Borrego Springs Watermaster
Technical Advisory Committee Meeting
December 18, 2023 @ 10:00 a.m.
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AGENDA

Items with supporting documents in the TAC Meeting Package are denoted with a page number.

I. **Roll Call**

II. **TAC Meeting Guidelines**

III. **Public Comments**
This is an opportunity for members of the public to address the TAC on items included on the agenda. Comments will be limited to three minutes per commenter

IV. **Final Technical Memorandum: *Task 3 to Redetermine the Sustainable Yield by 2025 – Correct Errors Identified in the 2021 BVHM* .... Page 2**

V. **Review TAC comments on methods for *Task 4 – Model Recalibration* to Redetermine the Sustainable Yield by 2025 .... Page 36**

VI. **Discuss potential methods for *Task 5 - Determine the Sustainable Yield* .... Page 49**

VII. **Process and Report Outline for the 5-Year Assessment of the Groundwater Management Plan....... .... Page 1 of Agenda Package Addendum**

VIII. **Status update on the expansion of the Groundwater Monitoring Program** (*time permitting, verbal update*)

IX. **Public Comments (time permitting)**
This is an opportunity for members of the public to address the TAC on items discussed during the meeting. Comments will be limited to three minutes per commenter, time permitting.

X. **Future Meetings**

XI. **Adjournment**

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

To: Technical Advisory Committee (TAC)

From: Andy Malone, PG and Lauren Salberg (West Yost), Technical Consultant

Date: December 11, 2023

Subject: Final Technical Memorandum: *Task 3 to Redetermine the Sustainable Yield by 2025 – Correct Errors Identified in the 2021 BVHM*

Background

West Yost prepared and distributed a draft technical memorandum (TM) on the methods and results of Task 3 (Draft Task 3 TM) to the TAC for review and comment on November 16, 2023. TAC members were requested to provide comments on the Draft Task 3 TM to Andy Malone (amalone@westyost.com) and Lauren Salberg (lsalberg@westyost.com) by Tuesday, December 5, 2023. The deadline was extended to Thursday, December 7, 2023 because no TAC comments had been received by the initial December 5, 2023 deadline. Two TAC members provided comments. Exhibit 1 is a table that summarizes the TAC comments and recommendations and the Technical Consultant's responses. Based on TAC comments, West Yost finalized the Task 3 TM (see Exhibit 2).

Next Steps

At the December 18, 2023 TAC meeting, West Yost will provide a summary of the Task 3 TM, present the TAC comments and responses, and facilitate any additional discussion.

The next step for the Redetermination of the Sustainable Yield by 2025 is to proceed with Task 4 – *Model Recalibration*.

Enclosures

Exhibit 1. Responses to TAC Comments/Recommendations on Task 3 to Redetermine the Sustainable Yield by 2025 - *Correct Errors Identified in the 2021 BVHM*

Exhibit 2. Final Technical Memorandum: *Task 3 to Redetermine the Sustainable Yield by 2025—Correct Errors Identified in the 2021 BVHM*

Exhibit 1. Responses to TAC Commment/Recommendations on Task 3 to Redetermine the Sustainable Yield by 2025 - *Correct Errors Identified in the 2021 BVHM*

Comments/Recommendations	TAC Member					Technical Consultant Responses
	AAWARE *Bob Wagner*	BWD *Trey Driscoll*	County of San Diego *Jim Bennett*	T2 Borrego *Tom Watson*	Roadrunner Club *John Peterson*	
Units used in the BVHM						
Has the Watermaster done a check on all of the MODFLOW input files to discern if there is any other unit conversion factors lurking in the model?				X		Yes, West Yost performed a thorough inspection of the BVHM, including the units used when the BVHM was first inherited. Upon this inspection, it was discovered that the units used in the Streamflow Routing package were incorrect (units were in feet, but the model uses meters). No additional unit errors were identified during this inspection, nor while performing any other tasks to redetermine the Sustainable Yield. Upon completion of Task 3, the units in the BVHM are consistent and correct.
No comments/responses						
No comment					X[1]	
No response	X	X	X			

Notes:

1. Responded that he has no comments on this TM on December 6, 2023.

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

To: Technical Advisory Committee (TAC)

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

Date: December 11, 2023

Subject: Task 3 to Redetermine the Sustainable Yield by 2025—*Correct Errors Identified in the 2021 BVHM*

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 water year (WY) 2016 through WY 2021 and use the model results to recommend additional model updates (if any) and/or model recalibration 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 the ability of the BVHM to accurately estimate the water budget and Sustainable Yield of the Basin.

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[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.

Based on this work, and in consideration of a TAC-majority recommendation, the Watermaster Board approved a scope of work and budget for 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 completed Task 1 and Task 2 in 2023.

This memorandum describes the methods and results of Task 3—*Correct Errors Identified in the 2021 BVHM* and quantifies the influence of the errors on the BVHM results.

Methods

In Task 3, the errors and discrepancies identified in the 2021 BVHM TM were corrected. These corrections include fixing errors in the Streamflow Routing (SFR), Flow and Head Boundary (FHB), Multi-Node Well (MNW2) packages, and in the FMP. Additionally, the screen depths of wells in the MNW2 package were compared to well construction information to validate the depth distribution of pumping in the BVHM.

Figure 1 is a map of the *Uncorrected* BVHM domain and identifies the extent of model cells assigned to the SFR, FHB, and MNW2 packages and the FMP. Table A-1 is the historical water budget for the *Uncorrected* BVHM[4] over the period WY 1945-2022.[5]

Each error was corrected individually and a version of a *Corrected* BVHM was run through WY 2022. For each version of a *Corrected* BVHM, an annual water budget was calculated for all inflows

[4] The *Uncorrected* BVHM is the 2022 BVHM that contains the errors identified and described in the 2021 BVHM TM. The *Uncorrected* BVHM does not use the updated crop coefficient (KC) and on-farm efficiency (OFE) values described and recommended in the Task 2 memo, available at: https://borregospringswatermaster.com/wp-content/uploads/2023/08/III_BVHM-Task-2.pdf

[5] Although the BVHM simulates the period of WY 1930 through WY 2022, the comparison of the average annual water budget begins in WY 1945, which is when pumping begins in the model.

(streambed recharge, unsaturated zone recharge, and subsurface inflow) and outflows (groundwater pumping, evapotranspiration [ET] of groundwater, and subsurface outflow). Tables A-2 through A-5 are the water budget tables for: the *Corrected FHB* BVHM; the *Corrected SFR* BVHM; the *Corrected MNW2* BVHM; and the *Corrected FMP* BVHM, respectively.

Once the errors in each individual model package were corrected and evaluated, the *Final Corrected* BVHM was developed and evaluated. The *Final Corrected* BVHM is the version of the BVHM with all errors corrected. The water budget for the *Final Corrected* BVHM is presented in Table A-6. Table 7 compares the average annual water budget from the *Uncorrected* BVHM to each individual *Corrected* BVHM and the *Final Corrected* BVHM to quantify the influence of the error(s) on the model results.

Results and Conclusions

This section describes the results and conclusions of Task 3 for each model package with errors identified in the 2021 BVHM TM and includes: i) a brief description of the package in the BVHM; ii) the error(s) identified in the package; iii) the corrections made to fix the errors; and iv) the impact of the error(s) on the water budget.

Flow and Head Boundary Package

Description of the FHB package in the BVHM

The FHB package is used in the BVHM to simulate subsurface inflow from adjacent upstream watersheds, including the San Ysidro and Vallecito Mountains. In the BVHM, 44 cells along the northern and western boundaries of the model domain are assigned monthly rates of subsurface inflow to specific model layers (Layers 1, 2, and/or 3). Cells assigned subsurface inflow in the FHB package are shown in Figure 1. The rates of subsurface inflow are constant over time, averaging 2,121 acre-feet per year (afy).

Error identified in the FHB package in the Uncorrected BVHM

Subsurface inflow was assigned to 17 inactive cells in Layer 1 (upper aquifer) in the FMP package of the *Uncorrected* BVHM. Because these cells are inactive in Layer 1, the subsurface inflow is essentially "lost" because it cannot be routed into the *Uncorrected* BVHM. A total of 754 afy of subsurface inflow was assigned to these 17 cells, indicating that approximately 36% of the total annual subsurface inflow (2,121 afy) was lost. As shown in Table A-1, average annual surface inflow was 1,367 afy for the *Uncorrected* BVHM water budget.

Corrections made to Corrected FHB BVHM

The subsurface inflow assigned to the 17 inactive cells in Layer 1 in the FHB package was re-assigned to an active layer or cell in the *Corrected FHB* BVHM. Most of these FHB cells were re-assigned from Layer 1 (inactive) to Layer 3 (active) in the same cell. Three FHB cells were reassigned from an inactive cell outside the model domain to an active adjacent cell within the model domain. Table 2 identifies the location (row, column, and layer) of FHB cells in the *Uncorrected* BVHM (assigned to inactive cells and/or layers) and the location of FHB cells in the *Corrected FHB* BVHM, where subsurface inflow is re-assigned so that all subsurface inflow is routed through the model. In Table 2, the re-assignment of subsurface inflow (in either the row, layer and/or column) is identified in red. Figure 2 is a map that compares the layer and location of FHB cells in the *Uncorrected* BVHM and the *Corrected FHB* BVHM.

Table 2. Assignment of Subsurface Inflow to Cells in the FHB Package in the *Uncorrected* BVHM and *Corrected FHB* BVHM

Location of Inactive FHB Cells in the *Uncorrected* BVHM			Location of Re-assigned, Active FHB Cells in the *Corrected FHB* BVHM		
Row	Column	Layer	Row	Column	Layer
12	11	1	**11**	11	1
13	12	1	13	**13**	1
27	30	1	27	30	**3**
27	32	1	27	32	**3**
27	33	1	27	33	**3**
27	34	1	27	34	**3**
27	36	1	27	36	**3**
27	37	1	27	37	**3**
27	38	1	27	38	**3**
26	42	1	26	42	**3**
25	44	1	25	44	**3**
24	47	1	24	47	**3**
24	49	1	24	49	**3**
23	50	1	23	50	**3**
22	51	1	22	51	**3**
21	54	1	**20**	54	**3**
19	57	1	19	57	**3**

Impact of errors in the FHB package on the Water Budget

The annual water budget from the *Corrected FHB* BVHM for WY 1945 through 2022 is presented in Table A-2.

Table 7 shows the average annual water budget of the *Corrected FHB* BVHM and compares it to the average annual water budget of the *Uncorrected* BVHM in (see columns *b* and *c*). Average annual subsurface inflow increased from 1,367 afy to 2,121 afy by assigning all subsurface inflow to active cells and layers in the *Corrected FHB* BVHM. Additional impacts of the correction in the FHB package on the average annual water budget include:

- Increasing unsaturated zone recharge by 6%.
- Increasing ET from groundwater by 9%. The increase in ET from groundwater is due to the increase of subsurface inflow to the *Corrected FHB* BVHM, which increased the amount of shallow groundwater available for consumption by ET.
- Increasing pumping from Non-FMP wells by 1%. As described in the MNW2 package section, several wells in the MNW2 package are unable to extract their assigned rates. The increase in

Non-FMP pumping is due to increasing the water available to be pumped by Non-FMP wells in the MNW2 package.

Streamflow Routing Package

Description of the SFR package in the BVHM

The SFR package is used in the BVHM to simulate streamflow discharge, routing, and streambed recharge across the Basin. Model cells assigned to the SFR package are shown in Figure 1. Surface-water inflow is assigned to 24 model cells along the boundary of the active cells in the BVHM to simulate runoff entering the Basin from the upstream watersheds in the San Ysidro and Vallecito Mountains. The SFR package then routes streamflow across the Basin to simulate streamflow discharge and streambed recharge in Coyote Creek, San Felipe Creek, Borrego Palm Creek, and other tributaries.

Errors identified in the SFR package in the Uncorrected BVHM

The following errors were identified in the SFR package in the *Uncorrected* BVHM:

- **Incorrect units assigned to streambed elevation.** The streambed elevation was assigned in feet to the SFR package, but the model uses meters as the length unit. This resulted in the stream being incorrectly constructed in the *Uncorrected* BVHM, where the streambed is essentially "floating" in the model domain.
- **Incorrect formatting of the SFR input file.** The first stress period of the SFR input file requires two datasets be specified to define the starting and ending widths of a stream segment.[6] These two datasets were incorrectly repeated for all stress periods in the SFR input file, which resulted in the stream segments being incorrectly connected throughout the entire simulation of the *Uncorrected* BVHM.
- **Absence of leap years.** Three leap years were unaccounted for in the SFR package of the *Uncorrected* BVHM. The SFR input file uses text files to assign monthly rates of surface-water inflow to each of the 24 cells assigned in the SFR package. In the *Uncorrected* BVHM, these surface-water inflow text files incorrectly reported February as being 28 days in length, instead of 29 days, during three leap years: February 1932, February 2012, and February 2016. Additionally, February 1931 was incorrectly reported as a leap year (assigned 29 days, instead of 28 days). The incorrect number of days assigned to these months resulted in a miscalculation of the water budget for these affected months.

[6] Data sets 6b and 6c in the SFR package are used to define WIDTH1 and WIDTH2, which establish the average width of the stream channel at the upstream and downstream segments.

Corrections made to the Corrected SFR BVHM

The following corrections were made to SFR package in the *Corrected SFR* BVHM to address the errors identified:

- **Converted units used to assign stream parameters from feet to meters**. The units used to assign streambed elevation were converted from feet to meters. Upon further review, it was identified that additional parameters, including stream slope, stream thickness, and vertical conductivity, were also reported in units of feet instead of meters in the *Uncorrected* BVHM. The units assigned to these parameters were also corrected from feet to meters. Table 3 presents the units assigned to the stream parameters in the *Uncorrected* BVHM and *Corrected SFR* BVHM.

