Borrego Springs Watermaster
Board of Directors Meeting
May 9, 2024
AGENDA ITEM V.F

To: Board of Directors

From: Andy Malone, Technical Consultant

Date: May 6, 2024

Subject: Status Update on the Redetermination of Sustainable Yield

☐ **Recommended Action**	☐ **Provide Direction to Staff**	✓ **Information and Discussion**
☐ **Fiscal Impact**	☐ **Cost Estimate: $**	

Recommended Action

Board discussion.

Fiscal Impact: None.

Background and Previously Related Actions by the Board

Section II.E of the Judgment requires the Sustainable Yield to be redetermined by January 1, 2025 through a process that includes: collecting additional data, refining the Borrego Valley Hydrologic Model (BVHM), and using model runs to update the Sustainable Yield. The Watermaster Board approved a scope of work and budget for water year (WY) 2023 and 2024 to update the BVHM and Redetermine the Sustainable Yield by 2025.[1] The scope of work includes the following tasks:

Task 1 – Compare FMP-estimated Pumping to Actual Pumping for WY 2022

Task 2 – Update Water-Use Factors in the Farm Process (FMP)

Task 3 – Correct Errors Identified in the 2021 BVHM

Task 4 – Model Recalibration

Task 5 – Determine the Sustainable Yield

At the January 8, 2024 Regular Board meeting, the Board requested monthly status updates on the efforts to redetermine the Sustainable Yield at each Regular Board meeting in 2024.

Status Update on the Effort to Redetermine the Sustainable Yield by 2025

To-date, West Yost has completed Tasks 1 through 3 of the scope of work and is currently executing Task 4 – *Model Recalibration.*

[1] https://borregospringswatermaster.com/wp-content/uploads/2023/02/TAC-Recommendation-Report_SY-2023-24_final.pdf

The following work was performed in April 2024:

- Began performing model recalibration.
- Per the TAC recommendation following its Ad-Hoc meeting on March 29, 2024, developed a methodology for using OpenET to validate the ability of the FMP to estimate crop water demands (evapotranspiration [ET]).[2] The proposed methodology was applied to evaluate the FMP results from the *Pre-Calibrated BVHM*.
- Prepared a presentation to summarize the proposed methodology for using OpenET data as a validation check (including the evaluation of the *Pre-Calibrated BVHM*) and distributed to the TAC for review. The presentation slides included: (i) a description of how OpenET estimates ET; (ii) a description of how the FMP estimates ET; (iii) the proposed method for using OpenET data as a validation check on the FMP; and, (iv) the results of applying the proposed method to evaluate the FMP-estimated ET from the *Pre-Calibrated BVHM*. Comments from the AAWARE TAC member were received prior to the meeting.
- Held an Ad-Hoc TAC meeting on May 1, 2024 to discuss the proposed methodology for using OpenET data as a validation check on the FMP (including the evaluation of the *Pre-Calibrated BVHM*). Some TAC members invited additional experts in OpenET and modeling to attend. Following the meeting, West Yost sent an email to the TAC with the following requests:

  1. Specific recommendations on how to use OpenET as a validation check on the ability of the FMP to estimate ET (*e.g.,* specific OpenET models; validation methods; etc.).
  2. Any other input on this topic.

  A TAC Comments Summary Table (attached) summarizes the TAC responses to these requests. Based on the comments received by the TAC, West Yost recommends proceeding with Task 4 as follows:

  1. Limit the set of OpenET models to use for FMP validation to the two models most-appropriate for Borrego Springs (geeSEBAL and EEMETRIC) and the Ensemble model.
  2. Do not use OpenET directly to adjust the FMP (as unanimously recommended by the TAC at its May 29, 2024 meeting).

Next Steps (May 2024)

West Yost is proceeding with the current scope-of-work to perform *Task 4 – BVHM Recalibration* with the addition of using OpenET as a validation check on the ability of the FMP to estimate ET. Results of model recalibration and validation of the FMP will be presented to the TAC during its next regular meeting, which will be scheduled for June to early July 2024. In the interim, West Yost will continue to keep the TAC informed of the progress made under Task 4 – *Model Recalibration.* Preliminary results of model recalibration will be emailed to the TAC as soon as available prior to the next TAC meeting.

[2] Following its March 29, 2024 meeting, the TAC unanimously agreed that: (i) OpenET should be used to validate the ability of the FMP to estimate crop water demands and (ii) OpenET should not be used directly in the 2025 Redetermination of the Sustainable Yield.

Attachments

Summary of TAC Comments from the May 1, 2024 Ad-Hoc TAC Meeting

Item V.F

Responses to TAC Comments/Recommendations on use of OpenET Data during the 2025 Redetermination of the Sustainable Yield

Comments/Recommendations	TAC Members					
	AAWARE *Bob Wagner*	**BWD** *Trey Driscoll*	**County of San Diego** *Jim Bennett*	**T2 Borrego** *Tom Watson*	**Roadrunner Club** *John Peterson*	**Borrego Springs Community** *Russell Detwiler*
Specific recommendations on how to use OpenET as a validation check on the ability of the FMP to estimate ET						
Use the range of ET estimates from the geeSEBAL and EEMETRIC models to validate the FMP.		X		X		
Use ET-estimates from the EEMETRIC model to validate the FMP.	X					
Use ET-estimates from the Ensemble model to validate the FMP.		X				X
Use OpenET as a validation check on the FMP.			X			
Additional Comments						
Replace crop coefficient (KC) values in the FMP with reference ET fractions from OpenET.	X					
Estimate the on farm efficiency (OFE) using EEMETRIC ET values and metered pumping data (where, OFE = ET/pumping)	X					
QAQC CIMIS station reference ET data	X					
Use EEMETRIC ET data directly in the FMP	X					
No Comment						
No comment or recommendation					X[1]	

Notes:

1) Replied via email that Mr. Peterson did not have any recommendations.

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Andy Malone PG and Lauren Salberg, Technical Consultant (West Yost)
Borrego Springs Watermaster – Technical Advisory Committee

From: Robert Wagner, P.E, A. Leonardo Urrego-Vallowe, EIT, and Dr. Jan Hendrickx, Professor Emeritus of Hydrology, New Mexico Tech

Date: May 3, 2024

Re: **Follow-up on Borrego Springs Watermaster Technical Advisory Committee Ad-Hoc Meeting May 1, 2024**

This memo provides response to the recommendations requested by Watermaster Technical Consultant during the May 1, 2023 ad-hoc TAC meeting regarding the methods to use OpenET as a validation check on the ability of the FMP to estimate evapotranspiration (ET).

We consider eeMETRIC the best OpenET model for Borrego Springs. We have prepared this brief statement with references that support our recommendation.

The six different ET models in OpenET have all been developed for different applications. PT-JPL was developed for global ET mapping at a pixel scale of about 25x25 miles on a monthly scale. This is hard to do so that the JPL scientists had to make simplifications to obtain reasonable global ET values from available global databases. The original publication of *Fisher et al.* [2008] has been cited 1047 times; about 1010 of these citations had the word "global" in their title. For global ET mapping the PT-JPL method would be the first choice; not so for field scale ET mapping because due to its needed simplifications it lacks internal calibration.

