RIVERSIDE COUNTY FLOOD CONTROL
AND WATER CONSERVATION DISTRICT
RIVERSIDE, CALIFORNIA

WARM SPRINGS CREEK – TRIBUTARY C

February 20, 2020

PREPARED BY: NORMA CUMMINGS and MANIK SETHI

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

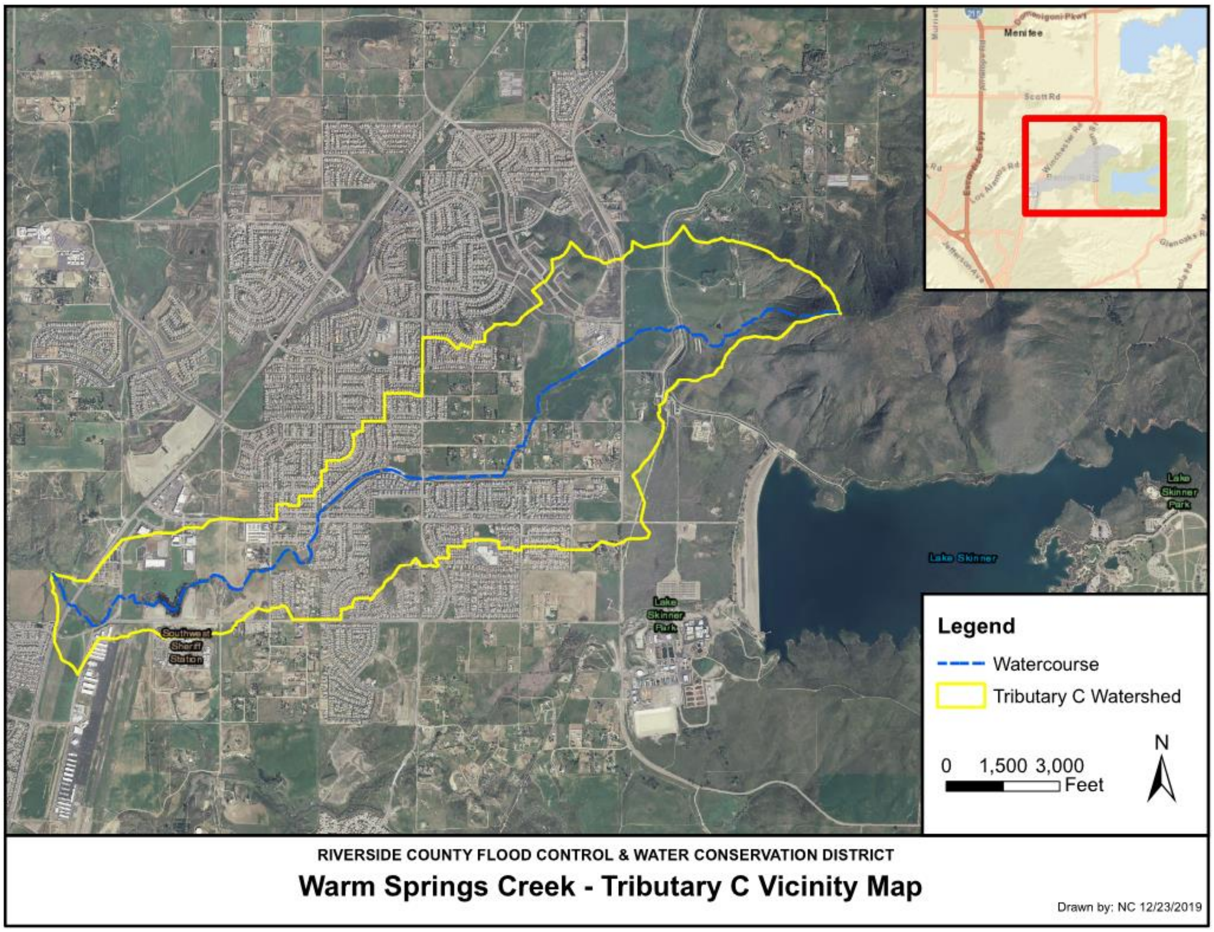
Appendix A: MT-2 Forms
Appendix B: Hydrology
Appendix C: Hydraulics
Appendix D: Work maps & Mapping
Appendix E: Plans
Appendix F: Public Notice Drafts
Appendix G: Floodplain Shapefiles

1. Introduction

The Warm Springs Creek – Tributary C watershed is 2.98 sq. mi. located in unincorporated Riverside County in the area between Winchester and the City of Murrieta. Tributary C has one reach named “Benton Creek”. Tributary C is part of the Warm Springs Creek Watershed, which ultimately discharges into Murrieta Creek within the City of Murrieta.

The Riverside County Flood Control and Water Conservation District’s (District) objective in this analysis is to map the floodplain as a Federal Emergency Management Agency (FEMA) Zone AE and remove the current Zone D designation.

Figure 1 – Vicinity Map



2. Hydrology

The FEMA Flood Insurance Study (FIS) does not include any hydrologic information for Warm Springs Creek. The area is currently mapped as a Zone D.

A new hydrologic study was performed by the District to obtain the 100-year flowrate for Tributary C. This study considers the existing conditions of the watershed. The guidelines in the Riverside County Flood Control & Water Conservation District Hydrology Manual (Hydrology Manual) were used to prepare a synthetic unit hydrograph rainfall-runoff model for the Tributary "C" watershed. Excerpts from the hydrology manual as well as the finalized hydrology study are included in Appendix B.

