CITY OF ROSEVILLE CALIFORNIA
Environmental Utilities
Wastewater Division
2005 Hilltop Circle
Roseville, California 95747

November 30, 2010

California Regional Water Quality Control Board
Central Valley Region
Attn: Wendy Wyels
NPDES Compliance and Enforcement Unit
11020 Sun Center Dr., Suite #200
Rancho Cordova, CA 95670-6114

Re: Dry Creek Wastewater Treatment Plant Site-Specific Salinity Study

Dear Ms Wyels,

In compliance with NPDES No. CA0079502, Order No. R5-2008-0077, Section VI.C.2.e, I am submitting the aforementioned study. The work plan was submitted on 9 December 2008 and approved by the Regional Board (Board) on 20 August 2009 making the final study due 20 November 2011.

On 9 February 2010, City staff met with Board staff to discuss the approved work plan. The City proposed revising the work plan to use existing site-specific studies as the basis for determination of a recommended EC value that is protective of beneficial uses. The City agreed to submit this report by November 2010. The Board agreed to this approach and said the work plan did not need revision and accepted the timeframe.

Please contact me at (916) 774-5754 if you have any questions.

Sincerely,

Art O'Brien
Wastewater Utility Manager

Cc: Diana Messina, RWQCB

NOVEMBER 2010

City of Roseville

Dry Creek Wastewater Treatment Plant Site-Specific Salinity Study

prepared by

LARRY WALKER ASSOCIATES

LARRY WALKER ASSOCIATES

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Executive Summary

The Dry Creek Wastewater Treatment Plant (DCWWTP), owned and operated by the City of Roseville, discharges tertiary treated effluent to Dry Creek, a tributary to Natomas East Main Drainage Canal which connects to the Sacramento River. Per Provisions VI.C.2.e in the City of Roseville's Dry Creek NPDES Permit (Order No. R5-2008-0077), the DCWWTP is required to conduct a site-specific study to determine a numeric value for electrical conductivity (EC) that that will protect beneficial uses of the receiving water (i.e., AGR and MUN).

Several salinity studies in the Central Valley have used similar site-specific conditions to determine EC levels protective of AGR beneficial uses (Hoffman, 2010; Grattan, 2006; Grattan, 2004). A comparison of site-specific model inputs was conducted between the DCWWTP study area and the other referenced study areas. This approach was discussed with Regional Board staff at a meeting on February 9, 2010 and was acceptable to Board staff.

The Area of Influence for the DCWWTP was defined as the portion of the Dry Creek watershed downstream of the DCWWTP (shown in Figure 2). Site specific conditions were considered, to compare conditions within the DCWWTP Area of Influence to the areas addressed in the previous studies by Hoffman and Grattan. Site-specific factors include sources and quality of irrigation water; effluent water quality compared to surface water and groundwater; sodium-adsorption ratio (SAR) of surface and groundwaters; soil chemistry (including soil SAR and alkalinity); climate; rainfall and crop patterns.

Based on the site-specific conditions in the DCWWTP Area of Influence , EC levels that are protective of the AGR beneficial use were higher than protective EC levels based on the conditions considered in previous site-specific salinity studies in other areas. Since the most protective EC levels based on conditions in the DCWWTP Area of Influence are more protective than EC levels determined based on site-specific conditions used by Grattan and Hoffman, and the proposed EC limits in those studies were higher than the secondary MCL of 900 µmhos/cm, a secondary MCL of 900 µmhos/cm EC for drinking water is proposed as a conservative limit for EC in the vicinity of the DCWWTP for the protection of AGR beneficial uses. The secondary MCL of 900 µmhos/cm would also be protective of the MUN beneficial use with Dry Creek waters in the vicinity of the discharge under reasonable worst-case conditions.

It is recommended that 900 µmhos/cm is the appropriate EC limit that is fully protective of the beneficial uses.

Introduction

PROJECT DESCRIPTION

The City of Roseville owns and operates the Dry Creek Wastewater Treatment Plant (DCWWTP), which has a facility design average dry weather flow of 18 million gallons per day (mgd). The treatment system consists of bar screens, grit chambers, primary clarification, secondary treatment consisting of aeration, and secondary clarification, and tertiary treatment consisting of chemical coagulation, filtration, nitrification, denitrification, ultraviolet (UV) disinfection, and cascade aeration.

The DCWWTP currently discharges an average of 6 MGD of tertiary-treated effluent in the summer and up to 14 MGD of tertiary-treated effluent in the winter to Dry Creek, a tributary of the Natomas East Main Drainage Canal. The Natomas East main Drainage Canal is a tributary of the Sacramento River within the Lower American River Watershed (Figure 1).

Beneficial uses of the surface receiving waters and groundwater receiving waters are shown in Table 1.

Table 1. Beneficial uses of DCWWTP surface and groundwater receiving waters

Receiving water	Beneficial use	Beneficial use designation
Surface water	Municipal and domestic supply	MUN
	Agricultural irrigation	AGR
	Water contact recreation, canoeing and rafting recreation	REC-1
	Other non-contact water recreation	REC-2
	Warm freshwater aquatic habitat	WARM
	Cold freshwater aquatic habitat	COLD
	Cold fish migration habitat	MIGR
	Warm and cold spawning habitat	SPWN
	Wildlife habitat	WILD
	Navigation	NAV
Groundwater	Municipal and domestic supply	MUN
	Industrial service supply	IND
	Industrial process supply	PRO
	Agricultural irrigation	AGR

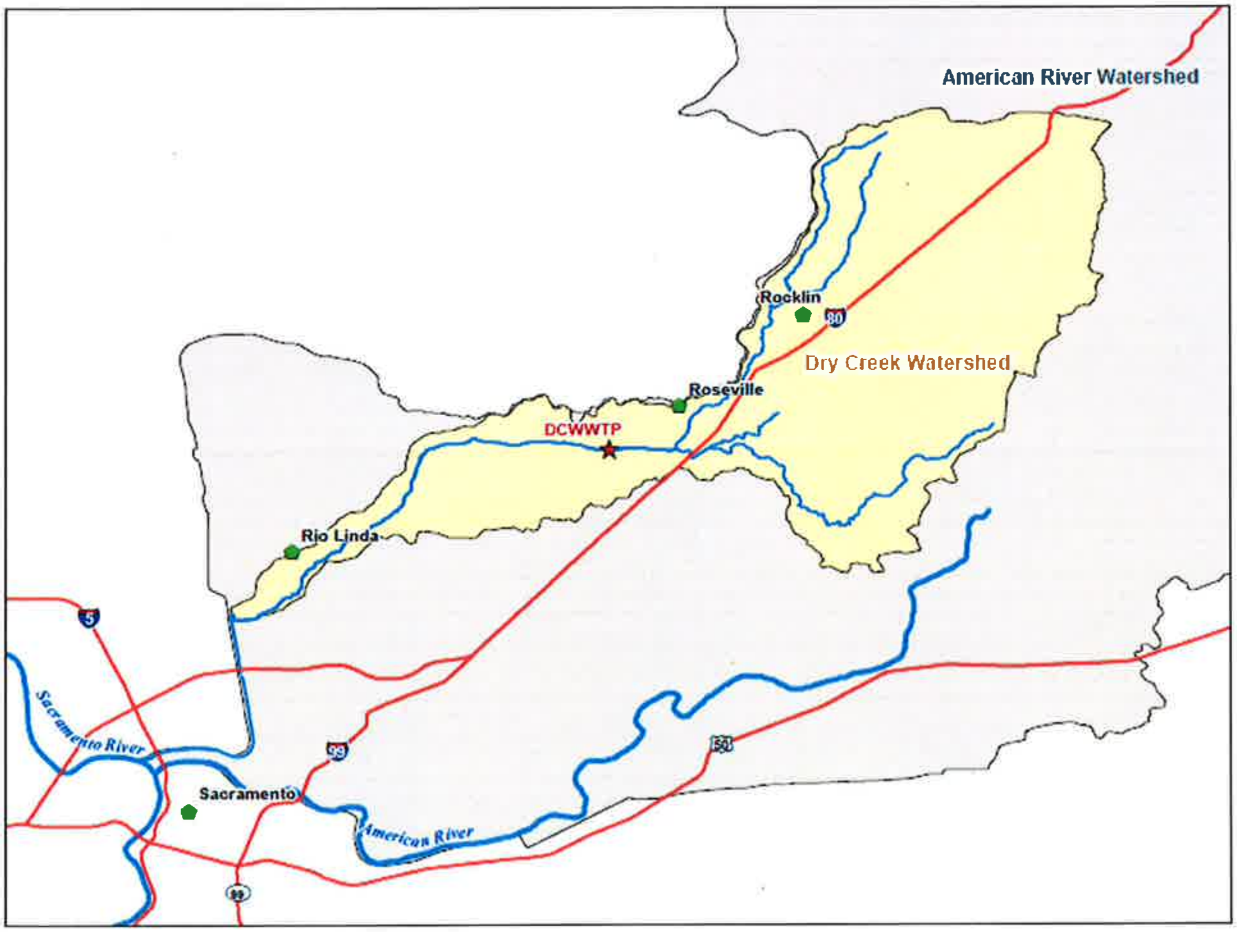

Figure 1. Location of the Dry Creek Wastewater Treatment Plant (DCWWTP) within the Dry Creek Subwatershed of the American River Watershed.

