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TECHNICAL MEMORANDUM

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From: Georgina King and Cameron Tana

Date: March 31, 2017

Subject: Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation (Task 2)

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1.0 Introduction

This technical memorandum documents the methodologies used for estimating the non-municipal water use component of consumptive use in the basin for input into the Santa Cruz Mid-County basin groundwater model that simulates conditions for Water Years 1985-2015. The components of consumptive use are water use and return flow. Water use estimates are required to estimate groundwater pumping where pumping is not metered or recorded. Water use estimates are also required to estimate return flow, the water used but then returned to the watershed. Watershed processes simulated by the Precipitation Runoff Modeling System (PRMS) will be integrated into the groundwater-surface water model using GSFLOW. An introductory discussion of the approach for estimates for return flow are also discussed in this memorandum.

Municipal pumping within the basin is metered, but for most areas without municipal supplies the amount of water use is not metered or recorded. For these non-metered areas, the amount of water use is estimated based on land use. The estimates for non-municipal domestic water use is described in this memorandum. The methodology for estimating institutional, recreational, and agricultural irrigation water use based on crop type and climate is also described in this memorandum. These estimates of water use will be used to define non-municipal pumping in the model.

The technical memorandum describes a number of assumptions for water use and return flow that will be incorporated into the Mid-County Groundwater Basin groundwater model. The sensitivity of these assumptions will be tested by the model. However, the amount of non-municipal domestic, institutional, recreational, and agricultural water use is small and likely less sensitive compared to some of the other model inputs, such as precipitation, and outputs, such as evapotranspiration.

2.0 Non-Municipal Domestic Water Use

2.1 Non-Municipal Domestic Water Use Methodology

For purposes of the groundwater model, non-municipal water use is considered use that is supplied by non-municipal sources of groundwater. Community water systems are included in the non-municipal water use estimate where metered data are not available. Non-municipal water use estimates are used for two purposes: to provide a volume for groundwater extraction where metered data are not available, and to estimate the amount of non-municipal use return flow from septic tanks and landscape irrigation as a proportion of the water used at each residence. Commercial water use is not considered in this estimate because according to Santa Cruz County's (the County's) 1994 land use dataset, there is no significant commercial land use, other than agriculture-related activities, in areas that do not receive municipal water supply.

To estimate the amount of non-municipal domestic water use within the model domain, two sources of data are used. The primary data source is the County's building footprint geographical information systems (GIS) layer that is used to identify individual residential buildings. The second data source, used to supplement the building footprints, is land use data from Santa Cruz County identifying residential parcels.
Santa Cruz County developed the building footprint layer from aerial photograph interpretation using photographs from 2003 and 2007. We applied a filter to exclude buildings that are not classed as habitable structures and have footprints that are less than 500 square feet in area. Residential buildings served by the City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), City of Watsonville, and Scotts Valley Water District were also excluded. To identify residential buildings served by the list of agencies above, a layer of municipal metered parcels was intersected with the building footprints. All residential building footprints falling within the metered parcel layer or that were part of a multi-parcel residential complex that included one metered parcel were excluded following the assumption that these residences are supplied water by an overlying water supply agency.[1]

Because the building footprint data comprises only residential buildings as of 2007, and because some buildings may have been missed in the County's building footprint layer due to tree cover, we also identified residential parcels that do not receive municipal supply and did not have an identified building footprint from Santa Cruz County's land use dataset. Residential parcels added to the dataset were selected using land use codes listed in Appendix A. Residential parcels not receiving municipal water were identified based on the layer of metered parcels. In order to determine the number of non-municipal water use residential buildings as of 2014, we assumed that each residential parcel without an identified building footprint had one building unless the land use description for the parcel specifically included the number of additional residences.

Table 1 shows the number of non-municipal water use residential buildings as of 2014 in the full model domain and within the Santa Cruz Mid-County Basin. The table also breaks down the number of non-municipal water use homes that are on septic and sewer. Sewered areas are those areas which are connected to sewer lines. The sewer spatial data was provided by the County and SqCWD. It is assumed that those homes not connected to the sewer are on septic systems.

[1] Central Water District does provide water to a few residences that also have private wells; those wells are seasonal and/or not reliable sources of drinking water (Bracamonte, 2016). Therefore, this small amount of private water use is not accounted for in the model. This same assumption was made for other areas supplied municipal water by other agencies.

Table 1: Summary of Non-Municipal Water Use Residential Building Count

Data Source	**Number of Non-Municipal Water Use Homes on Septic Systems**		**Number of Non-Municipal Water Use Homes on Sewer**		**Total Number of Non-Municipal Water Use Homes**	
	Model Area	**Mid-County Groundwater Basin**	**Model Area**	**Mid-County Groundwater Basin**	**Model Area**	**Mid-County Groundwater Basin**
Santa Cruz County Building Footprints	4,333	1,728	409	331	**4,742**	**2,059**
Santa Cruz County Land Use Residential Parcels Without Building Footprints	736	326	0	0	**736**	**326**
Total	**5,069**	**2,054**	**409**	**331**	**5,478**	**2,385**