2.1. Watershed Characteristics

Tributary C extends from Bachelor Mountain in the east to a confluence point just downstream of the State Route 79 (SR 79). The watershed has an area of 2.98 square miles and is composed of foothill regions in the east and valley regions in the west. The watercourse meanders from foothill slopes, to improved greenbelt channels, and then meanders through a natural creek in the lower third of the watershed. Most of the watershed is valley floor and therefore the valley s-graph was the most suitable for the watershed.

The watershed's longest watercourse is 5.34 miles long and ranges in elevation from 2408' (NAVD88), to 1274' (NAVD88) where it confluences with the main Warm Springs Creek.

A lag was determined for use in the synthetic unit hydrograph method. The lag was calculated based on the physical characteristics of the drainage area and the following empirical formulas. The visually estimated mean of the Manning's n values of all collection streams and channels determined to be 0.03 is based on aerial imagery and field visits within the watershed. This value was chosen because the watercourses flow in fairly straight, unimproved channels and although there are areas of residential development with paved roads, the majority of flow area is still natural. The calculated lag based on these values was 0.744 hours.

Figure 2 - Hydrology Manual Lag Equation

$$\text{Lag (hours)} = 24\bar{n}\left[\frac{L.Lca}{S^{1/2}}\right]^{(.38)}$$

where:

$\bar{n}$ = The visually estimated mean of the n (Manning's formula) values of all collection streams and channels within the watershed

L = Length of longest watercourse - miles

Lca = Length along longest watercourse, measured upstream to a point opposite the centroid of the area - miles

S = Overall slope of longest watercourse between headwaters and the collection point feet per mile

Table 1-Watershed Parameters

Tributary C Watershed	
Drainage area (square miles)	2.98
Length of longest watercourse (miles)	5.34
Lca (miles)	2.98
Slope (feet/miles)	212.4
'N' visually estimated mean	0.03
Lag (hrs)	0.744

2.2.Rainfall

The 100 year 3-hr, 6-hr, and 24-hr storm durations were analyzed. Point rainfall data is taken from the District Hydrology Manual 100-year rainfall isohyets. These represent data from California NOAA Atlas 2, Volume 11.

Table 2 – Average Impervious Percentage by Watershed

Duration	100-year Point Precipitation (inches)	Areal Adjustment Factor
3-hr	1.80	99.5%
6-hr	2.50	99.6%
24-hr	4.50	99.7%

The rainfall storm patterns were taken directly from the Hydrology Manual's Plate E-5.9. These storms are representative of typical storms in the Riverside County region. The 3- and 6-hour rainfall patterns are from the Indio storm of September 24, 1939 and the 24-hour rainfall pattern is based on the storm of March 2 through March 3 of 1938, both found in the District Hydrology Manual.

A precipitation depth-area adjustment factor was used to account for areal effects that would decrease the percent of point rainfall to a reasonable value for what is actually experienced in a large watershed. For Tributary "C" the depth area adjustment was minimal since the watershed is only 2.98 sq. mi. For the 3-hr, 6-hr, and 24-hr, storms the depth-area adjustments were 99.5%, 99.6%, 99.7%, respectively.

2.3. Soil & Land Use

In order to determine the infiltration for the Tributary C watershed the hydrologic soil groups were determined. These were based on the United States Department of Agriculture – Natural Resource Conservation Service – SSURGO Database. The database provides a map classifying the soil groups from "A" to "D" with soils classified as "A" having the highest infiltration rate and soils classified as "D" having the lowest infiltration rate. In some areas of the basin, the soil was assigned a dual classification such as "B/D". In these areas the soil group that generated the highest runoff was used. A description of the soil groups from the District Hydrology Manual is included in Table 3 below.

Table 3- Soil Group Descriptions

Soil Group	Description
A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

ArcGIS 10.3 was used to intersect the basin and sub-basin boundaries (delineated using MicroStation) with the NRCS soil database map and ultimately calculate the areas of each soil group. The Tributary “C” watershed consists of a combination of soil groups A, B, C, and D. The watershed area was approximately 22% soil type “B”, 53% soil type “C”, and 25% soil type “D.” The large percentage of soil types “C” and “D” indicate a moderately high runoff potential since these soils are less pervious. The hydrologic soil group map is shown in Figure 3.

Land use, another factor in determining the watershed’s infiltration rate, was determined based on existing condition. Existing land use was determined using aerial images and field visits. The areas corresponding to each land use category were drawn out using MicroStation, and were then exported to an ArcGIS shapefile so they could be intersected with the NRCS soil database. A land use map is included in Figure 4. The land use categories were designated to conform to the categories in the impervious cover table on Plate D-5.6 of the District’s Hydrology Manual. The ‘natural’ areas were further broken up so that different cover types could be used. Table 4 below shows the different types of land use & land cover found in the Tributary C watershed and the impervious percentage that is assigned to that land use & land cover. Table 5 shows the percentage of each land use in the watershed as well as the percentage of each soil type. Tributary “C” has an impervious percentage of 20.7%.

