershed is 28.6 sq mi and is located within Adams and Denver Counties. Within these counties, Second Creek passes through Brighton, Commerce City, DIA, and Aurora, from downstream to upstream. The project area is located fully within the MHFD boundary and Second Creek has a reach code of 3500.

It must be noted that while the hydrology was evaluated for the whole watershed, the hydraulics was only evaluated for the portions of Second Creek that are downstream of DIA. Since the hydrology for Second Creek was evaluated for the whole watershed, whereas the hydraulics were only evaluated for the watershed downstream of the Commerce City/DIA border, discussions of Lower, Middle, and Upper basins differ from discussions of reaches. See Sections 2.3 and 3.1 for descriptions clarifying the differences between reach and basin names.

The watershed includes several small tributaries to Second Creek, most notably: Gramma Gulch, West Fork Second Creek, Possum Gully, and Gopher Gulch. The watershed narrows downstream of DIA, with few sizeable tributaries contributing flow downstream of the West Fork Second Creek tributary. The Second Creek watershed is approximately 16 miles long, with a width that ranges from 3.6 miles at its widest point to about 0.5 miles at its narrowest point. The watershed generally drains to the northwest with the lowest and highest watershed elevations of 4,980 ft and 5,658 ft, respectively. The average slope of the main channel is approximately 0.0049 ft/ft.

Second Creek is not well-defined downstream of Brighton Rd. For this FHAD, beginning at the South Platte River and moving upstream, Second Creek passes through an inactive gravel pit in Willow Bay Open Space in Brighton and enters Adams County as it passes under Brighton Rd. Second Creek briefly re-enters Brighton as it crosses US 85, E 136th Ave, and the Union Pacific Railroad (UPR), before exiting to Adams County and passing under E 132nd Ave, through Fulton Ditch, and under Tucson Street, E-470, and E 124th Ave. At Potomac St, Second Creek re-enters Brighton, passes through Commerce City at E 120th Ave and goes back into Brighton under Sable Blvd. Back in Adams County, the Creek passes under I-76 and the Burlington Northern Santa Fe (BNSF) Railroad. The Creek enters Commerce City and passes through the O'Brian Canal and under several roads, including E 112th Ave, Chambers Rd, E 104th Ave and E 96th Ave. Moving upstream the Creek meets the Gramma Gulch, Buckley Draw, and West Fork Second Creek tributaries before crossing Tower Rd. Second Creek then jumps in and out of the limits of DIA in the City of Denver near E 81st Ave, then stays in Denver to pass under E-470 and Pena Blvd. Further upstream are the Second Creek confluences with Runaway Run and Cocklebur Run in Denver and Possum Gully and Gopher Gulch in unincorporated Adams County. The Creek then enters Aurora and passes under E 64th Ave and E 56th Ave before reaching the upstream study limit near the intersection of E 38th Ave and Monaghan Rd, about 2 miles east of E-470. See Figure 4-2 for a map showing the crossing locations for Second Creek.

2.1.2 Third Creek

Third Creek was studied from its crossing of E 132nd Ave to its confluence with the South Platte River for this FHAD. The following description for the watershed, however, comes from the 2018 FHAD (from which the baseline hydrology, cross section information, and crossing information were gleaned):

> The Third Creek watershed is approximately 30.8 square miles… The study area includes areas within the City of Aurora, Adams County, City of Commerce City and City of Brighton… The study area is approximately 3.38 miles wide and 10.57 miles long in lower reach, and 1.37 miles long in upper reach (total watershed length is 18.64 miles long including the reach through DEN).
>
> Topography of the watershed is sloped from the high ground east of [DIA] to the northwest toward the South Platte River. The highest point has an elevation of 5494 feet above sea level. The lowest point is at the downstream outfall to the South Platte and has an elevation of 4974 feet. The entire watershed is relatively flat except for the highest reaches south of 96th Avenue and along the upper reaches of the contributing tributaries. Slopes along the main drainageway average 0.5 percent, while the upper tributary watershed slopes vary from 1 to 3 percent. Existing vegetation along the drainageway consists of native rangeland grasses with little woody vegetation…
>
> Soil information was obtained from the Natural Resources Conservation Service (NRCS) Soils Survey of Adams County, Colorado. The significance of soil type for hydrologic analysis is in the infiltration rate. Soils are classified into four hydrologic classifications; namely, hydrologic soil group (HSG) Types A, B, C, and D. Infiltration rates range from 5.0 inches per hour for Type A soils to 3.0 inches per hour for Type C and D soils. Soils in the study area are mainly Type B and C soils that can be characterized as loamy to clayey.
>
> The Third Creek channel has an irregular natural section upstream of the O'Brian Canal. Historically, nearly all flows have entered the canal with only irrigation returns being passed downstream. Due to this situation, the channel section downstream of the O'Brian is nearly nonexistent. Large flood flows overtop the O'Brian and travel downstream to the South Platte River via a very wide and shallow floodplain. Irrigation ditches downstream (Burlington Ditch, the Fulton Ditch, and the McCann Ditch) have also historically intercepted Third Creek flows and have contributed to the lack of a significant low flow channel in the lower reaches.

Third Creek is located fully within the MHFD boundary and has a reach code of 3300.

2.2 LAND USE

Existing land use in the upper extents of the Second Creek watershed is primarily undeveloped pasture and agricultural land. Numerous residential developments exist further downstream, primarily located between E 96th Ave and I-76 in Commerce City. These developments are principally located on the outer edges of parks and open space along Second Creek. There are pockets of commercial land use, mainly in the lower extents of the basin and along major arterial streets such as E 104th Ave and US 85. Only a handful of industrial sites exist, most of which are next to I-76 and US 85. Notable development since the 1976 FHAD includes DIA, Pena Blvd, and E-470. The reader is referred to the 2018 Third Creek FHAD for in-depth descriptions of land use in that watershed.

2.3 HYDRAULIC REACH DESCRIPTIONS

The Second Creek main stem has been divided into three hydraulic reaches: Upper, Lower 2, and Lower 1 (from upstream to downstream). The Third Creek main stem has been divided into three hydraulic reaches: Lower 3, Lower 2, and Lower 1 (from upstream to downstream). There are four split flows in the hydraulic model: E470 Culvert Split, Fulton Split, Highway 85 Split, and Potomac Split.

The reaches in Second and Third Creeks were discretized based on where split flows have their confluence with the main stems. The boundary between Second Creek Upper and Lower 2 is the confluence of the Potomac Split with the main stem. The boundary between Second Creek Lower 2 and Lower 1 is the confluence of the E470 Culvert Split with the main stem. The boundary of Third Creek Lower 3 and Lower 2 is the confluence of the Fulton Split with the main stem. The boundary of Third Creek Lower 2 and Lower 1 is the confluence of the Highway 85 Split with the main stem. See Figure 2-1 and Figure B-1 in Appendix B – Hydrologic Analysis for maps showing every reach that was studied in this FHAD. See Appendix C for how the flow splits were delineated and their peak flows developed.

The reaches described herein were discretized and named for hydraulic modeling and analysis. The hydrologic modeling and analysis were performed for the entire Second Creek watershed, engendering different reach discretization and names from the FHAD hydraulic analysis. This is further clarified in Section 3 Hydrologic Analysis.

2.3.1 Second Creek

Upper

Upper is the largest reach of the Second Creek FHAD. It extends from the boundary of DIA to the boundary of the City of Brighton that is approximately 800 ft south of E-470 and 1,900 ft north of E 124th Ave. It first flows to the west and crosses Tower Rd, after which it flows in a general northwestern direction. It passes by the DIA Tech Center in Second Creek Open Space. After crossing E 88th Ave it flows past the Buffalo Highlands development. It then crosses E 96th Ave and passes both Fronterra Village and Buckley Ranch, all the while remaining in Second Creek Open Space. After it crosses E 104th Ave it flows past Buffalo Mesa and Second Creek Village, eventually crossing Chambers Rd. It then traverses farmland until it intersects the O'Brian Canal. After this intersection Second Creek flows north and crosses the Burlington Ditch, Burlington Northern Santa Fe Railroad, I-76, and Sable Blvd, all the while flowing through past fields and farmland. After its crossing with E 120th Ave it flows north past farmland, west to cross Potomac St, north to cross E 124th Ave, and then northwest until it reaches the boundary of the City of Brighton. It passes farmland and a small portion of development in its downstream section. Upper traverses the City of Brighton, City of Commerce City, and unincorporated Adams County.

Second Creek Upper contains crossings at Tower Rd, E. 88th Ave, Second Creek Trail (#4), E 96th Ave, Second Creek Trail (#3), Second Creek Trail (#2), E 104th Ave, Second Creek Trail (#1), Chambers Rd, E 112th Ave, the O'Brian Canal, the Burlington Ditch, the BNSF Railroad, Dirt Road (surveyed structure number 13A), Highway 6, I-76, Sable Blvd, E 120th Ave, Potomac St, and E 124th Ave.

The 100-year floodplain overtops E 88th Ave, Chambers Rd, E 112th Ave, E 120th Ave, Potomac St, and E 124th Ave. It abuts seven houses in the southwest corner of the Buffalo Highlands development.

Lower 2

Lower 2 starts at the boundary of the City of Brighton, approximately 800 ft upstream of its crossing with E-470. It flows in a northwestern direction until its downstream limit approximately 800 ft downstream of the crossing. Much of the channel in Lower 2 is engineered, with a large drop structure at the upstream end. The land use within the vicinity of Lower 2 include farmland and a junkyard. Lower 2 traverses unincorporated Adams County.

Lower 2 contains a crossing for E-470.

Lower 1

Lower 1 extends from approximately 800 ft downstream of the first crossing of Second Creek with E-470 to its confluence with the South Platte River. Lower 1 traverses agricultural fields in a northwestern direction, crossing the Fulton Ditch. It crosses the Union Pacific Railroad and makes an abrupt turn to the northeast. It flows between the railroad and US 85 for approximately 1300 ft and then makes an abrupt turn to the west, after which it crosses US 85. It continues in a sinuous fashion with two large oxbows and crosses Brighton Rd. It flows past farmland in this location. It then flows past gravel ponds until its confluence with the South Platte River. Land use within Lower 1 include reclaimed gravel mining operations along the banks of the South Platte River, existing farmland, and pockets of industrial areas. Lower 1 traverses the City of Brighton and unincorporated Adams County.

Lower 1 contains crossings for Tucson St, dirt road (surveyed structure number 21), E 132nd Ave, dirt road (surveyed structure number 23), Union Pacific Railroad, E 136th Ave, Highway 85, dirt road (surveyed structure number 27), and Brighton Rd.

The 100-year floodplain overtops Tucson St, E 132nd ave, the Union Pacific Railroad, US 85, E 136th Ave, and Brighton Rd. The floodplain comingles with the Third Creek floodplain in the Lower 1 reach of Second Creek.

2.3.2 Third Creek

Lower 3

The upstream portion of Lower 3 is at its intersection with E 132nd Ave, which happens to be the boundary with the City of Brighton. It flows northwest through vegetated areas, small agricultural fields, and past small residential developments. It continues past agricultural land until it intersects the Fulton Ditch. Lower 3 traverses unincorporated Adams County.

Lower 3 contains a crossing for E 132nd Ave. The 100-year floodplain overtops E 132nd Ave.