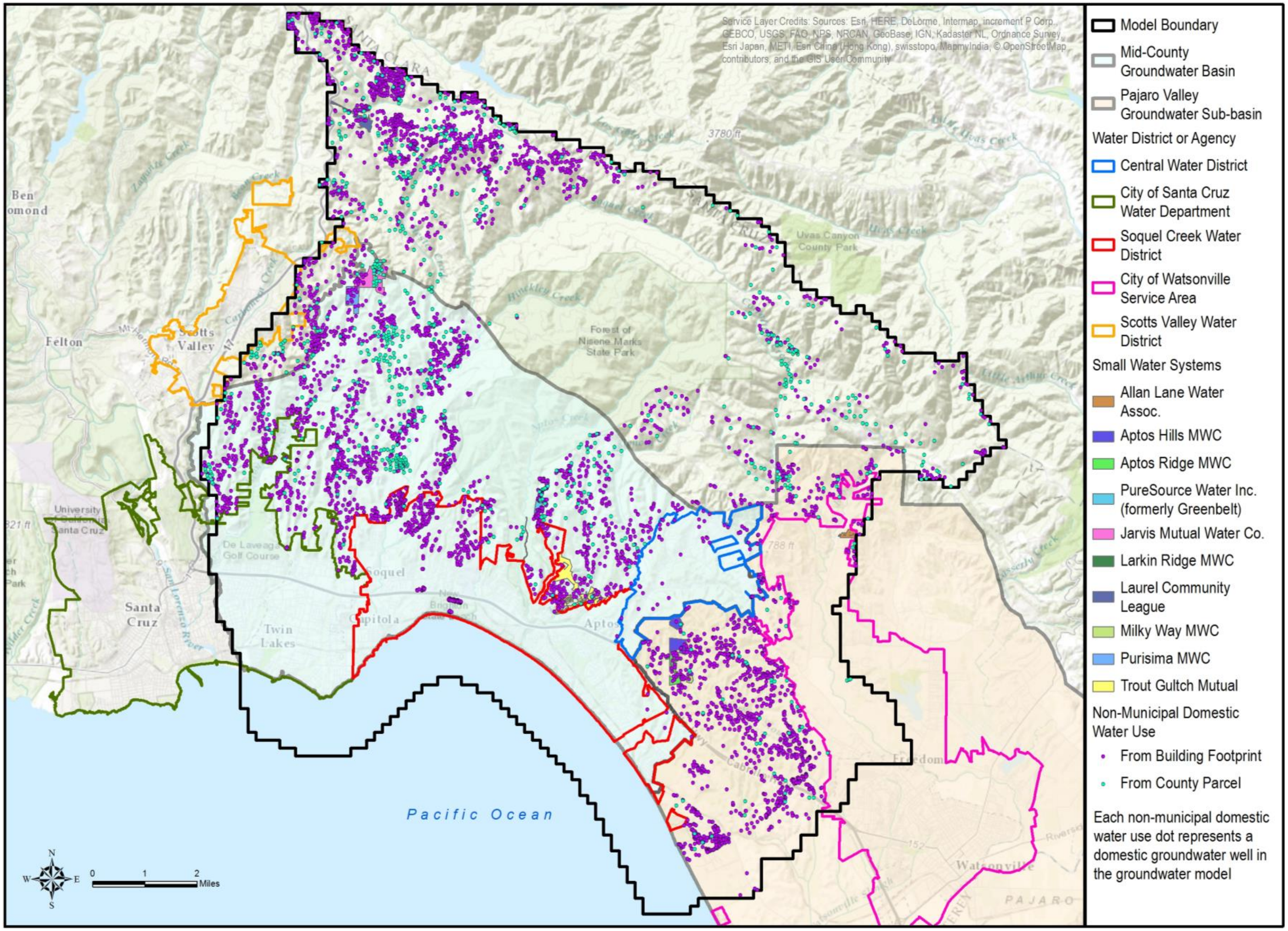

Figure 1: Non-Municipal Water Use Building Footprints and Residential Parcels

2.2 NON-MUNICIPAL DOMESTIC WATER USE FACTOR

An annual water use factor was developed to apply to the total number of non-municipal water use residences to obtain annual volumes of non-municipal groundwater pumped within the model area. The water use factor for 2015 was based on an evaluation of water use in 2015 by small water systems within and in close proximity to the model area (Table 2). From these data provided by the County, it was observed that water use per connection is greater for the larger of the small water systems in the Pajaro Valley Groundwater Sub-basin (Table 2). Based on this, the average 2015 water use factor for small water systems in the Pajaro Valley Groundwater Sub-basin is 0.50 acre-feet per year, and in the Mid-County Groundwater Basin (and remaining area within the model) it is 0.23 acre-feet per year (Table 2). These factors are applied to the non-municipal domestic dataset for Water Year 2015 according to the groundwater basin the water use falls in.

Table 2: Groundwater Pumped by Small Water Systems in 2015

Small System Name	Connections	2015 Use (gallons)	2015 Use / Connection (gallons)	2015 Water Use Factor (AFY)
Allan Lane Water Association	***16***	***4,326,708***	***270,419***	***0.83***
Aptos Hills Mutual Water Co.	***11***	***2,514,698***	***228,609***	***0.70***
Aptos Ridge Mutual Water Co.	***16***	***3,375,425***	***210,964***	***0.65***
Larkin Ridge Mutual Water Co.	***5***	***329,270***	***65,854***	***0.20***
Milky Way Mutual Water Co.	***9***	***420,975***	***46,775***	***0.14***
Trout Gulch Mutual	186	13,754,865	73,951	0.23
Purisima Mutual Water Co.	14	1,767,174	126,227	0.39
PureSource Water Inc.	80	5,315,289	66,441	0.20
Jarvis Mutual Water Co.	36	2,143,690	59,547	0.18
Laurel Community League	24	1,283,012	53,459	0.16
Average All				**0.37**
Average Mid-County Basin				**0.23**
Average Pajaro Valley Sub-basin				**0.50**

Five top small water systems in the table (in bold italics) are located in the Pajaro Valley Groundwater Sub-basin.

The water use factor was assumed to have been higher in years prior to 2015 because water conservation was not practiced to the extent that it is in the most recent years as evidenced by water use metered at several systems with data from 2013 through 2015 (Table 3). Based on this, percentage of water conserved between 2013 and 2015 in Pajaro Valley Groundwater Sub-basin was 20%, and in the Mid-County Groundwater Basin (and remaining area within the model) it was 34% (Table 2). These factors are applied to the 2015 water use factor to arrive at a water use factor for 2013. Water Year 2014's water use factor was assumed to be the mean of 2013 and 215 factors.

The water use factors are increased incrementally from 2013 backwards to the start of the model period. For the non-Pajaro Valley Groundwater Sub-basin areas, the period from 1989 through 2004 is assigned a water use factor 0.44 acre-feet per year based on Wolcott (1999), with a higher factor before that period and a declining factor since that period. For the Pajaro Valley Groundwater Sub-basin, a Proposition 218 service charge study by PVWMA estimated a water use factor of 0.59 acre-feet per year for 2009 based on small water system usage. This water use factor is the same as that estimated for 2015 based on 20% conservation of 2015 use, and thus was applied from 2009 through 2013. The water use factors prior to 2009 were increased incrementally over the same periods as the non-Pajaro Valley Groundwater Sub-basin factors. Table 4 provides the annual water use factors used to estimate historical non-municipal water use for the model area and for the Mid-County Groundwater Basin, as a subset of the model area.

Table 3: Observed Conservation from 2013 through 2015 for Small Water System with Metered Records

Small Water System	July – December Usage (AFY)			Conservation % 2013 – 2015
	2013	2014	2015	WUF (AFY)
Aptos Hills Mutual Water Co.	4.3	6.5	3.5	17%
Aptos Ridge Mutual Water Co.	9.0	3.5	6.9	23%
Trout Gulch Mutual	36.0	24.3	21.7	40%
PureSource Water Inc.	11.7	7.9	8.6	27%
Jarvis Mutual Water Co.	6.2	5.1	2.2	65%
Laurel Community League	2.0	2.0	1.9	4%
Average All				**29%**
Average Mid-County Basin				**34%**
Average Pajaro Valley Sub-basin				**20%**

Table 4: Summary of Non-Municipal Water Use Factors

Water Year	Non-Pajaro Valley Groundwater Sub-Basin (AFY)	Non-Pajaro Valley Groundwater Sub-Basin (AFY)
1985	0.46	0.62
1986	0.46	0.62
1987	0.46	0.62
1988	0.46	0.62
1989	0.44	0.62
1990	0.44	0.62
1991	0.44	0.62
1992	0.44	0.62
1993	0.44	0.62
1994	0.44	0.62
1995	0.44	0.62
1996	0.44	0.62
1997	0.44	0.62
1998	0.44	0.62
1999	0.44	0.62
2000	0.44	0.62
2001	0.44	0.62
2002	0.44	0.62
2003	0.44	0.62
2004	0.44	0.62
2005	0.41	0.61
2006	0.41	0.61
2007	0.41	0.61
2008	0.41	0.61
2009	0.38	0.59
2010	0.38	0.59
2011	0.38	0.59
2012	0.38	0.59
2013	0.35	0.59
2014	0.29	0.54
2015	0.23	0.5

2.3 NON-MUNICIPAL DOMESTIC WATER USE ESTIMATE

To estimate the annual non-municipal water use for all simulated years of the model period, the number of non-municipal residences was extrapolated from the count of residential buildings for 2014 obtained from Santa Cruz County building footprints and residential parcels. The number of buildings was assumed to increase or decrease in proportion to the increase or decrease in the County's unincorporated population relative to 2014's population (Table 5). Spatial distribution of water use was maintained consistent to the distribution for 2014.

