SUPPLY CREEK

SURFACE WATER SUPPLY STUDY

Prepared For:

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1 EXECUTIVE SUMMARY

The upper portion of Supply Creek, a tributary to the Trinity River, is located in Humboldt County, California. The lower portion of the watershed, approximately 70%, is within the Hoopa Valley Indian Reservation. The County has received applications for 14 proposed cultivation sites located in the upper portion of the Supply Creek watershed. Cumulatively, these applications request the right to cultivate approximately 9.2 acres.

The Hoopa Valley TEPA is concerned that intercepting rainwater for cultivation during the period of winter recharge will impact stream health. The purpose of this study is to evaluate the cumulative impacts the applications would have on the surface water resources within the Supply Creek watershed.

The study area, approximately 8,235 acres, encompasses the portion of Supply Creek watershed just above its confluence with Rock Creek, approximately 1.5 miles upstream of the Trinity River.

Hydrologic and hydraulic analysis of the Supply Creek watershed was conducted using SWMM to model runoff for the 5-, 10-, 25-, 50-, and 100-year, 24-hour design storm events and the hydrologic years from October 1, 2009 through September 30, 2019. The model was validated using regional regression analysis and observations from the USGS Supply Creek gauge.

The projected demand was estimated based on the maximum of typical demands reported by cultivators and should represent a conservatively high estimate of demand. For the hydrologic years modeled, including the driest on record and accounting for infiltration, depression storage, and evaporation, demand represented only 0.4% to 1.8% of total runoff from the study area. The analysis here represents runoff from only 80% of the watershed, excludes snowmelt, and does not account for cultivators utilizing groundwater disconnected from surface water; all of which would add to the total runoff to Supply Creek and reduce the cultivation impact on that runoff. Thus, the 9.2 acres of proposed cultivation within the Supply Creek watershed would not have a significant impact on surface water runoff within the Supply Creek watershed.

2 INTRODUCTION

2.1 Background

Supply Creek, a tributary to the Trinity River, is located in Humboldt County, California (Figure 1). The total watershed area is 10,254 acres, of this, the lower 7,184 acres (~70%) are within the Hoopa Valley Indian Reservation. The County of Humboldt (County) has received applications for 14 proposed cultivation sites located in the headwaters of the Supply Creek watershed. Cumulatively, these applications are for the right to cultivate approximately 9.2 acres.

The Hoopa Valley Tribal Environmental Protection Agency (TEPA) is concerned that cannabis cultivation within the Supply Creek watershed would impact the Tribe's water resources. The Hoopa Valley TEPA is concerned that intercepting rainwater for cultivation during the period of winter recharge will impact stream health. To address this concern, the applicants for cannabis cultivation within the watershed have been asked to conduct a Surface Water Supply Study to evaluate the cumulative impacts applications would have on surface water resources within Supply Creek watershed.

2.2 Study Area

The study area, approximately 8,235 acres, encompasses the portion of the Supply Creek watershed just above the confluence with Rock Creek, approximately 1.5 miles upstream of the Trinity River, within the Hoopa Valley Reservation. Drainage generally flows northeast, originating in the higher elevations in the mountainous terrain surrounding Supply Creek. Proposed cultivation areas are located on parcels within the upstream third of the study area.