Lower 2

After crossing the Fulton Ditch, Third Creek flows past agricultural fields in a northwesterly direction until it reaches the Union Pacific Railroad. After crossing the railroad, it takes a sharp turn to the northeast and flows straight for approximately 1,700 ft. It then takes another sharp turn to the west and crosses US 85. It then flows in a general northwesterly direction, passing agricultural fields and crossing E 144th Ave. Lower 2 ends downstream at Brighton Rd. Lower 2 mainly traverses unincorporated Adams County, except for when it is in the vicinity of US 85 and the Union Pacific Railroad (which is in the City of Brighton).

Lower 2 contains crossings for E 136th Ave, Highway 85, and E 144th Ave. The 100-year floodplain overtops E 136th Ave, the Union Pacific Railroad, US 85, and E 144th Ave.

Lower 1

After crossing Brighton Rd, Third Creek flows past reclaimed gravel ponds, gravel mines, and industry. The downstream limit is its confluence with the South Platte River. Lower 1 is almost completed contained within the City of Brighton, with the exception of approximately 450 ft at the upstream end of Lower 1.

At the time of this study, the Third Creek channel terminates at the confluence with the McCann Ditch. Future plans for Third Creek include bypassing the McCann Ditch and extending the stream channel through the Ken Mitchell Open Space to discharge into the South Platte River. Additionally, as of the publication of this study, the South Platte River floodplain is being re-studied by MHFD with the intent of revising the floodplain. Because of the uncertainty of both the future Third Creek channel location and the South Platte River floodplain, the decision was made to terminate the floodplain modeling for Lower Third Creek at the approximate boundary of the South Platte River floodplain (at the time of this study).

Lower 1 contains a crossing for Brighton Rd. The 100-year floodplain overtops Brighton Rd.

2.3.3 Flow Splits

The following text elaborates on the flow split alignments that were analyzed within this study. Additional flow splits were discovered and are discussed in more detail in Section 4.1.3 - Limits of Detailed Study.

E470 Culvert

The E470 Culvert Split is the result of the Second Creek floodplain extending to the west just upstream of E-470. The E470 Culvert Split starts approximately 700 ft upstream of E-470. It flows north and then turns sharply to the west to parallel E-470. It then has a sharp turn to the north and crosses E-470 via a culvert. It then has its confluence with Second Creek approximately 275 ft north of E-470. It is fully within unincorporated Adams County.

The E470 Culvert Split contains a crossing for E-470.

Fulton

The Fulton Split is a result of the Second Creek floodplain overtopping E 132nd Ave. The Fulton Split extends from its confluence with Third Creek to the intersection of the Fulton Ditch and E 132nd Ave, where it splits from Second Creek Lower 1. This split borders agricultural land and follows the path of the Fulton Ditch.

The Fulton Split contains no crossings. However, the 100-year floodplain in the Fulton Split overflows the berm of the Fulton Ditch and returns to the Second Creek floodplain.

Highway 85

The Highway 85 split is the result of overtopping US 85 from the Third Creek floodplain. The Second Creek and Third Creek floodplains merge in this location, engendering greater flows in Third Creek and overtopping of US 85. The Highway 85 Split extends from its confluence with Third Creek at Brighton Rd to its inception along US 85 between the channels of Second Creek (southwest) and Third Creek (northeast). This split borders light residential land in the downstream portions and agricultural land from its confinement at Brighton Rd to Hwy 85.

The Highway 85 Split contains no crossings. It flows over several dirt roads and through several agricultural fields.

Potomac

The Potomac Split is the result of overtopping E 124th Ave from the Second Creek floodplain. The Potomac Split extends from its confluence with Second Creek Lower 2 to near the intersection of Potomac St and E 124th Ave. This split occurs entirely within a field between the second crossing of E-470 and E 124th Ave. The channel is driven by backwater from the Potomac St crossing and is not well defined.

The Potomac Split contains no crossings. It passes through several agricultural fields.

2.4 FLOOD HISTORY

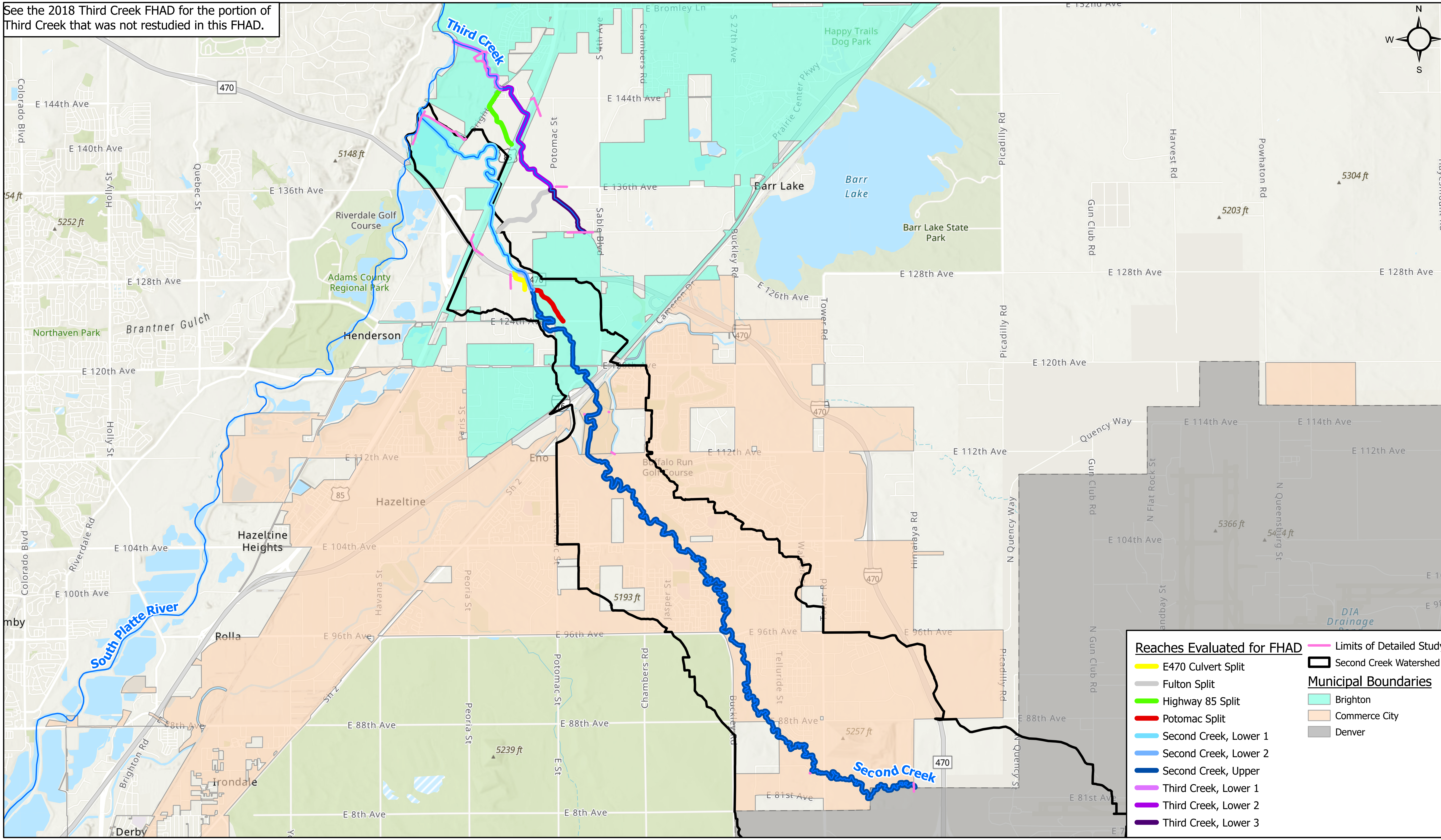
Little information is currently known about the flood history within the Second Creek watershed. There is not a stream gage along Second Creek; therefore, no recorded peak flow data exists. The upper and middle portions of the watershed have historically been agricultural land with little development and no anecdotal flood history is available. Additionally, the lower portion of the watershed currently does not experience flood flows due to the interception of Second Creek waters by the irrigation crossings of the O'Brian Canal, Burlington Ditch, and Fulton Ditch.

According to the 2018 Third Creek FHAD

> No stream gage information is available for the Third Creek watershed. The Third Creek watershed is currently only sparsely developed so rainfall typically infiltrates into the soil. Runoff that does flow in the Third Creek channel is usually intercepted by the major irrigation ditch crossings. Therefore, the Third Creek channel has not experienced many large stormwater runoff events in recent history. As the watershed develops further, future runoff will be significantly increase above the flood events experienced in the past if mitigation measures such as runoff reducing practices or regional detention are not provided.

2.5 ENVIRONMENTAL ASSESSMENT

There are multiple potential riparian zones and wetlands throughout Second Creek. The widths and areas of the zones vary throughout Second Creek. They generally have broader footprints in undeveloped, open spaces. They tend to be narrow in maintained parks and where development has constricted the floodplain, such as the Buffalo Mesa and Buffalo Highlands residential areas in the Second Creek watershed. They tend to occupy spaces between bends and are broader when the river is more sinuous. They are also larger in the vicinity of the O'Brian Canal and the Burlington Ditch. See Appendix E for maps showing potential wetlands and riparian zones for Second Creek. See the 2018 Third Creek FHAD for more detailed discussions on and maps about riparian zones and wetlands along Third Creek



RESPEC 720 S. Colorado Blvd. Suite 410 S Denver, CO 80246 (303) 757-3655 www.respec.com	Created by: J. Brown Date: 5/24/2022	Lower Second Creek and Lower Third Creek FHAD	Project Area	Figure 2-1

3 HYDROLOGIC ANALYSIS

3.1 OVERVIEW

The information contained within this section was taken from the 2022 Second Creek MDP. Due to the age and number of existing Second Creek hydrology models, the purpose of the hydrologic analysis was to update the baseline hydrology for the entire Second Creek watershed. A new hydrologic model was created by generating new hydrology for the lower end of the basin, updating hydrology from two previous studies for the middle and upper portions of the basin, and combining them into one model for the entire watershed.

The downstream portion of Third Creek that was analyzed for this FHAD comes the 2018 Third Creek FHAD. The peak flows were updated to reflect the comingling of floodplains that occurs at the Fulton Ditch and US 85. See Section 3.8 for a discussion on where these changes occur and the magnitude of the changes.

Since the hydrology was analyzed for the whole Second Creek watershed for the MDP, the basin terminology differs from the FHAD. When the hydrology is discussed, the Hydrologic Lower Basin refers to the reaches located between the confluence with the South Platte River and the confluence with the West Fork Second Creek tributary, which is approximately 7,300 stream ft downstream of the border with DIA, the Hydrologic Middle Basin refers to the reaches located between the confluence with the West Fork Second Creek tributary and the DIA/Aurora border, and the Hydrologic Upper Basin refers to reaches located upstream of the DIA/Aurora border.

The Second Creek baseline hydrology model created for this study was a combination of the following:

- **Hydrologic Lower Basin:** New hydrology was created for this study between the South Platte River and Tower Rd.
- **Hydrologic Middle Basin:** Hydrology was from the *Denver International Airport Drainage Masterplan Baseline Hydrology Report* (2014 DIA MP) prepared by RESPEC.
- **Hydrologic Upper Basin:** Hydrology was from the *Second Creek (Upstream of Denver International Airport) Flood Hazard Area Delineation and Major Drainageway Plan* (2011 MDP/FHAD) prepared by Olsson Associates and Matrix Design Group Inc.

This means, therefore, that the baseline hydrology for this FHAD is a combination of new hydrology downstream of Tower Rd (Hydrologic Lower Basin) and hydrology from previous studies (Hydrologic Middle and Upper Basins). Throughout this section (Section 3), references to the "Hydrologic Lower," "Hydrologic Middle," or "Hydrologic Upper" basins refer to the above locations; similarly, "previous studies" refers to the 2014 DIA MP and 2011 MDP/FHAD.

