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TECHNICAL MEMORANDUM

To: Ron Duncan, Soquel Creek Water District

From: Cameron Tana

Date: October 27, 2015

Subject: Estimated Effects on Sustainable Yield and Pumping Goals of Climate Change and Updated Basin Consumptive Use Using Water Balance Approach

At your request, we have performed additional evaluation of the District's post-recovery sustainable pumping yield and pre-recovery pumping goals using the water balance approach documented in our 2012 letter report and last updated in our July technical memorandum (HydroMetrics WRI, 2015c). This additional evaluation includes estimates accounting for climate change and updated basin consumptive use data to inform development of the District's Community Water Plan and 2015 Urban Water Management Plan.

We have recommended that future estimates of post-recovery pumping yield and pre-recovery pumping goals be based on the groundwater flow model currently under development instead of the water balance approach used previously. The use of the groundwater flow model for this purpose is described in more detail in a HydroMetrics WRI memo titled *Peer Review of Sustainable Yield Estimates – Refining Estimates with the Groundwater Model and Additional Studies* (2014). For the groundwater flow model, updated pumping estimates will be included and simulations based on different climate change scenarios will be performed. Therefore, future groundwater management planning should be based on those simulation results. The estimates presented in this technical memorandum are meant only for the District's use in the interim as the groundwater flow model is being developed. Development of these estimates reaffirmed the need to integrate climate change and updated consumptive use data within the groundwater flow model as opposed to roughly fitting them into the water balance approach.

The post-recovery pumping yields and pre-recovery pumping goals are estimated separately for the Purisima and Aromas areas as shown in Figure 1 which is replicated from the 2012 report. First, this water balance area is different from the basin boundary revision that is planned for a Groundwater Sustainability Agency (GSA) so the GSA and its Groundwater Sustainability Plan should not rely on estimates in this memorandum and instead use the groundwater model for planning and management. Second, as there has been no published estimate for outflows needed to protect the aquifers from seawater intrusion west of SC-1, recharge in the area west of SC-1 is removed from the water balance for the Purisima area. However, pumping from the area west of SC-1, including by the City of Santa Cruz, is included in the water balance as there has been some uncertainty of the source of recharge for those western wells.[1] The groundwater flow model will include all water recharge and discharge components for the entire Purisima, including the area west of SC-1.

The Valencia Creek watershed east of the creek has previously been included with the Purisima area (Johnson *et al*., 2004) because the Purisima F unit outcrops in this area. For the water balance, this area is grouped with the Aromas area where pumping occurs from both the Purisima F unit and overlying Aromas Red Sands aquifer. The groundwater flow model will simulate the Purisima F unit and Aromas Red Sands separately.

This memorandum is organized as follows:

1. Discusses effects of reduced recharge updated to include of recent rainfall data on the basinwide available consumptive use after basin recovery to protective elevations is achieved.
2. Discusses updated estimates for consumptive use in the basin and resulting changes to estimated cumulative pumping deficit and the consumptive use reduction needed to recover the basin.
3. Discusses pumping goals for the District based on different assumptions for non-District consumptive use.
4. Presents sensitivity of pumping goals for the District to additional reductions in recharge resulting from climate change.
5. Discusses why pumping goals for the District are not adjusted for effects of sea level rise.

[1] The peer review by Todd Groundwater (2014) interpreted the water balance to exclude City of Santa Cruz pumping and we did not previously identify that misinterpretation when reviewing Todd's report.

