Borrego Springs Watermaster
Technical Advisory Committee Meeting
August 29, 2023
AGENDA ITEM III

To: Technical Advisory Committee (TAC)

From: Andy Malone, PG (West Yost), Lead Technical Consultant

Date: August 22, 2023

Subject: Task 2 to Redetermine the Sustainable Yield by 2025 – *Update Water-Use Factors in the Farm Process*

Background

At its meeting on February 9, 2023, the Watermaster Board, in consideration of a TAC-majority recommendation, approved a revised scope of work and budget for water year (WY) 2023 and 2024 to update the Borrego Valley Hydrologic Model (BVHM) and Redetermine the Sustainable Yield by 2025. Exhibit 1 (attached) provides a detailed description, schedule, and cost estimate for each approved task. Table 1 below summarizes the Board-approved revised scope of work.

Table 1. Scope of Work to Redetermine the Sustainable Yield by 2025
WY 2023 and WY 2024

Task No.	Task	Cost Estimate
1	Compare FMP-estimated Pumping to Actual Pumping for WY 2022	$20,222
2	Update Water-Use Factors in the FMP	$39,196
3	Correct Errors Identified in 2021 BVHM	$22,577
4	Perform Model Recalibration	$128,510
5	Determine the Sustainable Yield (including documentation)	$137,699
	Total Cost for All Tasks	**$348,204**

Tasks 1 and 2 involve the Farm Process (FMP) in the BVHM, which is used to estimate groundwater pumping at historically unmetered wells in the Borrego Springs Subbasin (Basin). Metered pumping data became available in WY 2021 due to the Watermaster's well metering program, which resulted in nearly all wells in the Basin being metered.[1] In Task 1, the newly available metered groundwater pumping data in WYs 2021 and 2022 (*i.e.,* Actual Pumping) was compared to the FMP-estimated

[1] Pumping at a few unmetered wells are still estimated by Watermaster staff.

groundwater pumping to understand the ability of the FMP to estimate pumping. The result of this comparison was that the FMP underestimated Actual Pumping by 4,456 acre-feet (af) in WY 2021 and 3,224 af in WY 2022 (a 42% and 35% difference, respectively). Based on the results of this comparison, the TAC concluded that the difference between FMP-estimated pumping and Actual Pumping was significant and likely indicated that the BVHM is not sufficiently calibrated. The TAC recommended that *Task 2 – Update Water-Use Factors in the FMP* be performed to improve the ability of the FMP to estimate groundwater pumping.

<u>Water-Use Factors used in the FMP:</u>

The FMP estimates the irrigation demand for different land uses and crop types. The irrigation demand is first satisfied with precipitation and shallow groundwater from root uptake (if available). The remaining irrigation demand is met with groundwater pumping, which is estimated by the FMP as:

$$GW = \frac{ET_0 \times KC \times Area}{OFE} - P - RU \qquad \text{(Equation 1)}$$

where,

GW is the volume of groundwater pumping to satisfy the irrigation demand

ET_o is the reference evapotranspiration (ET)

KC is the crop coefficient—the ratio of the actual ET for a specific crop to the ET_o. KC is used to estimate how much water a specific crop needs to grow. Higher KC values result in higher estimates of groundwater pumping.

Area is the area of the farmland cultivating the crop with the specified KC.

OFE is the On-Farm Efficiency—the ratio of the actual ET to the applied irrigation. OFE is sometime referred to as "irrigation efficiency." OFE accounts for water losses from the irrigation method, such as runoff and infiltration of irrigation past the root zone (return flows). OFE typically ranges between 0 to 1. Low OFE represents inefficient irrigation methods with high water losses and high OFE represents efficient irrigation methods with low water losses. Lower OFE values result in higher estimates of groundwater pumping.

P is precipitation available to meet the actual ET

RU is root uptake of shallow groundwater available to meet the actual ET

The water-use factors KC and OFE currently used in the FMP were initially estimated based on various agricultural water-use studies (Allen et al., 1998[2]; Snyder et al., 1987a[3], Snyder et al., 1987b[4]) and adjusted during model calibration by the United States Geological Survey (USGS) during the initial

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[2] Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. *Crop evapotranspiration—Guidelines for computing crop water requirements*: Food and Agriculture Organization of the United Nations, Irrigation and Drainage Paper 56. https://www.fao.org/3/X0490E/X0490E00.htm.

[3] Snyder, R.L., Lamina, B.J., Shaw, D.A., and Pruitt, W.O. 1987a. *Using reference evapotranspiration (ETo) and crop coefficients to estimate crop evapotranspiration (ETc) for agronomic crops, grasses, and vegetable crops*. https://calisphere.org/item/e4408893-9141-4766-89f2-c25c667071a7/.

[4] Snyder, R.L., Lamina, B.J., Shaw, D.A., and Pruitt, W.O. 1987b. Using reference evapotranspiration (ETo) and crop coefficients to estimate crop evapotranspiration (ETc) for trees and vines. https://calisphere.org/item/fbc9dc78-de6e-4d99-a561-0028370f8107/.

development of the BVHM. The KC and OFE values currently used in the FMP of BVHM were reviewed and are summarized below.

Table 1 compares the KC values used in the FMP versus other published sources. Column (a) shows the initial KC values that were assigned to the FMP. These values were adjusted (scaled) during model calibration by using variable monthly scaling factors. Column (b) shows the range of the final scaled KC values used in the current FMP, which are highest during winter months. The remaining columns show KC values used in other studies. Column (c) lists the "Plant Factors" (i.e., KC values) used to establish the Baseline Pumping Allocation (BPA)[5] in the Basin. Column (d) shows the KC values used in a recent Coachella Valley study.[6] Column (e) shows the KC values from other sources.[7]

Table 1. Comparison of KC Values used in the FMP versus Other Sources

Crop Type	KC Values by Source				
	Initial KC Values	Scaled KC Used in FMP	Plant Factors used for BPA	KC used in Coachella Valley	KC from Other Sources
	(a)	*(b)*	*(c)*	*(d)*	*(e)*
Citrus	0.65	0.55 – 0.70	0.65	1	-
Dates	0.79 – 0.95	0.71 - 0.88	0.60	0.95	0.80 - 1.0
Golf courses	0.95	0.81 – 1.02	0.70	0.80	-
Nursery	0.95	0.81 – 1.02	0.60	1	0.70 – 1.0
Palm	0.96	0.82 – 1.04	0.50	-	-
Potatoes	0.1 – 1.15	0.09 – 1.04	-	0 – 1.1	0.5 – 1.15
Row Crops	0.70 – 0.90	0.60 – 0.97	-	0 – 0.91	0.3 – 1.15
Semiagricultural	0.50	0.43 – 0.54	-	-	-
Grapes	0.35 – 0.81	0.35 – 0.73	-	0.5 – 1.04	0.45 – 0.90

Table 2 compares the OFE values used in the FMP versus other published sources. Column (a) shows the initial OFE values that were assigned at the start of the BVHM simulation (WY 1930). The initial OFE values were adjusted (scaled) by using scaling factors to account for improvements in irrigation efficiencies over time. Column (b) shows the scaled OFE values used at the end of the BVHM simulation (WY 2009 through WY 2022). Column (c) shows the Irrigation Efficiencies (i.e., OFE values) used to

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[5] Dudek. 2019. Attachment B. Baseline Pumping Allocation Methodology.