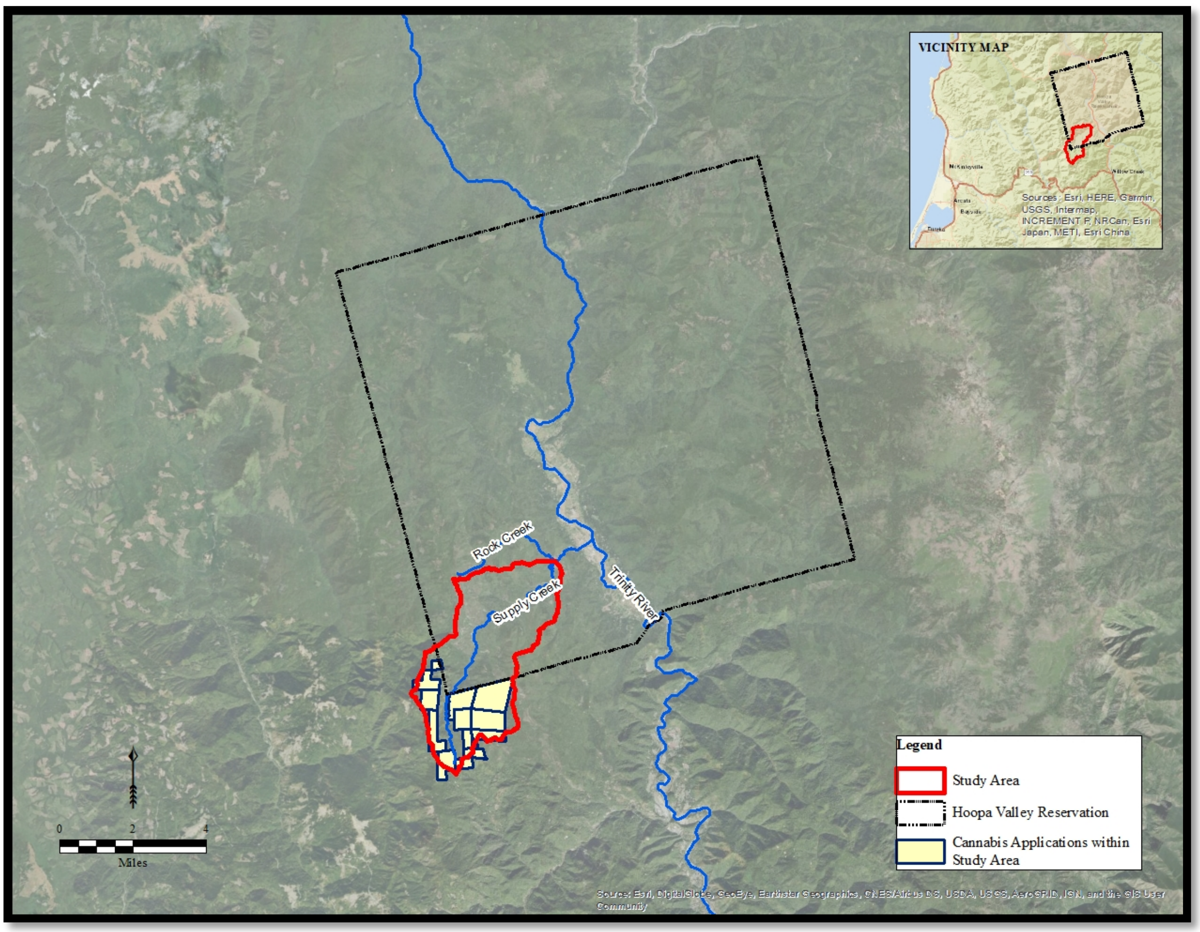

Figure 1. Supply Creek Watershed Study Area

3 DATA COLLECTION

3.1 Topographic Data

Topographic data used to delineate subcatchments was obtained from the USGS National Elevation Dataset as 1/3 arc-second (approximately 10 meter) Digital Elevation Model (DEM).

3.2 Soils Data

Soils data, used for modeling infiltration rates, was obtained in digital format from the Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database for the Humboldt County Area (NRCS 2009). There are 25 distinct soil classes within the study area.

3.3 Precipitation Data

3.3.1 Design Storms

Design storms for the 5-, 10-, 25-, 50-, and 100-year, 24-hour events were developed using rainfall depth data from NOAA Atlas 14, Volume 1, Version 5, revised 2011 (Bonin et al. 2011). Rainfall depths were taken at the centroid of the study area and are summarized in Table 1.

Table 1. Rainfall Depths for each Design Storm

Storm Event	Rainfall Depth (in)
5-year	7.98
10-year	8.98
25-year	10.7
50-year	12.0
100-year	13.4

3.3.2 Yearly Precipitation

Daily precipitation data recorded at the Willow Creek 1 NW, CA US weather station, approximately 6 miles southeast of the study area (Figure 2), was obtained from the National Oceanic and Atmospheric Administration (NOAA) Climate Data Online (CDO). The period of record covers 1968 through 2019. The most complete portion of the record covers the hydrologic years October 1, 2009 through September 30, 2019, and includes the driest year recorded since 1968, which was the 2013/2014 hydrologic year. The yearly precipitation is summarized in Figure 3.