Once the three sets of hydrology data were combined into a single Colorado Urban Hydrograph Procedure (CUHP) 2005 (version 2.0.0) model and a single companion Environmental Protectional Agency Stormwater Management Model (EPA SWMM) (version 5.1, release 5.1.010) routing file, storm runoff hydrographs and routing for the entire Second Creek watershed were generated. Peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods were analyzed for the watershed. Three model scenarios were run for each return period: existing conditions, future conditions, and natural conditions. Descriptions of each scenario are as follows:

- **Existing Conditions:** Represents the existing peak flows within the watershed.
- **Future Conditions:** Represents the future peak flows given the level of anticipated development that will occur within the watershed.
- **Natural Conditions:** Represents the peak flows within the watershed prior to development for the purposes of guiding proposed detention and other master planning efforts. The model was developed by assuming no existing detention within the watershed and an overall basin imperviousness of 2%.
    - It should be noted that natural conditions peak flows and volumes were determined for this study for use when identifying project alternatives (as discussed in the MDP report). Natural conditions peak flows and volumes were not used for preparing floodplain analysis or to develop the accompanying Second Creek FHAD.

Detailed hydrologic input and output are described in the following sections. See Table B-1 in Appendix B – Hydrologic Analysis for the CUHP subcatchment characteristics used in this study.

3.2 DESIGN RAINFALL

The 1-hour and 6-hour rainfall depths for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 8 – Midwestern States, Point Precipitation-Frequency Estimates for the centroid of the project area. The incremental rainfall depths were input into CUHP to model each design storm. The Point Rainfall Depths are shown in Table 3-1 and the CUHP storm hyetographs are available in Table B-5 in Appendix B – Hydrologic Analysis.

Table 3-1. Point Rainfall Depth

Return Period	Rainfall Depth, 1-hour [in]	Rainfall Depth, 6-hour [in]
2-year	0.86	1.33
5-year	1.15	1.74
10-year	1.41	2.12
25-year	1.8	2.71
50-year	2.13	3.2
100-year	2.47	3.74
500-year	3.38	5.16

Per the criteria presented in MHFD's *Urban Storm Drainage Criteria Manual* (USDCM), large watersheds require a Depth Reduction Factor (DRF) adjustment to reduce point precipitation values to area-average precipitation values. Because the Second Creek watershed is approximately 28.6 sq mi, a rainfall area correction was applied to the appropriate nodes for each storm event. For minor storms (2-year, 5-year, 10-year), a DRF was applied to design points (DP) with a contributing drainage area greater than or equal to 2.0 sq mi. For major storms (25-year, 50-year, 100-year, and 500-year), a DRF was applied to design points with a contributing drainage area greater than or equal to 15 sq mi. Design point M1012, located at the Second Creek confluence with West Fork Second Creek, is the point at which the tributary drainage area first exceeds 15 sq mi.

The DRF for all events was determined by CUHP. Tables 3-2 and 3-3 list the correction factors applied to the minor and major storm events. A handful of design points along the main channel of Second Creek were corrected for an area slightly greater than or less than the node's contributing drainage area to minimize severe transitions in peak flow. These locations were chosen systematically to maintain conservative peak flow values. See Table B-6 in Appendix B – Hydrologic Analysis for the area correction applied to each node.

Table 3-2. Area Correction Factors, Minor Storms (2-Year, 5-Year, 10-Year)

Upstream Area (sq mi)	Correction Area Applied in CUHP Raingage	Correction Factor*
≤2	0	1.0000
4	4	1.0154
7	7	1.0337
8	8	1.0387
10	10	1.0496
11	11	1.0510
12	12	1.0525
14	14	1.0561
15	15	0.9259
20	20	0.9175
21	21	0.9179
22	22	0.9183
23	23	0.9187
24	24	0.9191
25	25	0.9196
26	26	0.9200
27	27	0.9205
28	28	0.9210

*Values reflect the average area correction factor applied over the CUHP-calculated storm hyetograph

Table 3-3. Area Correction Factors, Major Storms

(25-Year, 50-Year, 100-Year, 500-Year)

Upstream Area (sq mi)	Correction Area Applied in CUHP Raingage	Correction Factor*
<15	0	1.0000
15	15	0.9503
20	20	0.9274
21	21	0.9272
22	22	0.9270
23	23	0.9268
24	24	0.9266
25	25	0.9265
26	26	0.9263
27	27	0.9262
28	28	0.9261

*Values reflect the average area correction factor applied over the CUHP-calculated storm hyetograph

3.3 SUBCATCHMENT CHARACTERISTICS

3.3.1 Subcatchment Delineation

Subcatchment boundaries for Second Creek were delineated using 1-ft contours developed from the 2013 post-flood DEM, created by FEMA, dated October 16, 2013. Preliminary boundary delineation was performed in ArcMap (version 10.2) using the ArcHydro (version 10.2) and HEC-GeoHMS (version 10.1) toolsets. Final subcatchment delineation was performed by hand in ArcMap. Preliminary subcatchments were compared to the neighboring Third Creek and First Creek watersheds prior to finalization to ensure contiguous boundaries.

A total of 284 subcatchments were delineated in the Second Creek watershed. Of these subcatchments, 123 were imported from the 2014 DIA Master Plan (Hydrologic Middle Basin), 68 were imported from the 2011 MDP/FHAD (Hydrologic Upper Basin), and 93 were developed for the remainder of the watershed (Hydrologic Lower Basin). The 93 subcatchments original to this study were delineated utilizing subcatchments from the 1976 FHAD and 1990 master plans to the greatest extent practical. The subcatchments range in size from 1.32 to 197.2 acres with a median drainage area size of 63.4 acres.

Five subcatchments (308, 309, 310, 311, and 312) incorporate drainage area that was once tributary to Third Creek. These subcatchments were added as a function of the Commerce City Tower Road Widening Improvements project, which consisted of widening the existing two-lane road to a six-lane thoroughfare between the Commerce City boundary and E 104th Ave. In an effort to coordinate the Tower Rd construction and future T-88 basin improvements, the *T-88 Bid Alternative System Drainage Report* (May 2016) by Huitt-Zollars Inc. proposed drainage improvements that would divert runoff to Second Creek via Gramma Gulch that was once tributary to the existing E 100th Ave sump and eventually the T-88 outfall to Third Creek. While the Tower Rd improvements were still under construction, this study considers the flow diversion as existing per discussions with Project Sponsors. The additional contributing area to Second Creek from the Tower Rd improvements was approximately 0.67 sq mi (430 ac).

A total of 9 subcatchments exceed 130 ac in area. These subcatchments were all from the 2014 DIA Master Plan. Re-delineation of subcatchments from the 2014 DIA Master Plan and the 2011 MDP/FHAD were not made as part of this study.

The subcatchment identification, area, and locations are displayed on Figure B-2 – Interactive Hydrology Map in Appendix B – Hydrologic Analysis.

3.3.2 Watershed Imperviousness

Land use and zoning data was collected from Adams County, Aurora, Brighton, Commerce City, and DIA. Due to the extensive plans for future development in the Second Creek watershed, land use and corresponding imperviousness values were created for both existing conditions and anticipated future conditions. The following is a list of land use sources:

- 2011 MDP/FHAD (Existing land use only)
- 2014 DIA Master Plan (Existing land use only)
- United States Geological Survey (USGS) National Land Cover Database (NLCD) Impervious Surface (30 meter, 2011)
- National Agriculture Imagery Program (NAIP) aerial imagery (2012)
- GIS and PDF municipal land use and zoning plans:
    - Adams County *Future Land Use Map* (November 2012)
    - Aurora *2016 Zone Map* (March 2016)
    - Aurora *2015 E-470 / Northeast Plains Zoning Map* (February 2015)
    - Brighton *Comprehensive Plan Future Land Use Map* (April 2016)
    - Commerce City *Future Land Use Plan* (September 2010)

- Proposed land development master plans and drainage reports
- Discussions with the Project Sponsors

The above sources were utilized to develop the existing and future land use maps. The foundation of the Hydrologic Lower Basin existing land use is the USGS NLCD Imperviousness raster (2011), which was tested by visual inspection using aerial imagery. The final existing land use for the Hydrologic Lower Basin consists of USGS Impervious Surface with overrides for existing development since 2012, identified manually. Additionally, the NLCD was updated to reflect a minimum imperviousness of 2% and permanent water surfaces were changed to 100%. The final existing land use for the Hydrologic Middle and Upper Basins consists of existing land use from the previous studies (2014 DIA MP, 2011 MDP/FHAD; previous studies), updated to reflect existing development that has occurred since each study was completed. See Appendix B – Hydrologic Analysis, Table B-7 for a list of the modified subcatchment values.

The impervious land use was developed for the entire watershed and consists of the USGS NLCD impervious surface with the following data: future land use identified by municipal zoning plans and subdivision master drainage reports; existing development since the NLCD data was collected in 2011 and existing development since the completion of the previous studies (2014 DIA MP, 2011 MDP/FHAD). This study used new weighted values of 37% and 63% for the Hydrologic Middle and Upper Basins, versus 54% and 73% in the original studies. The overall weighted land use imperviousness for existing and future conditions was 10.6% and 44.3%, respectively. Locations of future development and assigned imperviousness values were reviewed and approved by the Project Sponsors. See Table B-7 in Appendix B – Hydrologic Analysis for the imperviousness values assigned to future land use data collected from municipal plans.

See Figure B-7 in Appendix B – Hydrologic Analysis for municipal land use maps provided by the Project Stakeholders. Major points of future land use assignments were as follows:

- Because the Colorado Aerotropolis was still in the beginning phases of planning, future land use for this study was identified through municipal future land use plans and subdivision master drainage reports (such as the Porteos property) provided by the Project Sponsors. While the future land use imperviousness for this study did not identify significant future build-out within the watershed, it should be noted that specific land use plans would be subjected to change as planning for the Aerotropolis continues.
- The Porteos property was proposed to be developed as a mixture of commercial/retail zones, office/mixed-use zones and industrial zones. As part of the hydrologic analysis for the *Porteos Master Drainage Report: Harvest Road and 56th Avenue*, dated June 20, 2012, prepared by Martin/ Martin Consulting Engineers, the future developed conditions for the entire Porteos property was assumed to be 85% impervious. This same value was assigned to the Porteos property for this study.
- A large development called the Aurora Highlands was proposed at the upstream end of the watershed. The development proposed mixed uses, primarily single-family residential. A 60% imperviousness value was assigned to the Aurora Highland property.

Tables 3-4 and 3-5 list the percent area by subcatchment for several ranges of existing and future imperviousness. Table values are based on total percent imperviousness for each subcatchment in the Second Creek watershed. See Figure B-2 – Interactive Hydrology Map in Appendix B – Hydrologic Analysis for the existing and future land use maps.