Table 5 shows that estimates of annual non-municipal residential groundwater use in the model area have ranged from approximately 2,751 acre-feet in 1985 to a maximum of 3,223 acre-feet in 2000, subsequently falling to a minimum of 2,418 acre-feet in 2015. A subset of non-municipal estimates of groundwater use for the Santa Cruz Mid-County Basin are included in Table 5.

2.4 MONTHLY VARIATION OF NON-MUNICIPAL DOMESTIC WATER USE

Pumping will be applied to the model in monthly stress periods because municipal pumping for Water Years 1985-2015 is recorded on a monthly basis. Monthly variation of non-municipal domestic water use is assumed to result from variation in outdoor water use. Outdoor water use is assumed to average 30% of total domestic water use (Johnson *et al*., 2004). The variation of outdoor water use by month will be estimated from the variation of potential evapotranspiration (PET) minus actual evapotranspiration of rainfall as calculated by an initial simulation of watershed processes by PRMS.

Table 5: Estimated Non-Municipal Domestic Water Use based on Number of Residential Buildings and Population Change

Water Year	Unincorporated Population % of 2014	Estimated Number of Non-Municipal Supplied Residential Buildings		Non-Municipal Domestic Water Use (AFY)	
		Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin
1985	90.1%	4,938	2,147	2,880	988
1986	92.1%	5,046	2,194	2,943	1,009
1987	94.0%	5,148	2,239	3,003	1,030
1988	94.8%	5,194	2,259	3,029	1,039
1989	96.5%	5,289	2,300	3,060	1,012
1990	98.3%	5,383	2,341	3,115	1,030
1991	97.3%	5,329	2,317	3,084	1,019
1992	97.8%	5,357	2,330	3,100	1,025
1993	98.5%	5,398	2,347	3,124	1,033
1994	99.3%	5,439	2,365	3,147	1,041
1995	99.6%	5,456	2,372	3,157	1,044
1996	100.2%	5,489	2,387	3,176	1,050
1997	99.5%	5,449	2,370	3,153	1,043
1998	100.1%	5,483	2,384	3,173	1,049
1999	100.7%	5,518	2,399	3,193	1,056
2000	101.7%	5,570	2,422	3,223	1,066
2001	100.4%	5,500	2,392	3,183	1,052
2002	99.9%	5,472	2,379	3,166	1,047
2003	99.1%	5,429	2,361	3,142	1,039
2004	98.0%	5,368	2,334	3,106	1,027
2005	96.7%	5,298	2,304	2,988	945
2006	96.5%	5,287	2,299	2,982	943
2007	96.2%	5,270	2,292	2,973	940
2008	96.8%	5,305	2,307	2,992	946
2009	97.3%	5,333	2,319	2,882	881
2010	97.8%	5,360	2,331	2,897	886
2011	97.9%	5,364	2,332	2,899	886
2012	98.4%	5,392	2,344	2,914	891
2013	99.3%	5,439	2,365	2,900	824
2014	***100.0%***	***5,478***	***2,382***	2,660	689
2015	100.8%	5,520	2,400	2,418	552
			Average	**3,021**	**970**

Note: estimates based on estimated 2014 residential building/parcel count and 2014 unincorporated population

3.0 INSTITUTIONAL NON-MUNICIPAL WATER USE

Non-municipal, non-agricultural water use that is excluded from non-municipal domestic water use, because it cannot be accounted for by using residential buildings or parcels, is considered institutional non-municipal water use. This is water use by institutions or facilities within the model area that pump their own groundwater primarily for large scale irrigation of recreational turf.

The only small water system in the model area with available and consistent historical usage records is from Trout Gulch Mutual, where data are available from 2008 through 2015. This usage is included as institutional use because it is not supplied by municipal water and does not need to be estimated based on residential building footprints or parcels. Pumping for Trout Gulch Mutual prior to 2008 was assumed to be the same as its 2008 pumping. Estimates of pumping by other small water systems who do not have available and well-documented multi-year records of usage were developed by using the building footprints, parcels and water use factors described in Section 2.0.

Table 6 lists the non-municipal and non-agricultural water use institutions/facilities and provides their estimated water use. Estimates of water use are from a number of sources as referenced in the table. Figure 2 shows the locations of these institutions within the model area.

3.1 CALCULATION OF IRRIGATION USE

Some of the institutions use privately pumped groundwater to irrigate recreational turf in addition to potable supply for their institutions. Table 6 identifies areas of irrigation for these institutions. The amount of groundwater pumped for outdoor use based on the turf acreage provided will be estimated based on potential evapotranspiration (PET) minus rainfall evapotranspiration (ET demand) calculated by an initial simulation of watershed processes by PRMS that accounts for climatic conditions during the 1985-2015 model period. ET calculated by PRMS is for generalized plant cover, while the estimated irrigation for turf is based on crop evapotranspiration specific to turf (ET_c). ET_c is estimated by multiplying turfgrass' crop coefficient (K_c) by ET demand calculated by PRMS adjusted for the generalized crop coefficient applied in PRMS. Values of K_c for turf vary by month and are listed in Table 7. An irrigation inefficiency of 10-20% will be added to irrigation demand to estimate the pumping needed to meet this demand. Although PRMS calculates soil moisture that could affect irrigation demand, to avoid iterative calculation of irrigation demand using the model, we will estimate irrigation demand based only on ET_c minus actual evapotranspiration of rainfall calculated by PRMS adjusted for crop coefficients.

Table 6 also shows a preliminary estimate for outdoor water use at these areas prior to running the model using average monthly reference potential evapotranspiration (ET_o) from CIMIS Station No. 209 (Watsonville West II), and no irrigation between November and March to account for a typical rainy season. Based on the preliminary estimates, the preliminary water use factor for irrigation is approximately 1.8 acre-feet/acre. As reference, Wolcott (1999) used a similar factor of 1.7 acre-feet/acre.

Estimates by Kennedy (2015) for water use are also shown in Table 6 with notes where there are discrepancies from the preliminary estimates calculated based on the assumptions above.

Table 6: Estimated Groundwater Pumped by Institutions/Facilities in the Model Area

Institution/ Facility	Year	Area of Irrigated Turf (acres)	Preliminary Outdoor Water Use (AFY)	Indoor Water Use (AFY)	Preliminary Pumped Groundwater (AFY)	Kennedy Estimates of Total Water Pumped (AFY)/Comments on Current Status
Aptos High School		2.2	4.0[1]	9.3[3]	13.3	
KOA		-			11 estimate	26.7 - seems high
Monterey Bay Academy	2015	uncertain	577[8]	18[3]	595[6]	
Renaissance High School		1.8	3.2[1]	2.0[3]	5.3	1.7
7th Day Adventist Conference*		-	-	8.0[2]	8.0	11.0 / County confirms no current irrigation
Cabrillo College*	2014	12.7	22.9[1]	55.1	78.0[6]	95
Enchanted Valley*		-	-	5.4[2]	5.4	5 (rounded down)
Kennolyn Camp*		-		Included in non-municipal water use estimate		9
Land of Medicine Buddha*		-	-	1.7[2]	1.7	2 (rounded up)
Mountain Elementary School*		1.9	3.5[1]	1.5[1]	5.0	County has 0.02AFY reported pumping – this seems low given they irrigate turf
Seascape Golf Course*		136.1	108[6]	MS	108[6]	232 / County permit for 108 AFY
Seascape Greens*		11.5	20.6[1]	MS	20.6	Not included
Soquel High School*		6.4	11.5[1]	MS	11.5	Not included
St. Clare's Retreat Home*		-	-	2	2	Not included
Trout Gulch Mutual *	Ave 2008 –2014	-	20.4[7]	47.5[7]	67.9[5]	67.1
Total Model					**932.7**	
***Total Mid-County Groundwater Basin**					**308.1**	