Three of the six models in OpenET estimate each component of the energy balance: ALEXI/DisALEXI [*Anderson et al.*, 2018; *Anderson et al.*, 2007], eeMETRIC, and geeSEBAL. Unfortunately, ET from isolated irrigated areas in semi-arid regions may be underestimated by ALEXI/DisALEXI in some cases[1] so that this method is not recommended for Borrego. On the other hand, the eeMETRIC and geeSEBAL models have a robust internal calibration and a track record in arid regions that makes them suitable for Borrego.

[1] https://etdata.org/known-issues/

The internal calibration of the eeMETRIC and geeSEBAL models needs land surfaces with a clear hydrological contrast of dry and wet areas [*Allen et al.*, 2011; *Allen et al.*, 2007a; *Allen et al.*, 2007b; *Bastiaanssen et al.*, 1998a; *Bastiaanssen et al.*, 1998b]. The coldest and warmest of these areas are used to estimate the sensible heat flux. In the coldest areas such as a well-irrigated alfalfa field the sensible heat flux is zero and the latent heat flux, i.e. the ET, is the difference between the net radiation and the soil heat flux; in the warmest areas such as a fallow field or desert the sensible heat flux is at its maximum and the latent heat flux, the ET, is zero. By constraining the sensible heat fluxes to a known minimum and maximum, sensible heat flux outliers are prevented and latent heat flux, i.e. ET, estimates are greatly improved. On a clear day the net radiation can be estimated from Landsat images and meteorological data such as air temperature, pressure and humidity with an accuracy of about 5-10% [*Ferreira et al.*, 2020; *Mira et al.*, 2016; *Samani et al.*, 2007]. Given that the soil heat flux is relatively small, accurate ET estimates result by taking the net radiation and subtracting the sum of sensible heat flux and soil heat flux. A principal difference between geeSEBAL and eeMETRIC is that the latter uses hourly meteorological measurements to calculate the hourly reference ET so that it compensates for regional advection effects where ET can exceed daily net radiation. A feature that is certainly of importance for Borrego. Overall, eeMETRIC is the recommended method for Borrego because its performance in arid and semi-arid environments is excellent [*Allen et al.*, 2007a; *Hong*, 2008; *Madugundu et al.*, 2017; *Upper Colorado River Commission*, 2022; *Volk et al.*, 2024].

In areas without any agricultural fields, water bodies, or dense patches of vegetation internal calibration becomes challenging. The USGS is charged to study the landscape of the entire United States and its natural resources. Therefore, the USGS needs to deal with areas that have little or no hydrological contrast often in addition to a complex topography. For ET mapping in such areas *Senay et al.* [2013] developed SSEBop by predefining a temperature difference between "hot" and "cold" reference values for each pixel. This is very different from eeMETRIC and geeSEBAL that use only one pair of a "hot" and "cold" pixel for each uniform hydro-climate region and consider all four components of the energy balance for their internal calibration. SSEBop uses only the net radiation and empirically calculates the actual ET as the product of an ET-fraction times the reference evapotranspiration times a scaling coefficient for the reference evapotranspiration. The ET-fraction is a temperature ratio obtained by dividing the temperature difference between the land surface of a pixel minus its "cold" reference temperature by the temperature difference between the "hot" and "cold" reference temperatures. Since this is a simplified empirical method, it may need to be changed for different conditions. As a matter of fact, several adaptations of SSEBop have been published since 2013 [*Senay*, 2018; *Senay et al.*, 2023]. After a nine-year study the Consumptive Use Study Workgroup of the Upper Colorado River Basin[2] recommended the use of the Automated METRIC (eeMETRIC) model for regional ET estimation, as it consistently performed better than the SSEBOP model. The workgroup also recommended continued monitoring and increased understanding of eeMETRIC and other

[2] www.ucrcommission.com/wp-content/uploads/2022/08/Consumptive-Use-Study-Workgroup-Technical-Recommendation-updated-for-June-Mtg..pdf

methods and ensembles as developed by the OpenET platform. In short, the SSEBop model is not recommended for use in Borrego.

The SIMS model in OpenET assumes that the crop grown in a field is well-watered. If this is the case, the predictions of the SIMS model will be close to the predictions based on the crop coefficient. Under conditions of deficient soil moisture, the SIMS ET estimate will be too high. The SIMS model is not recommended for estimating the actual ET in an agricultural field.

Responses to Watermaster Consultant questions

1. Do you have specific recommendations on how to use OpenET as a validation check on the ability of the FMP to estimate ET (*e.g.,* specific OpenET models to use; validation methods; etc.)? If so, briefly describe:

   We recommend using eeMETRIC because this model is based on physics with a robust internal calibration, it is appropriate for evaluation of local arid environments, and it is adopted by the Colorado River Commission for ET studies in the Upper Colorado River Basin.

   The validation check of the FMP values should be done by comparing the total ET provided by eeEMTRIC vs. the ET predicted by the FMP instead of the range of the minimum and maximum for all six models. If there is a discrepancy, the FMP parameters need to be redefined to match OpenET data.

2. Do you have any other input on this topic? If so, briefly describe:

   We recommend replacing the KC value for each FMP active cell with the reference ET fraction (available as part of eeMETRIC, with a spatial resolution of 30mx30m). This methodology involves calculating the average reference ET fraction within each FMP active cell (600mx600m resolution).

   The new estimates for OFE can be obtained by dividing the new ET values estimated from eeMETRIC with the metered pumping.

   The section “Insertion of ET Fluxes in Hydrologic Models” in the attached publication by Hendrickx et al. (2016) provides information on how to incorporate eeMETRIC data into FMP.

   An important variable is the reference evapotranspiration (ETo) that is calculated from hourly weather data of a CIMIS station. The quality of this data needs to be tested and corrected if possible. This can be done using the QAQC approach by the University of Idaho REF-ET software and QAQC system. For the Borrego environment an aridity correction most probably needs to be applied to the weather data before calculating the

reference evapotranspiration. The Ref ET software can be downloaded at https://www.uidaho.edu/cals/kimberly-research-and-extension-center/research/water-resources/ref-et-software.

OpenET data could be used directly for the 2025 Redetermination of the Sustainable Yield. This approach has been shown to considerably improve hydrologic decision support tools compared to their traditional implementations. The attached paper by *Hendrickx et al.* [2016] shows how METRIC ET data can be used directly in hydrological models. The paper describes direct implementation in three operational hydrologic models for the prediction of (1) annual ET in the ET Toolbox developed by the United States Bureau of Reclamation, (2) rainfall runoff hydrographs for the Gridded Surface/Subsurface Hydrologic Analysis model developed by the U.S. Army Corps of Engineers, and (3) the average annual groundwater recharge for the Distributed Parameter Watershed Model used by Daniel B. Stephens & Associates. The 12 authors of this paper received the William R. Boggess Award for the most outstanding paper "Benchmarking Optical/Thermal Satellite Imagery for Estimating Evapotranspiration and Soil Moisture in Decision Support Tools" published in the Journal of the American Water Resources Association during 2016. Since OpenET will soon have ET data available since 1985, at least for the last 39-year ET data can be used directly for redetermination of the sustainable yield.

