FLOOD HAZARD AREA DELINEATION

# WEAVER CREEK

November 2021





olsson®
1525 Raleigh Street, Suite 400
Denver, CO 80204

JEFFERSON COUNTY COLORADO

MHFD MILE HIGH FLOOD DISTRICT

Lakewood Full of Possibilities.

November 15, 2021

Mrs. Brooke Seymour, PE, CFM
Engineering Service Manager
Mile High Flood District
2480 W. 26th Avenue, Suite 156B
Denver, CO 80211

**Re: Weaver Creek Flood Hazard Area Delineation**
**Agreement No. 15-11.20**
**Olsson Project No. 016-0858**

Dear Mrs. Seymour:

Olsson is pleased to submit the Weaver Creek Flood Hazard Area Delineation (FHAD). This report documents the baseline hydrology development process, hydraulic analysis, and floodplain mapping.

The FHAD report was prepared with the cooperation of MHFD, Jefferson County, and the City of Lakewood. The information from this study provides the project sponsors with guidance for future construction and development projects in the watershed.

We appreciate the opportunity to work with you on this project and look forward to working with you on future projects.

Sincerely,

Deb Ohlinger    Amy M. Gabor    Michelle Danaher

| | | |
|---|---|---|
| Deb Ohlinger, PE, CFM | Amy M. Gabor, PE, CFM, LEED® AP | Michelle Danaher, PE, CFM |
| Project Manager | Project Engineer | Associate Engineer |

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**ABBREVIATIONS INDEX**

Ave – Avenue
Blvd – Boulevard
BMP – Best Management Practice
CDOT – Colorado Department of Transportation
CMP – corrugated metal pipe
CUHP– Colorado Urban Hydrograph Procedure
D/S – downstream
E – East
EGL – energy grade line
EPA – Environmental Protection Agency
EURV – excess urban runoff volume
EX – existing
FEMA – Federal Emergency Management Agency
FHAD – Flood Hazard Area Delineation
FIRM – Flood Insurance Rate Map
FTR – future
HSG – hydrologic soils group
I/Imp. – Imperviousness
Lakewood – City of Lakewood
LiDAR – light detection and ranging
MHFD – Mile High Flood District
MDP – Major Drainageway Plan
N – North
NLCD – National Land Cover Database
No. – Number
NOAA – National Oceanic and Atmospheric Administration
NRCS – Natural Resources Conservation Service
Olsson – Olsson Associates
O&M – operations and maintenance
Rd – Road
RCBC – reinforced concrete box culvert
RCP – reinforced concrete pipe
S – South
SEO – State Engineer's Office
SSP – smooth steel pipe
St – Street
SWMM – Storm Water Management Model
UDFCD – Urban Drainage and Flood Control District
U/S – upstream
USACE – United States Army Corps of Engineers
USDCM – Urban Storm Drainage Criteria Manual
W – West
WQCV – water quality capture volume
WSE – water surface elevation
% – percent
ac – acre
AF/ac-ft – acre-feet
cfs – cubic feet per second
ft or ' – foot/feet
in or " – inch/inches
mi – mile

## 1.0 INTRODUCTION

### 1.1 Authorization

Olsson was retained to complete a Major Drainageway Plan (MDP) and Flood Hazard Area Delineation (FHAD) for Weaver Creek, co-sponsored by Mile High Flood District (MHFD), Jefferson County, and City of Lakewood (Lakewood). The Agreement Regarding Major Drainageway Plan and Flood Hazard Area Delineation for Weaver Creek (Agreement No. 15-11.20) was executed on April 18, 2016.

### 1.2 Purpose and Scope

The purpose of this study was to update the hydrology as part of the MDP, and update the floodplain mapping along Weaver Creek. No modifications to the scope of this study were made by the project sponsors.

The following tasks were completed as part of the major drainageway plan:

- Collected existing information, including a previous FHAD and outfall systems plan (OSP), development drainage studies, and drainage improvement as-built plans
- Solicited input from project sponsors
- Obtained base mapping, structure surveys, and GIS information from MHFD, Jefferson County, and Lakewood.
- Obtained future land use mapping from Lakewood and Jefferson County
- Determined subwatershed boundaries and parameters in accordance with MHFD criteria
- Developed existing and future (fully developed) conditions baseline hydrology using the Colorado Urban Hydrograph Procedure (CUHP) 2005, version 1.5.2b and the Environmental Protection Agency Stormwater Management Model (EPA SWMM) 5.1, version 5.1.010
- Reconciled the hydrology with previous studies
- Evaluated existing structure and channel capacities
- Identified problem areas
- Mapped the 100-year floodplain, 500-year floodplain, and floodway
- Completed a report

### 1.3 Planning Process

The effective hydrology of the Weaver Creek watershed was completed for the *Flood Hazard Area Delineation: Weaver Creek,* prepared by Leonard Rice Consulting Water Engineers, Inc. in May 1981 (1981 FHAD). The *Bergen Reservoir Tributary to Weaver Creek: Outfall Systems Planning* report, by J.F. Sato and Associates, was completed in December 1995 (1995 OSP) and included updated hydrology, alternatives analysis, and conceptual design of the selected plan for a portion of the Weaver Creek watershed.

The baseline hydrology developed for this study represents an updated analysis using CUHP 2005, version 1.5.2b and EPA SWMM, version 5.1.010. Further information regarding the hydrologic modeling process is included in Section 3.0.

A kickoff meeting and five progress meetings were held to discuss the project goals, project status, hydrologic analysis, and hydraulic modeling with MHFD, Jefferson County, and Lakewood. The meetings were held on May 2, June 30, October 24, 2016, June 22, 2017, March 1, 2018, and November 5, 2020. Minutes from the meetings are included in Appendix A. A public meeting was held on May 16, 2017 to provide information on the master plan process and solicit input from watershed residents. The sign-in sheets are included in Appendix A.

MHFD, Jefferson County, and Lakewood reviewed the draft baseline hydrology and returned comments on August 9, 2016. The comments were incorporated into this final report. Only minor review comments were received for the draft baseline hydrology report, so a summary of the comments and responses was not prepared and was not included in the appendix. The hydrology was approved by MHFD on August 9, 2016 when direction was provided to move on to hydraulics. MHFD reviewed the draft FHAD models and figures and returned comments on 4/12/2017, 2/8/2018, 4/19/2018, 5/27/2019,8/14/2020, 4/26/2021, and 6/25/2021. The comments were incorporated into this report. A summary of review comments and responses are included in Appendix A.

### 1.4 Mapping and Surveys

MHFD provided 1-foot (ft) interval 2014 LiDAR mapping for the entire Weaver Creek watershed. The LiDAR mapping is referenced to the NAVD 88 vertical datum and the NAD 83 horizontal datum. The road crossing structures were surveyed by Accurate EngiSurv, LLC. The lowest adjacent grade was surveyed at 7 insurable structures by Wilson & Company, Inc. in September 2021. MHFD provided 2012 aerial photography. Jefferson County and Lakewood provided GIS files of parcels, street centerlines, trails, zoning, and some utilities in the watershed.

### 1.5 Data Collection

Drainage studies and as-built plans were collected from MHFD, Jefferson County, and Lakewood. The Jefferson County, Colorado and Incorporated Areas Flood Insurance Rate Maps (FIRMs) were obtained from the Federal Emergency Management Agency (FEMA). The main studies and plans that were reviewed in the preparation of this report are shown in Table 1. A list of all studies reviewed in the preparation of this report is shown in Section 7.

*Table 1 – Data Collected*

| Title | Date | Author |
|---|---|---|
| Flood Hazard Area Delineation: Weaver Creek | May 1981 | Leonard Rice Consulting Water Engineers, Inc. |
| Bergen Reservoir Tributary to Weaver Creek: Outfall Systems | December 1995 | J.F. Sato and Associates |
| South Simms Street – U.S. 285 Interchange and Extension of South Simms Street – Quincy to U.S. 285 | May 10, 2002 | Washington Infrastructure Services, Inc. |
| West Belleview Avenue West Quincy Avenue to South Simms Street - Phase III Drainage Report | December 4, 2006 | Muller Engineering Company, Inc. |
| Zoning Map | February 17, 2016 | City of Lakewood |
| Zoning Maps (See Section 7.0) | August 18, 2010 | Jefferson County Planning and Zoning |

### 1.6 Acknowledgements

The FHAD was prepared with the cooperation of MHFD, Jefferson County, and Lakewood. The representatives who were involved with this study are listed in Table 2.

*Table 2 – Project Participants*

| Name | Representing | Assignment |
|---|---|---|
| Brooke Seymour | MHFD | Engineering Services Manager |
| Hung-Teng Ho | MHFD | Hydraulic Modeler |
| Lauren Copenhagen | Jefferson County | Project Sponsor |
| Chris Proper | Lakewood | Project Sponsor |
| Deb Ohlinger | Olsson | Project Manager |
| David Krickbaum | Olsson | Technical Advisor, QA/QC |
| Amy Gabor | Olsson | Project Engineer |
| Michelle Danaher | Olsson | Associate Engineer |

## 2.0 STUDY AREA DESCRIPTION

### 2.1 Project Area

**Watershed and Drainageway Description**
The approximate 7.2 square mile Weaver Creek watershed, Reuse number 5502, extends from west of Whale Rock Way to its confluence with Bear Creek, south of West Morrison Road and west of South Kipling Street. The watershed extends through Jefferson County and Lakewood, as shown on Figure 1. The watershed is approximately 7.0 miles long and 1.3 miles wide. Weaver Creek generally slopes down toward Bear Creek in a northeast direction, with slopes ranging from 0.4 to 11 percent (%). The lowest and highest watershed elevations are 5435 and 7952, respectively.

**Reservoirs**
Three large, off-stream reservoirs are located in the watershed: Bergen Reservoir No. 1, Bergen Reservoir No. 2, and Harriman Lake. None of these reservoirs were included in the baseline hydrology for this study.

According to the 1995 OSP, the Bergen Reservoirs are filled with water diverted from Weaver Creek and Turkey Creek. The reservoirs are used for the storage of irrigation water to be used for agricultural lands. The 1995 OSP states:

> *"During construction of Highway C-470 an agreement was signed between the Colorado Highway Department (now Colorado Department of Transportation) and the Bergen Reservoir and Ditch Company for some surcharge storage and spillway modifications on Reservoir No. 2 to limit the total 100-year flow across C-470 to 100 cfs…These modifications have not been implemented but the 100 cfs restriction is in place due to storage restriction by the State Engineer's Office. Modifications of the Bergen Reservoir No. 2 spillway to safely pass 75% of the Probable Maximum Flood peak have been requested by the State to be implemented by the end of year 1998. These modifications will not change the basic conclusions of the routing calculations performed in this study."*

The 1995 OSP included detention routing for Bergen Reservoirs No. 1 and 2, as well as inadvertent detention at both the southwest and the southeast corners of W. Belleview Avenue and C-470. The detention area in the southeast corner of W. Belleview Avenue and C-470 was later formalized and is described in more detail in the following "Existing Regional Detention Basins" section.

Harriman Lake is located on the east side of the Weaver Creek watershed. The lake stores municipal and irrigation water and is not used for flood control.

**Existing Regional Detention Basins**
One regional detention basin, which was included in the baseline hydrology, is located in the Weaver Creek watershed in unincorporated Jefferson County. The Southeast Belleview and C-470 Detention Basin is an off-line detention basin that was formalized in 2006 as part of the *West Belleview Avenue: West Quincy Avenue to South Simms Street* project, designed by Muller Engineering Company, Inc. More detailed hydrologic information is included in Section 3.4.