Figure 2. Map Showing Willow Creek 1 NW Weather Station

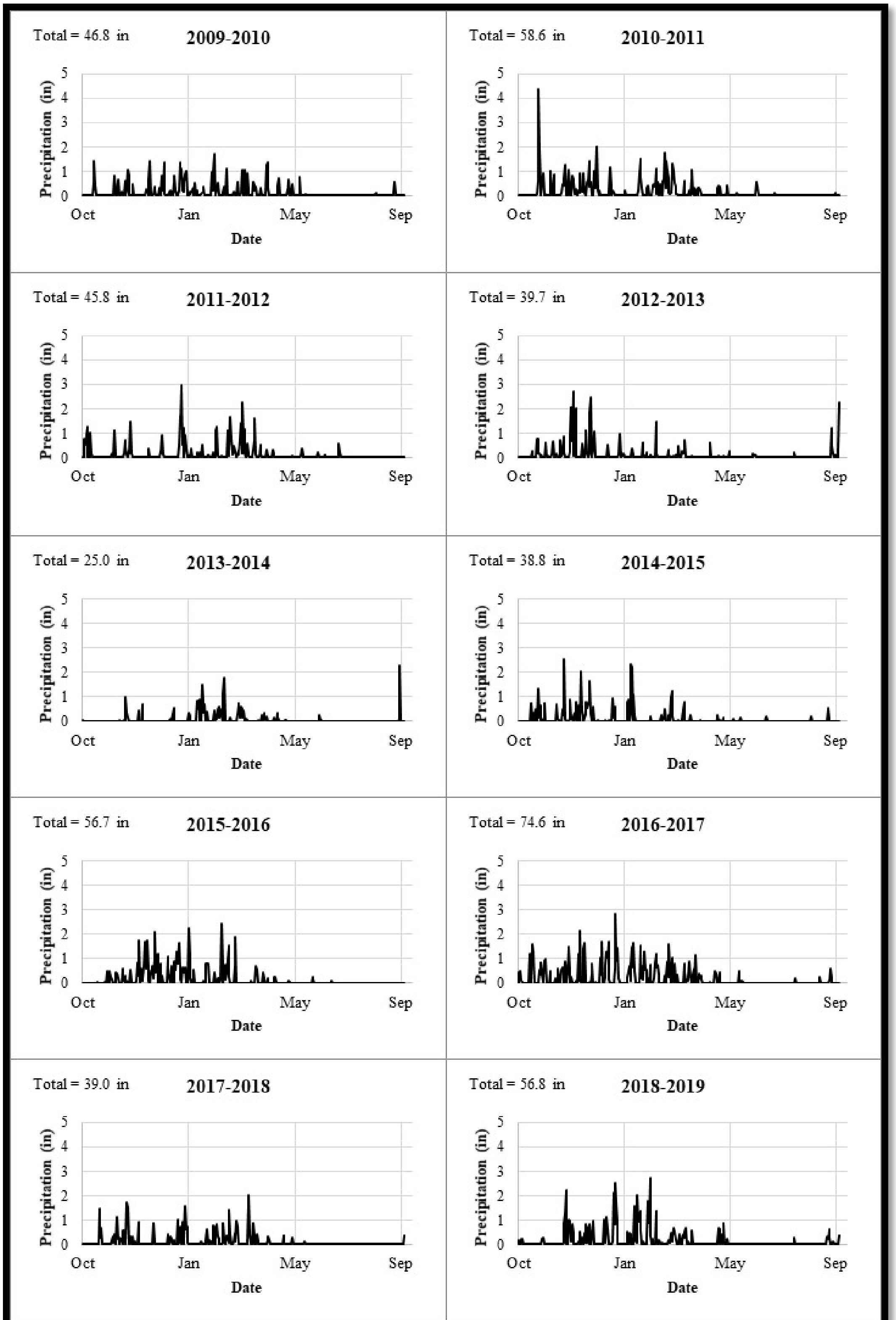

Figure 3. Yearly Precipitation for each Hydrologic Year from 2009 to 2019

3.4 Evaporation Data

Monthly average evaporation values at the Willow Creek 1 NW weather station were obtained from the Western Regional Climate Center (Figure 4). These monthly values represent averages recorded for the period 1968 through 2005. The average annual evaporation is about 27.1 inches.