Table 3-4. Existing Land Use Imperviousness Values

Subcatchment Percent Imperviousness	Example Land Use Type	Area		Percent of Area
		[ac]	[sq mi]	
<10	Parks, Open Space	13806	21.57	75%
10-20	Rural Residential	1591	2.49	9%
20-30	Rural Residential	690	1.08	4%
30-40	Rural Residential	713	1.11	4%
40-50	Public Facilities/Schools	761	1.19	4%
50-60	Low Density Residential	370	0.58	2%
60-70	Med. Density Res./Business Office	102	0.16	1%
70-80	High Density Res./Commercial	132	0.21	1%
80-90	Retail/Roadways	0	0.00	0%
90-100	Industrial	127	0.20	1%

Table 3-5. Future Land Use Imperviousness Values

Subcatchment Percent Imperviousness	Example Land Use Type	Area		Percent of Area
		[ac]	[sq mi]	
<10	Parks, Open Space	2938	4.59	16%
10-20	Rural Residential	1947	3.04	11%
20-30	Rural Residential	1503	2.35	8%
30-40	Rural Residential	1661	2.60	9%
40-50	Public Facilities/Schools	1606	2.51	9%
50-60	Low Density Residential	1425	2.23	8%
60-70	Med. Density Res./Business Office	3083	4.82	17%
70-80	High Density Res./Commercial	2591	4.05	14%
80-90	Retail/Roadways	1410	2.20	8%
90-100	Industrial	127	0.20	1%

Plans for future land development were widespread throughout the basin. Major plans include the Denver real estate Airport Layout Plan (ALP), Porteos property development in Aurora, the Tower Road Widening project in Commerce City, and the CDOT Aerotropolis Study.

3.3.3 Soils Information

Soil information for the Hydrologic Lower Basin was collected from the USDA NRCS Web Soil Survey (WSS), dated September 22, 2016. Soils for the Hydrologic Middle and Upper Basins were not revised from the previous studies (2014 DIA MP and 2011 MDP/FHAD). The watershed shows significant trends in the hydrologic soils group. Type A soils are primarily found in the western portion of the study area along the edge of the South Platte River floodplain. Type B soils are concentrated in the Hydrologic Lower Basin, with only a few sections in the Hydrologic Middle and Upper Basins. Type C soils are found widespread throughout the watershed but are concentrated in the Hydrologic Middle and Upper Basins. Type D soils are the least common soil across the basin, often found paralleling the drainageways and tributaries throughout the watershed.

Horton infiltration properties for the different hydrologic soil types are listed in Table 3-6. These values are in accordance with MHFD criteria, as referenced in the Runoff Chapter of the USDCM. The distribution of the soil types can be seen in Figure B-2 – Interactive Hydrology Map in Appendix B – Hydrologic Analysis.

Table 3-6. Horton Infiltration Properties

NRCS Hydrologic Soil Group	Infiltration (inches per hour)		Decay Coefficient
	Initial	Final	
A	5.0	1.0	0.0007
B	4.5	0.6	0.0018
C	3.0	0.5	0.0018
D	3.0	0.5	0.0018

3.4 DETENTION

There are two regional stormwater detention ponds included in the baseline hydrologic model. Both ponds, M4018 and M6108, are original to the 2014 DIA MP and were not modified for this study. M4018 is a 12 ac-ft detention pond located along Barberry Run in the northeast corner of Gun Club Rd and E 79th Ave at DIA. M6018 is a 112 ac-ft detention pond located in the northeast corner of Tower Rd and E 72nd Ave in the High Point at DIA subdivision. Other local and temporary detention ponds are located throughout the watershed but were not included in the baseline hydrology per MHFD criteria. See Appendix B – Hydrologic Analysis for additional detention pond description, characteristics, and stage-storage-discharge curves.

3.5 HYDROGRAPH ROUTING

The drainage network in this watershed is generally comprised of subcatchments, design points, open channels, and storage units. The Stormwater Management Model (SWMM) Schematic in Figure B-2 in Appendix B – Hydrologic Analysis illustrates the drainage system elements. It shows where the subcatchments connect into the drainage system and the specific design points defined at these locations. In addition, the routing elements illustrate where the runoff is connected to the next downstream design points.

The routing elements within this model are open channels and conduits. Within EPA SWMM, the routing was defined according to channel shape, maximum depth, length, and roughness as estimated by contours, aerial photography, and site visits. There are 12 flow diversions in the SWMM model. Each diversion is triggered when the node overflows. The diverted flow continues to the same downstream node to which the divider is connected before diversion occurs.

A summarized input file and example output files from the EPA SWMM model are included in Table B-2 in Appendix B – Hydrologic Analysis, which includes the physical attributes assigned to each conveyance element used in the EPA SWMM model.

3.6 REVISIONS TO PREVIOUS STUDIES

Minor edits were made to the Hydrologic Middle Basin (2014 DIA MP) and Hydrologic Upper Basin (2011 MDP/FHAD) CUHP subcatchment parameters and EPA SWMM routing as part of their combination into this study. A discussion of the applicable changes are as follows:

- Updated the existing land use imperviousness to account for development that has occurred within the watershed since the 2011 MDP/FHAD and 2014 DIA MP studies were completed. All revisions resulted in an increase in existing imperviousness. See Table B-7 in Appendix B – Hydrologic Analysis for a list of the modified subcatchment values.
- Replaced all future land use imperviousness values to account for the most current proposed development within the watershed. See Section 3.3.2 – Watershed Imperviousness for further details.
- Re-ran subcatchment parameters through CUHP 2005 (version 2.0.0).
- Corrected an error in the maximum depth of SWMM link M6161.
- Either "M" or "U" was inserted before all SWMM node, link, storage, and subcatchment names to identify data obtained from the Hydrologic Middle Basin (2014 DIA MP) or Hydrologic Upper Basin (2011 MDP/FHAD) studies.

3.7 PREVIOUS STUDIES

As noted in Section 1.3 – Planning Process, portions of Second Creek have been analyzed in the following major drainageway studies:

- *Second and Third Creek Flood Hazard Area Delineation,* prepared by Gingery Associates Inc, dated February 1976.
- *Second Creek and Direct Flow Area 0053 Outfall Planning Study,* prepared by Kiowa Engineering Corporation, dated May 1990.
- *Second Creek (Downstream of DIA) and Direction Flow Area (DFA) 0053 Watersheds Outfall Systems Planning Study Update*, prepared by Kiowa Engineering Corporation, dated August 2004.
- *Second Creek (Upstream of Denver International Airport) Flood Hazard Area Delineation and Major Drainageway Plan,* prepared by Olsson Associates and Matrix Design Group Inc*,* dated September 2011.
- *Denver International Airport Drainage Masterplan Baseline Hydrology Report*, prepared by RESPEC Consulting & Services, dated August 2014.

Table 3-7 compares this study's 100-year existing and future peak flows (RESPEC 2017) to flows published in former studies.

The 1976 Second Creek FHAD had significantly lower peak discharges compared to this study. The FHAD reported 100-year peak flows that averaged about 3,000 cfs less than this study between Tower Rd and Tucson St. These differences are due in large part to the different modeling approaches and the different versions of CUHP used in that Study. Additionally, the point rainfall depths have been updated since the original 1976 FHAD. For example, the 100-year point rainfall depth used in the 1976 FHAD was 2.4 in for a 2-hr design storm, compared to this study's point rainfall of 2.96 in. The 1976 FHAD used a total of 6 subcatchments for the entire Second Creek watershed, as compared to the 284 used in this study. Downstream of Tucson St, the 1976 FHAD's 100-year peak flows were an average of 6,600 cfs less than the peak flows calculated by this study; at the South Platte Outfall (DP 1010) the 1976 FHAD's 100-year peak flow was 1,265 cfs versus 8,577 cfs determined in this study. In this reach, approximately 60% of the FHAD flood peak flow (about 4,000 cfs) was diverted north to Third Creek due to problem areas noted by the 1976 FHAD, which included floodplain obstructions at US 85, the UPR, and the Fulton Ditch.

At the time of the 1990 Outfall Systems Plan (OSP), E-470 and DIA were in the planning stages and average subcatchment sizes exceeded 130 ac. The 2004 OSP served as an update to the 1990 OSP, focusing on the area downstream of DIA, and was the most recent study for the Lower Basin. The 2004 OSP's 100-year, future conditions peak flows were all within 16% of those in this study, ranging from 0.5% to 16% lower. While the average subcatchment size s was less than 90 ac for both studie, the OSP used the Rational Method for subcatchments of 90 ac or less in urban areas and 50 ac or less in areas with less than 20% imperviousness. This study used the re-calibrated version of CUHP 2005 (version 2.0.0) for all subcatchments. Similarities between the two studies included that no existing detention was modeled in the existing and future hydrology and that the average percent imperviousness value used in the OSP was 49% compared to this study's projected value of 44.3%.

As previously discussed, the baseline hydrology model created for this study is a combination of new hydrology downstream of Tower Rd (Hydrologic Lower Basin) combined with hydrology from the 2014 DIA MP (Hydrologic Middle Basin) and the 2011 MDP/FHAD (Hydrologic Upper Basin). The future conditions peak flows in the 2014 DIA MP and 2011 MDP/FHAD were on average 14% and 19% greater than the corresponding flows in this study. Because only minor changes were made to the original models, the causes for differing peak flows are more easily identified. One of the most significant differences between the studies is the version of CUHP that was used. Both the 2014 DIA

MP and 2011 MDP/FHAD used versions of CUHP 2005 prior to re-calibration of the software by MHFD in 2016. The other major difference between the studies was the future land use imperviousness. This study used new weighted values of 37% and 63% for the Middle and Upper Basins, versus 54% and 73% in the original studies. Values in this study were determined using subdivision master drainage reports and municipal zoning plans. Locations of future development and assigned imperviousness values were reviewed and approved by the Project Sponsors.

3.8 RESULTS OF ANALYSIS

The 2-, 5-, 10-, 25-, 50- 100-, and 500-year peak flows and volumes are presented in Tables B-3 and B-4 in Appendix B – Hydrologic Analysis for the existing, future, and natural conditions. Existing and future conditions peak flow profiles are plotted in Figures B-3 and B-4. Hydrographs for the 100-year existing and future conditions are shown in Figures B-5 and B-6 for several points of interest along Second Creek.

As previously discussed, the Second Creek watershed narrows downstream of DIA from an approximate width of 3 mi wide to 1 mi and has few sizeable tributaries that contribute flow downstream of the West Fork Second Creek tributary. The shape of the resulting hydrograph is significantly impacted by the shape of the overall watershed. Because the watershed is relatively narrow at the downstream end, the runoff generated from the Lower Basin has left the watershed long before the upstream hydrograph (generated by the Hydrologic Middle and Upper Basins) reaches the South Platte River. The result is a discharge that peaks near the DIA border line with Commerce City and then gradually decreases across the rest of the study area (as shown in Figures B-3 and B-4 in Appendix B – Hydrologic Analysis).

The resulting future conditions peak flows are an average of 49% greater than the existing conditions peak flows. This increase is due to the extensive land development plans throughout the watershed, which resulted in a 34% increase in land use imperviousness values.

The resulting natural conditions peak flows reflect the smaller flows associated with pre-development watershed conditions (2% imperviousness and no regional detention). On average, the natural conditions peak flows were 7% less than existing conditions peak flows and 53% less than future conditions peak flows.

Several floodplain obstructions restrict flow in the Hydrologic Lower Basin. Specifically, crossings at US 85, the Union Pacific Railroad, and the Fulton Ditch divert flow away from the path of the main channel during major storms. During hydraulic analysis of the 100-year event, it was determined that 550 cfs leaves the Second Creek watershed and enters the Third Creek watershed along the Fulton Ditch (enters at Cross Section 313648); 3250 cfs leaves the Second Creek watershed and enters the Third Creek watershed upstream of US 85 and around the Union Pacific Railroad (enters at Cross Section 311502) .