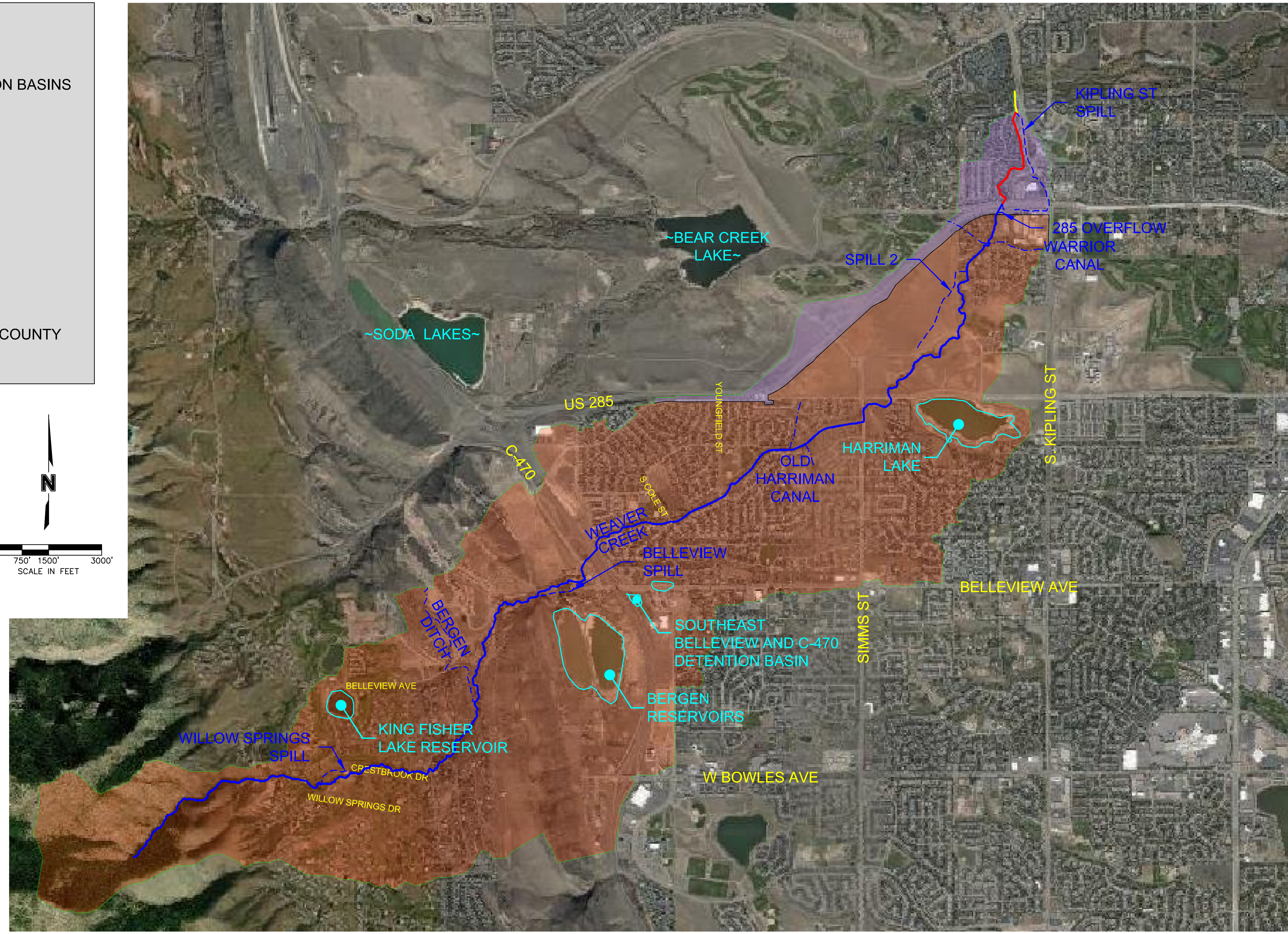
**Irrigation Ditches**
Three irrigation ditches cross the Weaver Creek watershed. Weaver Creek crosses under the Warrior Canal in an elliptical 60-inch corrugated metal pipe (CMP) upstream of U.S. 285. Harriman Canal crosses the creek approximately halfway between Simms Street and S. Youngfield Street. The canal appears to have been abandoned. Bergen Ditch joins Weaver Creek about 350 feet downstream of Crestbrook Dr and is carried within Weaver Creek through Structures 17 (Belleview Avenue) and 16 (Driveway). It then has two areas it draws water from: one directly downstream of Structure 17 and a second downstream of Structure 16, it then flows into the Bergen West Reservoir. The canals intercept some stormwater from adjacent developments.

**Planned Construction**
Several developments were under construction at the time of this study. Light industrial development was under construction at the southeast corner of W. Belleview Avenue and C-470, adjacent to the regional detention basin, and a low density single-family development was under construction west of Diamondback Road and W. Belleview Avenue. Both of these developments were included in the existing conditions hydrology.

**Soils**
Soil types were determined using the Natural Resources Conservation Service (NRCS) Web Soil Survey. The soils in the watershed consist primarily of hydrologic soils groups (HSG) C and D, which are generally characterized by low infiltration rates, as defined by the NRCS. Significant area of HSG B soils, generally characterized by moderate infiltration rates, are also present, primarily in the developed area west of C-470. Only a small area of HSG A soils, which are generally characterized by high infiltration rates, is present in the watershed. The soils map is included on Figure B-1 in Appendix B.

LEGEND

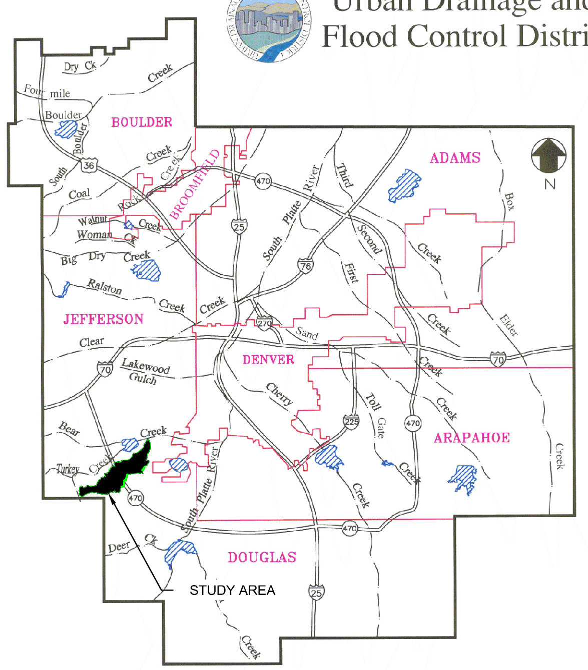
| | |
|---|---|
| | WATERSHED BOUNDARY |
| | LAKES / RESERVOIRS/ DETENTION BASINS |
| | WEAVER CREEK REACH 0 |
| | WEAVER CREEK REACH 1 |
| | WEAVER CREEK REACH 2 |
| | SPILL REACH |
| | CANAL |
| | JURISDICTIONAL BOUNDARY |
| | UNINCORPORATED JEFFERSON COUNTY |
| | CITY OF LAKEWOOD |




N

0' 750' 1500' 3000'
SCALE IN FEET

Urban Drainage and Flood Control District




February 2007

| | | | | |
|---|---|---|---|---|
| PROJECT: 016-0858 | MILE HIGH FLOOD DISTRICT, JEFFERSON COUNTY, AND CITY OF LAKEWOOD | WEAVER CREEK MDP & FHAD STUDY AREA MAP | olsson | FIGURE 1 |
| DRAWN BY: MD/ND | | | 1525 Raleigh Street Suite 400 Denver, CO 80204 TEL 303.237.2072 www.olsson.com | |
| DATE: 06/2021 | | | | PAGE 4 |

### 2.2 Land Use

The watershed is partially developed, with areas of land that remain undeveloped, primarily west of C-470. Existing development consists mostly of single-family residential, with lower densities west of C-470 and higher densities east of C-470. Pockets of industrial, commercial, and open space/recreational areas are also present. Existing land use was verified using aerial imagery and site visit observations.

Outside of the existing developed area, future land use will consist mostly of light industrial and low density residential areas, with pockets of commercial areas. Future land use information was obtained from Jefferson County and Lakewood zoning maps, included in Appendix B, and GIS information. Additional discussion of land uses and corresponding percent impervious values is included in Section 3.3.

### 2.3 Reach Description

Weaver Creek was divided into three reaches, as shown on Figure 1. Table 3 summarizes the major crossing structure inventory for Weaver Creek. Photos of the major structure crossings are included in Appendix C. The existing channel conditions are described in more detail below.

***Table 3 - Major Structure Crossing Inventory***

| Reach | Jurisdiction | Street Name | Structure Survey Number | Street Classification | Existing Structure | Width[1] (ft) | Condition |
|---|---|---|---|---|---|---|---|
| Weaver Creek - 1 | Lakewood | Dartmouth Avenue | 40 | Local (25 mph) | (2) 22.5-ft by 9.2-ft RCBC (Modified Drop Inlet) (14-ft by 9.2-ft RCBC at Throat) | 149.3 | Good - Clear |
| Weaver Creek - 2 | Lakewood | Pedestrian Walkway* | 39 | Trail | (3) 24-inch RCP (with Trash Rack) | 18 | Good - Clear |
| | CDOT | Hampden Avenue/Highway 285 | 38 | Parkway | (1) 15.5-ft by 6-ft RCBC (Modified Drop Inlet) (7-ft by 6-ft RCBC at Throat) | 386.7 | Good - Clear |
| | Jeffco | Pedestrian Bridge | 37 | --- | 90-ft Bridge (no piers) | 26.7 | Good - Clear |
| | Jeffco | Warrior Canal | 36 | --- | 96-inch by 60-inch Elliptical CMP | 61.2 | Good - Debris |
| | Jeffco | Private Drive* | 35 | Driveway | (2) 15-inch, (1) 18-inch Round Pipe (Material Unknown) | --- | Fair - Debris |
| | Jeffco | Private Drive* | 34 | Driveway | (1) 15-inch CMP | 20 | Fair - Debris |
| | Jeffco | Private Drive* | 33 | Driveway | (1) 15-inch CMP | 20 | Fair - Debris |
| | Jeffco | West Quincy Avenue | 32 | Minor Arterial (40 mph) | (2) 16-ft by 5-ft RCBC | 160 | Good |
| | Jeffco | Simms Street | 31 | Minor Arterial (40 mph) | (1) 12-ft by 10-ft RCBC<br>(1) 12-ft by 9-ft RCBC | 91.7 | Good - Clear<br>Good - Clear |
| | Jeffco | Pedestrian Bridge | 30 | --- | 60-ft Bridge (no piers) | 6.8 | Good - Clear |
| | Jeffco | Pedestrian Walkway | 29 | --- | (1) 36-inch RCP | 15.5 | Fair - Debris |
| | Jeffco | South Youngfield Street | 28 | Collector (25mph) | (2) 10-ft by 8-ft RCBC | 104.9 | Good - Clear |
| | Jeffco | Cole Street | 27 | Collector (20mph) | (1) 68-inch CMP<br>(1) 68-inch CMP | 82.5<br>80.6 | Poor - Debris<br>Poor - Debris |
| | Jeffco | Eldridge Street | 26 | Collector (25 mph) | (2) 10-ft by 6-ft RCBC | 76 | Fair - Debris |
| | Jeffco/CDOT | C-470 | 25 | Freeway | (1) 35-ft by 6-ft RCBC (Modified Drop Inlet) (16-ft by 6-ft RCBC at Throat) | 284.7 | Fair- Vegetation |
| | Jeffco | Quincy Avenue/ Frontage Road | 24 | Minor Arterial (35 mph) | (1) 20-ft by 8-ft RCBC | 117.8 | Fair - Vegetation |
| | Jeffco | Private Driveway | 23 | Driveway | (1) 72-inch CMP | 48.7 | Good - Clear |
| | Jeffco | Private Drive* | 22 | Driveway | (1) 22-inch by 15-inch Elliptical CMP | 19.2 | Poor - Debris |
| | Jeffco | Belleview Avenue | 21 | Minor Arterial | (1) 78-inch CMP | 65.7 | Fair - Debris |
| | Jeffco | Belleview Avenue | 19 | Minor Arterial | (1) 74-inch CMP | 120 | Fair - Bank Erosion |
| | Jeffco | Private Driveway | 18 | Driveway | (1) 72-inch CMP | 30.1 | Good - Clear |
| | Jeffco | Belleview Avenue | 17 | Minor Arterial | (1) 72-inch CMP | 86.8 | Fair - Debris |
| | Jeffco | Private Driveway | 16 | Driveway | (1) 6-ft by 3.7-ft Elliptical CMP | 29.4 | Good - Clear |
| | Jeffco | Crestbrook Drive | 15 | Local (30mph) | (1) 72-inch CMP | 62.3 | Good - Clear |
| | Jeffco | Willowbrook Drive | 14 | Local (30mph) | (1) 36-inch RCP | 60.9 | Good - Clear |
| | Jeffco | Meadowbrook Drive | 13 | Local (30mph) | (1) 36-inch RCP | 65.2 | Good -Clear |
| | Jeffco | Colorow Drive | 12 | Local (30 mph) | (1) 36-inch RCP | 66.4 | Fair - Debris |
| | Jeffco | Pedestrian Bridge | 11 | --- | 29.5-ft Bridge (1 pier) | 1.7 | Good - Clear |
| | Jeffco | Pedestrian Bridge | 10 | --- | 13-ft Bridge (no piers) | 5.1 | Good - Clear |
| | Jeffco | Private Driveway | 9 | Driveway | (1) 32-inch by 28-inch Elliptical CMP | 33.3 | Fair - Debris |
| | Jeffco | Private Driveway | 8 | Driveway | (1) 36-inch RCP | 32.7 | Good - Clear |
| | Jeffco | Pedestrian Bridge | 7 | --- | 19.5-ft Bridge (1 pier) | 5 | Fair - Debris |
| | Jeffco | W Roton Arena | 6 | Driveway | (1) 36-inch RCP | 30.9 | Fair - Debris |
| | Jeffco | Willow Springs Drive | 5 | Local (30 mph) | (1) 48-inch RCP (Modified Drop Inlet)<br>(1) 48-inch RCP (Modified Drop Inlet) | 73.3<br>74.3 | Good - Clear<br>Fair - Debris |
| | Jeffco | Golf Cart Path | 4 | Trail | (1) 24-inch ABS<br>(1) 36-inch Steel Pipe | 20.2<br>21.3 | Good - Clear<br>Good - Clear |
| | Jeffco | Golf Cart Path | 3 | Trail | (1) 36-inch Steel Pipe<br>(1) 36-inch Steel Pipe | 18 | Poor - Debris<br>Poor - Debris |
| | Jeffco | Whale Rock Way* | 2 | Local | (1) 15-inch CMP<br>(1) 18-inch RCP<br>(1) 29-inch RCP<br>(1) 29-inch RCP | 114.6<br>115.6<br>115.3<br>115.3 | Fair - Debris<br>Good - Clear<br>Good - Clear<br>Good - Clear |
| | Jeffco | Golf Cart Path* | 1 | Trail | (3) 18-inch RCP | 15.2 | Fair -Debris |