PURPOSE OF REPORT

The purpose of this report is to develop a numeric value for EC that will provide reasonable protection for the agricultural supply use (AGR) designation in Dry Creek, per Provisions VI.C.2.e in the City of Roseville's Dry Creek NPDES Permit (Order No. R5-2008-0077). The proposed EC level will also be compared to the secondary drinking water MCL for EC (900 µmhos/cm) to evaluate protection of the MUN beneficial use.

DCWWTP DISCHARGE AREA OF INFLUENCE

The Dry Creek Watershed is situated within the Lower American Hydrologic subarea and overlies the North American Groundwater Subbasin (ARB, 2006). Agriculture in the region is predominantly supplied by groundwater resources, which are recharged by surface water (ARB, 2006; PCWA, 2006). The Dry Creek watershed has an area of 101 square miles ranging from just west of the City of Auburn and Folsom Lake, and extending southwest through the City of Rocklin and Roseville, Rio Linda area, and terminating at the Natomas East Main Drainage Canal (Placer and Sacramento Counties, 2003). Twenty percent of the watershed is located downstream of the DCWWTP effluent discharge. The "area of influence" is the area of the watershed surrounding Dry Creek downstream of the DCWWTP discharge where nearby agricultural users may extract water for irrigation from Dry Creek. This Area of Influence is a logical and reasonable area to protect Dry Creek AGR beneficial use (Figure 2).

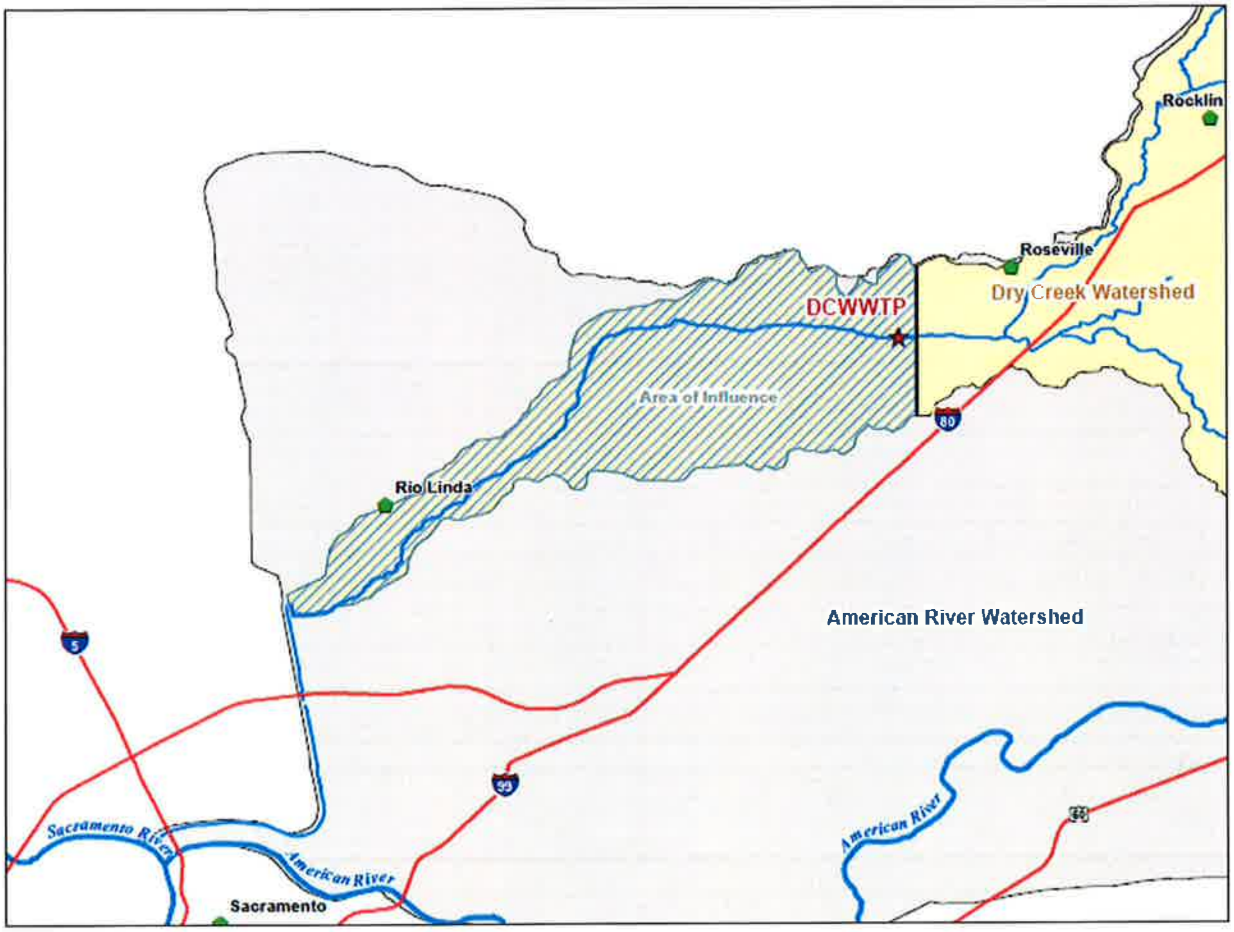

Figure 2. The Area of Influence of DCWWTP discharge within the Dry Creek watershed.

APPROACH TO ANALYSIS

This analysis takes site-specific conditions into account to ensure protection of the dominant salt sensitive crops grown in the area irrigated within the area of influence and considers the MUN secondary MCLs for EC. The resultant EC level will provide reasonable protection to the AGR and MUN beneficial uses.

Determining a level of salinity which will be protective of crops requires consideration of site-specific information to calculate average electrical conductivity in the crop root zone over the crop season. Important site-specific conditions include soil type and chemistry, water quality of irrigation water, climate including temperature, humidity, and rainfall/flooding patterns, as well as current and potential crops grown in the area. For this analysis, reasonable worst-case conditions were considered for the Area of Influence.

Several site-specific salinity studies have been performed in the Central Valley, in Yolo County, and the Sacramento-San Joaquin Delta. These studies (Hoffman, 2010; Grattan, 2006; Grattan,

2004) have found that EC levels in irrigation water which protect the AGR beneficial use in the respective study areas are above the MUN secondary MCL of 900 µmhos/cm (Table 2). Because several studies with similar site-specific conditions have been completed in the region, a comparison of site-specific model inputs was conducted between the DCWWTP Area of Influence and the study areas listed in Table 2. The conditions existing in the Area of Influence were found to be similar to or less restrictive than the conditions found in the referenced studies in that higher EC levels would be tolerated; thus, the results from the other studies are applicable. Therefore site-specific modeling is not necessary to determine the appropriate EC levels for the protection of the AGR beneficial use.

Table 2. Proposed EC Limits of Previous Studies in the Central Valley

Study	Location	Most Salt Sensitive Crop	EC Limit (µmhos/cm) Protective of Crops Grown in the Study Area
Hoffman, 2010	Southern Sacramento-San Joaquin Delta	Bean	900-1100
Grattan, 2006	Woodland, Yolo County	Corn, rice	1400
Grattan, 2004	Central/Southern San Joaquin County	Bean	1000

Site-Specific Factors Affecting AGR and MUN Beneficial Use

To protect the AGR and MUN beneficial uses, the influence of several site-specific factors on salinity should be considered. Site-specific factors including sources and quality of irrigation water; effluent water quality compared to surface water and groundwater; sodium-adsorption ratio (SAR); soil chemistry (including soil SAR and alkalinity); climate; rainfall and crop patterns are discussed in the following sections

SOURCES AND QUALITY OF IRRIGATION WATER

Irrigation water quality affects the potential for salts to accumulate in the soil horizon. This accumulation could result in decreased crop production as well as foliar (leaf) injury if certain constituents are present in toxic levels when irrigated by sprinklers (Hoffman, 2010).

Several water agencies supply municipal water to Placer County and Sacramento County near the Dry Creek watershed. In Sacramento County, water supply agencies include California-American Water Company (which provides a combination of groundwater and American River water), Rio Linda/Elverta Community Water District (RLECWD; which is entirely groundwater), and the City of Sacramento (ARB, 2006). In western Placer County, municipal supply is mainly derived from surface water, and is provided by the City of Roseville (source water originating from Folsom Lake, supplied with contract Central Valley Project (CVP) water and PCWA water), Placer County Water Agency, or California-American Water Company, CAL-AM (PCWA, 2006). Placer County Water Agency water supply consists of water from the Yuba and Bear Rivers, Middle Fork Project (MFP) water from the American River, and CVP water from the American River. The City of Roseville supplements surface water supplies with groundwater in dry and driest years.