References

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Item V.F

Lauren Salberg

From: Russ Detwiler <detwiler@uci.edu>
Sent: Saturday, May 4, 2024 3:14 PM
To: Andy Malone
Cc: LUEG, GroundWater, PDS; Trey Driscoll; John Peterson; Tom Watson; Robert Wagner; Leonardo Urrego; Samantha Adams; Lauren Salberg; Eric W.H. Chiang
Subject: Re: Notice of Ad-Hoc Technical Advisory Committee Meeting on May 1, 2024 at 9:00 am
Attachments: Volk(2024a) - Assessing the accuracy of OpenET satellite-based evapotranspiration data to support water resource and land management applications.pdf

Hi Andy,

Thanks for the opportunity to comment on this issue. Here are my responses:

1. Do you have specific recommendations on how to use OpenET as a validation check on the ability of the FMP to estimate ET (*e.g.,* specific OpenET models to use; validation methods; etc.)? If so, briefly describe:

   I do not have extensive experience with OpenET and the models it uses to convert satellite images into ET estimates. However, based on my current understanding of these various models, I recommend continuing to use the approach presented during the Ad Hoc TAC Meeting on May 1. That is, compare ET estimates derived resulting from the FMP parameters in the updated model to the ensemble estimates from OpenET.

   While reasonable arguments can be made for the relative merits of the different models used by OpenET, a recently published comparison of ET estimates from the different OpenET models to on-the-ground measurements suggests the ensemble estimates perform as well or better than any of the individual models for a range of conditions and crop types (Volk et al., Nature Water, 2024; attached). Using the ensemble minimizes the risk of introducing potential biases that may result from a single model. It also inherently accounts for the uncertainty associated with each of the models by providing estimates of upper and lower bounds.

2. Do you have any other input on this topic? If so, briefly describe:

   No.

Best,
Russ

Russell Detwiler
Associate Professor
Civil and Environmental Engineering
University of California, Irvine

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On Wed, May 1, 2024 at 2:22 PM Andy Malone <amalone@westyost.com> wrote:

> Thank you for attending today's ad-hoc TAC meeting on the subject of using OpenET during ***Task 4 – BVHM Recalibration***. The meeting presentation and recording have been posted to the website here. The Board's intention is

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WORKING DRAFT TECHNICAL MEMORANDUM

To:	Andy Malone, Borrego Springs Watermaster, BorregoSpringsWM@westyost.com
From:	Trey Driscoll, PG, CHG, Erick Fox, Guillermo Martinez
Subject:	2025 Redetermination of the Sustainable Yield Using OpenET as a Validation Check on the FMP Yield By 2025 – Response for May 1, 2024 TAC Meeting
Date:	May 3, 2024
cc:	Geoff Poole, Borrego Water District

INTERA previously presented a review of OpenET for Water Years 2021 and 2022 in our technical memorandum titled Farm Process (FMP) Update to Redetermine the Sustainable Yield By 2025 – Response for August 29, 2023 TAC Meeting dated September 15, 2023. The preliminary review of Open ET presented in our previous technical memorandum is provided here for ease of review along with additional information and comments based on the May 1, 2024 Technical Advisory Committee (TAC) meeting.

Review of OpenET for Water Years 2021 and 2022

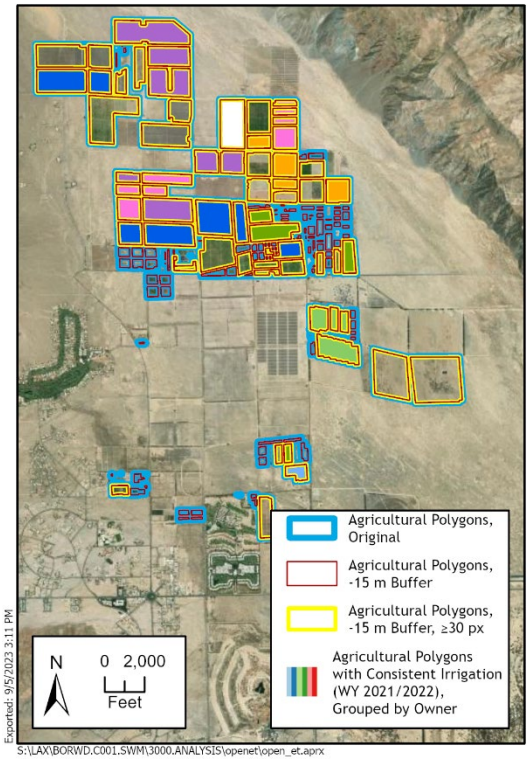


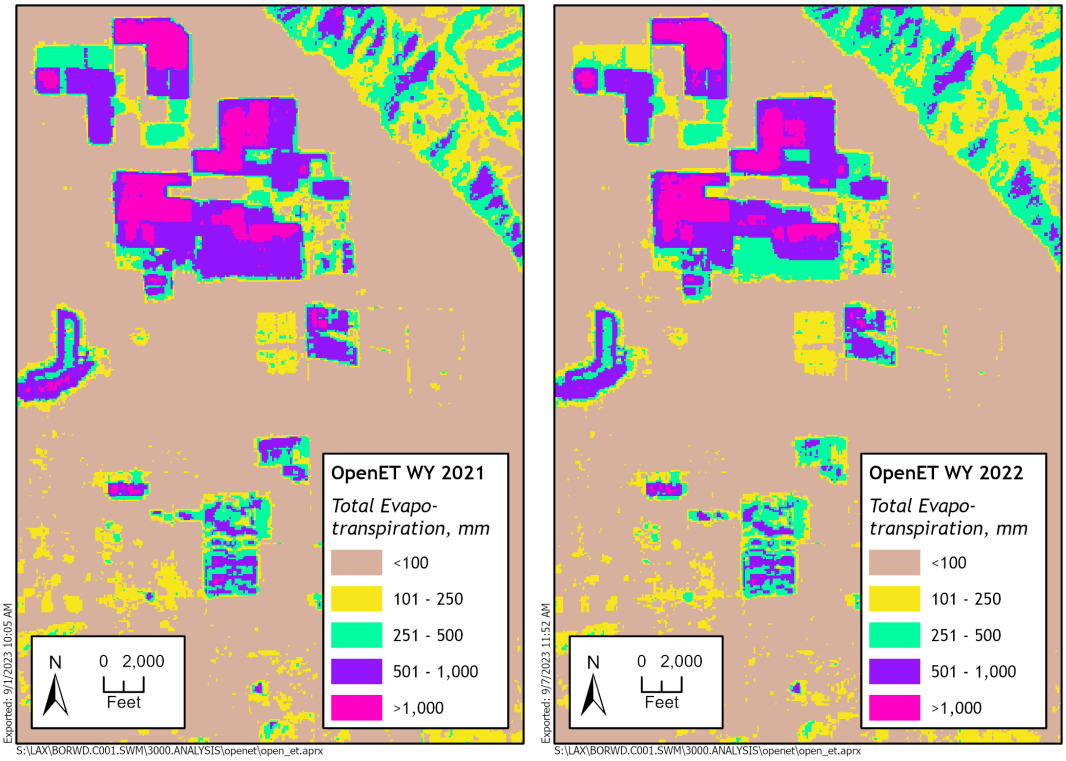
Figure 1. Selected and Filtered Agricultural Polygons

INTERA has completed a preliminary comparison of actual evapotranspiration (ET) as measured by OpenET to metered pumping for selected agricultural areas in the Subbasin for WY 2021 and WY 2022. OpenET is a gridded dataset of ET across the Western United States comprising six sub-models as well as an ensemble model, which was used in this exercise. The data are made available on the Google Earth Engine (GEE) cloud computing platform at a 30-meter resolution on a monthly timestep for calendar years 2016 to 2022.