[6] Todd Groundwater et al. 2021. *2022 Indio Subbasin Water Management Plan Update*. Prepared for the Indio Subbasin GSAs. http://www.indiosubbasinsgma.org/wp-content/uploads/2022/02/Indio-SGMA-AlternativePlan-V1_2-FINAL-Adopted-Dec-2021.pdf

[7] University of California Cooperative Extension and California DWR. 2018. *The Landscape Coefficient Method and Water Use Classification of Landscape Species IV (WULCOS IV).* https://ccuh.ucdavis.edu/wucols-dbv. Snyder, R.L, Lanini, B.J., Shaw, D.A, and Pruitt, W.O. 1987. *Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Trees and Vines.* https://calisphere.org/item/fbc9dc78-de6e-4d99-a561-0028370f8107/. Snyder, R.L, Lanini, B.J., Shaw, D.A, and Pruitt, W.O. 1987. *Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Agronomic Crops, Grasses, and Vegetable Crops.* https://wwwcimis.water.ca.gov/Content/PDF/21427-KcAgronomicGrassandVeg.pdf. Snyder, R.L, Shaw, D.A, and Pruitt, W.O. 1995. *Determining Daily Reference Evapotranspiration (ETo).* https://wwwcimis.water.ca.gov/Content/PDF/21426.pdf. Allen, R.G, Pereira, L.S., Raes, D., and Smith, M. 1998. *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements.* https://www.fao.org/3/X0490E/x0490e00.htm#Contents. British Columbia Ministry of Agriculture, Food and Fisheries. 2001. *Crop Coefficients for Use in Irrigation Scheduling* http://ruralenergy.wisc.edu/PDF/CropCoefficientsForIrrigationScheduling-BC.pdf.

establish the BPA.[5] Column (d) shows the Irrigation Efficiency values used in a Coachella Valley study.[6] Column (e) shows the Irrigation Efficiency values from other sources.[8]

Table 2. Comparison of OFE Values used in the FMP versus Other Sources

<table>
<tr><th rowspan="3">Crop Type</th><th colspan="5">OFE Values by Source</th></tr>
<tr><th>Initial OFE in WY 1930</th><th>Scaled OFE in WY 2022</th><th>Irrigation Efficiencies for BPA[1]</th><th>Irrigation Efficiency in Coachella Valley</th><th>Irrigation Efficiencies From Other Sources</th></tr>
<tr><th>(a)</th><th>(b)</th><th>(c)</th><th>(d)</th><th>(e)</th></tr>
<tr><td>Citrus</td><td>0.78</td><td>0.98</td><td>0.80</td><td rowspan="9">0.70</td><td rowspan="9">Micro sprinkler[2] in Borrego: 0.78
Broadcast sprinkler[3] in Borrego: 0.86
Sprinkler method: 0.60 – 0.90
Flood and furrow method: 0.60
Center pivot: 0.70 – 0.90
Drip irrigation (surface and subsurface): 0.77 – 0.97</td></tr>
<tr><td>Dates</td><td>0.79</td><td>0.99</td><td>0.80</td></tr>
<tr><td>Golf courses</td><td>0.75</td><td>0.94</td><td>0.70</td></tr>
<tr><td>Nursery</td><td>0.79</td><td>0.99</td><td>0.80</td></tr>
<tr><td>Palm</td><td>0.79</td><td>0.99</td><td>0.80</td></tr>
<tr><td>Potatoes</td><td>0.79</td><td>0.99</td><td>0.80</td></tr>
<tr><td>Row Crops</td><td>0.74</td><td>0.93</td><td>0.80</td></tr>
<tr><td>Semiagricultural</td><td>0.76</td><td>0.95</td><td>-</td></tr>
<tr><td>Grapes</td><td>0.77</td><td>0.96</td><td>0.80</td></tr>
<tr><td colspan="6">Notes:
1. Assumed 0.70 for rotor irrigation method and 0.80 for drip irrigation method.
2. Micro sprinklers are defined as a single sprinkler under the canopy of a tree and are typically used for the irrigation of citrus (Netto, 2001).
3. Broadcast sprinklers are defined as a “wide area broadcast type of water sprinkler”, commonly used at golf courses in Borrego Springs (Netto, 2001).</td></tr>
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Based on these comparisons, West Yost staff made the following observations and recommendations:

- **The KC scaling factors produce unrealistic seasonal crop demands**. The scaled KC values resulted in unrealistic seasonal changes in crop coefficients, where the greatest crop demands occur during winter months instead of during the growing season. The initial KC values are more realistic seasonal trends in crop demands and are typically more consistent with values used in other published studies. By using the initial KC values, the FMP should simulate more groundwater pumping because the crop demand would increase during most months, which should improve the ability of the FMP to match Actual Pumping during WY 2021 and WY 2022.
- **The OFE scaling factors simulate nearly 100% irrigation efficiencies, which is unrealistic**. The scaled OFE values in the FMP simulate nearly 100% irrigation efficiency by the end of the BVHM simulation (WY 2009 through WY 2022), which is not a valid assumption based on current irrigation practices in the Basin. The initial (unscaled) OFE values are more consistent with other published studies, especially the irrigation efficiencies used to establish the BPA,

[8] Netto, S.P. 2001. *Water Resources of Borrego Valley San Diego County.* California. Master’s Thesis, San Diego State University; Amasson, S., Almas, L., Girase, J.R., Kenny, N., Guerrero, B., Vimlesh, K., and Marek, T. 2011. *Economics of Irrigations Systems*. Accessed on August 17, 2023 on http://amarillo.tamu.edu/files/2011/10/Irrigation-Bulletin-FINAL-B6113.pdf; Sandoval-Solis, S., Orang, M., Snyder, R.L., Williams, K.E, and Rodriguez, J.M. 2013. *Spatial Analysis of Application Efficiencies in Irrigation for the State of California*. Accessed on August 17, 2023 on https://watermanagement.ucdavis.edu/research/application-efficiency.

which are specific to the Basin. By using the initial OFE values over the entire historical simulation period, the FMP will simulate more groundwater pumping because of the decrease in irrigation efficiency, which should improve the ability of the FMP to match Actual Pumping during WY 2021 and WY 2022. Additionally, lowering OFE values may result in increased irrigation return flows.

The TAC met on June 5, 2023 to review these results and recommendations described above for the approach to complete *Task 2 – Update Water-Use Factors in the FMP*. Following the meeting, TAC members submitted written comments and recommendations on the approach for completing Task 2. The TAC agreed with West Yost's recommended approach, and in addition, requested that West Yost investigate the ET_o values used in the FMP.

In summary, the TAC-recommended approach for performing Task 2 was to:

1. Reset the KC scaling factor to 1.
2. Reset the OFE scaling factor to a factor representative of current irrigation methods.
3. Compare ET_o values used in the FMP to other sources of ET_o.

Results and Conclusions

This section describes the results and conclusions that were derived from performing Task 2.

Resetting KC and OFE Scaling Factors

The scaling factors applied to the KC and OFE values were reset to 1 so that the *initial* (*i.e.* unscaled) values of KC and OFE (columns (a) on Tables 1 and 2, respectively) were used in the BVHM simulation.[9] The BVHM was then run through WY 2022 to generate new FMP-estimated pumping, which were then compared to (i) FMP-estimated pumping from the 2022 BVHM using *scaled* KC and OFE values and (ii) Actual Pumping for WYs 2021 and 2022. The results are shown in Tables 3 and 4 below.