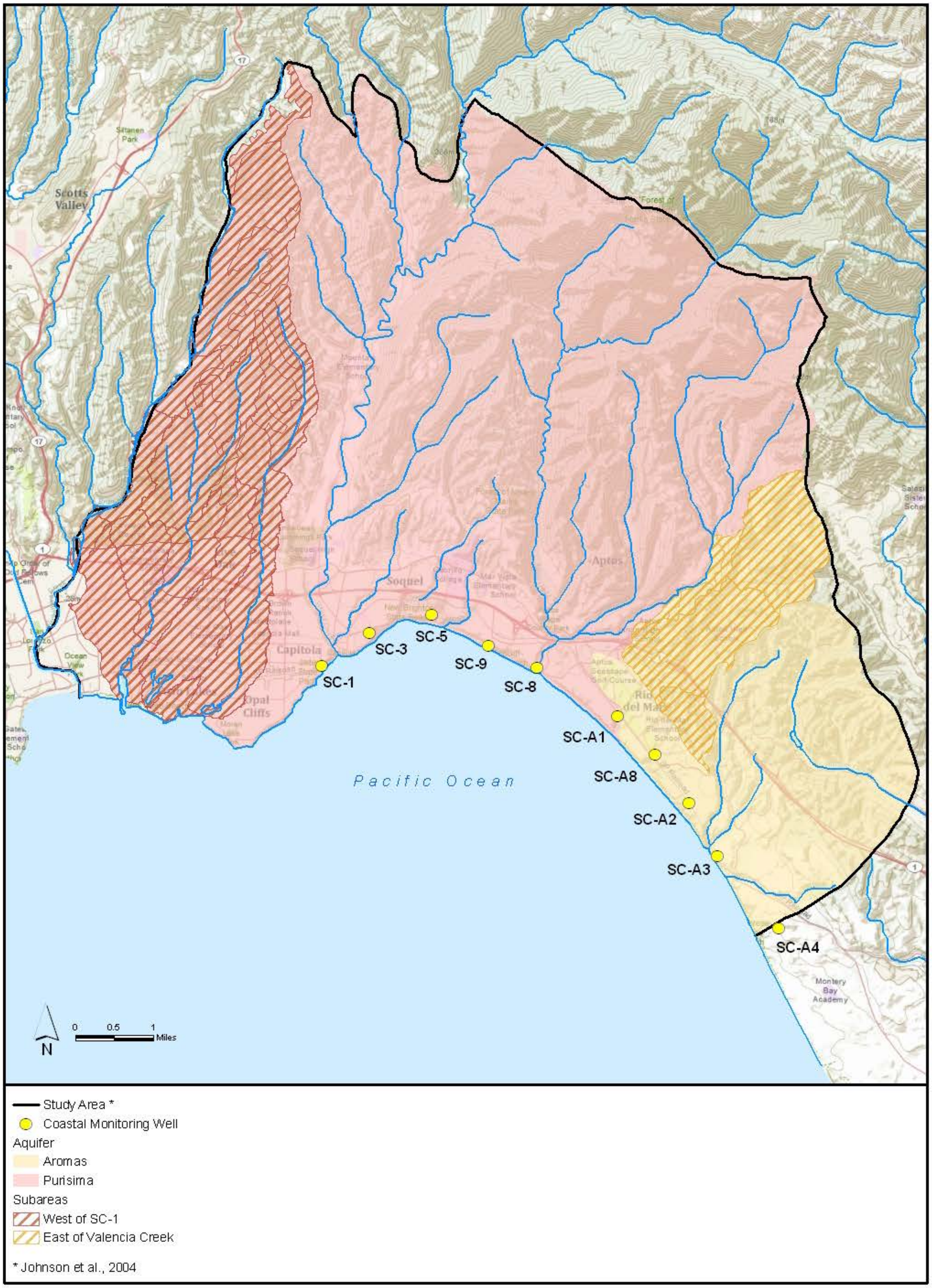

Figure 1. Purisima and Aromas Water Balance Areas (HydroMetrics WRI, 2012)

REDUCED RECHARGE BASED ON INCLUSION OF RECENT RAINFALL DATA

The recharge estimates used in the water balance are based on Precipitation Runoff Modeling System (PRMS) watershed model results for the Water Years (WY) 1984-2009 calibration period (HydroMetrics WRI, 2011). The model also provides a relationship that has been used to estimate recharge based on rainfall for Water Years 2010-2014. Combining the uncalibrated recharge estimates for this relatively dry five year period with calibrated model results for the previous 26 years provide an estimate of long-term recharge that is 6.5% lower than what has been used in the water balance previously (HydroMetrics WRI, 2015a). The third column of Table 1 shows the effect of the 6.5% decreased recharge for the Purisima and Aromas water balance areas.

Table 1. Effects of Decreased Recharge on Water Balance Components

Water Balance Component	Recharge Simulated by PRMS for WY 1984-2009[1]	Recharge Estimated for WY 1984-2014[2]
Purisima Area		
Recharge from precipitation excluding west of SC-1 (afy[3])	5,400	5,050
Modeled protective outflows to Ocean: 70th percentile (afy)	-775	-775
Total available for consumptive use post-recovery (afy)	***4,625***	***4,275***
Aromas Area		
Recharge from precipitation (afy)	4,200	3,927
Modeled protective outflows to ocean -70th percentile (afy)	-1,950	-1,950
Flow to Pajaro Valley	-370	-370
Total available for consumptive use post-recovery (afy)	***1,880***	***1,607***