Table 3. Stream Parameters and Units used in the *Uncorrected* BVHM and the *Corrected SFR* BVHM

SFR Parameter	Value in *Uncorrected* BVHM	Value in *Corrected SFR* BVHM
Stream Elevation	90 – 2,155 ft	27 – 657 m
Stream Slope	0 – 3.70 ft/m	0 – 1.13 m/m
Stream Thickness	15 ft	4.57 m
Vertical Conductivity	150 ft/day	45.72 m/day

- **Corrected format of SFR input file**. The format of the SFR input file was changed so that the start and end widths of the stream segment are defined only during the first stress period, which corrected the connection of the stream segments.
- **Corrected the length of timesteps.** To account for leap years in 1932, 2012, and 2016, the length of the month of February in these years was changed to 29 days (from 28 days) in each of the surface-water inflow text files. Additionally, the length of February 1931 was corrected to 28 days (from 29 days), since 1931 was not a leap year.

Impact of errors in the SFR package on the Water Budget

The annual water budget of the *Corrected SFR* BVHM for WY 1945 through 2022 is presented in Table A-3.

Table 7 shows the average annual water budget of the *Corrected SFR* BVHM and compares it to the average annual water budget of the *Uncorrected* BVHM in (see columns *d* and *e*). Overall, the corrections made in the SFR package in the *Corrected SFR* BVHM had minimal impact on the average annual water budget. The greatest impact of the errors in the SFR package on the average annual water budget was on streambed recharge, which increased by 3% in the *Corrected SFR* BVHM. This increase in streambed recharge is primarily due to the stream segments being correctly routed and the streambed widths being correctly defined. The unit correction results in a minor increase of streambed recharge.

Multi-Node Well Package

<u>Description of the MNW2 package in the BVHM</u>

Groundwater pumping from the Basin is simulated with the MNW2 package. Input data is assigned to the MNW2 package for two main sets of wells, which are shown on Figure 1:

- **FMP Wells.** Pumping at FMP wells is estimated by the FMP and assigned in the MNW2 package to satisfy water demands of the 52 Water-Balance Subregions (WBS) across the Basin (as described in the FMP section). These are fictitious FMP wells represent the actual wells that satisfy the water demands of the 52 WBS, because historically the location of the actual wells was uncertain and metered pumping data was unavailable. Figure 1 shows the locations of the FMP wells at centroids of specified BVHM grid cells.
- **Non-FMP Wells.** Pumping at Non-FMP wells is metered or estimated on a monthly time step and is assigned directly to the MNW2 package. Most of these wells are owned by the Borrego Water District (BWD) or golf courses. Figure 1 shows the location of the Non-FMP wells in the MNW2 package at the centroid of the BVHM grid cell where the Non-FMP well is located.

<u>Errors identified in the MNW2 package</u>

The errors identified in the MNW2 include:

- **Unaccounted-for pumping from following Non-FMP wells:**
  - **Rams Hill wells in WY 2014 and WY 2015**. Four wells owned by the Rams Hill Golf Course (RH-3, RH-4, RH-5, and RH-6) were installed between 2014 and 2015. All four wells began pumping groundwater from the Basin in 2015 and pumped a total volume of 1,254 acre-feet (af) from January 2015 through September 2016. However, these wells were not included in the 2016 BVHM and, therefore, the 1,254 AF of pumped groundwater was unaccounted-for in the 2016 BVHM. These wells were added to the model during the 2021 BVHM model extension, but the pumping from WY 2014 and 2015 was not assigned and remains unaccounted-for in the *Uncorrected* BVHM.
  - **Anza Borrego Desert State Park well**. The Anza Borrego Desert State Park well (Auxiliary 2) is metered but pumping from this well was not assigned to a Non-FMP well, nor was pumping estimated by an FMP well in the MNW2 package. Approximately 96.35 af of pumping from the Auxiliary 2 well from WY 2010 through WY 2022 was unaccounted-for in the *Uncorrected* BVHM.
  - **Wells unable to pump their assigned rates**. There are several wells that are assigned pumping rates in the BVHM from metered data but pumped less than the assigned rate as groundwater levels declined in the model simulation. The MNW2 package estimates the pumping capacity for a well based on the simulated groundwater level at the well. When the estimated pumping capacity is lower than the assigned rate, the estimated pumping capacity is used as the pumping rate for that well. Consequently, the well is not able to pump its assigned rate in the model.

- ***De minimis* wells**. There are an estimated 53 *de minimis* wells in the Basin that are assumed to pump a total of 26.5 afy (assuming each well pumps 0.5 afy). Pumping from these wells is unaccounted-for in the MNW2 package because these wells are not assigned pumping as Non-FMP wells, nor is pumping estimated by FMP wells.

- **Assigning groundwater pumping from two wells to one well.** The ID3 and CDZ wells are in the same grid cell in the *Uncorrected* BVHM and historical pumping from both the ID3 and CDZ wells is assigned to the same "ID3" Non-FMP well in the MNW2 package. The ID3 well was formerly owned by the Rancho Borrego Mutual Water Company and the Golden Sand Mutual Water Company, which joined BWD in 1990. ID3 has been inactive since 2011[7] and was destroyed in 2020. Pumping assigned to ID3 through from WY 1945 through WY 2016 is believed to be estimated using an evapotranspiration method. Located within the same grid cell in the BVHM is the CDZ well, which is owned by La Casa del Zorro, LLC. The CDZ well has actively pumped since 2011. During the extension of the BVHM through WY 2021, historical estimates of pumping for the CDZ well were assigned to the "ID3" model well, because the source for pumping data used in the 2016 BVHM could not be reproduced. The 2021 BVHM TM recommended to evaluate the transition of model well ID3 to the CDZ Well.

In addition to the errors identified in the MNW2 package in the *Uncorrected* BVHM, the TAC requested that the depth distribution of pumping in the MNW2 package be compared and validated against well construction information.

Corrections made to the MNW2 package in the Corrected MNW2 BVHM

The following corrections were made to MNW2 package in the *Corrected MNW2* BVHM to address the errors identified in the 2021 BVHM TM:

- **Assigned missing pumping data to address unaccounted-for pumping.** As shown in Table 4, a total of 1,350.85 af of groundwater pumping was assigned to Non-FMP wells in the MNW2 package in the *Corrected MNW2* BVHM.
  - The majority of previously unaccounted-for pumping was from Rams Hill wells RH-3, RH-4, RH-5, and RH-6 from January 2015 through September 2016. Pumping data for the Rams Hill wells was based off monthly production data reported in annual reports of production to the County of San Diego.
  - The Anza Borrego Desert State Park well, Auxiliary 2, was added to the MNW2 package and pumping was assigned for WY 2011 through WY 2022. The top and bottom screened intervals assigned in the MNW2 package for the Auxiliary 2 well were informed using the Well Completion Report for the well. Pumping assigned to Auxiliary 2 was based off multiple sources, including i) the value of production used to establish the Baseline Pumping Allocation (BPA), ii) fully and partially-estimated pumping data published in the

[7] Per correspondence with BWD staff.

WY 2019[8] and 2020[9] Borrego Springs Subbasin Annual Reports and, iii) metered production data.

Table 4. Unaccounted-for Pumping Assigned to Non-FMP Wells in the *Corrected MNW2* BVHM

Well Name	Period Pumping added to *Corrected MNW2* BVHM	Total Pumping (af)
RH-3	January 2015 –September 2016	292.10
RH-4	January 2015 –September 2016	236.60
RH-5	June 2015 –September 2016	437.40
RH-6	August 2015 –September 2016	288.40
Auxiliary 2	October 2010 – September 2022	96.35
	Total Pumping Added	**1,350.85**

- **Added the La Casa del Zorro (CDZ) well.** The CDZ well was added to the MNW2 package to resolve the confusion related to pumping assigned to the ID3 well, which was assigned historical pumping data for both the ID3 well and the CDZ well. In the *Corrected MNW2* BVHM, the CDZ well is located in the same grid cell as well ID3. The top and bottom screened intervals assigned to the CDZ well were informed using a Well Completion Report believed to be for the CDZ well. A total of 549.40 af of pumping previously assigned to the ID3 from WY 2011 through WY 2022 was re-assigned to the CDZ well. No pumping is assigned to ID3 from WY 2011 through WY 2022 to reflect the end of operation and eventual destruction of this well.
- **Evaluated Non-FMP wells unable to pump their assigned rates**. Pumping assigned to Non-FMP wells in the MNW2 package was compared to the pumping modeled by Non-FMP wells in the MNW2 package to identify which wells are unable to pump their assigned rates and how much less pumping is being modeled than assigned. Table 5 compares pumping assigned to Non-FMP wells in the MNW2 package for WY 2021 and WY 2022 (using metered pumping data) to the pumping modeled in the *Uncorrected* BVHM and *Corrected MNW2* BVHM. As shown in Table 5, wells ID3, CDZ[10], and RH-4 were unable to pump their assigned rates in WY 2021 and 2022. To identify why these wells are unable to the rates of pumping assigned, the construction information and location of these wells was evaluated in tandem with the depth distribution evaluation. See the description below related to the depth distribution for additional detail.

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[8] Dudek, 2020. Available at: https://borregospringswatermaster.com/wp-content/uploads/2021/04/1st-annual-report-borrego-springs-groundwater-subbasin.pdf

[9] West Yost, 2021. Available at: https://borregospringswatermaster.com/wp-content/uploads/2021/04/wy-2020-sgma-annual-report-final_20210401.pdf

[10] The CDZ well is unable to pump its assigned rate when pumping from the CDZ well was assigned to well ID3 in the *Uncorrected* BVHM. Note that well ID3 has historically been unable to pump its assigned rate, even prior to WY 2011 when pumping was intended to represent pumping solely from well ID3.

- **Performed depth distribution of pumping.** Table 6 summarizes and compares the well construction information assigned to Non-FMP wells in the *Uncorrected* BVHM[11] to the well construction information available based on well completion reports and the Watermaster's well database. If screened interval information was unavailable, the total depth of the well was considered to inform the bottom elevation of the modeled well screen. Based on the review of the depth distribution of pumping assigned to Non-FMP wells in the MNW2 package, the elevation of the top and/or bottom screen of Non-FMP wells was updated to match the well construction information. Of note is the corrections made to wells ID3, CDZ, and RH-4, which were identified as wells unable to pump their assigned rates in the MNW2 package in Table 5. Based on the review of the top and bottom screen intervals assigned, the bottom elevation of the screen was deepened for ID3, CDZ, and RH-4. In addition, the CDZ well was added as a unique well to the model model using well construction information, with a screened interval from 185 to 430 feet below ground surface (ft-bgs), which is deeper than the screened interval of 25 to 35 ft-bgs previously assigned to the ID3 well. As shown in Table 5, updating the construction information for these wells improved the ability of these wells to pump their assigned rates in the MNW2 package.

The following correction was *not* made to MNW2 package in the *Corrected MNW2* BVHM:

- **Addressing unaccounted-for pumping from *de minimis* wells**. Unaccounted-for pumping from *de minimis* wells was not addressed during Task 3 due to i) uncertainty in where *de minimis* wells are located in the Basin (and therefore where they should be added in the BVHM); ii) uncertainty in the depth from which these wells pump; and iii) acknowledgement that the estimated 26.5 afy of pumping from *de minimis* wells represents approximately 1% of average annual pumping in the *Uncorrected* BVHM and accounting for this pumping would not materially impact the water budget.

[11] The BVHM uses meters as units. Table 6 presents the well construction information in feet to be consistent with the information presented in the well completion reports.

Table 5. Comparison of Assigned and Modeled Pumping in the *Uncorrected* BVHM and the *Corrected MNW2* BVHM

Well Name	Assigned Pumping in the *Uncorrected* and *Corrected MNW2* BVHM *(afy)*		Modeled Pumping in the *Uncorrected* BVHM *(afy)*		Modeled Pumping in the *Corrected MNW2* BVHM *(afy)*	
	WY 2021	WY 2022	WY 2021	WY 2022	WY 2021	WY 2022
ID1-1	7.19	0.07	7.19	0.07	7.19	0.07
ID1-2	99.04	90.05	99.04	90.05	99.04	90.05
RH-3	86.12	110.40	86.12	110.40	86.12	110.40
RH-4	152.53	147.64	**135.01**	**119.90**	152.53	147.64
RH-5	210.40	99.76	210.40	99.76	210.40	99.76
RH-6	237.67	142.13	237.67	142.13	237.67	142.13
ID1-8	7.74	28.62	7.74	28.62	7.74	28.62
ID1-10	0.67	0.44	0.67	0.44	0.67	0.44
ID1-12	207.54	144.55	207.54	144.55	207.54	144.55
ID1-16	124.50	247.68	124.50	247.68	124.50	247.68
ID4-4	420.36	267.81	420.36	267.81	420.36	267.81
ID4-9	242.79	330.61	242.79	330.61	242.79	330.61
ID4-11	176.87	160.93	176.87	160.93	176.87	160.93
ID4-18	41.35	33.65	41.35	33.65	41.35	33.65
WILCOX	0.06	0.08	0.06	0.08	0.06	0.08
ID5-5	342.13	331.09	342.13	331.09	342.13	331.09
ID4-2	0.00	0.00	0.00	0.00	0.00	0.00
ID4-3	0.00	0.00	0.00	0.00	0.00	0.00
ID4-5	0.00	0.00	0.00	0.00	0.00	0.00
ID4-10	0.00	0.00	0.00	0.00	0.00	0.00
ID3[1]	19.59 / 0.00	32.22 / 0.00	**0.00**	**0.00**	0.00	0.00
CDZ[2]	19.59	32.22	**0.00**	**0.00**	19.59	32.22
BAR	10.02	6.45	10.02	6.45	10.02	6.45
BSPCSD	0.00	0.00	0.00	0.00	0.00	0.00
State Park	10.10	15.20	10.10	15.20	10.10	15.20
Total	**2,396.67**	**2,189.38**	**2,359.56**	**2,129.42**	**2,396.67**	**2,189.40**

1. Pumping assigned to ID3 in the *Uncorrected* BVHM is from both ID3 and CDZ wells. Pumping assigned to ID3 in the *Corrected MNW2* BVHM is only for the ID3 well.
2. Pumping from the CDZ well was assigned to well ID3 in the *Uncorrected* BVHM and assigned to the CDZ well in the *Corrected MNW2* BVHM.