Figure 3 - Soils Map

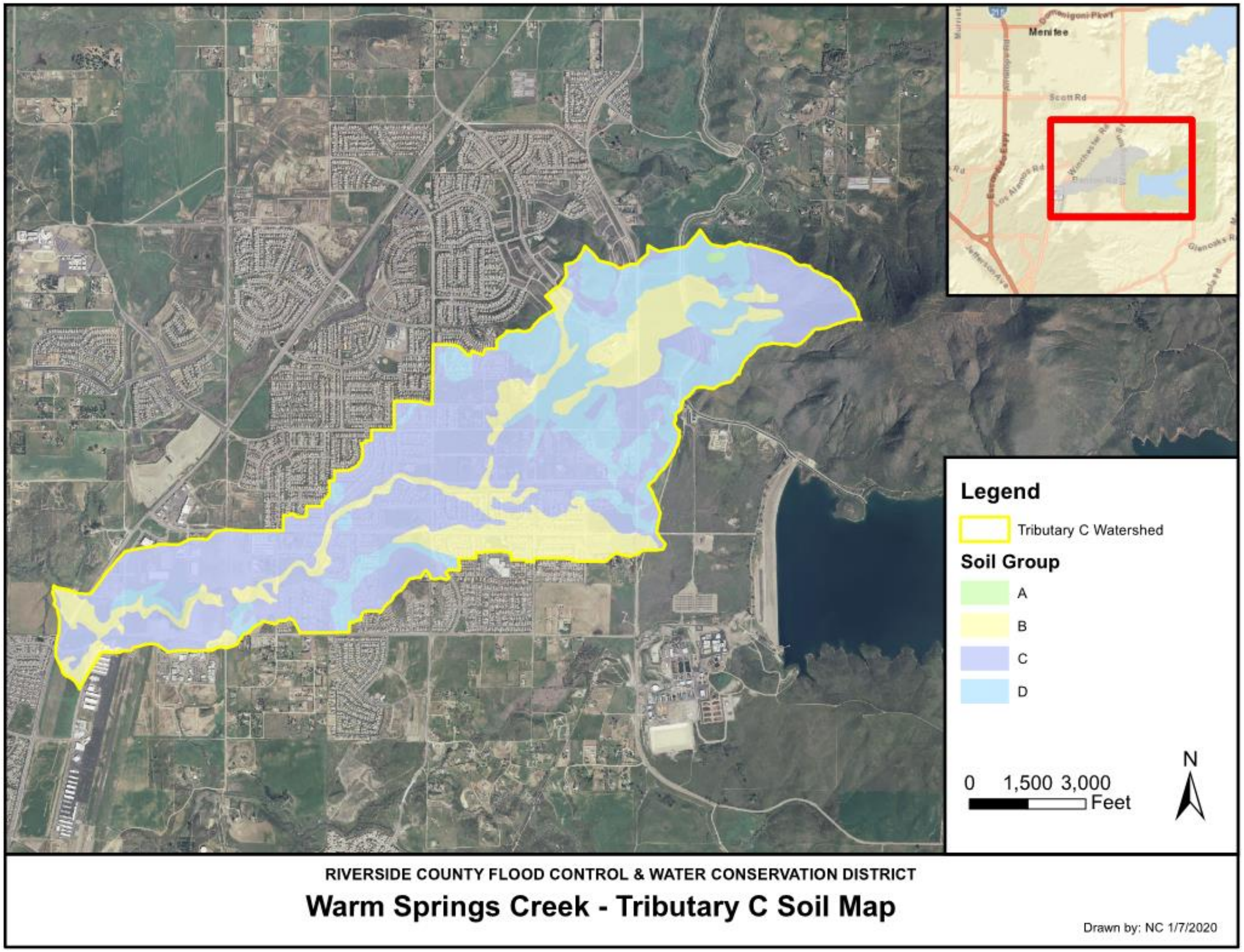


Figure 4 - Land Use map

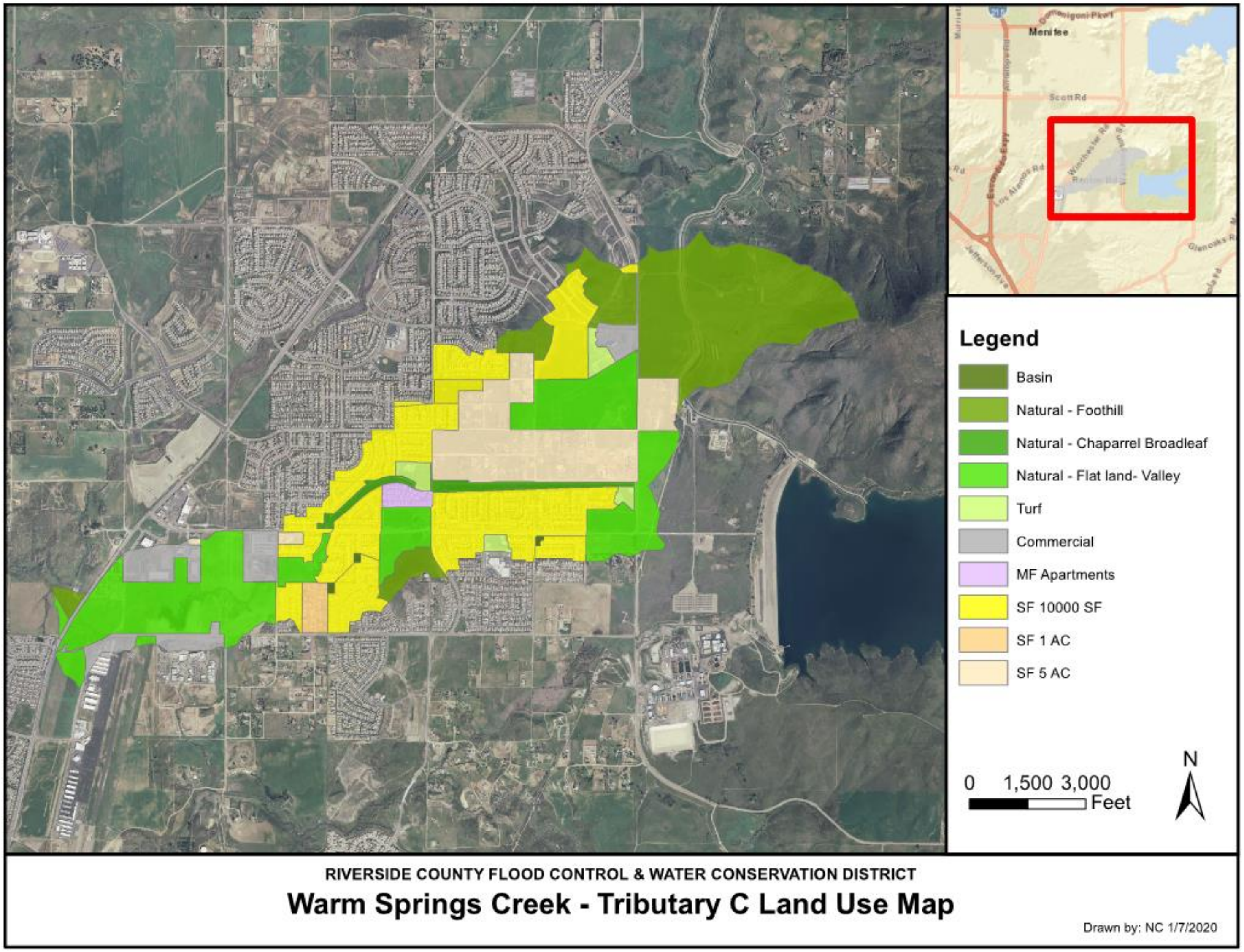


Table 4 – Cover Type

Land Use Type	Land Cover Type	Impervious (%)
Basin	Urban landscaping	0%
Commercial	Urban landscaping	90%
Apartments	Urban landscaping	80%
Natural Chaparral	Chaparral broadleaf, fair	0%
Natural Flatland	Grass fair	0%
Natural Foothill	Open brush fair	0%
Single Family 1 acre	Urban landscaping	20%
Single Family 10,000 sq. ft.	Urban landscaping	50%
Single Family 5 acre	Grass poor	5%
Turf	Turf	0%

Table 5 - Soil Group Descriptions

	Soil A (acres)	Soil B (acres)	Soil C (acres)	Soil D (acres)	Total (acres)
Basin	0	0.88	0.84	1.26	2.98
Commercial	0	25.89	92.68	6.4	124.99
MF Apartments	0	1.37	14.4	0	15.76
Natural - Chaparral Broadleaf	0	11.51	24.01	0.34	35.86
Natural - Flat land- Valley	0	123.34	233.62	107.29	464.25
Natural - Foothill	2.55	87.25	155.44	203.46	448.7
SF 1 AC	0	0.0	18.82	0.24	19.05
SF 10000 SF	0	125.16	281.51	99.37	506.04
SF 5 AC	0	23.73	182.13	50.57	256.44
SF 5000 SF	0	0	0	0	0.0
Turf	0	15.23	11.85	6.78	33.86
Total acres/ soil type	2.55	414.37	1015.3	475.7	1907.94
Percentage of soil type	0%	22%	53%	25%	100%

2.4.Infiltration Losses & Runoff Index

Infiltration losses are also dependent on the Antecedent Moisture Condition (AMC), the degree of soil saturation prior to a flood producing storm event. The AMC ranges from I to III with AMC III having the highest runoff potential. Per the criteria in the District's Manual, AMC II was used for the 100-year frequency storm analyzed in this report. This AMC II condition was used to determine the infiltration rate once the runoff index (RI) was determined.