Table 3 compares FMP-estimated pumping from the 2022 BVHM using the *scaled* and *initial* KC and OFE values for the entire BVHM simulation period for which groundwater pumping is simulated (WY 1946 through WY 2022). On average, FMP-estimated pumping from the 2022 BVHM using *initial* KC and OFE values is 2,581 acre-feet per year (afy) greater than FMP-estimated pumping from the 2022 BVHM using *scaled* KC and OFE values (a 26% difference).

[9] Additionally, ET_o and precipitation data from the BCM for WY 2021 and WY 2022 were used to replace the estimated ET_o and precipitation values previously used for WY 2021 and WY 2022 in the FMP. At the time of the extension of the 2021 BVHM, BCM data for WY 2021 was not yet available; instead, PRISM data were used to identify a historical month with similar climate, and the ET_o and precipitation BCM data of that historical month was used to extend the FMP through WY 2021. During the extension of the 2022 BVHM, the same ET_o and precipitation data used for WY 2021 in the 2021 BVHM were used for WY 2022 in the 2022 BVHM (as described in the scope of work). As of August 2023, ET_o and precipitation data BCM data were available. The BCM data were used in 2022 BVHM for WYs 2021 and 2022 and resulted in a slight increase in FMP-estimated pumping (8,428 af and 7,649 af in WYs 2021 and 2022 respectively, compared to 8,401 af and 7,639 af in WYs 2021 and 2022, respectively, using the estimated BCM data). Data available at: https://www.sciencebase.gov/catalog/item/5f29c62d82cef313ed9edb39.

Table 3. Comparison of FMP-Estimated Pumping using Scaled and Initial KC and OFE Values
WY 1946 - 2022

WY	FMP-Estimated Pumping (af)			
	Using *Scaled* KC and OFE Values	Using *Initial* KC and OFE Values	Difference	% Difference
	(a)	*(b)*	*(c) = (b) - (a)*	*(d) = (c) / ([(a)+(b)]/2)*
1946	846	931	86	10%
1947	1,339	1,489	150	11%
1948	2,748	3,041	293	10%
1949	3,540	3,952	412	11%
1950	4,325	5,258	933	19%
1951	5,231	6,415	1,184	20%
1952	6,679	8,245	1,566	21%
1953	8,731	10,670	1,939	20%
1954	9,243	11,327	2,083	20%
1955	8,978	11,055	2,077	21%
1956	10,485	12,740	2,255	19%
1957	10,688	13,040	2,351	20%
1958	9,750	11,998	2,247	21%
1959	10,458	12,765	2,307	20%
1960	9,385	12,086	2,702	25%
1961	9,994	12,724	2,730	24%
1962	9,795	12,492	2,697	24%
1963	9,134	11,735	2,602	25%
1964	8,591	10,933	2,342	24%
1965	8,578	10,972	2,394	24%
1966	4,716	6,002	1,286	24%
1967	4,554	5,796	1,242	24%
1968	5,026	6,405	1,379	24%
1969	4,579	5,865	1,286	25%
1970	4,502	5,726	1,224	24%
1971	4,382	5,565	1,183	24%
1972	4,582	5,795	1,213	23%
1973	3,891	4,966	1,075	24%
1974	4,251	5,422	1,170	24%
1975	4,097	5,222	1,125	24%
1976	4,161	5,297	1,136	24%
1977	4,384	5,608	1,225	25%
1978	4,561	5,860	1,299	25%
1979	4,617	6,003	1,386	26%
1980	5,892	7,609	1,718	25%
1981	6,673	8,483	1,810	24%
1982	6,237	7,978	1,741	24%
1983	4,622	6,084	1,462	27%
1984	6,671	8,480	1,809	24%
1985	6,324	8,096	1,773	25%
1986	6,129	7,863	1,734	25%
1987	6,761	8,578	1,817	24%
1988	6,645	8,512	1,867	25%
1989	7,057	8,952	1,895	24%
1990	7,162	9,232	2,069	25%
1991	6,465	8,435	1,970	26%
1992	6,380	8,349	1,969	27%
1993	8,433	11,035	2,602	27%
1994	10,389	13,438	3,049	26%
1995	11,648	15,157	3,509	26%
1996	13,653	17,566	3,913	25%
1997	11,571	15,032	3,461	26%
1998	10,169	13,342	3,174	27%
1999	11,480	14,808	3,328	25%
2000	12,314	16,326	4,012	28%
2001	11,669	15,552	3,883	29%
2002	13,029	17,179	4,150	27%
2003	11,956	15,903	3,947	28%
2004	12,804	16,992	4,187	28%
2005	11,100	15,031	3,931	30%
2006	13,988	18,562	4,574	28%
2007	15,331	20,202	4,871	27%
2008	14,074	18,732	4,658	28%
2009	14,568	19,240	4,672	28%
2010	14,310	19,459	5,148	30%
2011	13,948	18,894	4,947	30%
2012	12,919	17,689	4,771	31%
2013	13,953	19,045	5,092	31%
2014	14,964	20,219	5,256	30%
2015	13,538	18,383	4,845	30%
2016	13,141	17,847	4,706	30%
2017	11,474	15,959	4,484	33%
2018	12,656	17,372	4,716	31%
2019	9,072	12,648	3,577	33%
2020	7,466	10,410	2,944	33%
2021	8,428	11,625	3,197	32%
2022	7,649	10,551	2,902	32%
Total	**655,529**	**854,250**	**198,721**	**26%**
Minimum	**846**	**931**	**86**	**10%**
Maximum	**15,331**	**20,219**	**5,256**	**33%**
Average	**8,513**	**11,094**	**2,581**	**25%**

Table 4 compares Actual Pumping for WYs 2021 and 2022 versus the FMP-estimated pumping from the 2022 BVHM when using the *scaled* and *initial* KC and OFE values:

- Column (a) shows the Actual Pumping for WYs 2021 and 2022.
- Column (b) shows the FMP-estimated pumping when using the *scaled* KC and OFE values. The FMP-estimated pumping was significantly less than Actual Pumping for both WY 2021 and WY 2022.
- Column (c) shows the difference between FMP-estimated pumping when using the *scaled* KC and OFE values and Actual Pumping for WYs 2021 and 2022.
- Column (d) shows the percent difference between FMP-estimated pumping when using the *scaled* KC and OFE values and Actual Pumping for WYs 2021 and 2022.
- Column (e) shows the FMP-estimated pumping when using the *initial* KC and OFE values. FMP-estimated pumping was still less than the Actual Pumping, but significantly closer.
- Column (f) shows the difference between FMP-estimated pumping when using the *initial* KC and OFE values and Actual Pumping for WYs 2021 and 2022.
- Column (g) shows the percent difference between FMP-estimated pumping when using the *initial* KC and OFE values and Actual Pumping for WYs 2021 and 2022. For both WYs, the percent difference between FMP-estimated pumping and Actual Pumping is 10% or less, which is a significant improvement over the use of the *scaled* KC and OFE values.