Table 6. Comparison of Well Construction Assigned in the *Uncorrected* BVHM and Well Construction Information

Well Name	Construction Information in the *Uncorrected* BVHM *ft-bgs*		Construction Information from Well Completion Reports used in *Corrected MNW2* BVHM *ft-bgs*			Difference in *Uncorrected* BVHM and *Corrected MNW2* BVHM *ft*	
	Depth to Top of Screen	Depth to Bottom of Screen	Depth to Top of Screen	Depth to Bottom of Screen	Total Depth of Well	Top of Screen	Bottom of Screen
ID1-1	50	172	55	177	183	-5	-5
ID1-2	40	223	37	219	223	3	4
ID1-8	24	255	22	253	259	2	2
ID1-10	39	103	49	113	119	-10	-10
ID1-12	74	172	76	173	177	-2	-1
ID1-16	56	172	49	167	215	7	5
ID3	25	35	no data	no data	85	na	na
CDZ[1]	25	35	185	430	500	-35	-405
ID4-18	74	171	73	171	174	1	0
ID4-2	76	115	73	113	116	3	2
ID4-3	6	183	no data	no data	189	na	na
ID4-4	143	239	143	240	244	0	-1
ID4-9	137	241	140	244	250	-3	-3
ID4-10	126	177	128	192	192	-2	-15
ID4-5	156	193	158	195	198	-2	-2
ID4-11	137	232	137	229	235	0	3
ID5-5	117	209	122	213	213	-5	-4
BAR	35	108	37	116	116	-2	-8
BSPCSD	117	209	no data	no data	118	na	na
RH-3	98	277	90	270	271	8	7
RH-4	87	130	85	204	206	2	-74
RH-5	77	141	82	247	248	-5	-106
RH-6	81	295	73	286	289	8	9
WILCOX	81	161	74	153	153	7	8

1. Modeled as well ID3 in the *Uncorrected* BVHM

Impact of errors in the MNW2 package on the Water Budget

The annual water budget of the *Corrected MNW2* BVHM for WY 1945 through 2022 is presented in Table A-4.

Table 7 shows the average annual water budget of the *Corrected MNW2* BVHM and compares it to the average annual water budget of the *Uncorrected* BVHM in (see columns *f* and *g*). Overall, the corrections made to the errors in the MNW2 package and revision of the depth distribution of Non-FMP well pumping in the *Corrected MNW2* BVHM had minimal impact to the average annual water budget. The greatest impact to the water budget is a 3% increase in Non-FMP pumping and an overall 1% increase in average annual groundwater pumping. This increase in Non-FMP pumping is due to i) adding in previously unaccounted-for pumping (from Rams Hill and Anza Borrego Desert State Park wells), and ii) refining the depth distribution of Non-FMP pumping so that wells were able to pump their assigned rates.

Farm Process

Description of the FMP in the BVHM

The FMP estimates the use of water from natural, urban, and agricultural vegetation in a demand-driven and supply-constrained model structure to estimate groundwater pumping and surface-water deliveries[12] to satisfy irrigation demands. In the BVHM, the FMP simulates the climatic, land use, and water use conditions for 52 WBS. The spatial extent of the WBS (shown in Figure 1). Each WBS is comprised of one or more model cells which are individually assigned land use types. The FMP computes a water budget for each WBS using data and information on land use, crop type and rooting depths, crop coefficients, and irrigation efficiencies.[13] Output from the FMP includes estimates of the required groundwater pumping to meet the irrigation demands, the infiltration of excess applied water past the root zone that recharges the unsaturated zone, and surface-water runoff that returns to the streams. The FMP outputs are linked to the SFR, MNW2, and Unsaturated Zone Flow (UZF) packages in the BVHM.

Errors identified in the FMP in the Uncorrected FMP BVHM

The Agri Empire potato farm (WBS 23 in the BVHM) was fallowed in 2014. No groundwater was pumped for the Agri-Empire potato farm during WYs 2014 and 2015, but the BVHM simulates approximately 1,640 af of groundwater pumped from WBS 23 for the same period. The land use classification for WBS 23 is not changed from "potato" to "fallowed" until October 2016 in the *Uncorrected* BVHM.[14]

[12] In the Borrego Valley, surface-water deliveries are not used to satisfy irrigation demands.
[13] See the Task 2 memo for a more in-depth description of the FMP process, available at: https://borregospringswatermaster.com/wp-content/uploads/2023/08/III_BVHM-Task-2.pdf
[14] The land use classification of WBS 23 in the *Uncorrected* BVHM is "potato" from January 2000 until October 2016. Prior to the "potato" land use classification, the land use classification was "row crop" (1995 – 2000), and "native" prior to 1995.

Corrections made to the FMP in the Corrected FMP BVHM

The land use classification associated with the Agri-Empire potato farm in WBS 23 was changed from "potato" to "fallowed" starting in January 2014 in the *Corrected FMP* BVHM to reflect the fallowing of the Agri-Empire potato farm in 2014. Because the Agri-Empire pumped 342.26 af in 2016[15], a Non-FMP well was added to the MNW2 package to simulate groundwater pumping by the Agri-Empire farm in 2016.

Impact of errors in the FMP on the Water Budget

The annual water budget of the *Corrected FMP* BVHM for WY 1945 through 2022 is presented in Table A-5.

Table 7 shows the average annual water budget of the *Corrected FMP* BVHM and compares it to the average annual water budget of the *Uncorrected* BVHM in (see columns *h* and *i*).The corrections made to the error in the FMP in the *Corrected FMP* BVHM had no impact on the average annual water budget.

Final Corrected BVHM

The *Final Corrected* BVHM contains the corrections made to the FHB, SFR, and MNW2 packages, and the FMP described above. Figure 3 is a map of the *Final Corrected* BVHM domain and identifies the extent of cells assigned to the SFR, FHB, and MNW2 packages and the FMP after corrections were made to each of these model packages. The annual water budget for WY 1945-2022 from the *Final Corrected* BVHM is presented in Table A-6.

Table 7 shows the average annual water budget for WY 1945 through 2022 is shown and compared to the average annual water budget for the *Uncorrected* BVHM in (see columns *j* and *k*). The cumulative impact of all the errors identified in the *Uncorrected* BVHM on the average annual water budget include:

- **Increase in total inflows by 14%.** Total inflows increased by 999 afy in the *Final Corrected* BVHM**.** All components of inflow to the model domain increased, including streambed recharge, unsaturated zone recharge, and subsurface inflow. However, the main increase was to subsurface inflows due to the correction made to the FHB package.
- **Increase in total outflows by 2%.** Total outflows increased by 261 afy in the *Final Corrected* BVHM. The increase in total outflow was primarily in ET of groundwater, which increased by 7% compared to the *Uncorrected* BVHM. The increase in ET of groundwater was due to an increase of total inflows, which increased the amount of shallow groundwater available for consumption by ET. Average annual groundwater pumping from Non-FMP wells in the MNW2 package also increased by 3%, which was due to the corrections made to well screen intervals that enabled Non-FMP wells to pump their assigned rates in the *Final Corrected* BVHM.

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[15] Based on Table 1. Borrego Springs Groundwater Subbasin 5-Year (2015-2019) Estimated Annual Groundwater Production reported in Dudek, 2019, *Working Draft De Minimis and Non-De Minimis Water Users.*

- **Reduction in the average annual storage decline by 11%.** The estimated annual storage decline changed from 7,163 afy to 6,425 afy – a reduction in the annual storage decline of 738 afy. This change was mainly driven by the correction to the FHB package which increased the subsurface inflows by 754 afy.

Table 7. Comparison of the Average Annual Water Budget in the *Uncorrected* BVHM and the *Corrected* Versions of the BVHM

Water Budget Component -- Annual Average	Annual Average Water Budget over the Simulation Period October 1944 - September 2022										
	Uncorrected BVHM	*Corrected FHB* BVHM		*Corrected SFR* BVHM		*Corrected MNW2* BVHM		*Corrected FMP* BVHM		*Final Corrected* BVHM	
	afy	*afy*	*% Difference*	*afy*	*% Difference*	*afy*	*% Difference*	*afy*	*% Difference*	*afy*	*% Difference*
	(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	*(h)*	*(i)*	*(j)*	*(k)*
Total Inflows	**6,633**	**7,487**	**12%**	**6,768**	**2%**	**6,639**	**0%**	**6,640**	**0%**	**7,632**	**14%**
Streambed Recharge	3,775	3,776	0%	3,889	3%	3,775	0%	3,775	0%	3,888	3%
Unsaturated Zone Recharge	1,490	1,590	6%	1,511	1%	1,496	0%	1,497	0%	1,622	8%
Subsurface Inflow	1,367	2,121	43%	1,367	0%	1,367	0%	1,367	0%	2,121	43%
Total Outflows	**13,796**	**14,069**	**2%**	**13,753**	**0%**	**13,851**	**0%**	**13,790**	**0%**	**14,057**	**2%**
Groundwater Pumping	10,630	10,661	0%	10,631	0%	10,687	1%	10,624	0%	10,693	1%
Non-FMP Wells	2,226	2,257	1%	2,226	0%	2,283	3%	2,231	0%	2,300	3%
FMP Wells	8,404	8,404	0%	8,405	0%	8,404	0%	8,394	0%	8,394	0%
Evapotranspiration	2,644	2,885	9%	2,601	-2%	2,643	0%	2,644	0%	2,841	7%
Subsurface Outflow	521	523	0%	521	0%	521	0%	521	0%	523	0%
Total Change in Storage	**-7,163**	**-6,582**	**8%**	**-6,985**	**3%**	**-7,212**	**-1%**	**-7,150**	**0%**	**-6,425**	**11%**

Notes:

1. Percent difference is calculated as the change in the water budget component, divided by the average of the two values and multiplied by 100. For example, (c)=((b)-(a))/(((b)+(a))/2).

Recommendations

West Yost recommends using the following to perform *Task 4 – Model Recalibration*:

- Corrected packages from the *Final Corrected* BVHM developed during Task 3 – *Correct Errors in the 2021 BVHM*.
- Updated crop coefficient (KC) and on-farm efficiency (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.

Next Steps

The TAC was asked to review the draft Task 3 TM and provide comments and recommendations. Exhibit 2 is a table that summarizes the TAC comments and recommendations and the Technical Consultant's responses.

The next step is to proceed with Task 4 – *Model Recalibration*.

Enclosures

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

Exhibit 2: TAC Comments on the Draft Task 3 TM

Figure 1. *Uncorrected* BVHM Domain

Figure 2. FHB Cells in the *Uncorrected* BVHM and the *Corrected FHB* BVHM

Figure 3. *Final Corrected* BVHM Domain

Table A-1. *Uncorrected* BVHM Water Budget, WY 1945 - 2022

Table A-2. *Corrected FHB* BVHM Water Budget, WY 1945 – 2022

Table A-3. *Corrected SFR* BVHM Water Budget, WY 1945 – 2022

Table A-4. *Corrected MNW2* BVHM Water Budget, WY 1945 - 2022

Table A-5. *Corrected FMP* BVHM Water Budget, WY 1945 – 2022

Table A-6. *Final Corrected* BVHM Water Budget, WY 1945 - 2022

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.”