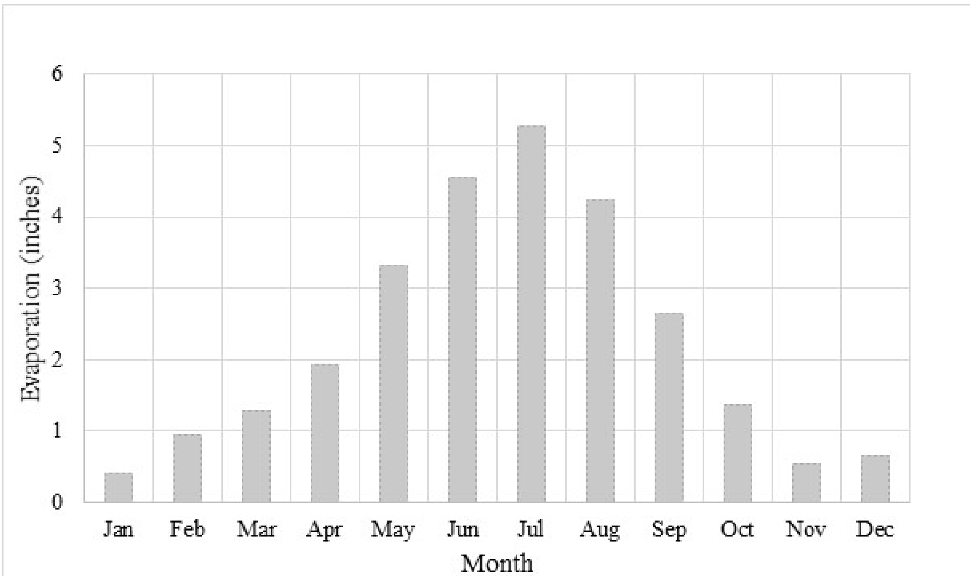

Figure 4. Average Monthly Evaporation

4 MODEL SETUP

Hydrologic and hydraulic analysis of the Supply Creek watershed was conducted using Computational Hydraulic Institute's PCSWMM version 7.2 which is a user interface used to create and run the U.S. Environmental Protection Agency (USEPA) Stormwater Management Model (SWMM). SWMM is used for single events (design storms) or long-term simulations (e.g., yearly or multiple years) of water runoff. SWMM utilizes the dynamic wave method, which solves the one-dimensional Saint-Venant equations for continuity and momentum for model channels. The SWMM model generates flow hydrographs for each subcatchment and hydraulic link and accounts for rainfall, interception, infiltration, depression storage, and evaporation.

4.1 Precipitation

4.1.1 Design Storms

Using the NOAA Atlas 14 precipitation data, the PCSWMM Design Storm Creator tool was used to develop a SCS Type IA (NRCS 1986) design storm for the 5-, 10-, 25-, 50-, and 100-year, 24-hour events.

4.1.2 Yearly Precipitation

Daily time series data for each hydrologic year from October 1, 2009 through September 30, 2019 was compiled within PCSWMM into ten distinct yearly storm events as shown in Figure 3.

4.2 Evaporation

Average monthly evaporation data (Figure 4) was entered into the PCSWMM Climatology Editor. The Climatology Editor is used to describe climate characteristics within the study area.

4.3 Subcatchment Delineation

The watershed was subdivided into subcatchments delineated in Esri® ArcGIS using USGS topographic data. GIS software was used to develop area-weighted averages of model input parameters for each subcatchment. A total of 12 subcatchments, ranging in areas between 238 acres (0.4 mi^2) and 1,066 acres (1.7 mi^2), were delineated within the study area (Figure 5).