[1] HydroMetrics WRI, 2012
[2] HydroMetrics WRI, 2015a
[3] acre-feet per year

CONSUMPTIVE USE CHANGES BASED ON PEER REVIEW

The Todd Groundwater (2014) peer review recommended some changes to assumptions used to calculate consumptive use. Two of these recommendations are adopted for this evaluation. The first recommendation was to account for water system losses as a source of return flow. Seven percent loss is assumed for Soquel Creek Water District based on information from the District (HydroMetrics WRI and Kennedy/Jenks, 2014). The second recommendation was to use a return flow percentage of 10% for outdoor irrigation instead of 20% to account for increased use of efficient irrigation systems. The groundwater model may be used to evaluate whether 90% irrigation efficiency results in 10% return flow to recharge or whether some water flows to streams.

This evaluation does not update the return flow percentage for septic systems from 75% to 98% as suggested by Todd Groundwater. The higher percentage appears to represent indoor use that flows to septic systems and does not account for whether water is evaporated or flows to stream instead of recharging. This may be further evaluated by the groundwater flow model, but the conservative estimate of 75% is used for the water balance.

UPDATED CONSUMPTIVE USE ESTIMATES FOR WATER AGENCIES

Estimates for consumptive use by Soquel Creek Water District, Central Water District, and City of Santa Cruz are from average production for Water Years 2009-2013. Pumping over that five year period was consistently lower than previous years, but higher than the last two years of extraordinary conservation during the current drought. Estimated deliveries of approximately 27 acre-feet per year by Central Water District for agricultural use based on 2010-2011 data (HydroMetrics WRI and Kennedy/Jenks, 2014) is subtracted to calculate non-agricultural consumptive use. Four percent system loss resulting in return flow is assumed for Central Water District based on data from 2008-2009 (HydroMetrics WRI and Kennedy/Jenks, 2014). Seven percent system loss resulting in return flow is assumed for the City of Santa Cruz.

Non-agricultural consumptive use is calculated using the return flow percentages discussed above and the assumption that 30% of the use is applied outdoors. Table 2 summarizes the estimated consumptive use by water agency.

The 2009-2013 averages for Central Water District and City of Santa Cruz are consistent with long-term (1984-2013) average pumping for the two agencies and are therefore used in calculating the cumulative consumptive use deficit for estimating pre-recovery pumping goals.

Table 2. Estimated Consumptive Use by Water Agencies

Agency	Pumping (afy)	Septic Percentage	Overall Return Flow Percentage	Consumptive Use (afy)
Purisima Area				
Soquel Creek Water District	2,625	6%	12.5%	2,297
City of Santa Cruz	536	0%	9.8%	483
Total	***3,160***		***12.0%***	***2,780***
Aromas Area				
Soquel Creek Water District	1,554	30%	24.4%	1,175
Central Water District (non-ag)	504	100%	57.3%	215
Total	***2,058***		***32.4%***	***1,390***

UPDATED CONSUMPTIVE USE ESTIMATES FOR NON-WATER AGENCY USE

Consumptive use estimates for non-water agency use are updated based on ongoing work being performed for the groundwater flow model. These results are preliminary and subject to revision. Full documentation of this work will be provided for the groundwater flow model Technical Advisory Committee review in a draft technical memorandum within the next two months. The following summarizes the different components of these estimates.

1. For areas not served by municipal water agencies, residential building footprints are counted based on data provided by Santa Cruz County for 2007 and are compared to the number of residential parcels for the same

area. The higher of the two numbers are used to represent the number of residences.[2]

2. An updated uniform 0.4 acre foot per year water use factor is applied to each residence.
3. Estimates for several small water systems are available. If unavailable, estimates based on the number of residences are used.
4. Sewered areas identified based on data from the District and County.
5. Current agricultural land use is mapped and total areas calculated based on data from Pajaro Valley Water Management Agency, a California Department of Water Resources land survey, and a current aerial photograph.
6. Previously published crop water use factors are used to calculate agricultural use. This is not the method that will be used for the groundwater flow model which will be based on crop water demand and evapotranspiration estimates.
7. Water use for Seascape Golf Course is reduced from the estimate documented in Johnson et al (2004) to reflect increased efficiency, but consumptive use remains the same.

Table 3 shows updated estimates for consumptive use by non-agencies for non-agricultural use in the Purisima and Aromas areas. These estimates are lower than what was used in 2012 for the water balance based primarily on Johnson *et al.*, 2004.

Although these values represent current use, they are used in estimating the cumulative consumptive use deficit as historical consumptive use is likely similar because lower outdoor efficiency would be associated with a higher water use factor.