The first step was to identify agricultural polygons on which to perform the analysis. A geographic information systems (GIS) shapefile of agricultural polygons developed for the Baseline Pumping Allocation (BPA) evaluation was used to define the area of interest. The polygons were preprocessed in the following ways: 1) an inward buffer of 15 meters was applied, to ensure that the 30-meter OpenET pixels fall fully within the polygon; 2) filtered to only include polygons with ≥30 pixels (approximately 6.5 acres), for improved statistical validity; 3) filtered to only include polygons with higher-than-background ET for ≥9 months for each water year

for improved signal to noise characteristics; and 4) associating groups of polygons with metered well pumping records. Figure 1 shows the original, buffered, and filtered polygons, grouped by owner. These groups were manually matched to the well pumping records using the best available information. Not all groups were able to be matched.

A script was used to extract the gridded monthly OpenET data from the GEE platform and used to compute the average the ET values (in millimeters) for each of the agricultural polygons. The cumulative ET for each water year is shown in Figures 2a and 2b.



Figures 2a and 2b. Cumulative Evapotranspiration for Water Years 2021 and 2022

The monthly ET data was converted to acre-feet and plotted against the metered pumping values (Figure 3). The resulting scatterplot shows a strong correlation coefficient of 0.87, indicating a good match between measured ET and metered pumping. However, some polygon groups (notably the dark blue and green groups) show much more pumping than ET, possibly indicating that not all agricultural fields supplied by these wells were successfully matched to the pumping records. Conversely, the orange group shows a number of months with ET of approximately 10 to 25 acre-feet without any associated pumping, another indication that the matching of metered wells to actual supplied acreage is an area for improvement.

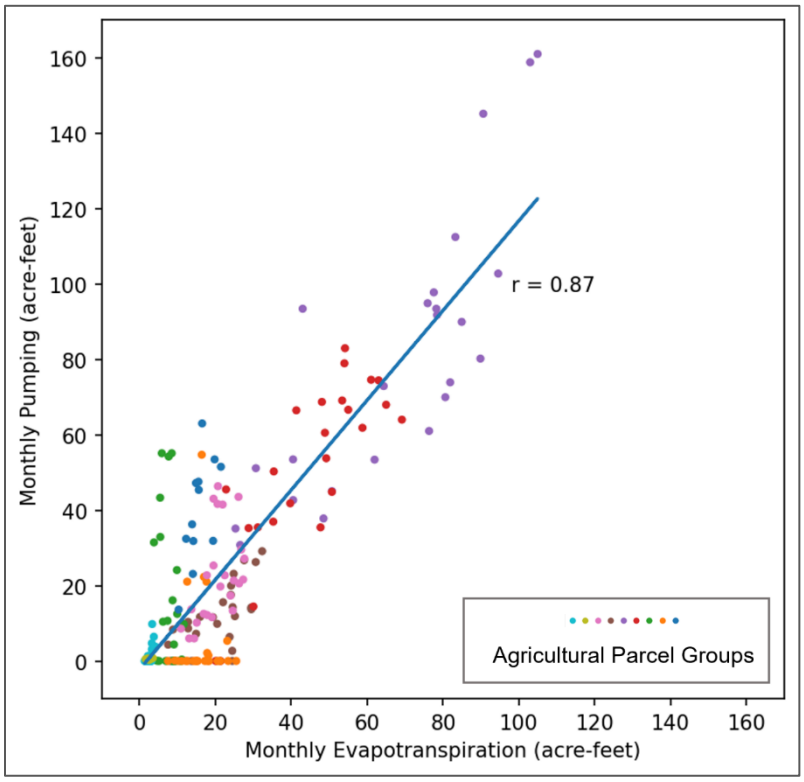


Figure 3. Correlation of Evapotranspiration and Pumping

The OpenET data provides a good estimate of metered pumping and may be used to help verify metered data or as proxy when metered data is not available. The OpenET data may be used to help constrain estimated FMP pumping for the current available 5-year period for calendar years 2016 to 2022 and back to 1985 once OpenET releases the historical data set.

West Yost presented a comparison of the January 2016 to September 2022 Open ET data to the active farms in the FMP using monthly data and the ensemble ET value[1] (Figures 4a and 4b). The Open ET data indicated average annual ET of 12,200 acre-feet per year (AFY) and the FMP data[2] indicated average annual ET of 14,700 AFY.

Figure 5 shows that the January 2016 to September 2022 average annual difference in ET by farm (OpenET minus FMP). The FMP calculated ET is greater than the OpenET data by 2,500 AFY. Closer inspection of the spatial distribution of the 2016 to 2022 Difference in ET indicates that Open ET underestimates ET compared to FMP for several Farm IDs. This 19 percent difference may partially be attributed to the OpenET model (ensemble ET value) used or may be a result of the coarse grid size of the FMP.

[1] The OpenET ensemble ET value is currently calculated as the average of all models after excluding outliers. Outliers are flagged and removed based on the median absolute deviation (MAD) approach, using a threshold of +/- 2*MAD (OpenET 2024; see Attachment B, Methodologies).
[2] Farm Process ET is estimated based on knowledge of crop type, crop area, and reference ET for each "Water Balance Subregion" in the FMP using a monthly timestep and spatial resolution of approximately 600 meters[2].