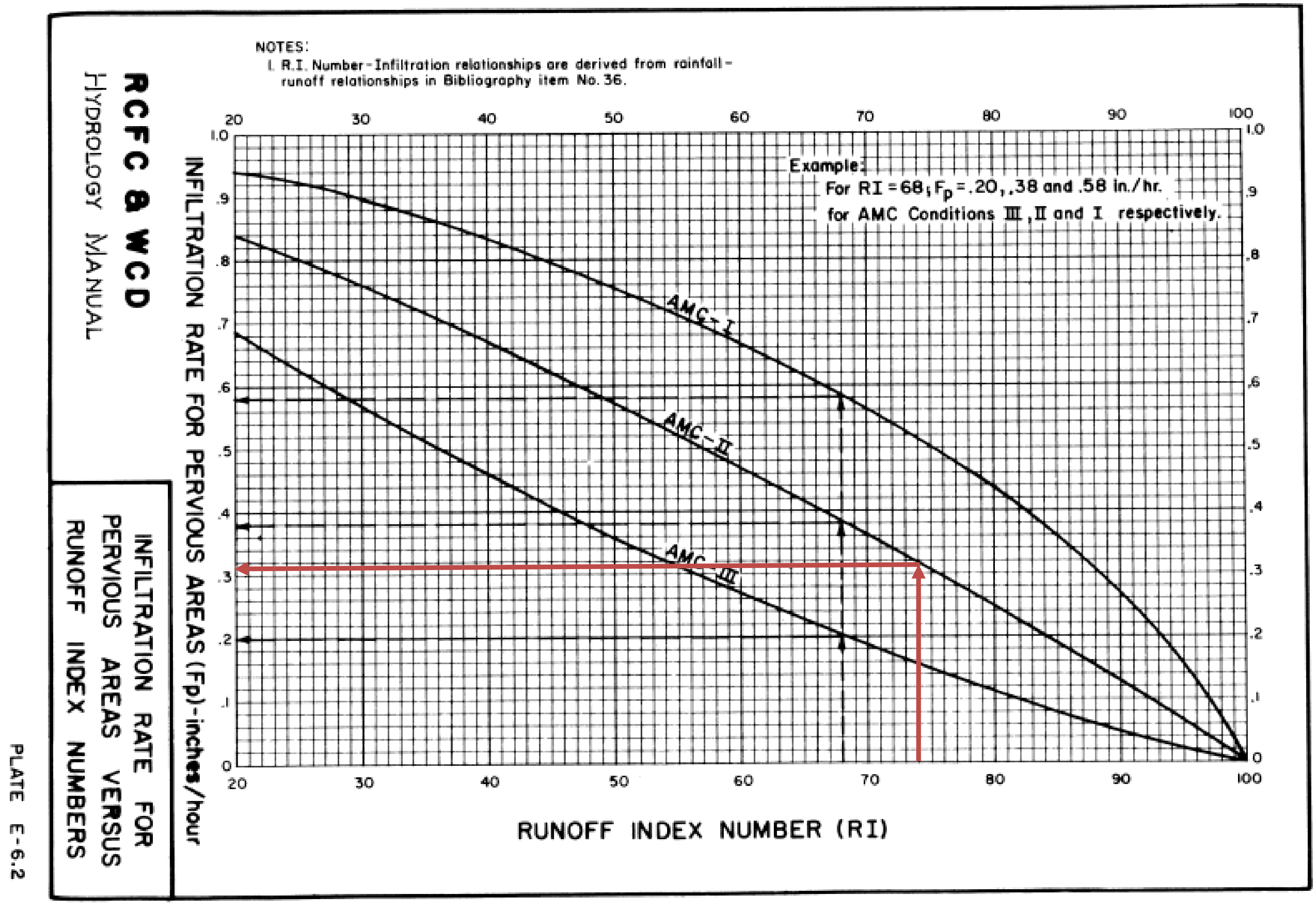
The Soil Conservation Service (now the National Resources Conservation Service) method outlined in the Hydrology Manual uses Runoff Index numbers in calculating infiltration rates. The runoff index numbers represent 'runoff potential' and range from zero to 100 with 100 having the highest runoff potential (i.e., lowest infiltration). Plate E-6.1 (Figure 2 below) of the District Hydrology manual tabulates runoff index numbers for AMC II condition for each cover type/quality of cover and each soil group. Plate E-6.2 of the District Hydrology manual was then used to determine an infiltration rate (Fp) in inches/hour, Figure 3 below. The infiltration rate (Fp) for pervious areas was calculated to be 0.31 inches/hour. The calculations for the assigned RI value is included in Appendix B.

Figure 5 – RI Table -Manual Plate E 6-1

RUNOFF INDEX NUMBERS OF HYDROLOGIC SOIL-COVER COMPLEXES FOR PERVIOUS AREAS-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
NATURAL COVERS -					
Barren (Rockland, eroded and graded land)		78	86	91	93
Chaparrel, Broadleaf (Manzonita, ceanothus and scrub oak)	Poor	53	70	80	85
	Fair	40	63	75	81
	Good	31	57	71	78
Chaparrel, Narrowleaf (Chamise and redshank)	Poor	71	82	88	91
	Fair	55	72	81	86
Grass, Annual or Perennial	Poor	67	78	86	89
	Fair	50	69	79	84
	Good	38	61	74	80
Meadows or Cienegas (Areas with seasonally high water table, principal vegetation is sod forming grass)	Poor	63	77	85	88
	Fair	51	70	80	84
	Good	30	58	72	78
Open Brush (Soft wood shrubs - buckwheat, sage, etc.)	Poor	62	76	84	88
	Fair	46	66	77	83
	Good	41	63	75	81
Woodland (Coniferous or broadleaf trees predominate. Canopy density is at least 50 percent)	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	28	55	70	77
Woodland, Grass (Coniferous or broadleaf trees with canopy density from 20 to 50 percent)	Poor	57	73	82	86
	Fair	44	65	77	82
	Good	33	58	72	79
URBAN COVERS -					
Residential or Commercial Landscaping (Lawn, shrubs, etc.)	Good	32	56	69	75
Turf (Irrigated and mowed grass)	Poor	58	74	83	87
	Fair	44	65	77	82
	Good	33	58	72	79

Figure 6 – Infiltration Rate Table - Manual Plate E 6-2



Since the SCS method only considers infiltration rates in pervious areas, the infiltration rate (Fp) found was adjusted to account for the percentage of impervious area using the equation on pg E-8 of the Manual, shown below. The adjusted loss rate for Tributary C is 0.252 in/hr.

Equation for adjusted infiltration rate, from Pg E-8 of the Manual:

$F = F_p(1.00-0.9A_i)$

$F=0.29(1-0.9(0.201))=0.252$ in/hr

where,

F_p = Loss rate for pervious areas in inch/hr. (Plate E 6.2)

F = Adjusted loss rate in inch/hr.

