1.0 HYDROLOGY

This section describes model development and analysis performed to estimate hydrologic runoff within the Jimmy Camp Creek Drainage Basin. Developing representative and appropriate hydrologic inflows on both a sub-basin and basin-wide level have a direct influence on correctly selecting and sizing stormwater management alternatives. The objective of the hydrologic analysis is to produce a defensible approach to rainfall/runoff modeling that both the County and the development community accept moving forward.

Development of hydrologic flows for the Jimmy Camp DBPS were performed using the Environmental Protection Agency's (EPA's) Storm Water Management Model (SWMM) 5 (version 5.1.015). Model development, scenario management, and model execution was performed using the Innovyze InfoSWMM software (version 14.7, Update #6). Final model deliverables are provided in the SWMM 5 software. The hydrologic modeling methods and parameters are described in this report. Hydraulic routing of runoff for use in the hydraulic model is also executed using SWMM 5 methods, which are also described in this report.

1.1 PURPOSE OF HYDROLOGIC ANALYSIS

The hydrologic analysis for the Jimmy Camp Creek DBPS provides an estimate of the drainage basin's runoff and peak flow response to the 2-, 5-, 10-, 25-, 50- and 100-year recurrence interval rainfall events. The hydrologic methods applied in this DBPS involved developing suitable GIS based surface and subsurface model parameters based on various applicable documentation, including:

- Drainage Criteria Manual County of El Paso, Colorado (El Paso County, downloaded April 2021)
- City of Colorado Springs Drainage Criteria Manual (DCM) (Colorado Springs, 2014, 2020)
- EPA SWMM Reference Manual (EPA, 2016)
- Mile High Flood District (MHFD) (formally Urban Drainage and Flood Control District [UDFCD]) Urban Storm Drainage Criteria Manual (MHFD, 2016)

The purpose of the Jimmy Camp Creek DBPS hydrologic analysis is to develop peak flows for planning and design based on current conditions in the basin. The results of the hydrologic analysis feed into the hydraulic analysis portions of this DBPS. As such, peak flows are developed for key design points along the Jimmy Camp Creek main stem and the tributary channels within the Jimmy Camp Creek Drainage Basin. Hydraulic routing was also included in the hydrologic analysis to determine peak flows at key points in the Jimmy Camp Creek Drainage Basin for use in the hydraulic analysis.

SWMM 5 model construction was performed using GIS tools to improve efficiency and apply standardized and reproducible methods for determining model input parameters. SWMM 5 methods are used to simulate both hydrologic runoff from individual sub-basins and hydraulic routing through sub-basins to Jimmy Camp Creek and its major tributaries. Detailed hydraulic modeling and analysis along Jimmy Camp Creek and its tributaries are completed using the USACE HEC-RAS model as described in ____. This involves developing simulated water surface elevations and flood potential using the peak flows developed from the SWMM 5 model results.

1.2 DATA SOURCES USED IN HYDROLOGIC ANALYSIS

The hydrology for this DBPS was generated using the best available information provided by the County and acquired from public sources. Sources of information and their use include the data listed below.

2018 LiDAR Topography – 2018 LiDAR Digital Elevation Model (DEM), two-foot by two-foot square, provided by El Paso County.
2020 El Paso County Aerial Photography (received April 2021) – Aerial photography provided by the County in single raster dataset with a resolution of 1 foot by 1 foot (square).
Soil Survey Geographic (SSURGO) Soil Data – The United States Department of Agriculture (USDA) National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database was used to develop soil-based infiltration parameters.
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
NOAA Atlas 14 Rainfall Data – National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States was used for the source of design rainfall depths (Perica et al., 2013).
http://hdsc.nws.noaa.gov/hdsc/pfds
County GIS Database – County GIS database, *DPW_data.gdb*, provided on April 16, 2021 contained the feature classes listed below.

Bridge
Channel
Culvert _Ln
Culvert_pts
CityLimits
Dentention_Ponds
EPC_Roads
Inlet
Junction
Outfall
ROW
StormPipe

County GIS Shapefiles (provided on April 16, 2021) – Floodplains.shp, Lakes.shp, Parcels.shp, WaterLine.shp, and Wetlands.shp
County Provided Existing and Future Impervious Percentage GIS File (provided on July 24, 2021) – Future_LUse_JCC_SubBasins feature class
County Field Data for Crossing Information (provided on November 29, 2021) – JCC_missing_crossing_data_locations_EPC.doc
Colorado Department of Transportation (CDOT) Inspection Structures – Used for determining the structure size of various crossings
Pond Design Plan and As-Built Information – Design plan information was available for the West Fork in Channel Pond for the Glen at Widefield Subdivision (Kiowa, 2008).

County GIS Data (Downloaded) – Parcel, major highway, parks, zoning, and land use data.

1.3 HYDROLOGIC METHODS

Hydrologic and hydraulic modeling and system analyses follow the guidelines and criteria set forth in the Drainage Criteria Manual Volume 1 of El Paso County and the City of Colorado Springs DCM for SWMM 5, with the SWMM 5 model use approved by the County. Runoff hydrographs and associated peak flows were developed using the EPA SWMM Nonlinear Reservoir Method (Runoff Method) as described in the SWMM Reference Manual (EPA, 2016). This method provides for a detailed hydrologic representation of the watershed and flexibility when used for both event-based and continuous simulation. By using the runoff method, the model can be directly applied to design storms of various durations and temporal distributions. The Runoff Method is used in conjunction with Horton's method for modeling infiltration. The hydrology methods and parameters are described in the subsequent sections.

1.4 SUB-BASIN DISCRETIZATION

One of the key tasks in building a hydrologic model is to divide the study area into relatively homogeneous sub-basins and allocate flows from individual sub-basins to their respective conveyance element. In addition, the spatial arrangement between these sub-basins needs to represent ground conditions. Sub-basins were delineated to outlets (design points) within the conveyance channels, with sub-basin areas generally developed to be about 160 acres in size.

1.5 SUB-BASIN DELINEATION

Sub-basins were delineated for design points along the open channels within the project area at key locations and key land features (roads, railroads, ditches, etc.) based on both existing and proposed conditions. Sub-basin outfalls and design points correspond to any location along open channels where existing and future facilities require evaluation, including where there are pipes greater than 60-inches in diameter and at major roadway crossings.

Sub-basin boundaries were based on the 1-foot contours, aerial photography, the County's culvert GIS database, and the County's GIS storm sewer database. Sub-basins were delineated, to the extent practicable, based on maintaining consistent size, shape, and slope throughout the area. Delineations were made to design points on the main channels, with the intent of keeping the size to be about 160 acres. Considerations were made for having relatively homogenous land uses within each sub-basin so that basin parameters and resulting runoff response were correctly represented. Experience has shown that a sub-basin containing both developed and open space land uses will under-predict the runoff rates of the developed areas and over-predict the runoff rates from the open space. The same consideration was also made with soil types such that sub-basins have uniform soils to correctly estimate infiltration response. However, deviations to the above considerations were necessary, with some basins being larger due to the need for flow routing (such that there is a sufficiently channelized flow route to develop cross-sections) and some basins being smaller due to the convergence of tributaries or the requirement to add a design point.

Figure 1-1 presents the major subbasins developed for this DBPS. A detailed subbasin map is included in Appendix __.

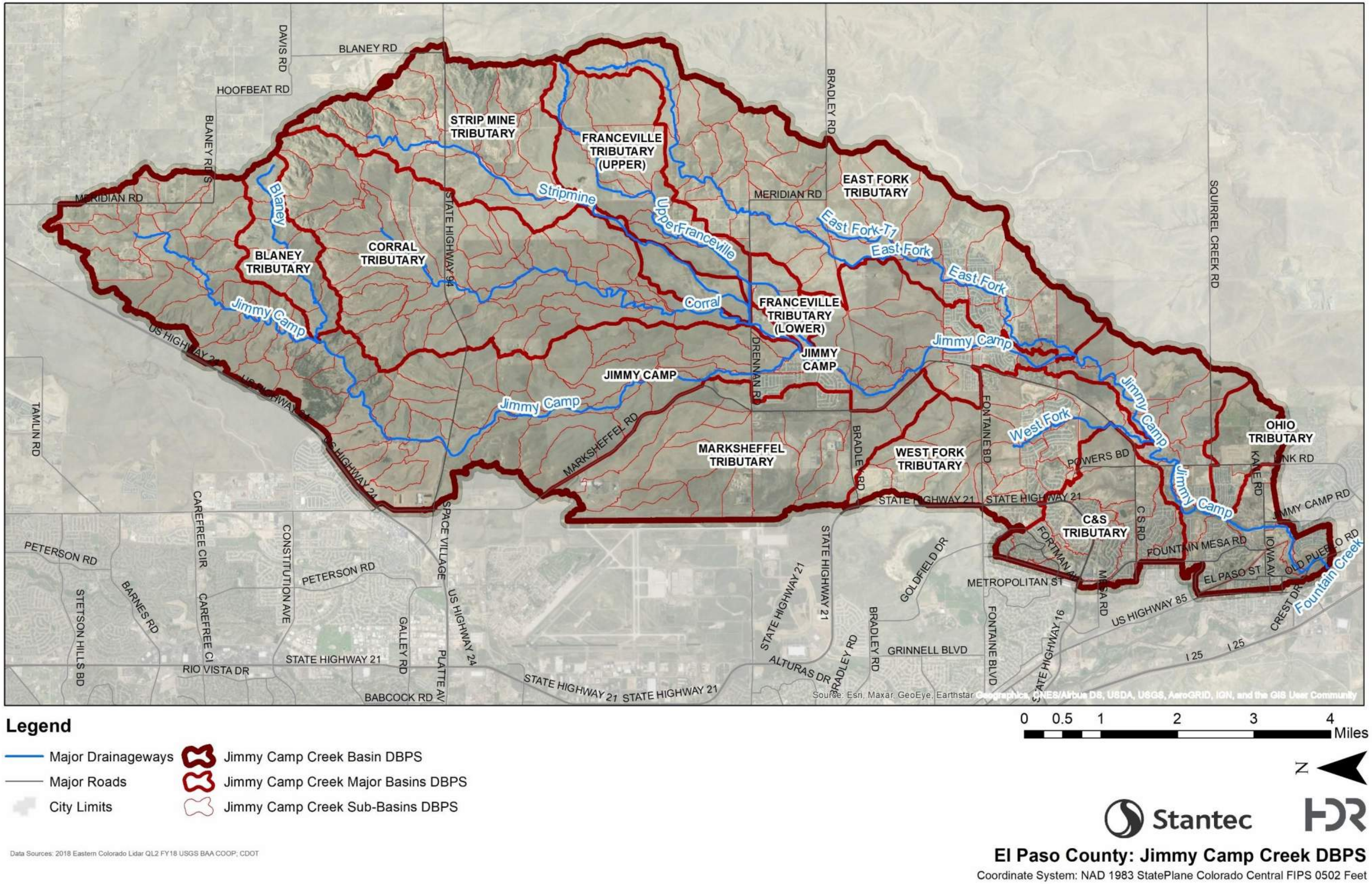


Figure 1-1. Sub-basin Map

1.6 SUB-BASIN NAMING CONVENTION

The SWMM model element naming was based on a convention that starts with the sub-basin names, with model nodes and then model links named accordingly to tie back to the sub-basins. Sub-basins were labeled systematically, with the labeling associating the sub-basins with their corresponding channel main stems and tributaries. Sub-basins, design points, and conveyance elements were labeled systematically and consistently to the greatest extent practical to represent their relation to each other. Sub-basins were then grouped and labeled based on their connection to the channel main stems or tributaries to identify major sub-basins. The general approach in naming modeling elements is provided in the following sections.

1.6.1 Sub-basin Naming

Sub-basin naming is based on the branch names and abbreviations. Sub-basins within each branch are then named consecutively starting from the downstream end. Sub-basins are named based on the first letter of the branch name.

<u>Example:</u> If the branch is the Franceville Tributary, then the most downstream sub-basin to this branch is *F1_1*, with the next upstream being *F1_2*.

If two sub-basins drain to the same location, then the sub-basin's location in relation to the channel is added to the number. If there are more than two sub-basins contributing to a design point, then additional compass directions are used.

<u>Example:</u> On the East Fork Tributary (E1) there is an additional small tributary (T1) that has another additional small tributary (3E). The two most upstream sub-basins go to the same design point. These sub-basins are therefore named *E1-T1_3E_N* and *E1-T1_3E_S*.

1.6.2 Model Node Naming

Model node names used the sub-basin names as a base. If a node is a design point serving as an outfall to a corresponding sub-basin(s), the runoff node starts with a designation of DSNPT_ followed by the sub-basin name. If there are multiple sub-basins to a design point, the compass direction is not included in the node name.