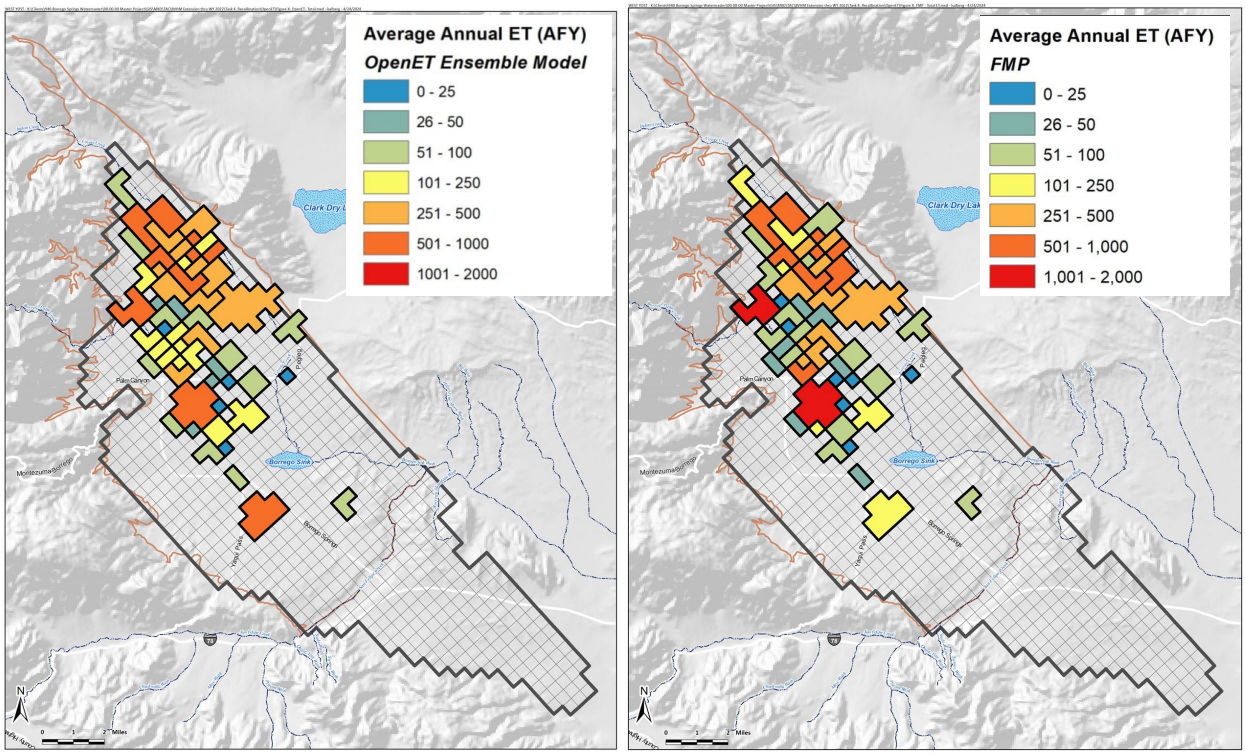


Figure 4a and 4b. 2016 to 2022 Average Annual Open ET (Ensemble Model) and FMP ET, West Yost 2024

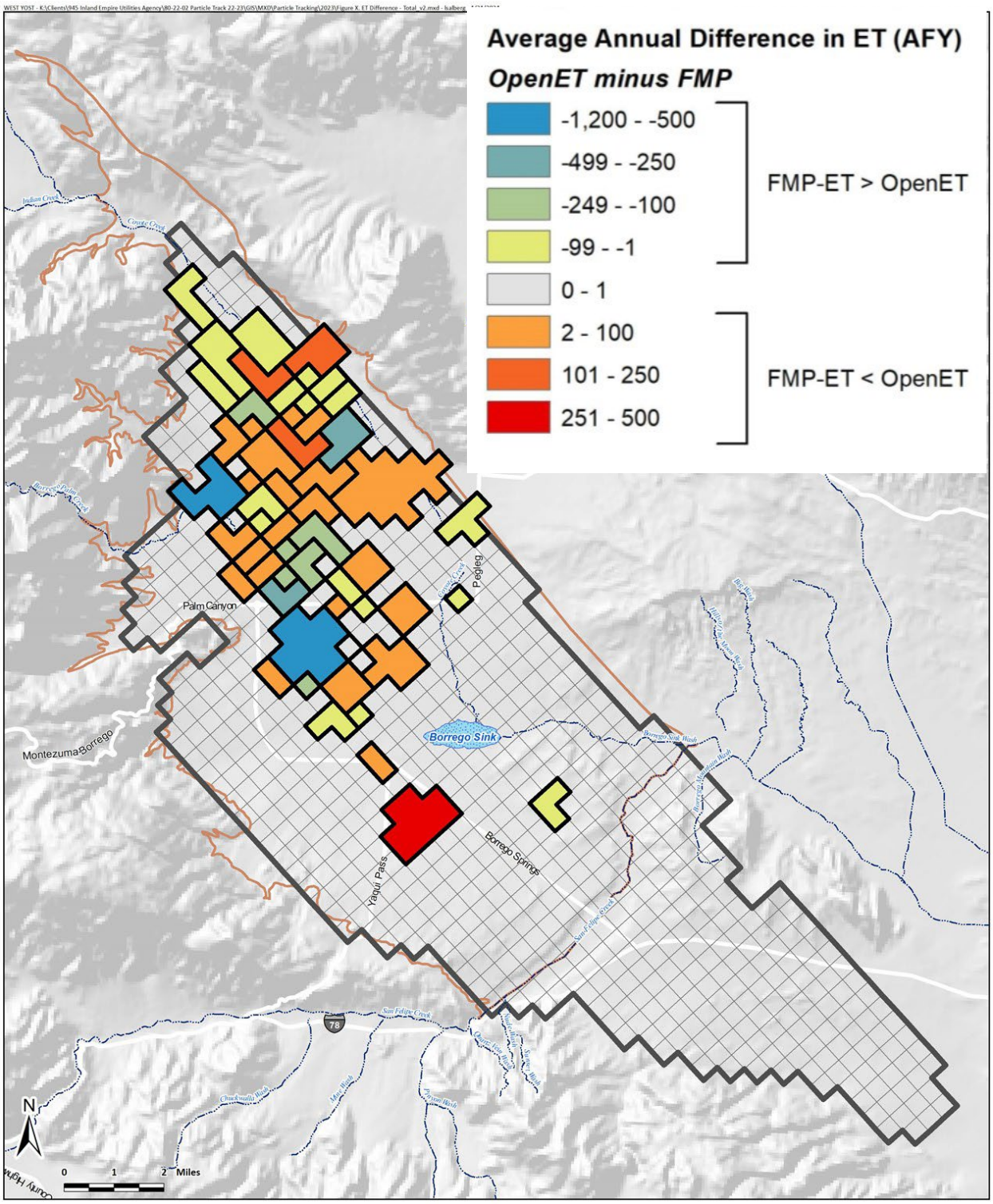


Figure 5. 2016 to 2022 Difference in ET (OpenET minus FMP Pumping) West Yost, 2024

CIMIS Data and OpenET Reference Evapotranspiration

Reference evapotranspiration (ETo) data in the Borrego Springs Subbasin is available from California Irrigation Management Information System (CIMIS) Station No. 207 and operated and maintained by the California Department of Water Resources (DWR). Data from CIMIS Station No. 207 is available from January 2008 to April 2024 as displayed in Figure 4 and provided in Attachment A (DWR 2023). It is recommended that CIMIS Station No. 207 be compared to the Basin Characterization Model (BCM) data downscaled from Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate data used by the Borrego Valley Hydrologic Model (BVHM). Note declining ETo documented from 2017 to 2023. DWR was contacted by INTERA in 2023 to verify calibration of Station No. 207; however, as of to date no response has been received from DWR.

