Borrego Springs Watermaster
Technical Advisory Committee Meeting
December 18, 2023
AGENDA ITEM V

To: Technical Advisory Committee (TAC)

From: Andy Malone, PG and Eric Chiang, PhD (West Yost)

Date: December 11, 2023

Subject: Task 4 to Redetermine the Sustainable Yield by 2025— *Model Recalibration Methods*

Background and Objectives

The Borrego Valley Hydrologic Model (BVHM) and its supporting tools, the Basin Characterization Model (BCM) and the Farm Process (FMP), were originally developed by the USGS[1] and were used to improve the hydrogeologic understanding of the Borrego Springs Subbasin (Basin) and evaluate future management scenarios that would eliminate conditions of overdraft (initial BVHM).

The initial BVHM was updated and extended by Dudek and used to simulate historical groundwater conditions from October 1929 through September 2016 (2016 BVHM).[2] The 2016 BVHM results were used to characterize the water budget for the Basin and estimate the Sustainable Yield for the Basin at 5,700 acre-feet per year (afy).

Section II.E of the Judgment established the initial Sustainable Yield at 5,700 afy and requires it to be redetermined by January 1, 2025 through a process that includes: collecting additional data, refining the BVHM, and using model runs to update the Sustainable Yield.

As a first step, and based on the TAC recommendations, the Watermaster Board approved a technical scope of work to extend the BVHM from WY 2016 through WY 2021 and to use the model results to recommend additional model updates and/or model recalibration (if any) that are necessary to redetermine the Sustainable Yield by 2025. West Yost performed this work in 2022 and published a technical memorandum (2021 BVHM TM)[3] documenting the model results and recommendations. In summary, the conclusions of this work were:

- The BVHM significantly underestimates groundwater pumping.
- Several other errors and discrepancies were identified in the BVHM. Some of these errors relate to the assignment of recharge in the BVHM, which could adversely impact

[1] USGS. 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California.
[2] Dudek. 2019. Update to USGS Borrego Valley Hydrologic Model for the Borrego Valley GSA (draft final).
[3] West Yost. 2022. Extension of the Borrego Valley Hydrologic Model through Water Year 2021. Prepared for the Technical Advisory Committee of the Borrego Springs Watermaster. September 21, 2023.

the ability of the BVHM to accurately estimate the water budget and Sustainable Yield of the Basin.

Based on this work, and in consideration of a TAC-majority recommendation, 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. Exhibit 1 (attached) provides a detailed description, schedule, and cost estimate for each approved task. Table 1 below summarizes the Board-approved scope of work with a cost estimate of $348,204.

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**

West Yost has completed Task 1, Task 2, and Task 3, and is now proceeding with Task 4—*Model Recalibration.* The objective of model recalibration is to improve the ability of the BVHM to estimate hydrology of the groundwater basin, including groundwater elevations, groundwater pumping, and the water budget. The water budget, as estimated by the BVHM, will be used to redetermine the Sustainable Yield of the Basin in Task 5.

The objective of this memorandum is to describe the proposed methods to perform Task 4 - *Model Recalibration* for TAC review and comment.

Previous Calibration/Validation of the BVHM

The initial BVHM is a three-layer, finite-difference, numerical, groundwater-flow model of the Borrego Valley. The initial BVHM was calibrated by the USGS[1] by using manual trial-and-error and automated parameter-estimation methods. The automated nonlinear regression-based parameter-estimation software, referred to as PEST, was used to help with the calculation of sensitivities and parameter estimation. The model was calibrated over the historical period of October 1945 through December 2010, although the total simulation period was from October 1929 through December 2010, with the years 1930–45 used as a model "spin-up" period.

The objective of the model calibration was to determine the set of parameter values that minimized misfits (residuals) between model-simulated and observed values. The main calibration targets were the time-series of observed groundwater levels at wells. However, some qualitative information and observations were also used, such as visual comparison of simulated versus hand-drawn groundwater

elevation contour maps and visual observations of surface water discharge in San Felipe Creek and the Borrego Sink during very wet years.