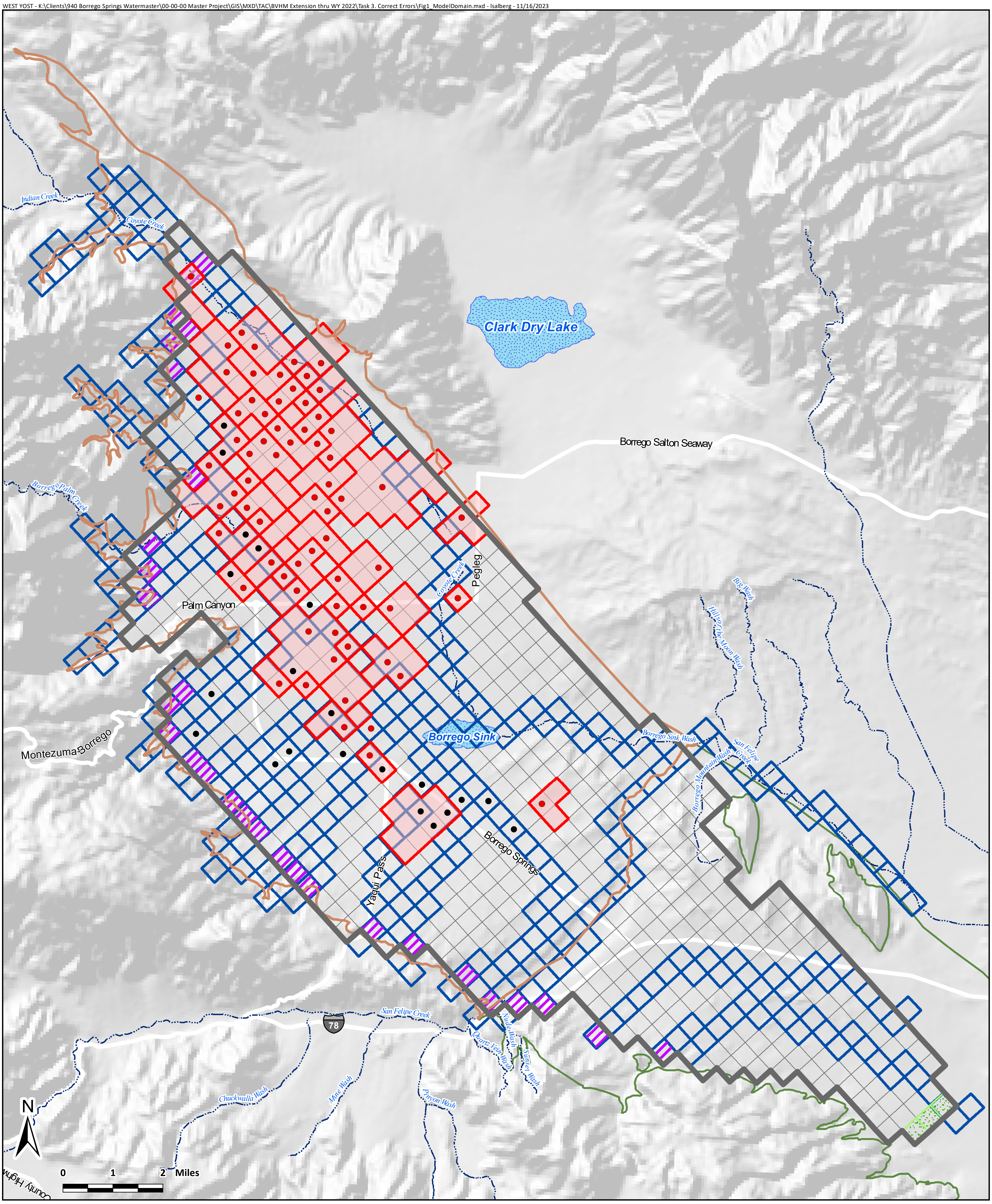
Exhibit 2. Responses to TAC Commment/Recommendations on Task 3 to Redetermine the Sustainable Yield by 2025 - *Correct Errors Identified in the 2021 BVHM*

Comments/Recommendations	TAC Member: AAWARE *Bob Wagner*	TAC Member: BWD *Trey Driscoll*	TAC Member: County of San Diego *Jim Bennett*	TAC Member: T2 Borrego *Tom Watson*	TAC Member: Roadrunner Club *John Peterson*	Technical Consultant Responses
Units used in the BVHM						
Has the Watermaster done a check on all of the MODFLOW input files to discern if there is any other unit conversion factors lurking in the model?				X		Yes, West Yost performed a thorough inspection of the BVHM, including the units used when the BVHM was first inherited. Upon this inspection, it was discovered that the units used in the Streamflow Routing package were incorrect (units were in feet, but the model uses meters). No additional unit errors were identified during this inspection, nor while performing any other tasks to redetermine the Sustainable Yield. Upon completion of Task 3, the units in the BVHM are consistent and correct.
No comments/responses						
No comment					X[1]	
No response	X	X	X			

Notes:

1. Responded that he has no comments on this TM on December 6, 2023.

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 3. Correct Errors\Fig1_ModelDomain.mxd - lsalberg - 11/16/2023



BVHM Packages

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

Farm Process Features

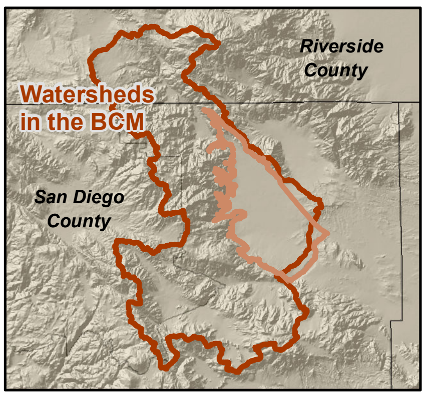
- Water Budget Subregion in the FMP
- FMP Well in MNW2 Package

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

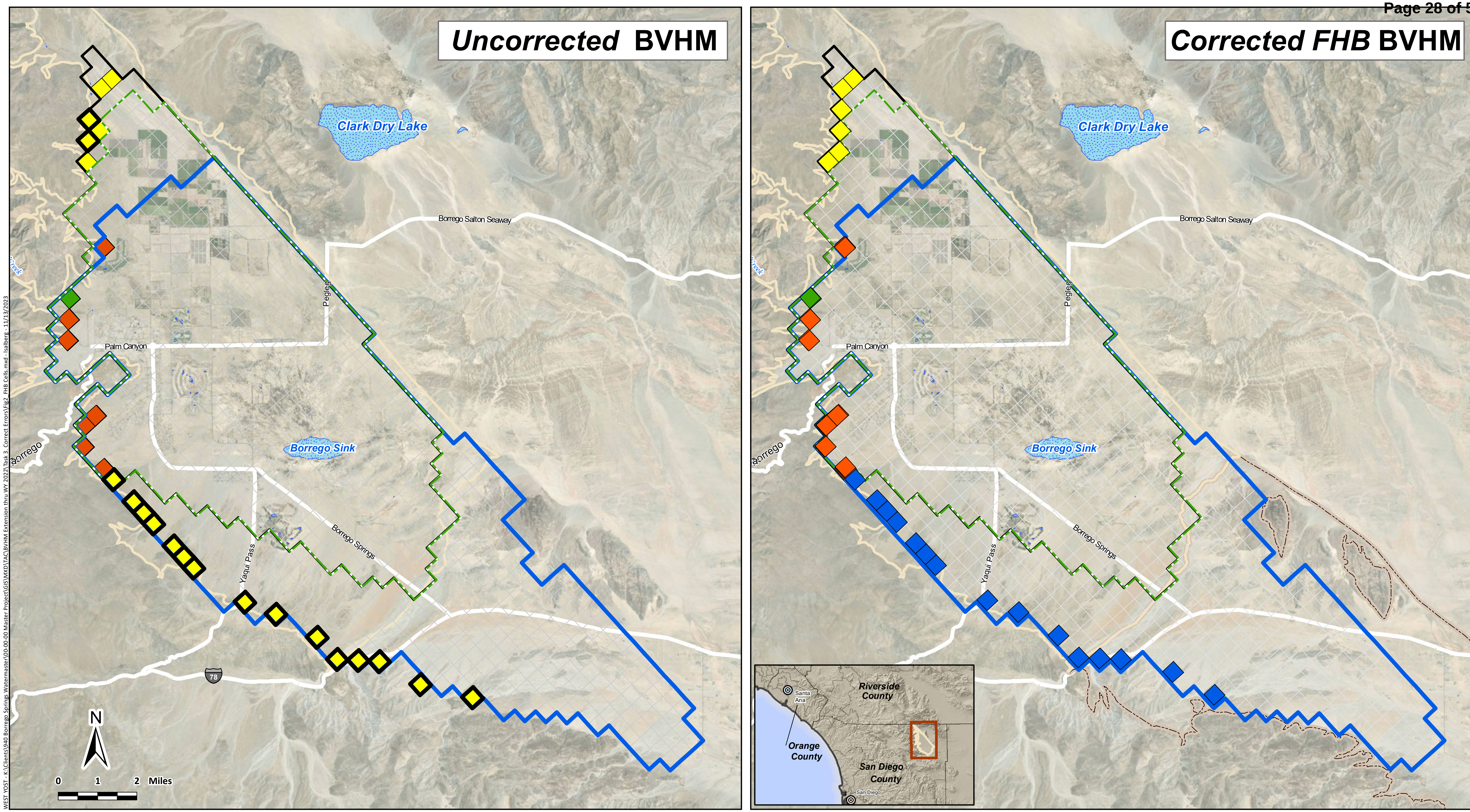
Prepared by:

WEST YOST

Figure 1

Uncorrected

Borrego Valley Hydrologic Model (BVHM) Domain



FHB Cells assigned in the BVHM by Layer

- FHB assigned to Layer 1
- FHB assigned to Layers 1 and 2
- FHB assigned to Layer 3
- FHB assigned to Layers 1, 2, and 3
- FHB assigned to inactive cell or layer

Extent of Active Layers in the BVHM

- Layer 1
- Layer 2
- Layer 3

Other Features

- Active Cells in the BVHM
- Borrego Springs Groundwater Subbasin

Prepared by:

WEST YOST

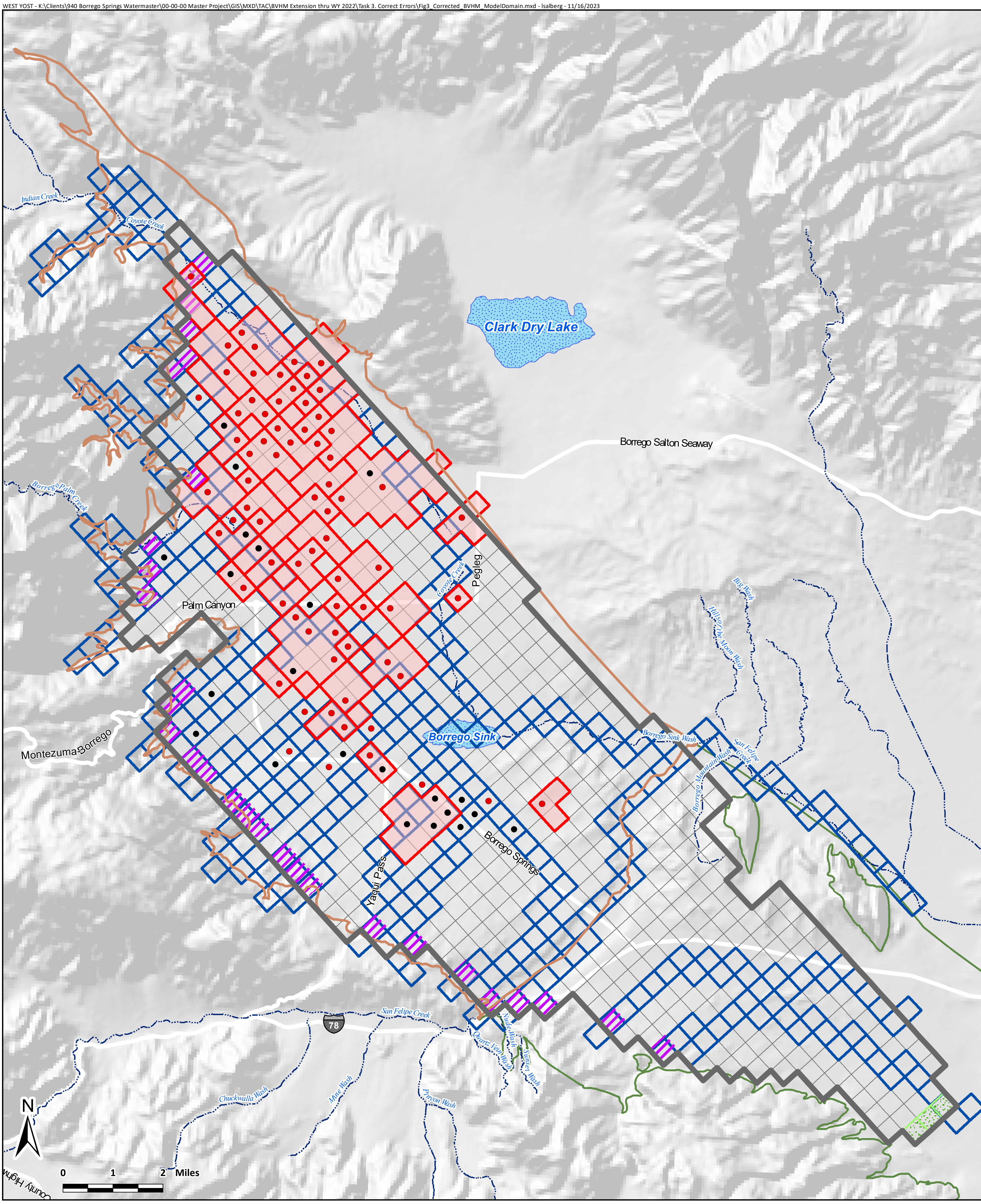
Borrego Springs Watermaster

Correct errors identified in the 2021 BVHM TM

Figure 2

FHB Cells in the *Uncorrected* BVHM and the *Corrected FHB* BVHM

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 3. Correct Errors\Fig3_Corrected_BVHM_ModelDomain.mxd - lsalberg - 11/16/2023



BVHM Packages

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

Farm Process Features

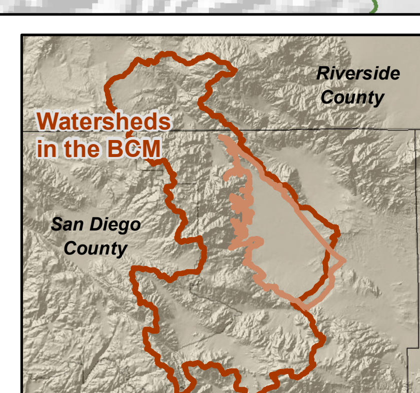
- Water Budget Subregion in the FMP
- FMP Well in MNW2 Package