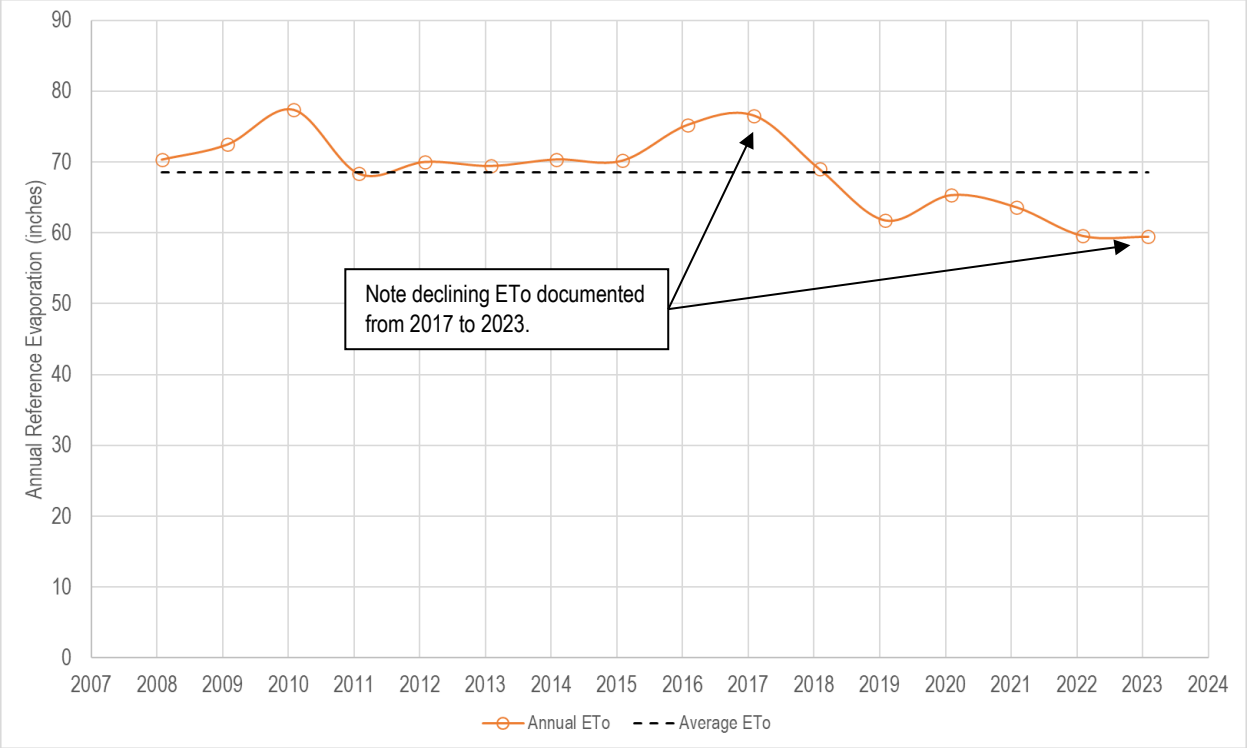


Figure 6. Calendar Year Reference Evapotranspiration (ETo) Totals for Borrego Springs CIMIS Station No. 207 from 2008 to 2023 (inches)

Closer inspection of the monthly CIMIS Station No. 207 and comparison to the available monthly OpenET Reference Evapotranspiration indicates that the CIMIS Station appears to underpredict maximum ETo and that for a period around September 2022 CIMIS Station 207 was out of service potentially for maintenance (Figure 7). We recommend that additional quality assurance/quality control be performed

to evaluate the CIMIS Station 207 calculation of ETo using the hourly data[3]. In particular, the station specific cloud factors values used in the CIMIS Penman equation for Station 207 should be evaluated to determine if they are appropriate for the site-specific conditions in Borrego Springs.

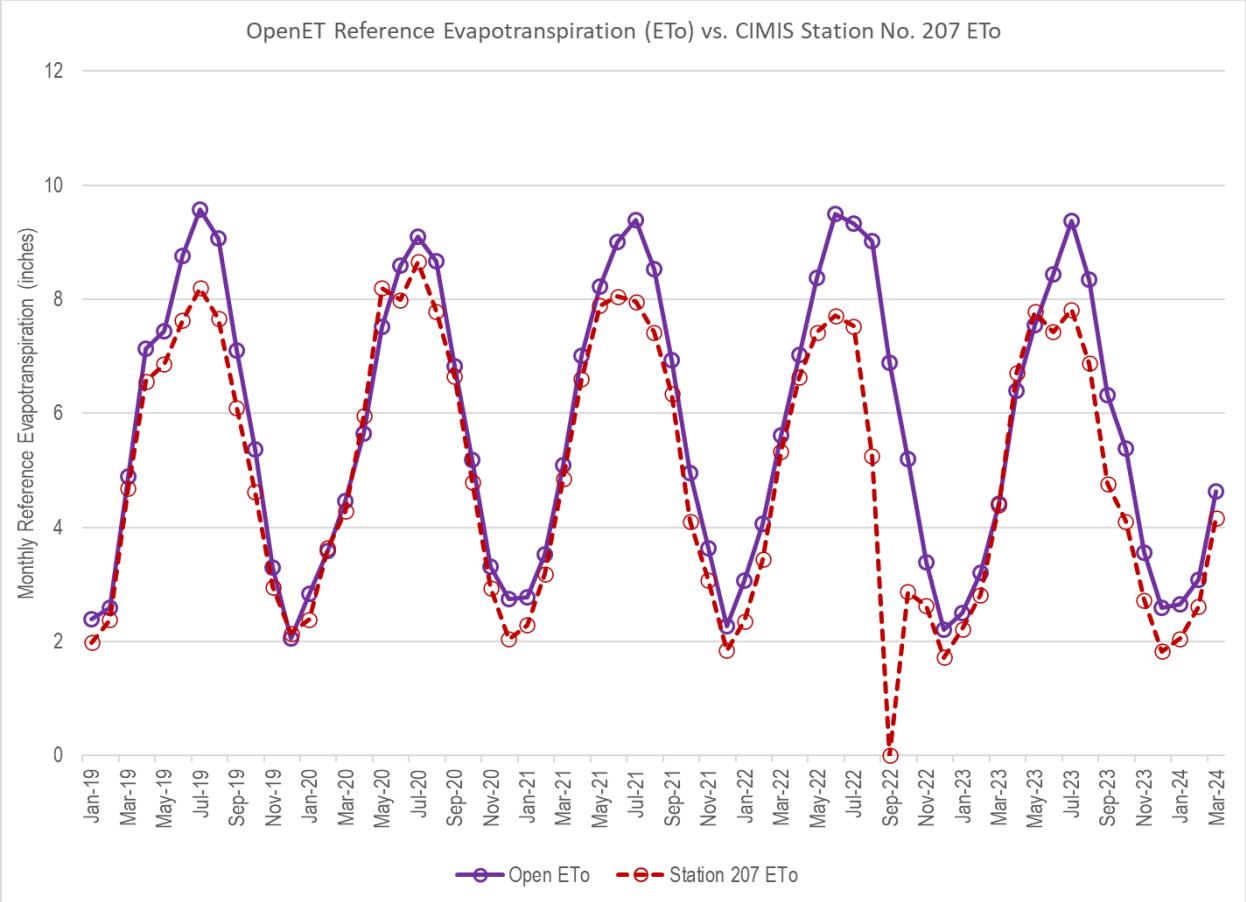


Figure 7. Monthly OpenET Reference Evapotranspiration (ETo) and CIMIS Station 207 (inches)

Conclusions and Recommendations

As per the March 29, 2024 TAC meeting consensus, OpenET should be used to validate the ability of the FMP to estimate crop demands; however it is premature to use the data directly at this time in the 2025 Redetermination of the Sustainable Yield. INTERA concurs that OpenET should be evaluated to provide a validation check on the ability of the FMP to estimate ET. As previously described, a preliminary analysis

[3] The CIMIS version of the Pruitt/Doorenbos modified Penman equation uses a wind function developed at the University of California, Davis and unique cloud factor values for each station location to calculate "CIMIS ETo." Because of those modifications, the equation is referred to as the "CIMIS Penman" equation (CIMIS 1998).

of OpenET data provided a good estimate of metered pumping and may be used to help verify metered data or as proxy when metered data is not available.