The types of parameters that were adjusted during model calibration included:

- Hydraulic conductivities, such as vertical and horizonal conductivities of the aquifer-system sediments in model layers 1-3; vertical hydraulic conductivity of the streambed; and the vertical hydraulic conductivity of within the unsaturated zone.
- Storage properties, such as specific yield and specific storage of model layers 1–3 and the saturated water content and initial water content of the unsaturated zone.
- Scalar multipliers for runoff and underflow from the upstream portions of the watershed.
- Scalar multipliers over time for irrigation efficiencies, crop coefficients, and fractions of runoff both from precipitation and irrigation.

The number of model parameters to be estimated was large and many vary over space and/or time. Therefore, model parameterization techniques, such as zonation, were used to estimate a limited number of parameter values that sufficiently defined the simulated processes. Some of the parameters were specified, and 137 parameters were estimated during the automated calibration process (within ranges of reasonable values).

The calibration results indicated that the overall fit of model-simulated versus observed groundwater elevations at about 73 wells was generally good. The trends in simulated groundwater levels generally followed the observed declines over time, and simulated groundwater-elevation contour maps generally matched contour maps drawn from observed data. About 90 percent of the residuals (observed minus simulated groundwater elevations) were between −20 and +20 ft, and more than 50 percent were between −5 and 5 ft. The comparison showed little bias as indicated by an average residual of 0.1 ft and the relatively small magnitude of most of the residuals. Overall, the residuals tended to underestimate groundwater levels slightly (positive residuals). The residuals ranged from −100 to 53 ft and the standard deviation and root mean square error (RMSE) were both approximately 17 ft.

As stated previously, Dudek updated and extended the BVHM in 2019 and used it to simulate historical groundwater conditions from October 1929 through September 2016. Dudek conducted an exercise of model validation over the extended simulation period (January 2011 to September 2016) to evaluate the model's ability to accurately predict future conditions. The model validation results indicated a similar goodness of fit between simulated and observed groundwater elevations compared to the USGS calibration results.

Description of the Updated 2022 BVHM (model version that will be calibrated)

The initial tasks to Redetermine the Sustainable Yield by 2025 included various model updates, evaluations, and improvements to the BVHM:

- ***Task 1 – Extend the BVHM through WY 2022 and compare FMP-estimated pumping to actual metered pumping in WY 2021 and 2022***. In this task, the BVHM was extended from 2016 through 2022 and then re-ran from WY 1930 through WY 2022. The model results were

then evaluated to compare FMP-estimated pumping to actual metered pumping in WY 2021 and 2022. The evaluation showed that the FMP significantly underestimates groundwater pumping, which indicated that the water-use factors used in the FMP to estimate actual ET and groundwater pumping are inaccurate, and hence, the BVHM needs to be improved and recalibrated.

- ***Task 2 – Update Water-Use Factors in the FMP***. In this task, the water-use factors used in the FMP were evaluated and updated to more realistic/defensible values to improve the ability of the FMP to estimate pumping. The two water-use factors that were updated were: crop coefficient (KC) and on-farm efficiency (OFE), or irrigation efficiency. These updates improved the ability of the FMP to estimate groundwater pumping in WY 2021 and 2022. However, the updated OFE values are probably not reflective of historical irrigation methods in the Basin because historical irrigation methods (e.g., flood and furrow irrigation) were likely less efficient than current irrigation methods. West Yost recommended that, during model recalibration, historical OFE values should be revised to reflect the evolution of irrigation methods used in the Basin since WY 1946. In addition, adjustments to KC and OFE values during model recalibration, if any, should be constrained to defensible ranges.
- ***Task 3 – Correct Errors Identified in the BVHM***. In this task, several errors and discrepancies that were identified in the BVHM were corrected, and the model was re-ran from WY 1930 through WY 2022 to quantify the influence of the errors on the BVHM results. The corrections resulted in a 14% increase in annual average inflows; a 2% increase in annual average outflows; and, an 11% reduction in the average annual storage decline.