Table 3-7. Comparison of 100-Year Peak Flows to Previous Studies

Design Point	Location	Jurisdiction	100-year Peak Flows (cfs)												
			Second Creek MDP/FHAD			DIA MP		Second Creek (U/S of DIA) MDP/FHAD		Second Creek (D/S of DIA) & DFA 0053 OSP		Second Creek & DFA 0053 OSP		Second and Third Creek FHAD[1]	08001CV001C[2]
			RESPEC			RESPEC		Olsson / Matrix		Kiowa		Kiowa		Gingery	Effective FIS
			2017			*2014*		*2011*		*2004*		*1990*		*1976*	*2017*
			Existing	Future	Natural	Existing	Future	Existing	Future	Existing	Future	Existing	Future	Future	Future
1010	Outfall to South Platte River	Brighton	4,481	8,559	4,078	n/a	n/a	n/a	n/a	3,981	8,154	4,241	8,128	1,265	1,265
1060	Brighton Rd	Brighton	4,466	8,532	4,074	n/a	n/a	n/a	n/a	3,981	8,149	--	--	1,265	1,265
1080	US Hwy 85	Brighton	4,479	8,649	4,096	n/a	n/a	n/a	n/a	4,121	8,469	4,471	8,327	2,660	2,660
1090	Fulton Ditch at E 132nd Ave	Adams County	4,480	8,673	4,101	n/a	n/a	n/a	n/a	4,147	8,531	--	--	2,980	2,980
1100	Tucson St	Adams County	4,505	8,704	4,134	n/a	n/a	n/a	n/a	--	--	--	--	6,200	6,200
1110	E-470 at 128th Ave	Adams County	4,506	8,710	4,135	n/a	n/a	n/a	n/a	4,167	8,563	--	--	--	--
1130	E 124th Ave	Brighton	4,506	8,732	4,140	n/a	n/a	n/a	n/a	4,217	8,659	--	--	6,200	6,200
1140	Potomac St	Brighton	4,507	8,744	4,142	n/a	n/a	n/a	n/a	4,218	8,665	--	--	--	--
1160	E 120th Ave	Brighton/Commerce City	4,549	8,801	4,188	n/a	n/a	n/a	n/a	4,237	8,681	4,471	8,374	6,100	6,100
1170	I-76	Brighton	4,549	8,803	4,190	n/a	n/a	n/a	n/a	4,246	8,694	--	--	6,000	6,000
1180	Burlington Northern Santa Fe (BNSF) RR	Adams County	4,544	8,799	4,190	n/a	n/a	n/a	n/a	4,249	8,696	--	--	6,000	6,000
1200	Burlington Ditch	Adams County	4,532	8,790	4,190	n/a	n/a	n/a	n/a	4,273	8,742	--	--	6,000	6,000
1220	O'brian Canal/ E 112th Ave	Commerce City	4,575	8,872	4,238	n/a	n/a	n/a	n/a	4,302	8,812	4,699	8,461	6,000	6,000
1250	Chambers Rd	Commerce City	4,598	8,980	4,282	n/a	n/a	n/a	n/a	4,337	8,868	--	--	5,800	5,800
1280	E 104th Ave	Commerce City	4,624	9,037	4,328	n/a	n/a	n/a	n/a	4,356	8,910	--	--	5,700	5,700
1331	E 96th Ave	Adams County	4,634	9,295	4,404	n/a	n/a	n/a	n/a	4,575	9,285	4,608	8,571	--	--
1334	Confluence with Gramma Gulch	Commerce City	4,658	9,409	4,442	n/a	n/a	n/a	n/a	--	--	--	--	--	--
1350	E 88th Ave/ Irondale Road	Commerce City	4,815	9,529	4,620	n/a	n/a	n/a	n/a	4,408	9,260	--	--	5,000	5,000
1380	Confluence with Buckley Draw	Adams County	4,789	9,484	4,598	n/a	n/a	n/a	n/a	--	--	--	--	--	--
M1012	Confluence with Second Creek West Fork	Adams County/Commerce City	4,783	9,622	4,606	5,960	11,900	n/a	n/a	--	--	--	--	--	--
M1010	Tower Road	Commerce City	4,859	9,465	4,742	5,240	10,600	n/a	n/a	3,431	8,147	4,204	8,647	4,700	4,700
M1030	DIA Border/ Commerce City Border	DIA (Downstream Border)	4,885	9,590	4,778	5,270	10,700	n/a	n/a	3,317	8,053	--	--	--	--
M1100	E-470	DIA	4,508	9,007	4,422	4,910	10,100	n/a	n/a	n/a	n/a	2,732	7,997	--	--
M1110	Confluence with Buckhorn Draw/ Picadilly Rd	DIA	4,464	8,948	4,381	4,860	10,000	n/a	n/a	n/a	n/a	2,558	8,039	--	--
M1200	Confluence with Barberry Run	DIA	4,221	8,589	4,149	4,620	9,610	n/a	n/a	n/a	n/a	--	--	--	--
M1210	Pena Blvd	DIA	3,858	8,073	3,799	4,580	9,750	n/a	n/a	n/a	n/a	2,139	7,482	--	--
M1234	Confluence with Runaway Run	DIA	3,831	8,053	3,772	4,550	9,730	n/a	n/a	n/a	n/a	--	--	--	--
M1270	Confluence with Cocklebur Run	DIA	3,761	7,934	3,699	4,480	9,610	n/a	n/a	n/a	n/a	--	--	--	--
MUS_IN	DIA Border/City of Aurora Border	DIA (Upstream Border)	3,442	7,348	3,392	4,390	9,420	4,386	9,454	n/a	n/a	--	--	--	4,386
U159T	Confluence with Possum Gully	DIA	3,442	7,348	3,392	n/a	n/a	4,122	8,905	n/a	n/a	--	--	--	4,122
U138T	Confluence with Gopher Gulch	DIA	2,470	5,311	2,461	n/a	n/a	2,967	6,472	n/a	n/a	--	--	--	2,967
U126	E 64th Ave	Aurora	1,752	3,736	1,751	n/a	n/a	2,106	4,549	n/a	n/a	--	--	2,150	2,106
U117T	E 56th Ave	Aurora	1,126	2,471	1,126	n/a	n/a	1,356	3,315	n/a	n/a	833	3,330	--	1,356

1. Peak flows from the 1976 Second and Third Creek FHAD by Gingery Associates included considerations of planned future development in the 1975 Comprehensive Plan prepared and adopted by Adams County; therefore, no representative existing conditions peak flows are available for comparison. Additionally, peak flows reported in the 1976 FHAD were reduced to reflect anticipated flow diversion into the Third Creek watershed at the Fulton Ditch, Union Pacific Railroad, and US 85 crossings.

2. Peak flows reported in the Effective FIS include considerations of planned future development, except for flows upstream of the Adams County and DIA border. These flows were inherited from the existing conditions analysis completed in the 2011 Olsson/Matrix MDP and FHAD.

4 HYDRAULIC ANALYSIS

4.1 HYDRAULIC MODEL DEVELOPMENT

The existing condition model is a one-dimensional (1D) hydraulic model that was created using HEC-RAS (v5.0.7). The modeled input parameters are discussed in the subsections below. Additionally, Table 4-1 provides a summary of the HEC-RAS geometry input by reach.

Table 4-1. Summary of HEC-RAS Input

Reach	Reach Length (ft)	Manning's N		# Cross Sections	Avg. Spacing (ft)	Culverts	Bridges	Drop Structures	Avg. Slope (ft/ft)
		Overbank	Channel						
Second Creek Upper	71119	0.02 – 0.1	0.045, 0.05, 0.055, 0.06	212	333	6	10	0	0.0026
Potomac Split	2344	0.055, 0.06	0.055, 0.06	9	293	0	0	0	0.0043
Second Creek Lower 2	1475	0.013 – 0.1	0.03, 0.045, 0.055	8	187	0	1	0	0.0045
Second Creek Lower 1	15650	0.02 – 0.1	0.04, 0.045, 0.05, 0.055, 0.06	64	246	7	2	0	0.0037
Highway 85 Split	3626	0.045	0.045	19	209	0	0	0	0.0028
Fulton Split	2111	0.055	0.055	5	422	0	0	0	0.00038
E-470 Culvert Split	1311	0.045, 0.055	0.045, 0.055	8	191	1	0	0	0.0057
Third Creek Lower 3	2954	0.045 – 0.07	0.045, 0.055, 0.06, 0.075	14	252	1	0	0	0.0034
Third Creek Lower 2	8318	0.045 – 0.1	0.045, 0.055, 0.06, 0.065, 0.07	35	239	3	0	0	0.0040
Third Creek Lower 1	4506	0.04 – 0.1	0.035, 0.045, 0.05, 0.055	17	281	1	0	0	0.0037

4.1.1 Peak Flows

Flow data in the HEC-RAS models were taken from the existing conditions peak discharges discussed in Section 3.0. Flood profiles for the 10-, 50-, 100-, and 500-year storm events were modeled using steady, sub-critical flow. Flows were determined at the downstream border of DIA. Second Creek is a "losing stream" and attenuates as flows progress downstream. However, because the attenuation is minor relative to the overall peak flows, the HEC-RAS model did not include attenuated peak flows. So, the flows at the DIA border were used throughout all of Second Creek. Split flows were not subtracted from the main stem at the Fulton Split and the Highway 85 Split. They were, however, subtracted for the E470 Culvert Split and Potomac Split; these flows were then added back to the main stem where it recombines with the splits. It must be noted that the 500-year event was only analyzed for Second Creek Upper and the Potomac Split using the 1D hydraulic model. The 500-year floodplain was evaluated for Second Creek Lower 1 and 2, all of Third Creek, the E470 Culvert Split, the Highway 85 Split, and the Fulton Split using HEC-RAS 2D models.

Peak flows and flow changes are found in Table 4-2. Even though the 500-year floodplain was not evaluated via the 1D hydraulic model for Second Creek Lower 2, there is a 500-year peak flow in the model to allow Second Creek Upper and the Potomac Split to solve for the event across the junction with Second Creek Lower 2. See Appendix C for a description of the peak flows modeled at the crossing of Second Creek at Highway 85.

Table 4-2. Flow Changes[1]

River	Reach	River Station	10-year [cfs]	50-year [cfs]	100-year [cfs]	500-year [cfs]
E470 Culvert Spl	1	401534	10	120	650	-
Fulton Split	1	203933	-	330	550	-
Highway 85 Split	Reach 1	503947	-	40	1094	-
Potomac Split	1	102568	80	1790	2790	5270
Second Creek	Upper	91554	290	3260	4890	8960
Second Creek	Upper	224417	210	1460	2100	3680
Second Creek	Lower 2	20008	290	3260	4890	-
Second Creek	Lower 2	19813	290	3140[2]	4240[2]	-
Second Creek	Lower 1	16194	290	3260	4890	-
Second Creek	Lower 1	10361	290	1838	1838	-
Second Creek	Lower 1	9659	290	3260	4890	-
Third Creek	Lower 3	316602	590	2690	4000	-
Third Creek	Lower 3	313648	590	3020	4550	-
Third Creek	Lower 2	313061	590	3020	4550	-
Third Creek	Lower 2	311502	826	3766	7800	-
Third Creek	Lower 1	304663	826	3766	7800	-

[1] Main channel flows do not decrease at the Fulton Split and Highway 85 Split.
[2] Reduction in peak flows along main stem of Second Creek due to the E-470 relief culvert (i.e. the E470 Culvert Split).

4.1.2 Boundary Conditions

The downstream boundary condition was set to the effective (dated March 5, 2007) FEMA 10-year water surface elevation of the South Platte River for all profiles for Second Creek. At the time of this study, the South Platte River was being restudied by MHFD, but the project was in preliminary stages and a revised 10-year water surface elevation was not yet available.