Existing groundwater is generally used for agriculture, particularly in the unincorporated areas of western Placer County (PCWA, 2006). Groundwater is predominantly recharged by precipitation to the valley floor and surface water in the lower half of the Dry Creek Watershed (Placer and Sacramento Counties, 2003), therefore the quality of groundwater used for agriculture is somewhat influenced by the surface water quality in the watershed. Surface water is generally higher quality, with significantly lower levels of salinity and other constituents when compared with local groundwater supplies (Table 3). For the data shown in Table 3, the EC levels in surface water range from 68 to 88 µmhos/cm, whereas groundwater levels were up to an order of magnitude greater, ranging from 333 to 614 µmhos/cm.

Table 3. Water Quality in Dry Creek Watershed Area, Various Water Purveyor Consumer Confidence Reports

				City of Roseville		
Constituent	**Units**	**PCWA, Surface Water (2009)**	**CAL-AM, Surface Water (2009)**	**Surface Water (2005-2009)**	**Groundwater (2007-2009)**	**RLECWD, Groundwater (2005-2009)**
EC	µmhos/cm	68	88	73.8	614	333
Sodium	mg/L	4.1	4	3.96	68.4	23.3
Calcium	mg/L	---(1)	11	8.20	31.3	22.0
Magnesium	mg/L	---(1)	2	1.57	14.9	13.1
Chloride	mg/L	3.8	3.8	3.42	118	30.7
Fluoride	mg/L	0.85	0.80	0.83	0.78	0.22
TDS	mg/L	39	58	47.6	399	226
SAR(2)	mEq/L	---	0.29	0.33	2.52	0.97

(1) Constituent concentrations not reported
(2) Sodium Adsorption Ratio calculated using equation defined in SAR section of report

DRY CREEK WASTEWATER TREATMENT PLANT WATER QUALITY

Surface Water

The Dry Creek Wastewater Treatment Plant discharges to Dry Creek year round. In the summer, flows in the creek consist of irrigation return (excess irrigation flow), groundwater baseline flow, and tertiary treated effluent from the Dry Creek Wastewater Treatment Plant (Placer County, 1990). In the winter, precipitation largely influences creek flow in the watershed and dilutes the contribution of irrigation return flow and effluent discharge to the creek. The City of Roseville currently monitors Dry Creek water 200 feet upstream and 200 feet downstream of the DCWWTP effluent discharge outfall (Figure 3) for a variety of constituents, including weekly measurements of EC.

Figure 3. City of Roseville monitoring locations in the vicinity of the DCWWTP effluent discharge outfall.

Average EC levels for DCWWTP effluent, surface water upstream (RSW-001) and downstream of treatment plant discharge (RSW-002) are shown in Figure 4. On average, background surface water (RSW-001) EC ranges from around 125 µmhos/cm in September, to 235 µmhos/cm in March. Dry Creek water downstream from the DCWWTP outfall (RSW-002) exhibits less temporal fluctuation and instead reflects the effluent discharge trends. The downstream receiving water EC levels are generally lowest in the winter (averaging 278 µmhos/cm in February) and slightly greater in the summer (just over 300 µmhos/cm May through August), but are still substantially less than the effluent EC levels, which range from an average of 475 µmhos/cm in December up to 534 µmhos/cm in August.

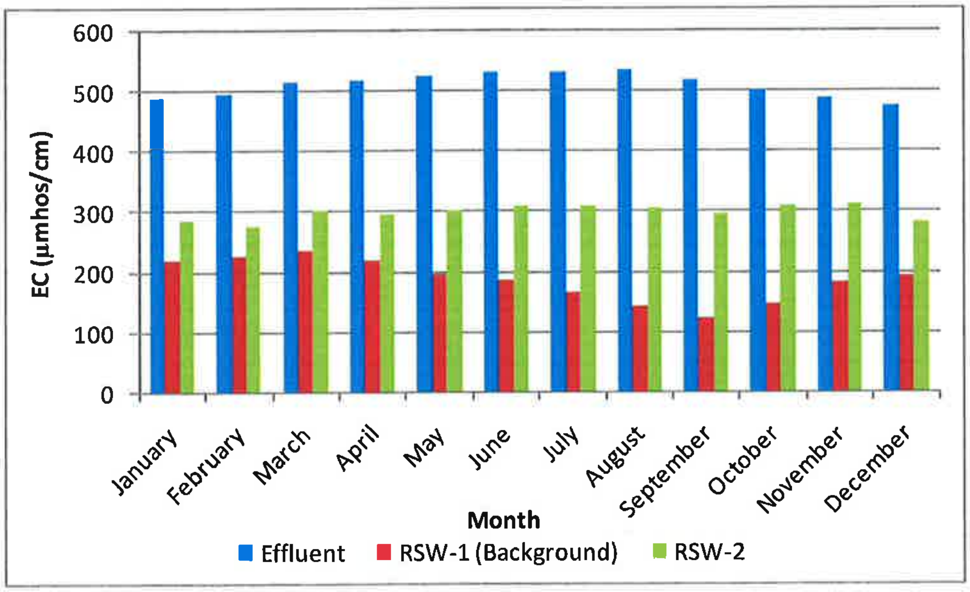

Figure 4. Average Monthly Effluent and Surface Water EC (µmhos/cm), From January 2004 Through July 2010.

Groundwater

Groundwater is monitored at three locations on the Dry Creek Wastewater Treatment Plant facility (Figure 3). As shown in Figure 5, salinity levels in the effluent, background groundwater samples, and downgradient groundwater samples are fairly constant, with a slight decline over time, and show little variation between sampling locations. EC levels in the groundwater range from 380 to 530 µmhos/cm, and average 460 µmhos/cm. These values are consistent with other groundwater salinity measurements in the watershed (shown previously in Table 3), and indicate that the DCWWTP activities do not impact groundwater salinity.

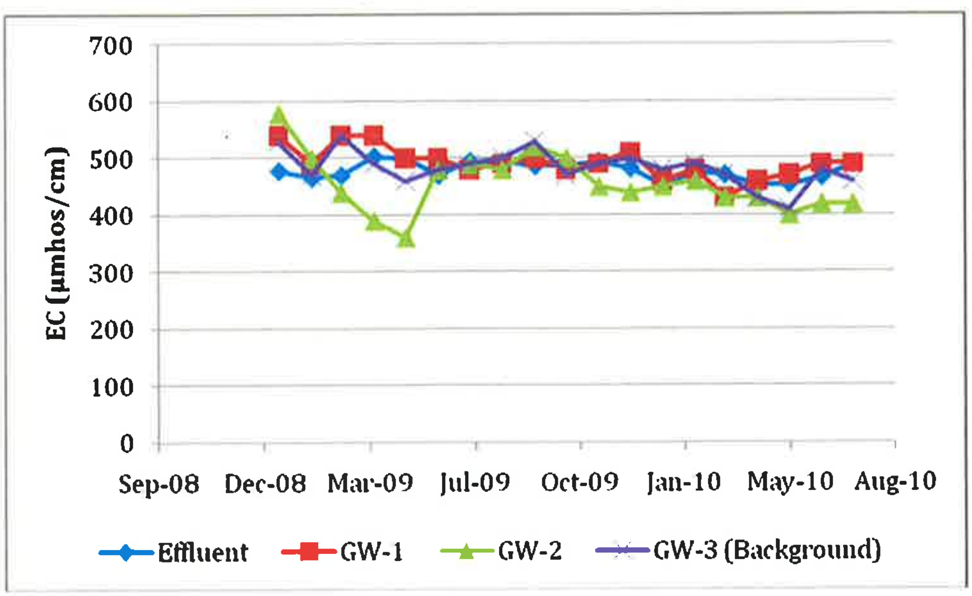

Figure 5. Average Monthly Effluent and Groundwater EC (µmhos/cm), From January 2009 Through July 2010.

DCWWTP Effluent Water Quality

Average monthly effluent EC levels are compared with discharge volumes for February 2008 to July 2010 (Figure 6). Data prior to February 2008 was not included in the analysis because a portion of the influent flow to Pleasant Grove Wastewater Treatment Plant (PGWWTP) was diverted to DCWWTP to accommodate a project at the PGWWTP. The diversion of wastewater flow from the PGWWTP sewershed to DCWWTP was discontinued in January 2008. DCWWTP effluent discharge to Dry Creek demonstrated distinct seasonality, highest in the winter and lowest in the summer. The effluent EC levels did not show seasonality; however, they were slightly higher in 2008 than during 2009 or 2010. The effluent EC level was highest in August 2008, with a monthly average of 569 µmhos/cm. However, monthly average effluent EC levels were all lower than 500 µmhos/cm during 2009-2010.