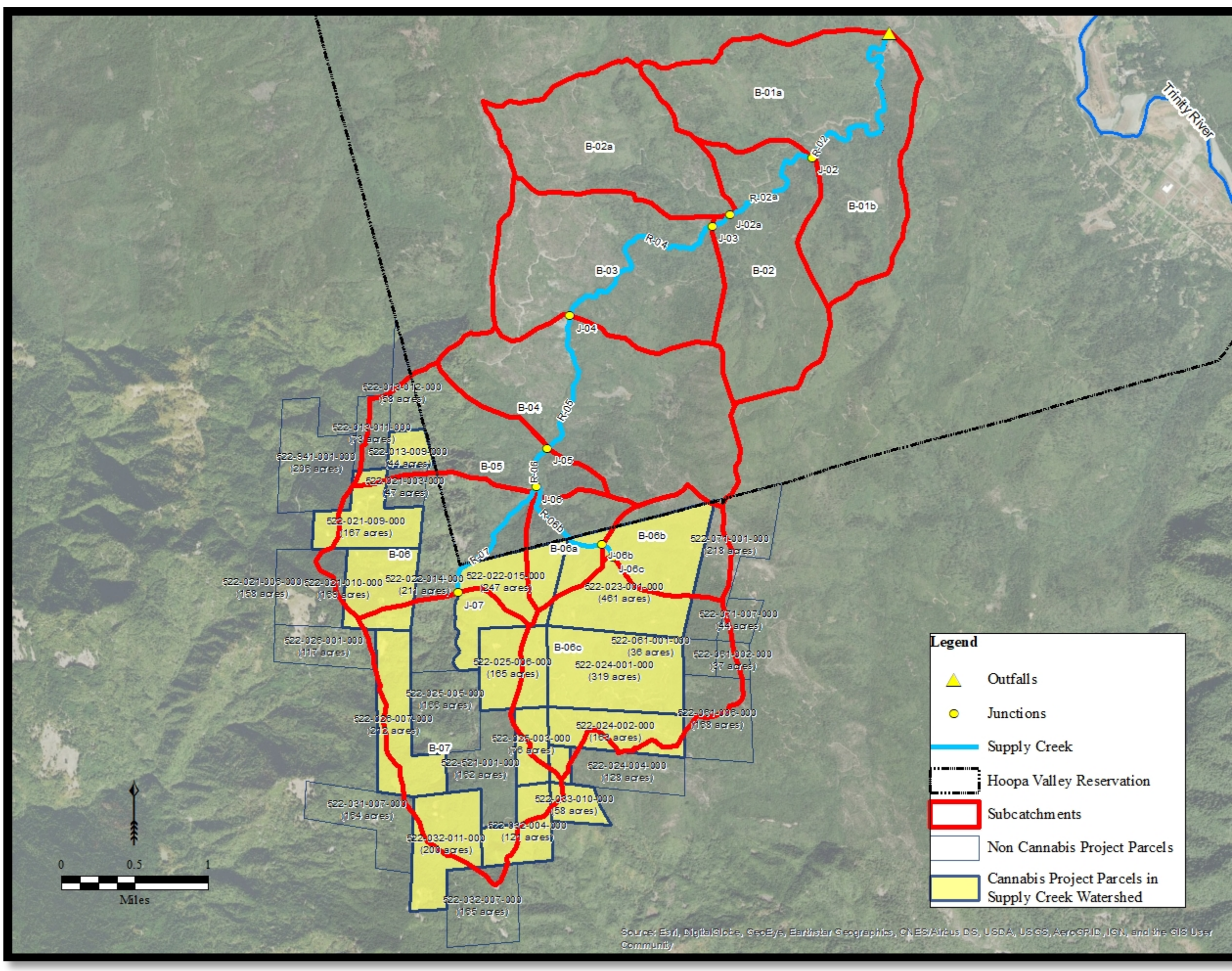

Figure 5. Model Layout and Cannabis Project Parcels within the Study Area

4.4 Subcatchment Parameters

The runoff potential within a subcatchment is estimated in SWMM using runoff curve numbers (CNs), depression storage, percent impervious, Manning's *n* for pervious and impervious areas, longest flow path, and subcatchment slope. The subcatchment parameters are summarized in Table 2.

Runoff for each subcatchment is calculated after subtracting the depression storage and infiltration (estimated using the CN method). Depression storage represents water storage provided by ponding, surface wetting, and interception. Depression storage for forested areas is approximately 0.30 inches (ASCE 1992).

CNs were determined based on land use and Hydrologic Soil Group (HSG). General land use was developed from aerial imagery and characterized based on the NRCS Land Use classification system (NRCS 1986). The general land use within the Supply Creek watershed is "Woods, Good Condition". Soils are classified into four HSGs (A, B, C, and D) from low runoff potential (HSG A) to high runoff potential (HSG D). HSGs were obtained from the SSURGO Database. HSGs and CNs are summarized in Figure 6. A weighted CN was determined for each subcatchment.

To account for roads and development, the percent impervious area within each subcatchment was assumed to be 5%.

Subcatchments are modeled in SWMM as nonlinear reservoirs. Subcatchment inflow is calculated as the amount of precipitation falling on a subcatchment combined with the runoff from upstream subcatchments.

Surface runoff, Q, occurs only when the depth of water, d, exceeds the maximum depression storage, d_p, and is calculated as follows:

$$Q = W * (1.49/n)(d - d_p)^{2/3} S^{1/2}$$

where:
W = Subcatchment width
S = Subcatchment slope, and
n = Manning roughness value for the subcatchment

Depth of water over the subcatchment is continuously updated with time by numerically solving a water balance equation over the subcatchment. Subcatchment slope is estimated as the average slope of overland flow. The subcatchment pervious Manning's *n* value recommend for woods is 0.4 (FHWA 2002).

The subcatchment width is calculated based on the following formula:

$$W = \frac{A_{sub}}{L_{ov}}$$

where:
W = Subcatchment width (ft)
A_{sub} = Subcatchment area (ft^2)
L_{ov} = Length of overland sheet flow

Length of overland sheet flow is estimated as the longest flow path within the subcatchment.

Table 2. Subcatchment Parameters

Name	Area (ac)	Width (ft)	Flow Length (ft)	Slope (%)	Impervious (%)	Manning's *n*		Depression Storage (in)	
						Impervious	Pervious	Impervious	Pervious
B-01a	631	3232	8500	14.3	5	0.01	0.40	0.05	0.30
B-01b	505	2786	7900	19.7	5	0.01	0.40	0.05	0.30
B-02	699	3714	8200	25.0	5	0.01	0.40	0.05	0.30
B-02a	667	2907	10000	25.9	5	0.01	0.40	0.05	0.30
B-03	898	7115	5500	17.0	5	0.01	0.40	0.05	0.30
B-04	1053	6281	7300	21.4	5	0.01	0.40	0.05	0.30
B-05	500	3252	6700	22.7	5	0.01	0.40	0.05	0.30
B-06	715	3621	8600	22.2	5	0.01	0.40	0.05	0.30
B-06a	238	2463	4200	31.4	5	0.01	0.40	0.05	0.30
B-06b	308	2984	4500	34.4	5	0.01	0.40	0.05	0.30
B-06c	955	6026	6900	20.4	5	0.01	0.40	0.05	0.30
B-07	1066	4644	10000	11.6	5	0.01	0.40	0.05	0.30