[2] The number of building footprints is higher than the number of parcels for Aromas reflecting multiple buildings on some parcels. The number of parcels is higher than the number of building footprints in the Purisima, possibly because some buildings are obscured by canopy.

Table 3. Updated Estimates for Consumptive Use by Non-Agencies for Non-Agricultural Use

	Pumping (afy)	Septic Percentage	Overall Return Flow Percentage	Consumptive Use (afy)
Purisima Area				
6 Small Water Systems	185	49%	31%	127
Residential Parcels	742	82%	47%	392
Seascape Golf	206		10%	186
Total	***1,133***		***38%***	***705***
Aromas Area				
2 Small Water Systems	13	100%	56%	6
Building Footprints	190	99.6%	55%	85
Total	***203***		***55%***	***91***

Table 4 shows the updated estimates of consumptive use by agriculture in the Purisima and Aromas areas. These estimates are higher than what was used in 2012 for the water balance based on Johnson *et al.*, 2004. It should be noted however that over 1,000 acre-feet per year of the estimated agricultural consumptive use in the Aromas occurs southeast of the District's Service Area 4 where the District no longer pumps. This is also near the boundary of the Aromas water balance area and since the Aromas Red Sands aquifer is extensive outside of the boundary, it is likely recharge from outside the area supplies a good portion of this agricultural pumping. The groundwater flow model can be used to evaluate the specific effect of this pumping, but for the water balance estimates only half of the agricultural pumping near the boundary to account for likely recharge from outside of the boundary. Approximately 645 acre-feet per year agricultural consumptive use is assumed for the water balance estimates of the Aromas area.

The agricultural land use in the Aromas area has been fairly consistent so these estimates of agricultural consumptive use are used to estimate the cumulative consumptive use deficit.

Table 4. Updated Estimates for Agricultural Consumptive Use

Crops	Crop Factor Range	Source	Purisima Consumptive Use (afy)	Aromas Consumptive Use (afy)
Bamboo, Apple Orchard, Vineyards	0.23-0.43	CWD data for 2011-2012[1]	72	16
Vegetable Row Crop, Other Ag.	1.7	JM Montgomery (1992)	123	296
Pasture, Strawberries	2	JM Montgomery (1992) Cahn *et al.* survey (2010)	138	432
Nurseries/Flowers /Tropical Plants	3	JM Montgomery (1992)	34	415
Total			***367***	***1,159***[2]

[1] HydroMetrics WRI and Kennedy/Jenks, 2014
[2] 645 afy assumed for water balance calculation to approximate recharge south outside of water balance area.

UPDATED CUMULATIVE CONSUMPTIVE USE DEFICIT AND PRE-RECOVERY CONSUMPTIVE USE GOAL

The changes to the consumptive use estimates result in changes to the calculation of the consumptive use deficit used to estimate pre-recovery goals for consumptive use and pumping. As discussed above, the non-District consumptive use estimates presented above are used as constant values to calculate the consumptive use deficit. The District's consumptive use is estimated from Purisima and Aromas pumping through Water Year 2015 based on the return flow percentages shown in Table 2. The basinwide pre-recovery consumptive use goal is calculated based on eliminating the cumulative consumptive use deficit in 20 years.

Table 5. Cumulative Consumptive Use Deficit and Basinwide Pre-Recovery Consumptive Use Goals

	Purisima	Aromas	Total
Available Basinwide Consumptive Use for 1984-2014 Recharge (afy)	4,274	1,607	5,881
Non-SqCWD Consumptive Use (afy)	1,643	951	2,594
Remaining Available Consumptive Use for Comparison to SqCWD Historical Use[1] to Calculate Cumulative Deficit (afy)	2,631	656	3,287
Cumulative Basinwide Consumptive Use Deficit Based on SqCWD Pumping through WY 2015 (af)[2]	3,551	24,933	28,483
Annual Reduction in Available Basinwide Consumptive Use to Recover in 20 Years (afy)	178	1,247	1,424
Basinwide Consumptive Use Goal to Recover in 20 Years (afy)	4,096	360	4,457

[1] SqCWD annual consumptive use is estimated from pumping using return flow percentages of 12.5% in Purisima area and 24.4% in Aromas area as shown in Table 2.

[2] Acre-feet. This is calculated as the total of annual differences between SqCWD consumptive use and remaining consumptive use starting the first water year remaining consumptive use is exceeded through Water Year 2015

In the groundwater flow model, recovery will not be assessed based on eliminating the cumulative deficit but by comparing simulated groundwater levels to protective elevations.