After completion of these tasks, West Yost recommends the following for the BVHM to perform ***Task 4 – Model Recalibration***:

- The geometry/layering and the spatial/temporal resolution of the model will be the same as the initial BVHM and will not be modified in this calibration.
- Use the corrected model packages developed during *Task 3 – Correct Errors Identified in the BVHM*.
- Use the updated KC and OFE water-use factors in the FMP developed during *Task 2 – Update Water Use Factors*, which includes:
    - The initial KC values for the entire model simulation period (*i.e.* no scaling).
    - The initial OFE values during recent years in the simulation period (e.g., WYs 2021 and 2022).
    - Adjusted OFE values in the historical simulation period to reflect the evolution of irrigation methods used in the Basin since WY 1946. The work to estimate the historical OFE values will be performed in Task 4.

Figure 1 is a map that displays the updated BVHM domain and the model cells that will be used to simulate the boundary conditions (e.g., mountain front recharge). These updates were developed during Task 3.

Proposed Methods for Calibration of the 2022 BVHM

Model calibration is the process of adjusting model parameters during model simulation over a historical period to produce the best match between simulated and observed system responses, such as the time series of observed groundwater elevations at wells. Typically, model parameters are adjusted during calibration (subject to reasonable bounds) using manual methods and/or automatic parameter estimation techniques.

The methods proposed to recalibrate the BVHM in Task 4 include the following:

1. **Select adjustable model parameters**. The USGS and Dudek performed model sensitivity analyses and evaluations of model uncertainty, and identified the model parameters that were most sensitive, and therefore, were most appropriate for adjustment during model calibration: water-use factors in the FMP, stream runoff and subsurface inflows to the model domain, and the hydraulic and storage properties of the aquifer sediments. Based on the USGS interpretations and the results of Tasks 1-3, West Yost recommends the following model parameters for adjustment during calibration (within defined reasonable bounds):

    - Hydraulic and storage properties of the aquifer-system sediments (by model layer)
    - Vertical hydraulic conductivity of the unsaturated zone
    - Hydraulic conductivity of the streambed channels
    - Subsurface inflows to the model domain
    - Stream runoff to the model domain

2. **Select calibration methods to adjust the model parameters**. West Yost proposes to use a combination of (i) automated parameter estimation using the software code PEST and (ii) manual adjustments of model parameters based on professional judgment. PEST minimizes the objective function (i.e., the sum of squared weighted residuals between the observed and calculated groundwater levels) by iteratively adjusting the model parameters using the Gauss-Marquardt-Levenberg method described in the PEST book[4] (Doherty, 2015) and the PEST user's manual.[5]

    The model parameters will be adjusted via two approaches:

    - The "Pilot Points" approach will be used to adjust the hydraulic and storage properties of the aquifer-system sediments. Pilot Points will be chosen to represent locations in the model domain where the parameters are allowed to vary. The parameter values of Pilot Points are interpolated to model cells during the calibration process.
    - "Scalar Multipliers" will be used to adjust all other model parameters.

3. **Select calibration period.** The USGS selected the calibration period of 1945-2010 for the initial BVHM. West Yost proposes to extend the calibration to 1945-2022. However, based on the

[4] Doherty, J., 2015. *Calibration and Uncertainty Analysis for Complex Environmental Models*. Watermark Numerical Computing, Brisbane, Australia. ISBN: 978-0-9943786-0-6.

[5] https://pesthomepage.org/documentation

results of (4) below, we may recommend a shorter calibration period with a more recent start date.

4. **Select calibration targets/data.** The main calibration targets will be groundwater-elevations at wells and surface-water discharge measurements/observations. All historical data will be charted and reviewed.