[1]Length for culverts, and widths for bridges
*Crossings not included in HEC-RAS Model

## Weaver Creek Reaches 0 and 1: Bear Creek Confluence to Lakewood/Jefferson County Border at US-285 (City of Lakewood)

**Existing Channel Conditions**
Weaver Creek consists of both vegetated and concrete open channels with drop structures within these reaches, which correspond to MDP Reach WC-1. The approximate 0.8-mile reach lies within the City of Lakewood, primarily in residential neighborhoods, and has an approximate longitudinal slope of 1.1%. A large concrete baffle drop structure is located upstream of West Dartmouth Avenue. The downstream channel consists of a trapezoidal channel with a concrete low flow that flows parallel to South Kipling Parkway. Upstream of the concrete baffle drop structure, the channel is a broad, more natural, channel that meanders along residential apartment complexes. The channel geometry consists of side slopes ranging from approximately 3 horizontal feet to 1 vertical foot (3:1) to 6:1, and bottom widths between 2 and 160 feet. The channel and overbanks consist primarily of native and nonnative grasses with several areas of more condensed vegetation bankside in the form of shrubs and the occasional tree. The channel appears to be in good condition.

Photo 1: MDP Reach WC-1

## Weaver Creek Reach 2: Lakewood/Jefferson County Border at US-285 to Upstream Study Limit (Jefferson County)

**Existing Channel Conditions**
Weaver Creek consists of a vegetated, open channel with drop structures within this reach, which corresponds to MDP Reach WC-2. The approximate 0.6-mile reach lies within Jefferson County, primarily in residential neighborhoods, and has an approximate longitudinal slope of 0.9%. Most of the channel in this reach has a defined, vegetated, low flow channel and a broader floodplain. The channel geometry consists of side slopes ranging from 3:1 to 10:1, and bottom widths between 2 and 45 feet. The channel and overbanks consist primarily of native and nonnative grasses, several dense areas of bushes, shrubs and trees, especially downstream of the Warrior Canal. The channel appears to be in good condition.

Photo 2: MDP Reach WC-2

## *Weaver Creek Reach 2: South of S Nelson Court to West Quincy Avenue (Jefferson County)*

**Existing Channel Conditions**
Weaver Creek consists of a vegetated, open channel with drop structures within this reach, which corresponds to MDP Reach WC-3. The approximate 0.9-mile reach lies within Jefferson County open space and has an overall longitudinal slope of 0.8%. The channel generally has a well-defined, vegetated low flow channel that is incised in some areas, and a broader floodplain. The channel geometry consists of side slopes ranging from 1:1 in the low flow channel to 50:1 outside of the low flow channel. The channel bottom widths vary between 2 and 20 feet. The channel and overbanks consist primarily of native and nonnative grasses with several areas of bushes, shrubs and areas of dense wetland vegetation. The channel appears to be in fair condition.

Photo 3: MDP Reach WC-3 –
Existing Crossing Underneath Quincy Avenue

## *Weaver Creek Reach 2: West Quincy Avenue to C-470 (Jefferson County)*

**Existing Channel Conditions**
Weaver Creek consists of a vegetated, open channel with drop structures within this reach, which corresponds to MDP Reach WC-4. The approximate 2-mile reach lies within Jefferson County, primarily in residential neighborhoods, and has an overall longitudinal slope of 1.1%. Approximately 2,000 feet of this segment borders Weaver Hollow Park. The channel geometry generally consists of a vegetated trapezoidal section with side slopes ranging from 2:1

Photo 4: MDP Reach WC-4

to 20:1 and bottom widths between 3 and 30 feet. The channel and overbanks consist of primarily native and nonnative grasses with several areas of bushes, shrubs and a few trees. The channel appears to be in good condition.

***Weaver Creek Reach 2: C-470 to Upstream Study Limit (Jefferson County)***

**Existing Channel Conditions**
Weaver Creek consists of a vegetated, more natural, open channel with drop structures within this reach, which corresponds to MDP Reach WC-5. The approximate 3.0-mile reach lies in Jefferson County, primarily in large-lot residential neighborhoods and open land and has an overall longitudinal slope of 3.3%. The channel geometry generally consists of a vegetated trapezoidal section with side slopes ranging from 1:1 to 10:1, and bottom widths between 1 and 30 feet. Channel and overbanks consist of primarily native and nonnative grasses with some dense areas of bushes, shrubs and trees. The channel appears to be in good condition.

Photo 5: Existing Bank Conditions of MDP Reach WC-5

## 2.4 Flood History

The FIRMs show a FEMA-designated Zone AE floodplain on Weaver Creek from the upstream limit, west of Whale Rock Way, to just downstream of U.S. 285. A Zone A floodplain is shown downstream of U.S. 285 to the confluence with Bear Creek. The spills from Weaver Creek, located at W. Belleview Avenue, W. Saratoga Place, and W. Quincy Avenue are mapped as Zone AO floodplains. The FEMA FIRM panels are included in Appendix C. Several Letters of Map Revisions (LOMR) have been completed along Weaver Creek.

Areas of concern and observed problem areas were discussed at the kickoff meeting. Flood-related problems include:

- The culvert at Cole Street is undersized. Jefferson County receives reports of flooding annually.

- Ponding occurs in the pedestrian cell of the Simms Street culvert. Jefferson County noted that concrete aprons were installed upstream and downstream of the culvert to improve maintenance access. A floodwall was installed to prevent flooding of the pedestrian cell during frequent storms.

## 2.5 Environmental Assessment

Wetland and riparian zones within the Weaver Creek watershed primarily occur in riverine areas, freshwater ponds, or lakes. Areas where there is increased urbanization or a concrete channel will be less likely to have wetland qualities. Areas directly alongside the banks of Weaver Creek or any of its tributaries are likely to qualify as a wetland. This information was acquired through the U.S. Fish & Wildlife Service's National Wetlands Inventory. See Appendix D for the delineation of wetland areas for Weaver Creek.

# 3.0 HYDROLOGIC ANALYSIS

## 3.1 Overview

Hydrology was developed for the baseline condition using existing infrastructure, for both existing and future (fully developed) land uses. Peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period storms were analyzed using CUHP 2005, version 1.5.2b, to generate hydrographs for each subwatershed. Hydrographs for the subwatersheds were routed using EPA SWMM, version 5.1.010, to determine peak discharge rates at select design points. The updated EPA SWMM results were compared to the 1981 FHAD. The hydrology comparison is detailed in Section 3.6 and shown in Table 8. Future land use 100-year peak flows are less than 130% of existing land-use peak flows. Therefore, future land-use hydrology was used for the FHAD.

## 3.2 Design Rainfall

One-hour rainfall depths from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 were input into CUHP 2005 to model the watershed hydrology for each storm event and are shown in Table 4. Area adjustments were used for the 2-, 5-, and 10-year storm events with tributary drainage basins greater than 5 square miles. Area correction values are included in Table 5. No area adjustment factors were necessary for the 25-, 50-, 100-, and 500-year storm events. Tables of the adjusted and unadjusted rainfall distributions for each storm event are included as Tables B-1, in Appendix B.

*Table 4 - One-Hour Point Rainfall (inches)*

| Duration | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year | 500-Year |
|---|---|---|---|---|---|---|---|
| 1-Hour | 0.769 | 1.04 | 1.28 | 1.63 | 1.91 | 2.21 | 2.94 |
| 6-Hour | 1.23 | 1.62 | 1.96 | 2.47 | 2.89 | 3.33 | 4.45 |

*Table 5 - Depth Reduction Factors for Design Rainfall Distributions 2-, 5-, and 10-yr Design Rainfall*

| Time (minutes) | Correction Factor by Watershed Area in Square Miles | |
|---|---|---|
| | 2 | 5 |
| 5 | 1 | 1 |
| 10 | 1 | 1 |
| 15 | 1 | 0.97 |
| 20 | 1 | 0.86 |
| 25 | 1 | 0.86 |
| 30 | 1 | 0.86 |
| 35 | 1 | 0.97 |
| 40 | 1 | 0.97 |
| 45-120 | 1 | 1 |

## 3.3 Subwatershed Characteristics

A summary of the CUHP 2005 model parameters can be found in Appendix B. LiDAR mapping, structure survey information, as-built drawings, and drainage studies were used to determine input parameters.

**Subwatershed Delineation**

The overall watershed boundary was delineated using LiDAR mapping and by referencing adjacent watershed boundaries, where applicable. The adjacent watershed boundaries were delineated using less detailed topography; therefore, the overall watershed boundary was delineated solely based on the LiDAR mapping and then checked for general agreement with the surrounding watersheds.