* = Mid-County Groundwater Basin
MS = municipal supply
[1] Irrigated area multiplied by water use factor of 1.8 acre-feet/acre
[2] Wolcott (1999) Appendix E
[3] Using per capita rates and other assumptions for schools from Wolcott (1999) Appendix E
[4] HydroMetrics (2015)
[5] Trout Gulch Mutual's pumping records
[6] Santa Cruz County records
[7] Based on 30/70 Outdoor/Indoor usage
[8] Difference between groundwater pumped and indoor use

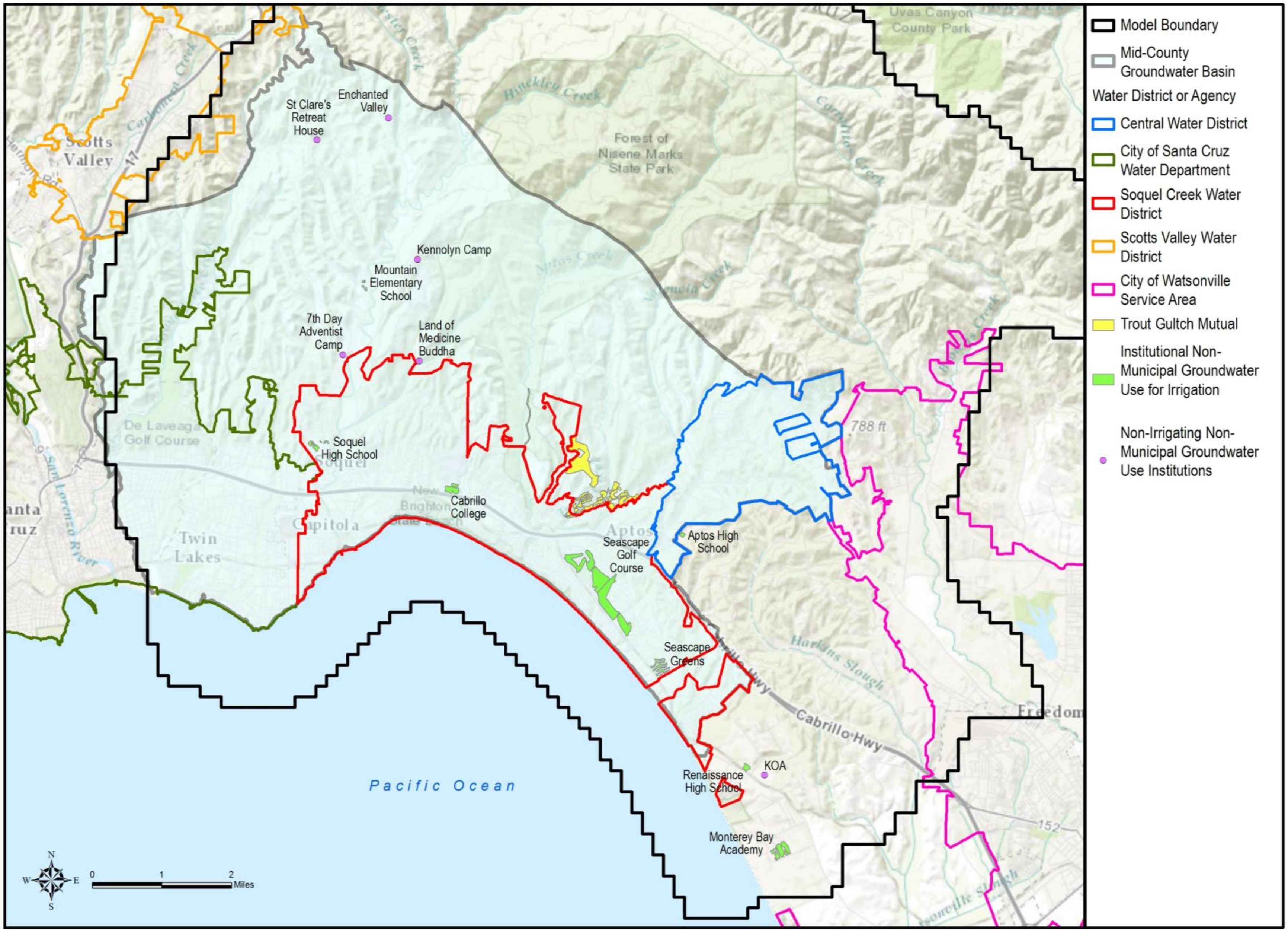

Figure 2: Non-Municipal Groundwater Use Institutions

4.0 AGRICULTURAL WATER USE

4.1 AGRICULTURAL IRRIGATION USE METHODOLOGY

An estimate of the amount of agricultural irrigation applied in the groundwater model is estimated based on crop evapotranspiration (ET_c). The amount of groundwater pumped for agricultural use will be estimated based on potential evapotranspiration (PET) minus rainfall evapotranspiration calculated by an initial simulation of watershed processes by PRMS that accounts for climatic conditions during the 1985-2015 model period as described in the previous section. For agriculture, crop coefficient (K_c) is affected by crop type, stage of growth, soil moisture, the health of the plants, and cultural practices. Values for K_c (unitless) are primarily those used in the PVWMA groundwater model developed by the USGS (Hanson *et al.*, 2014). Exceptions to Pajaro Valley K_c are coefficients for apple orchards, vineyards, pastures, and nurseries/greenhouses.

Apple orchards within the Mid-County Groundwater Basin are mostly well-established and require limited irrigation. We assumed only irrigation in the warmer months of April through October. The Pajaro Valley model April through October K_c values were reduced until the annual water demand approximated measured water use used in the CWD model for apple orchards (HydroMetrics WRI and Kennedy/Jenks, 2014). This same approach of reducing monthly K_c based on measured water use for the CWD model was taken for all vineyards (irrigated April through September) and pastures (irrigated April through November) in the model. The Pajaro Valley model used a K_c value of 0.1 for all 12 months for nurseries/greenhouses. A review of published papers on crop coefficients indicated that the coefficient should be much higher. Therefore we have assumed a K_c of 0.8 for all months for nurseries/greenhouses. The monthly K_c to be used in the GSFLOW model for each crop type are summarized in Table 7.