   For groundwater elevations, the calibration targets and data will be selected pursuant to the following criteria:

   - Wells should be spatially distributed across the model domain by model layer (if possible). This will require the evaluation of well screens versus model layers.
   - Groundwater-elevation measurements at wells should be evenly distributed over time. To avoid bias toward wells with high-frequency water level measurements (i.e., measurement recorded by transducers), a subset of measurements from such wells at least 30-days apart should be selected.

   For surface-water discharge, it has been observed that flood flows in stream channels to not exit the Basin except during very wet years/periods. These years/periods will be identified and used to validate the calibration results.

5. **Configure PEST settings and prepare input files for PEST**. The initial model parameter values will be based on the parameter estimates of the initial BVHM and the results of Tasks 1-3. However, updates to the initial model parameter values will be made where new data/information indicate that revisions are appropriate (e.g., new pumping test results at the Rams Hill wells). At this point, weights can be assigned to the groundwater-elevation data to reflect confidence in the data as outlined in published guidelines by Hill (1998)[6] and Hill and Tiedeman (2007).[7]

6. **Perform model calibration with PEST**. PEST will be used to minimize the objective function by iteratively updating the model parameters. At the end of the parameter estimation process, a final MODFLOW simulation will be executed with the updated parameters.

7. **Review calibration results**. The final calibration results will be displayed and analyzed as follows:

   - Table and map of final model parameters.
   - Table of calibration statistics.
   - Map of mean residual by well.
   - Table and time-series chart of the annual water budget over the calibration period.

[6] Hill, C Mary, 1998. Methods and guidelines for effective model calibration. USGS Water -Resources Investigation Report 98-4005.

[7] Hill, C. Mary and Tiedeman, R. Claire, 2007. Effective groundwater model calibration. John Wiley & Sons, Inc. ISBN: 978-0-471-77636-9.

- Scatter plots and time-series charts that compare simulated versus observed groundwater elevations at wells.
- Time series chart of simulated surface-water discharge from the model domain versus precipitation (for model validation).

If analysis of the calibration results is unsatisfactory, West Yost will repeat the above steps by modifying PEST settings, adjustable model parameters, and other input values until an acceptable calibration is achieved.

The calibration processes and results will be documented in a draft technical memorandum (TM) for TAC review. A TAC meeting will be held to review the draft TM and receive verbal feedback. TAC members will have a subsequent period to submit written comments and suggestions.

Next Steps

At the December 18, 2023 TAC meeting, West Yost will review the model calibration methods proposed herein and solicit verbal feedback from the TAC. TAC members are requested to provide comments on this TM to Andy Malone (amalone@westyost.com) and Lauren Salberg (lsalberg@westyost.com) by Monday, January 8, 2023.