Table 4. Comparison of Actual Pumping to FMP-Estimated Pumping

WY	Actual Pumping (af)	Using *Scaled* KC and OFE Values			Using *Initial* KC and OFE Values		
		FMP-Estimated Pumping (af)	Difference (af)	% Difference	FMP-Estimated Pumping (af)	Difference (af)	% Difference
	(a)	*(b)*	*(c) = (b) - (a)*	*(d) = (c)/ ([(a)+(b)]/2)*	*(e)*	*(f) = (e) - (a)*	*(g) = (f)/ ([(a)+(e)]/2)*
2021	12,857	8,428	-4,429	-42%	11,625	-1,232	-10%
2022	10,863	7,649	-3,214	-35%	10,551	-312	-3%

Conclusions: Based on the use of *initial* and *scaled* KC and OFE values in the 2022 BVHM:

- The *initial* values of KC and OFE are more realistic for current conditions and irrigation practices in the Basin for WY 2021 and WY 2022 compared to the *scaled* values.
- Using the *initial* KC and OFE values increased FMP-estimated pumping and improved the ability of the FMP to estimate Actual Pumping during WYs 2021 and 2022.
- The *initial* OFE values probably are not reflective of historical irrigation methods in the Basin because historical irrigation methods (e.g., flood and furrow irrigation) were likely less efficient compared to current irrigation methods.

Recommendations:

- The *initial* KC values should be used in *Task 4 – Perform Model Recalibration*. Adjustments to KC values during model recalibration, if any, should be constrained to a defensible range.
- The *initial* OFE values should be used in *Task 4 – Perform Model Recalibration* during recent years (e.g., WYs 2021 and 2022), but should be revised historically to reflect the evolution of irrigation methods used in the Basin since WY 1946. Adjustments to OFE values during model recalibration, if any, should be constrained to a defensible range.

Evaluation of ET_o

The ET_o values used in the FMP were evaluated and compared to other sources of ET_o to assess if the ET_o values used in the FMP are reasonable. The three sources that were compared are:

- **Basin Characterization Model** (BCM) – The FMP uses potential evapotranspiration (PET) data from the BCM as ET_o in the estimation of groundwater pumping (see Equation 1). The BCM is a regional model that estimates a water-balance using different climatic parameters, such as precipitation, PET, and temperature. The BCM estimates PET using a solar radiation model and the Priestly-Taylor equation,[10] which rely on solar radiation and air temperature data, seasonal atmospheric transmissivity, and site parameters such as slope, aspect, and shading.[11] The modeled PET data is then calibrated using measured PET from the California Irrigation Management Information System (CIMIS), which is used as ET_o data in the BCM. Monthly PET data from the BCM were assigned to each grid cell in the BVHM for WYs 1930 through 2022.[12] Total ET_O assigned to grid cells in the BVHM for WY 2022 is shown in Figure 1.

- **CIMIS Station #207 (CIMIS-207)**[13] – CIMIS-207 is a weather station operated by the DWR located in Borrego Springs. The weather data collected at this station is used to calculate ET_o using a modified version of the Penman-Monteith equation, known as the CIMIS Penman equation. The calculated ET_o values are available from January 2008 to June 2023. The location of CIMIS-207 in the Basin is shown in Figure 1.
- **OpenET**[14] – OpenET is an online database that provides ET_o data on a grid and field-scale. ET_o is modeled using publicly available weather data, CIMIS, and gridMET datasets. OpenET also uses satellite imagery of land use/crop cover to estimate crop demands based on crop type and estimated ET_o. Data from Open ET are available from January 2018 through March 2023.[15]

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[10] The Priestly-Taylor method calculates PET using the following factors: the Priestly-Taylor coefficient, the slope of the vapor pressure-temperature curve, net solar radiation, daily soil heat flux, the psychrometric constant, and the latent heat of vaporization.

[11] Flint, L.E., Flint, A.L, Thorne, J.H, and Boynton, R. 2013. *Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance*. Accessed at: https://ecologicalprocesses.springeropen.com/articles/10.1186/2192-1709-2-25 on August 3, 2023.

[12] Figure 1 plots actual PET data from the BCM, downloaded in August 2023. Using the actual BCM PET and precipitation data resulted in a 0.58-inch increase in total precipitation and a 1.35-inch increase in PET for WYs 2021 and 2022 compared to the estimated values (comparison for one grid cell in the BVHM). See Footnote #9 for more information.

[13] Data available at: https://cimis.water.ca.gov/WSNReportCriteria.aspx

[14] Data available at: https://explore.etdata.org/#14/33.2559/-116.3750

[15] LandIQ is another source of ET_o data, which are typically derived from local CIMIS stations. Since CIMIS station data were already included in this evaluation, LandIQ was not hired to estimate ET_o and this source was not evaluated herein.

Figure 1 is a map that shows the spatial distribution of total ET_o for WY 2022 used in the FMP. Also shown on this figure is the location of CIMIS-207 and the OpenET parcel located in the same area as CIMIS-207.

Figure 2 shows the comparison of monthly ET_o values from the BCM, CIMIS-207, and OpenET for the period 2008-2022. The main observations from Figure 2 are:

- The monthly ET_o estimates from BCM are similar to CIMIS-207 and OpenET, but are generally lower, particularly during the spring and summer months when ET_o from BCM is up to two inches less than ET_o from CIMIS-207 and OpenET.
- The ET_o estimates from BCM and CIMIS-207 more closely match during WY 2021 and WY 2022.

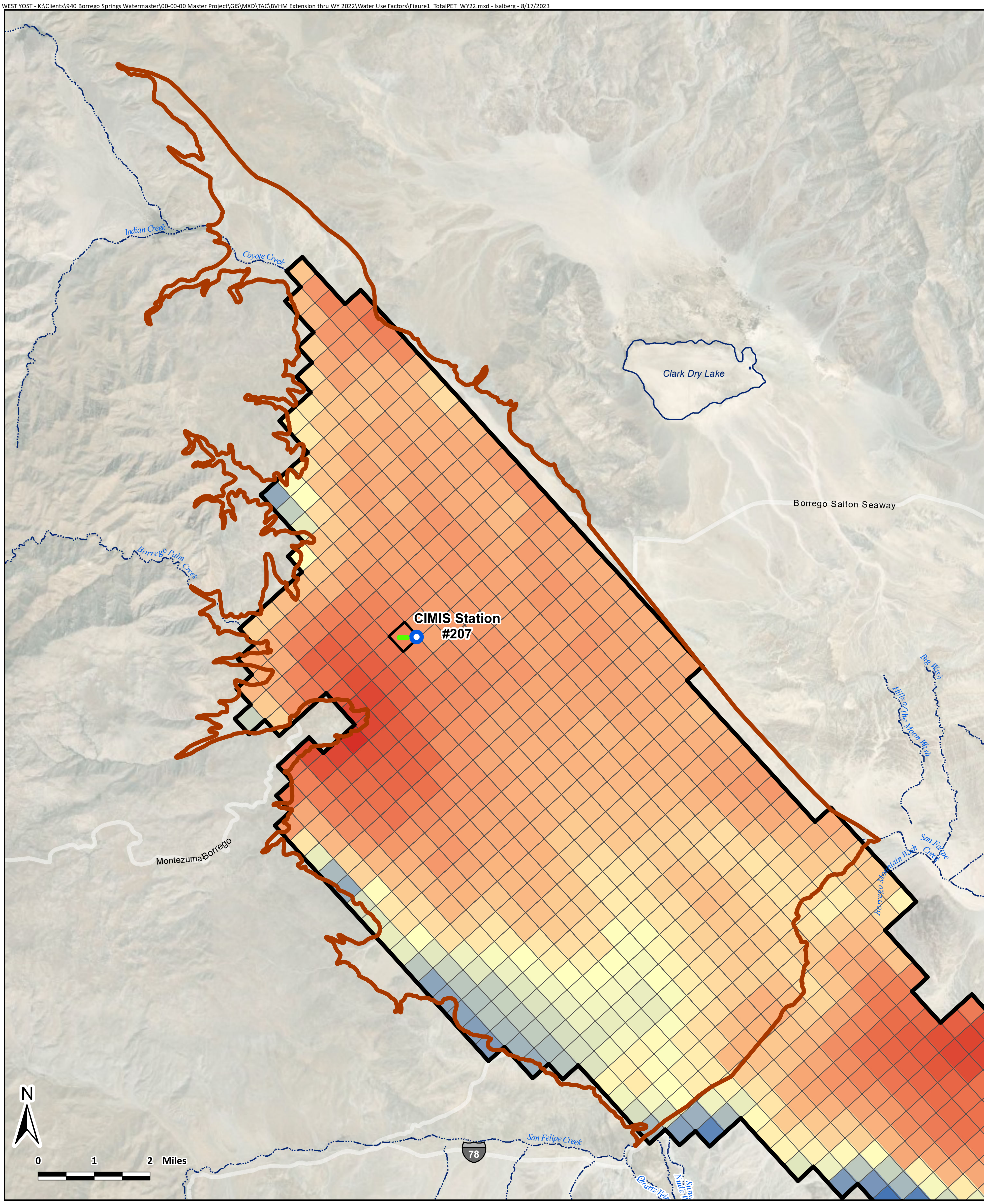
To assess the influence of ET_o on the FMP estimates of groundwater pumping, a sensitivity analysis was performed by scaling the BCM ET_o estimates to more closely match the historical CIMIS-207 estimates for ET_o and then running the BVHM to generate FMP estimates of groundwater pumping.