A_i = Impervious area in decimal percent

2.5. Resulting Flowrate

Finally, the effective rainfall was calculated using the District's HEC-HMS Preprocessor. The preprocessor requires point precipitation values, areal adjustment factors and an average adjusted loss rate, and will tabulate effective rainfall for each desired storm duration. The HEC-HMS Preprocessor will also account for low loss rate during the early stages of a storm when the adjusted loss rate might exceed the rainfall intensity. In these early stages, a 90% low loss rate is used and is typical for hydrology studies at the District. The tabulated effective rainfall is then used in HEC-HMS as a precipitation gage, with no loss rate method specified. Appendix B includes a table of the tabulated effective rainfall for each storm duration considered.

HEC-HMS was used to run the analysis. The model is included in Appendix B. The result for each storm event is summarized in Table 6 below. The 3-hour storm governed a peak flowrate of 1,160 CFS was used in the hydraulic analysis.

Table 6 - Peak Flowrates

Storm Event	Peak Flowrate (CFS)
3 hour	1,160
6-hour	1,113
24 hour	530

3. Hydraulic Analysis

3.1. Effective Model/Duplicate Effective Model

The area is currently mapped as a FEMA Zone D. There is no effective model or duplicate effective model. This study will delineate the first FEMA floodplain in the area.

3.2. Proposed Floodplain

The proposed floodplain was modeled from Washington Street to the section directly upstream of highway 79. The proposed floodplain is split into three parts due to roadway crossings and is contained either by constructed channels or natural channels.

The Benton Creek Channel was constructed in multiple stages as part of the development of multiple housing tracts. These improvements to the Benton Creek Channel were built from 2003 to 2007 and were built to contain the 100-year ultimate condition flood flows. The channel is a graded earthen channel with a meandering low flow and it is densely vegetated due to a conservation easement. This vegetation was accounted for with a higher manning's n-value in the hydraulic model. The flow exits Benton Creek Channel directly into a natural channel.

3.2.1. Topography

Digital Terrain Models (DTMs) were created for this region using LiDAR data. The data was collected in January of 2012 and was converted to DTMs by the District. The study used 200 scale/4 foot contour intervals and had a contour factor less than 1800, which is a National Map Accuracy Standard. The vertical datum is NAVD 88.

3.2.2. Section Geometry

Sections were cut from the RCFC&WCD DTMs along the Tributary C reaches. The DTMs did not always accurately represent the section geometry because of vegetation in the way or because the level of detail of the mapping. The HEC-RAS sections were modified to accurately represent "as-built" conditions of the improved areas of the channel. This was done with the help of the as-built drawings for the Benton Creek Channel along TR29214, TR29875, and TR30098 and field visits.. The elevations from some of these drawings were converted from NGVD 29 using the National Geodetic Survey 'Vertcon' to match the NAVD88 datum (2.4' conversion). Due to these adjustments, some of the edited cross sections deviate in elevation from the DTM, however, they are more accurate compared to the DTM.

Benton Creek cross sections RS5781 through RS5128 are artificially elevated in the DTM due to ponded water when the area was surveyed. These sections were left as is because using the ponded water elevation as the ground surface is a conservative assessment for the model.

Table 7 below indicates the various drawing plans that were considered when building the hydraulic model. This table also includes the plans that were used to model the structures along Puorroy Road, Benton Road and Van Gaale Lane. These drawings and As-Builts are included in Appendix E.

Table 7 - Plans Used

DWG No.	As-built	Title	Tributary	Tract	Sections Affected
7-351, 928kk	As-built 2/13/04, As-built 01/18/04	Coral Tree Court Storm Drain Stage 2 Benton Creek Channel, Street Improvement Plans	C ‘Benton Creek’	TR30098, TR30098	XS 11732 and Benton Road Cross
7-370	As-built 10/5/05	Benton Creek Channel Stage 2	C ‘Benton Creek’	TR29875	XS11893-XS1504 and Benton/Pourroy Road Cross
7-401	As-built 10/3/2010	Warm Springs Valley –Benton Creek Channel	C ‘Benton Creek’	TR29214	XS15208 – XS20172
928-BB	As-built 2/27/04	Tract No. 30097 Street Improvement Plans Storm Drains	C ‘Benton Creek’ Van Gaale Lane	TR30097	Road Crossing RS9165 Van Gaale Road Cross Culvert

3.2.3. Structures

Three bridge structures were modeled in the Benton Creek reach. Puorroy road was modeled based on the Benton Creek Channel Stage 2 drawings and accounts for the four 8’X4’ RCBs under the road. Benton Road has three (3) 6’X10’ RCBs that were modeled. Van Gaale Lane was modeled based on the street improvement plans for TR 30097 included in Appendix E. Based on the HEC-RAS modeling, Van Gaale Lane is overtopped and functioning as a weir for the flow. All of the other bridges modeled had enough capacity in the culverts and were not overtopped. The Briggs road bridge/culvert was not modeled because the culverts under the road are undersized and contain sediment. We do not expect these culverts to function during a 100-year storm event and are assuming all flow will overtop the road. Therefore, Briggs road is modeled as an inline weir structure in order to accurately capture the backwater effect. Elevations for the top of the road were generated using the DTM points at the centerline of the roadway. A similar weir was generated for SR-79 due to lack of as-built data on the culvert under the road. Note that these weir structures are not incorporated into the MT-2 Forms as they are not actual weirs.