Intermediate nodes are locations between design points that help describe conveyance geometry, including open channels and road crossings. Intermediate nodes are labeled with consecutive numbers along that reach to the next design point. If the node is a channel point, it is labeled with a CH. Nodes upstream and downstream of culverts are considered channel points.

<u>Example:</u> Assume the branch is identified as J2. If there are two channel section changes upstream of a design point, the naming would be: *DSNPT_J2*, *CH1_J2*, and *CH2_J2*.

1.6.3 Model Link Naming

Model link names are based on the upstream node name and the conveyance element type. The following examples assume the link is the first node upstream of a design point in sub-basin J1_1. The node is a channel section change (CH1).

Natural channels: NAT-

Example: NAT-CH1_ J1_1

Trapezoidal channels: TRAP-

Example: TRAP- J1_1

Circular culverts: CUL-

Example: CUL- J1_1

Box culverts: BOX-

Example: BOX- J1_1

1.7 SUB-BASIN PERCENT IMPERVIOUSNESS

The County provided both existing and future impervious estimates for the Jimmy Camp Creek DBPS. These feature classes provided complete coverage across the DBPS area, based on the El Paso County Master Plan (El Paso County, 2021), and were the basis for both existing and future percent imperviousness estimations used for the DBPS modeling. The resulting existing impervious coverage, or "hydrologic land use", is presented in Figure 1-2. The percent imperviousness feature class was intersected with the sub-basins in GIS and an area weighted impervious percentage was calculated for each sub-basin. For sub-basins that are in a current developed state, percent imperviousness values were increased slightly by 5 percent based on impervious calculation performed for the Sand Creek 2021 DBPS for developments of similar densities (City of Colorado Springs, 2021). Directly connected impervious areas (DCIAs) were not evaluated separately from the percent imperviousness calculations described above given the planning level nature and scale of this DBPS.

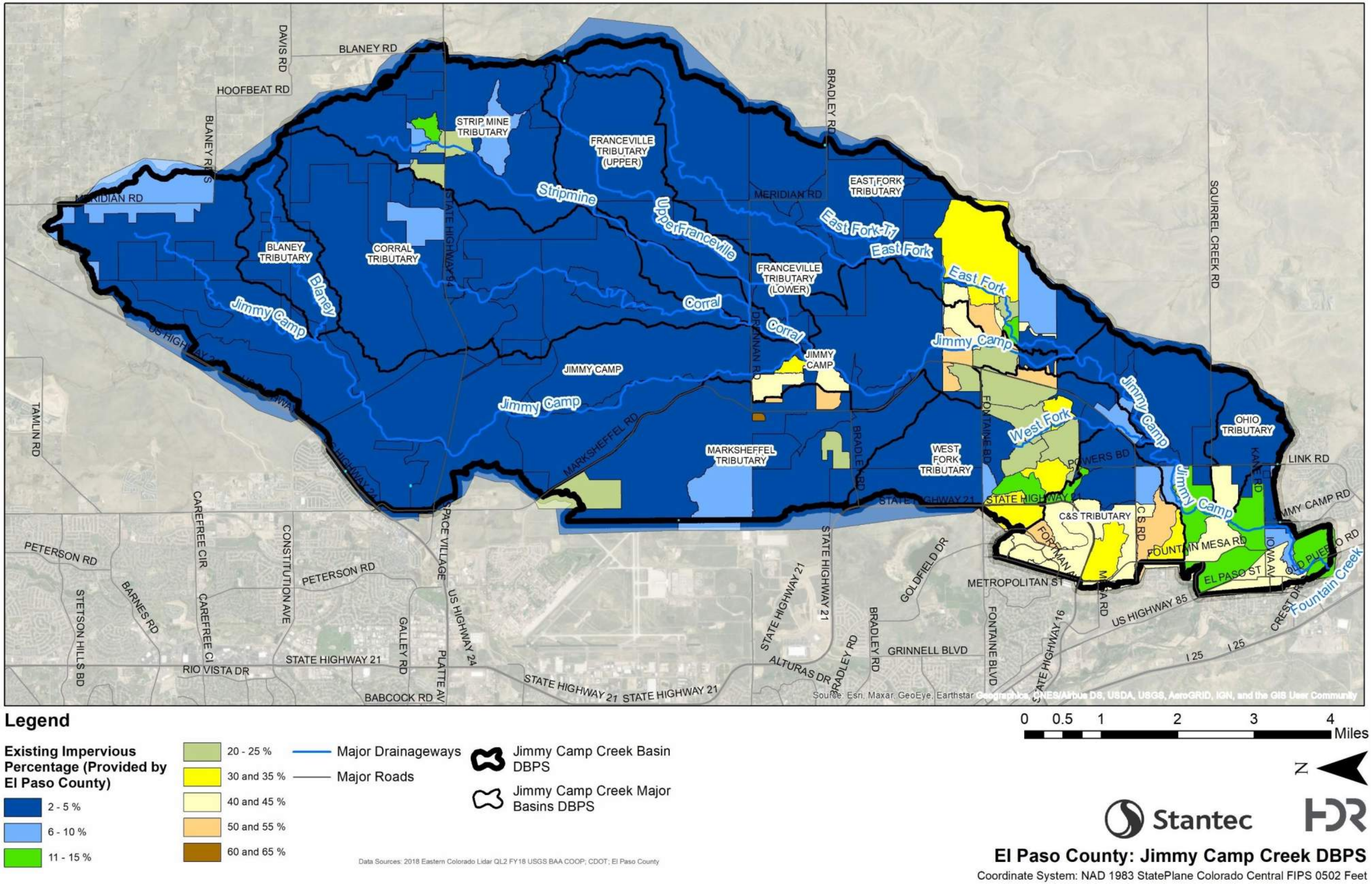


Figure 1-2. Existing Impervious Percentage Map

1.8 SUB-BASIN SLOPE

Use of the Runoff Method in SWMM 5 requires determination of the average sub-basin slope. Sub-basin slope influences the runoff travel time and resulting hydrograph shape. The average slope (ft/ft) for each sub-basin was calculated using the County's 2018 DEM data and ESRI's ArcHydro extension. The DEM is a grid format and the area-weighted average slope for each individual sub-basin was calculated by measuring the average difference in elevation between each grid cell within that sub-basin. Sub-basin slope is considered a calibration parameter and, as such, has variability in interpretation for individual sub-basins. Due to the need to increase flows through the Jimmy Camp Creek Basin to better reflect downstream gage data (discussed more in Section 1.16), the calculated slope values were increased 50 percent for all sub-basins (ie. if a sub-basin had a calculated average slope of 1 percent, it was increased 50 percent to 1.5 percent).

1.9 SUB-BASIN WIDTH

Sub-basin width in the Runoff Method represents the physical width of overland flow and is a variable in determining the time lag between peak precipitation and peak runoff. The process for estimating sub-basin width for the DBPS was made as straight forward and reproducible as possible.

The sub-basin widths were estimated using standard EPA-SWMM guidelines and were based on the main channel length. As with sub-basin slope, sub-basin width is considered a calibration parameter and, as such, has variability in interpretation for individual sub-basins. Because of this, two different methods, as described in the SWMM 5 reference manual (Rossman and Huber, 2016, p. 72-73), were evaluated for this study. Based on flows at the USGS stream gage on the downstream end of the basin, sub-basin width was only further modified on a skew factor (as opposed to using both a skew and shape factor).

To incorporate the use of skew factors, the following process was used to estimate the width parameters. The SWMM 5 reference manual contains a full discussion on this method (Rossman and Huber, 2016, p. 72-73).

W = estimation of watershed width

A = total sub-basin area

L = length of the sub-basin's main channel (pathway) length

A_m = larger of the two areas on each side of the main channel (pathway)

Z = skew factor, which is the ratio of areas on either side of L (the main drainage channel)

With

$Z = A_m/A$ (Eq. 3-10, p. 71)

The estimate for watershed width is then the weighted sum between the two limits of the main channel length, with twice the main channel length (2L) being the upper limit and the main channel length (L) being the lower limit. This results in the following equation:

W = L + 2*L*(1 – Z) (Eq. 3-11, p. 72)

In this process, once the sub-basin areas are delineated, main channel length (L) is the only unknown. Main channel lengths for each sub-basin are determined by measuring the distance from the upper-most point in the sub-basin, through the overland and storm drain conveyance path, to the most downstream point in the sub-basin. This often correlates to the longest flow path. For the purposes of this calculation, main channels are any conveyance element that transfers runoff through the sub-basin and include open channels, streets, the main drainageway of creeks, or a combination of these.

There are four general types of sub-basins in this DBPS. These types and the associated approach to determining the main channel length for each type are described below.

Type 1: Developed (urban) sub-basins that are served by drainage pipes with the outflow point going directly into an open channel (there are no open channels within the sub-basin). L is defined as the longest flow path that follows the main street and trunk storm drains to the sub-basin outlet at the channel.

Type 2: Developed (urban) sub-basins that are served by drainage pipes that outflow directly into an open channel and include the main channel itself (there are is an open channel bisecting the sub-basin). L is defined as the longest flow path that follows the streets, the trunk storm drains, and then the open channel itself to the sub-basin outlet.

Type 3: Undeveloped (rural) sub-basins that drain directly into an open channel (there are no open channels within the sub-basin). L is defined as the longest flow path along the small channels as well as some sheet/shallow concentrated flow to the open channel.

Type 4: Undeveloped (rural) sub-basins that are served by small drainage channels that outflow directly into an open channel and include the main channel itself (there is an open channel bisecting the sub-basin). L is defined as only the main channel itself and represents the only exception to the longest flowpath approach.

1.10 SUB-BASIN OVERLAND FLOW ROUGHNESS

Sub-basin overland flow roughness is used in the Runoff Method and is one of the influences used for estimating the time it takes for precipitation to be transformed to runoff. Higher values of Manning's "n" represent rougher surfaces, like lawns or pastures, where runoff times will be delayed. Low values represent impervious areas such as roads or parking lots and produce higher peak flows with little or no runoff delay. These values were estimated from Table 3-5 from the SWMM 5 reference manual (Rossman and Huber, 2016, p. 75) based on Yen (2001), which computed values based on kinematic wave analysis. Table 1-1 describes overland flow roughness values assumed for this DBPS for both pervious and impervious surfaces. These roughness assumptions tend toward being conservative (lower roughness). As with sub-basin width, it is common to consider overland flow roughness a calibration parameter (Rossman and Huber, 2016, p. 74).

Table 1-1. Assumed Overland Flow Runoff Roughness Coefficients

General Land Use Types	Assumed Land Surface	Roughness Coefficient*
All Land uses	Impervious areas: smooth surface (concrete, asphalt, gravel)	0.011
Residential, Commercial, Industrial, Institutional, Municipal, Public, Transportation Right-Of-Way, Parking Lots, Utility/Drainage Rights-Of-Ways and Easements, Military Installation	Dense residential land use	0.04
Agriculture	Pasture	0.055
* Values obtained from the EPA SWMM Reference Manual, 2016, Table 3-5, based on values from Yen (2001).		

1.11 INFILTRATION

Infiltration is the process by which surface water percolates into the subsurface soil and groundwater column. Infiltration is an important hydrologic process because it governs groundwater recharge, soil moisture storage, and surface water runoff volume. As modeled in the SWMM 5 Runoff Method, soil infiltration is one of several processes that represent a withdrawal of a portion of total storm precipitation that could otherwise generate surface runoff.

Infiltration parameters were developed for the Horton infiltration method based on information for soil types and characteristics compiled and grouped from the NRCS SSURGO dataset. The Horton infiltration method was used because parameters can be estimated from existing soil surveys without performing extensive field testing. The SWMM 5 reference manual (Rossman and Huber, 2016, p. 88-99) and the Mile High Flood District (MHFD) criteria was used as a reference for determining Horton infiltration parameters using NRCS Hydrologic Soil Groups (HSGs) as a reference. HSG soils within the Jimmy Camp Creek DBPS are mapped in Figure 1-3. Hydrologic Soil Groups (HSGs) were developed for each sub-basin based on the 'dominant' condition of the soil profile using the NRCS Soil Data Viewer. The Horton infiltration parameters used for modeling, including max infiltration rate, asymptotic infiltration rate, and decay rate of infiltration, are described in Table 1-2. For the Jimmy Camp Creek DBPS, the dominant soils are HSG A and B. Given the dominance of these soil types, high infiltration and low runoff is expected from undeveloped, pervious areas.