The factor to scale the BCM ET_o data was determined by computing the average difference between BCM and CIMIS-207 ET_o datasets for each month from January 2008 to September 2022 at the BVHM grid where CIMIS-207 is located. Table 5 lists the monthly scaling factors, which increase the BCM ET_o values for all months except January and December.

Table 5. Monthly Scaling Factors Applied to BCM ET_o Data

Month	Scaling Factor
January	0.95
February	1.21
March	1.28
April	1.23
May	1.21
June	1.18
July	1.08
August	1.07
September	1.06
October	1.09
November	1.05
December	0.94

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Water Use Factors\Figure1_TotalPET_WY22.mxd - lsalberg - 8/17/2023



Total PET per BVHM Grid Cell
WY 2022

63 inches
61 inches
59 inches

BVHM Features

Location of CIMIS Station in BVHM Grid
(Row 17, Column 24)

Active BVHM Grid Cell

ETo Sources

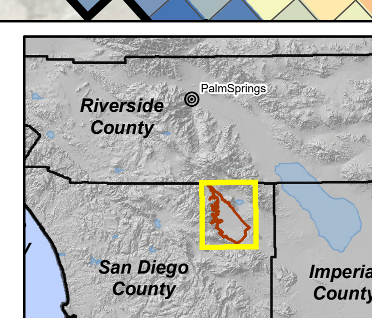
CIMIS Station #207

OpenET Parcel with Data

Other Features

Extent of BVHM

Borrego Springs Subbasin

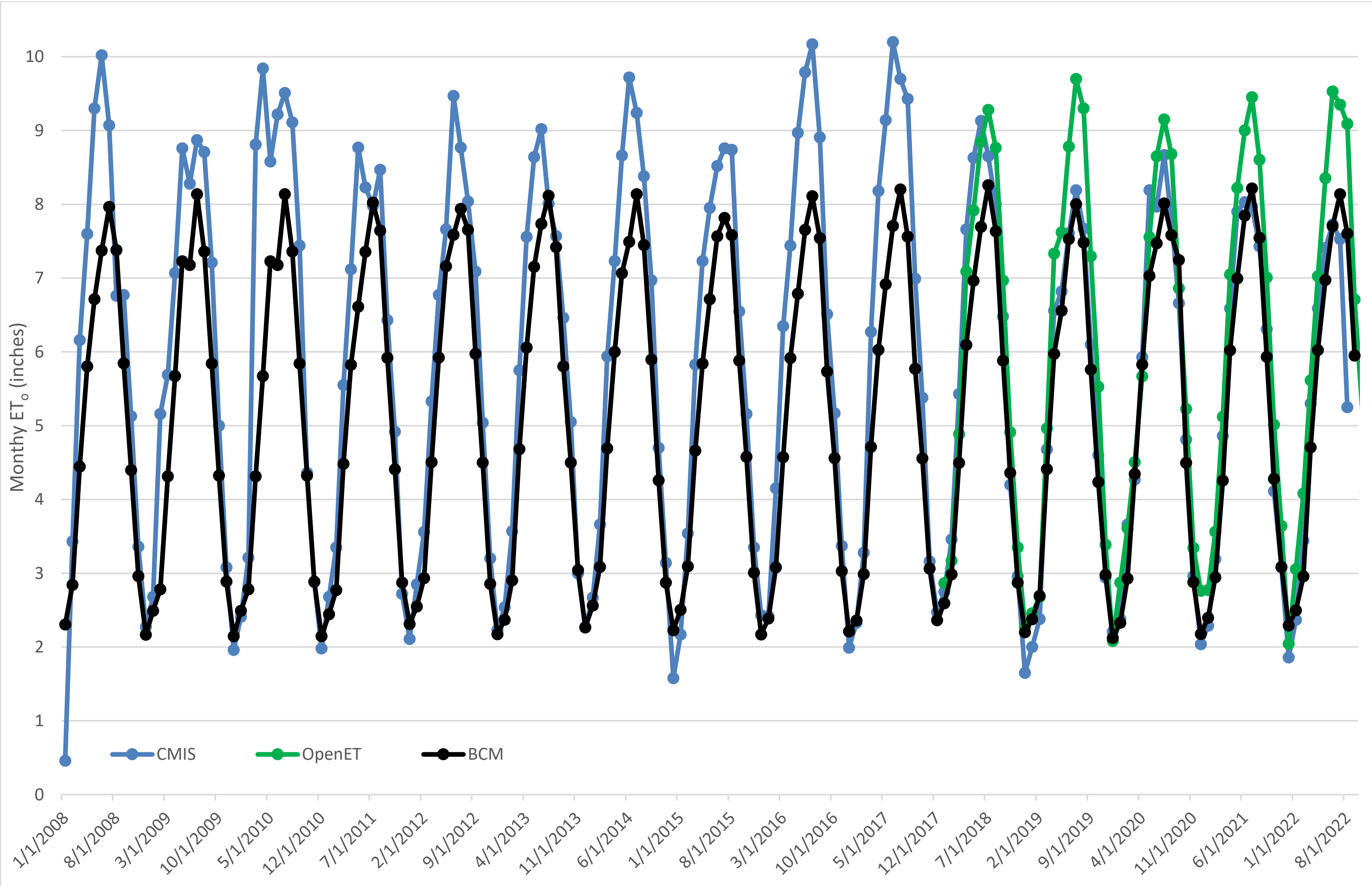


Borrego Springs Watermaster
August 2023 TAC Memo

Prepared by:
WEST YOST

Figure 1
Total WY 2022 PET used in the FMP
and Location of CIMIS Station and OpenET Data

Figure 2. Monthly ET_o at the CIMIS-207 Location, by Source



The monthly scaling factors were then multiplied by the BCM ET_o values at all BVHM grid cells. Figure 3 displays the *scaled* BCM ET_o values compared to the *unscaled* BCM ET_o and CIMIS ET_o at the CIMIS-207 location. The *scaled* BCM ET_o data were assigned to the 2022 BVHM with the *initial* KC and OFE values. The 2022 BVHM was then run through WY 2022 to compare FMP-estimated pumping to Actual Pumping for WYs 2021 and 2022. Table 6 presents the results of this sensitivity analysis.