INTERA offers the following recommendations on how to use OpenET as a validation check to estimate historical water use in the Borrego Springs Subbasin:

- INTERA was able to use OpenET data to achieve a good estimate of metered pumping using the agricultural polygons developed for the BPA. The spatial resolution of the FMP is approximately 600m x 600m (89 acres) and the spatial resolution of the OpenET is 30m x 30m (0.22 acres). While we understand that the scale of the grid size for each "Water Balance Subregion" in the FMP is driving the scale of the analysis, this spatial scaling will inherently introduce error. As such, to compare the OpenET more accurately with metered pumping, we recommend that in addition to the "Water Balance Subregion" analysis that separate analysis be performed at the field scale (i.e., BPA polygons). This will inform whether future updates to BVHM require finer discretization of land use.
- Sample time series shown during the TAC meeting in the OpenET online viewer and reported for CIMIS Station No. 207 (Figure 6 and 7) indicate a decrease of ETo. Evaluate the ETo time series used by OpenET by comparing with other stations and forcings. For California, OpenET uses Spatial CIMIS meteorological datasets generated by the DWR to compute American Society of Civil Engineers grass reference ET[4]. Review of the Borrego Springs CIMIS station timeseries indicates a possible recent anomaly at CIMIS station No. 207 with the last 5 years of the 16-year record below the long-term average ETo (Figures 6 and 7). Reference ET values produced by CIMIS and OpenET could be scaled to a revised ETo, if necessary.
- Evaluate weighted area crop coefficient (Kc) approach as opposed to calculating a single Kc value per model cell. The fraction of ETo from OpenET could be used to evaluate the methodology to estimate Kc.
- Check which OpenET models are being excluded from the model ensemble and contrast with models suitable for the conditions of the area based on literature review, the approach recommended in Attachment B for arid environments and feedback from the TAC meeting.

We understand that the current scope of work and schedule to Redetermine the Sustainable Yield by 2025 require use of the FMP and associated scale of analysis. To better understand the potential error introduced by scale, especially for land use, we recommend that in addition to performing the analysis at Water Balance Subregion-level in the FMP that the same analysis should be performed at the BPA polygon scale to evaluate which approach provides a better fit. While this analysis is not necessary to complete the current scope of work, it will inform the potential error introduced by the FMP limitations described in the presentation (i.e., coarse grid cell size does not always match the farmed area and account for in farm variations in crop density and consumptive use).

INTERA looks forward to working with the TAC and Borrego Springs Watermaster staff to further improve historical water estimates within the Borrego Springs Subbasin.

[4] https://etdata.org/methodologies/

References

CIMIS (California Irrigation Management Information System), 1998. Technical Elements of CIMIS. California Department of Water Resources. December 1998. https://cimis.water.ca.gov/Content/PDF/Technical%20Elements%20of%20CIMIS%20(1998).pdf

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Attachment A
CIMIS Data for Station No. 207

Monthly and Yearly Reference Evapotranspiration (ETo) Totals for Borrego Springs CIMIS Station No. 207 from 2008 to 2024

Year[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (Inches)	Annual Total (Feet)
2008	0.46	3.43	6.16	7.6	9.3	10.02	9.07	6.76	6.77	5.13	3.36	2.27	70.33	5.86
2009	2.68	5.16	5.69	7.07	8.76	8.28	8.87	8.71	7.21	5	3.08	1.96	72.47	6.04
2010	2.41	3.21	8.81	9.84	8.58	9.22	9.51	9.11	7.44	4.36	2.88	1.98	77.35	6.45
2011	2.68	3.35	5.55	7.12	8.77	8.23	7.98	8.47	6.43	4.92	2.72	2.11	68.33	5.69
2012	2.85	3.56	5.33	6.77	7.66	9.47	8.77	8.04	7.09	5.04	3.2	2.23	70.01	5.83
2013	2.54	3.57	5.75	7.56	8.64	9.02	8.01	7.57	6.46	5.05	3	2.27	69.44	5.79
2014	2.67	3.66	5.94	7.23	8.66	9.13	8.83	8	6.97	4.55	3.14	1.58	70.36	5.86
2015	2.17	3.54	5.82	7.22	7.96	8.51	8.76	8.74	6.54	5.15	3.37	2.4	70.18	5.85
2016	2.42	4.15	6.35	7.44	8.97	9.79	10.17	8.91	6.51	5.17	3.37	1.99	75.24	6.27
2017	2.33	3.28	6.27	8.18	9.14	10.2	9.7	9.43	6.99	5.38	3.16	2.47	76.53	6.38
2018	2.77	3.44	5.39	7.66	8.64	9.12	8.64	8.01	6.46	4.23	2.95	1.68	68.99	5.75
2019	1.98	2.38	4.69	6.56	6.86	7.63	8.2	7.66	6.1	4.62	2.96	2.14	61.78	5.15
2020	2.39	3.64	4.28	5.96	8.2	7.99	8.66	7.79	6.65	4.8	2.94	2.04	65.34	5.45
2021	2.29	3.19	4.85	6.6	7.89	8.05	7.96	7.42	6.34	4.11	3.07	1.84	63.61	5.30
2022	2.36	3.44	5.33	6.64	7.42	7.71	7.53	5.25	6.71	2.87	2.63	1.72	59.61	4.97
2023	2.22	2.82	4.39	6.71	7.78	7.43	7.82	6.88	4.77	4.11	2.73	1.83	59.49	4.96
2024	2.05	2.61	4.17	6.3										
15-Year Average	**2.45**	**3.49**	**5.63**	**7.24**	**8.26**	**8.65**	**8.63**	**8.00**	**6.58**	**4.62**	**3.01**	**2.02**	**68.58**	**5.72**

Notes: Provisional Data. Additional quality assurance/quality control of CIMIS data to be completed.

a. 2008 does not have a complete record for January and is not included in the 15-Year Average.

Item V.F

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Attachment B
Calculating the OpenET Ensemble Value

Differences in model physics, assumptions, and input data result in a range of ET estimates from the ensemble of models included in OpenET. The use of multi-model ensembles is a common practice within the climate science, hydrology, and decision-making communities. For many applications, it has been shown previously that when estimates from an ensemble of models are combined, they yield estimates that are, on average, equally or more accurate than any individual model (Thompson, 1977; Branzei et al., 2001; Kirtman et al., 2014; Arsenault et al., 2015). In addition to improved accuracy, the use of a single estimate calculated from an ensemble of ET models reduces confusion about which ET model to use, provides a path toward acceptance and consistency, and is useful for identifying both model outliers and potential errors in ground-based ET datasets. In cases where ET estimates vary substantially, legitimate questions around model accuracy and which model is "the best" can present significant barriers to the operational use and adoption of satellite-based ET data. A key objective of OpenET is to provide a single ET estimate for each location and time step, calculated from an ensemble of six models, while making individual model results available to provide transparency and support assessment and increased understanding of uncertainties. The use of a single ET value calculated from the ensemble of models can reduce barriers to use and adoption of remotely-sensed ET for a wide range of water management applications.

Many multi-model ensemble averaging approaches exist, ranging from the simple arithmetic average, weighted average, to stochastic Bayesian model averaging. Each approach has strengths and weaknesses related to simplicity, speed, accuracy, and ease of operational implementation. The optimal approach ideally addresses most, if not all, of these factors. Limitations due to small sample size, outliers, and overfitting also need to be considered.