Table 1-2. Estimated Horton Infiltration Values

NRCS Hydrologic Soil Group	Associated Soil Textures within the Jimmy Camp Creek Drainage Basin	Percentage within the Jimmy Camp Creek Drainage Basin	Maximum (Initial) Infiltration Rate (Inches/hour)*	Minimum Infiltration Rate (Inches/hour)**	Decay rate of Infiltration (1/second)***
A	loamy sand; loamy coarse sand; gravelly loam; sandy loam, sand	21%	2.5	0.3	0.001
B	loam; sandy loam; fine sandy loam; gravelly loamy sand; silt loam	53%	2.0	0.15	0.002
C	clay loam; silt loam, Clay	10%	0.8	0.05	0.002
D	silty clay loam, clay loam, fine sandy loam	15%	0.8	0	0.002

* Values obtained from the EPA SWMM Reference Manual, 2016, low end of Table 4-6, p. 99

** Values obtained from the EPA SWMM Reference Manual, 2016, low end of Table 4-4, p. 97

*** Values obtained from MHFD, 2016, Table 6-7

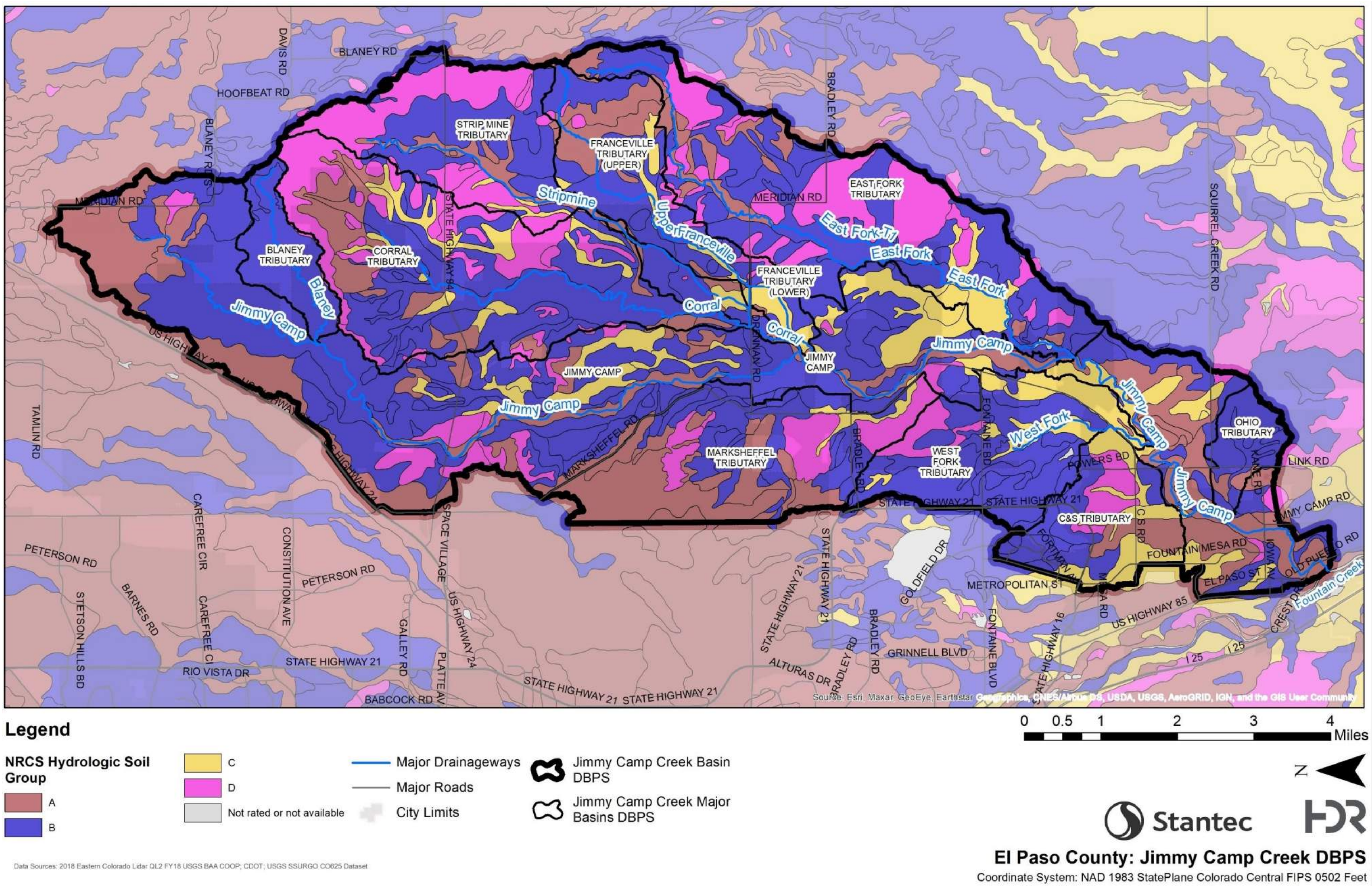


Figure 1-3. Jimmy Camp Creek Hydrologic Soils Map

1.12 DEPRESSION LOSSES

Rainwater that is collected and held in small depressions or intercepted by vegetation and does not become part of the general surface runoff is referred to as abstraction or depression loss. Depression losses include interception losses in the context of this DBPS. Most of this water eventually infiltrates or is evaporated and does not contribute to runoff. Depression losses are calculated in conjunction with infiltration and are dependent upon land use cover. Ultimately, depression loss defines the depth of rain that must fall before runoff can occur in a sub-basin. Table 1-3 describes the depression storage losses assumed for this DBPS for both pervious and impervious runoff surfaces.

Table 1-3. Assumed Depression Losses

Surface Type	Depression Loss* (in)	Types of Land Uses
Large Paved Areas	0.07	Impervious areas within all land uses
Pervious Areas	0.1	Residential, Commercial, Industrial, Institutional, Municipal, Public, Transportation Right-Of-Way, Parking Lots, Utility/Drainage Rights-Of-Ways and Easements, Military Installation
Wooded areas and open fields	0.25	Parks, Cemetery, Agriculture, Vacant Land, Airport
*Values obtained from EPA SWMM Reference Manual, 2016, p. 77 (Includes Interception Losses)		

1.13 RAINFALL

How rainfall is simulated greatly impacts modeled runoff flow rates, which in turn impacts hydraulic design downstream. Rainfall simulation is modeled by use of a Design Storm, which is defined by both rainfall depths for given rainfall frequencies and by a temporal distribution.

1.13.1 Rainfall Depths

NOAA Atlas 14 was used to estimate rainfall depths for the simulated rainfall frequencies. Data relating to NOAA Atlas 14 is published through the Precipitation Data Server (PDS) and is correlated to specific rain gage stations throughout the country. This results in Point Precipitation Estimates that can be extracted at any location within the County. The County has two rain gage stations located in or near the Jimmy Camp Creek Basin:

- City of Fountain (Station ID: 05-3063)
- Colorado Springs Airport (Station ID: 05-1778)

The City of Fountain gage is located near the outlet of the Jimmy Camp Creek Basin and the airport gage is located outside of the Jimmy Camp Creek Basin. Due to the locations of these gages, NOAA Atlas 14 Point Precipitation Estimates were extracted from three locations within the Jimmy Camp Creek Basin, with one being in the northern location of the basin, one being near the basin center, and one being in a southern location of the basin. Evaluation of these three locations showed little variation in the three data extraction locations, therefore only the North location was used for the Jimmy Camp Creek DBPS. For further discussion, please refer to Appendix _. Table 1-4 summarizes the rainfall depths extracted at the North location. Following discussions with the County, the rainfall depths in Table 1-4 were increased by 7 percent based on guidance from the Office of the State Engineer (State of Colorado, 2020) that states that "…an atmospheric moisture factor of 1.07 must be applied to account for expected future increases in temperature and associated increases in atmospheric moisture availability." Essentially, this is in reference to an empirical calculation that the atmosphere can hold 7 percent more moisture with every 1-degree Celsius increase in temperature. Provided that Atlas 14 Volume 8 was published in 2013, most of the 1-hour data used in NOAA Atlas 14 was collected prior to 2010, and that there are indications that average daily maximum temperatures in El Paso County have increased by 0.5 degrees Celsius since 2010[1], therefore this 7 percent increase in rainfall depths is warranted for this DBPS. Table 1-4 also provides the resulting rainfall depths with the 7 percent increase, as used for the current hydrologic analysis. As can be seen from Table 1-4, the 7 percent increase in rainfall depths are still within the upper limit of the 90 percent confidence interval of the NOAA Atlas 14 data.

Table 1-4. NOAA Atlas 14 Point Based Precipitation Frequency Estimates for 24-Hour Rainfall Depths for the North Location in the Jimmy Camp Creek Basin *

Rainfall Recurrence Interval	24-Hour Rainfall Depth* (in)	(90% Confidence Interval)* (in)	24-Hour Rainfall Depth Increased by 7 Percent and Used in this DBPS (in)
2-Year	1.92	(1.65-2.26)	**2.05**
5-Year	2.44	(2.09-2.88)	**2.61**
10-Year	2.93	(2.50-3.48)	**3.14**
25-Year	3.71	(3.09-4.65)	**3.97**
50-Year	4.38	(3.54-5.54)	**4.69**
100-Year	5.11	(3.97-6.63)	**5.47**

*http://hdsc.nws.noaa.gov/hdsc/pfds for
Latitude: 38.8406°
Longitude: -104.6332°
Elevation (ft): 6148.29 ft

1.13.2 Temporal Distributions

Temporal distributions define the pattern with which rainfall depth/volume is simulated in a model. It defines peak rainfall intensities and directly influences excess rainfall in relation to infiltration rates. While Atlas 14 provides Point Precipitation Estimates, it does not provide guidance on temporal distributions that can be used for engineering purposes. As part of the Jimmy Camp Creek Drainage Basin Planning Study (DBPS), the County requested a new rainfall

[1] https://crt-climate-explorer.nemac.org/climate_graphs/?city=Colorado+Springs%2C+CO&county=El%2BPaso%2BCounty&area-id=08041&fips=08041&zoom=7&lat=38.8338816&lon=-104.8213634

temporal distribution be developed based on depth-duration-frequency (DDF) data from the Atlas 14 and guidance provided in Chapter Four of the National Engineering Handbook (NEH) Part 630 Hydrology (NRCS, 2019). These distributions as well and their development is described in detail in Appendix __.

1.14 HYDRAULIC ROUTING

In addition to the development of hydrologic runoff, SWMM 5 was also used to route runoff through the drainageway channels to the outlet of Jimmy Camp Creek at its confluence with Fountain Creek. This section discusses the development of the hydraulic routing parameters used in the SWMM model analysis.

1.14.1 Routing Method

For SWMM 5, the St. Venant equations govern the translation of flows through the basin. There are three options available in SWMM 5 for modeling a basin of this scale: steady-state, the Kinematic Wave, and the Dynamic Wave solutions, with the Kinematic and Dynamic Wave solutions using the St. Venant equations.

The Kinematic Wave solution does not solve the full St. Venant equations as it removes the inertial and pressure terms. This means that the Kinematic Wave solution does not account for downstream boundary conditions, backwater impacts, flow reversal, pressurized flow, or losses through model junctions. The Kinematic Wave solution is generally applicable to steeply-sloped conduits with shallow flows and higher velocities. It is typically used to reduce model run times compared to Dynamic Wave simulations and reduce the potential for model instabilities in cases where downstream boundary conditions would not impact model results. With the Kinematic Wave solution, only one outlet is allowed per node, meaning that diversion structures and other assumptions need to be applied for flow splits and dual drainage. The Kinematic Wave method also does not produce realistic hydraulic grade line (HGL) profiles.

The Dynamic Wave solution solves the full St. Venant equations, which accounts for downstream conditions, backwater impacts, pressurized flow, and losses through junctions. Therefore, the Dynamic Wave solution produces more theoretically accurate results as compared to the Kinematic Wave solution. The Dynamic Wave solution will also produce more theoretically accurate results and more realistic HGL profiles. For this DBPS, hydraulic routing is therefore performed with the Dynamic Wave solution.

1.14.2 Routing Parameters

The general approach in this DBPS is to route flows in a manner to achieve reasonable results to meet the objectives of the DBPS. This section describes the routing parameters used to route hydrologic design flows through the Jimmy Camp Creek Drainage Basin.

1.14.2.1 Open Channels

The majority of model conveyance routing throughout the Jimmy Camp Creek Drainage Basin is via open channels. Most of these open channels are reflected in the SWMM 5 model as irregular conduits with associated cross section geometry taken from the 2018 DEM.