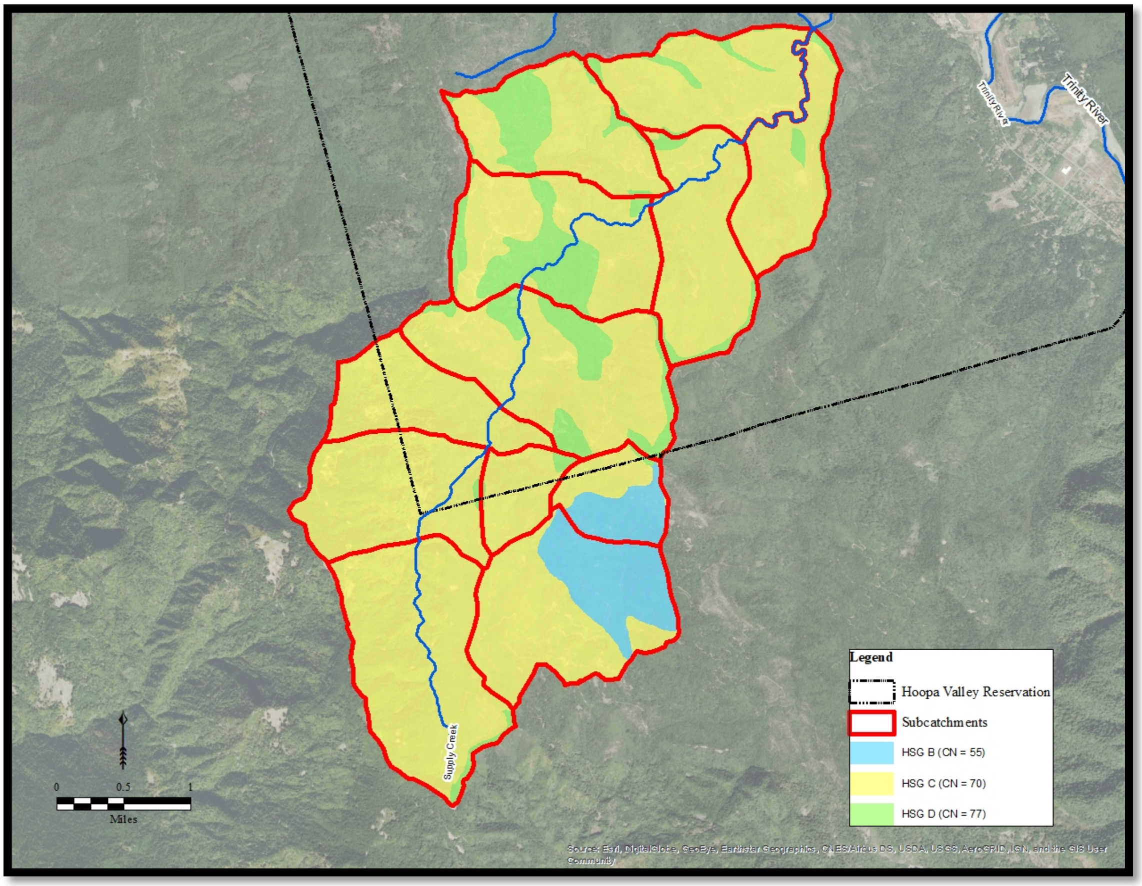

Figure 6. Hydrologic Soil Groups

4.5 Hydrograph Routing (Hydraulics)

Hydrographs developed from the rainfall-to-runoff response of each subcatchment are routed downstream through the watershed via channel reaches. Routing calculations account for peak flow attenuation and hydrograph timing created by the channels. Cross sections for each channel reach were estimated using the USGS topographic data. Channel routings were modeled using the Dynamic Wave method with channel Manning's *n* values of 0.05.

4.6 Model Results and Validation

The model was used to simulate the 5-, 10-, 25-, 50-, and 100-year, 24-hour events and runoff for the hydrologic years from October 1, 2009 through September 30, 2019. Since the design storms are event based, representing a short duration, evaporation was assumed to be insignificant and therefore was not included. For long term simulation, however, evaporation would be significant, thus, average monthly evaporation was subtracted from runoff for the yearly simulations.

The model was validated by comparing modeled 5-, 10-, 25-, 50-, and 100-year, 24-hour peak flows to results of regional regression analysis and by comparing the modeled average yearly runoff to the average yearly runoff observed at the USGS stream gauge on Supply Creek (11530020 SUPPLY C A HOOPA CA).

The use of frequency analysis, based on the annual maximum peak flows recorded at the gauge, to validate the design storms is inappropriate because the period of record of the Supply Creek, which is (7) years, is too small.

4.6.1 Design Storms

A regional regression analysis was performed, to estimate the 5-, 10-, 25-, 50-, and 100-year peak flows at the outfall of the study area, using USGS StreamStats (streamstats.usgs.gov) and following guidance from *Methods for Determining Magnitude and Frequency of Floods in California* (Gotvald et. al., 2012). The regression results are compared to the model results for the same events (Table 3). The model flows are similar to the regression estimates and fall well within the regression prediction intervals.