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 3

Corrected

Borrego Valley Hydrologic Model (BVHM) Domain

Table A-1. Water Budget for the *Uncorrected* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping: FMP Wells	Groundwater Pumping: Non-FMP Wells	ET	Subsurface Outflow	Total Outflows		
1945	8,563	2,814	1,366	12,743	0	87	7,700	532	8,319	4,424	4,424
1946	5,253	2,976	1,366	9,595	846	149	10,089	549	11,632	-2,037	2,386
1947	190	1,744	1,366	3,301	1,339	193	8,948	551	11,031	-7,731	-5,344
1948	112	1,071	1,370	2,554	2,748	236	8,673	551	12,208	-9,655	-14,999
1949	6,058	1,410	1,366	8,834	3,540	280	7,999	555	12,374	-3,540	-18,539
1950	127	993	1,366	2,487	4,325	324	8,311	547	13,506	-11,020	-29,559
1951	7,750	860	1,366	9,976	5,231	366	7,441	542	13,579	-3,604	-33,163
1952	619	876	1,370	2,865	6,679	410	6,105	542	13,736	-10,871	-44,034
1953	4,344	1,068	1,366	6,778	8,731	454	7,237	538	16,960	-10,182	-54,216
1954	710	735	1,366	2,812	9,243	496	5,952	531	16,223	-13,411	-67,627
1955	171	759	1,366	2,297	8,978	540	5,389	525	15,432	-13,135	-80,762
1956	2,025	670	1,370	4,065	10,485	583	5,717	521	17,306	-13,241	-94,003
1957	3,518	657	1,366	5,541	10,688	627	4,995	516	16,826	-11,285	-105,288
1958	797	682	1,366	2,846	9,750	671	4,411	513	15,345	-12,499	-117,787
1959	1,131	653	1,366	3,151	10,458	713	4,551	509	16,232	-13,081	-130,868
1960	686	679	1,370	2,736	9,385	757	3,925	509	14,576	-11,840	-142,708
1961	812	607	1,366	2,786	9,994	800	3,924	505	15,223	-12,438	-155,146
1962	163	581	1,366	2,110	9,795	844	3,553	502	14,694	-12,583	-167,729
1963	1,412	616	1,366	3,395	9,134	962	3,087	499	13,682	-10,287	-178,017
1964	4,078	1,373	1,370	6,821	8,591	1,030	3,477	516	13,613	-6,792	-184,809
1965	9,103	835	1,366	11,303	8,578	1,075	3,008	510	13,170	-1,867	-186,676
1966	7,336	1,160	1,366	9,863	4,716	1,118	2,876	517	9,228	635	-186,041
1967	1,175	1,033	1,366	3,574	4,554	1,161	2,677	516	8,908	-5,334	-191,375
1968	13,544	1,385	1,370	16,299	5,026	1,204	2,583	516	9,330	6,969	-184,406
1969	450	941	1,366	2,758	4,579	1,248	2,418	514	8,759	-6,002	-190,408
1970	331	954	1,366	2,652	4,502	1,291	2,329	512	8,634	-5,982	-196,390
1971	327	1,016	1,366	2,709	4,382	1,334	2,238	509	8,463	-5,754	-202,144
1972	2,173	1,077	1,370	4,619	4,582	1,705	2,261	509	9,058	-4,439	-206,582
1973	1,464	1,209	1,366	4,040	3,891	1,655	1,986	507	8,040	-4,000	-210,582
1974	644	1,141	1,366	3,151	4,251	1,684	1,997	505	8,438	-5,287	-215,868
1975	2,024	1,155	1,366	4,546	4,097	1,812	1,898	503	8,310	-3,764	-219,633
1976	3,697	1,357	1,370	6,424	4,161	1,934	1,837	505	8,437	-2,014	-221,647
1977	21,782	2,870	1,366	26,018	4,384	2,069	2,071	515	9,039	16,980	-204,667
1978	9,016	1,824	1,366	12,207	4,561	2,208	2,071	523	9,363	2,844	-201,823
1979	22,303	3,521	1,366	27,190	4,617	2,321	1,940	522	9,399	17,791	-184,032
1980	3,330	1,799	1,370	6,499	5,892	2,478	2,283	529	11,182	-4,683	-188,714
1981	1,978	1,225	1,366	4,569	6,673	2,596	2,421	525	12,214	-7,645	-196,359
1982	9,908	1,517	1,366	12,792	6,237	2,706	2,110	521	11,574	1,219	-195,141
1983	7,763	2,448	1,366	11,577	4,622	2,836	1,858	529	9,844	1,733	-193,407
1984	1,935	1,821	1,370	5,126	6,671	2,936	2,586	538	12,731	-7,605	-201,012
1985	3,102	1,728	1,366	6,196	6,324	3,058	2,208	534	12,123	-5,927	-206,939
1986	1,365	1,577	1,366	4,309	6,129	3,051	2,110	534	11,823	-7,515	-214,454
1987	911	1,478	1,366	3,755	6,761	3,332	2,131	530	12,755	-9,000	-223,454
1988	1,938	1,662	1,370	4,970	6,645	4,036	1,903	531	13,116	-8,146	-231,600
1989	230	1,386	1,366	2,982	7,057	3,836	1,914	524	13,331	-10,349	-241,948
1990	6,897	1,738	1,366	10,001	7,162	3,774	1,754	522	13,211	-3,211	-245,159
1991	2,486	1,468	1,366	5,321	6,465	4,005	1,522	518	12,511	-7,190	-252,349
1992	20,684	3,233	1,370	25,288	6,380	4,267	1,550	514	12,711	12,576	-239,773
1993	5,817	2,810	1,366	9,994	8,433	4,097	1,837	521	14,889	-4,895	-244,668
1994	8,202	1,934	1,366	11,503	10,389	3,923	1,845	518	16,675	-5,172	-249,840
1995	759	1,611	1,366	3,736	11,648	3,787	1,598	516	17,549	-13,814	-263,653
1996	652	1,314	1,370	3,336	13,653	4,003	1,628	515	19,800	-16,464	-280,117
1997	8,306	1,778	1,366	11,450	11,571	4,188	1,349	512	17,620	-6,170	-286,287
1998	2,979	1,948	1,366	6,293	10,169	3,975	1,339	523	16,006	-9,713	-296,000
1999	314	1,290	1,366	2,971	11,480	4,002	1,336	521	17,339	-14,369	-310,369
2000	436	1,319	1,370	3,125	12,314	4,196	1,187	519	18,216	-15,091	-325,460
2001	283	1,397	1,366	3,047	11,669	3,657	978	516	16,820	-13,773	-339,234
2002	422	1,517	1,366	3,305	13,029	4,096	951	513	18,588	-15,283	-354,517
2003	895	1,597	1,366	3,858	11,956	3,902	769	510	17,138	-13,279	-367,796
2004	10,531	1,715	1,370	13,616	12,804	3,902	740	510	17,956	-4,340	-372,136
2005	8,609	3,153	1,366	13,129	11,100	3,563	904	527	16,094	-2,965	-375,101
2006	2,421	1,883	1,366	5,671	13,988	3,766	978	530	19,262	-13,591	-388,692
2007	292	1,499	1,366	3,157	15,331	4,516	776	525	21,148	-17,991	-406,684
2008	1,199	1,280	1,370	3,849	14,074	3,838	580	523	19,015	-15,165	-421,849
2009	1,517	1,220	1,366	4,103	14,568	3,970	590	522	19,651	-15,548	-437,397
2010	238	1,281	1,366	2,885	14,310	3,118	499	521	18,448	-15,562	-452,959
2011	1,161	1,325	1,366	3,853	13,948	2,714	430	517	17,608	-13,755	-466,714
2012	6,220	1,964	1,370	9,554	12,919	1,814	507	529	15,769	-6,215	-472,929
2013	1,931	1,735	1,366	5,033	13,953	1,856	498	525	16,832	-11,799	-484,728
2014	1,649	1,572	1,366	4,588	14,964	2,057	473	522	18,016	-13,428	-498,156
2015	2,096	1,658	1,366	5,120	13,538	2,109	369	520	16,536	-11,417	-509,573
2016	1,862	1,670	1,370	4,902	13,141	1,751	380	523	15,795	-10,893	-520,465
2017	3,545	1,515	1,366	6,426	11,474	2,357	329	520	14,680	-8,254	-528,720
2018	2,640	1,326	1,366	5,332	12,656	2,346	322	517	15,841	-10,510	-539,229
2019	3,271	1,826	1,366	6,463	9,072	2,188	274	514	12,048	-5,585	-544,815
2020	3,983	1,831	1,370	7,184	7,466	2,231	263	515	10,475	-3,291	-548,105
2021	2,628	1,384	1,366	5,378	8,428	2,349	260	509	11,547	-6,169	-554,274
2022	3,196	1,494	1,366	6,055	7,649	2,114	234	506	10,502	-4,447	-558,721
Average	**3,775**	**1,490**	**1,367**	**6,633**	**8,404**	**2,226**	**2,644**	**521**	**13,796**	**-7,163**	-
Minimum	**112**	**581**	**1,366**	**2,110**	**0**	**87**	**234**	**499**	**8,040**	**-17,991**	
Maximum	**22,303**	**3,521**	**1,370**	**27,190**	**15,331**	**4,516**	**10,089**	**555**	**21,148**	**17,791**	

Table A-2. Water Budget for the *Corrected FHB* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping		ET	Subsurface Outflow	Total Outflows		
					FMP Wells	Non-FMP Wells					
1945	8,564	2,835	2,120	13,520	0	87	7,816	532	8,435	5,085	5,085
1946	5,252	3,011	2,120	10,383	845	149	10,242	549	11,785	-1,403	3,682
1947	190	1,794	2,120	4,104	1,339	193	9,121	551	11,205	-7,100	-3,418
1948	113	1,111	2,126	3,349	2,748	236	8,865	551	12,400	-9,051	-12,469
1949	6,058	1,478	2,120	9,656	3,540	280	8,185	555	12,560	-2,904	-15,373
1950	127	1,033	2,120	3,279	4,325	324	8,535	547	13,730	-10,451	-25,824
1951	7,750	896	2,120	10,766	5,231	366	7,660	542	13,799	-3,032	-28,856
1952	619	946	2,126	3,690	6,673	410	6,311	542	13,936	-10,246	-39,102
1953	4,344	1,148	2,120	7,612	8,724	454	7,472	538	17,188	-9,576	-48,678
1954	710	812	2,120	3,642	9,235	496	6,188	531	16,450	-12,809	-61,487
1955	172	832	2,120	3,123	8,970	540	5,625	525	15,660	-12,537	-74,023
1956	2,026	744	2,126	4,896	10,479	583	5,978	521	17,561	-12,666	-86,689
1957	3,519	736	2,120	6,375	10,688	627	5,238	516	17,068	-10,694	-97,383
1958	798	762	2,120	3,680	9,750	671	4,635	513	15,569	-11,890	-109,272
1959	1,131	713	2,120	3,964	10,458	713	4,800	509	16,481	-12,517	-121,789
1960	687	733	2,126	3,546	9,385	757	4,155	509	14,807	-11,261	-133,050
1961	812	650	2,120	3,582	9,994	800	4,171	505	15,470	-11,888	-144,938
1962	164	587	2,120	2,870	9,795	844	3,792	502	14,933	-12,063	-157,001
1963	1,414	677	2,120	4,212	9,134	962	3,306	499	13,901	-9,690	-166,690
1964	4,076	1,504	2,126	7,706	8,591	1,030	3,729	516	13,866	-6,160	-172,851
1965	9,103	950	2,120	12,173	8,578	1,075	3,251	511	13,414	-1,242	-174,092
1966	7,337	1,306	2,120	10,763	4,716	1,118	3,117	517	9,469	1,294	-172,798
1967	1,176	1,099	2,120	4,395	4,554	1,161	2,902	517	9,134	-4,739	-177,537
1968	13,545	1,492	2,126	17,162	5,026	1,204	2,806	517	9,553	7,609	-169,928
1969	451	1,033	2,120	3,603	4,579	1,248	2,641	515	8,982	-5,379	-175,308
1970	332	1,021	2,120	3,473	4,502	1,291	2,561	513	8,867	-5,394	-180,702
1971	327	1,099	2,120	3,545	4,382	1,335	2,476	510	8,703	-5,157	-185,859
1972	2,173	1,162	2,126	5,460	4,582	1,715	2,515	510	9,322	-3,862	-189,721
1973	1,465	1,295	2,120	4,880	3,891	1,676	2,219	508	8,294	-3,414	-193,135
1974	645	1,236	2,120	4,001	4,251	1,704	2,247	506	8,708	-4,707	-197,842
1975	2,026	1,251	2,120	5,396	4,097	1,846	2,151	504	8,599	-3,203	-201,045
1976	3,700	1,533	2,126	7,359	4,161	1,981	2,089	506	8,738	-1,379	-202,424
1977	21,781	3,111	2,120	27,012	4,384	2,120	2,359	516	9,378	17,634	-184,790
1978	9,017	1,981	2,120	13,117	4,561	2,256	2,353	524	9,694	3,423	-181,367
1979	22,305	3,816	2,120	28,241	4,617	2,375	2,221	523	9,736	18,505	-162,862
1980	3,330	1,915	2,126	7,371	5,892	2,530	2,601	530	11,553	-4,182	-167,044
1981	1,978	1,232	2,120	5,330	6,673	2,662	2,790	526	12,652	-7,321	-174,365
1982	9,911	1,688	2,120	13,719	6,237	2,783	2,444	523	11,985	1,734	-172,632
1983	7,769	2,697	2,120	12,586	4,622	2,915	2,144	530	10,211	2,376	-170,256
1984	1,933	2,027	2,126	6,086	6,671	3,016	2,994	540	13,221	-7,135	-177,391
1985	3,105	1,773	2,120	6,997	6,324	3,143	2,568	535	12,570	-5,573	-182,964
1986	1,366	1,713	2,120	5,199	6,129	3,142	2,463	536	12,269	-7,070	-190,034
1987	911	1,667	2,120	4,698	6,761	3,410	2,502	532	13,204	-8,506	-198,540
1988	1,938	1,932	2,126	5,995	6,645	4,093	2,239	533	13,509	-7,513	-206,054
1989	230	1,517	2,120	3,868	7,057	3,882	2,277	526	13,742	-9,874	-215,927
1990	6,897	1,903	2,120	10,921	7,162	3,814	2,112	523	13,611	-2,690	-218,618
1991	2,486	1,608	2,120	6,214	6,465	4,043	1,824	520	12,851	-6,637	-225,254
1992	20,686	3,348	2,126	26,160	6,380	4,340	1,878	516	13,115	13,045	-212,209
1993	5,818	2,885	2,120	10,823	8,433	4,187	2,191	523	15,335	-4,512	-216,720
1994	8,204	2,081	2,120	12,405	10,389	4,006	2,228	520	17,142	-4,737	-221,458
1995	760	1,712	2,120	4,592	11,648	3,881	1,948	518	17,995	-13,403	-234,861
1996	652	1,440	2,126	4,217	13,653	4,072	2,005	518	20,248	-16,031	-250,892
1997	8,311	1,934	2,120	12,364	11,571	4,235	1,670	514	17,989	-5,625	-256,517
1998	2,977	2,126	2,120	7,223	10,169	4,032	1,643	526	16,370	-9,147	-265,664
1999	314	1,478	2,120	3,912	11,480	4,045	1,665	523	17,714	-13,801	-279,465
2000	437	1,404	2,126	3,967	12,314	4,281	1,503	522	18,619	-14,653	-294,117
2001	285	1,620	2,120	4,025	11,669	3,738	1,249	518	17,174	-13,149	-307,266
2002	423	1,512	2,120	4,055	13,029	4,168	1,221	515	18,934	-14,879	-322,145
2003	897	1,455	2,120	4,472	11,956	3,966	993	513	17,428	-12,956	-335,101
2004	10,531	1,787	2,126	14,443	12,804	3,963	952	513	18,232	-3,789	-338,890
2005	8,613	3,217	2,120	13,950	11,100	3,624	1,121	530	16,374	-2,425	-341,315
2006	2,421	1,897	2,120	6,439	13,988	3,823	1,224	533	19,568	-13,129	-354,444
2007	292	1,383	2,120	3,795	15,331	4,555	985	528	21,399	-17,605	-372,049
2008	1,200	1,392	2,126	4,717	14,074	3,866	753	526	19,219	-14,501	-386,550
2009	1,518	1,394	2,120	5,032	14,568	4,009	761	525	19,863	-14,832	-401,382
2010	237	1,452	2,120	3,809	14,310	3,144	653	523	18,631	-14,822	-416,203
2011	1,161	1,513	2,120	4,794	13,947	2,737	565	520	17,769	-12,976	-429,179
2012	6,222	2,368	2,126	10,716	12,919	1,837	641	532	15,928	-5,211	-434,390
2013	1,931	1,826	2,120	5,877	13,953	1,888	634	528	17,003	-11,127	-445,517
2014	1,649	1,712	2,120	5,480	14,964	2,081	607	525	18,177	-12,696	-458,213
2015	2,098	1,700	2,120	5,918	13,538	2,133	483	523	16,677	-10,759	-468,973
2016	1,861	1,671	2,126	5,658	13,141	1,773	493	526	15,932	-10,274	-479,247
2017	3,546	1,653	2,120	7,319	11,474	2,383	460	523	14,840	-7,521	-486,767
2018	2,640	1,387	2,120	6,147	12,656	2,359	447	520	15,982	-9,836	-496,603
2019	3,272	1,795	2,120	7,187	9,072	2,194	348	518	12,131	-4,944	-501,547
2020	3,985	1,902	2,126	8,013	7,466	2,232	351	518	10,567	-2,555	-504,102
2021	2,627	1,371	2,120	6,118	8,428	2,351	360	512	11,652	-5,534	-509,636
2022	3,199	1,546	2,120	6,864	7,649	2,116	331	509	10,605	-3,741	-513,377
Average	**3,776**	**1,590**	**2,121**	**7,487**	**8,404**	**2,257**	**2,885**	**523**	**14,069**	**-6,582**	-
Minimum	**113**	**587**	**2,120**	**2,870**	**0**	**87**	**331**	**499**	**8,294**	**-17,605**	
Maximum	**22,305**	**3,816**	**2,126**	**28,241**	**15,331**	**4,555**	**10,242**	**555**	**21,399**	**18,505**	