Channel alignments for modeling were based on the County's GIS data, the SIMP data, FEMA data, and 2018 aerial photography. Model nodes, in addition to design points and the corresponding channel segments, were used where there are appreciable changes in channel geometry, or channel slope.

Channel cross sections were cut along the channel (left to right looking downstream) to represent the irregular shape of the channel geometry. If a node was placed for a slope change, and the cross-section shape did not change between the upstream and downstream sections of channel, then the same cross section was assigned to both links.

There are also several instances of conveyance locations with undefined channels in the study area. These conveyance elements were represented as trapezoidal channels with the corresponding channel width and side slopes based on aerial photography.

Upstream and downstream channel invert elevations were extracted from the 2018 DEM and were assigned to reflect the hydraulic conditions of the channel. Invert elevations may not match the underlying DEM at specific locations due to simplification of the geometry and invert profile.

The El Paso County DCM was used to select typical Manning's roughness values for channel segments. Average roughness values were used to represent entire channel reaches, with most open channels being assigned a Manning's roughness of 0.04 and concrete pipe culverts a roughness of 0.013.

1.14.2.2 Road Crossings

Jimmy Camp Creek and its tributaries has numerous crossings, with the majority being box culverts, circular culverts, or bridge road crossings. The first source of determining culvert geometry was the County stormwater GIS data. Other sources of information included County field measurements, as-built information, and CDOT inspection data. In the absence of the above information, culvert sizes were estimated from the aerial photography. Bridges were simplified and represented as either large box culverts or trapezoidal channels, whichever was more applicable.

Upstream and downstream minor conduit losses were assigned accordingly. For channels discharging into a culvert, FHWA inlet types were assigned. If there are multiple culverts at a crossing, then the number of barrels in the culvert were included in the model.

Upstream and downstream invert elevations were extracted from the 2018 LiDAR DEM. For instances where preliminary model runs for 100-year flows indicated overtopping at a road crossing, overflow weirs were added to the model at the road surface so that peak flows would not be over attenuated.

1.14.3 Storage

Throughout the Jimmy Camp Creek Drainage Basin, in both developed and undeveloped areas, there are several locations of detention that include local development ponds, stock ponds, reservoirs, and natural depressions. However, only a few locations of detention are specifically modeled as either storage elements within SWMM (requiring storage curves) or as channel cross-sections. These ponds are located either in line with or at the upstream end of modeled channel reaches. For the ponds that were modeled explicitly as storage areas, storage-elevation curves were developed from 2018 contours. Pond outlet characteristics were estimated from aerial photography and 2018 LiDAR. Ponds that are on private property were excluded from the routing. The modeling schematic used for the Jimmy Camp Creek DBPS is presented in Figure 1-4.

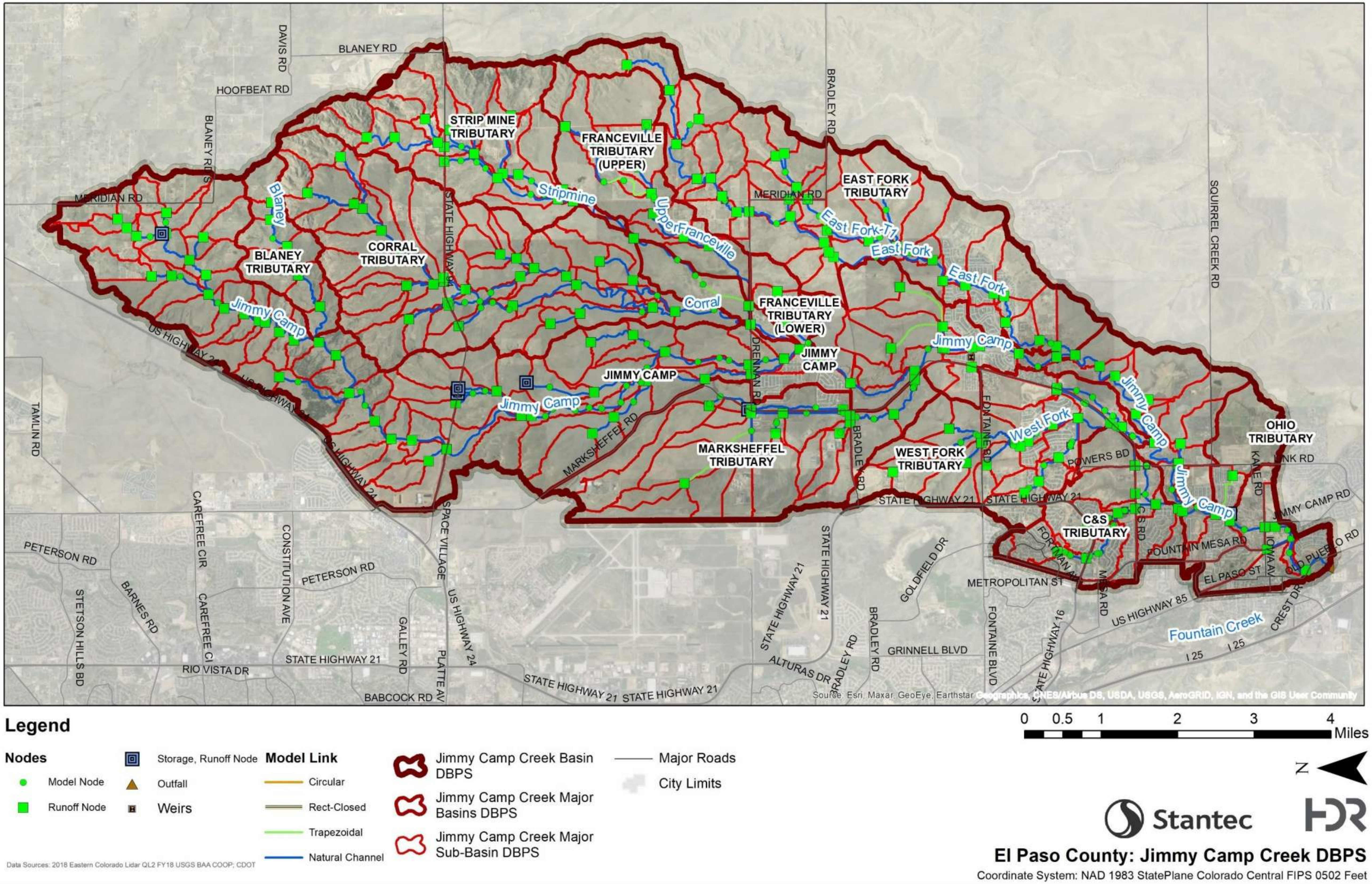


Figure 1-4. Schematic Routing Map

1.15 EXISTING CONDITION MODEL RESULTS

The existing conditions model was executed for the 2-, 5- 10-, 25-, 50- and 100-year rainfall depths presented in Table 1-5. Existing condition sub-basin runoff model results and channel flows at key analysis points were analyzed and are provided in this section.

1.15.1 Existing Condition Sub-Basin Model Results

Sub-basin existing condition peak runoff flows and total runoff volumes are provided on a sub-basin map contained in Appendix __.

1.15.2 Existing Condition Flow Rates through the DBPS

Analysis points throughout the entire DBPS area were chosen for the presentation of flow rates. These analysis points are presented in Figure 1-5. Flows for these corresponding analysis points are provided in Table 1-5.

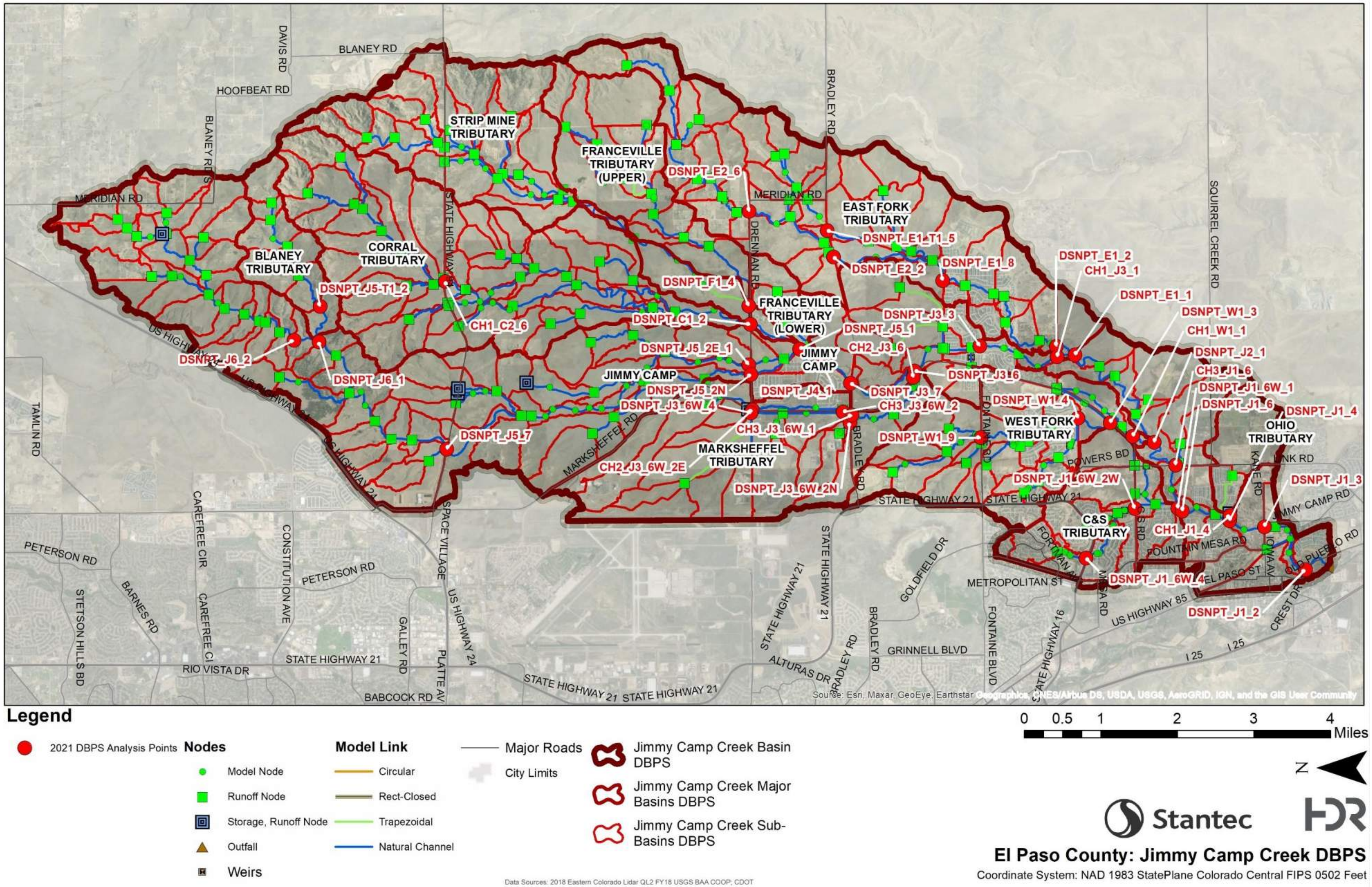


Figure 1-5. Analysis Points used in the Jimmy Camp Creek DBS for the Presentation of Peak Flow Rates