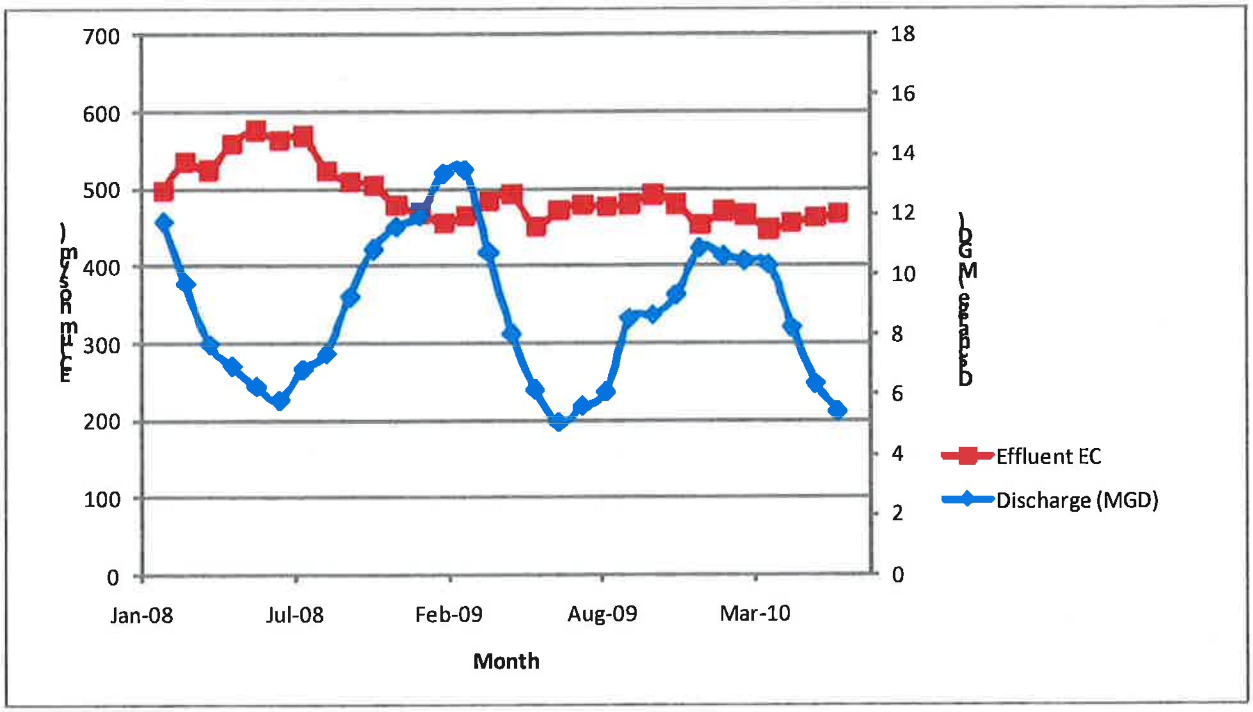

Figure 6. Average Monthly Effluent Discharge and EC (µmhos/cm) to Dry Creek, from February 2008 through July 2010

Sodium-adsorption-ratio of Potential Irrigation Water

The sodium-adsorption-ratio (SAR) is a measure of the sodium hazard (sodicity) in soils or the suitability of water for use in agricultural irrigation. High sodium concentrations in water can affect the permeability of soil and cause infiltration problems, since excess sodium can replace calcium and magnesium adsorbed on soil clays, causing dispersion of soil particles. The dispersion of soil particles results in a breakdown of soil aggregates, causing soil to become harder and more compact when dry. The SAR is defined as:

$$SAR = \frac{C_{Na}}{\sqrt{\frac{1}{2}(C_{Ca}+C_{Mg})}}$$ **(SAR calculation formula)**

where C_{Na}, C_{Ca}, and C_{Mg} are the concentrations in meq/L (the molar equivalent per L) of sodium, calcium, and magnesium ions in the soil solution or irrigation water (Hoffman, 2010). In general, the higher the SAR of water, the less suitable it is for agricultural irrigation. When the SAR of a soil solution rises above 13, reduced saturated hydraulic conductivity and aeration may result in a general degradation of soil structure (NRCS, Web Soil Survey[1]). To evaluate the effect of sodium on soil permeability, the SAR should be considered in conjunction with the irrigation water's electrical conductivity, shown in Figure 7.

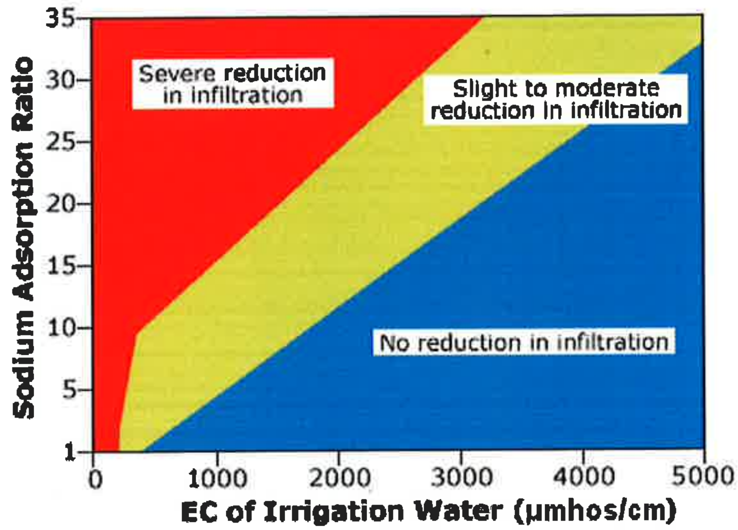

Figure 7. SAR Versus EC of Irrigation Water to Assess Soil Infiltration Reduction Potential (www.salinity management.org)

To assess whether DCWWTP effluent will degrade the infiltration rates of soils in the area of influence over time, the levels of EC, sodium, magnesium, and calcium in the effluent, surface water, and groundwater were evaluated in terms of the SAR. Table 4 shows monitoring results from the DCWWTP, including average monthly effluent discharge (EFF-001), upstream and downstream surface water (RSW-001, RSW-002), and upgradient and downgradient groundwater (GW-001, GW-002 and GW-003). The monitoring data is used to calculate the SAR using the SAR calculation formula. The calculated SAR is listed in the last row of Table 4.

[1] Information obtained from the Chemical Properties descriptions of the Placer County, CA, Western Part NRCS web report.

Table 4. Quality of Wastewater Treatment Plant Effluent, Surface Water, and Groundwater

Constituent	Units	EFF-001[4]	RSW-001[5]	RSW-002[6]	GW-001[7]	GW-002[7]	GW-003[7]
Wet Season EC[1]	μmhos/cm	497	213	294	495	455	490
Dry Season EC[2]	μmhos/cm	525	161	306	489	464	482
Sodium[3]	mg/L	42.3	8.3	24	49	47	49
	meq/L	1.84	0.36	1.04	2.13	2.04	2.13
Calcium[3]	mg/L	31.3	13.3	23	35	25	26
	meq/L	1.56	0.65	1.15	1.75	1.25	1.30
Magnesium[3]	mg/L	3.4	4.8	5.3	14.6	9.6	14.5
	meq/L	0.28	0.39	0.44	1.20	0.79	1.19
SAR		1.91	0.50	1.17	1.76	2.03	1.91

(1) Wet Season EC is defined as average monthly EC from November through April
(2) Dry Season EC is defined as average monthly EC from May through October
(3) Average of samples taken in September-November 2010
(4) Effluent was sampled on 9/16/2010, 10/21/2010 and 11/3/2010
(5) Background receiving water was sampled on 9/16/2010, 10/21/2010 and 11/3/2010
(6) Downstream receiving water was sampled on 11/3/2010
(7) Groundwater locations were sampled on 10/15/2010 and 10/22/2010

The SAR and EC values from Tables 3 and 4 were compared using effects levels in Figure 7 to interpret the soil infiltration reduction potential. As shown in Table 5, the potential irrigation water from water purveyors or water influenced by Dry Creek Wastewater Treatment Plant effluent should pose minimal impact on the infiltration reduction potential of soils in the Dry Creek Watershed.

Table 5. Soil Infiltration Reduction Potential of Irrigation Water Potentially Used in Dry Creek

Irrigation Water Source	SAR Irrigation Water	EC Irrigation Water (µmhos/cm)	Soil Infiltration Reduction Potential
PCWA	---	68	---
CAL-AM	0.29	88	None
City of Roseville SW	0.33	73.8	None
City of Roseville GW	2.52	614	Very Slight
RLECWD	0.97	333	Very Slight
DCWWTP Wet Season			
Effluent	1.91	497	Very Slight
Background SW	0.50	213	Very Slight
Downstream SW	1.73	294	Very Slight
Background GW(1)	1.91	490	Very Slight
Downgradient GW(2)	1.90	470	Very Slight
DCWWTP Dry Season			
Effluent	1.91	525	Very Slight
Background SW	0.50	161	None
Downstream SW	1.73	306	Very Slight
Background GW(1)	1.91	482	Very Slight
Downgradient GW(2)	1.90	477	Very Slight

(1) Background groundwater well is GW-3
(2) Downgradient groundwater data averaged between GW-1 and GW-2

SOIL TYPE AND SOIL CHEMISTRY

Soils in the Dry Creek watershed are alluvial in origin, and most have limited permeability due to a dense subsoil of clay. Root depth potential is typically shallow due to the dense clay, except for the soils within the Dry Creek floodplain (lowland adjacent to Dry Creek which is defined by a 100-year flood recurrence interval) which have higher permeability (Placer County, 1990). Most soils in the watershed have low permeability and are characterized for agricultural suitability between Class III and Class IV, which are well suited for rice. The soils in the Dry Creek floodplain are an exception, where the Ramona sandy clay loam has a capability of Class I or II when irrigated; however these soils mostly are present within the Dry Creek floodplain and therefore are protected as riparian habitat through the Community Plan for the region (Placer County, 1990). The NRCS SURRGO GIS spatial representations of soil types are shown in Figure 18. The floodplain generally consists of the area shown in Figure 8 as “stratified loamy sand to fine sandy loam”.