The Weaver Creek watershed was divided into 60 subwatersheds that were delineated based on the LiDAR mapping MHFD provided (Section 1.4), various drainage studies, and site observations. Subwatershed boundaries reflect the major storm event conditions. The subwatersheds range in size from 7.7 acres to 130.3 acres, with an average subwatershed size of 77.2 acres.

Subbasins 13 and 14 are tributary to Harriman Lake and will not reach Weaver Creek unless either the lake overtops, or the dam is breached. If the lake overtops, water will flow both to the west, toward Weaver Creek, and to the east, toward Marston Lake North Drainageway. The Harriman Lake tributary area was not included in the Marston Lake North Drainageway watershed area. Pursuant to MHFD policy, Warrior Canal, Harriman Ditch, and Bergen Ditch were assumed to be at full capacity for the baseline hydrology, so stormwater runoff would flow over the canals. The subwatersheds are shown on Figure B-1 in Appendix B.

**Length, Distance to Centroid, Slope**

The LiDAR data and structure survey information were used to determine subwatershed flow path lengths, distance to centroid values, and slopes. Flow paths were based on major drainage overland paths and, therefore, storm drain systems were not modeled. Private detention facilities and irrigation reservoirs were not included in the model. Where private detention basins and irrigation reservoirs were present, flow paths were determined based on the overflow path from the ponds, assuming the outlets would be clogged.

Subwatersheds were generally delineated to avoid shapes with elongated tails and very narrow and long shapes. To check these two scenarios, the following equations were used:

$r$ = Length to Centroid / Total Length (if $0.1 \leq r < 0.3$, the subwatershed may have an elongated tail)
$r$ = Length$^2$ / Area (if $r > 4$, the subwatershed may be very narrow and long)

If the r value of a subwatershed indicated that it may have an elongated tail, or be very narrow and long, it was checked. Many of the subwatersheds in question did not have an elongated tail and were not long and narrow in shape. The questionable r values were generally a result of the nature of the urbanized portion of the watershed. Flow paths were generally delineated following streets, which resulted in longer paths than a more direct, undeveloped path. The majority of subwatersheds with questionable r values had reasonable unit discharges, as compared to similar subwatersheds.

The Weaver Creek watershed generally slopes down toward the northeast. Subbasin flow path slopes ranged from 0.1 to 32 percent (%). The lowest and highest watershed elevations are 5435 and 7952, respectively. Slopes were estimated using the weighted slope equation from the CUHP manual.

$$((L_1 s_1^{0.24} + \ldots + L_n s_n^{0.24}) / (L_1 + \ldots + L_n))^{4.17}$$

For subbasins with slopes greater than 4 percent, a slope correction was applied based on Figure 6-4: Slope Correction for Streams and Vegetated Channels, in the MHFD *Urban Storm Drainage Criteria Manual Volume 1.* These subbasins were generally in the upper watershed.

**Watershed Imperviousness**

The existing and future land uses are discussed in Section 2.2. To determine the existing conditions percent imperviousness, the National Land Cover Database (NLCD) was used. Several changes to the NLCD information were made to determine the existing percent imperviousness:

- The NLCD 0% imperviousness value used for water was changed to 100%
- All 0% NLCD values that were not water were changed to 2%
- The database was developed in 2011. Aerial imagery from 2011 was compared to 2016 aerial imagery to determine areas in the watershed that developed after the database was compiled. These areas of post-2011 development were added into the existing conditions percent imperviousness calculations.
- Several developments were under construction at the time of this study. Light industrial development was under construction at the southeast corner of W. Belleview Avenue and C-470, adjacent to the Southeast Belleview and C-470 regional detention basin, and a low density single-family development was under construction west of Diamondback Road and W. Belleview Avenue. These areas of development were added into the existing conditions percent imperviousness calculations.

After the aforementioned changes were made to the NLCD percent imperviousness values, the percent impervious values were spot checked for accuracy and were determined to be acceptable. The overall existing percent imperviousness of the watershed is 21.1%. The existing percent impervious values for each subbasin are shown on Figure B-1, in Appendix B.

Future land use designations were discussed with the project sponsors. Many of the residential land uses include ranges of densities and would allow denser development to occur than what the existing development showed. It was decided that future land use designations and percent imperviousness values would only be used in undeveloped areas, or areas that showed different zoning categories than existing. The future land use areas are shown on Figure B-1, in Appendix B.

To determine appropriate future land use percent imperviousness values in the undeveloped portions of the watershed, the zoning descriptions and MHFD's Urban Storm Drainage Criteria Manual (USDCM) Table 6-3 were used. The future land use designations and corresponding percent imperviousness values are shown in Table 6. The overall future percent imperviousness of the watershed was estimated to be 27.5%, which compares well to the 1981 FHAD estimated 28.8%. The future percent impervious values for each subbasin are shown on Figure B-1, in Appendix B.

***Table 6 – Land Uses and Corresponding Impervious Values***

| Land Use Plan | Land Use Designation from Corresponding Plan | Figure Designation | % IMP |
|---|---|---|---|
| Jefferson County | Bergen Reservoir Subarea (Average density < 1 du/10 acre) | Very Low Density Residential | 5 |
| Jefferson County | Residential (1 du/10 acre) | | |
| Lakewood | R-1-12 (Large Lot Residential) | Low Density Residential | 10 |
| Jefferson County | Belleview Subarea (<1 du/5acre) | | |
| Jefferson County | Residential < 4 du/acre | Medium Low Density Residential | 45 |
| Jefferson County | NC (Neighborhood Commercial) | Limited Commercial | 75 |
| Jefferson County | LC (Limited Commercial) | | |
| Jefferson County | Limited Commercial, Residential, Mixed Use | | |
| Jefferson County | OLI (Office, Light Industrial) | Light Industrial | 80 |
| Jefferson County | OLI/MU (Office, Light Industrial, Mixed Use) | | |
| Jefferson County | OLI/MF (Office, Light Industrial, Multi-Family) | | |
| Jefferson County | LSC (Large Scale Commercial) | Commercial | 95 |

**Depression Losses**

Depression losses were determined using Table 6-6 in the USDCM. A weighted average was used for the depression losses in each subbasin, based on land use designation. A pervious depression loss of 0.35 inches, which represents lawns and grass, was used for the developed portions of the watershed, and a value of 0.4, which represents open fields, was used for the undeveloped portions of the watershed. An average of an impervious depression loss of 0.05, which represents sloped roofs, and 0.1, which represents large paved areas, was used for residential areas. A value of 0.1, which represents flat roofs and large paved areas, was used for commercial, office, and industrial areas.

**Infiltration**

Initial and final infiltration rates and Horton's decay rate were determined using Table 6-7 in the USDCM and are shown in Table 7. A weighted average of soil type was used to determine subwatershed rates. The hydrologic soil groups are shown on Figure B-1, in Appendix B.

***Table 7 - Horton's Equation Parameters***

| 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

Pursuant to MHFD's policy to recognize only regional and publicly-owned facilities, private detention basins, irrigation reservoirs, and inadvertent detention areas were not modeled. One regional detention basin, southeast of C-470 and W. Belleview Avenue, was included in the baseline hydrology. The Southeast Belleview and C-470 Detention Basin, owned by Jefferson County and maintained by MHFD, is an off-line regional detention basin that was formalized in 2006 as part of the *West Belleview Avenue: West Quincy Avenue to South Simms Street* project, designed by Muller Engineering Company, Inc.

The Phase III Drainage Report for the project included detention basin stage-storage-discharge information. It appears that the 1995 OSP hydrology was used as a basis for the detention basin analysis and was updated to reflect the proposed storm drain and detention basin design. The 1995 OSP included detention routing through Bergen Reservoirs No. 1 and No. 2, and an inadvertent detention area southwest of W. Belleview Avenue and C-470, resulting in lower 100-year peak flows reaching the Southeast Belleview and C-470 Detention Basin than what is shown in this study. The pond stage-storage-discharge information from the Phase III Drainage Report needed to be extended to higher elevations for this study to avoid stacking storage in the EPA SWMM model. The area, storage, and outlet structure discharge were extrapolated using the design information. LiDAR data was used to develop a rating curve for the roadway overtopping discharge and was added to the extrapolated outlet discharge to determine a total discharge rating curve for the higher elevations.

The detention basin tributary area shown in the Phase III Drainage Report generally matches the tributary area delineated for this study. However, the drainage report also included three additional tributary areas, Subbasins 18, 19, and 20 (shown on an excerpt in Appendix B), that will reach the detention basin via storm drain. This study delineated the major system flow overland paths and, therefore, these areas were not modeled as tributary to the pond in this study. In addition, runoff could bypass the storm drain system and the detention basin if the inlets or pipe became clogged.

The detention basin stage-storage-discharge information can be found in Table B-2 in Appendix B. Excerpts from the drainage study are also included in Appendix B.

### 3.5 Hydrograph Routing

The parameters for the EPA SWMM model conveyance elements were determined using the LiDAR data, structure survey information, as-built drawings, and drainage reports. Many conveyance elements in the SWMM model contain multiple drop structures, steep culverts, and short, steep sections. The slope used for the conveyance element in the model reflects the actual slope of the ground between drop structures and not the calculated slope between two design points. To adjust the slope in the SWMM model, the drops were modeled in EPA SWMM as one large drop at the downstream end of the conveyance element.

Channel geometry was determined using the LiDAR mapping. For flows that are conveyed via streets, the street sections were modeled as trapezoidal sections with a 5-foot depth, 1-foot bottom width, and 20-foot horizontal to 1-foot vertical (20:1) side slopes, consistent with the EPA SWMM manual. Overflow elements were added where they were needed to convey the full future 100-year storm event to ensure no inadvertent detention was being modeled at these locations. The underground storm drain system was not modeled, with the exception of Subbasin 11, near the interchange of US-285 and Simms Street. This subbasin drains to a significant low point, where it enters a storm drain system that outfalls into Weaver Creek.

The Manning's n values for engineered conveyance elements, including engineered channels, pipe, and street, were increased 25 percent in accordance with the USDCM. Channel section Manning's n values ranged from 0.035 to 0.05625 in the model. Street section Manning's n values were set at 0.016, or 0.02 in the model. Concrete pipe Manning's n values were set at 0.015, or 0.01875 in the model.

The EPA SWMM 5.1 input parameters and 100-year future conditions output are included in Appendix B. EPA SWMM 5.1 model elements, including subwatersheds, design points and conveyance elements are shown on Figure B-1 and a schematic of the model is shown on Figures B-2 in Appendix B. No flow diversions were included in the analysis.

### 3.6 Previous Studies

Two previous studies of the Weaver Creek watershed have been completed: the 1981 FHAD, and the 1995 OSP, which studied only a small portion of the watershed.

A comparison of peak flows between this study and the 1995 OSP was not completed. The 1995 OSP only studied a small portion of the watershed, in the Bergen Reservoirs area. In addition, the OSP modeled detention at the Bergen Reservoirs and inadvertent detention southwest of W. Belleview Avenue and C-470, in addition to the southeast Belleview and C-470 detention basin.

A comparison of 100-year peak flows from the 1981 FHAD and this study is shown in Table 8. A summary of peak discharges is shown in Table 9. Differences and similarities between the 1981 FHAD and this study are noted below.

- Peak flows for the upper 2 subbasins in the 1981 FHAD were analyzed using SYNHYD. The rest of the subbasins were analyzed using CUHP.
- A 3-hour rainfall distribution was used for the 1981 FHAD.
- The 1981 FHAD was based on future conditions. The overall 1981 FHAD future percent imperviousness was 28.8%, which is similar to this study's future percent imperviousness of 27.5%.
- The 1981 FHAD overall watershed area was 6.52 square miles, compared to 7.2 square miles in this study.
- The 1981 FHAD did not include any detention. This study included one regional detention basin.
- The uppermost 1981 FHAD Subbasins 1 and 2 had 10% and 15% imperviousness values, respectively. Comparing roughly the same area, Subbasins 55-60 in this study are all much closer to 2%.