Table 7: Monthly Crop Coefficients (K_c)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turf (Urban)	0.56	0.56	0.56	0.73	0.73	0.73	0.73	0.7	0.62	0.56	0.56	0.56
Vegetable Row Crops	0.61	0.61	0.61	0.92	0.71	0.6	1.04	0.92	0.59	1	0.85	0.61
Strawberry	0.62	0.62	0.62	0.86	0.66	0.58	1.01	0.9	0.56	1.06	0.86	0.62
MGB Deciduous (Orchards)	0	0	0	0.025	0.075	0.1	0.125	0.15	0.15	0.025	0	0
Non-MGB Deciduous (Orchards)	0.03	0.03	0.03	0.1	0.3	0.4	0.5	0.6	0.6	0.1	0.03	0.03
Subtropical	0.56	0.56	0.56	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.56
Vines/Grapes	0	0	0	0.17	0.22	0.23	0.23	0.22	0.12	0	0	0
Pasture	0	0	0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0
Grains (Field Crops)	0.25	0.25	0.25	1.17	0.87	0.17	0.17	0.17	0.17	0.17	0.17	0.25
Nurseries/Greenhouses	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raspberries/ Blackberries/Blueberries	0.16	0.16	0.16	0.51	0.75	0.78	0.78	0.75	0.45	0.25	0.2	0.16
Semi-agriculture	0.31	0.31	0.31	0.62	0.74	0.7	0.7	0.53	0.34	0.27	0.27	0.31

Coefficients are unitless
Sources of data: PVWMA Groundwater Model (Hanson *et al.*, 2014) and HydroMetrics WRI & Kennedy/Jenks (2014)

There are some apple orchards and pastures in the model that have been identified by the County as dry farmed and therefore no irrigation demand is estimated for those areas.

Annual agricultural demand is estimated by summing the product of the monthly crop coefficients (K_c), a monthly reference evapotranspiration (ET_o) that is measured at a nearby CIMIS station, and the crop acreage:

$$Agricultural\ Demand\ (acre - feet) = K_c\ (unitless) \times ET_o(feet) \times crop\ area\ (acres)$$

4.2 PRELIMINARY AGRICULTURAL IRRIGATION DEMAND ESTIMATE

Using the methodology described in the section above, Table 8 summarizes the crops, their 2014 acreages, and preliminary estimates for water demand for 2014 based on monthly reference crop evapotranspiration (ET_o) in 2014 from CIMIS Station No. 209 (Watsonville West II. The acreages and locations of crops were obtained primarily from PVWMA, which maps crop coverages at least annually. Current aerial photographs were used to supplement crop locations and types in areas to the west of the data provided by PVWMA. The County also provided some field verification and identified some areas within the Mid-County Groundwater Basin that are dry farmed.

The locations of horse and cattle related operations were identified through an internet search and confirmed by aerial photographs. Figure 3 shows the 2014 distribution of crops by type within the model area. Some of the agricultural demand in the model area is met by water supplied by CWD, as indicated in Table 8.

For the water demand from livestock related agriculture, horses are estimated by head count instead of acreage. It was assumed that horse boarding, breeding, and training facilities use 30 gallons per horse per day[2]. The number of horses at each facility was estimated by counting the number of stalls from aerial photographs. The one cattle ranch that we have identified has been excluded because it appears small based on aerial photographs. Water use data for the one egg ranch within the model area was provided by CWD.

[2] Horses require on average 10 gallons per day for direct consumption. We assumed 20 gallons per day per horse additional water use for other activities at the facility such as cleaning and dust control. Assuming 35 horses, a total water use of 30 gallons per day per head is also the Barn Boarding Stable's 2005-2015 average metered records from CWD.

Table 8: Summary of 2014 Agricultural Water Demand

Crop/Activity	Unirrigated Acreage (acres)		Irrigated Acreage (acres)		Estimated 2014 Water Demand by Supply (AFY)		Estimated 2014 Water Demand by Area (AFY)	
	Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin	Private Supply	CWD Supply	Model Area	Mid-County Groundwater Basin
Deciduous (Apple Orchards)	89	89	1,515	350	1,185	10	1,195	81
Strawberries	-	-	653	0	1,706	0	1,706	0
Vegetable Row Crop	-	-	652	88	1,705	33	1,738	235
Nurseries/Flowers/Tropical Plants	-	-	566	27	1,555	0	1,555	74
Raspberries and Blackberries	-	-	520	0	912	0	912	0
Vine/Grapes	-	-	280	186	115	10	125	83
Fallow	-	-	206	0	0	0	0	0
Pasture	33	33	205	74	440	0	440	160
Greenhouse	-	-	75	3	206	0	206	8
Other Agriculture	-	-	31	0	54	0	54	0
Bamboo	-	-	30	30	0	13	13	13
Ag. Unknown	-	-	4	1	6	0	6	3
Olive Orchard (similar to apple orchard demand)	-	-	1	1	0	0.2	0.2	0.2
Citrus	-	-	22	22	48	0	48	48
Horses	-	-	-	-	13.7	0.3	14	7
Egg Ranch	-	-	-	-	0	2	2	2
Total Crops and Livestock	**122**	**122**	**4,759**	**784**	**7,946**	**69**	**8,015**	**715**