Table 6. Comparison of Actual Pumping to FMP-Estimated Pumping

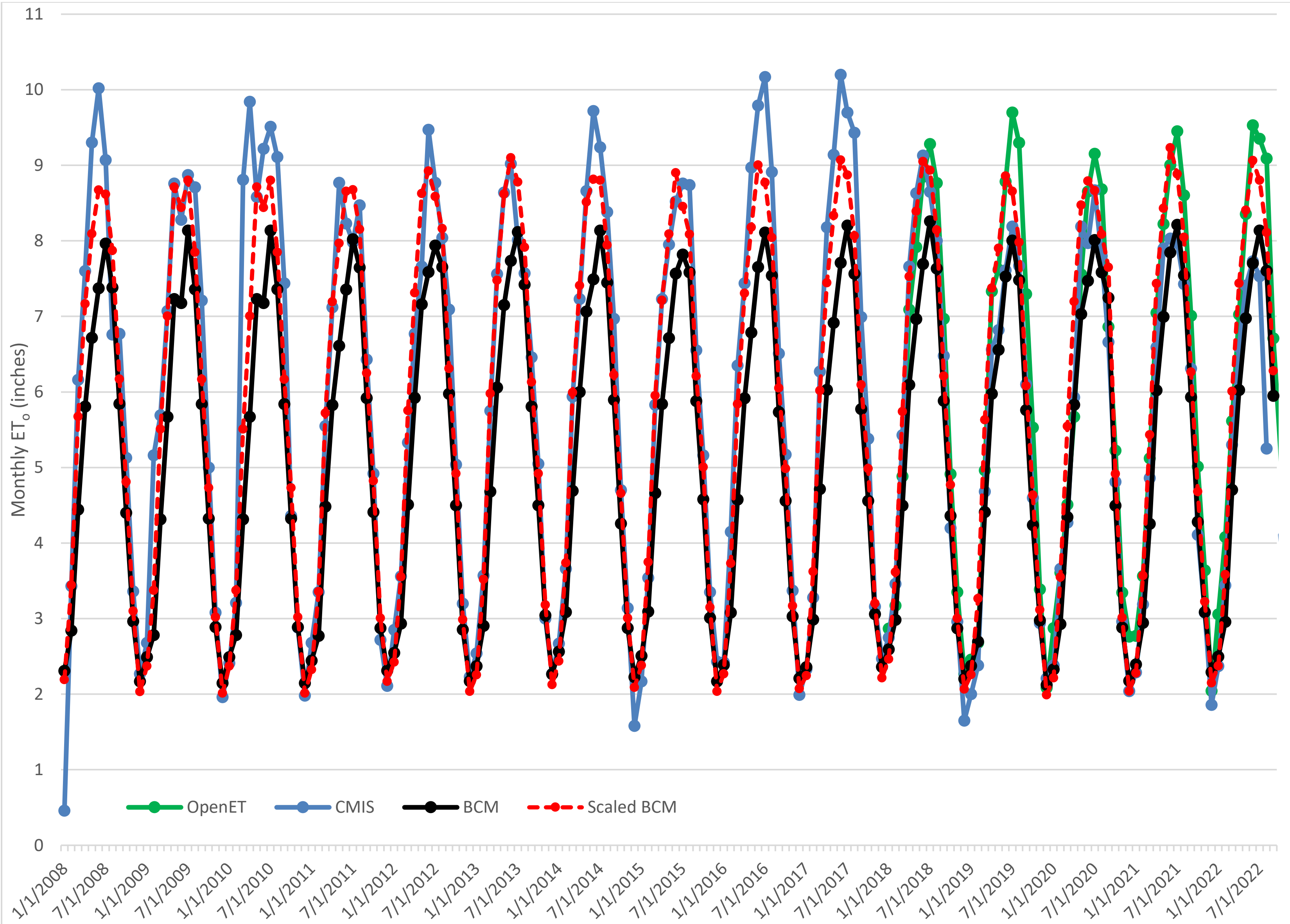
WY	Actual Pumping	Using *Initial* KC and OFE Values and *Unscaled* BCM ET_o values			Using *Initial* KC and OFE Values and *Scaled* BCM ET_o values		
		FMP-Estimated Pumping (afy)	Difference	% Difference	FMP-Estimated Pumping (afy)	Difference	% Difference
	(a)	*(b)*	*(c) = (b) - (a)*	*(d) = (c)/ ([(a)+(b)]/2)*	*(e)*	*(f) = (e) - (a)*	*(g) = (f)/ ([(a)+(e)]/2)*
2021	12,857	11,625	-1,232	-10%	13,167	310	2%
2022	10,863	10,551	-312	-3%	11,971	1,108	10%

Conclusions: Based on this sensitivity analysis:

- The FMP estimation of groundwater pumping appears to be sensitive to the assumptions for ET_o.
- The FMP overestimated Actual Pumping by 310 af (2%) in WY 2021 and by 1,108 af (10%) in WY 2022 when using the *scaled* BCM ET_o data that more closely matches the CIMIS-207 ET_o data.
- The sensitivity analysis did not indicate a defensible adjustment or alternative dataset for historical ET_o for use in the BVHM.

Recommendation: Continue the use of BCM ET_o data in the BVHM.

Figure 3. Scaled-Up Monthly BCM ET_o Data used for Sensitivity Analysis at the CIMIS-207 Location



Next Steps

The TAC was asked to review the draft Task 2 TM and provide comments and recommendations. Specifically, Watermaster staff requested that TAC members respond to the following recommendations described in the TM, which included:

1. Should the OFE values over the historical BVHM simulation period be revised to reflect the evolution of irrigation methods used in the Basin since 1930? If so, how?
2. Should the BVHM continue to use the historical BCM ET_o data? If not, what ET_o dataset should be used?

The TAC also provided other comments and recommendations on the subsequent tasks to redetermine the Sustainable Yield in 2025. Exhibit 2 is a table that summarizes each TAC member's comments and recommendations and the Technical Consultant's responses. The comments, recommendations, and responses will inform the execution of subsequent tasks to redetermine the Sustainable Yield in 2025.

Enclosures

Exhibit 1. Scope of Work to Redetermine the Sustainable Yield by 2025
Exhibit 2. Summary of TAC Comments and Recommendations on the Task 2 TM

EXHIBIT 1

SCOPE OF WORK TO REDETERMINE THE SUSTAINABLE YIELD BY 2025

The Borrego Springs Watermaster's current scope of work to Redetermine the Sustainable Yield by 2025 was recommended by a TAC majority and was approved by the Watermaster Board at its meeting on February 9, 2023. The scope of work is summarized in the table below:

Table 1. Scope of Work to Redetermine the Sustainable Yield by 2025

WY 2023 and WY 2024

Task No.	Task	Cost Estimate
1	Compare FMP-estimated Pumping to Actual Pumping for WY 2022	$20,222
2	Update Water-Use Factors in the FMP	$39,196
3	Correct Errors Identified in 2021 BVHM	$22,577
4	Perform Model Recalibration	$128,510
5	Determine the Sustainable Yield (including documentation)	$137,699
	Total Cost for All Tasks	**$348,204**

The scope of work is described below by task, including: a problem statement, the objective of the task to address the problem statement, a description of the work to complete the task, a cost estimate, the schedule to complete the task, a description of the consequences of not performing each task.