The downstream boundary condition for Third Creek was set to a known water surface elevation. These elevations were determined from a supplementary HEC-RAS model. The supplementary model was extended a sufficient distance downstream from the boundary so that a sound water surface elevation could be determined. The supplemental model is available for review and study in the technical appendix.

4.1.3 Limits of Detailed Study

The following sections describe the limits of detailed study found within the FHAD. Limits of detailed study were generally delineated between the ends of cross sections that bound the limit. Any computed losses were reported within this document and within the flood maps in Appendix G. They were not, however, subtracted from main stem flow to facilitate conservative results.

West Fork Second Creek

There is a limit of detailed study at the 500-year floodplain's boundary on the West Fork Second Creek tributary. This location was chosen because the 100-year floodplain is controlled by the tributary at this location, not upstream flow from the Second Creek main stem. Because this location leads to higher ground, there are no risks of spills and outflow from the Second Creek main stem.

O'Brian Canal at Second Creek

There is a limit of detailed study for all events at the eastern intersection of the O'Brian Canal and the Second Creek floodplain. Because of the gradual slope of the canal, the flood waters would continue a significant distance down the canal. It was therefore decided to place a limit of detailed study between the cross sections that bound the canal. A lateral structure was optimized to calculate the flows that would leave at this location: less than 100 cfs for the 100-year event. There are flood risks for the canal to overtop its embankments downstream of this location from additional flows from Second Creek.

Burlington Ditch at Second Creek

The Burlington Ditch fills with water during the 100-year event. Because of the gradual slope of the ditch, the 100-year flow continues to inundate the structure in both the (generally) northern and southern directions. Per MHFD's direction, the limit of detailed study was placed at Cross Section 29917. The potential outflow was determined by two optimized lateral structure because the bounding cross sections: 130 cfs in the northern direction for the 100-year event and 370 cfs in the southern direction for the 100-year event. There are flood risks for the ditch to overtop its embankment in both directions from additional flows from the Second Creek floodplain.

E-470 at the E470 Culvert Split

The terrain at the western boundary of the E470 Culvert Split is very flat, leading to shallow flooding in the left overbank. This flow, in general, abuts E-470 and continues to the west until it enters a pond and hits the embankment of the Fulton Ditch. This shallow flooding only currently crosses agricultural fields and grassland. See Appendix C for further discussions and calculations pertaining to the shallow flooding.

Intersection of US-85 and E-470 at Second Creek

A limit of detailed study exists in the left overbank of the Second Creek floodplain in the vicinity of the intersection of US-85 and E-470. The flatness of this location would otherwise necessitate that the 100-year floodplain be extended a great distance past the floodplain boundaries of Second Creek. A 2D HEC-RAS model that was analyzed in this location showed that the average depth of the 100-year was less than 1 ft, indicating shallow flooding in this location. The flows would be on both side of the Fulton Ditch and endanger grassland, agricultural fields, industrial processes and warehouses, and storage facilities.

Between Bright Rd and the South Platte River at Second Creek

A limit of detailed study was placed at the northern edge of retired gravel ponds at the downstream end of the Second Creek floodplain. There exists a series of ponds in this location that gradually slopes northward. The cross sections could not be extended far enough to contain all events, so a limit of detailed study was placed in this location. There are no significant hazards from Second Creek in this area because the 100-year floodplain is controlled by the South Platte River.

E 136th Ave at Third Creek

A 2D analysis was done to determine the 500-year floodplain in the portions of Third Creek that were in this study. The 500-year floodplain continued northward for a good distance north of E 136th Ave between Potomac St and E 140th Ave. It was, therefore, decided to place a limit of detailed study on the northern end of E 136th Ave. The 500-year floodplain in this location covered agricultural fields.

Intersection of US-85 and E 144th Ave at Third Creek

Both the 100-year and 500-year floodplain continue north/northeast near the intersection of US-85 and E 144th Ave at Third Creek. The terrain gently slopes to the north at this location without any nearby natural features to detain the water. It was, therefore, decided that a limit of detailed study should be placed in this location. The water would flow over agricultural lands, some storage, and some roads, providing potential flood risk downstream of the study limits. Furthermore, a 2D model was used to calculate flows that would split along US-85 towards Brighton (see Combined Second Creek and Third creek Hydraulic Modeling memo dated February 6, 2019, in Appendix A). It was estimated that 3,200 cfs would split towards Brighton during the 100-year event. The US Army Corps of Engineers published a study for this location called *Second and Third Creek Inundation and South Outfall Prevention Reanalysis* in March 2022. Please refer to this study for additional flooding information.

Old Gravel Ponds near the South Platte River at Third Creek

The left bank of the cross sections in this location (Cross Sections 301789 through 302759) overlap with the current FEMA effective South Platte River floodplain. Because of this and because of the existing geometry the 100-year floodplain could not be contained on the left side between Cross Sections 301789 and 303006. Because it is known that this area is inundated within the South Platte River floodplain it was decided to place a limit of detailed study between their left overbanks and to not model the area in detail with this study.

4.1.4 South Platte River & Third Creek

The downstream study limit of Third Creek was placed so that it intersects the FEMA effective 100-year floodplain for the South Platte River at the time of this study. Because the South Platte River controls the floodplain in this area and because the South Platte River is being restudied by MHFD at the time of the publication of this report, it was determined to set the downstream study limit of Third Creek to be the boundary of the South Platte River floodplain. The area will be re-delineated in the future with the results of the South Platte River study.

4.1.5 Stream Centerline

The centerline of the Second Creek channel was estimated using contours derived from the 2014 FEMA DEM. The channel invert was difficult to identify in several locations due to the small size of the low flow channel, the multiple crossings that obstruct and divert flow away from the main channel (e.g., O'Brian Canal, US 85) and the tendency for true channel inverts to not be captured by LiDAR data. Where possible, survey data was used to define low flow invert elevations at major crossings. Invert elevations were interpolated between major crossings.

4.1.6 Cross Sections

Three hundred and ninety-one cross sections with an average spacing of 298 channel ft were used in the model. Second Creek and cross section geometry was populated using the 2014 FEMA DEM in HEC-GeoRAS. Third Creek cross sections mimic the geometry of the 2018 FHAD. Split flow cross sections (e.g. E470 Culvert and Highway 85) were cut from the terrain after the split was deemed necessary. Cross sections were oriented perpendicular to both the low-flow channel and the floodplain where possible.

4.1.7 Bridge & Culvert Model Development

Bridges and culverts within the HEC-RAS model were analyzed using a combination of structure surveys and terrain. The deck/roadway was cut from the terrain and modified per the structure surveys where appropriate. Bridge openings and culverts were developed using the structure surveys. Upstream and downstream invert elevations were often amended to correspond with the structure survey data. See HEC-RAS cross sections in Appendix C for structure conditions. Nineteen culverts and 13 bridges exist in the HEC-RAS model. Structure geometry was defined using MHFD ground survey and construction as-builts as needed. Crossing structures with diameters less than 36 in were not modeled.

Crossings were, in general, modeled with the standard four cross sections, two upstream and two downstream. Each side of the structure had a cross section placed at its toe and a cross section placed far enough away that it would not be affected by either expansion of contraction into or from the structure.

The following crossings used internal cross sections to better model the transition through the structure:

- Tower Rd at Second Creek
- E 96th Ave at Second Creek
- E 104th Ave at Second Creek
- Sable Blvd at Second Creek
- E 120th Ave at Second Creek
- E-470 at Second Creek
- Fulton Ditch at Second Creek
- A dirt road (crossing 23) just upstream of the Union Pacific Railroad at Second Creek
- E-470 crossing at the E470 Culvert Split

The following crossings used skewed bridges/culverts:

- Second Creek Trail Footbridge #9 has a deck roadway skew angle of 35
- E 120th Ave has a deck roadway skew angle of 45

The following crossings had their bounding cross sections skewed to account for the angle at which the reach enters and exits:

- E-470 at Second Creek with a skew angle of 25
- Tucson St at Second Creek with a skew angle of 39

- Union Pacific Railroad at Second Creek with a skew angle 23
- Highway 85 at Second Creek with a skew angle of 27

4.1.8 Manning's n Values

Estimates of channel and overbank roughness for existing conditions were made using aerial photography and field visits. The values were estimated for the dense vegetative growth that would be present during summer and growing season. Manning's n values in the model range from 0.02 to 0.1. See Appendix C for pictures depicting typical Manning's n values.

4.1.9 Coinciding Floodways & Floodplains

Because of the conservativeness of the flows in this project, it was determined that the floodway and the 100-year floodplain would be coincident in certain portions of the study area (see correspondence with MHFD about this decision in Appendix A). This occurred for the locations:

- Second Creek: At and downstream of the Fulton Ditch (Cross Section 13669 and downstream).
- Third Creek: Downstream of the comingling with the Fulton Split (Cross Section 313648 and downstream)
- E470 Culvert split: Everywhere
- Fulton Split: Everywhere
- Highway 85 Split: Everywhere

The Potomac Split does not have a delineated floodway because there is strong potential for development in this location in the future.

4.1.10 Shallow Flooding

Shallow flooding for the 100-year event was determined on a case-by-case basis throughout the study area. Shallow flooding would often occur where the floodplain barely overtopped a roadway or where the transition downstream was extremely abrupt, prompting an investigation into potential shallow flooding. Per MHFD's directives (February 15, 2022), the shallow flooding across Brighton Rd at Third Creek was absorbed into the 100-year floodplain. It is not designated as shallow flooding on the flood map. Furthermore, it was absorbed into the floodway because the floodplain and floodway are coincident in that location. See Appendix C for calculations and justifications for all shallow flooding locations.

4.1.11 Irrigation Canal Crossings

From downstream to upstream, Second Creek crosses the Fulton Ditch, the Burlington Ditch, and the O'Brian Canal and Third Creek crosses the Fulton Ditch. Per MHFD policy, the canals were assumed to be full in the model and were not allowed to carry additional flood flows from Second and Third Creeks. None of the canals have existing culverts large enough to pass flood flows from Second Creek and Third Creek; therefore, the canal structures were modeled as perpendicular embankments acting like an in-line weir to Second Creek and Third Creek.

4.1.12 Ineffective Flow Areas & Blocked Obstructions

Ineffective flow was utilized to account for flow areas with little or no flow conveyance. Deep pools and detention areas hydraulically connected to the main channel were blocked using permanent ineffective areas. They were blocked to the lowest berm height of the feature. Blocked obstructions were used to account for large structures and buildings within the floodplain.

The hydraulic analysis for this study was based on unobstructed flow at all structures, with exception of Tucson St at Second Creek (which was nearly completely buried at the time of the study). It was otherwise assumed that all bridges, culverts, and channels were free of silt and debris. The flood elevations determined by the model are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

A blocked obstruction was placed in the left overbank of Cross Section 53086 in Second Creek Upper because development occurred in that location since the inception of the model and terrain. This was done per MHFD directives (October 20, 2021): "Our recommendation is to block the low-lying area in the model and support it with a photo from the field." See Figure 4-1 for a photo from the field showing that the location has since been developed. The photo was taken November 2, 2021.

Furthermore, per MHFD direction, blocked obstructions were also used to remove hydraulically disconnected areas whose depths were less than 0.5 ft on a case-by-case basis. This was done for the following cross sections: 78968, 74608, 74372, 73786, 50438, and 46426 in Second Creek Upper, as well as 503788 in Highway 85 Split.

Figure 4-1. A photo from the field showing development in the left overbank of Cross Section 53086.