Table 1-5. Existing Conditions Peak Flow Rates at Analysis Points

Major Drainage Way	Model Node ID	Location Description	Contributing Area (mi^2)	100-Year Flow (cfs)	50-Year Flow (cfs)	25-Year Flow (cfs)	10-Year Flow (cfs)	5-Year Flow (cfs)	2-Year Flow (cfs)	Notes
Jimmy Camp Creek	DSNPT_J5_2E_1	Drennan Rd (East)	2.24	388	239	122	42	20	11	
	DSNPT_J6_2	Upstream of confluence with Blaney Trib	4.82	913	467	242	122	82	56	
	DSNPT_J6_1	Confluence with Blaney	6.51	1,290	623	304	148	99	68	
	DSNPT_J5_7	State Highway 94	9.51	1,392	646	307	145	96	64	
	DNSPT_J5_2N	Drennan Rd (West)	13.31	1,514	766	366	150	95	62	
	DSNPT_J5_1	Confluence with Corral Trib	33.99	6,644	3,989	2,212	914	462	215	
	DSNPT_J4_1	Confluence with Franceville Trib	34.70	6,712	4,002	2,221	920	465	217	
	DSNPT_J3_7	Bradley Rd	35.47	6,570	4,013	2,211	925	470	235	
	DSNPT_J3_6	Confluence with Marksheffel	41.75	7,124	4,343	2,352	1,027	520	249	
	DSNPT_J3_3	Fountain Blvd	43.97	7,248	4,424	2,390	1,049	538	360	
	CH1_J3_1	Peaceful Valley Rd	44.29	7,161	4,388	2,366	1,034	533	303	
	DSNPT_E1_1	Confluence with East Fork	53.57	8,036	4,923	2,643	1,028	529	305	Long, flat, rough slope to next design point
	DSNPT_J2_1	Confluence with West Fork	59.32	7,935	4,851	2,639	1,033	639	372	
	CH3_J1_6	Link Rd	60.22	7,874	4,792	2,523	923	483	268	
	DSNPT_J1_6	Confluence with C and S Trib	63.25	8,745	5,350	2,817	1,081	578	395	
	DSNPT_J1_3	Ohio Ave	65.36	8,715	5,295	2,798	1,087	582	365	
	DSNPT_J1_2	Outfall to Fountain Creek	66.51	8,731	5,204	2,642	1,088	586	367	
East Fork Tributary	DSNPT_E1_T1_5	Bradley Rd (East)	0.30	172	121	78	34	15	4	
	DSNPT_E2_6	Drennan Rd	2.45	486	215	97	66	49	34	
	DSNPT_E2_2	Bradley Rd (West)	4.42	568	267	112	51	33	22	
	DSNPT_E1_8	At City of Colorado Springs Boundary	6.89	699	432	252	104	52	25	
	DSNPT_E1_2	Upstream of Confluence with JCC (Peaceful Valley Rd)	8.92	1,087	660	308	85	27	19	
West Fork tributary	DSNPT_W1_9	Fountain Blvd	1.23	271	162	92	40	21	15	
	DSNPT_W1_4	Mesa Ridge Pkwy	3.44	881	689	538	383	297	209	
	DSNPT_W1_3	S Marksheffel Rd	3.94	701	425	260	175	127	104	Tailwater condition due to Marksheffel culvert impacting peak flow rates
	CH1_W1_1	Upstream of Confluence with JCC	4.33	134	118	105	86	71	55	The culvert under Marksheffel Road is 24"and does not have the capacity to carry the flow. Overflows to this culvert continue along the Marksheffel ditch to the southwest and crosses under Marksheffel Rd at the crossing just east of Link Rd (within in the C&S Tributary).

Table 1-5 Continued

Major Drainage Way	Model Node ID	Location Description	Contributing Area (mi^2)	100-Year Flow (cfs)	50-Year Flow (cfs)	25-Year Flow (cfs)	10-Year Flow (cfs)	5-Year Flow (cfs)	2-Year Flow (cfs)	Notes
Corral Tributary	CH1_C2_6	State Highway 94	3.93	2,719	1,861	1,119	500	267	133	
	DSNPT_C1_2	At confluence with Strip Mine Trib (Upstream of confluence with JCC)	18.00	4,876	3,140	1,764	753	374	156	
Stripmine Tributary	DSNPT_S1_7	State Highway 94	1.40	1,972	1,492	1,070	630	380	179	
Franceville Tributary	DSNPT_F1_4	Confluence of Franceville and Strip Mine	8.18	2,236	1,432	820	359	180	68	
Marksheffel Tributary	DSNPT_J3_6W_2N	Bradley Rd (West)	0.67	794	576	398	228	150	90	Small, separate west tributary at Bradley Rd; Connects with main trib. approximately 360' downstream of CH3_J3_6W_1
	CH2_J3_6W_2E	Drennan Rd (East)	1.31	335	183	94	34	12	5	
	CH3_J3_6W_2	Marksheffel Rd (North of Bradley Rd)	1.64	268	210	165	119	94	67	Flows reduced by Marksheffel Rd crossing
	DSNPT_J3_6W_4	Drennan Rd (West)	1.93	430	264	157	83	58	38	Not on the same tributary as CH3_J3_6W_2
	CH3_J3_6W_1	Bradley Rd (East)	4.58	933	587	377	229	156	96	
	CH2_J3_6	Upstream of Confluence with JCC	5.88	1,355	1,063	723	363	261	144	
Blaney Tributary	DSNPT_J5-T1_2	Upstream of Confluence with JCC	1.32	459	263	145	70	45	32	
C&S Tributary	DSNPT_J1_6W_4	Mesa Ridge Pkwy	0.50	648	595	473	335	257	183	
	DSNPT_J1_6W_2W	C and S Rd	1.50	617	474	342	247	198	144	Flows controlled by a large detention pond upstream (Cross Creek Park pond)
	DSNPT_J1_6W_1	Upstream of Confluence with JCC	2.74	1,595	1,288	1,022	724	549	379	
Ohio Trib.	CH1_J1_4	Upstream of Confluence with JCC	1.06	119	107	103	118	114	46	Flows controlled by a large detention pond upstream

1.16 HYDROLOGIC MODEL COMPARISON TO OTHER STUDIES

The Jimmy Creek Drainage Basin has been studied in the past. There are four known sources of published flow rates available for the Jimmy Creek Drainage Basin:

- The Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for El Paso County (FEMA, 2018).

- The 2015 Jimmy Creek Drainage Basin Planning Study (Kiowa, 2015).

- The USGS Paleoflood Investigations to Improve Peak-Streamflow Regional-Regression Equations for Natural Streamflow in Eastern Colorado (USGS, 2016).

- The USGS streamgage on Jimmy Camp Creek at Fountain, Colorado (https://waterdata.usgs.gov/co/nwis/uv?site_no=07105900).

This section describes the updated existing conditions flow rates in the context of this published data.

1.16.1 2018 FEMA FIS

Existing condition flow rates from the current model were compared to the published flow rates in the FEMA FIS (FEMA, 2018). According to the FIS, these flows were obtained from previous studies. The FIS states that hydrologic analyses used for Jimmy Camp Creek and its tributaries came from the United States Department of Agriculture, the Soil Conservation Service (SCS), and Flood Hazard Analysis reports. It also states that the SCS report used the SCS hydrologic method to develop peak flows for the 10-, 50-, and 100-year recurrence interval rainfall events with the 5-year obtained by a log-probability extrapolation from the other events. SCS hydrologic methods were used due to inadequate streamflow data and it complied with state statutory requirements at that time. The FIS bibliography references are listed below:

- U.S. Department of Agriculture, Soil Conservation Service, Colorado Water Conservation Board, Flood Hazard Analyses, Portions of Jimmy Camp Creek and Tributaries, El Paso County, Colorado, October 1975.
- U.S. Department of Agriculture, Soil Conservation Service, in Cooperation with the Colorado Water Conservation Board, Flood Hazard Analysis, Sand Creek, City of Colorado Springs and El Paso County, Colorado, July 1973.

The FIS then states that for flows below Peaceful Valley Road, the peak flow rates were developed by the USACE from the following report:

- U.S. Department of the Army, Corps of Engineers, Albuquerque District, Report on Hydrologic Investigations for the Flood Insurance Study of Colorado Springs and El Paso County, Colorado, December 1976.

Flow rates from the current modeling are lower than the FIS in all modeled tributaries within the Jimmy Camp Creek basin for 10-, 50-, and 100-year flows. Table 1-6 compares the FIS flows to the current DBPS model flows. Reasons for the differences include more detailed routing (more refined cross-section and crossing data), more robust routing methods (dynamic wave currently being used that better represents in-channel storage), more detailed infiltration modeling (impervious percentage and Horton infiltration modeling versus Curve Numbers), and different runoff computations (non-linear reservoir routing versus unit hydrograph).

Table 1-6. Flow Rates for the Current DBPS Compared to the 2018 FEMA FIS

Drainageway	Location	FEMA Drainage Area (mi^2)	Current DBPS Drainage Area (mi^2)	10-Year Maximum Flow				50-year Maximum Flow				100-Year Maximum Flow				Location Notes
				FEMA FIS (cfs)	Current DBPS Existing Conditions Model (cfs)	Difference	% Difference***	FEMA FIS	Current DBPS Existing Conditions Model (cfs)	Difference	% Difference***	FEMA FIS	Current DBPS Existing Conditions Model (cfs)	Difference	% Difference***	
Jimmy Camp Creek	At Confluence with Fountain Creek	66.4	66.51	8,500	1088	-7,412	-155%	12,400	5,204	-7,196	-82%	16,000	8,731	-7,269	-59%	
East Tributary	At Confluence with Jimmy Camp Creek	9.2	8.92	2,800	85	-2,715	-188%	4,600	660	-3,940	-150%	5,500	1,087	-4,413	-134%	Location is upstream of confluence
West Tributary	At Confluence with Jimmy Camp Creek	3.93	4.33	1,160	86	-1,074	-172%	2,280	118	-2,162	-180%	2,780	134	-2,646	-182%	Location is upstream of confluence
Franceville Tributary*	At Confluence with Jimmy Camp Creek	4.1	3.03	1,700	359	-1,341	-130%	2,800	1,432	-1,368	-65%	3,500	2,236	-1,264	-44%	Downstream area diverted to the Strip Mine Tributary for the present analysis
Corral Tributary**	At Confluence with Jimmy Camp Creek	15.9	18	3,800	753	-3,047	-134%	6,000	3,140	-2,860	-63%	7,300	4,876	-2,424	-40%	Corral Tributary includes the Strip Mine and Franceville Tributaries for the present analysis

*Franceville Tributary does not have a means to cross Drennan Road; Topography indicates that it now drains to the Strip Mine tributary, which then drains to the Corral Tributary

**Corral Tributary now includes the Strip Mine and Franceville Tributaries

*** % difference = Difference between the flow rates divided by the average of the flow rates

1.16.2 2015 DBPS

Existing condition flow rates from the current DBPS model were compared to the published flow rates from the 2015 DBPS developed for Colorado Springs (Kiowa, 2015). The 2015 DBPS used the SCS curve number method with a SCS Type II rainfall distribution, with hydraulics routed in HEC-HMS. Table 1-7 compares the 2015 DBPS design point flows to the current DBPS model flows. Flow rates from the current study are lower than the corresponding flow rates presented in the 2015 DBPS. Similar to the FEMA results, reasons for the differences include more detailed routing (more refined cross-section and crossing data), more and robust routing (dynamic wave currently being used that better represents in-channel storage versus Muskingum-Cunge), more detailed infiltration modeling (impervious percentage and Horton infiltration modeling versus Curve Numbers), and different runoff computations (non-linear reservoir routing versus unit hydrograph).

Table 1-7. Flow Rates for the Current DBPS Compared to the 2015 DBPS

Drainageway*	Location	2015 DBPS Drainage Area (mi^2)	Current DBPS Drainage Area (mi^2)	10-Year Maximum Flow				100-Year Maximum Flow				Location Notes
				2015 DBPS Existing (cfs)	Current DBPS Existing Conditions Model (cfs)	Difference	% Difference**	2015 DBPS Existing 100-year (cfs)	Current DBPS Existing Conditions Model (cfs)	Difference	% Difference**	
Jimmy Camp Creek	@ Fountain Creek	67.11	66.51	9,443	1,088	-8,355	-159%	22,094	8,731	-13,363	-87%	Outfall to Fountain Creek
	@Ohio Ave	66.11	65.36	9,447	1,087	-8,360	-159%	22,139	8,715	-13,424	-87%	Ohio Ave
	@Link Rd	60.93	60.22	9,310	923	-8,387	-164%	21,878	7,874	-14,004	-94%	Link Rd
	@ West Fork	59.77	59.32	9,296	1,033	-8,263	-160%	21,875	7,935	-13,940	-94%	Confluence with West Fork
	@ East Fork	53.92	53.57	9,243	1,028	-8,215	-160%	21,784	8,036	-13,748	-92%	Confluence with East Fork
	@Peaceful Valley Rd	44.16	44.29	7,731	1,034	-6,697	-153%	17,790	7,161	-10,629	-85%	Peaceful Valley Rd
	@ Marksheffel Trib	41.99	41.75	7667	1,027	-6,640	-153%	17,361	7,124	-10,237	-84%	Confluence with Marksheffel
	@Bradley Rd	36.64	35.47	7153	925	-6,228	-154%	16,502	6,570	-9,932	-86%	Bradley Rd
	@ Franceville Trib	36.19	34.7	7,116	920	-6,196	-154%	16,422	6,712	-9,710	-84%	Confluence with Franceville Trib
	@ Corral Trib	31.6	33.99	6,834	914	-5,920	-153%	15,382	6,644	-8,738	-79%	Confluence with Corral Trib
	@Drennan Rd	14.84	13.31	2,509	150	-2,359	-177%	5,881	1,514	-4,367	-118%	Drennan Rd (West)
	@State Highway 94	9.62	9.51	2,300	145	-2,155	-176%	5,031	1,392	-3,639	-113%	State Highway 94
	@ Blaney Trib	6.39	6.51	1,959	148	-1,811	-172%	4,107	1,290	-2,817	-104%	Confluence with Blaney
	U/S of Blaney	4.67	4.82	1,254	122	-1,132	-165%	2,773	913	-1,860	-101%	Upstream of confluence with Blaney Trib
Jimmy Camp Creek Corral Trib.	@Jimmy Camp Creek	8.25	18	2885	753	-2,132	-117%	6,212	4,876	-1,336	-24%	At confluence with Strip Mine Trib (Upstream of confluence with JCC)
Jimmy Camp Creek East Fork Trib.	@Jimmy Camp Creek	9.77	8.92	2030	85	-1,945	-184%	4,677	1,087	-3,590	-125%	Upstream of Confluence with JCC (Peaceful Valley Rd)