TASK 1 – COMPARE FMP-ESTIMATED PUMPING TO ACTUAL PUMPING FOR WY 2022

Problem Statement: In WY 2022, West Yost extended the BVHM from WY 2017 through WY 2021 (2021 BVHM). For this effort, the Farm Process (FMP) was used to estimate pumping at historically unmetered wells, and then the FMP-estimated pumping was compared against newly-metered pumping at those same wells (*i.e.,* Actual Pumping) during WY 2021 to understand the ability of the FMP to estimate pumping.[1,2] The result of this comparison was that the FMP underestimated Actual Pumping by 4,456 af in WY 2021—a 42% difference. The TAC considers this difference to be significant, which likely indicates that the BVHM is not sufficiently calibrated based on newly collected pumping data. However, the comparison in WY 2021 relied on only one year of actual pumping data. Additional comparisons of FMP-estimated pumping versus Actual Pumping are necessary to confirm, modify, or refute the conclusions of the extension of the BVHM through WY 2021.

Objective: The objective of this task is to confirm, modify, or refute the conclusions of the extension of the 2021 BVHM by extending the BVHM through WY 2022 and then comparing FMP-estimated pumping

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[1] West Yost. 2022. *Extension of the Borrego Valley Hydrologic Model through Water Year 2021* (2021 BVHM TM).

[2] Pumping at a few unmetered wells was estimated by Watermaster staff in WY 2021.

to Actual Pumping in WY 2022. This task was recommended by the TAC in May 2021 and approved by the Watermaster Board in July 2022 for inclusion in the WY 2023 budget with a budget of $31,598.

Task Description: In this task, the 2021 BVHM will be extended through WY 2022 and the FMP-estimated pumping in WY 2022 will be compared against Actual Pumping as metered by the Watermaster in WY 2022. Efforts for this task will include extending the Multi-Node Well Package (MNW2) using metered pumping data from WY 2022; extending the Streamflow Routing (SFR) and Flow and Head Boundary (FHB) packages through WY 2022; and extending the FMP through WY 2022. To reduce the cost of this task, it is recommended that the boundary conditions from WY 2021 be applied to the SFR and FHB packages and the FMP. The results and conclusions of this task will be summarized and distributed to the TAC via email. The email will request TAC feedback before the Technical Consultant proceeds with Task 2.

Budget: $20,222 [Note: A $31,500 budget for this task was approved by the Watermaster Board for WY 2023. The Watermaster Technical Consultant has re-estimated the scope and budget for this task.]

Schedule: February to March 2023

Consequence of Not Completing Task 1: The ability of the FMP to estimate groundwater pumping is of upmost importance because groundwater pumping is a main stress to the Subbasin. If the FMP continues to significantly underestimate Actual Pumping in WY 2022, then it is likely that the FMP needs improvement and the BVHM needs re-calibration to accurately estimate the water budget and Sustainable Yield of the Subbasin as identified in the Judgment.

By not completing Task 1, the TAC will not be able to confirm the results and conclusions from the extension of the 2021 BVHM, and therefore, would be basing many of its subsequent recommendations for improvements to the FMP and BVHM on a single evaluation.

TASK 2 – UPDATE WATER-USE FACTORS IN THE FMP

Problem Statement: Water-use factors are used to estimate the consumptive use of water of different crop and land-use types in the FMP. The water-use factors currently used in the FMP were developed by the United States Geological Survey (USGS) during the initial development of the BVHM. The factors were initially based on various agricultural water-use studies (Allen et al., 1998[3]; Snyder et al., 1987a[4], Snyder et al., 1987b[5]) and adjusted during model calibration.

It appears from the results of the 2021 BVHM extension that the FMP significantly underestimates pumping. If so, this would indicate that the water-use factors currently used in the FMP are inaccurate.

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[3] Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. Crop evapotranspiration—Guidelines for computing crop water requirements: Food and Agriculture Organization of the United Nations, Irrigation and Drainage Paper 56. Accessed December 12, 2022 on https://www.fao.org/3/X0490E/X0490E00.htm.

[4] Snyder, R.L., Lamina, B.J., Shaw, D.A., and Pruitt, W.O. 1987a. Using reference evapotranspiration (ET_o) and crop coefficients to estimate crop evapotranspiration (ET_c) for agronomic crops, grasses, and vegetable crops. Accessed December 12, 2022 on https://calisphere.org/item/e4408893-9141-4766-89f2-c25c667071a7/.

[5] Snyder, R.L., Lamina, B.J., Shaw, D.A., and Pruitt, W.O. 1987b. Using reference evapotranspiration (ET_o) and crop coefficients to estimate crop evapotranspiration (ET_c) for trees and vines Accessed December 12, 2022 on https://calisphere.org/item/fbc9dc78-de6e-4d99-a561-0028370f8107/.

Since the FMP is an important component of the BVHM, inaccuracies in the FMP could significantly affect the ability of the BVHM to accurately estimate the water budget and Sustainable Yield of the Subbasin.

Objective: The objective of this task is to develop updated estimates of the water-use factors used in the FMP to improve the ability of the FMP to estimate groundwater pumping.

Task Description: To update the water-use factors, a new methodology will be developed. Previous efforts have been undertaken to estimate water-use factors in the Subbasin, which could be used to achieve the objective of this task. Specifically, in estimating the Baseline Pumping Allocation (BPA) for agricultural parties in the Subbasin, Dudek developed a method for estimating water-use factors for various crop types and documented the data sources and methodology. The methods used to estimate water-use factors in the FMP will need to be researched to determine if the water-use factors estimated by Dudek can be directly compared to and used in the FMP. If a comparison cannot be made, additional methods will be evaluated for estimating water-use factors.

The updated water-use factors will be used to run the BVHM through WY 2022 and the updated FMP-estimated pumping will be compared to prior estimates of FMP-estimated pumping for the entire model simulation period (WY 1930-2022). Additionally, the updated FMP-estimated pumping will be compared to the Actual Pumping for WYs 2021 and 2022 to determine if the updated water-use factors improved the FMP's ability to estimate groundwater pumping. If the updated FMP still fails to accurately estimate Actual Pumping, the water-use factors will need to be adjusted during the model recalibration (Task 6). The approach and results from comparing FMP-estimated Pumping to Actual Pumping for WY 2022 (Task 1) and updating water-use factors in the FMP (Task 2) will be presented to the TAC.

Budget: $39,196

Schedule: March through April 2023

Consequence of Not Completing Task 2: By not completing Task 2, the FMP will continue to use the existing water-use factors initially developed by the USGS, and as a result, may continue to underestimate groundwater pumping. As noted under Task 1, the FMP's ability to estimate groundwater pumping is critical for redetermining the Sustainable Yield. If the FMP significantly underestimates pumping, then it is likely that the BVHM is not well calibrated, the BVHM cannot be satisfactorily re-calibrated, and any redetermined Sustainable Yield using the FMP and BVHM may not be accurate.