The “EX Q100” and “FTR Q100” peak flows shown in Table 8 represent the baseline hydrology from this study and include the Southeast Belleview and C-470 Detention Basin. For comparison purposes, the detention basin was removed from the model and conveyance elements were adjusted to avoid flooded nodes in the model. The results are presented as “FTR Q100 No Det” in Table 8.

To better compare the upper portion of the watershed, the percent impervious values in Subbasins 55-60 were increased to match the 1981 FHAD Subbasin 1 and 2 percent impervious values of 10% and 15%, respectively. The results are presented as “FTR Q100 No Det, % Imp” in Table 8.

***Table 8 – Previous Studies Hydrology Reconciliation***

| 1981 FHAD | | | | | 2017 MDP and FHAD | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Point | Reference Location | Peak Discharges (cfs) | | | Design Point | Peak Discharges (cfs) | | | | % Diff (FTR No Det to FHAD) | % Diff (FTR No Det %, Imp to FHAD) |
| | | QI0 | Q50 | QI00 | | EX Q100 | FTR Q100 | FTR Q100 No Det | FTR Q100 No Det, % Imp | | |
| A | U/S Limit | 112 | 170 | 182 | 158 | 98 | 99 | 99 | 168 | -46% | -8% |
| B | | 220 | 332 | 353 | 156T | 140 | 141 | 141 | 273 | -60% | -23% |
| C | U/S Crestbrook Drive | 370 | 538 | 603 | 151 | 296 | 301 | 301 | 476 | -50% | -21% |
| D | West Belleview Hogback Ridge | 733 | 1020 | 1153 | 139 | 619 | 666 | 666 | 861 | -42% | -25% |
| E | Old Harriman Canal | 1329 | 1812 | 2080 | 120T | 1178 | 1276 | 1935 | 2096 | -7% | 1% |
| F | U.S. 285 | 1819 | 2472 | 2809 | 103 | 1902 | 2277 | 2979 | 3006 | 6% | 7% |
| G | Confluence with Bear Creek | 1875 | 2547 | 2895 | 101 | 1991 | 2382 | 3079 | 3103 | 6% | 7% |

Removing the detention basin from the baseline model resulted in similar peak flows in the lower portion of the watershed (Design Points E through G). Differences in the upper-most design points (A through C) appear to be due to higher percent impervious values being used in the 1981 FHAD model. Adjusting the percent imperviousness in the upper portions of the watershed to better match the FHAD resulted in closer peak flows. Design Point D shows larger differences between the 1981 FHAD and this study. The 1981 FHAD routed the Bergen Reservoirs area to this location, whereas the Bergen Reservoir area is routed farther downstream in this study. The larger differences are due to a much larger tributary area to Design Point D in the 1981 FHAD model as compared to this model. The peak flows in the lower watershed compare well to the 1981 FHAD peak flows, when the detention basin was removed and the upper watershed percent impervious values were adjusted; therefore, calibration was not warranted.

### 3.7 Results of Analysis

The baseline peak discharges compared fairly well to the 1981 FHAD, as described in Section 3.6. In general, the peak flows are lower than the 1981 FHAD, since the 1981 FHAD did not include any detention in the hydrologic models. The Southeast Belleview and C-470 Detention Basin was formalized in 2006 and was included in this study. The baseline peak discharges and volumes for the 2-, 5-, 10-, 25-, 50-, 100-year, and 500-year storm events for all of the EPA SWMM 5.1 design points can be found in Table B-3 and B-4, respectively, in Appendix B. A summary of key peak flows and runoff volumes are listed in Tables B-5 and B-6, respectively, in Appendix B. The peak discharges versus channel station are shown in Figure B-3 and select SWMM generated hydrographs are included in as Figure B-4, in Appendix B.

***Table 9 – Baseline Peak Flows Along Drainageway Centerline***

| Design Point | Location | Length (feet) | Future Peak Flows (cfs) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $Q_2$ | $Q_5$ | $Q_{10}$ | $Q_{25}$ | $Q_{50}$ | $Q_{100}$ | $Q_{500}$ |
| 101 | Confluence with Bear Creek | 0 | 262 | 421 | 594 | 1,382 | 1,801 | 2,382 | 3,620 |
| 102 | | 1,991 | 255 | 409 | 576 | 1,347 | 1,753 | 2,316 | 3,520 |
| 103 | U.S. 285 / West Hampden Avenue | 4,301 | 251 | 403 | 566 | 1,329 | 1,727 | 2,277 | 3,459 |
| 106T | | 6,158 | 241 | 386 | 541 | 1,273 | 1,649 | 2,177 | 3,329 |
| 108T | | 8,515 | 227 | 361 | 504 | 1,199 | 1,550 | 2,060 | 3,251 |
| 110T | | 11,767 | 224 | 355 | 494 | 1,173 | 1,509 | 1,987 | 3,171 |
| 112 | West Quincy Avenue | 12,203 | 207 | 327 | 455 | 1,082 | 1,391 | 1,865 | 3,074 |
| 115T | | 13,202 | 174 | 272 | 376 | 895 | 1,159 | 1,595 | 2,788 |
| 116 | South Simms Street | 13,541 | 156 | 243 | 336 | 807 | 1,071 | 1,488 | 2,682 |
| 120T | | 15,236 | 130 | 200 | 272 | 661 | 908 | 1,276 | 2,432 |
| 123T | | 16,665 | 126 | 188 | 273 | 533 | 751 | 1,059 | 2,146 |
| 125 | South Youngfield Street | 18,467 | 84 | 122 | 183 | 450 | 636 | 897 | 1,963 |
| 126T | | 19,487 | 82 | 118 | 177 | 439 | 621 | 880 | 1,935 |
| 127T | South Cole Street | 20,084 | 73 | 107 | 165 | 421 | 595 | 865 | 1,891 |
| 139 | Quincy Avenue / C-470 | 22,863 | 30 | 46 | 89 | 310 | 457 | 666 | 1,092 |
| 140 | | 23,901 | 12 | 26 | 71 | 270 | 400 | 589 | 966 |
| 141 | West Belleview Avenue | 25,110 | 11 | 25 | 69 | 261 | 387 | 570 | 934 |
| 142T | | 26,400 | 11 | 25 | 69 | 260 | 385 | 567 | 929 |
| 145T | | 27,797 | 10 | 22 | 64 | 236 | 348 | 510 | 833 |
| 148 | West Belleview Avenue | 28,607 | 4 | 9 | 40 | 169 | 252 | 373 | 616 |
| 149 | | 29,967 | 3 | 9 | 37 | 159 | 236 | 350 | 576 |
| 151 | Crestbrook Drive | 30,175 | 3 | 7 | 33 | 138 | 204 | 301 | 494 |
| 152T | | 31,660 | 2 | 6 | 28 | 119 | 176 | 259 | 425 |
| 154 | Meadowbrook Drive | 32,758 | 1 | 4 | 21 | 92 | 136 | 201 | 329 |
| 155 | | 35,349 | 1 | 3 | 19 | 80 | 118 | 174 | 285 |
| 156T | | 36,389 | 1 | 2 | 16 | 66 | 96 | 141 | 228 |
| 157 | | 37,994 | 1 | 2 | 14 | 57 | 83 | 121 | 196 |
| 158 | | 40,933 | 1 | 2 | 12 | 47 | 68 | 99 | 159 |
| 159T | | 43,343 | 0 | 1 | 8 | 29 | 42 | 62 | 99 |

## 4.0 HYDRAULIC ANALYSIS

### 4.1 Evaluation of Existing Facilities

Jefferson County, City of Lakewood, and CDOT criteria were used to determine the crossing structure capacities. A summary of the criteria used to evaluate existing crossing structure capacities is included in Table 10. Weaver Creek was assumed to have low to moderate debris for future land use conditions when evaluating bridge freeboard capacities based on CDOT criteria. The floodplain analysis and mapping assumed no clogging at the crossing structures.

The HEC-RAS model that was developed for this study, as described in Section 4.2, was used to determine structure capacities based on the criteria listed in Table 10. Many of the crossings do not have capacity for the 100-year storm event. A detailed structure capacity summary table for the existing infrastructure and future land use flows is included in Table 11.

***Table 10 – Crossing Structure Criteria***

| Jurisdiction | Max. Culvert Headwater:Depth | Bridge Freeboard | Street Overtopping |
|---|---|---|---|
| CDOT | Rise/Diameter:<br><36" – 2<br>36"-60" – 1.7<br>>60"-<84" – 1.5<br>84"-120" – 1.2<br>≥120" – 1.0 | 4' (high debris),<br>$0.1Q^{0.3} + 0.008V^2$<br>(low-moderate debris) | No overtopping |
| Jefferson County | ≤1.5 | Minimum clearance between the low chord or culvert crown and the energy grade line is 6 inches for basins less than 2 square miles, 1 foot for basins up to 10 square miles and 2 feet for basins greater than 10 square miles. | No overtopping |
| City of Lakewood | ≤1.5 | See CDOT | No overtopping |