*West Fork Tributary not included in DBPS 2015 and is not included here for comparison

** % difference = Difference between the flow rates divided by the average of the flow rates

Table 1-7 Continued

Drainageway*	Location	2015 DBPS Drainage Area (mi^2)	Current DBPS Drainage Area (mi^2)	10-Year Maximum Flow				100-Year Maximum Flow				Location Notes
				2015 DBPS Existing (cfs)	Current DBPS Existing Conditions Model	Difference	% Difference**	2015 DBPS Existing 100-year (cfs)	Current DBPS Existing Conditions Model	Difference	% Difference**	
Jimmy Camp Creek Markshelfel Trib.	@Jimmy Camp Creek	5.18	5.88	832	363	-469	-78%	1,916	1,355	-561	-34%	Upstream of Confluence with JCC
Jimmy Camp Creek Strip Mine Trib.	@Jimmy Camp Creek	5.18	#N/A	2451	#N/A	#N/A	#N/A	4,627	#N/A	#N/A	#N/A	Strip Mine Trib combines with Franceville Trib for the present analysis; There is not a separate design point that represents Strip Mine Trib
Jimmy Camp Creek Franceville Trib.	@Jimmy Camp Creek	4.32	8.18	640	359	-281	-56%	1,515	2,236	721	38%	Confluence of Franceville and Strip Mine, Strip Mine Trib combines with Franceville Trib for the present analysis
Jimmy Camp Creek C&S Trib.	@Jimmy Camp Creek	2.07	2.74	898	724	-174	-21%	1,770	1,595	-175	-10%	Upstream of Confluence with JCC
Jimmy Camp Creek Blaney Trib.	@Jimmy Camp Creek	1.55	1.32	1102	70	-1,032	-176%	1,927	459	-1,468	-123%	Upstream of Confluence with JCC
Jimmy Camp Creek Ohio Trib.	@Jimmy Camp Creek	1.22	1.06	268	118	-150	-78%	661	119	-542	-139%	Upstream of Confluence with JCC

*West Fork Tributary not included in DBPS 2015 and is not included here for comparison

** % difference = Difference between the flow rates divided by the average of the flow rates

1.16.3 USGS Regional-Regression Equation Analysis

In 2016, the USGS, in cooperation with the Colorado Department of Transportation, developed regional regression equations for Eastern Colorado (USGS, 2016). As part of this Scientific Investigations Report (SIR), flood frequency statistics were produced for the one known stream gage in the Jimmy Camp Creek Drainage Basin, which is the USGS gage 07105900 located at the downstream end of Jimmy Camp Creek near its mouth to Fountain Creek. Table 1-8 provides the published results of this analysis at the gage as developed by the USGS using Bulletin 17B methods. Compared to this SIR, the current modeling produced peak flows that are less than the SIR published flow rates for 2-, 5-, 10-, 25-, 50-, and 100-year flood frequencies.

Table 1-8. USGS Bulletin 17B Gage Analysis for Jimmy Camp Creek at USGS Gage 07105900

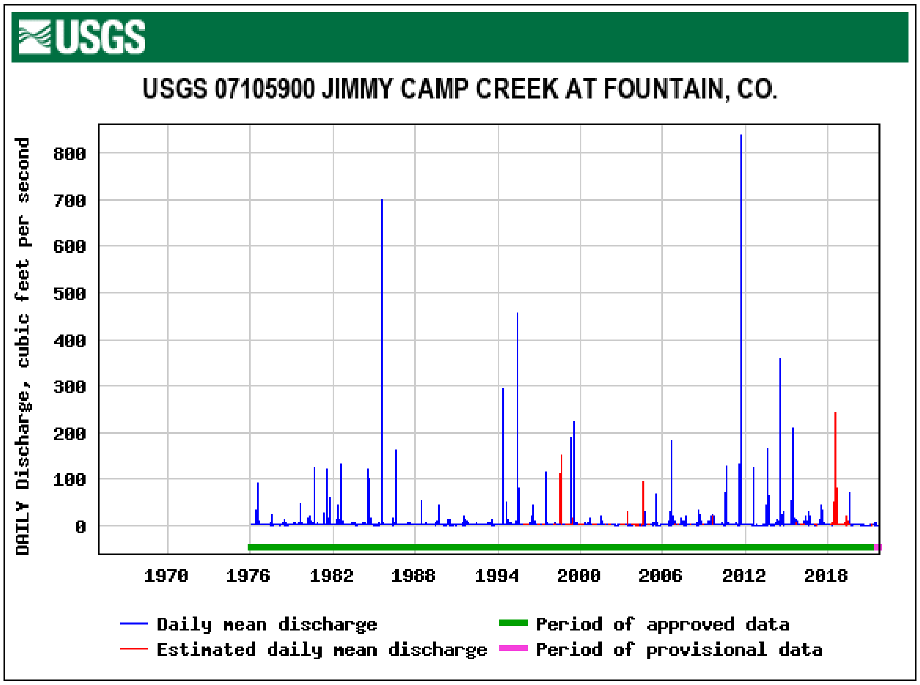
Flow Statistic	USGS Flow Statistics Flow Rate (cfs)*	USGS Confidence Interval**		Current DBPS Existing Conditions Model – Jimmy Camp Creek at Ohio Avenue
		Lower 95% Confidence Limit	Upper 95% Confidence Limit	
2 Year Peak Flood (50 Percent Annual Chance)	516	305.7	900.8	365
5 Year Peak Flood (20 Percent Annual Chance)	2,050	1,141	4,365	582
10 Year Peak Flood (10 Percent Annual Chance)	4,470	2,292	12,140	1,087
25 Year Peak Flood (4 Percent Annual Chance)	10,800	4,789	45,120	2,798
50 Year Peak Flood (2 Percent Annual Chance)	19,500	7,661	121,300	5,295
100 Year Peak Flood (1 Percent Annual Chance)	33,900	11,640	325,500	8,715

*Source: Kohn et. al., 2016, Appendix 5

**Source: USGS StreamStats Data-Collection Station Report, https://streamstatsags.cr.usgs.gov/gagepages/html/07105900.htm#300

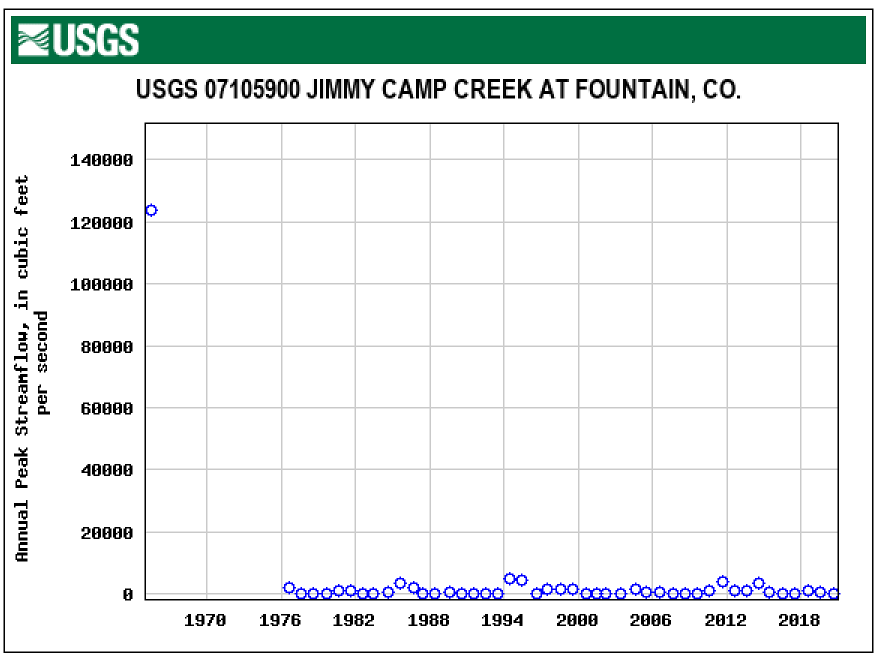
1.16.4 USGS Gage 07105900

As stated in Section 1.16.3, there is one known stream gage in the Jimmy Camp Creek Drainage Basin, (USGS gage 07105900). Gage 07105900 has been in operation since 1976. However, the annual statistics include the flood event of 1965. Figure 1-6 presents the flow data corresponding to this gage over its entire period of record (1976 through 2021). Figure 1-7 provides the graph of the annual peaks associated with the gage, which includes the estimated discharge associated with the 1965 flood event.



Source:
https://nwis.waterdata.usgs.gov/co/nwis/uv/?cb_00060=on&cb_00065=on&format=gif_stats&site_no=07105900&period=&begin_date=1960-01-01&end_date=2021-09-23

Figure 1-6. Flow Data at the USGS gage 07105900 from 1976 – 2021



Source: https://nwis.waterdata.usgs.gov/co/nwis/peak/?site_no=07105900&agency_cd=USGS

Figure 1-7. Annual Peak Flow Data at the USGS gage 07105900 from 1965 – 2021

It should be noted that the annual peak flow associated with the gage in 1965 is a significant outlier, producing a peak flow of 124,000 cfs. The next closest peak flow occurred in 1994 with a peak flow of 4,810 cfs. It should also be noted that within Fountain Creek, at USGS gage 0710600 downstream of the Jimmy Camp Creek confluence[2] , the highest recorded peak flow is 22,100 cfs. The Fountain Creek gage has been in operation from 1939 – 1955 and 1985 – 2021, so unfortunately, the 1965 event was not captured. The 124,000 cfs measurement taken on Jimmy Camp Creek is well above any peak flow recorded both within Jimmy Camp Creek and its receiving water of Fountain Creek, both of which have significant periods of record. The 1965 flood event is described in detail by the USGS in SIR 2008-5164, *An Evaluation of Selected Extraordinary Floods in the United States Reported by the U.S. Geological Survey and Implications for Future Advancement of Flood Science* (Costa et. Al., 2008). Appendix A in this document reviews this peak discharge and concludes that this estimate is ‘poor’. Annual peak flows with the 1965 event excluded is presented in Figure 1-8.