Table 3. Summary of Peak Flows Estimated using Regional Regression and Model Results

Storm Event	Peak Flow (cfs)		Regression Prediction Interval
	Regression	Model	
5-year	2,770	2,440	1,320-5,800
10-year	3,490	3,290	1,720-7,060
25-year	4,410	4,640	2,250-8,620
50-year	5,080	5,750	2,590-9,980
100-year	5,770	7,010	2,870-11,600

4.6.2 Hydrologic Years

The model was used to simulate the yearly runoff for hydrologic years from October 1, 2009 through September 30, 2019. Total runoff at the outfall of the study area for each hydrologic year is summarized in Table 4. The average yearly runoff of the ten years modeled is 7,041 Million Gallons (MG), and ranges between 2,040 MG and 13,100 MG. In the Water Quality Control Plan for the Hoopa Valley Indian Reservation (Hoopa Valley TEPA 2008), the estimated the water yield in the region was given as 2,126 acre-feet per square mile, which equates to 8,914 MG.

Table 4. Total Runoff at the Outfall of the Study Area for each Hydrologic Year Modeled

Hydrologic Year	Precipitation (in)	Runoff (MG)
2009-2010	46.8	6,900
2010-2011	58.6	8,920
2011-2012	45.8	5,740
2012-2013	39.7	4,850
2013-2014	25.0	2,040
2014-2015	38.8	5,590
2015-2016	56.7	9,740
2016-2017	74.6	13,100
2017-2018	39.0	4,120
2018-2019	56.8	9,410

The average daily runoff observed from 1981 through 1987 at the Supply Creek gauge was plotted with the average daily runoff of all the hydrologic years simulated (Figure 7). The yearly trends observed and modeled are similar.

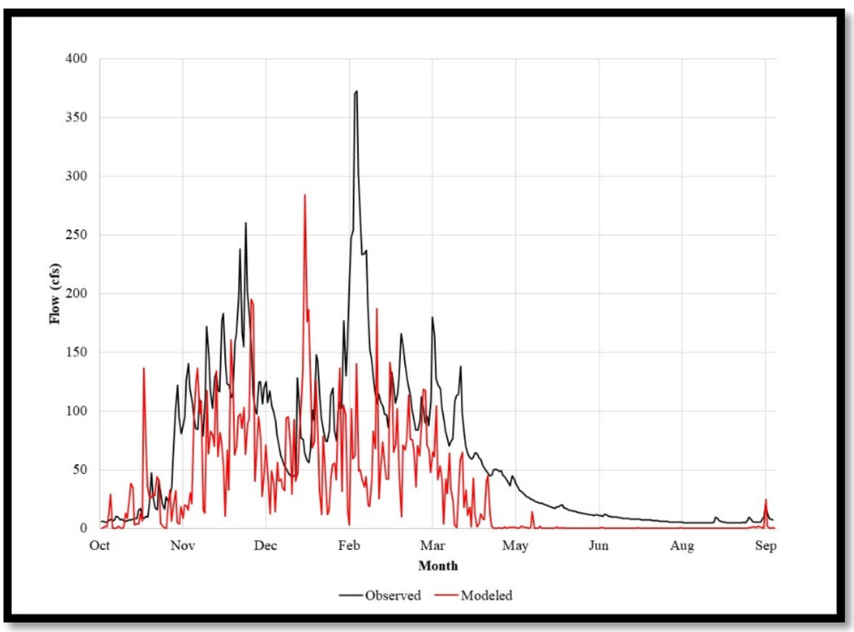

Figure 7. Average Daily Flows Observed at the USGS Supply Creek Gauge from 1981 to 1987 and Average Daily Flows for all Modeled Hydrologic Years

5 CULTIVATION WATER DEMAND

5.1 Typical Demand

There is limited published data regarding water demand for cannabis cultivation. Demand is a function of the cultivation area, density of plants grown within the cultivation area, cultivation season, and climate.

Wilson et. al. (2019) conducted a survey of 101 cultivators to investigate and characterize specific aspects of cannabis cultivation, including water use. Most cultivators reported using variable amounts of water over the growing season, with the highest use from May through September. When Wilson et. al. standardized the water use by cultivation area, application rates were shown to be similar for both indoor and outdoor cultivation. The average annual rates reported by the study ranged between 0.004 and 0.49 gallons per square foot of cultivation area per day.

Bauer et. al. (2015) suggested the use of 6.0 gallons per plant per day with an average of 12.0 square feet per plant. This equates to 0.50 gallons per square foot of cultivation area per day and is the same as the maximum reported by Wilson et. al. (2019). Cultivators and cultivation representatives have long argued that the rate recommended by Bauer et. al. (2015) is much higher than the actual rate applied.