**_Table 11 – Crossing Structure Capacities (Existing Infrastructure, Future Land Use Hydrology)_**

| MDP Reach | Station | Jurisdiction | Street Name | Structure Survey Number | Existing Structure | $Q_{10}$ (cfs) | $Q_{10}$ Overtop Depth (ft) | $Q_{100}$ (cfs) | $Q_{100}$ Overtop Depth (ft) | Bridge Freeboard Height (ft) | Bridge Freeboard Elevation | HW/D Criteria | HW:D Criteria Elev | Overtop Elev[1] | Controlling Criteria | Controlling Elevation | Capacity (cfs) | Criteria Met? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WC-1 | 772 | Lakewood | Dartmouth Avenue | 40 | (2) 22.5-ft W by 9.2-ft H RCBC (Modified Drop Inlet) (14-ft W by 9.2-ft H RCBC at Throat) | 594 | --- | 2,382 | --- | --- | --- | 1.50 | 5,466.86 | 5,469.79 | HW:D | 5,466.86 | 3640 | YES |
| WC-1 | 4116 | Jeffco/ Lakewood/ CDOT | Hampden Avenue/Highway 285 | 38 | (1) 15.5-ft W by 6-ft H RCBC (Modified Drop Inlet) (7-ft W by 6-ft H RCBC at Throat) | 566 | --- | 2,277 | 1.9 | --- | --- | 1.50 | 5,529.32 | 5,529.00 | Overtopping | 5,529.00 | 1250 | NO |
| WC-2 | 4808 | Jeffco | Pedestrian Bridge | 37 | 90-ft Bridge (no piers) | 541 | --- | 2,177 | --- | 1.40 | 5,535.10 | --- | --- | 5,540.00 | Bridge FB | 5,535.10 | 2360 | YES |
| WC-2 | 5175 | Jeffco | Warrior Canal | 36 | 96-inch by 60-inch Elliptical CMP | 541 | 0.5 | 2,177 | 1.7 | --- | --- | 1.50 | 5,542.34 | 5,542.51 | HW:D | 5,542.34 | 335 | NO |
| WC-3 | 12144 | Jeffco | West Quincy Avenue | 32 | (1) 16-ft W by 7-ft H RCBC, (1) 16-ft W by 7.5-ft H RCBC (with 2 and 2.5-ft of fill) | 455 | --- | 1,865 | 1.4 | --- | --- | 1.50 | 5,608.75 | 5,608.53 | Overtopping | 5,608.53 | 1090 | NO |
| WC-4 | 13493 | Jeffco | Simms Street | 31 | (1) 12-ft W by 10-ft H RCBC<br>(1) 12-ft W by 9-ft H RCBC | 336 | --- | 1,488 | --- | --- | --- | 1.50<br>1.50 | 5,623.74<br>5,623.01 | 5,621.02 | Overtopping<br>Overtopping | 5,621.02<br>5,621.02 | 2700 | YES |
| WC-4 | 15686 | Jeffco | Pedestrian Bridge | 30 | 60-ft Bridge (no piers) | 273 | --- | 1,059 | --- | 1.25 | 5,652.48 | --- | --- | 5,652.83 | Bridge FB | 5,652.48 | 1090 | YES |
| WC-4 | 16809 | Jeffco | Pedestrian Walkway | 29 | (1) 36-inch RCP | 183 | 1.6 | 897 | 3.4 | --- | --- | 1.50 | 5,665.32 | 5,664.05 | Overtopping | 5,664.05 | 35 | NO |
| WC-4 | 18418.5 | Jeffco | South Youngfield Street | 28 | (2) 10-ft by 8-ft RCBC | 183 | --- | 897 | --- | --- | --- | 1.50 | 5,698.76 | 5,697.13 | Overtopping | 5,697.13 | 1995 | YES |
| WC-4 | 20048.5 | Jeffco | Cole Street | 27 | (1) 68-inch CMP<br>(1) 68-inch CMP | 165 | --- | 865 | 1.1 | --- | --- | 1.50<br>1.50 | 5,725.32<br>5,725.37 | 5,724.79 | Overtopping<br>Overtopping | 5,724.79<br>5,724.79 | 525 | NO |
| WC-4 | 22368 | Jeffco | Eldridge Street | 26 | (2) 10-ft W by 6-ft H RCBC | 89 | --- | 666 | --- | --- | --- | 1.50 | 5,768.17 | 5,770.50 | HW:D | 5,768.17 | 1430 | YES |
| WC-4 | 22725 | Jeffco/CDOT | C-470 | 25 | (1) 35-ft W by 6-ft H RCBC (Modified Drop Inlet) (16-ft W by 6-ft H RCBC at Throat) | 89 | --- | 666 | --- | --- | --- | 1.50 | 5,780.00 | 5,779.50 | Overtopping | 5,779.50 | 2085 | YES |
| WC-5 | 23092.5 | Jeffco | Quincy Avenue/Frontage Road | 24 | (1) 20-ft W by 8-ft H RCBC | 71 | --- | 589 | --- | --- | --- | 1.50 | 5,786.42 | 5,787.00 | HW:D | 5,786.42 | 2090 | YES |
| WC-5 | 23876.5 | Jeffco | Private Driveway | 23 | (1) 72-inch CMP | 71 | --- | 589 | 1.8 | --- | --- | 1.50 | 5,795.00 | 5,793.01 | Overtopping | 5,793.01 | 235 | NO |
| WC-5 | 25083 | Jeffco | Belleview Avenue | 21 | (1) 78-inch CMP | 69 | --- | 570 | 2.4 | --- | --- | 1.50 | 5,819.83 | 5,821.50 | HW:D | 5,819.83 | 355 | NO |
| WC-5 | 27217 | Jeffco | Belleview Avenue | 19 | (1) 74-inch CMP | 64 | --- | 510 | 3.5 | --- | --- | 1.50 | 5,872.80 | 5,869.28 | Overtopping | 5,869.28 | 300 | NO |
| WC-5 | 27889 | Jeffco | Private Driveway | 18 | (1) 72-inch CMP | 40 | --- | 373 | 0.4 | --- | --- | 1.50 | 5,883.13 | 5,882.79 | Overtopping | 5,882.79 | 305 | NO |
| WC-5 | 28475 | Jeffco | Belleview Avenue | 17 | (1) 72-inch CMP | 40 | --- | 373 | --- | --- | --- | 1.50 | 5,900.26 | 5,908.50 | HW:D | 5,900.26 | 290 | NO |
| WC-5 | 29117 | Jeffco | Private Driveway | 16 | (1) 6-ft by 3.7-ft Elliptical CMP | 40 | --- | 373 | 1.3 | --- | --- | 1.50 | 5,908.37 | 5,910.74 | HW:D | 5,908.37 | 140 | NO |
| WC-5 | 30106 | Jeffco | Crestbrook Drive | 15 | (1) 72-inch CMP | 33 | --- | 301 | --- | --- | --- | 1.50 | 5,938.44 | 5,941.55 | HW:D | 5,938.44 | 290 | NO |
| WC-5 | 31934 | Jeffco | Willowbrook Drive | 14 | (1) 36-inch RCP | 21 | --- | 201 | 1 | --- | --- | 1.50 | 5,997.97 | 6,003.68 | HW:D | 5,997.97 | 50 | NO |
| WC-5 | 32680 | Jeffco | Meadowbrook Drive | 13 | (1) 36-inch RCP | 21 | --- | 201 | 0.8 | --- | --- | 1.50 | 6,021.36 | 6,028.80 | HW:D | 6,021.36 | 50 | NO |
| WC-5 | 33285 | Jeffco | Colorow Drive | 12 | (1) 36-inch RCP | 21 | --- | 201 | 0.6 | --- | --- | 1.50 | 6,043.27 | 6,048.51 | HW:D | 6,043.27 | 50 | NO |
| WC-5 | 33586 | Jeffco | Pedestrian Bridge | 11 | 29.5-ft Bridge (1 pier) | 21 | --- | 201 | 0.1 | 0.60 | 6,056.96 | --- | --- | 6,056.48 | Overtopping | 6,056.48 | 180 | NO |
| WC-5 | 33711 | Jeffco | Pedestrian Bridge | 10 | 13-ft Bridge (no piers) | 21 | --- | 201 | --- | 0.77 | 6,062.11 | --- | --- | 6,062.48 | Bridge FB | 6,062.11 | 185 | NO |
| WC-5 | 33847 | Jeffco | Private Driveway | 9 | (1) 32-inch by 28-inch Elliptical CMP | 21 | --- | 201 | 0.8 | --- | --- | 1.50 | 6,068.25 | 6,070.00 | HW:D | 6,068.25 | 30 | NO |
| WC-5 | 33925 | Jeffco | Private Driveway | 8 | (1) 36-inch RCP | 21 | --- | 201 | 1.3 | --- | --- | 1.50 | 6,072.92 | 6,072.71 | Overtopping | 6,072.71 | 60 | NO |
| WC-5 | 34200 | Jeffco | Pedestrian Bridge | 7 | 19.5-ft Bridge (1 pier) | 21 | --- | 201 | 0.3 | 0.67 | 6,082.10 | --- | --- | 6,083.37 | Bridge FB | 6,082.10 | 50 | NO |
| WC-5 | 35411 | Jeffco | W Roton Arena | 6 | (1) 36-inch RCP | 19 | --- | 174 | 1.6 | --- | --- | 1.50 | 6,138.30 | 6,139.77 | HW:D | 6,138.30 | 55 | NO |
| WC-5 | 36308 | Jeffco | Willow Springs Drive | 5 | (1) 48-inch RCP (Modified Drop Inlet)<br>(1) 48-inch RCP (Modified Drop Inlet) | 16 | --- | 141 | --- | --- | --- | 1.50<br>1.50 | 6,191.46<br>6,191.35 | 6,189.00 | Overtopping<br>Overtopping | 6,189.00<br>6,189.00 | 240 | YES |
| WC-5 | 36383 | Jeffco | Golf Cart Path | 4 | (1) 24-inch ABS<br>(1) 36-inch Steel Pipe | 16 | --- | 141 | 2.2 | --- | --- | 1.50<br>1.50 | 6,195.34<br>6,197.08 | 6,194.97 | Overtopping<br>Overtopping | 6,194.97<br>6,194.97 | 50 | NO |
| WC-5 | 36651 | Jeffco | Golf Cart Path | 3 | (1) 36-inch Steel Pipe<br>(1) 36-inch Steel Pipe | 14 | --- | 121 | --- | --- | --- | 1.50<br>1.50 | 6,199.39<br>6,200.16 | 6,200.58 | HW:D<br>HW:D | 6,199.39<br>6,200.16 | 110 | NO |

1. Overtopping elevation based on lowest road elevation from the survey where water could overtop.

### 4.2 Flood Hazards

**Hydraulic Modeling General Approach**

The FHAD study limits of Weaver Creek encompass 7.4 miles of stream length, which generally slopes to the northeast with slopes ranging from 0.4 to 11 percent.

The U.S. Army Corps of Engineers' HEC-RAS River Analysis System, version 5.0.7 was used to evaluate both the floodplain and the infrastructure crossing structure capacities. Cross sections for HEC-RAS were developed electronically using 1-foot interval LiDAR data. Land survey data was collected at all major bridges, culverts, and drop structures. Cross section locations were set upstream and downstream of all crossings and drop structures, spaced no farther than 400 feet apart throughout long reaches, and were based on the LiDAR and survey data, described in Section 1.4. Bank stations were typically set at the low flow channel. To better represent existing conditions, survey data at crossing structures and drop structures was input into the model. The HEC-RAS cross sections are included in Appendix C.

Manning's "n" values were determined based on observations made during site visits and supplemented with aerial photography. The channel and bank roughness values ranged from 0.04 to 0.1. Areas that appeared to have short grasses were set to 0.04. Areas with longer grass and scattered trees were set to 0.045 to 0.05. Areas with thick trees and brush ranged from 0.06 to 0.08. Developed areas with privacy fence were set to 0.1. Photos illustrating the Manning's "n" values for sample reaches are shown below. A table of Manning's "n" values for all cross sections is included in Table C-1, in Appendix C.

Channel Manning's "n" = 0.05
Overbank Manning's "n" = 0.05-0.1

Channel Manning's "n" = 0.05
Overbank Manning's "n" = 0.04-0.045

Channel Manning's "n" = 0.07
Overbank Manning's "n" = 0.05

**Structure Modeling Approach**

Considerable attention was given to each location in determining appropriate modeling techniques. Photos of the major crossing structures that were surveyed are included in Appendix C. The general modeling techniques used at the structures are summarized below.

- The floodplain analysis and mapping assumed no clogging at the crossing structures.
- Cross section orientation – At the road crossing structures, cross sections were oriented perpendicular to the channel. Survey data was used to input the crossing structures so that bridge openings were not exaggerated at skewed crossings.
- Ineffective flow area contraction and expansion ratio ranges – In general, a 1:1 contraction ratio and a 3:1 expansion ratio were used to determine ineffective areas upstream and downstream of crossings, respectively. The skewed crossings required special consideration to determine reasonable ineffective areas.
- Contraction and Expansion coefficients – The contraction coefficient was changed from the default value of 0.1 to 0.3 and the expansion coefficient was changed from the default value of 0.3 to 0.5 at the upstream and downstream bounding cross section of all major crossing structures, in accordance with the HEC-RAS manual. The increased expansion and contraction coefficients better represent losses from the change in effective flow area as the channel transitions to and from the crossing.
- Ineffective flow areas – Ineffective flow area elevations upstream of crossing structures were typically set 0.1 foot below the top of roadway. Ineffective flow area elevations downstream of crossing structures were set between the pipe crown/bridge low chord elevation and the top of roadway elevation to more accurately model roads that overtop. Some ineffective areas were modified to increase model stability or better represent the crossing.
- HEC-RAS "Bridge Modeling Approach" – HEC-RAS contains numerous options to model each crossing within the "Bridge Modeling Approach" form. If piers existed on bridges, the pier information and coefficients were input into the momentum and Yarnell equations and the highest energy answer was selected. This approach applies only to low flow methods. Pressure and/or weir flow was selected for high flows.