Table A-3. Water Budget for the *Corrected SFR* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping		ET	Subsurface Outflow	Total Outflows		
					FMP Wells	Non-FMP Wells					
1945	8,919	2,968	1,366	13,253	0	87	7,469	532	8,088	5,165	5,165
1946	4,522	2,898	1,366	8,786	846	149	9,663	552	11,210	-2,424	2,741
1947	295	1,813	1,366	3,475	1,339	193	8,656	553	10,742	-7,267	-4,526
1948	161	1,102	1,370	2,633	2,748	236	8,427	552	11,964	-9,332	-13,858
1949	6,030	1,427	1,366	8,823	3,540	280	7,764	556	12,140	-3,317	-17,174
1950	131	1,004	1,366	2,502	4,325	324	8,075	547	13,271	-10,770	-27,944
1951	7,994	891	1,366	10,251	5,231	366	7,251	542	13,391	-3,139	-31,084
1952	504	866	1,370	2,740	6,683	410	5,934	543	13,570	-10,830	-41,914
1953	4,243	1,091	1,366	6,700	8,736	454	7,011	538	16,740	-10,040	-51,954
1954	710	735	1,366	2,812	9,249	496	5,780	531	16,056	-13,244	-65,198
1955	219	762	1,366	2,347	8,983	540	5,237	525	15,285	-12,938	-78,136
1956	2,063	668	1,370	4,102	10,487	583	5,570	521	17,161	-13,059	-91,195
1957	3,607	662	1,366	5,635	10,688	627	4,879	516	16,710	-11,074	-102,269
1958	808	682	1,366	2,856	9,750	671	4,315	513	15,249	-12,393	-114,662
1959	1,139	652	1,366	3,157	10,458	713	4,446	509	16,127	-12,970	-127,632
1960	703	686	1,370	2,760	9,385	757	3,834	509	14,485	-11,726	-139,358
1961	852	605	1,366	2,824	9,994	800	3,832	505	15,131	-12,308	-151,666
1962	153	582	1,366	2,102	9,795	844	3,474	502	14,615	-12,513	-164,179
1963	1,942	638	1,366	3,946	9,134	962	3,017	499	13,612	-9,666	-173,845
1964	3,439	1,356	1,370	6,165	8,591	1,030	3,354	516	13,490	-7,326	-181,170
1965	9,350	831	1,366	11,547	8,578	1,075	2,929	510	13,092	-1,546	-182,716
1966	7,392	1,160	1,366	9,918	4,716	1,118	2,797	517	9,148	770	-181,945
1967	1,281	1,034	1,366	3,681	4,554	1,161	2,608	516	8,839	-5,159	-187,104
1968	14,257	1,454	1,370	17,081	5,026	1,204	2,515	516	9,261	7,820	-179,285
1969	372	964	1,366	2,702	4,579	1,248	2,355	514	8,696	-5,994	-185,278
1970	324	961	1,366	2,652	4,502	1,291	2,266	512	8,572	-5,920	-191,198
1971	308	1,013	1,366	2,688	4,382	1,332	2,182	509	8,405	-5,717	-196,915
1972	2,163	1,065	1,370	4,598	4,582	1,703	2,204	509	8,998	-4,400	-201,315
1973	1,480	1,189	1,366	4,036	3,891	1,652	1,938	507	7,989	-3,953	-205,268
1974	627	1,138	1,366	3,131	4,251	1,681	1,950	505	8,387	-5,256	-210,524
1975	2,349	1,170	1,366	4,885	4,097	1,808	1,856	503	8,263	-3,378	-213,902
1976	4,242	1,379	1,370	6,991	4,161	1,929	1,795	505	8,390	-1,399	-215,300
1977	21,896	2,938	1,366	26,200	4,384	2,064	2,033	515	8,995	17,205	-198,096
1978	8,852	1,816	1,366	12,034	4,561	2,203	2,030	523	9,316	2,718	-195,378
1979	25,281	4,065	1,366	30,713	4,617	2,316	1,897	522	9,351	21,362	-174,016
1980	3,189	1,938	1,370	6,498	5,892	2,473	2,236	528	11,130	-4,632	-178,648
1981	1,961	1,153	1,366	4,480	6,673	2,591	2,390	525	12,178	-7,697	-186,345
1982	10,183	1,590	1,366	13,139	6,237	2,701	2,106	521	11,565	1,574	-184,772
1983	8,129	2,567	1,366	12,062	4,622	2,833	1,860	529	9,843	2,219	-182,553
1984	1,434	1,807	1,370	4,611	6,671	2,933	2,575	539	12,717	-8,106	-190,659
1985	3,096	1,637	1,366	6,100	6,324	3,056	2,216	534	12,130	-6,030	-196,689
1986	1,277	1,587	1,366	4,230	6,129	3,051	2,125	534	11,838	-7,608	-204,297
1987	893	1,479	1,366	3,738	6,761	3,332	2,146	530	12,769	-9,031	-213,329
1988	1,923	1,652	1,370	4,945	6,645	4,036	1,921	531	13,134	-8,190	-221,518
1989	195	1,378	1,366	2,939	7,057	3,836	1,937	524	13,354	-10,415	-231,934
1990	7,340	1,713	1,366	10,420	7,162	3,774	1,780	521	13,238	-2,818	-234,752
1991	2,485	1,462	1,366	5,313	6,465	4,006	1,549	518	12,538	-7,225	-241,976
1992	24,489	3,707	1,370	29,566	6,380	4,269	1,600	514	12,763	16,803	-225,173
1993	5,810	2,894	1,366	10,070	8,433	4,100	1,894	522	14,949	-4,879	-230,053
1994	8,286	1,984	1,366	11,636	10,389	3,926	1,918	518	16,751	-5,115	-235,167
1995	737	1,605	1,366	3,709	11,648	3,792	1,662	516	17,617	-13,909	-249,076
1996	615	1,313	1,370	3,298	13,653	4,007	1,695	515	19,870	-16,573	-265,648
1997	9,177	1,824	1,366	12,367	11,571	4,192	1,410	512	17,684	-5,317	-270,965
1998	2,256	1,918	1,366	5,540	10,169	3,979	1,385	523	16,057	-10,516	-281,481
1999	266	1,269	1,366	2,902	11,480	4,006	1,394	521	17,401	-14,499	-295,980
2000	452	1,320	1,370	3,143	12,314	4,202	1,245	519	18,280	-15,137	-311,118
2001	259	1,389	1,366	3,014	11,669	3,662	1,024	516	16,870	-13,856	-324,974
2002	380	1,513	1,366	3,258	13,029	4,100	996	513	18,637	-15,379	-340,353
2003	1,038	1,597	1,366	4,001	11,956	3,905	808	510	17,180	-13,179	-353,532
2004	10,407	1,823	1,370	13,600	12,804	3,905	768	510	17,988	-4,388	-357,920
2005	8,634	3,082	1,366	13,082	11,100	3,566	915	527	16,109	-3,027	-360,947
2006	2,335	1,895	1,366	5,596	13,988	3,769	1,000	530	19,287	-13,691	-374,638
2007	217	1,495	1,366	3,077	15,331	4,518	802	525	21,177	-18,099	-392,738
2008	1,224	1,279	1,370	3,873	14,074	3,842	606	523	19,045	-15,172	-407,910
2009	1,529	1,224	1,366	4,119	14,568	3,974	608	523	19,673	-15,554	-423,463
2010	154	1,272	1,366	2,792	14,310	3,121	515	521	18,466	-15,674	-439,137
2011	1,144	1,322	1,366	3,832	13,948	2,714	440	517	17,619	-13,787	-452,924
2012	6,404	1,999	1,370	9,773	12,919	1,816	519	529	15,782	-6,009	-458,933
2013	1,918	1,737	1,366	5,022	13,953	1,856	502	525	16,836	-11,814	-470,747
2014	1,446	1,550	1,366	4,363	14,964	2,057	480	522	18,022	-13,660	-484,407
2015	2,465	1,739	1,366	5,570	13,538	2,109	375	520	16,542	-10,973	-495,380
2016	1,488	1,590	1,370	4,448	13,141	1,751	385	523	15,800	-11,351	-506,731
2017	3,501	1,500	1,366	6,368	11,474	2,357	335	520	14,687	-8,319	-515,050
2018	2,586	1,329	1,366	5,281	12,656	2,346	327	517	15,846	-10,565	-525,615
2019	3,264	1,810	1,366	6,440	9,072	2,188	280	514	12,054	-5,614	-531,228
2020	3,969	1,799	1,370	7,138	7,466	2,231	267	515	10,479	-3,340	-534,568
2021	2,558	1,371	1,366	5,295	8,428	2,350	264	509	11,550	-6,256	-540,824
2022	3,613	1,514	1,366	6,494	7,649	2,114	238	506	10,507	-4,014	-544,837
Average	**3,889**	**1,511**	**1,367**	**6,768**	**8,405**	**2,226**	**2,601**	**521**	**13,753**	**-6,985**	-
Minimum	**131**	**582**	**1,366**	**2,102**	**0**	**87**	**238**	**499**	**7,989**	**-18,099**	
Maximum	**25,281**	**4,065**	**1,370**	**30,713**	**15,331**	**4,518**	**9,663**	**556**	**21,177**	**21,362**	