Detention basins exist adjacent to Benton Creek channel near just north and south of Benton Road. To avoid modeling any kind of levee condition, it was assumed that any land between the basins and Benton Creek Channel did not exist when generating the floodplain shape. The cross sections only take into account Benton Creek Channel, however the shape applies the water surface on the basins as well. This is a highly conservative assessment because the cross-sectional area of the basins is not considered in the water surface elevation.

3.2.4. Manning's N-value

The n-value was chosen to account for the irregularity of the channel and to model effect of vegetation in the floodplain. Through the improved channels of Benton Creek there were areas designated as conservation easement. These areas will not be maintained, as shown in the typical section in Figure 7 below. A very conservative n-value of 0.1 was used in the conservation easement since it is unmaintained and the density of vegetation is unknown. Sections near Briggs Road have raised main channel Manning n-values based on a field visit where it was noted that vegetation density was higher than previously thought. The new n value for these areas is 0.045. Table 8 below summarizes the typical n-values used.

Figure 7 - Typical Section Conservation Easement

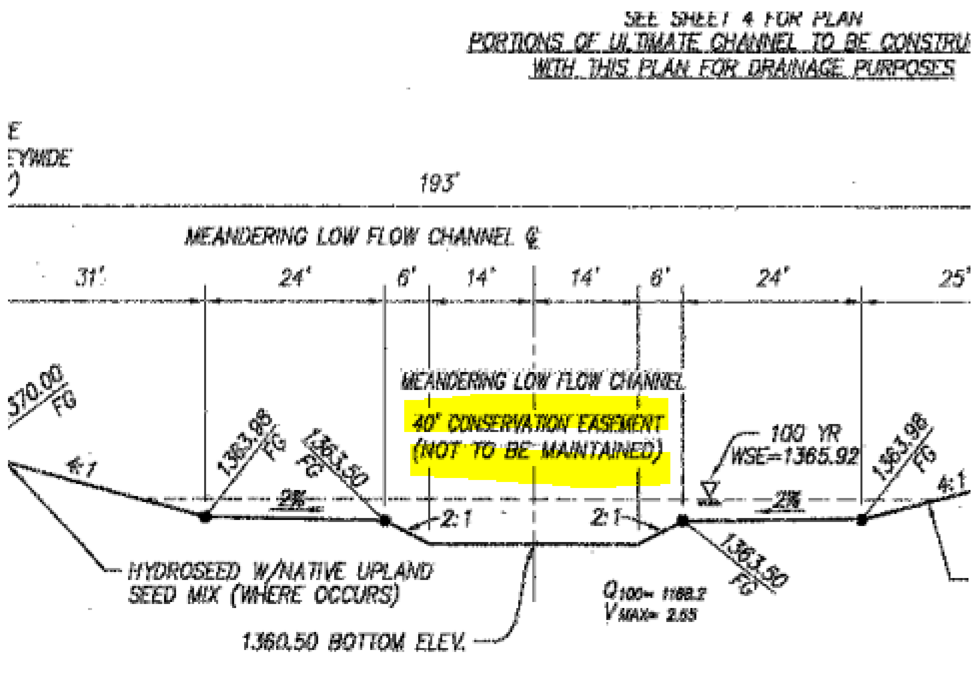


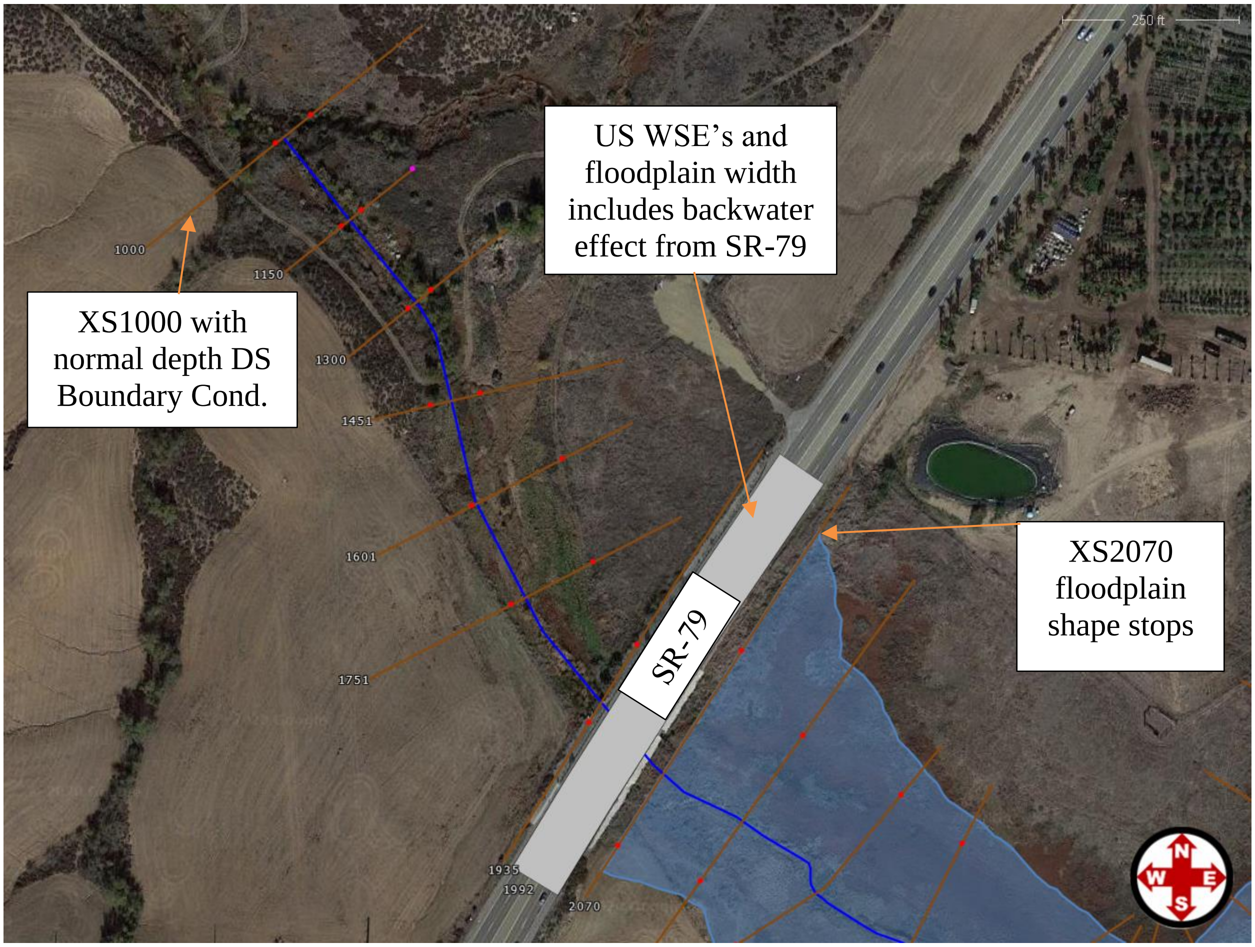
Table 8 - N-Value Summary

Conservation easement	**0.1**
Rip rap	0.045
Earthen/graded	0.035 (0.045 near Charlois and Briggs)
Concrete lined	0.01

3.2.5. Flow Regime & Boundary Conditions

The downstream boundary condition used for the Benton Creek Reach was normal depth based on the slope of the creek. At the downstream end the slope is 0.026 ft/ft at XS1000. The hydraulic model will default to subcritical and use the downstream slope as the control downstream. However, the District's goal is to terminate the floodplain just upstream of highway SR-79 at XS2070. There is no known WSE to use as a boundary condition that is representative of the backwater caused by the overtopping of the SR-79 and it would be inaccurate to calculate a normal depth at that location. Therefore, the model was extended downstream of the SR-79 by approximately 1070 feet in order to allow the flow upstream of XS1000 to normalize and to capture the backwater effect caused at SR-79. The addition of the backwater creates more representative water surfaces upstream of the highway and therefore, a more accurate floodplain. As such, the floodplain shape for Benton Creek is stopped at RS2070, but the model sections extend downstream. Figure 8 shows the locations given above.