**Modified Inlet Culverts and Set Internal Water Surface Elevations**

Weaver Creek contains four culverts with modified drop inlets:

- Cross Section 36354 – The Willow Springs Drive culverts are 48-inch broken back culverts initially dropping at a 45-degree angle and then flattening to a 0.3 percent slope.
- Cross Section 22881 – The C-470 culvert has a face opening that is 34.8-feet by wide by 6-feet high and constricts and drops in elevation to a 16-foot wide by 6-foot high concrete culvert at the throat.
- Cross Section 4339 – The Hampden Avenue/Highway 285 culvert has a face opening that is 15.5-feet by wide by 6-feet high and constricts and drops in elevation to a 7-foot wide by 6-foot high concrete culvert at the throat.
- Cross Section 873 – The Dartmouth Avenue culverts have face openings that are 22.5-feet by wide by 9.2-feet high and constricts and drops in elevation to be 14-foot wide by 6-foot high concrete culverts at the throat.

A separate hydraulic analysis of each of these structures was completed to model the water surface elevations more accurately. Set water surface elevations, based on the outside analysis, were then input into the HEC-RAS model at the cross sections noted above. Calculations for the modified inlets are included in Appendix C. FHWA nomographs (FHWA, 2012) were used to check for face control conditions or throat control conditions for the slope tapered inlets. The resultant headwater depths of the controlling condition were compared to critical depth at the upstream cross section of the culverts in HEC-RAS.

Each culvert was input in HEC-RAS with the culvert invert set to the inlet elevation. The Highway 285 culvert was not modeled in HEC-RAS, rather a rating curve for the overtopping flow was developed using outside calculations and input as a set water surface elevation. The culverts use Chart 59 in HEC-RAS, which contains a slope tapered inlet option and refers to Federal Highway Administration (FHWA) charts from *Hydraulic Design of Highway Culverts, Hydraulic Design Series Number 5* (FHWA, 2012). It was assumed that the culvert face was not beveled.

### Spill Modeling Approach

During the major storm event, Weaver Creek will spill in four locations and will also spill into streets that were not modeled in HEC-RAS in four additional locations. The four main spills were modeled as separate reaches in HEC-RAS. The 285 Overflow reach contains two additional spills. The spills were quantified using different methods, as described in this section. The spill flows are summarized in Table 12. The full flow was used for main channel calculations downstream of the spill locations.

#### Willow Spill

Weaver Creek will overtop Willow Springs Drive during the major storm event. The water in the left overbank of cross section 36360, upstream of the crossing, was assumed to be the amount of water spilling.

#### Belleview Spill

Weaver Creek will spill at the downstream most Belleview crossing. The cross section contains the extent of the floodplain. The flow in the right overbank of cross section 25121 was assumed to be the amount of water spilling. Water will flow along the south side of Belleview Avenue, eventually overtopping Belleview Avenue and joining Weaver Creek downstream of the Private Driveway crossing. A small swale on the south side of Belleview will convey some water out of the system, as described in the Additional Street Spills section. The right bank was moved to elevation 5823.64 in the model to estimate the spill flow, in a separate model run. The results are summarized in Table 12 and included in Appendix C.

#### Spill 2

A spill will also occur in Fehringer Ranch Park. The flow in the left overbank of cross section 10166 was assumed to be the amount of water spilling. The left bank was moved to elevation 5590.79 in the model to estimate the spill flow, in a separate model run. The results are summarized in Table 12 and included in Appendix C.

#### 285 Overflow

The overtopping flow at Highway 285 was modeled with the 285 Overflow reach. The reach models the overland flow path. Water will initially flow to the low area between Highway 285 and W Hampden Avenue. Flow will then split, with most of the flow continuing north and rejoining Weaver Creek, downstream of the crossing. The flow split to the east was quantified using a lateral structure. The weir flow was then input into the Kipling St Spill reach.

The Kipling St Spill reach follows the spill flow path east along the Highway 285 off ramp and then turns north along Kipling Street. At the intersection of W Girton Avenue and Kipling Street, flow splits again. Sump inlets convey water to a channel that returns to Weaver Creek. For this analysis, the inlets were considered clogged, and only flows that overtopped the high ground were routed to the swale, which returns to Weaver Creek. The spill flow is 10 cfs and 19 cfs for the 100-year and 500-year events, respectively. Normal depth was calculated for the swale, included in Appendix C, and the average depth is less than 1 foot. The swale was mapped as shallow flooding. The flow was not removed for the downstream analysis. At the north end of the Kendall Reservoir, flows begin to return to Weaver Creek, sheet flowing down the bank. The flows returning to Weaver were quantified using a lateral structure, and a flow change was added at cross section 80162. At the intersection of W Dartmouth Avenue and Kipling Street, a flow split occurs, as described in the Additional Street Spills section.

#### Additional Spills

Weaver Creek spills into the road at South Miller Court (from upstream of the Warrior Canal), into the parking lot at the Pheasant Creek Townhomes, along Belleview form the Belleview Spill reach, and north along Kipling Street from the Kipling St Spill reach. Weaver Creek also spills into a north drainage channel upstream of the pedestrian crossing near Swarthmore Avenue. At S Van Gordon Way and W Radcliff Ave, Weaver Creek does not spill, but the high ground between the creek and the roads acts as a non-levee embankment. The calculations are included in Appendix C.

- At South Miller Court the amount spilling was based on right overbank flow of cross section 5270. The right overbank flow at cross section 5270 was measured as the flow above elevation 5443, which is the elevation at which the spill would occur. The bank was moved in a separate model run to estimate this flow. The floodplain was mapped based on the depth of water calculated using the street capacity section of UD-Inlet v. 4.05. Normal depth was calculated using FlowMaster to verify the shallow flooding area and was less than 1 foot. The area was mapped as shallow flooding.

- Just upstream of the large baffle drop, at cross section 1734, Weaver Creek spills into the parking lot at the Pheasant Creek Townhomes in the 100- and 500-year events. The spills were estimated by calculating the discharge in FlowMaster based on the water surface elevations calculation in HEC-RAS at cross section 1734. Normal depth was calculated at four locations through the parking lot, and the floodplain was mapped based on the results. The depths at the four locations analyzed is less than 1 foot. The area was mapped as shallow flooding.

- A small swale on the south side of Belleview along the Belleview Spill reach will convey some water out of the system. The flow leaving was estimated based on a normal depth calculation based on the swale capacity, calculated using FlowMaster. Approximately 2.5 cfs flows out of the system, along Belleview Avenue in the 100- and 500-year events. The minor flows are conveyed by the local drainage system and further analysis was not warranted. The flow was not removed for calculations downstream.

- At the intersection of W Dartmouth Avenue and Kipling Street, a flow split occurs with most flow returning to Weaver Creek and some flow continuing along Kipling Street, leaving the system. The flow in Kipling street will continue north, ultimately reaching Bear Creek. Kipling Street has capacity for the remaining flow and the spill was not mapped. The capacity calculations, completed in UD-Inlet v. 4.05, are included in Appendix C.

- At the pedestrian crossing near Swarthmore Avenue, Structure 30, Weaver Creek spills into the drainage channel that is located north of the creek upstream of the bridge and then re-enters Weaver Creek through a culvert downstream of the bridge. The spill was quantified by looking at the flow in the left overbank of cross section 15758 when the bank is set at the top of the Weaver Creek channel, Station 403.80, Elevation 5653.99. A total of 0.2 cfs will spill in the 100-year storm event. The 500-year floodplain encompasses this area and was not quantified at this location. The spill flow was not subtracted from the overall Weaver Creek flow.

- At S Van Gordon Way (cross sections 15937 through 16323) and W Radcliff Ave (cross sections 13709 through 14475), the high ground between Weaver Creek and the streets acts as a non-levee embankment. While the creek does not spill in the 100-year at these locations, the street capacities were analyzed. The streets have capacity for the potential overbank flow at a flow depth of 12-inches at the flowline. The overbank flow was estimated by changing the left bank at cross sections 15937 and 13970 to station 292.63 and 250.28, respectively. Since the flow depth is less than 1-foot, the streets were mapped within the 500-year but excluded from the 100-year mapping.

***Table 12. Spill Flow Summary***

| Spill Location | Spill Flow Source (Program) | RAS Node/XS | Q (cfs) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 10-YR | 25-YR | 50-YR | 100-YR | 500-YR |
| **Spill Reaches** | | | | | | | |
| Willow Springs Drive | HEC-RAS[1] | 36360 | 7 | 50 | 76 | 117 | 197 |
| Belleview | HEC-RAS[1] | 25121 | -- | -- | -- | 33 | 148 |
| Spill 2 (Fehringer Ranch Park) | HEC-RAS[1] | 10166 | -- | 3 | 38 | 192 | 775 |
| 285 Overflow | Rating Curve (nomographs & HY-8) | -- | -- | 362 | 736 | 1259 | 2401 |
| Kipling Street Spill | HEC-RAS[1] | 70220 | -- | 122 | 227 | 317 | 489 |
| **Spills into Streets** | | | | | | | |
| South Miller Court | HEC-RAS[1] | 5270 | -- | 2 | 5 | 13 | 36 |
| Parking Lot | FlowMaster | 1734 | -- | -- | -- | 69 | 450 |
| **Out of System Spills** | | | | | | | |
| Belleview Swale | FlowMaster | -- | -- | -- | -- | 3 | 3 |
| Kipling Street | HEC-RAS[1] | 80162 | -- | 26 | 61 | 88 | 122 |

[1]Results from the HEC-RAS plan titled *2 - Weaver Creek Spill Quantification*

## Shallow Flooding

An additional area of shallow flooding (depth 2-foot) was mapped along Crestbrook Drive, between W Roton Arena driveway and the pedestrian bridge (crossing 7). The shallow flooding area was mapped downstream of cross section 34340 since that is the last cross section in which the channel BFE is higher than the overbank. The shallow flooding depth was based on the depth of the ineffective flow in the right overbank of cross sections 34340 and 34374.

## Detention Pond Mapping

Hydraulically connected ponds were mapped as floodplains without base flood elevations, encompassing the entire footprint of the pond.

## Boundary Conditions

The Bear Creek 10-year water surface elevation at the Weaver Creek confluence was not available; therefore, the normal depth boundary condition with a 0.005 ft/ft slope, which represents the Bear Creek slope, was used for Weaver Creek.

## Floodway Modeling Approach

A 0.5-foot floodway analysis was completed for Weaver Creek. The existing conditions HEC-RAS model of 100-year future flow was used as the basis for the 100-year floodway model. The floodway was modeled using Method 1, and encroachments were set at or between the bank stations and the 100-year floodplain water surface elevation stations. Encroachments were typically set in a way that would allow for smooth floodway transitions when mapping.

At cross-sections where floodplain was equal to floodway negative surcharges in the HGL and EGL were typical. Per discussions with MHFD, negative surcharges up to -0.04 were left in the model where they resulted from setting encroachments at the floodplain limits. Encroachment stations were kept in the model where defining encroachments at the floodplain limits did not result in negative surcharges.

When mapping the floodway, the general shape followed Weaver Creek centerline geometry while avoiding necking and providing a smooth transition from embankment to embankment between cross-sections.

## Drainage Problems

Problem areas as determined by the hydraulic model are shown in Figure 2, included at the end of this section. The following flood hazards are described as they relate to the future peak flows (future land use, existing infrastructure). Only major road crossings are listed below.

Hampden Avenue/Highway 285 is overtopped during the 25-year storm event.

Warrior Canal is overtopped during the 5-year storm event, which could potentially lead to flooding along the canal.

Quincy Avenue is overtopped during the 50-year storm event. The crossing only has slightly more capacity than the 25-year storm event.

Cole Street is overtopped in the 50-year storm events. Jefferson County has received complaints of flooding at the Cole Street crossing for many years. This is most likely due to the large amount of sediment that has filled in the culverts. The capacities were evaluated assuming a clean condition. The pedestrian trail crossing at Weaver Hollow Park (crossing 29) is overtopped in the 2-year storm event.