Table A-4. Water Budget for the *Corrected MNW2* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping		ET	Subsurface Outflow	Total Outflows		
					FMP Wells	Non-FMP Wells					
1945	8,563	2,834	1,366	12,763	0	87	7,700	532	8,319	4,444	4,444
1946	5,253	3,003	1,366	9,622	846	149	10,089	549	11,633	-2,011	2,433
1947	190	1,765	1,366	3,321	1,339	193	8,949	551	11,033	-7,712	-5,279
1948	113	1,090	1,370	2,573	2,748	236	8,675	551	12,210	-9,637	-14,916
1949	6,058	1,433	1,366	8,857	3,540	280	8,000	555	12,376	-3,519	-18,435
1950	127	1,012	1,366	2,505	4,325	324	8,312	547	13,508	-11,003	-29,437
1951	7,750	881	1,366	9,997	5,231	366	7,442	542	13,581	-3,584	-33,021
1952	619	897	1,370	2,886	6,679	410	6,106	542	13,737	-10,852	-43,873
1953	4,344	1,089	1,366	6,799	8,731	454	7,239	538	16,962	-10,162	-54,035
1954	710	752	1,366	2,828	9,243	496	5,954	531	16,224	-13,396	-67,431
1955	171	775	1,366	2,313	8,978	540	5,390	525	15,433	-13,121	-80,552
1956	2,025	685	1,370	4,080	10,485	583	5,719	521	17,308	-13,228	-93,779
1957	3,518	672	1,366	5,556	10,688	627	4,997	516	16,827	-11,271	-105,051
1958	797	697	1,366	2,861	9,750	671	4,412	513	15,346	-12,485	-117,536
1959	1,131	667	1,366	3,165	10,458	713	4,552	509	16,233	-13,068	-130,604
1960	686	694	1,370	2,751	9,385	757	3,926	509	14,577	-11,827	-142,431
1961	812	621	1,366	2,799	9,994	800	3,925	505	15,224	-12,425	-154,856
1962	163	594	1,366	2,124	9,795	844	3,554	502	14,695	-12,571	-167,427
1963	1,412	631	1,366	3,409	9,134	962	3,088	499	13,683	-10,274	-177,701
1964	4,078	1,391	1,370	6,839	8,591	1,030	3,477	516	13,614	-6,775	-184,475
1965	9,103	850	1,366	11,318	8,578	1,075	3,008	510	13,171	-1,852	-186,328
1966	7,336	1,181	1,366	9,883	4,716	1,118	2,877	517	9,228	655	-185,673
1967	1,175	1,048	1,366	3,589	4,554	1,161	2,677	516	8,908	-5,319	-190,992
1968	13,544	1,403	1,370	16,317	5,026	1,204	2,583	516	9,330	6,987	-184,005
1969	450	956	1,366	2,773	4,579	1,248	2,419	514	8,759	-5,986	-189,991
1970	331	968	1,366	2,666	4,502	1,291	2,329	513	8,634	-5,969	-195,960
1971	327	1,028	1,366	2,721	4,382	1,333	2,238	509	8,462	-5,741	-201,701
1972	2,173	1,085	1,370	4,628	4,582	1,704	2,264	509	9,059	-4,431	-206,133
1973	1,465	1,219	1,366	4,050	3,891	1,653	1,997	507	8,049	-3,999	-210,131
1974	644	1,150	1,366	3,160	4,251	1,682	2,004	505	8,442	-5,282	-215,414
1975	2,024	1,162	1,366	4,553	4,097	1,809	1,904	503	8,313	-3,760	-219,174
1976	3,697	1,367	1,370	6,434	4,161	1,933	1,843	505	8,442	-2,008	-221,181
1977	21,782	2,885	1,366	26,033	4,384	2,071	2,079	515	9,048	16,985	-204,196
1978	9,016	1,838	1,366	12,221	4,561	2,214	2,079	523	9,377	2,844	-201,352
1979	22,303	3,539	1,366	27,208	4,617	2,334	1,950	522	9,422	17,786	-183,566
1980	3,330	1,811	1,370	6,511	5,892	2,494	2,296	529	11,210	-4,699	-188,265
1981	1,978	1,239	1,366	4,583	6,673	2,619	2,436	525	12,252	-7,669	-195,934
1982	9,908	1,529	1,366	12,804	6,237	2,739	2,123	521	11,620	1,184	-194,750
1983	7,763	2,453	1,366	11,582	4,622	2,876	1,870	529	9,896	1,686	-193,063
1984	1,935	1,820	1,370	5,125	6,671	2,976	2,603	538	12,788	-7,663	-200,726
1985	3,102	1,728	1,366	6,196	6,324	3,113	2,223	534	12,194	-5,997	-206,723
1986	1,365	1,587	1,366	4,318	6,129	3,124	2,121	534	11,908	-7,590	-214,313
1987	911	1,479	1,366	3,756	6,761	3,415	2,140	530	12,846	-9,090	-223,403
1988	1,938	1,650	1,370	4,957	6,645	4,123	1,909	531	13,208	-8,250	-231,654
1989	230	1,370	1,366	2,966	7,057	3,953	1,919	524	13,454	-10,488	-242,141
1990	6,897	1,726	1,366	9,989	7,162	3,848	1,755	522	13,287	-3,298	-245,440
1991	2,486	1,479	1,366	5,332	6,465	4,061	1,520	518	12,564	-7,232	-252,672
1992	20,684	3,211	1,370	25,265	6,380	4,329	1,547	514	12,771	12,494	-240,177
1993	5,817	2,767	1,366	9,950	8,433	4,154	1,828	521	14,936	-4,986	-245,163
1994	8,202	1,926	1,366	11,495	10,389	3,968	1,828	518	16,702	-5,208	-250,371
1995	759	1,626	1,366	3,751	11,648	3,830	1,581	516	17,575	-13,824	-264,195
1996	652	1,316	1,370	3,338	13,653	4,110	1,607	515	19,886	-16,548	-280,743
1997	8,306	1,771	1,366	11,443	11,571	4,266	1,327	512	17,676	-6,232	-286,975
1998	2,979	1,962	1,366	6,307	10,169	4,032	1,319	523	16,043	-9,736	-296,711
1999	314	1,297	1,366	2,978	11,480	4,067	1,314	521	17,382	-14,405	-311,116
2000	436	1,304	1,370	3,110	12,314	4,252	1,167	519	18,252	-15,142	-326,258
2001	283	1,405	1,366	3,055	11,669	3,736	964	516	16,885	-13,831	-340,088
2002	422	1,518	1,366	3,307	13,029	4,189	937	513	18,667	-15,360	-355,449
2003	895	1,603	1,366	3,864	11,956	4,001	756	510	17,224	-13,360	-368,809
2004	10,531	1,712	1,370	13,613	12,804	3,988	729	510	18,032	-4,419	-373,228
2005	8,609	3,054	1,366	13,029	11,100	3,628	893	527	16,148	-3,119	-376,347
2006	2,421	1,926	1,366	5,714	13,988	3,832	966	530	19,315	-13,601	-389,948
2007	292	1,547	1,366	3,205	15,331	4,613	766	525	21,235	-18,030	-407,978
2008	1,199	1,285	1,370	3,854	14,074	3,978	572	523	19,147	-15,293	-423,270
2009	1,517	1,229	1,366	4,112	14,568	4,112	583	522	19,785	-15,673	-438,943
2010	238	1,285	1,366	2,889	14,310	3,282	492	521	18,605	-15,716	-454,660
2011	1,161	1,331	1,366	3,858	13,948	2,807	425	517	17,696	-13,838	-468,498
2012	6,219	1,956	1,370	9,545	12,919	1,886	503	529	15,836	-6,290	-474,788
2013	1,932	1,674	1,366	4,972	13,953	1,946	492	525	16,916	-11,944	-486,733
2014	1,649	1,636	1,366	4,651	14,964	2,132	468	522	18,086	-13,435	-500,167
2015	2,095	1,569	1,366	5,031	13,538	2,601	365	520	17,023	-11,993	-512,160
2016	1,862	1,660	1,370	4,892	13,141	2,671	376	523	16,710	-11,818	-523,978
2017	3,545	1,554	1,366	6,465	11,474	2,436	325	520	14,755	-8,290	-532,269
2018	2,640	1,316	1,366	5,322	12,656	2,424	318	517	15,914	-10,593	-542,861
2019	3,270	1,811	1,366	6,448	9,072	2,251	251	514	12,089	-5,641	-548,502
2020	3,983	1,864	1,370	7,217	7,466	2,290	273	515	10,544	-3,327	-551,829
2021	2,628	1,383	1,366	5,378	8,428	2,397	260	509	11,593	-6,216	-558,045
2022	3,195	1,488	1,366	6,050	7,649	2,189	230	506	10,574	-4,525	-562,569
Average	**3,775**	**1,496**	**1,367**	**6,639**	**8,404**	**2,283**	**2,643**	**521**	**13,851**	**-7,212**	-
Minimum	**113**	**594**	**1,366**	**2,124**	**0**	**87**	**230**	**499**	**8,049**	**-18,030**	
Maximum	**22,303**	**3,539**	**1,370**	**27,208**	**15,331**	**4,613**	**10,089**	**555**	**21,235**	**17,786**	

Table A-5. Water Budget for the *Corrected FMP* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping: FMP Wells	Groundwater Pumping: Non-FMP Wells	ET	Subsurface Outflow	Total Outflows		
1945	8,563	2,829	1,366	12,759	0	87	7,700	532	8,319	4,439	4,439
1946	5,253	2,996	1,366	9,615	846	149	10,089	549	11,633	-2,018	2,421
1947	190	1,761	1,366	3,317	1,339	193	8,949	551	11,033	-7,716	-5,294
1948	112	1,086	1,370	2,569	2,748	236	8,674	551	12,210	-9,641	-14,935
1949	6,058	1,427	1,366	8,851	3,540	280	8,000	555	12,375	-3,524	-18,459
1950	127	1,008	1,366	2,502	4,325	324	8,312	547	13,508	-11,006	-29,466
1951	7,750	877	1,366	9,993	5,231	366	7,442	542	13,581	-3,588	-33,053
1952	619	893	1,370	2,882	6,679	410	6,106	542	13,737	-10,856	-43,909
1953	4,344	1,084	1,366	6,794	8,731	454	7,239	538	16,961	-10,167	-54,076
1954	710	748	1,366	2,824	9,243	496	5,953	531	16,224	-13,399	-67,475
1955	171	771	1,366	2,309	8,978	540	5,390	525	15,433	-13,124	-80,600
1956	2,025	681	1,370	4,077	10,485	583	5,718	521	17,307	-13,231	-93,830
1957	3,518	669	1,366	5,553	10,688	627	4,997	516	16,827	-11,274	-105,105
1958	797	694	1,366	2,857	9,750	671	4,412	513	15,346	-12,489	-117,593
1959	1,131	664	1,366	3,162	10,458	713	4,552	509	16,233	-13,071	-130,664
1960	686	691	1,370	2,747	9,385	757	3,926	509	14,577	-11,830	-142,494
1961	812	618	1,366	2,796	9,994	800	3,925	505	15,224	-12,428	-154,922
1962	163	591	1,366	2,121	9,795	844	3,554	502	14,695	-12,574	-167,496
1963	1,412	627	1,366	3,406	9,134	962	3,088	499	13,683	-10,277	-177,774
1964	4,078	1,386	1,370	6,835	8,591	1,030	3,477	516	13,614	-6,779	-184,553
1965	9,103	847	1,366	11,315	8,578	1,075	3,008	510	13,171	-1,856	-186,409
1966	7,336	1,176	1,366	9,878	4,716	1,118	2,877	517	9,228	650	-185,759
1967	1,175	1,045	1,366	3,586	4,554	1,161	2,677	516	8,908	-5,322	-191,081
1968	13,544	1,399	1,370	16,313	5,026	1,204	2,584	516	9,330	6,983	-184,098
1969	450	954	1,366	2,771	4,579	1,248	2,419	514	8,760	-5,989	-190,087
1970	331	965	1,366	2,663	4,502	1,291	2,329	513	8,634	-5,972	-196,059
1971	327	1,026	1,366	2,719	4,382	1,334	2,238	509	8,463	-5,744	-201,803
1972	2,173	1,084	1,370	4,627	4,582	1,705	2,262	509	9,058	-4,431	-206,234
1973	1,464	1,217	1,366	4,048	3,891	1,655	1,986	507	8,040	-3,992	-210,226
1974	644	1,147	1,366	3,158	4,251	1,684	1,997	505	8,437	-5,280	-215,506
1975	2,024	1,161	1,366	4,552	4,097	1,812	1,898	503	8,310	-3,758	-219,264
1976	3,697	1,364	1,370	6,431	4,161	1,934	1,836	505	8,437	-2,006	-221,269
1977	21,782	2,883	1,366	26,031	4,384	2,069	2,071	515	9,038	16,993	-204,277
1978	9,016	1,835	1,366	12,217	4,561	2,208	2,070	523	9,362	2,855	-201,421
1979	22,303	3,533	1,366	27,202	4,617	2,321	1,939	522	9,398	17,804	-183,617
1980	3,330	1,811	1,370	6,510	5,892	2,478	2,283	529	11,181	-4,671	-188,288
1981	1,978	1,235	1,366	4,579	6,673	2,595	2,420	525	12,213	-7,634	-195,922
1982	9,908	1,529	1,366	12,803	6,237	2,706	2,110	521	11,573	1,230	-194,692
1983	7,763	2,453	1,366	11,583	4,622	2,836	1,857	529	9,843	1,739	-192,952
1984	1,935	1,824	1,370	5,129	6,671	2,935	2,586	538	12,730	-7,601	-200,553
1985	3,102	1,730	1,366	6,198	6,324	3,058	2,208	534	12,123	-5,925	-206,478
1986	1,365	1,580	1,366	4,312	6,129	3,051	2,109	534	11,823	-7,511	-213,989
1987	911	1,480	1,366	3,757	6,761	3,332	2,131	530	12,754	-8,997	-222,986
1988	1,938	1,664	1,370	4,972	6,645	4,036	1,903	531	13,115	-8,143	-231,129
1989	230	1,388	1,366	2,984	7,057	3,836	1,913	524	13,330	-10,346	-241,475
1990	6,897	1,740	1,366	10,003	7,162	3,773	1,753	522	13,211	-3,208	-244,682
1991	2,486	1,470	1,366	5,323	6,465	4,005	1,522	518	12,510	-7,187	-251,870
1992	20,684	3,235	1,370	25,289	6,380	4,267	1,550	514	12,711	12,578	-239,292
1993	5,817	2,813	1,366	9,997	8,433	4,097	1,837	521	14,889	-4,892	-244,184
1994	8,202	1,937	1,366	11,505	10,389	3,923	1,844	518	16,674	-5,169	-249,352
1995	759	1,613	1,366	3,738	11,648	3,787	1,598	516	17,549	-13,811	-263,163
1996	652	1,316	1,370	3,338	13,653	4,003	1,628	515	19,799	-16,461	-279,624
1997	8,306	1,780	1,366	11,453	11,571	4,188	1,348	512	17,619	-6,167	-285,790
1998	2,979	1,954	1,366	6,299	10,169	3,975	1,339	523	16,006	-9,707	-295,497
1999	314	1,292	1,366	2,972	11,480	4,002	1,336	521	17,339	-14,367	-309,864
2000	436	1,321	1,370	3,127	12,314	4,196	1,187	519	18,216	-15,089	-324,953
2001	283	1,401	1,366	3,050	11,669	3,657	978	516	16,820	-13,770	-338,723
2002	422	1,519	1,366	3,308	13,029	4,096	951	513	18,588	-15,280	-354,003
2003	895	1,599	1,366	3,860	11,956	3,902	769	510	17,137	-13,277	-367,281
2004	10,531	1,715	1,370	13,616	12,804	3,902	740	510	17,956	-4,340	-371,621
2005	8,609	3,155	1,366	13,130	11,100	3,563	904	527	16,094	-2,964	-374,584
2006	2,421	1,885	1,366	5,672	13,988	3,766	978	530	19,262	-13,589	-388,174
2007	292	1,499	1,366	3,158	15,331	4,516	776	525	21,148	-17,991	-406,164
2008	1,199	1,281	1,370	3,850	14,074	3,838	580	523	19,014	-15,164	-421,329
2009	1,517	1,221	1,366	4,104	14,568	3,970	590	522	19,651	-15,547	-436,875
2010	238	1,282	1,366	2,886	14,310	3,118	499	521	18,448	-15,561	-452,437
2011	1,161	1,327	1,366	3,854	13,948	2,714	430	517	17,608	-13,753	-466,190
2012	6,220	1,966	1,370	9,555	12,919	1,814	507	529	15,769	-6,214	-472,404
2013	1,931	1,736	1,366	5,034	13,953	1,856	498	525	16,832	-11,798	-484,202
2014	1,649	1,578	1,366	4,594	14,164	2,057	473	522	17,216	-12,622	-496,824
2015	2,095	1,672	1,366	5,133	13,538	2,109	369	520	16,536	-11,403	-508,227
2016	1,862	1,673	1,370	4,904	13,141	2,093	380	523	16,137	-11,232	-519,459
2017	3,545	1,511	1,366	6,422	11,474	2,357	330	520	14,680	-8,258	-527,717
2018	2,640	1,330	1,366	5,336	12,656	2,346	323	517	15,842	-10,505	-538,223
2019	3,271	1,817	1,366	6,453	9,072	2,188	275	514	12,049	-5,595	-543,818
2020	3,983	1,831	1,370	7,184	7,466	2,231	263	515	10,475	-3,291	-547,108
2021	2,628	1,400	1,366	5,394	8,428	2,349	261	509	11,547	-6,153	-553,262
2022	3,196	1,498	1,366	6,060	7,649	2,114	234	506	10,503	-4,443	-557,704
Average	**3,775**	**1,497**	**1,367**	**6,640**	**8,394**	**2,231**	**2,644**	**521**	**13,790**	**-7,150**	-
Minimum	**112**	**591**	**1,366**	**2,121**	**0**	**87**	**234**	**499**	**8,040**	**-17,991**	
Maximum	**22,303**	**3,533**	**1,370**	**27,202**	**15,331**	**4,516**	**10,089**	**555**	**21,148**	**17,804**	