TASK 3 – CORRECT ERRORS IDENTIFIED IN THE 2021 BVHM TM

Problem Statement: During the 2021 BVHM extension, West Yost identified several errors and discrepancies in the BVHM and documented the errors and discrepancies in the technical memorandum *Extension of the Borrego Valley Hydrologic Model through Water Year 2021* (2021 BVHM TM). Some of these errors relate to the assignment of recharge in the BVHM, which may adversely impact the ability of the BVHM to accurately estimate the water budget and Sustainable Yield of the Subbasin.

Objective: The objective of this task is to fix known errors in the BVHM and quantify the influence of the errors on the BVHM results.

Task Description: In this task, the errors and discrepancies identified in the 2021 BVHM TM will be corrected. These corrections include fixing errors in the SFR, FHB, MNW2 packages, and in the FMP. Additionally, the screen depths of wells in the MNW2 package will be compared to well completion data to validate the depth distribution of pumping in the BVHM. Once all identified errors have been corrected, the BVHM will be run through WY 2022. The results from the corrected BVHM will be compared to the historical BVHM results to quantify the influence of the errors on the model results. The approach and results from completing this task will be presented to the TAC.

Budget: $22,577

Schedule: April through May 2023

Consequence of Not Completing Task 3: The known errors in the BVHM are virtually certain to impact the model estimates of:

- Subsurface inflows
- Stream inflows
- Groundwater pumping

While the magnitude of these errors on the BVHM results remains unknown, it is certain that the errors are influencing the model-estimated water budget, including the typically important sources of recharge. Estimates of historical recharge were used to establish the current Sustainable Yield of 5,700 afy.

By not completing Task 3, the known errors will remain in the BHVM and may adversely influence the BVHM-estimated water budget and Sustainable Yield. The impact of these errors on the BVHM results (*e.g.,* water budget, recharge, groundwater pumping, and the Sustainable Yield) will remain unknown.

TASK 4 – PERFORM MODEL RECALIBRATION

Problem Statement: Past modeling efforts have indicated that the BVHM may require a recalibration. Examples include:

- The results from the 2016 BVHM extension found that the model underestimated hydraulic heads compared to measured values (Dudek, 2019).
- The results from the 2021 BVHM extension found that the FMP significantly underestimated groundwater pumping compared to Actual Pumping in the Subbasin (West Yost, 2021).
- The results from the 2021 BVHM extension identified several other discrepancies with the BVHM that could have adversely impacted its initial calibration, such as inaccurate estimates of recharge and errors in the SFR, FHB, and MNW2 packages and the FMP (West Yost, 2021).

If the BVHM is not appropriately calibrated, then the BVHM results, and interpretations derived from the BVHM results such as the Sustainable Yield, are likely inaccurate.

Objective: The objective of this task is to improve the ability of the BVHM to estimate groundwater elevations, groundwater pumping, the water budget, and the Sustainable Yield of the Subbasin by recalibrating the BVHM after completing the tasks to update the FMP and fix the errors in the BVHM.

Task Description: To recalibrate the BVHM, input files will be prepared to perform calibration using the parameter estimation code PEST. Selected measured pumping and head values will be used as calibration targets. During the model calibration, the values of aquifer parameters (such as hydraulic conductivity and storage coefficient) and, if needed, the water-use factors in the FMP will be adjusted to minimize the differences between the model estimated and measured pumping and head values. The calibration results will include time series of simulated vs. measured values, along with calibration statistics and calculated residuals. The approach and results of the calibration will be documented in a TM and presented to the TAC. The TM will be finalized based on TAC comments and the calibrated BVHM will be used in Task 7 to determine the Sustainable Yield.

Budget: $137,699

Schedule: December 2023 through May 2024

Consequence of Not Completing Task 4: By not completing Task 6, the BVHM results will continue to be produced from a model that likely is not sufficiently calibrated, which will result in inaccurate estimates of groundwater pumping, hydraulic heads, the water budget, and the Sustainable Yield.

TASK 5 – DETERMINE THE SUSTAINABLE YIELD (INCLUDING DOCUMENTATION)

Objective: The objective of this task is to determine the Sustainable Yield for WY 2026 through WY 2030 and document the methods, results, and conclusions of all work perform for this effort. This task is required by the Judgment and must be completed and adopted by the Board no later than January 1, 2025.

Task Description: Projection scenarios and methods to interpret model results will be developed and proposed to the TAC via a draft TM. The projection scenarios will include the Rampdown of pumping to the Sustainable Yield and future precipitation and ET based on climate projections, which may use either a change factor method or projected BCM data based on Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models. The TAC will have the opportunity to provide feedback on the proposed projection scenarios and the methods for redetermining the Sustainable Yield. Once the projection scenarios and methods for redetermining the Sustainable Yield are finalized, the projection scenarios will be constructed and run with the BVHM. A draft report describing the methods and results of this task will be presented to the TAC for review and comment. The report will be finalized based on TAC comments. The final report and the TAC recommendation for the redetermined Sustainable Yield will be presented to the Watermaster Board for their consideration during the September 2024 Board meeting. The Watermaster Board will then have time to review the Sustainable Yield prior to approving it by December 2024.

Budget: $137,699 [Note: A $155,000 budget for this task was assumed in the SGM grant application. The Watermaster Technical Consultant has re-estimated the scope and budget for this task.]

Schedule: May through September 2024

Consequence of Not Completing Task 5: This task must be completed. Section III.F.3 of the Stipulated Judgement states that "By January 1, 2025, the Watermaster will, following receipt of input and recommendations from the Technical Advisory Committee, revise the determination of the Sustainable Yield for Water Years 2025/2026 through 2029/2030."

Responses to TAC Recommendations on *Task 2 - Update Water-Use Factors in the FMP*

Recommendation(s)	TAC Committee Member Party and Representative: AAWARE *Bob Wagner*	BWD *Trey Driscoll*	County of San Diego[1] *Jim Bennett*	T2 Borrego, LLC *Tom Watson*	Technical Consultant Response to TAC Member Recommendations
Reset crop coefficent (KC) scaling factor to 1	x	x			KC values will be updated during Task 2.
Reset on-farm efficiency (OFE) scaling factor to a factor representative of current irrigation methods	x	x			OFE values will be updated during Task 2.
Compare Reference ET (ET_o) to other sources of ET, including:	x	x		x	Reference ET (ET_o) used in the FMP will be compared to other sources of ET during Task 2. Results of the comparison will determine whether (and how) ET_o values used in the FMP should be updated.
CIMIS Station #207		x		x	
Open ET	x	x		x	
LandIQ ET		x			
Meet with the TAC to dicuss findings/results of updating KC and OFE scaling factors		x			A TAC meeting will be held to discuss results of Task 2.
Calibrate the model using: Open ET, measured groundwater levels, and metered groundwater pumping				x	Task 2 is a "manual calibration" of the FMP. *Task 4 - Model Recalibration* will include a numerical recalibration of the BVHM.
Estimate on-farm return flows by subtracting the applied water (i.e., metered groundwater pumping) from the consumed water (i.e., actual ET remotely sensed satellite data).		x			This recommendation is beyond the scope of work for Task 2, but may be a useful exercise during *Task 4 - Model Recalibration.* The TAC should discuss this prior to implementing Task 4.
Update historical land use to improve historical pumping estimates		x			This recommendation is beyond the scope of work for Task 2, but may be a useful exercise during *Task 4 - Model Recalibration* . The TAC should discuss this prior to implementing Task 4.

Notes:
1. Responded that they had no comments on the recommended approach.