Enclosures

Figure 1: *Corrected* BVHM Domain

Exhibit 1: Scope of Work to Redetermine the Sustainable Yield by 2025

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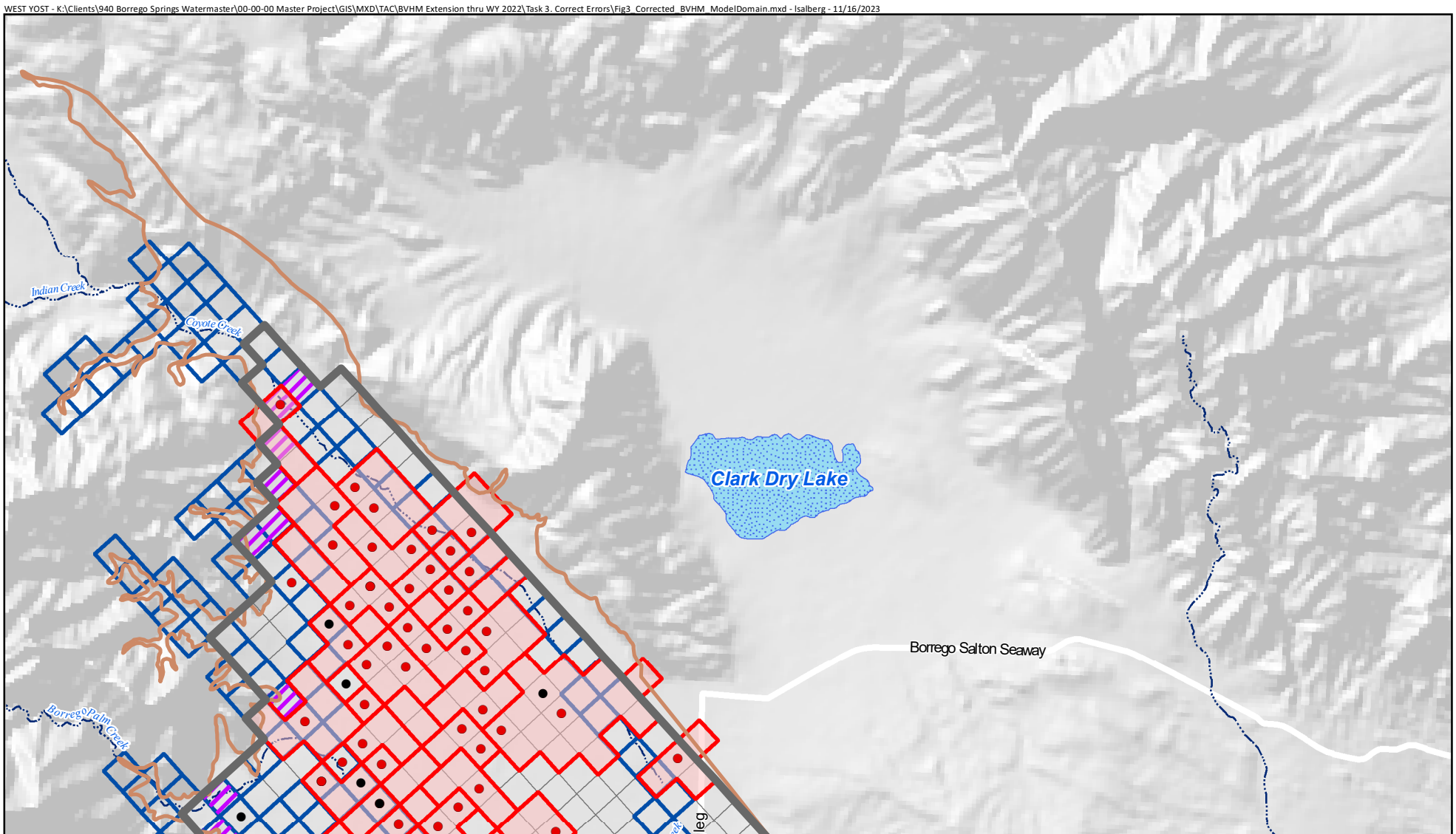


BVHM Packages

- Streamflow Routing
- Flow and Head Boundary
- Constant Head
- Non-FMP Well in MNW2 Package

Farm Process Features

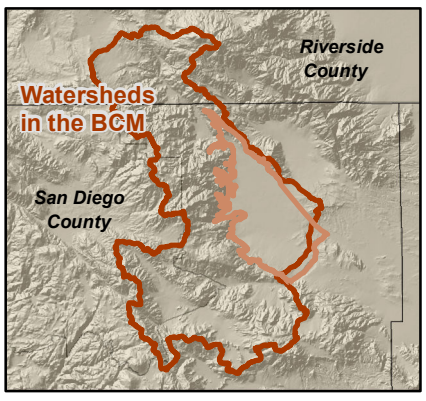
- Water Budget Subregion in the FMP
- FMP Well in MNW2 Package

BVHM Cells

- Boundary of Active Cells in the BVHM

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)
- Ocotillo Wells Groundwater Subbasin (7-024.02)



Borrego Springs Watermaster

Task 3 - Correct errors identified in the 2021 BVHM TM

Prepared by:

WEST YOST

Figure 1

Corrected

Borrego Valley Hydrologic Model (BVHM) Domain

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
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	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

[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."