PUMPING GOALS BASED ON DECREASED RECHARGE AND ASSUMPTIONS ABOUT NON-DISTRICT CONSUMPTIVE USE

To evaluate the pumping goals based on decreased recharge and assumptions about non-district consumptive use, there are two approaches shown in Table 6 that could be used for this analysis:

Approach 1: District plans pumping goals and yields based on eliminating 100% of cumulative deficit and preventing future overdraft

In the past the District has calculated its pre-recovery pumping goal and post-recovery pumping yield based on the assumption that non-District consumptive use would remain constant and that the District would assume 100% of pumping reductions and/or supplemental supply to recover the basin and maintain recovery. Table 6 shows the calculation of these pumping goals based on this assumption. Note that the calculation shows recovery in the Aromas area cannot be achieved just by eliminating District pumping in the area alone. In contrast, current consumptive use in the Purisima is below the pre-recovery goal for that area so this shows that the District can actually increase its pumping in the Purisima if non-District consumptive use remains constant. The combined Purisima and Aromas pre-recovery pumping goal may facilitate Aromas recovery with a transfer of water from the Purisima to other users in the Aromas.

Approach 2: District plans pumping goals and yields to reduce cumulative deficit and prevent future overdraft based on maintaining its proportion of consumptive use

Table 6 also shows the pumping goals assuming that the District's percentage share of consumptive use will remain constant. This second assumption would require non-District pumpers to proportionally reduce consumptive use to recover the basin. District pumping goals are calculated from consumptive use goals based on the return flow percentages in Table 2.

Table 6. Pre-Recovery Goal and Post-Recovery Yields for District Based on Different Assumptions for Non-District Use

	Purisima	**Aromas**	**Total**
Basinwide Pre-Recovery Consumptive Use Goal (afy)	4,096	360	4,457
Basinwide Post-Recovery Consumptive Use Yield (afy)	4,274	1,607	5,881
Return Flow Percentage	12.5%	24.4%	16.9%
Approach 1: Based on Eliminating 100% of Cumulative Deficit and Preventing Future Overdraft			
Non-SqCWD Consumptive Use (afy)	1,643	951	2,594
SqCWD Pre-Recovery Consumptive Use Goal (afy)	2,453	-591	1,863
SqCWD Pre-Recovery Pumping Goal (afy)	***2,800***	***-780***	***2,020***
SqCWD Post-Recovery Consumptive Use (afy)	2,631	656	3,287
SqCWD Post-Recovery Pumping Yield (afy)	***3,010***	***870***	***3,880***
Approach 2: Based on Maintaining Proportion of Consumptive Use			
SqCWD Consumptive Use (afy)	2,297	1,175	3,472
Total Consumptive Use (afy)	3,940	2,126	6,066
SqCWD Share of Consumptive Use	58.3%	55.3%	57.2%
SqCWD Pre-Recovery Consumptive Use Goal(afy)	2,388	199	2,587
SqCWD Pre-Recovery Pumping Goal (afy)	***2,730***	***260***	***2,990***
SqCWD Post-Recovery Consumptive Use (afy)	2,492	888	3,380
SqCWD Post-Recovery Pumping Yield (afy)	***2,850***	***1,170***	***4,020***

REDUCED RECHARGE BASED ON CLIMATE CHANGE SCENARIOS

In addition to reduced long-term recharge estimated based on recent low rainfall that led to the pumping goals in Table 6, changes to recharge from rainfall could also occur due to climate change. We have identified two separate mechanisms for climate change that both could affect rainfall from recharge. The first mechanism relates to changes in temperature and total precipitation. The second mechanism relates to changes in temporal precipitation patterns.

The USGS has estimated effects of the first mechanism on recharge based on downscaling of climate change models to a 270 meter grid for California (Flint *et al*., 2013). The datasets for the historical 1981-2010 simulation and 18 future climate changes scenarios for 2010-2039 were downloaded (Flint *et al*., 2014) and mapped to the Purisima and Aromas water balance areas.

The 1981-2010 historical simulation results by the USGS in overall higher recharge than the PRMS simulation used in the water balance. The 1981-2010 historical simulation results show average recharge from rainfall of 5.5 and 7.7 inches per year for the Purisima and Aromas areas, respectively, representing 16% and 30% of rainfall. These percentages for amount of rainfall that becomes recharge are higher than what is typical in California. In comparison, the PRMS simulation calibrated for 1984-2009 estimated recharge being 7% and 22% of rainfall in the Purisima and Aromas areas, respectively. Therefore, in using the estimated recharge change in future scenarios from the 1981-2010 simulation we recognize there may be issues with the magnitude of the recharge estimates. For the groundwater flow model being developed, we are currently scoped to use downscaled climate data provided by the USGS that will be calibrated to basin conditions. Results from the groundwater flow model should represent a more realistic baseline recharge.