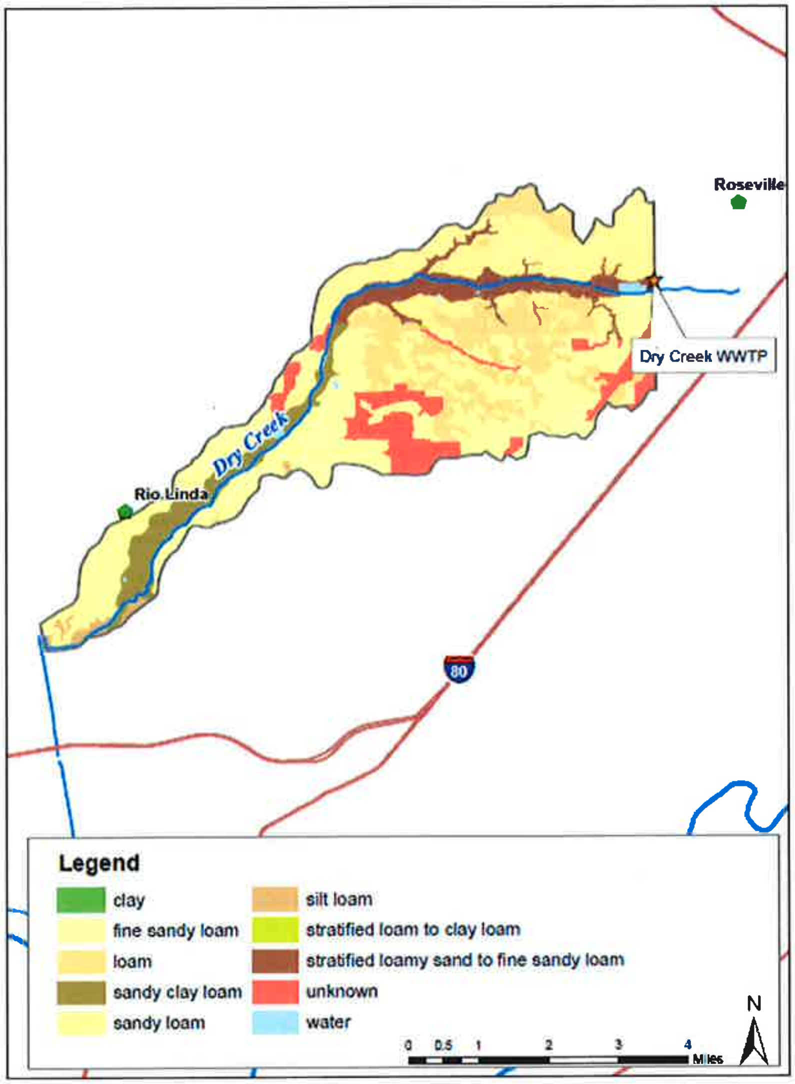

Figure 8. Map of Soil Textures in the DCWWTP Area of Influence within the Dry Creek Watershed (GIS Data From the NRCS-SURRGO SURRGO Database.

Sodium-Adsorption Ratio of Soils Near DCWWTP

According to the NRCS Soil Survey for Western Placer County and Sacramento County, the SAR of soils in the Dry Creek Watershed are very low (NRCS, 1980; NRCS, 1993). Most soils (all reported horizons) have an SAR of 0, very few are undefined (and are generally the deepest soil horizon), and only the Capay Clay has a SAR potential of 10-15 (NRCS, 1988), but is situated outside of the Dry Creek Watershed area. The low SAR soil water values in the region, coupled with the SAR and EC of potential irrigation water (Table 5), indicate that soil structure and permeability should not be negatively impacted by irrigation water influenced by DCWWTP effluent.

pH of Soils Near Dry Creek

The pH of a soil, along with the soil type and presence or absence of ions that can complex with fluoride are all factors that influence whether fluorine will accumulate in plants (Grattan, 2004).

The solubility of fluorine in soil is controlled mainly through its adsorption by organic constituents and the soil pH, with greater solubility under acidic conditions. Since soluble F content is biologically important to plants, the greater fluorine solubility in acidic soils can lead to fluorine accumulation. In the Dry Creek Watershed, 83% of soils are neutral or only slightly acidic (Figure 9), with the most alkaline soils located in the floodplain. In the upper part of the watershed, 7 % of the soils tend to be slightly more acidic, with pH's ranging between 5.5 and 6.0. Potential source waters have a fluoride concentration ranging between 0.22 and 0.85 mg/L, with groundwater concentrations at the lower end of the spectrum and domestic water at the upper end. Roseville's municipal water supply is treated with fluoride for human health benefits. Most soils in the Dry Creek watershed have a pH between 6 and 8.5, and source water fluoride concentrations are less than the recommended 1.0 mg/L for long term plant and animal health (Grattan, 2006), therefore, fluoride toxicity is not an issue in the Area of Influence.

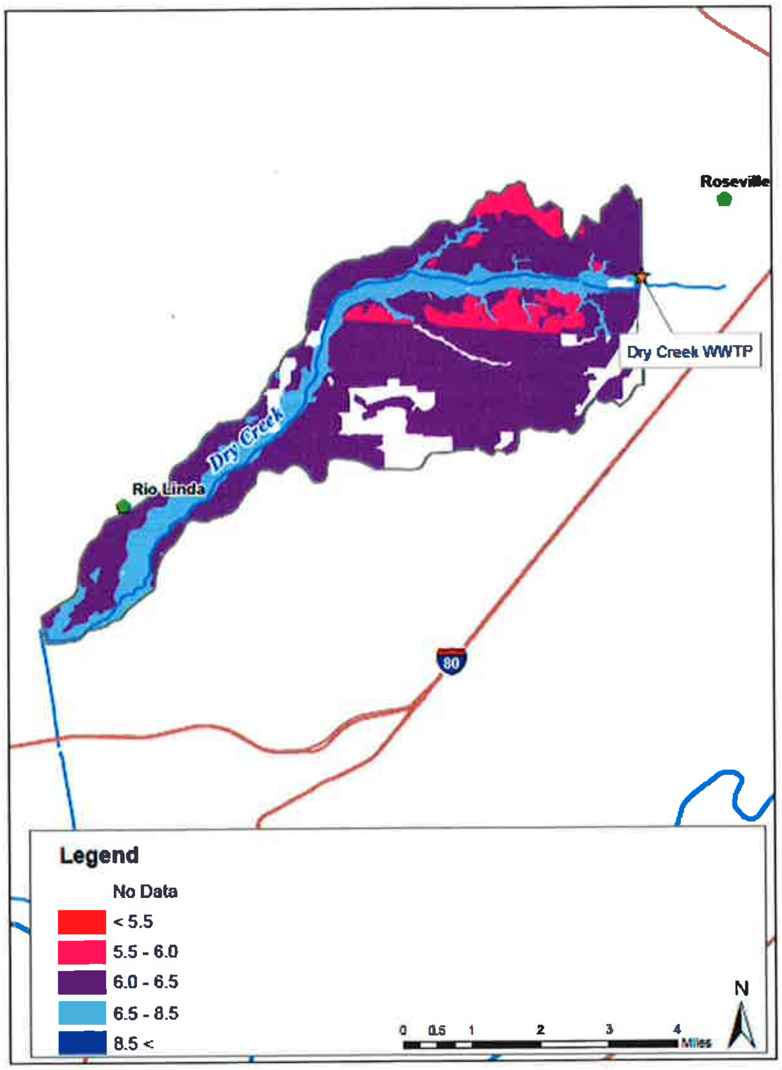

Figure 9. Map of Soil pH in the DCWWTP Area of Influence within the Dry Creek Watershed (GIS Data From the NRCS-SURRGO Database).

CLIMATE

The climate of a region can affect the salt tolerance of crops grown. Crops can generally tolerate greater salt stress in cooler, more humid regions as opposed to hotter and drier regions. Most of the experiments to establish salt crop tolerance have been conducted at the U.S. Salinity Laboratory in Riverside, CA where the climate is generally hot and dry (Grattan, 2006). To compare how the climate in the Dry Creek watershed might affect the crop tolerance of crops grown in the region relative to Riverside, temperature and humidity at the two weather stations nearest to Roseville were compared to temperature and humidity in Riverside.