Figure 8 – Downstream Control Exhibit



Additionally, a known water surface elevation was used as an interior change at Benton Creek Section 14192. The known water surface elevation of 1361.96 (from the as-built drawings 7-0370) was used as the ponding depth in the park basin built as part of TR29875.

Along the Benton Creek reach the flow change locations were determined based on how much area was tributary to that point. The entire Tributary C watershed is about 3 square miles, the flowrate was increased every additional 0.5 sq. mi. tributary to ‘Benton. Table 9 below summarizes the location and increase in flowrate.

Table 9 - Benton Creek Flowrate Changes

Benton Creek Section	Flowrate	Fraction of Final Flowrate
20172	160	1/10
18280	195	1/6
17879	390	1/3
16376	580	½
14192	775	2/3
9575	965	5/6
7900	1160	1

Table 10 below summarizes the model parameters associated with Warm Springs Tributary C.

Table 10 – Model Parameters

Warm Springs Tributary C	Benton Creek
Geometry Name	Benton FINAL
Flow Name	Updated_Existing
Plan	Benton FINAL
D/S Boundary Cond.	Normal Depth
Flow Regime	Subcritical
D/S Limits	XS1000
D/S Floodplain Extent	XS2070
U/S Limits	XS20172
n-Values	.035, .045, 0.1

3.3.HEC-RAS 1D Results

The HEC-RAS detailed study water surface elevation results are shown on the Topographic WorkMap in Appendix D as well as in the attached HEC-RAS Hydraulic Model attached in Appendix C. The mapped floodplain will stay within the improved channel along the upper ‘Benton Creek’ reach and does not impact any structures.

4. Resulting Floodplain

The resulting floodplain will be mapped as a FEMA Zone AE. A floodway will not be designated. Approximately 11,000 feet on the upstream side of Benton Creek is improved and already includes conservation easements and/or has been dedicated for flood control purposes. The rest is open space with no structures nearby. The study will delineate a new FEMA Zone D area outside of the watershed and the FEMA Zone AE detailed study for Warm Springs Tributary C inside the watershed.

The proposed Tributary C floodplain adds 26 parcels to the FEMA Zone AE floodplain. The remainder area removed from FEMA Zone D is proposed to be mapped as FEMA Zone X (areas of minimal flooding).

An annotated FIRM map was not created since FIRM panels 06065C-2730G and 06065-2710G were not printed and the area is in a Zone D. The topographic work map will delineate the new FEMA Zone D outline. A total of 76 acres is added to FEMA Zone AE without a floodway.