For OpenET, a simple yet robust approach was chosen where the single ensemble ET estimate is computed at monthly time steps as the simple arithmetic average after outlier ET estimates are removed. Outlier ET estimates are detected and removed using the Median Absolute Deviation (MAD) method initially developed by Carl Friedrich Gauss, and more recently rediscovered and popularized by Hampel (1974) and Leys et al. (2013). The MAD is a measure of scale, or spread of the data, based on the median of the absolute deviations from the median of the distribution. Huber (1981) describes the method as "the single most useful ancillary estimate of scale" since it overcomes many limitations of more common standard deviation and interquartile approaches for identifying outliers. The MAD parameters used for identifying outliers were a multiplier of 2, which is a commonly used cutoff for screening outliers, and an additional scaling factor of 1.4826 applied to the MAD, which is a theoretically derived value related to the assumption of normality in the sample data (Rousseeuw and Croux, 1993). A refinement was added to the MAD outlier detection approach to account for the small size of the OpenET ensemble of models. Rather than exclude all models that may be flagged as outliers, a minimum of four models was always retained to calculate the single ensemble value. This approach still consistently eliminates outliers in most settings, while also taking advantage of an ensemble of models to improve the accuracy of ET estimates, especially for desert areas during the warm season where many, but not all models commonly estimate ET at or near zero.

From close inspection of the ensemble average, median, and individual model ET estimates, both spatially and temporally, it is clear that all models can produce erroneous ET estimates, and that these

errors include both random and systematic errors. These erroneous ET estimates are often easily identified as outliers relative to the ensemble average and median. In some instances, however, the 'outlier' ET estimates may be the more correct estimate, though comparison against data collected from 148 eddy covariance stations shows that this is a rare occurrence. In other cases, the range of model results is large enough that the MAD approach fails to detect and remove outliers. Results from application of the MAD approach, using a threshold of plus-or-minus two times the MAD to eliminate outliers, indicate that it is rare that more than one model is dropped within cropland areas. Where one or more models are dropped within cropland areas, these models are usually estimating significantly lower ET than the majority. These limited instances mostly occur in arid to semi-arid regions where advection plays an important role in the land surface energy balance. In mountainous and complex terrain, one or more models are commonly dropped due to generation of ET estimates at extreme ends of the ensemble range, likely due to differences in model physics and assumptions for these regions. In rainfed arid and semi-arid grasslands and desert regions with low vegetation cover, it is common that two models are dropped due to complexities in estimating and accounting for precipitation and soil water balances, and accurately representing the land surface energy balance when ET is exceptionally low, or near zero.

There are some circumstances in which the MAD approach fails to detect outliers. When the range of modeled ET is large relative to the ensemble median, the utility of the MAD outlier detection approach (and others) is limited, and models with systematic biases may not be flagged as outliers and removed prior to calculation of the ensemble average. As a result, it is possible in some regions for models with local or regional systematic biases to be included in the calculation of the OpenET ensemble value.

Based on the OpenET team's experience, and results of the intercomparison and accuracy assessment to date, the ensemble average value appears to provide the most reliable and stable estimate of ET for expansive regions with well-watered crops, and for many natural land cover types. Examples include most of California's Central Valley and Delta, and most agricultural regions in the Midwest. However, from the limited number of cropland in-situ flux stations located in arid and semi-arid environments, it is evident that some models have a systematic low bias for smaller agricultural areas in arid regions, and the MAD outlier filtering approach does not filter outliers as desired due to the large range in model estimates. This can result in a low bias for the ensemble ET value. These areas are often indicated by a wide range of ET estimates across the ensemble of ET models for the majority of fields within a region. Over the coming months, the OpenET team will continue to conduct additional research in these more challenging settings and develop a Best Practices Manual that will provide more region and application specific guidance. Note that the ensemble value is likely to evolve in the coming year as the team conducts additional research and designs more region-specific approaches for calculation of the ensemble ET value. We strongly encourage users to rely upon their knowledge of local conditions in applying the ensemble ET value, or selecting a single model or subset of models for use in their application. When the Best Practices Manual is complete, it will be made prominently available on the OpenET website.

Item V.F

Lauren Salberg

From: Andy Malone
Sent: Friday, May 3, 2024 9:27 AM
To: Lauren Salberg; Eric W.H. Chiang
Subject: FW: Open ET validation

Follow Up Flag: Follow up
Flag Status: Flagged

FYI

From: Tom Watson <tom.watson@aquilogic.com>
Sent: Friday, May 3, 2024 9:23 AM
To: Andy Malone <amalone@westyost.com>; LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>; Trey Driscoll <tdriscoll@intera.com>; John Peterson <petersonenv@hotmail.com>; Robert Wagner <rcwagner@wbecorp.com>; Leonardo Urrego-Vallowe <lurrego@wbecorp.com>; Russ Detwiler <detwiler@uci.edu>
Cc: Shannon Smith <shannon@ramshill.com>; Cathy Milkey <cmilkey@considinecos.com>
Subject: Open ET validation

Andy,

Per your request and based on our review of the various Open ET methods, and our discussion at the TAC earlier this week, we are recommending that the Watermaster utilize geeSEBA and EMETRIC Open ET ranges to help validate the modeled FMP estimate of ET for the 2025 update report. The rationale for this recommendation is the subject methods are, in our opinion, the only ET methods that are best suited for the physical and hydrogeologic conditions found in Borrego.

Best,

Tom

Thomas Watson, P.G.

Principal Geologist

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Item V.F

Lauren Salberg

From: John Peterson <petersonenv@hotmail.com>
Sent: Saturday, May 4, 2024 11:07 AM
To: Andy Malone; LUEG, GroundWater, PDS; Trey Driscoll; Tom Watson; Robert Wagner; Leonardo Urrego; Russ Detwiler
Cc: Samantha Adams; Lauren Salberg; Eric W.H. Chiang
Subject: Re: Notice of Ad-Hoc Technical Advisory Committee Meeting on May 1, 2024 at 9:00 am

Thanks much Andy. I do not have direct knowledge of working with OpenET and as a result I do not have any recommendation in regard to the incorporation of the program into the calibration process.

JP

John Peterson
Peterson Environmental Services
California Professional Geologist #3713 Certified Hydrogeologist #90
P.O. Box 512 Borrego Springs Ca. 92004
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From: Andy Malone <amalone@westyost.com>
Sent: Wednesday, May 1, 2024 2:22 PM
To: LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>; Trey Driscoll <tdriscoll@intera.com>; John Peterson <petersonenv@hotmail.com>; Tom Watson <tom.watson@aquilogic.com>; Robert Wagner <rcwagner@wbecorp.com>; Leonardo Urrego <lurrego@wbecorp.com>; Russ Detwiler <detwiler@uci.edu>
Cc: Samantha Adams <sadams@westyost.com>; Lauren Salberg <lsalberg@westyost.com>; Eric W.H. Chiang <echiang@westyost.com>
Subject: RE: Notice of Ad-Hoc Technical Advisory Committee Meeting on May 1, 2024 at 9:00 am

Thank you for attending today's ad-hoc TAC meeting on the subject of using OpenET during ***Task 4 – BVHM Recalibration***. The meeting presentation and recording have been posted to the website here. The Board's intention is to maintain TAC consensus on the methods being employed to Redetermine the Sustainable Yield by 2025. The Board will receive a report from me on the outcome of the TAC meeting and this follow-up email correspondence.

As you may recall, following the March 29 ad-hoc TAC meeting, there was unanimous TAC agreement that:

- OpenET *should* be used to validate the ability of the FMP to estimate crop demands, and