Data from the California Irrigation Management Information System (CIMIS) were used to compare historic climate data between the two stations near the Dry Creek watershed and a weather station in Riverside. Relevant station information is provided in Table 6. Available data were averaged over each month. As shown in Figures 10 through 13, the two stations near the Dry Creek watershed have similar climates, with the station in Fair Oaks showing slightly warmer and less humid trends throughout the year than the Nicolaus station. In general, the Dry Creek watershed is slightly cooler and significantly more humid than Riverside throughout the year, and thus, most crops should experience less salt stress compared to crops grown in Riverside. Therefore, crop tolerance in the Dry Creek watershed is higher than the crop tolerance in Riverside.

Table 6. California Irrigation Management Information System (CIMIS) Weather Stations

CIMIS Station #	Station Name/Location	Year Activated	Elevation (Ft)*
30	Nicolaus – Sacramento Valley, Sutter County	1983	32
131	Fair Oaks – Sacramento Valley, Sacramento County	1997	265
44	Riverside – Los Angeles Basin, Riverside County	1985	1020

*For comparison, elevation of the City of Roseville is around 165 ft, and Dry Creek WWTP is at 125 feet above mean sea level

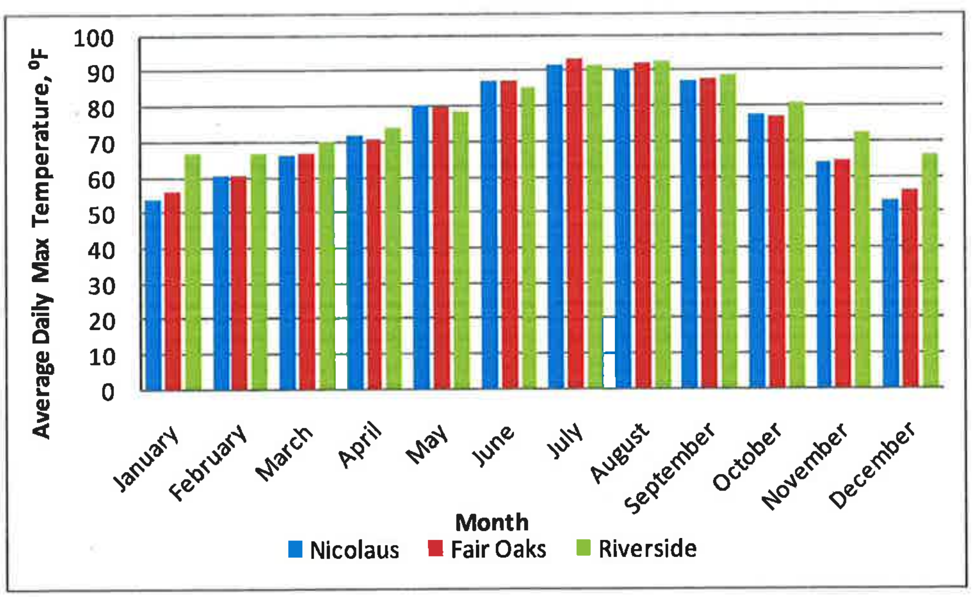

Figure 10. Dry Creek Watershed vs. Riverside Average Daily Maximum Temperature, in Degrees F

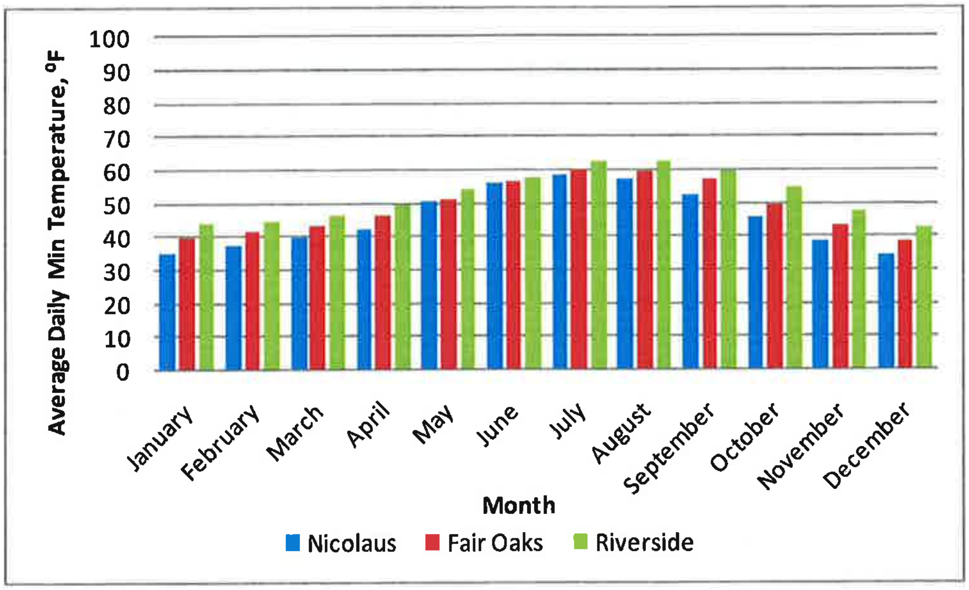

Figure 11. Dry Creek Watershed vs. Riverside Average Daily Minimum Temperature, in Degrees F

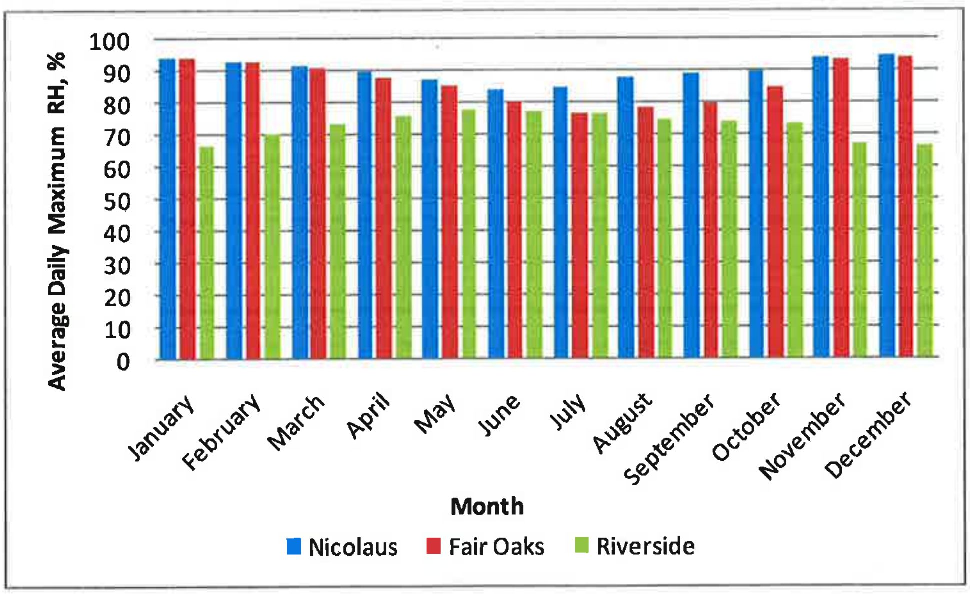

Figure 12. Dry Creek Watershed vs. Riverside Average Daily Maximum Relative Humidity (Percent)

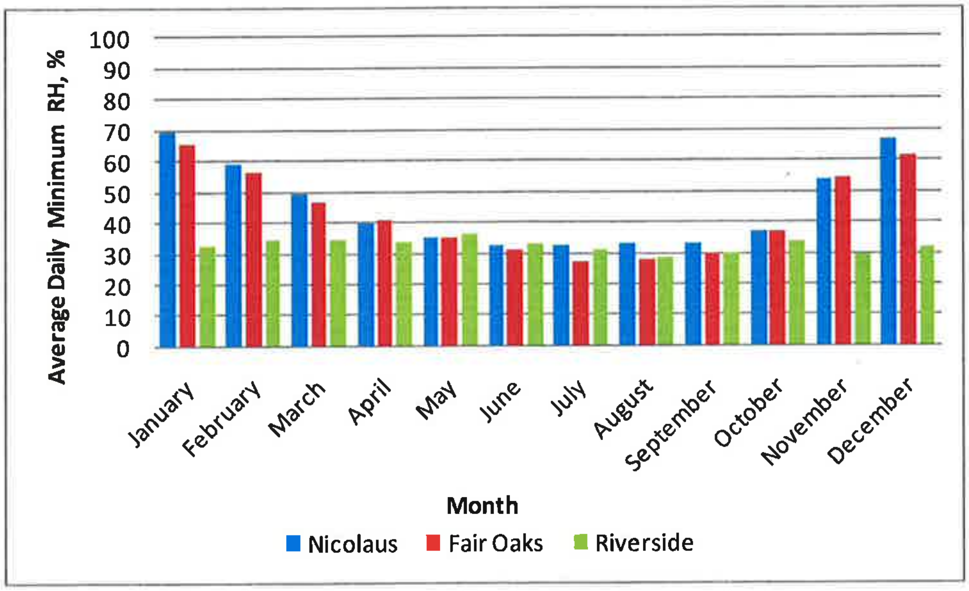

Figure 13. Dry Creek Watershed vs. Riverside Average Daily Minimum Relative Humidity (Percent)

RAINFALL

As is typical on the floor of the Central Valley, rainfall in the Dry Creek watershed occurs primarily in the winter months as displayed in Figure 14. Both rainfall and flooding can induce leaching of salts from the root zone as the infiltrating water dissolves precipitated salts and displaces existing pore water.