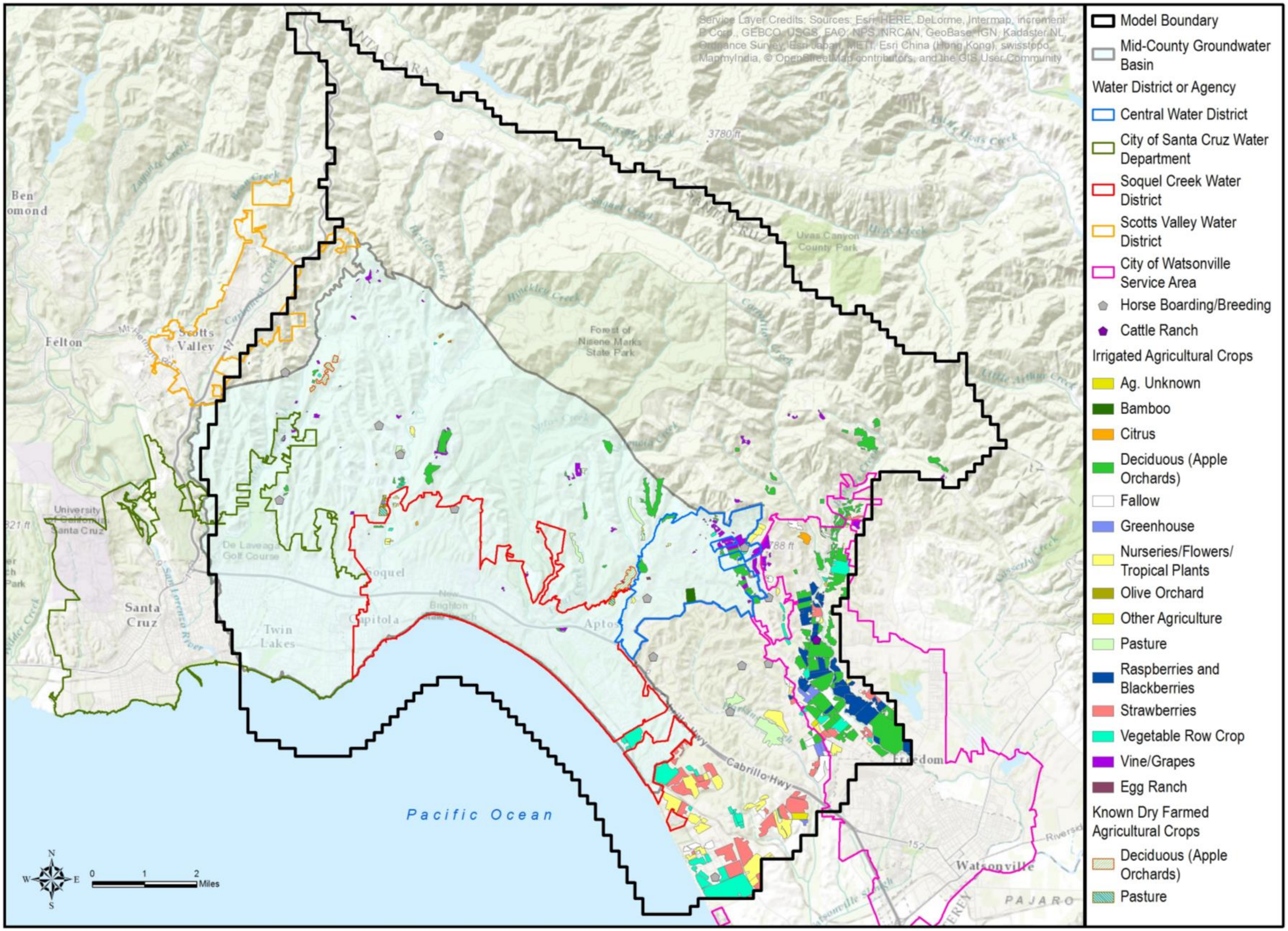

Figure 3: 2014 Agriculture in the Model Area

5.0 Implementing Non-Municipal Pumping in Model

All non-municipal domestic and institutional, and agricultural water use is assumed to be supplied by privately pumped groundwater. This pumping will be aggregated and estimated for each applicable model cell; specific wells will not be explicitly simulated in the model. The pumping estimates will be added to the Multi-Node Well (MNW2) package file as multi-layer wells screened from the top layer to the lowest likely layer of production for the grid cell. Pumping will be distributed to layers by the model based on simulated layer transmissivity. If the shallowest layers become dry in the model, pumping is distributed to lower saturated layers so that all of the estimated pumping is included in the model's water budget.

6.0 Simulating Return Flow Components

There are a number of return flow components that will be included in the groundwater model. This memorandum introduces these components and how we propose to estimate them. The final estimates and resultant model input will be discussed in the memorandum documenting the integrated GSFLOW model.

In general, return flow components include:

1. System losses: water, sewer and septic systems,
2. The inefficient portion of municipal and non-municipal domestic and institutional irrigation (outdoor applied water), and
3. The inefficient portion of agricultural irrigation.

A phased approach is planned for implementing return flow components in the GSFLOW model. Initially, all return flow components will be added in GSFLOW's UZF package, which is applied below the root zone (Table 9). The US Geological Survey recently added this capability to UZF under its joint funding agreement with SqCWD. Using only the single package that is integral to GSFLOW will expedite model results that will allow MGA and members evaluate groundwater management alternatives and supplemental supply options by early 2017. However, adding return flow components to UZF will preclude calculation of near surface runoff of the return flow components to surface water.

Future work will continue use of UZF for simulating return flow from water and sewer system losses, and septic systems, which is assumed to occur below the soil root zone. However, there is an option to simulate return flow from the inefficient portions of irrigation using the newly developed Water Use Module (WUM) for PRMS, which adds water to the near surface capillary zone (Table 9). This module effectively allows for the inefficient portions of return flow near surface runoff to surface water as well as groundwater recharge. The need to implement WUM will be evaluated in 2017 when the model will be used to analyze relative impacts from various water use classifications under a County Proposition 1 grant.

Table 9: Summary of Packages Used to Simulate Return Flow in the Model

Return Flow Component	Package used in Model Implementation	
	Initial (2016)	Future Option (2017)
Water system losses	UZF	UZF
Sewer losses	UZF	UZF
Septic system losses	UZF	UZF
Municipal & non-municipal irrigation	UZF	WUM
Agricultural irrigation	UZF	WUM

The following sections describe our proposed approach for simulating the different return flow components using UZF only for this first phase of return flow implementation.

6.1 Water System Losses

Water system losses will be calculated as percentage of estimated deliveries to each service area and applied in UZF to model cells overlying those service areas.

For the Central Water District (CWD) model, the system loss percentage for CWD was varied over time based on unaccounted water losses by fiscal year through 2009 (HydroMetrics WRI and Kennedy/Jenks, 2014). The approximate range of CWD system loss estimated for the CWD model for 1984-2009 was 4-14%. This percentage will be updated for fiscal years through 2015.

For the CWD model, the system loss percentage for Soquel Creek Water District (SqCWD) was estimated as 7% which was confirmed through a SqCWD water audit for 2010-2013 (Mead, 2014) . The Cities of Santa Cruz and Watsonville water system losses will be 7.5% and 6%, respectively, per their 2015 Urban Water Management Plans (UWMP)

6.2 Wastewater Return Flows

Wastewater return flows will be based on indoor use that becomes wastewater. Indoor use has generally been assumed to be 70% of total water use (Johnson et al., 2004 and USEPA, 2008) and 90% of indoor water use is assumed to become wastewater. There are a range of available estimates for this value with measurements at mountain residences in Colorado indicating approximately 81% (Stennard et al, 2010) and California Department of Water Resources (1983) estimating 98%.

For wastewater return flows from sewer losses in sewered areas, the same loss percentage of 7% used in the CWD model based on the SqCWD system loss percentage will be applied to model cells overlying all sewered areas. These sewer losses will be added in UZF to infiltrate below the root zone.

All of indoor water use that becomes wastewater for septic systems will be also be added in UZF below the root zone for model cells in unsewered areas. Although there has been research indicating additional evapotranspiration from septic systems than surrounding areas (Stannard et al., 2010), typical leachfield depth in Santa Cruz County is 4 to 50 feet and County staff has rarely observed increased vegetation overlying or nearby leachfields that would indicate root zone evapotransporation from septic systems (Ricker, 2016).

Santa Cruz County has observed that the percentage of indoor use is influenced by overall water use and climatic conditions (Ricker, personal communication). In years of drought, such as from 2013 – 2015, water conservation is practiced to a greater extent by the public. Outdoor use is usually the first place where water use is cut, thus the percentage of indoor use is greater in those years than years when the overall water use is higher. For the period through 2013, the percentage of indoor use in the model will be 70% and will increase to 75% for 2014, and to 80% for 2015.

6.3 IRRIGATION RETURN FLOWS

The portion of water from irrigation that returns to the watershed as runoff or groundwater recharge is the inefficient portion of irrigation. The amount of water applied in UZF is just the inefficient irrigation calculated in the model cell because UZF represents what is below the capillary zone where the crop's evapotranspiration demand is met. The inefficiency factor, or the percentage of crop ET demand that does not evapotranspirate, will range from 10% (Todd, 2014) to 20% (Johnson et al., 2004).

7.0 CALCULATING RETURN FLOW COMPONENTS

Calculation of return flow components depends on water source and wastewater destination in addition to type of water use. The following sections describe our proposed approach for calculating the different return flow components.

7.1 MUNICIPAL RETURN FLOW

Figure 4 illustrates how we plan to estimate return flows from municipally supplied water including system losses and wastewater return flows discussed above as well as irrigation return flows. From available water supply records, we will distribute return flows spatially based on land use and service areas. Municipal water use for the Cities of Santa Cruz and Watsonville includes both surface water and groundwater. Land use factors affecting municipal return flow include defining areas of large-scale irrigation versus primarily residential and commercial use where irrigation is at a smaller scale. Figure 5 shows the locations of municipal service areas and various land use categories used for different applied water types.

To estimate the amount of residential and commercial water use for each municipal service area, water system losses as described above and water used for large-scale irrigation will be subtracted from the amount of water supplied to each service area. The amount of irrigation applied will vary monthly based on local potential evapotranspiration (Figure 4). Return flow comprised of the inefficient portion of outdoor use, sewer losses in sewered areas, and septic system leakage will be distributed to model cells overlying those service areas. Areas that are not supplied water, such as open space and undeveloped land will be excluded.