Water spills onto Belleview Avenue at two locations, crossings 19 and 21. Approximately 33 cfs in a 100-year storm event spills out of the channel at crossing 21. The golf cart path (crossing 4), and several private driveways (crossings 8, 9, and 23) are overtopped in the 25-year storm event. Belleview Avenue (crossing 19), W Roton Arena driveway, Colorow Drive, Meadowbrook Drive, Willowbrook

Drive, and a private driveway (crossing 16) are overtopped in the 50-year storm event. Belleview Avenue (crossing 21) and pedestrian crossings 7 and 18 are overtopped in the 100-year storm event. Crestbrook Drive, Belleview Avenue (crossing 17), pedestrian crossing 10, and golf cart crossing 3 are not overtopped in the 100-year storm event, but do not meet local criteria.

A total of 14 insurable structures are in the FHAD 100-year floodplain, as shown on the floodplain map in Appendix E.

**Erosion Analysis**

Maximum allowable shear stresses for various types of channel materials were taken from the USDA Agricultural Handbook No. 667 and are shown in Table 13.

***Table 13 - Maximum Permissible Shear Stress (USDA's AG HBK 667)***

| Channel Material Class | Veg. Height | Max. Permissible Shear ($lbs/ft^2$) | |
|---|---|---|---|
| | | Short Duration | Long Duration |
| A | >24" | 7.5 | 7.5 |
| B | 12"-24" | 5.73 | 5.73 |
| C | 6"-12" | 4.2 | 4.2 |
| D | 2"-6" | 3.33 | 3.33 |
| E | <2" | 2.16 | 2.16 |
| Riprap | --- | (4xD50) | (4xD50) |
| Concrete | --- | 100 | 100 |

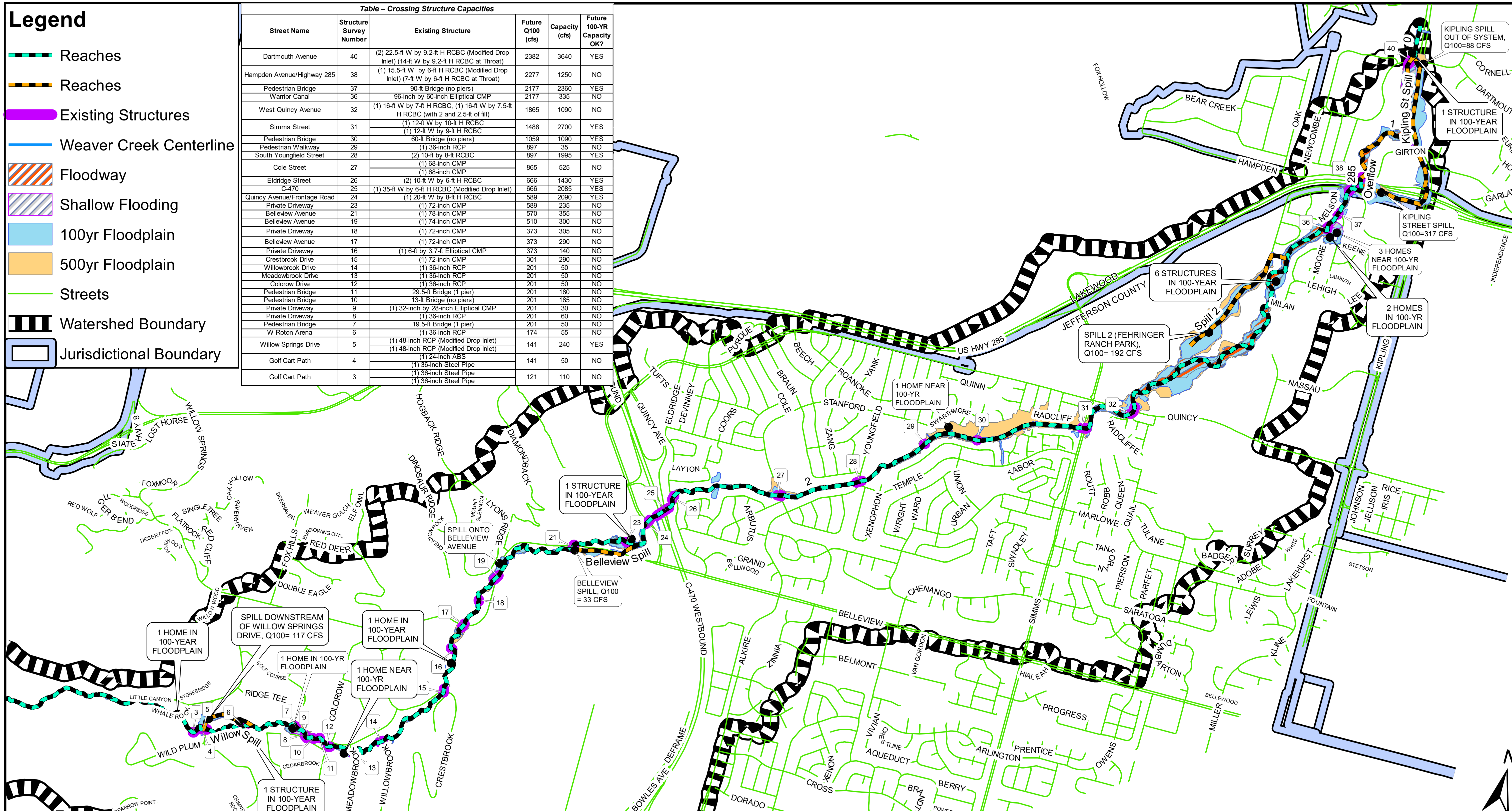
The short and long duration values are the same. The HEC-RAS data was used to determine the shear stresses at each cross section for the future land use 100-year storm event. High shear stresses are present at several locations. Typically, the highest shear stresses are located at drop structures and at road crossings, where the water backs up as a result of the road embankment. Steeper reaches will also have higher shear stresses. The shear stresses for the major storm are high in many areas, due to the steep longitudinal slope of the channel. The channel is more stable in the minor storm events, with the high shear stresses located at drop structures.

**Water Quality Analysis**

No regional water quality facilities are located in the watershed.

### 4.3 Previous Analysis

The effective floodplain is based on the 1981 FHAD which utilized HEC-2 for the hydraulic analysis. A Letter of Map Revision (LOMR) has been completed near C-470, along Weaver Creek. The LOMR utilized HEC-RAS for the hydraulic analysis. The FIRMs show a FEMA-designated Zone AE floodplain on Weaver Creek from the upstream limit, west of Whale Rock Way, to just downstream of U.S. 285. A Zone A floodplain is shown downstream of U.S. 285 to the confluence with Bear Creek. The spills from Weaver Creek, located at W. Belleview Avenue, W. Saratoga Place, and W. Quincy Avenue are mapped as Zone AO floodplains. The FEMA FIRM panels are included in Appendix C. The effective floodplains and existing infrastructure floodplains developed for this study for both the existing land use (existing) and future land use (FHAD) conditions are shown on Figure C-1, in Appendix C. A total of 14 insurable structures are in the FHAD 100-year floodplain, as compared to a total of 92 in the effective Zone AE 100-year floodplain and 20 in the effective Zone AO 100-year floodplain.




## Legend

- Reaches
- Reaches
- Existing Structures
- Weaver Creek Centerline
- Floodway
- Shallow Flooding
- 100yr Floodplain
- 500yr Floodplain
- Streets
- Watershed Boundary
- Jurisdictional Boundary

*Table – Crossing Structure Capacities*

| Street Name | Structure Survey Number | Existing Structure | Future Q100 (cfs) | Capacity (cfs) | Future 100-YR Capacity OK? |
|---|---|---|---|---|---|
| Dartmouth Avenue | 40 | (2) 22.5-ft W by 9.2-ft H RCBC (Modified Drop Inlet) (14-ft W by 9.2-ft H RCBC at Throat) | 2382 | 3640 | YES |
| Hampden Avenue/Highway 285 | 38 | (1) 15.5-ft W by 6-ft H RCBC (Modified Drop Inlet) (7-ft W by 6-ft H RCBC at Throat) | 2277 | 1250 | NO |
| Pedestrian Bridge | 37 | 90-ft Bridge (no piers) | 2177 | 2360 | YES |
| Warrior Canal | 36 | 96-inch by 60-inch Elliptical CMP | 2177 | 335 | NO |
| West Quincy Avenue | 32 | (1) 16-ft W by 7-ft H RCBC, (1) 16-ft W by 7.5-ft H RCBC (with 2 and 2.5-ft of fill) | 1865 | 1090 | NO |
| Simms Street | 31 | (1) 12-ft W by 10-ft H RCBC<br>(1) 12-ft W by 9-ft H RCBC | 1488 | 2700 | YES |
| Pedestrian Bridge | 30 | 60-ft Bridge (no piers) | 1059 | 1090 | YES |
| Pedestrian Walkway | 29 | (1) 36-inch RCP | 897 | 35 | NO |
| South Youngfield Street | 28 | (2) 10-ft by 8-ft RCBC | 897 | 1995 | YES |
| Cole Street | 27 | (1) 68-inch CMP<br>(1) 68-inch CMP | 865 | 525 | NO |
| Eldridge Street | 26 | (2) 10-ft W by 6-ft H RCBC | 666 | 1430 | YES |
| C-470 | 25 | (1) 35-ft W by 6-ft H RCBC (Modified Drop Inlet) | 666 | 2085 | YES |
| Quincy Avenue/Frontage Road | 24 | (1) 20-ft W by 8-ft H RCBC | 589 | 2090 | YES |
| Private Driveway | 23 | (1) 72-inch CMP | 589 | 235 | NO |
| Belleview Avenue | 21 | (1) 78-inch CMP | 570 | 355 | NO |
| Belleview Avenue | 19 | (1) 74-inch CMP | 510 | 300 | NO |
| Private Driveway | 18 | (1) 72-inch CMP | 373 | 305 | NO |
| Belleview Avenue | 17 | (1) 72-inch CMP | 373 | 290 | NO |
| Private Driveway | 16 | (1) 6-ft by 3.7-ft Elliptical CMP | 373 | 140 | NO |
| Crestbrook Drive | 15 | (1) 72-inch CMP | 301 | 290 | NO |
| Willowbrook Drive | 14 | (1) 36-inch RCP | 201 | 50 | NO |
| Meadowbrook Drive | 13 | (1) 36-inch RCP | 201 | 50 | NO |
| Colorow Drive | 12 | (1) 36-inch RCP | 201 | 50 | NO |
| Pedestrian Bridge | 11 | 29.5-ft Bridge (1 pier) | 201 | 180 | NO |
| Pedestrian Bridge | 10 | 13-ft Bridge (no piers) | 201 | 185 | NO |
| Private Driveway | 9 | (1) 32-inch by 28-inch Elliptical CMP | 201 | 30 | NO |
| Private Driveway | 8 | (1) 36-inch RCP | 201 | 60 | NO |
| Pedestrian Bridge | 7 | 19.5-ft Bridge (1 pier) | 201 | 50 | NO |
| W Roton Arena | 6 | (1) 36-inch RCP | 174 | 55 | NO |
| Willow Springs Drive | 5 | (1) 48-inch RCP (Modified Drop Inlet)<br>(1) 48-inch RCP (Modified Drop Inlet) | 141 | 240 | YES |
| Golf Cart Path | 4 | (1) 24-inch ABS<br>(1) 36-inch Steel Pipe | 141 | 50 | NO |
| Golf Cart Path | 3 | (1) 36-inch Steel Pipe<br>(1) 36-inch Steel Pipe | 121 | 110 | NO |

PROJECT: 016-0858

DRAWN BY: MD

DATE: 11/2021

**MILE HIGH FLOOD DISTRICT, JEFFERSON COUNTY, AND CITY OF LAKEWOOD**

**WEAVER CREEK FHAD DRAINAGE AREA PROBLEMS**

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FIGURE 2

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