Effective rainfall is the amount of rain actually utilized by crops, which depends on both climate and characteristics of the particular plant and soil (Hoffman, 2010). Average annual rainfall in the Dry Creek watershed area is between 19 and 20 inches, almost five more inches per year than the South Delta (conditions used in the Hoffman study). Climates in the Dry Creek watershed and the South Delta are similar (both are cooler and more humid than the Riverside conditions used to calculate salt tolerance values for crops). Thus, modeling soil salinity using effective rainfall values estimated for the South Delta would provide higher estimates of soil salinity than soil salinity based on effective rainfall in the Roseville region.

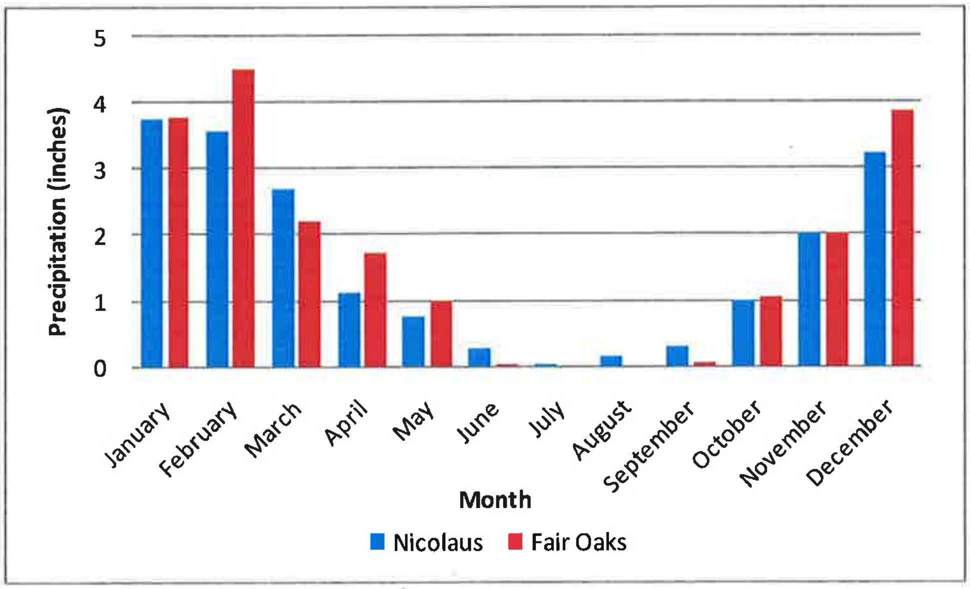

Figure 14. Dry Creek Watershed Area Average Total Monthly Precipitation, in Inches

CROPPING PATTERNS

Historically, the primary land use in the DCWWTP Area of Influence has been agriculture, with the dominant crops consisting of rice fields, vineyards, orchards, grazing land, and field crops. In recent years the urban area has increased 30 percent, substantially reducing agricultural and undeveloped land acreage (Placer and Sacramento Counties, 2003). The most recent DWR land use surveys of Sacramento County and Placer County were used to estimate the most salt sensitive crops grown in the DCWWTP Area of Influence, and were checked against land use surveys reported in the Dry Creek Watershed Coordinated Resource Management Plan (Placer and Sacramento Counties, 2003). Land usage and crops in the DCWWTP Area of Influence are shown in Figure 15 and Table 7. Currently, less than five percent of the land use classifications contain salt sensitive crops, such as orchards, vineyards, or fruits and nuts. In the Hoffman study (Hoffman, 2010) of the South Delta, salt-sensitive crops (fruit and nuts, vineyards) comprised a similar portion of the total crop acreage at approximately 7%.

A majority of the current land use in the watershed is non-agricultural, with more than 50% urban, and 28% native vegetation. Grain and hay crops, which could include wheat, barley, and oats, constitute the largest cropped area (56% of the cropped area). Pasture, which could include alfalfa and clover, constitutes 23.6%, and deciduous fruits and nuts cover 12.3%. Together these comprise the majority of crops in the DCWWTP Area of Influence. Threshold values for the salt sensitivity of crops (measured as the EC of the saturated soil extract taken form the root zone, EC_e) were taken from the literature (Hoffman, 2010). Almonds (EC_e of 1,500 µmhos/cm) and alfalfa (EC_e of 2,000 µmhos/cm) are potentially the most salt sensitive crops from the major land use categories, and therefore would be the crops of concern if grown in the Area of Influence. Barley, wheat, and oats, although comprising the majority of cropped acreage in the area, are not a concern because they are fairly salt tolerant (EC_e of 6,000 to 8,000 µmhos/cm). Truck crops, which could potentially include beans, make up 3.18% of the cropped acreage. Although beans were not identified in the DWR land use surveys, they are potentially the most salt sensitive crop (EC_e of 1,000 µmhos/cm) in the watershed, and were the basis for the EC limits proposed by

Hoffman (2010). Therefore, bean will be considered as a potential minor crop for the DCWWTP Area of Influence, and would be protected by a proposed EC limit of 900 μmhos/cm.

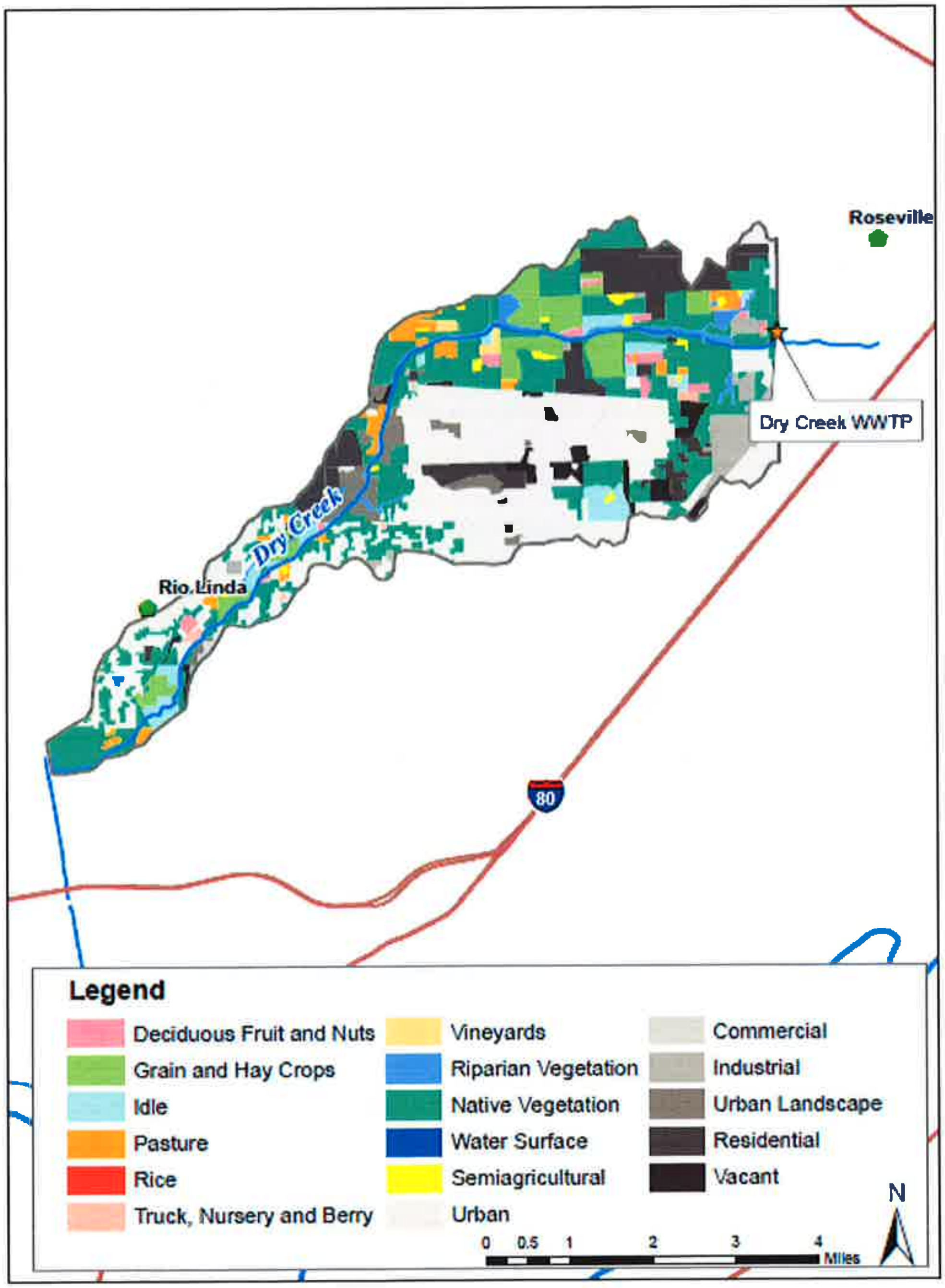

Figure 15. Map of Crops in the DCWWTP area of influence within the Dry Creek Watershed (DWR Land Use Surveys, 1994 and 2000).