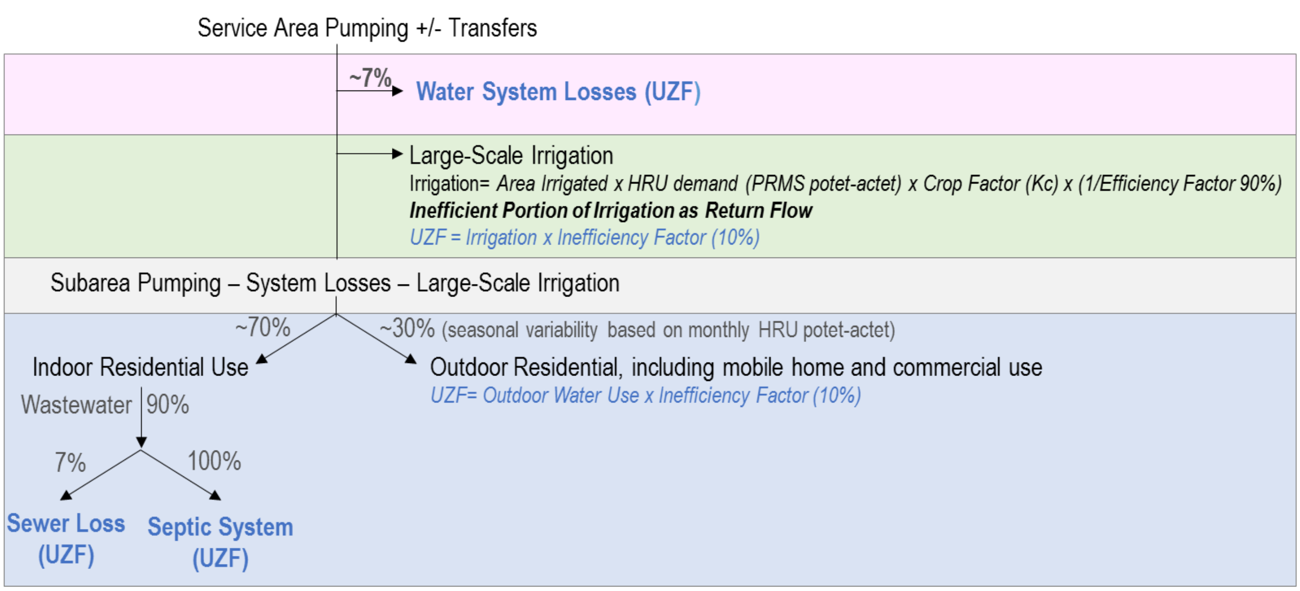

Figure 4: Approach to Estimating Municipal Return Flow

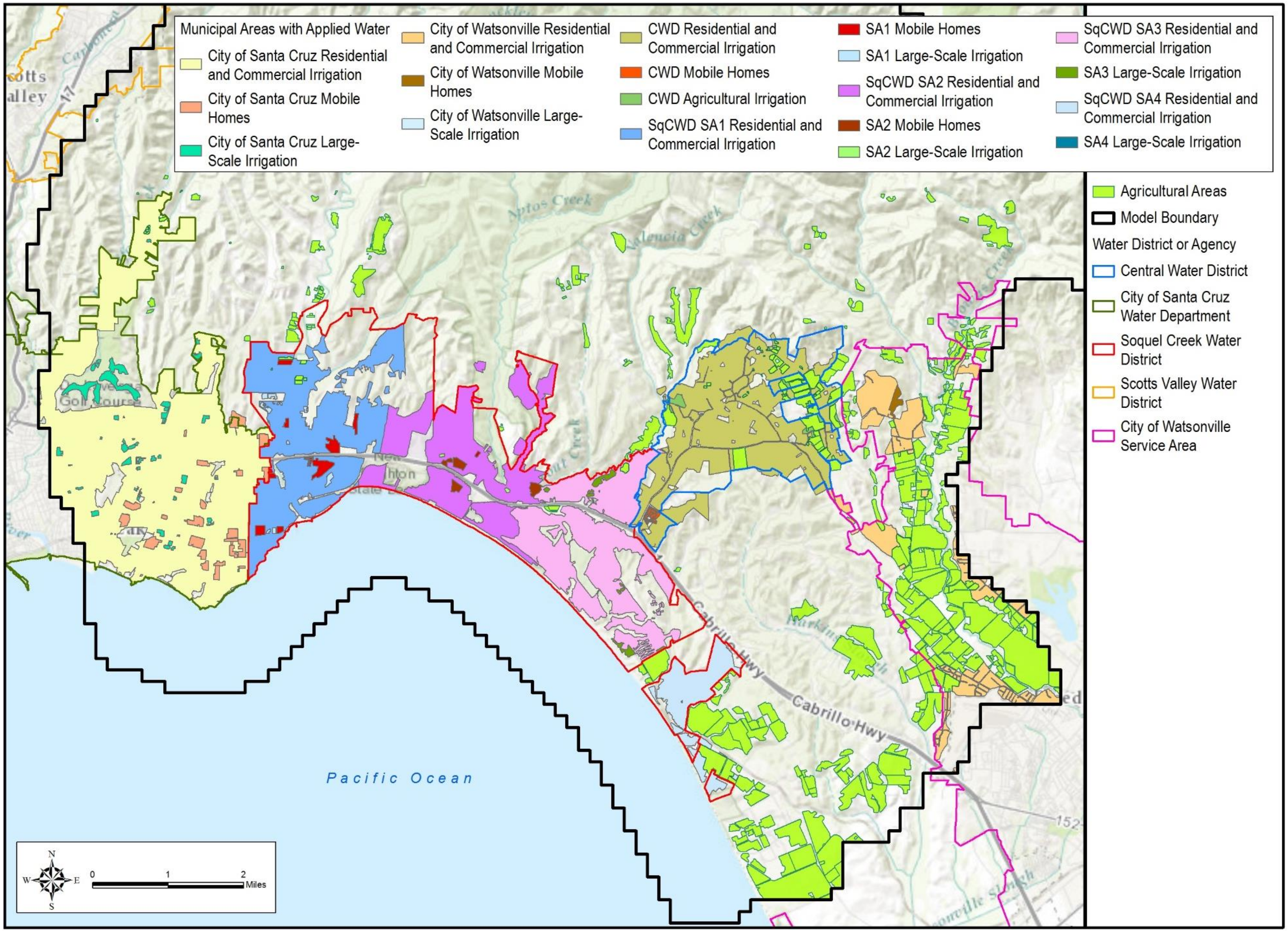

Figure 5: Municipal Applied Water Areas

Return flow represented by the inefficient portion of large-scale irrigation of sports fields and parks will also be applied to model cells that overlie those irrigated areas. Estimates of large-scale irrigation will rely on irrigation demand as estimated by the difference between capillary zone PET and actual rainfall ET simulated by PRMS, the area of the cell being irrigated, a crop factor, and irrigation inefficiency.