4.1.13 Non-Levee Berm Features

In consultation with MHFD, floodplains were delineated across non-levee berm features to reflect the hydraulic model results. Per MHFD's directions with regards to pond embankments (see Appendix A), unless the water is connected to the main floodplain via surface water, the berm/embankment was treated as high ground and the floodplain was delineated to the appropriate station and elevation within the pond. When the non-levee berm/embankment was a road, though, the high ground of the road embankment was included in the floodplain shading. The two ponds where this occurred were on the west side of Tower Rd and to the west of the Buffalo Highlands neighborhood. The roads where this occurred were west of the Buffalo Highlands on the other side of Second Creek, north of E 88th Ave between Cross Sections 69649 and 68020 in the right overbank, north of E 88th Ave between Cross Sections 68977 and 67257 in the left overbank, and across Tucson St in the right overbank of Cross Section 15179.

4.1.14 Static & Assumed Elevations

There were two locations within the project's domain that were assumed to have static elevations. Both locations are in Upper Second Creek. The first location is east of Tower Rd and just south of the Tower Rd Landfill. The pond in this was assumed to have an elevation of 5231 ft for the 100-year event and 5232.5 for the 500-year event. These values came from base flood elevations that were determined just downstream of Cross Section 85210. The second location was just upstream of the O'Brian Canal in the left overbank. The static water surface elevation for the 100-year event was determined as 5110.7 ft and for the 500-year event as 5111.7 ft. These values were determined to be the same as the upstream cross section (34845).

4.1.15 Adverse Slopes & Channel Inverts

Adverse slopes were originally present in the HEC-RAS model because of the terrain. These were addressed by assuming that the offending cross sections' invert elevation was linearly projected between the invert elevations of the upstream and downstream cross sections. Channel invert elevations upstream and downstream of surveyed structures were set to the survey's values. Adverse slopes that resulted from surveyed crossings were kept in the model.

4.1.16 Pedestrian & Small Farm Bridges

Pedestrian and small farm bridges were present in both Second and Third Creeks. These small crossings were modeled using blocked obstructions. Cross sections would be placed upstream and downstream of the structure. A blocked obstruction was then put in the channel of the upstream cross section at the elevation of the crossing. For Third Creek this occurred for the following cross section pairs:

- 314570 and 314502
- 314073 and 314025
- 312532 and 312422
- 311262 and 311222
- 310923 and 310898

For Second Creek this occurred for the following cross section pair: 26313 and 26269.

4.1.17 2-Dimensional Supplemental Analysis & Portions of the 500-Year Floodplain

The floodplain in Second Creek Lower 2 and Lower 1 is flat and wide with several split flows. In many areas the Second Creek floodplain merges with the Third Creek floodplain (to the north) and the South Platte River floodplain (to the west). Because the flood waters split in multiple directions, a 2-dimensional (2D) analysis was created in HEC-RAS (v5.0.7) to supplement the 1D analysis. The 2D analysis was created to inform the 1D analysis as well as delineate the 500-year floodplain for the Second Creek downstream of Cross Section 13710, the Fulton Split, the Highway 85 Split, the E470 Culvert Split, and Third creek downstream of Cross Section 313867.

4.2 EVALUATION OF EXISTING FACILITIES

An inventory of existing crossings along the Second Creek and Third Creek study reaches was compiled based on MHFD survey, construction as-builts, and field reconnaissance. In total, there are 36 existing crossing structures comprised of the following: 19 culverts, 9 vehicular bridges, 4 footbridges, and 4 irrigation ditch crossings. The conveyance capacity of these crossing structures varies from less than a 10-year capacity to 500-year capacity. Maximum capacity events were defined as the largest event passed by the structure in the HEC-RAS model without overtopping the existing roadway. Table 4-2 summarizes the location, crossing type, structure type, configuration, and structure capacity per existing conditions hydrology and Figure 4-2 contains a map showing the location of surveyed crossing structures. See Appendix C for HEC-RAS profiles for all structures.

Table 4-3. Evaluation of Existing Hydraulic Structures

Surveyed Structure Number	River Station	Location	Jurisdiction	Crossing Type	Structure Type	Structure Configuration	Estimated Capacity (Existing Flows)
Second Creek							
28	3563	Brighton Road	Brighton	Roadway	Culvert	1-48" CMP	< 10-year
27	5511	Dirt Road	Adams County	Roadway	Culvert	1-30" CMP	< 10-year
26	10239	Highway 85	Brighton	Roadway	Culvert	2-9'x6' CBC & 1-12'x6' CBC	< 10-year
25	10596	E. 136th Avenue	Brighton	Roadway	Bridge	1-span of 46.9'	10-year
24	11852	Union Pacific Railroad	Brighton	Railroad	Bridge	1-span of 62.4'	10-year
23	12111	Dirt Road	Brighton	Private Road	Culvert	1-48" CMP	< 10-year
22	13484	E. 132nd Avenue	Adams County	Roadway	Culvert	1-48" RCP	< 10-year
--	13669	Fulton Ditch	Adams County	Irrigation Ditch	Flume	Flume across ditch	n/a
21	13691	Dirt Road	Adams County	Private Road	Culvert	2-24" RCP	< 10-year
20	15775	Tucson Street	Adams County	Roadway	Culvert	1-54" CMP	< 10-year
19	17106	E-470	Adams County	Roadway	Bridge	Twin 2-span of 198.5' & 2-10'x4' CBC*	500-year
18	21102	E. 124th Avenue	Brighton	Roadway	Culvert	1-36"x24" Elliptical CMP	< 10-year
17	22840	Potomac Street	Brighton	Roadway	Culvert	1-7'x3' CBC	< 10-year
16	25845	E. 120th Avenue	Brighton	Roadway	Bridge	1-span of 88.4'	50-year
15	27532	Sable Boulevard	Brighton	Roadway	Bridge	1-span of 87.2'	500-year
14	27978	Highway 6/ I-76	Adams County	Roadway	Bridge	1-span of 79.3'	100-year
13A	28537	Dirt Road	Adams County	Maintenance Road	Culvert	5-30" RCP	< 10-year
13	28502	BNSF Railroad	Adams County	Railroad	Culvert	1-20'x15.2' CBC, 1-20.1'x15.2' CBC, & 1-20.3'x14.9' CBC	500-year
--	32257	Burlington Ditch	Commerce City	Irrigation Ditch	Unknown	Unknown	n/a
--	34845	O'Brian Canal	Commerce City	Irrigation Ditch	Flume	Flume entering canal	n/a
11	35209	E. 112th Avenue	Commerce City	Roadway	Culvert	3-18" RCP	< 10-year
10	42437	Chambers Road	Commerce City	Roadway	Bridge	1-span of 28.3'	10-year
9	45287	Second Creek Trail (#1)	Commerce City	Pedestrian Trail	Foot Bridge	1-span of 59.5'	10-year
8	46316	E. 104th Avenue	Commerce City	Roadway	Bridge	Twin 1-span of 87.2'	500-year
7	54342	Second Creek Trail (#2)	Commerce City	Pedestrian Trail	Foot Bridge	1-span of 32.8'	10-year
6	58636	Second Creek Trail (#3)	Commerce City	Pedestrian Trail	Foot Bridge	1-span of 36.0'	10-year
5	60288	E. 96th Avenue	Commerce City	Roadway	Bridge	1-span of 75.0'	500-year
4	60822	Second Creek Trail (#4)	Commerce City	Pedestrian Trail	Foot Bridge	1-span of 35.2'	10-year
3	69785	E. 88th Avenue	Commerce City	Roadway	Culvert	1-20.2'x7.8' CBC	10-year
2	78551	Tower Road	Commerce City	Roadway	Culvert	1-12'x11.6' CBC & 4-12'x8' CBC	100-year
E470 Culvert Split							
--	342	E-470 Relief Culvert	Adams County	Roadway	Culvert	2-10' x 4' CBC	500-year
Third Creek							
28	4635	Brighton Road	Brighton	Roadway	Culvert	1-30'' CMP & 1-60'' CMP	< 10-year
27	6020	E 144th Avenue	Adams County	Roadway	Culvert	1-52'' CMP	< 10-year
26	7200	Highway 85	Brighton	Roadway	Bridge	2-span of 11' & 1-span of 14 ft	10-year
21	12894	E 136th Avenue	Adams County	Roadway	Culvert	1-48'' CMP	< 10-year
--	13061	Fulton Ditch	Adams County	Irrigation Ditch	Culvert	1-36'' CMP	< 10-year
17	16561	E 132nd Avenue	Brighton	Roadway	Culvert	1-39" CMP	< 10-year

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Lower Second Creek and Lower Third Creek FHAD Structure Crossings

0 0.5 1 2 Miles

Figure 4-2

4.3 FLOOD HAZARDS

The topography for Second Creek is characterized by two distinct regions. The land upstream of E-470 predominately slopes to the northwest and there is a relatively well-defined floodplain. Downstream of the E-470 crossing, Second Creek enters an area that can be described as the historic floodplain for the South Platte River. Land in this area generally slopes to the northeast. Additionally, a possible faint alluvial fan is visible where both Second Creek and Third Creek enter the historical South Platte River floodplain. Historic man-made changes to the topography have occurred along the creeks, such as tilling of the land for agricultural uses, gravel mining, and development. These alterations impact the delineation of the floodplain.

The existing conditions 100-year floodplain boundary upstream of E-470 is similar to the effective FEMA 100-year floodplain. Most of the FHAD floodplain is larger than the effective, except for between the O'Brian Canal and Sable Blvd. A majority of the floodplain is either located on undeveloped lands or in areas with development that has been intentionally set back from the floodplain boundary. The exception was in areas located immediately upstream and downstream of road crossings where the existing and effective floodplains experience significant backwater or roadway overtopping.

Downstream of E-470, the slope of the channel and overbanks flatten out as Second Creek enters the historic South Platte River floodplain. Like Second Creek, the slope of the Third Creek channel flattens out as it enters the historic South Platte River floodplain and forms a confluence with the South Platte River channel. Just downstream of E-470 and upstream of US 85, the 100-year floodplains for Second and Third Creeks overlap and merge into one large floodplain. In general, the topography for both Second and Third Creeks slopes to the north; however, there are several road, railroad, and irrigation ditch crossings that cause the floodplains to split and form a complex mesh of flow paths. Both the effective FEMA floodplain and the existing conditions 100-year floodplain are a hydraulically complex combination of flows from Second and Third Creeks.

4.3.1 Insurable Structures

There are currently 178 insurable structures within the effective FEMA floodplain for Second Creek and the portions of Third Creek that were evaluated. According to the existing conditions model, if a 100-year flood occurred without any future improvements, a total of 195 insurable structures would experience some level of flood inundation. Table 4-4 summarizes the number of structures in the current FEMA effective 100-year floodplain and the existing conditions floodplain, sorted by jurisdiction. Table 4-5 summarizes the structures in the current FEMA effective 100-year floodplain and the existing conditions floodplain, sorted by river (flow splits included). See Figure 4-3 for a map showing the locations of the insurable structures that are within both the FEMA effective and FHAD 100-year floodplains, only the FEMA effective 100-year floodplain, and only the FHAD 100-year floodplain.