Table 7. DCWWTP Area of Influence Land Use Percentage Breakdown, DWR Land Use Surveys

Land Use	Acres	Percent of Total Watershed	Percent of Cropped Acreage
Citrus and Subtropical	21.73	0.17%	1.48%
Deciduous Fruits and Nuts	180.28	1.39%	12.28%
Grain and Hay Crops	821.29	6.33%	55.96%
Idle	408.98	3.15%	
Riparian Vegetation	525.48	4.05%	
Native Vegetation	3640.48	28.05%	
Water Surface	0.08	0.00%	
Pasture	346.95	2.67%	23.64%
Semiagricultural and incidental to agriculture	89.59	0.69%	
Truck, Nursery and Berry Crops	46.62	0.36%	3.18%
Urban	6846.41	52.75%	
Vineyards	50.72	0.39%	3.46%
Total	12978.62	100%	100%

Assessment of Other Models

The approach for completing the EC study involved comparing DCWWTP Area of Influence site-specific data, such as salt-sensitive crops, climate and water quality data to assumptions used in previous modeling studies in the South Delta by Hoffman (2010) and the Woodland area by Grattan (2006) to estimate likely protective values of EC.

Historic EC objectives for the South Delta were 700 µmhos/cm April-August (based on the salt sensitivity of beans without consideration of precipitation), and 1000 µmhos/cm during Sept-March (based on the salt sensitivity of the alfalfa seeding stage, without consideration of precipitation). In an effort to reevaluate the salinity objectives for the Southern Delta, the Hoffman report was produced to provide a scientific basis to evaluate the salinity objective that is protective of the AGR beneficial use.

Hoffman summarized information on irrigation water quality, soil types, crop surveys, salt tolerance of crops, effective rainfall, irrigation methods, crop water uptake distribution, climate, salt precipitation/dissolution in soil, shallow groundwater, and leaching fraction. He evaluated published steady-state and transient models, compared model results with experimental or field results, and drew conclusions from the model results using data applicable to the South Delta.

Hoffman determined modeling results for beans and alfalfa using a steady-state model developed for the South Delta. The steady-state model is based on an assumption that inputs of irrigation and precipitation are equal to crop evapotranspiration plus drainage. The following input parameters are used in Hoffman's model:

- Soil water salinity (dependent on irrigation water salinity)

- Crop evapotranspiration (dependent on climate)
- Precipitation
- Leaching fraction

It is most useful to compare conditions in the DCWWTP Area of Influence to Hoffman's model results, as alfalfa is one of the most salt-sensitive major crops and beans are one of the most salt-sensitive potential crops in the DCWWTP Area of Influence within the Dry Creek watershed. Hoffman noted that alfalfa is most often grown on clay soils which have a low infiltration rate along with a high water requirement due to high evapotranspiration. Hoffman used a worst-case scenario (leaching fraction of 0.10). He found that an irrigation water salinity level (EC_i) of 1200 µmhos/cm would protect alfalfa production in all but the very driest years, where a yield loss of 2% would be predicted. An EC_i of 1000 µmhos/cm would protect alfalfa regardless of annual rainfall. When beans were evaluated using the steady-state model with an EC_i of 1000 µmhos/cm, there was some risk of bean yield loss when annual rainfall was low. The worst case found was a yield reduction of 11% at a leaching fraction of 0.15. However, almost no risk was predicted for bean when an exponential model was used. Hoffman concluded that all of the models evaluated indicate that a water quality standard for EC could range from 900 to 1100 µmhos/cm, which would be protective of all crops grown in the South Delta.

Grattan and Isidoro-Ramirez (2006) proposed site-specific criteria for EC, taking into account site-specific conditions to protect dominant crops in the area affected by the City of Woodland wastewater treatment plant discharges (i.e. the Yolo Bypass and areas just outside of the Bypass). The study used and further modified a model developed by Ayers and Westcot (1985) that determines seasonal average root zone salinity taking into account a number of site-specific factors including crop type, soil type, climate (daily rainfall and temperature), irrigation practices, soil water movement, root water extraction, evapotranspiration and leaching.

Grattan defined the dominant or major crops in the study area as those that comprise 90-95% of the cropped area, and only considered the major crops in the study area. Of the dominant crops, corn and rice were the most salt-sensitive. Modeling simulations indicated that the yield of both crops can be fully maintained using irrigation water with a salinity of 1400 µmhos/cm. They concluded that by setting an EC limit of 1400 µmhos/cm, other dominant crops would be protected as well.

The major site-specific parameters that influenced Hoffman's and Grattan's model results are compared with site-specific parameters in the DCWWTP Area of Influence in Table 8. In all cases, the parameters for the DCWWTP Area of Influence result in conditions where crops can tolerate higher EC levels than the EC levels based on input parameters for the previous modeling studies. Because Hoffman's model used bean, the most salt-sensitive of the crops potentially grown in the DCWWTP Area of Influence, Hoffman's modeling results using bean would be appropriate to use as a protective estimate for EC criteria for the Area of Influence. Using Hoffman's EC value for the South Delta would represent worst-case scenarios for the Area of Influence by considering the most salt-sensitive potential crop and the most restrictive soil.

Table 8. Comparison of site-specific parameters use in previous modeling studies by Hoffman and Grattan to the DCWWTP Area of Influence within the Dry Creek watershed

Parameter	Hoffman (2010)	Grattan (2006)	DCWWTP area of influence (this study)	Comparison
Sensitive crops	Bean (threshold EC_e of1,000 µmhos/cm)	Corn (threshold EC_e of 1,700 µmhos/cm) and Rice (threshold EC_e of 1,900 µmhos/cm)	Sensitive crops in <5% of land use classification. Alfalfa (threshold EC_e of 2,000 µmhos/cm) and Bean(threshold EC_e of1,000 µmhos/cm)	The most salt sensitive crops in the DCWWTP Area of Influence have similar tolerances to the crops considered in the Woodland study and are more tolerant than the sensitive crops considered in the South Delta.
Soil Type	Predominately clay, clay loam, and silty clay loam. Soil class was not provided.	Class 4 – moderately to poorly drained soils used in analysis	Class 3 and 4 in most of watershed – low permeability with shallow root depth potential; Class 1 or 2 in the Dry Creek floodplain	The soils in the DCWWTP Area of Influence have similar or higher permeability than soils used in previous modeling efforts.
SAR	2.4 -- very slight soil infiltration reduction potential	4.3 – water infiltration problems unlikely	0.50-1.9 – none to very slight soil infiltration reduction potential	The SAR in DCWWTP Area of Influence is lower or similar to the South Delta SAR, and lower than the Woodland SAR, therefore modeling using either estimate would produce a more stringent EC limit than Roseville conditions.
Climate	Mean annual precipitation of 13.8 inches Temperature is lower than Riverside	Mean annual precipitation of 18.4 inches Mean temperature of 16 C (60 F)	Mean annual precipitation of 19-20 inches Temperature is lower than Riverside	Similar rainfall to Woodland, and higher rainfall than South Delta. Using South Delta estimates would produce a more stringent EC limit than conditions in the DCWWTP Area of Influence. Temperature is cooler and more humid than Riverside (used for literature crop tolerance values), therefore literature crop tolerance values would produce a more stringent EC limit than conditions using the DCWWTP Area of Influence.
Leaching Fraction	Average leaching fractions between 0.21 and 0.27	Assumed a reasonable leaching fraction of 0.15 to 0.20	Has not been determined for the DCWWTP Area of Influence, but is likely similar to the South Delta and Woodland	Leaching fraction is likely similar between the DCWWTP Area of Influence and the South Delta and Woodland areas.

Recommended EC Threshold

The site-specific conditions used in previous modeling studies by Grattan and Hoffman generate proposed EC limits more protective of the AGR beneficial use than the EC limits that would be generated based on site-specific conditions in the DCWWTP Area of Influence. Specifically, EC limits proposed by Grattan and Hoffman were 1400 µmhos/cm to protect corn and rice, and 900-1,000 µmhos/cm to protect bean. As shown in Table 8, Area of Influence site-specific inputs to both models would result in higher EC values.

The other standard that would drive EC limits based on beneficial uses would be the secondary MCL for protection of drinking water. The 900 µmhos/cm secondary MCL is less than the values proposed by Grattan and Hoffman for protection of AGR beneficial uses.

Therefore, the secondary MCL for drinking water of 900 µmhos/cm would be a fully-protective limit for EC in the vicinity of the DCWWTP to protect AGR beneficial uses. The drinking water secondary MCL of 900 µmhos/cm would also be protective of MUN beneficial use with Dry Creek Waters in the vicinity of the discharge used for municipal and domestic water supply under reasonable worst-case conditions.

It is recommended that the appropriate EC limit that is fully protective of the beneficial uses is 900 µmhos/cm.

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