Application rates reported by a cultivator in the Willow Creek area located at an elevation of approximately 2,300 feet above sea level, ranged between 0.05 and 0.07 gallons per square foot of cultivation area per day for a cultivation season starting approximately on May 1 and ending on October 15. The proposed cultivation areas in the Supply Creek watershed are at locations ranging in elevation between 2,200 feet and 4,000 feet above sea level.

The cultivation season for cultivators within the upper Supply Creek watershed is limited by climate. Due to the harsh winters in the upper elevations of the watershed where the proposed cultivation is located, both mixed-light and outdoor cultivation is limited to the months of May through October, with typical cultivation periods ranging between 150 to 180 days.

For the purposes of this study, to be conservative (high), a typical demand of 0.50 gallons per square foot of cultivation area per day and a cultivation season length of 180 days was used to estimate projected demand. Mixed-light and outdoor cultivation were assumed to have the same demand.

5.2 Projected Demand

Proposed cultivation area for each parcel within the Supply Creek watershed obtained from the County and information from the previous section was used to estimate demand. The results are summarized in Table 5. The estimated cumulative project demand for the applicants in the Supply Creek watershed is 35.9 MG/Year.

Table 5. Projected Cultivation Water Demand

Parcel APN	Area (ft^2)	Type	Demand (MG/Year)
522-023-001-000	61,150	Outdoor	5.5
522-024-001-000	43,560	Outdoor	3.9
522-024-002-000	13,643	Outdoor	1.2
	21,875	Mixed-Light	2.0
522-025-003-000 & 522-024-005-000	10,000	Outdoor	0.9
522-032-004-000	27,400	Outdoor	2.5
522-033-010-000	10,000	Outdoor	0.9
522-025-006-000	7,235	Outdoor	0.7
	7,048	Mixed-Light	0.6
522-032-011-000	43,560	Outdoor	3.9
522-021-009-000	16,400	Outdoor	1.5
	13,700	Mixed-Light	1.2
522-021-010-000	35,250	Outdoor	3.2
	14,800	Mixed-Light	1.3
522-026-007-000	43,560	Outdoor	3.9
522-022-015-000	19,950	Outdoor	1.8
522-013-009-000	10,000	Mixed-Light	0.9
Total	**399,131**	**Total**	**35.9**

6 RESULTS AND DISCUSSION

6.1 Results

The purpose of this study is to evaluate the cumulative impacts of proposed cannabis cultivation on surface water within the Supply Creek watershed. Proposed demand and total runoff from the study area for each hydrologic year modeled, including the driest year on record, are summarized in Table 6. For the years modeled, the demand represents between 0.3% and 1.8% of the runoff from the study area. Even during the driest year on record, the demand represents only 1.8% of the runoff.

Table 6. Total Runoff from the Study Area Compared to Projected Cultivation Water Demand

Hydrologic Year	Precipitation (in)	Total Runoff (MG)	Demand's % of Runoff
2009-2010	46.8	6,900	0.5
2010-2011	58.6	8,920	0.4
2011-2012	45.8	5,740	0.6
2012-2013	39.7	4,850	0.7
2013-2014	25.0	2,040	1.8
2014-2015	38.8	5,590	0.6
2015-2016	56.7	9,740	0.4
2016-2017	74.6	13,100	0.3
2017-2018	39.8	4,120	0.9
2018-2019	56.8	9,410	0.4

6.2 Discussion

For the purposes of this study, rainwater catchment was assumed to be the source of water that would be used for proposed cultivation. This is a worst case scenario as some of the proposed cultivators may source some or all of their cultivation water from existing groundwater wells disconnected from surface water.

The proposed cultivation sites are located in the upper portion of Supply Creek watershed, at elevations ranging between 2,200 feet and 4,000 feet above sea level, and experience significant snowfall. Snowfall and snowmelt were not considered as part of this study. Snowfall and snowmelt would increase the runoff and surface water supply within the Supply Creek watershed.

The projected demand was estimated based on maximum demand rates reported by cultivators and should represent a conservatively high estimate of demand. For the hydrologic years modeled, including the driest on record, the projected demand represents only 0.4% to 1.8% of the total runoff of the area studied. The portion of the Supply Creek watershed evaluated here is that portion upstream of the confluence with Rock Creek and represents only 80% of the total area available for runoff. Thus, the demand would represent even less of the runoff from the entire watershed.

7 CONCLUSION

The upper portion of Supply Creek, a tributary to the Trinity River, is located in Humboldt County, California. The lower portion of the watershed, approximately 70%, is within the Hoopa Valley Indian Reservation. The County has received applications for 14 proposed cultivation sites located in the upper portion of the Supply Creek watershed. Cumulatively, these applications request the right to cultivate approximately 9.2 acres.

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