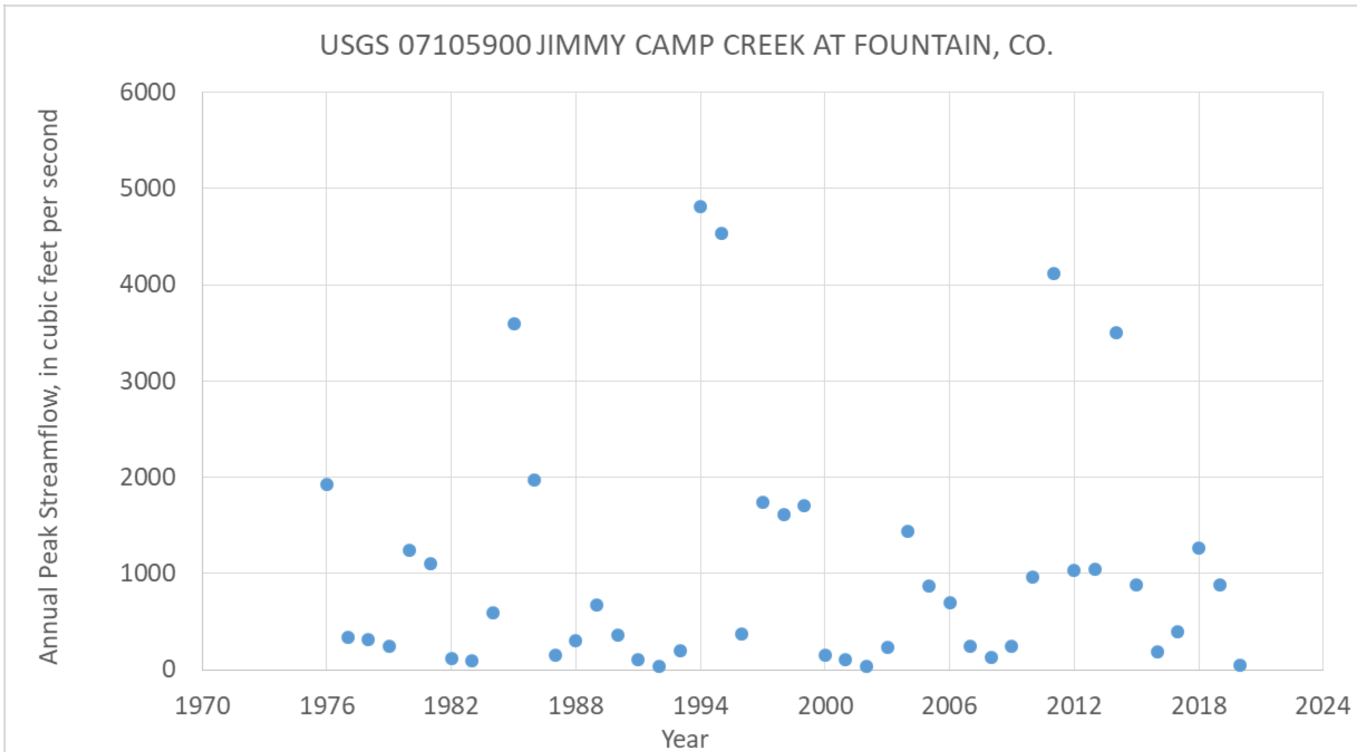


Figure 1-8. Annual Peak Flow Data at the USGS gage 07105900 from 1976– 2021

Given how the 124,000 cfs flow impacts the USGS flood frequency statistics, a Bulletin 17 Log-Pearson Type II frequency analysis was performed to exclude the 1965 event. The analysis was performed using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's (HEC) Statistical Software Package (HEC-SSP) (version 2.2) based on the flow data on record at the gage. HEC-SSP is used to develop flood flow frequency analysis based on Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) and Bulletin 17C (England, et al.,

[2] https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=07106000

2018). Both Bulletin 17B (consistent with the USGS analysis presented in Section 1.16.3) and Bulletin 17C analyses (more refined analysis) were performed on the gage data and are presented in Table 1-9. Bulletin 17B and 17C produced similar results for the computed flows, with the differences being in how confidence limits are calculated . Results of this analysis indicate that the currently modeled flow rates are close to what is indicated by the Bulletin 17 analysis for the 100-year flow rates. It should be noted that rainfall frequencies do not always produce the same flood frequencies, especially for more frequent rainfall and flood events. Given that there is only one gage serving this 67 square mile watershed, this statement is even more true in that there are many factors that can influence the flow rates at this gage at its location at the downstream end of the watershed. These factors include the timing of rainfall, the distribution of rainfall over the watershed, antecedent moisture conditions, culvert blockages, etc. It should be noted that total daily rainfall was checked against peak daily stream flows, and it was observed that there are numerous instances in the period of available record where approximate 2- to 5- year 24-hour rainfall depths produced flow rates under 500 cfs.

Table 1-9. Results of a Bulletin 17 Analysis of the USGS Gage 07105900 Accounting for Only the Period of Gaged Flow

		Bulletin 17B Flows (Using Years 1976 - 2021)			Bulletin 17C Flows (Using Years 1976 - 2021)			Current DBPS Existing Conditions Modeled Flows– Jimmy Camp Creek at Ohio Avenue
Percent Chance Exceedance	Rainfall Return	Computed Curve	90% Confidence Interval Lower 95% Confidence Limit	90% Confidence Interval Upper 95% Confidence Limit	Computed Curve	90% Confidence Interval Lower 95% Confidence Limit	90% Confidence Interval Upper 95% Confidence Limit	
		Flow, (cfs)	Flow, (cfs)		Flow, (cfs)	Flow, (cfs)		Flow (cfs)
50	2-year	523	377	725	523	367	742	365
20	5-year	1,532	1,082	2,329	1,532	1,080	2,261	582
10	10-year	2,634	1,782	4,322	2,634	1,817	4,311	1,087
5	20-year	4,077	2,643	7,180	4,077	2,701	7,733	N/A
2	50-year	6,592	4,051	12,625	6,592	4,006	15,484	5,295
1	100-year	9,021	5,341	18,298	9,022	5,041	25,059	8,715

HEC-SSP was also used to perform a volume frequency analysis on USGS gage 07105900. The results of this analysis are presented in Table 1-10. Results of this analysis indicate that the currently modeled 24-hour flow volumes are greater than what is indicated by the volume frequency analysis for all modeled flow rates.

Table 1-10. Results of a Volume Frequency Analysis of the USGS Gage 07105900 (1976 - 2021)

Percent Chance Exceedance	Rainfall Return	Volume Frequency Curve for a 24-Hour Period (ac-ft)	Current DBPS Existing Conditions Modeled Volumes – Jimmy Camp Creek at Ohio Avenue (ac-ft)
50	2-year	110	386
20	5-year	358	577
10	10-year	644	829
5	20-year	1,030	N/A
2	50-year	1,719	1,976
1	100-year	2,396	2,810

1.17 FUTURE CONDITION MODELING

For this DBPS, future conditions modeling focuses on the changes in sub-basin impervious percentages due to projected build out conditions in undeveloped areas. Changes in sub-basin boundaries or slopes due to development grading are not included. Future stormwater infrastructure such as closed conduits, open channels, or detention ponds are also not included.

1.17.1 Future Land Use Development

As described in Section 1.7, the County provided future impervious estimates for the Jimmy Camp Creek DBPS. These future imperviousness estimates were developed by the County based on the El Paso County Master Plan currently being developed. The resulting future impervious coverage, or "hydrologic land use", is presented in Figure 1-9. As with the existing conditions analysis, the future impervious feature class was intersected with the sub-basins in GIS and an area weighted impervious percentage was calculated for each sub-basin.

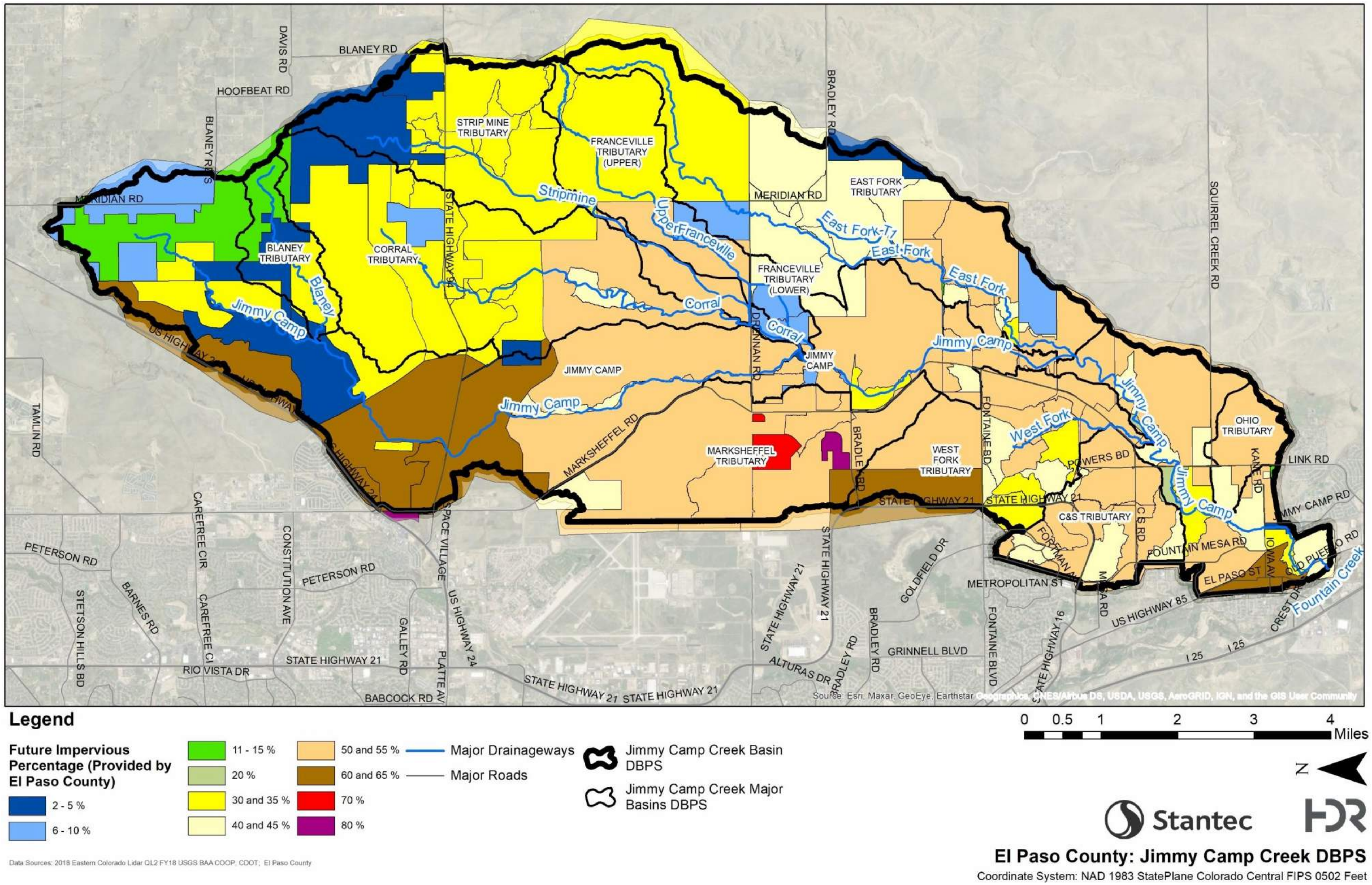


Figure 1-9. **Future Impervious Percentage Map**

1.17.2 Future Condition Model Results

The future conditions model was executed for the 2-, 5-, 10-, 25-, 50- and 100-year rainfall depths presented in Table 1-4. The future conditions model was then evaluated for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals.

Sub-basin future condition peak runoff flows and total runoff volumes are provided on a sub-basin map contained in Appendix _. As with the existing conditions figure, this figure also provides model results at the sub-basin level throughout the DBPS area. Future conditions flow rates corresponding to the analysis points presented in Figure 1-5 are provided in Table 1-11. A comparison of existing and future 100-year flows is presented in Table 1-12.

Table 1-11. Future Conditions Peak Flow Rates at Analysis Points

Major Drainage Way	Model Node ID	Location Description	Contributing Area (mi²)	100-Year Flow (cfs)	50-Year Flow (cfs)	25-Year Flow (cfs)	10-Year Flow (cfs)	5-Year Flow (cfs)	2-Year Flow (cfs)	Notes
Jimmy Camp Creek	DSNPT_J5_2E_1	Drennan Rd (East)	2.24	1,898	1,530	1,221	886	680	485	
	DSNPT_J6_2	Upstream of confluence with Blaney Trib	4.82	2,604	1,951	1,468	1,034	782	555	
	DSNPT_J6_1	Confluence with Blaney	6.51	3,602	2,661	2,001	1,377	1,020	727	
	DSNPT_J5_7	State Highway 94	9.51	5,925	4,490	3,430	2,340	1,755	1,256	
	DNSPT_J5_2N	Drennan Rd (West)	13.31	8,494	6,665	5,066	3,419	2,552	1,815	
	DSNPT_J5_1	Confluence with Corral Trib	33.99	21,838	16,944	12,601	8,623	6,414	4,443	
	DSNPT_J4_1	Confluence with Franceville Trib	34.70	22,038	17,074	12,672	8,664	6,139	4,452	
	DSNPT_J3_7	Bradley Rd	35.47	22,100	17,122	12,738	8,710	6,072	4,499	
	DSNPT_J3_6	Confluence with Marksheffel	41.75	26,498	20,788	15,718	10,766	7,701	5,715	
	DSNPT_J3_3	Fountain Blvd	43.97	26,998	21,007	15,465	11,077	7,951	5,874	
	CH1_J3_1	Peaceful Valley Rd	44.29	26,919	20,925	15,403	10,977	7,849	5,879	
	DSNPT_E1_1	Confluence with East Fork	53.57	29,722	23,080	17,157	12,156	8,669	6,362	Long, flat, rough slope to next design point
	DSNPT_J2_1	Confluence with West Fork	59.32	29,494	22,755	16,895	12,034	8,695	6,322	
	CH3_J1_6	Link Rd	60.22	29,423	22,666	16,831	11,982	8,684	6,295	
	DSNPT_J1_6	Confluence with C and S Trib	63.25	32,409	24,974	18,447	13,051	9,403	6,698	
	DSNPT_J1_3	Ohio Ave	65.36	30,358	24,729	18,430	13,107	9,492	6,754	
	DSNPT_J1_2	Outfall to Fountain Creek	66.51	27,655	24,197	18,373	13,101	9,505	6,696	
East Fork Tributary	DSNPT_E1_T1_5	Bradley Rd (East)	0.30	289	221	157	103	70	43	
	DSNPT_E2_6	Drennan Rd	2.45	1,593	1,305	1,042	754	576	404	
	DSNPT_E2_2	Bradley Rd (West)	4.42	1,645	1,472	1,255	992	783	581	
	DSNPT_E1_8	At City of Colorado Springs Boundary	6.89	2,540	1,942	1,507	1,035	763	541	
	DSNPT_E1_2	Upstream of Confluence with JCC (Peaceful Valley Rd)	8.92	3,630	2,813	1,990	1,243	873	593	
West Fork tributary	DSNPT_W1_9	Fountain Blvd	1.23	1,385	1,067	815	593	460	330	
	DSNPT_W1_4	Mesa Ridge Pkwy	3.44	2,722	2,118	1,579	1,069	786	483	
	DSNPT_W1_3	S Marksheffel Rd	3.94	2,759	2,104	1,524	985	740	449	Tailwater condition due to Marksheffel culvert impacting peak flow rates
	CH1_W1_1	Upstream of Confluence with JCC	4.33	145	136	124	108	98	80	The culvert under Marksheffel Road is 24"and does not have the capacity to carry the flow. Overflows to this culvert continue along the Marksheffel ditch to the southwest and crosses under Marksheffel Rd at the crossing just east of Link Rd (within in the C&S Tributary).