7.2 NON-MUNICIPAL DOMESTIC RETURN FLOW

The inefficient portion of non-municipal outdoor domestic use will be applied in the model using the non-municipal domestic water use described earlier in this technical memorandum. Figure 6 shows approximately 30% of total domestic water use will be assumed for outdoor use based on the average outdoor water use for 1985-2013, and a portion of this outdoor use, based on an inefficiency factor, will be applied to cells overlying the areas identified in this memo as having non-municipal domestic water use. The percentage of outdoor water use is assumed to decrease for 2014-2015 to achieve recent conservation as described in Section 6.2, and will vary monthly to simulate changing seasonal demands. Figure 6 also shows the wastewater return flow of indoor use from septic systems as described above.

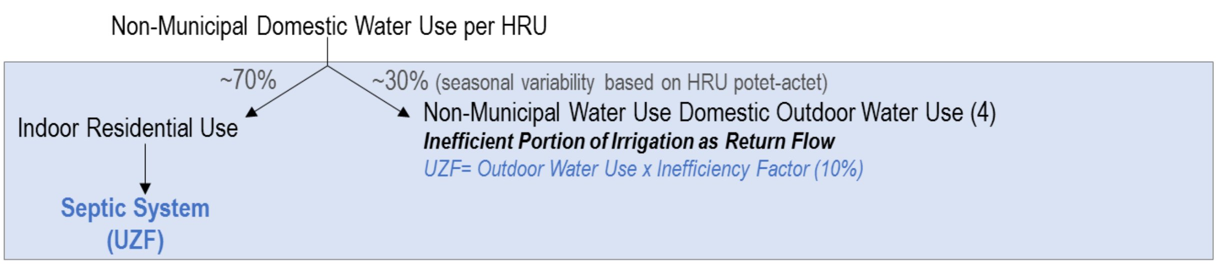

Figure 6: Approach for Estimating Non-Municipal Domestic Return Flow

7.3 INSTITUTIONAL NON-MUNICIPAL IRRIGATION RETURN FLOW

Similar to municipal large-scale irrigation, the inefficient portion of municipal institutional irrigation will be applied to model cells that overlie institutional irrigated areas (Figure 2), and will represent a proportion of applied water based on an assumed inefficiency factor. The calculation of return flow for each model cell is shown in Figure 7.

7.4 AGRICULTURAL IRRIGATION RETURN FLOW

The inefficient portion of agricultural irrigation to apply in the model will be based on the difference between PRMS estimated PET and actual ET (irrigation demand), the area of the cell being irrigated, a specific crop factor, and irrigation inefficiency (Figure 7).

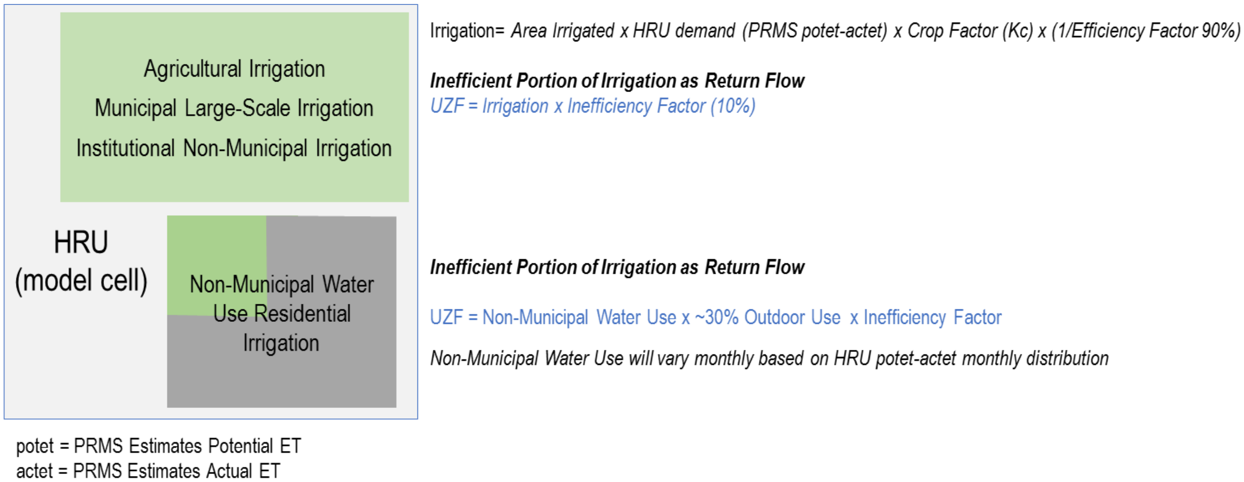

Figure 7: Return Flow Estimate Approach from Irrigation per Model Cell

8.0 Sensitivity of Water Use and Return Flow Assumptions

This technical memorandum describes a number of assumptions for water use and return flow that will be incorporated into the Mid-County Groundwater Basin groundwater model. These assumptions can be tested with sensitivity runs using the model that test the effect of changing the assumptions on model predictions. However, when making any changes, the model calibration to groundwater level data and streamflow must be checked and the model potentially will need to be re-calibrated based on the changes. Only a calibrated model should be used to assess changes to model predictions.

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Appendix A

List of Santa Cruz County land use codes used to identify non-municipal water use residential parcels. Those in bold are codes that did not contain residential building footprints.

010-LOT/RESIDENTIAL ZONE
015-LOT/MISC RES IMPS
016-BUILDING IN PROGRESS
020-SINGLE RESIDENCE
021-CONDOMINIUM UNIT
023-NON-CONFORMING RES
024-SFR W/ SECONDARY USE
025-AFFORDABLE HOUSING
027-TOWNHOUSE
028-SFR + SECOND UNIT
029-SFR + GRANNY UNIT
030-SINGLE DUPLEX
031-TWO SFRS/1 APN
032-3 OR 4 UNITS/2+ BLDGS
033-TRIPLEX
034-FOUR-PLEX
040-VACANT APARTMENT LOT
041-5 - 10 UNITS
042-11 - 20 UNITS
043-21 - 40 UNITS
044-41 - 60 UNITS
045-60 - 100 UNITS
046-OVER 100 UNITS
050-LOT/RURAL ZONE
051-1-4.9 ACRE/RURAL
052-5-19.9 ACRE/RURAL
053-20- 49.9 ACRE/RURAL
054-50- 99.9 ACRE/RURAL
055-100-199.9 ACRE/RURAL
05B-MISC IMPS 1-4.9 ACRE
05C-MISC IMPS 5-19.9 ACRE
05D-MISC IMPS 20-49.9 ACRE
05F-MISC IMPS 100-199.9 ACR

060-HOMESITE/< 1 ACRE
061-HOMESITE/1-4.9 ACRES
062-HOMESITE/5-19.9 ACRE
063-HOMESITE/20-49.9 ACRES
064-HOMESITE/50-99.9 ACRES
065-HOMESITE/100-199.99 ACRE
068-RURAL DWELLINGS/1 APN
070-MOTEL/UNDER 20 UNITS
071-MOTEL/20 TO 49 UNITS
072-MOTEL/50 + UNITS
074-RESORT MOTEL
080-HOTEL
085-BED AND BREAKFAST
262-NURSERY W/ RES
411-ORCHARD/RESIDENCE
421-VINEYARD/RESIDENCE
431-BERRY FARM/RESIDENCE
432-BERRY FARM/MISC IMPS
451-VEGIE FARM/RESIDENCE
480-POULTRY RANCH
490-DIVERSIFIED FARM
500-TPZ/NO RESIDENCE
501-TPZ/RESIDENCE
511-CLCA/RESIDENCE
520-OSE/NO RESIDENCE
521-OSE/RESIDENCE
711-OTHER CHURCH PROPERTY