Because of the identified magnitude issue in the USGS recharge estimates described above, we summarize the percentage change in recharge for each of the 2010-2039 future climate change simulations against the 1981-2010 historical simulation to evaluate possible changes to recharge in the water balance area for the Purisima and Aromas. A majority of the climate change simulations show an increase in recharge for the water balance area (Figure 2). However, using the simulation representing the 70th percentile recharge sorted from high to low would be consistent with the level 70th percentile protective ocean outflow used in the water balance. The 70th percentile climate change simulation is the

Fgoals_rcp85 simulation which predicts a recharge decrease of 6% for the combined Purisima and Aromas water balance area.

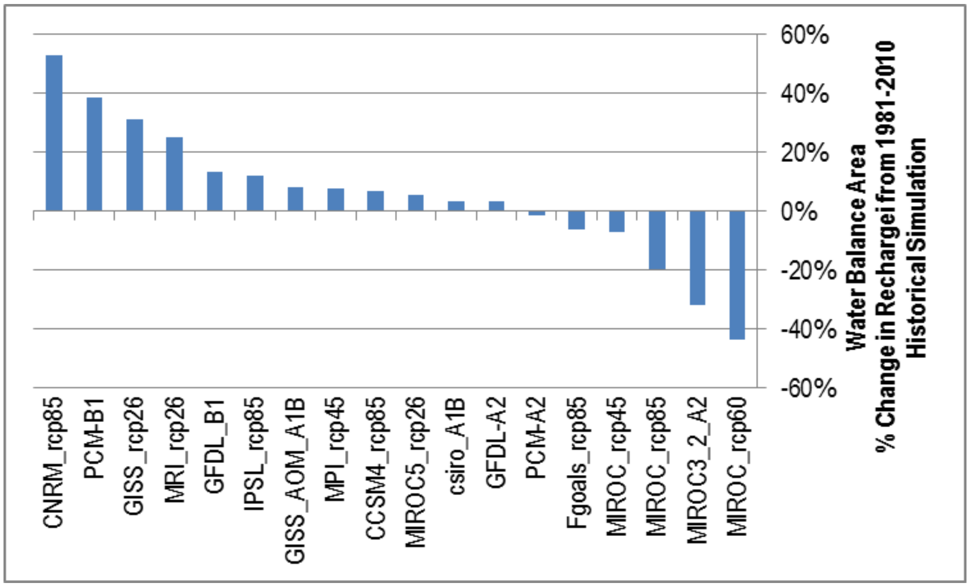

Figure 2. Change in Recharge for Climate Change Scenarios (Flint et al., 2014) for Purisima and Aromas Combined Water Balance Area

Dr. Bruce Daniels, the District Board President, evaluated the second mechanism, changes in temporal rainfall patterns, for his doctoral dissertation. The dissertation identified changes in rainfall pattern trends over the sub-monthly timescale and tested the continuation of those trends into the future with the daily PRMS recharge model for the Soquel-Aptos area. These trends include an increase in storm duration, decrease in storm intensity, and an increase in time between storms. The model results continuing these trends would result in an approximate decrease in recharge of 7% for the model area (Daniels, 2014), which encompasses the combined Purisima and Aromas water balance area used for the pumping goal estimates in this memorandum.

Although these two climate change mechanisms are separate and would both have an effect on future recharge, the combined effect on future recharge has not been modeled. It is unclear how the two mechanisms would interact in the hydrologic system. It does seem likely that the second mechanism based on rainfall pattern trends would decrease recharge greater than the 6% decrease in recharge based on the 70th percentile of decreases from temperature and precipitation changes alone. Adding the two decrease percentages together provides an estimate of the upper limit for the combined decrease – approximately 13%.

Figure 3 shows the sensitivity of the combined pre-recovery pumping goal and post-recovery pumping yield to decreases in recharge. Table 7 shows the pre-recovery pumping goals and post-recovery pumping yields associated with recharge decreases estimated for each of the two climate change mechanisms and an estimated upper limit on the combined effects.