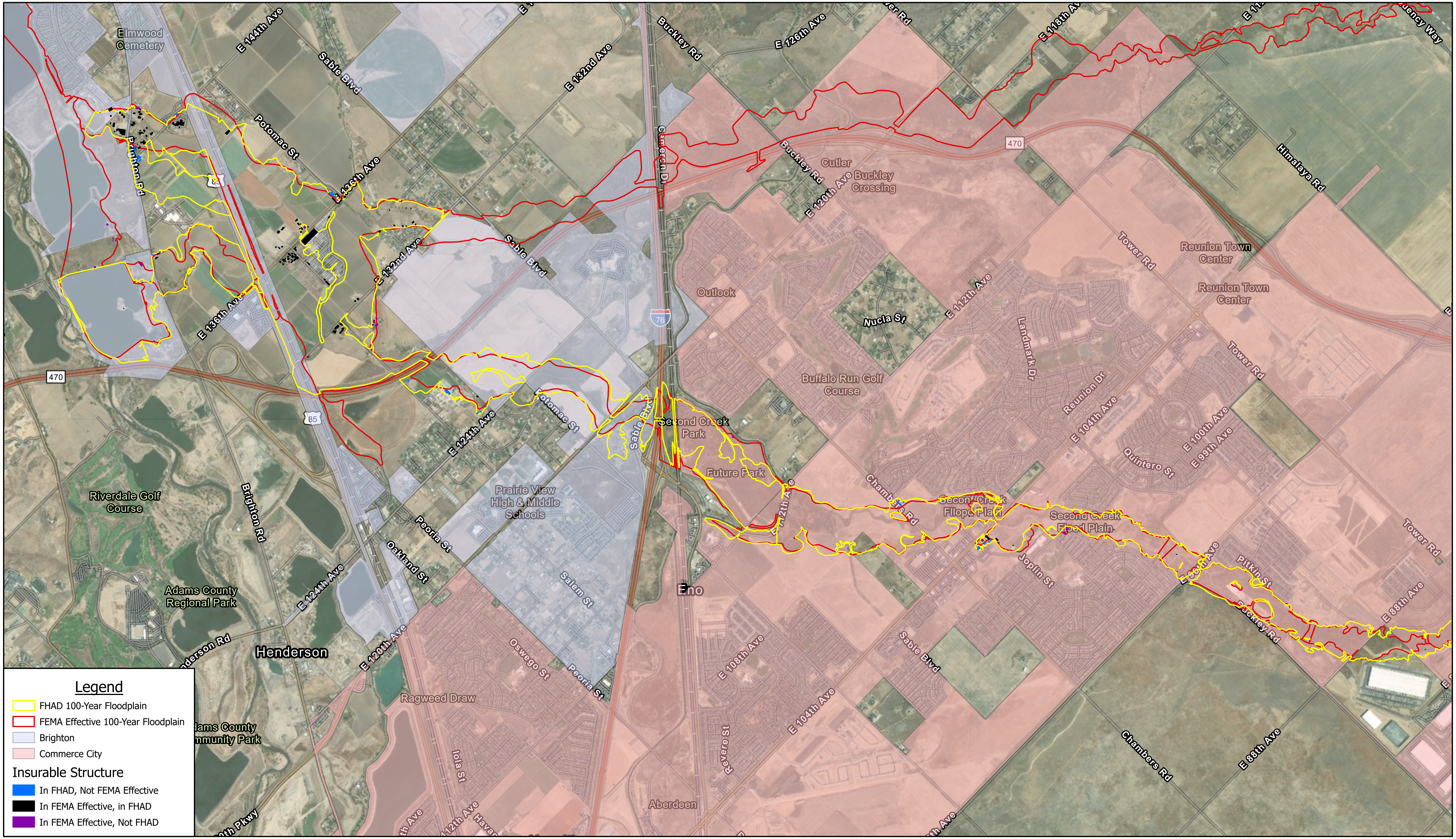
Table 4-4. Structures in the 100-Year Floodplain, Sorted by Jurisdiction

Jurisdiction	Insurable Structures	
	FEMA Effective	Existing Conditions
Adams County	159	173
Brighton	7	3
Commerce City	12	19
Total	**178**	**195**

Table 4-5. Structures in the 100-Year Floodplain, sorted by River

Jurisdiction	Insurable Structures	
	FEMA Effective	Existing Conditions
Second Creek	67	71
Third Creek	107	110
Potomac Split	0	0
E470 Culvert Split	0	1
Fulton Split	2	2
Highway 85 Split	0	11
Total	**178**	**195**

Most of the current inundated structures are in the downstream reaches of the study (Second Creek Lower 1 and 2 and Third Creek Lower 2 and Lower 1) where there is not currently a well-defined channel for Second Creek, the topography is very flat, and the floodplain is splitting in multiple directions. Additionally, there is flooding that is a result of undersized crossings, primarily at Chambers Rd, E 132nd Ave, and Brighton Rd.



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Insurable Structures in the FEMA Effective and FHAD 100-Year Floodplains

0 0.5 1 2 Miles

Figure 4-3

4.3.2 Previous Analyses

Previous hydraulic analysis for Second Creek downstream of the DIA/Commerce City border was completed in the *Second and Third Creek Flood Hazard Area Delineation,* prepared by Gingery Associates Inc., dated February 1976. The effective FEMA Flood Insurance Study (FIS) report, dated February 17, 2017, is based on the peak flows and hydraulic modeling presented in the 1976 FHAD for the downstream section of Second Creek between Tower Road and the South Platte River.

FIRM panels 08001C0635H, 08001C0343H, 08001C0339H, 08001C0336H, 08001C0337H, 08001C0329H, 08001C0328H effective March 5, 2007, for Adams County, Commerce City, Brighton, and Denver show the FEMA floodplain extents and designations. The effective mapping for Second Creek through the study area consists of a Zone A 100-year floodplain. Several LOMC's have been completed or started since the effective FIRM date in 2007 and are as follows:

- 02-08-507P, E-470, effective November 29, 2002
- 09-08-0550P, 104th Avenue Corridor Improvements, effective September 30, 2009
- 13-08-0755R, Second Creek and 96th Avenue Roadway Improvements
- 15-08-1339R, Tower Road
- 18-08-0619P, Buffalo Highlands

In general, the 100-year floodplain delineations along Second Creek are similar, with some areas where the floodplain is slightly larger and some areas that are slightly smaller. This FHAD provides higher resolution mapping than the 1976 FHAD, as well as a mapped floodway. The differences between the effective and study floodplains are a result of new crossings and topography, new hydrology, and new hydraulic modeling. 41 new insurable structures will be added to the regulatory floodplain, and 24 insurable structures will be removed. See Table 4-6 for an enumeration of the structures that will be removed from the FEMA effective floodplain and those that will be added to the FHAD floodplain, sorted by jurisdiction. Figure 4-3 above displays which structures are in both the FEMA effective and FHAD floodplains, only in the FEMA effective floodplain, and only in the FHAD floodplain.

Table 4-6. Structures Removed from the FEMA Effective and Added to the FHAD 100-Year Floodplains, Sorted by Jurisdiction

Jurisdiction	Insurable Structures	
	Removed from FEMA Effective 100-Year Floodplain	Added to FHAD Floodplain
Adams County	16	30
Brighton	4	0
Commerce City	4	11
Total	**24**	**41**

5 REFERENCES

2012 aerial imagery obtained from Mile High Flood District, March 2014.

ArcGIS files from Adams County: Cities, county boundary, future land use, railroads, rivers, roads, trails, zoning, January 2017.

ArcGIS files from Aurora: Building footprints, centerlines, detention ponds, drop structures, headwalls, hydrants, outlet structures, mains, inlets, manholes, valves, March 2017.

ArcGIS files from Mile High Flood District: Third Creek Watershed, March 2017.

ArcGIS files obtained from Colorado GeoData Cache: LiDAR data acquired after the 2013 flood by FEMA, October 16, 2013.

Colorado Aerotropolis Visioning Study. Colorado Department of Transportation (CDOT), May 2016.

Colorado Urban Hydrograph Procedure (CUHP) 2005 User Manual – Version 2.0.0, Mile High Flood District, September 9, 2016.

CUHP, SWMM, Land Use data obtained from 2011 Second Creek MDP/FHAD and 2014 DIA MP, May 2017.

Denver International Airport Drainage Master Plan: Baseline Hydrology Report, RESPEC Consulting & Services, August 2014.

Esri, Maxar, Earthstar Geographics, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community. "Flood Hazard Area Delineation, Second Creek" [basemap]. 1:2400. “World Imagery”. January 13, 2022. https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9. (February 7, 2022).

Final Drainage Report for Tower Road Widening. Huitt-Zollars Inc., May 2017.

Flood Insurance Study Adams County, Colorado and Incorporated Areas Volumes 1-3 (08001CV001C, 08001CV002C, 08001CV001C), Management Agency, Effective February 17, 2017.

Hydraulic structure survey obtained from Mile High Flood District: Second Creek and Third Creek Bridge/Culvert Information Sheets, survey points and CAD drawings, July 2018, January 2019, June 29 2020, and March 18 2021,.

Land use data from Adams County: Future Land Use map, November 2012

Land use data from Aurora: 2015 E-470/ Northeast Plains Zoning Map (Feb. 18, 2015), 2016 Zoning Map (March 8, 2016).

Land use data from Brighton: Comprehensive Plan: Future Land Use Map (April 5, 2016).

Land use data from Commerce City: Future Land Use Plan (Figure 3.2) map (Sept. 10, 2010).

Plans obtained from Brighton: Adams Crossing Preliminary Plat (Nov. 11, 2015), Contract Drawings for Woodbury Corporation Adams Crossing 30% Set (May 2016), Preliminary Drainage Report (Volumes 1 & 2) Adams Crossing Preliminary Plat (May 27, 2016), Southgate Brighton Preliminary Plans (Dec. 7, 2015).

Porteos, Harvest Road and 56th Avenue, Aurora, Colorado, Master Drainage Report. Martin/Martin Consulting Engineers. January, 2012. Revised June 20, 2012.

Porteos – Master Drainage Report (COA #212052) Amendment No. 1 Letter, Martin/Martin Consulting Engineers. September 4, 2013.

Second and Third Creek Inundation and South Outfall Damage Prevention Reanalysis, US Army Corps of Engineers – Walla Walla & Omaha Districts, March 2022.

Second Creek & Third Creek Flood Hazard Area Delineation, Gingery Associates Inc., February 1976.

Second Creek, Third Creek, DFA 0053 & Barr Lake Drainage Basin Planning: Hydrology Report (Including Addendum), Kiowa Engineering Corporation, November 1988, Reprinted: February 1989.

Second Creek and Direct Flow Area 0053 Outfall Planning Study: Preliminary Design, Kiowa Engineering Corporation, May 1990.

Second Creek (Downstream of DIA) and DFA 0053 Watersheds Outfall Systems Planning Study Update: Alternatives Development and Evaluation Report, Kiowa Engineering Corporation, October 2002.

Second Creek (Downstream of DIA) and DFA 0053 Watersheds Outfall Systems Planning Study Update: Preliminary Design Report, Kiowa Engineering Corporation, August 2004.

Second Creek (Upstream of Denver International Airport) Flood Hazard Area Delineation, Olsson Associates and Matrix Design Group Inc., May 2011.

Second Creek (Upstream of Denver International Airport) Major Drainageway Plan, Olsson Associates and Matrix Design Group Inc., September 2011.

REFERENCES

Storm Water Management Model User's Manual Version 5.0 (EPA SWMM), National Risk Management Research Laboratory, May 2005.

T-88 Bid Alternative System Drainage Report: A part of the Tower Road Improvements, Huitt-Sollars Inc., May 2016.

Third Creek Flood Hazard Area Delineation, Matrix Design Group. November 2018.

Urban Storm Drainage Criteria Manual – Volume 1, Mile High Flood District, June 2001, revised April 2008.

U.S. Geological Survey, 20141010, NLCD 2011 Percent Developed Imperviousness (2011 Edition, Amended 2014) - National Geospatial Data Asset (NGDA) Land Use Land Cover: None, U.S. Geological Survey, Sioux Falls, SD.

World Imagery, Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community