Table 1-11. Continued

Major Drainage Way	Model Node ID	Location Description	Contributing Area (mi^2)	100-Year Flow (cfs)	50-Year Flow (cfs)	25-Year Flow (cfs)	10-Year Flow (cfs)	5-Year Flow (cfs)	2-Year Flow (cfs)	Notes
Corral Tributary	CH1_C2_6	State Highway 94	3.93	4,471	3,295	2,518	1,625	1,224	876	
	DSNPT_C1_2	At confluence with Strip Mine Trib (Upstream of confluence with JCC)	18.00	11,590	9,033	6,611	4,466	3,282	2,233	
Stripmine Tributary	DSNPT_S1_7	State Highway 94	1.40	2,122	1,636	1,187	714	445	221	
Franceville Tributary	DSNPT_F1_4	Confluence of Franceville and Strip Mine	8.18	4,925	3,884	2,902	1,929	1,394	911	
Marksheffel Tributary	DSNPT_J3_6W_2N	Bradley Rd (West)	0.67	2,146	1,862	1,577	1,197	941	669	Small, separate west tributary at Bradley Rd; Connects with main trib. approximately 360' downstream of CH3_J3_6W_1
	CH2_J3_6W_2E	Drennan Rd (East)	1.31	1,149	1,173	1,168	884	701	513	
	CH3_J3_6W_2	Marksheffel Rd (North of Bradley Rd)	1.64	1,185	1,062	851	608	513	399	Flows reduced by Marksheffel Rd crossing
	DSNPT_J3_6W_4	Drennan Rd (West)	1.93	2,744	2,211	1,752	1,262	982	708	Not on the same tributary as CH3_J3_6W_2
	CH3_J3_6W_1	Bradley Rd (East)	4.58	4,257	3,582	2,934	2,257	1,802	1,316	
	CH2_J3_6	Upstream of Confluence with JCC	5.88	4,768	4,011	3,160	2,316	1,866	1,377	
Blaney Tributary	DSNPT_J5-T1_2	Upstream of Confluence with JCC	1.32	852	618	467	326	249	183	
C&S Tributary	DSNPT_J1_6W_4	Mesa Ridge Pkwy	0.50	651	606	485	344	265	189	
	DSNPT_J1_6W_2W	C and S Rd	1.50	667	520	383	259	209	154	Flows controlled by a large detention pond upstream (Cross Creek Park pond)
	DSNPT_J1_6W_1	Upstream of Confluence with JCC	2.74	3,462	2,461	1,802	1,089	736	511	
Ohio Trib.	CH1_J1_4	Upstream of Confluence with JCC	1.06	320	174	163	151	139	133	Flows controlled by a large detention pond upstream

Table 1-12. Existing Condition Versus Future Conditions Peak Flow Rates at Analysis Points

Major Drainage Way	Model Node ID	Location Description	Contributing Area (ac)	Existing 100-Year Flow (cfs)	Future 100-Year Flow (cfs)
Jimmy Camp Creek	DSNPT_J5_2E_1	Drennan Rd (East)	2.24	388	1,898
	DSNPT_J6_2	Upstream of confluence with Blaney Trib	4.82	913	2,604
	DSNPT_J6_1	Confluence with Blaney	6.51	1,290	3,602
	DSNPT_J5_7	State Highway 94	9.51	1,392	5,925
	DNSPT_J5_2N	Drennan Rd (West)	13.31	1,514	8,494
	DSNPT_J5_1	Confluence with Corral Trib	33.99	6,644	21,838
	DSNPT_J4_1	Confluence with Franceville Trib	34.70	6,712	22,038
	DSNPT_J3_7	Bradley Rd	35.47	6,570	22,100
	DSNPT_J3_6	Confluence with Marksheffel	41.75	7,124	26,498
	DSNPT_J3_3	Fountain Blvd	43.97	7,248	26,998
	CH1_J3_1	Peaceful Valley Rd	44.29	7,161	26,919
	DSNPT_E1_1	Confluence with East Fork	53.57	8,036	29,722
	DSNPT_J2_1	Confluence with West Fork	59.32	7,935	29,494
	CH3_J1_6	Link Rd	60.22	7,874	29,423
	DSNPT_J1_6	Confluence with C and S Trib	63.25	8,745	32,409
	DSNPT_J1_3	Ohio Ave	65.36	8,715	30,358
	DSNPT_J1_2	Outfall to Fountain Creek	66.51	8,731	27,655
East Fork Tributary	DSNPT_E1_T1_5	Bradley Rd (East)	0.30	172	289
	DSNPT_E2_6	Drennan Rd	2.45	486	1,593
	DSNPT_E2_2	Bradley Rd (West)	4.42	568	1,645
	DSNPT_E1_8	At City of Colorado Springs Boundary	6.89	699	2,540
	DSNPT_E1_2	Upstream of Confluence with JCC (Peaceful Valley Rd)	8.92	1,087	3,630
West Fork tributary	DSNPT_W1_9	Fountain Blvd	1.23	271	1,385
	DSNPT_W1_4	Mesa Ridge Pkwy	3.44	881	2,722
	DSNPT_W1_3	S Marksheffel Rd	3.94	701	2,759
	CH1_W1_1	Upstream of Confluence with JCC	4.33	134	145
Corral Tributary	CH1_C2_6	State Highway 94	3.93	2,719	4,471
	DSNPT_C1_2	At confluence with Strip Mine Trib (Upstream of confluence with JCC)	18.00	4,876	11,590
Stripmine Tributary	DSNPT_S1_7	State Highway 94	1.40	1,972	2,122

Table 1-12. Continued

Major Drainage Way	Model Node ID	Location Description	Contributing Area (ac)	Existing 100-Year Flow (cfs)	Future 100-Year Flow (cfs)
Franceville Tributary	DSNPT_F1_4	Confluence of Franceville and Strip Mine	8.18	2,236	4,925
Marksheffel Tributary	DSNPT_J3_6W_2N	Bradley Rd (West)	0.67	794	2,146
	CH2_J3_6W_2E	Drennan Rd (East)	1.31	335	1,149
	CH3_J3_6W_2	Marksheffel Rd (North of Bradley Rd)	1.64	268	1,185
	DSNPT_J3_6W_4	Drennan Rd (West)	1.93	430	2,744
	CH3_J3_6W_1	Bradley Rd (East)	4.58	933	4,257
	CH2_J3_6	Upstream of Confluence with JCC	5.88	1,355	4,768
Blaney Tributary	DSNPT_J5-T1_2	Upstream of Confluence with JCC	1.32	459	852
C&S Tributary	DSNPT_J1_6W_4	Mesa Ridge Pkwy	0.50	648	651
	DSNPT_J1_6W_2W	C and S Rd	1.50	617	667
	DSNPT_J1_6W_1	Upstream of Confluence with JCC	2.74	1,595	3,462
Ohio Trib	CH1_J1_4	Upstream of Confluence with JCC	1.06	119	320

2.0 REFERENCES

City of Colorado Springs. (2021). Sand Creek Drainage Basin Planning Study. Prepared by Stantec, HDR, and Dewberry.

City of Colorado Springs. (May 2014). "Drainage Criteria Manual Volume 1". City of Colorado Springs, Colorado. www.springsgov.com

Costa, J.E., R.D. Jarrett. (2008). An Evaluation of Selected Extraordinary Floods in the United States Reported by the U.S. Geological Survey and Implications for Future Advancement of Flood Science. Scientific Investigations Report 2008-5164. U.S. Department of the Interior, U.S. Geological Survey.

El Paso County. (2021). Your El Paso County Master Plan. Adopted May 26, 2021. El Paso County, Colorado.

El Paso County. (2015). Jimmy Camp Creek Drainage Basin Planning Study, Development of Alternatives and Design of Selected Plan Report. Prepared by Kiowa Engineering Corporation.

El Paso County. Date Unknown. Drainage Criteria Manual County of El Paso, Colorado. Volume 1, Stormwater Quality Policies, Procedures, and Best Management Practices (BMPs). Downloaded April 2021. https://library.municode.com/co/el_paso_county/codes/drainage_criteria_manual

England, J.F., Cohn, T.A, Faber, B.A, Stedinger, J.R., Thomas, W.O., Veilleus, A. Mason, R.R. (2018). Guidelines for Determining Flood Flow Frequency, Bulletin 17C. Washington D.C. U.S. Department of the Interior.

Federal Emergency Management Agency. (2018). Flood Insurance Study El Paso County, Colorado, and Incorporated Areas. Flood Insurance Study Number 08041CV001A.

Interagency Advisory Committee on Water Data. 1982. Guidelines for Determining Flood Flow Frequency, Bulletin 17B. Reston, VA. U.S. Geological Survey.

Kiowa Engineering Corporation (2008). Design Plans: The Glen at Widefield Filing No. 6. Residential Subdivision Construction Drawings. Prepared for: New Generation Homes.

Kiowa Engineering Corporation (2015). Jimmy Camp Creek Drainage Basin Planning Study Development of Alternatives & Design of Selected Plan Report. Prepared for: City of Colorado Springs.

Kohn et. al. 2016. Paleoflood Investigations to Improve Peak-Streamflow Regional-Regression Equations for Natural Streamflow in Eastern Colorado, 2015. Scientific Investigations Report 2016–5099. U.S. Department of the Interior, U.S. Geological Survey.

Mile High Flood District (MHFD) (Formally Urban Drainage and Flood Control District [UDFCD]). (January 2016). Urban Storm Drainage Criteria Manual: Volume 1

Management, Hydrology, and Hydraulics. Urban Drainage and Flood Control District. Denver, Colorado. www.udfcd.org

Perica, S., D. Martin, S. Pavlovic, I. Roy, M. St. Laurent, C. Trypaluk, D. Unruh, M. Yekta, G. Bonnin. (2013). NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA, National Weather Service. Silver Spring, MD. http://hdsc.nws.noaa.gov/hdsc/pfds

Rossman, Lewis and Wayne Huber. (July 2016). "Storm Water Management Model Reference Manual Volume 1 – Hydrology". Environmental Protection Agency (EPA). Office of Research and Development Water Supply and Water Resources Division.

State of Colorado. (January 2020). "Guideline for Project Review". State of Colorado. Department of Natural Resources. Division of Water Resources. Office of the State Engineer. Dam Safety.

U.S. Department of Agriculture National Resources Conservation Service. Soil Survey Geographic (SSURGO) Database. Data extracted 2019. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

U.S. Department of Agriculture, Soil Conservation Service. (1975). Flood Hazard Analyses, Portions of Jimmy Camp Creek and Tributaries, El Paso County, Colorado. In cooperation with Colorado Water Conservation Board.

U.S. Department of Agriculture Natural Resources Conservation Service (NRCS). (2019). Title 210 – National Engineering Handbook, Part 630 Hydrology. Chapter 4, Storm Rainfall Depth and Distribution. 210-630-H., Amend. 88. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=43924.wba

Yen, B.C. (2001). "Hydraulics of Sewer Systems," Chapter 6 in Stormwater Collection Systems Design Handbook, L.M. Mays, ed., McGraw-Hill, New York