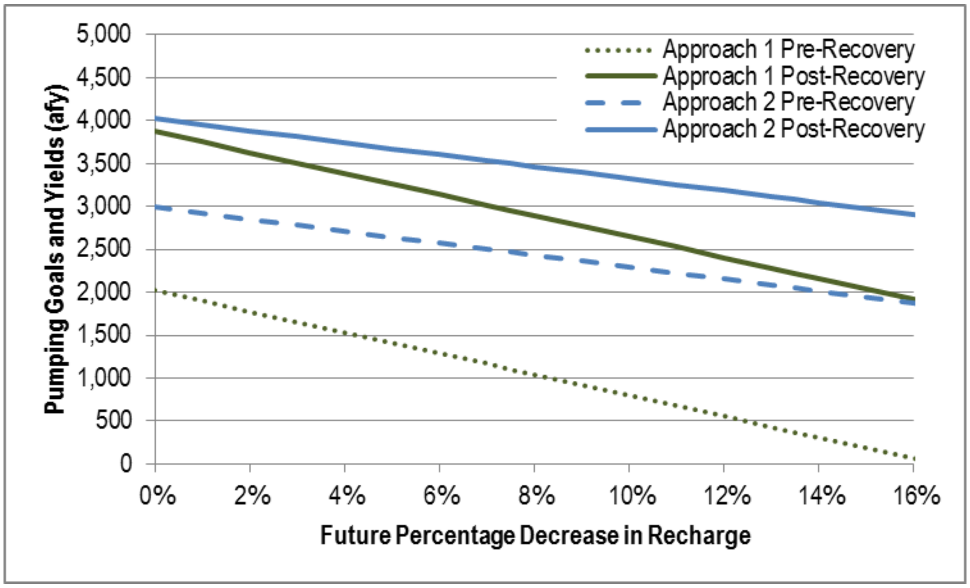

Figure 3. Sensitivity of Pre-Recovery Pumping Goals and Post-Recovery Pumping Yields to Future Decreases in Recharge

Table 7. Pre-Recovery Pumping Goals and Post-Recovery Pumping Yields for Recharge Decreases Estimated for Climate Change Mechanisms

Percentage Decrease	70th Percentile Decrease Based on Temperature and Total Precipitation Changes 6%	Rainfall Monthly Trends 7%	Possible Upper Limit of Combined Effects 13%
Approach 1: Based on Eliminating 100% of Cumulative Deficit and Preventing Future Overdraft			
SqCWD Pre-Recovery Pumping Goal (afy)	1,360	1,250	600
SqCWD Post-Recovery Pumping Yield (afy)	3,220	3,110	2,450
Approach 2: Based on Maintaining Proportion of Consumptive Use			
SqCWD Pre-Recovery Pumping Goal (afy)	2,620	2,560	2,180
SqCWD Post-Recovery Pumping Yield (afy)	3,650	3,590	3,210

EFFECTS ON PROTECTIVE OUTFLOWS OF SEA LEVEL RISE

The effects of sea level rise on outflows needed to protect against seawater intrusion are not included in this evaluation. The effects on the Soquel-Aptos basin would require more substantial modeling than has already been done. The groundwater modeling scope includes integration of the seawater interface code SWI2 in fiscal year 2016-17 that will allow for this type of evaluation.

However, literature indicates that the long-term effect of sea level rise on the long-term location of the saltwater interface may be relatively minor. Chang *et al.* (2011) concluded that there would be no change caused by sea level rise in the long-term location of the saltwater interface in confined aquifers (such as the aquifers in the Purisima). Chang *et al.* did conclude however, that sea level rise would cause long-term intrusion in unconfined aquifers (conditions more likely to occur in the Aromas). In modeling sea-level rise effects on groundwater in the Seaside Basin (Monterey County), Loaiciga *et al.* (2012) concluded that sea level rise had a minor effect relative to groundwater extractions.

SUMMARY

In order to facilitate interim planning for supplemental supply with the Community Water Plan and water resource planning with the Urban Water Management Plan, this memorandum updates estimates for District pre-recovery pumping goals and post-recovery pumping yields based on changes to consumptive use estimates and historical recharge. The memorandum also shows sensitivity of the pre-recovery pumping goals and post-recovery pumping yields to possible decreases in recharge resulting from climate change. The District is funding development of a groundwater model which will be the planning tool that replaces the interim estimates included in this memorandum. The model will also be the appropriate tool for Groundwater Sustainability Agency planning and management.

At the October 20, 2015 meeting, the Board set the interim pre-recovery pumping goal for the District at 2,300 acre-feet per year and the interim post-recovery pumping yield for the District at 3,300 acre-feet per year. This is consistent with estimates based on 11% reduction in recharge due to climate change. 11% was selected based on adding 5% reduction from the additional effect due to monthly rainfall trends to the 6% reduction representing the 70th percentile decrease based on temperature and total precipitation changes. The Board chose to add 5% reduction from monthly rainfall trends to be consistent with 70th percentile estimate for temperature and total precipitation changes as 5% is approximately 70% of the reduced recharge effect estimated by the Daniels study.

The interim values set by the Board will inform the District's supplemental supply strategy, Community Water Plan, and the Urban Water Management Plan while the groundwater flow model is being developed.

REFERENCES

Cahn, M., B. Farrara, T. Hartz, T. Bottoms, and M. Bolda. 2011. Strawberry water use on the Central Coast, *Monterey County Crop Notes*, http://cemonterey.ucanr.edu/files/171007.pdfm, June/August.

Chambers Group. 2011. *Beltz Well No. 12 Draft Environmental Impact Report*, prepared for City of Santa Cruz Water Department, August.

Chang, S.W., T.P. Clement, M.J. Simpson, and K.K. Lee. 2011. Does sea-level rise have an impact on saltwater intrusion, *Advances in Water* Resources 34:1283-1291.

Daniels, B.K. 2014. *Hydrologic response to climate change in California: Observational and Modeling Studies*. Dissertation for Ph.D. in Earth Sciences, University of California, Santa Cruz, December.

Flint, L. E., A. L. Flint, J. H. Thorne, and R. Boynton. 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. *Ecological Processes* 2:25.

Flint, L. E., A. L. Flint, J. H. Thorne, and R. Boynton. 2014. *2014 California BCM (Basin Characterization Model) Downscaled Climate and Hydrology - 30-year Summaries*, California Climate Commons, http://climate.calcommons.org/dataset/2014-CA-BCM, downloaded September 2015.

HydroMetrics LLC. 2009b. *Groundwater levels to protect against seawater intrusion and store freshwater offshore,* prepared for Soquel Creek Water District, January.

HydroMetrics WRI. 2011. *Estimation of deep groundwater recharge using a precipitiation-runoff watershed model Soquel-Aptos, California*. Prepared for Soquel Creek Water District, Central Water District, and the City of Santa Cruz. September.

———. 2012. *Revised Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin,* letter to Laura Brown, Soquel Creek Water District, March 30.

———. 2014. *Peer Review of Sustainable Yield Estimates – Refining Estimates with the Groundwater Model and Additional Studies,* Technical Memorandum to Kim Adamson and Taj Dufour, Soquel Creek Water District, from C. Tana and D. Williams, October 8.

———. 2015a. *Water Shortage Stage for Water Year 2015,* Technical Memorandum to Kim Adamson, Soquel Creek Water District, from C. Tana, April 15.

———. 2015b. *Soquel-Aptos Area Groundwater Management Annual Report and Review, Water Year 2014*, prepared for Soquel-Aptos Groundwater Management Committee, May.

———. 2015c. *Updated Sustainable Yield Estimates and Pumping Goals to Achieve Recovery*, Technical Memorandum to Ron Duncan, Soquel Creek Water District, from C. Tana, July 15.

HydroMetrics WRI and Kennedy/Jenks Consultants. 2014. *Aromas and Purisima Basin Management Technical Study,* prepared for Central Water District, March.

Johnson, N.M., D. Williams, E.B. Yates, and G. Thrupp. 2004. *Groundwater assessment of alternative conjunctive use scenarios- draft technical memorandum 2: hydrogeologic conceptual model*, prepared for Soquel Creek Water District, September.

J.M. Montgomery, 1992, *Re: Soquel Creek Water District Water Use Factors,* technical memorandum by K.E. Johnson to Stephanie Strelow, Denise Duffy & Associates, April 6.

Loaicga, H.A., T.J. Pingel, and E.S. Garcia. 2012. Sea Water Intrusion by Se-Level Rise: Scenarios for the 21st Century, *Ground Water*, 50:37-47.

Soquel Creek Water District and Central Water District. 2007. *Groundwater management plan -2007 Soquel-Aptos area,* Santa Cruz County, California, April.

Soquel Creek Water District. 2012. *2012 Integrated Resources Plan Update*, September 18.

Todd Groundwater. 2014. *Peer Review of Technical Water Resources Studies Prepared for Soquel Creek Water District—Summary of Yield Estimates*, technical memorandum to Kim Adamson and Taj Dufour, Soquel Creek Water District, from G. Yates, September 8.