Table A-6. Water Budget for the *Final Corrected* BVHM
Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streambed Recharge	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping FMP Wells	Groundwater Pumping Non-FMP Wells	ET	Subsurface Outflow	Total Outflows		
1945	8,911	3,008	2,120	14,038	0	87	7,581	532	8,201	5,838	5,838
1946	4,521	2,965	2,120	9,606	846	149	9,806	552	11,352	-1,746	4,091
1947	306	1,884	2,120	4,310	1,339	193	8,824	553	10,910	-6,600	-2,508
1948	172	1,169	2,126	3,466	2,748	236	8,614	552	12,151	-8,685	-11,194
1949	6,030	1,517	2,120	9,667	3,540	280	7,946	556	12,323	-2,656	-13,849
1950	139	1,068	2,120	3,327	4,325	324	8,296	547	13,492	-10,165	-24,014
1951	8,000	955	2,120	11,074	5,231	366	7,465	542	13,604	-2,530	-26,544
1952	515	974	2,126	3,615	6,678	410	6,138	543	13,769	-10,154	-36,698
1953	4,239	1,196	2,120	7,555	8,730	454	7,240	538	16,962	-9,407	-46,105
1954	716	834	2,120	3,670	9,241	496	6,009	531	16,278	-12,608	-58,713
1955	227	856	2,120	3,203	8,975	540	5,465	525	15,505	-12,303	-71,015
1956	2,067	768	2,126	4,960	10,483	583	5,822	521	17,409	-12,449	-83,465
1957	3,610	757	2,120	6,487	10,688	627	5,113	516	16,944	-10,458	-93,922
1958	809	784	2,120	3,713	9,750	671	4,534	513	15,468	-11,755	-105,678
1959	1,139	732	2,120	3,992	10,458	713	4,690	509	16,371	-12,379	-118,057
1960	704	760	2,126	3,590	9,385	757	4,061	509	14,713	-11,123	-129,180
1961	854	667	2,120	3,641	9,994	800	4,072	505	15,371	-11,730	-140,910
1962	155	611	2,120	2,886	9,795	844	3,708	502	14,849	-11,963	-152,873
1963	1,945	723	2,120	4,788	9,134	962	3,235	499	13,830	-9,042	-161,915
1964	3,425	1,507	2,126	7,058	8,591	1,030	3,603	516	13,740	-6,681	-168,596
1965	9,352	966	2,120	12,438	8,578	1,075	3,161	511	13,324	-886	-169,482
1966	7,388	1,343	2,120	10,851	4,716	1,118	3,027	517	9,378	1,472	-168,010
1967	1,283	1,127	2,120	4,530	4,554	1,161	2,825	517	9,057	-4,526	-172,536
1968	14,255	1,590	2,126	17,970	5,026	1,204	2,734	516	9,481	8,490	-164,046
1969	375	1,077	2,120	3,572	4,579	1,248	2,572	515	8,913	-5,342	-169,388
1970	328	1,054	2,120	3,502	4,502	1,291	2,494	513	8,800	-5,298	-174,686
1971	311	1,112	2,120	3,543	4,382	1,335	2,416	509	8,643	-5,100	-179,786
1972	2,166	1,160	2,126	5,451	4,582	1,715	2,458	510	9,265	-3,814	-183,599
1973	1,482	1,297	2,120	4,899	3,891	1,675	2,182	508	8,256	-3,357	-186,957
1974	630	1,245	2,120	3,995	4,251	1,704	2,208	506	8,669	-4,674	-191,631
1975	2,352	1,334	2,120	5,806	4,097	1,843	2,114	504	8,559	-2,752	-194,383
1976	4,234	1,529	2,126	7,890	4,161	1,976	2,053	506	8,696	-807	-195,190
1977	21,879	3,196	2,120	27,194	4,384	2,116	2,325	516	9,340	17,854	-177,335
1978	8,851	2,005	2,120	12,976	4,561	2,254	2,317	524	9,656	3,320	-174,015
1979	25,224	4,392	2,120	31,736	4,617	2,373	2,174	523	9,687	22,049	-151,966
1980	3,189	2,026	2,126	7,341	5,892	2,528	2,558	530	11,507	-4,167	-156,133
1981	1,969	1,280	2,120	5,368	6,673	2,659	2,771	526	12,629	-7,261	-163,393
1982	10,184	1,764	2,120	14,068	6,237	2,782	2,458	523	11,999	2,069	-161,324
1983	8,109	2,749	2,120	12,978	4,622	2,919	2,164	530	10,234	2,743	-158,581
1984	1,435	2,013	2,126	5,574	6,671	3,020	3,001	540	13,232	-7,658	-166,239
1985	3,100	1,804	2,120	7,024	6,324	3,158	2,602	536	12,620	-5,596	-171,835
1986	1,281	1,707	2,120	5,108	6,129	3,171	2,500	536	12,335	-7,227	-179,062
1987	896	1,644	2,120	4,660	6,761	3,450	2,534	532	13,277	-8,617	-187,679
1988	1,926	1,911	2,126	5,963	6,645	4,139	2,269	533	13,586	-7,623	-195,302
1989	199	1,502	2,120	3,821	7,057	3,956	2,313	526	13,851	-10,031	-205,333
1990	7,340	1,879	2,120	11,339	7,162	3,848	2,146	523	13,680	-2,342	-207,674
1991	2,495	1,606	2,120	6,222	6,465	4,065	1,857	520	12,908	-6,686	-214,360
1992	24,444	3,798	2,126	30,367	6,380	4,370	1,939	516	13,206	17,162	-197,199
1993	5,790	2,976	2,120	10,886	8,433	4,215	2,242	523	15,414	-4,528	-201,727
1994	8,285	2,119	2,120	12,524	10,389	4,016	2,294	520	17,219	-4,694	-206,421
1995	741	1,721	2,120	4,582	11,648	3,894	2,000	518	18,060	-13,478	-219,899
1996	618	1,445	2,126	4,188	13,653	4,138	2,066	517	20,374	-16,186	-236,085
1997	9,180	2,008	2,120	13,308	11,571	4,270	1,724	514	18,078	-4,770	-240,855
1998	2,254	2,101	2,120	6,475	10,169	4,049	1,687	526	16,430	-9,955	-250,810
1999	269	1,462	2,120	3,851	11,480	4,071	1,715	523	17,788	-13,937	-264,748
2000	456	1,418	2,126	3,999	12,314	4,306	1,553	522	18,695	-14,695	-279,443
2001	262	1,626	2,120	4,008	11,669	3,783	1,292	518	17,262	-13,254	-292,696
2002	381	1,515	2,120	4,016	13,029	4,239	1,265	516	19,048	-15,032	-307,728
2003	1,041	1,469	2,120	4,631	11,956	4,042	1,026	513	17,537	-12,906	-320,635
2004	10,407	1,812	2,126	14,345	12,804	4,037	982	513	18,337	-3,992	-324,626
2005	8,623	3,265	2,120	14,008	11,100	3,670	1,125	531	16,425	-2,417	-327,043
2006	2,334	1,901	2,120	6,355	13,988	3,871	1,240	534	19,633	-13,278	-340,321
2007	217	1,375	2,120	3,712	15,331	4,638	1,005	529	21,504	-17,792	-358,113
2008	1,225	1,392	2,126	4,743	14,074	3,993	774	527	19,367	-14,624	-372,737
2009	1,527	1,398	2,120	5,044	14,568	4,135	779	526	20,008	-14,963	-387,701
2010	154	1,396	2,120	3,670	14,310	3,287	666	524	18,788	-15,117	-402,818
2011	1,144	1,493	2,120	4,757	13,947	2,807	575	520	17,850	-13,093	-415,911
2012	6,401	2,307	2,126	10,835	12,919	1,886	651	532	15,987	-5,152	-421,064
2013	1,922	2,004	2,120	6,045	13,953	1,947	633	528	17,061	-11,016	-432,079
2014	1,443	1,712	2,120	5,275	14,164	2,133	611	525	17,432	-12,157	-444,237
2015	2,471	1,698	2,120	6,289	13,538	2,602	486	523	17,149	-10,860	-455,097
2016	1,486	1,549	2,126	5,161	13,141	2,671	497	526	16,834	-11,674	-466,771
2017	3,499	1,627	2,120	7,246	11,474	2,436	460	523	14,893	-7,647	-474,418
2018	2,586	1,394	2,120	6,100	12,656	2,424	447	520	16,047	-9,947	-484,365
2019	3,264	1,758	2,120	7,142	9,072	2,251	350	518	12,191	-5,049	-489,414
2020	3,969	1,816	2,126	7,912	7,466	2,290	350	518	10,624	-2,712	-492,126
2021	2,558	1,375	2,120	6,053	8,428	2,397	358	512	11,695	-5,642	-497,768
2022	3,619	1,572	2,120	7,311	7,649	2,189	331	509	10,678	-3,367	-501,135
Average	**3,888**	**1,622**	**2,121**	**7,632**	**8,394**	**2,300**	**2,841**	**523**	**14,057**	**-6,425**	-
Minimum	**139**	**611**	**2,120**	**2,886**	**0**	**87**	**331**	**499**	**8,201**	**-17,792**	
Maximum	**25,224**	**4,392**	**2,126**	**31,736**	**15,331**	**4,638**	**9,806**	**556**	**21,504**	**22,049**	

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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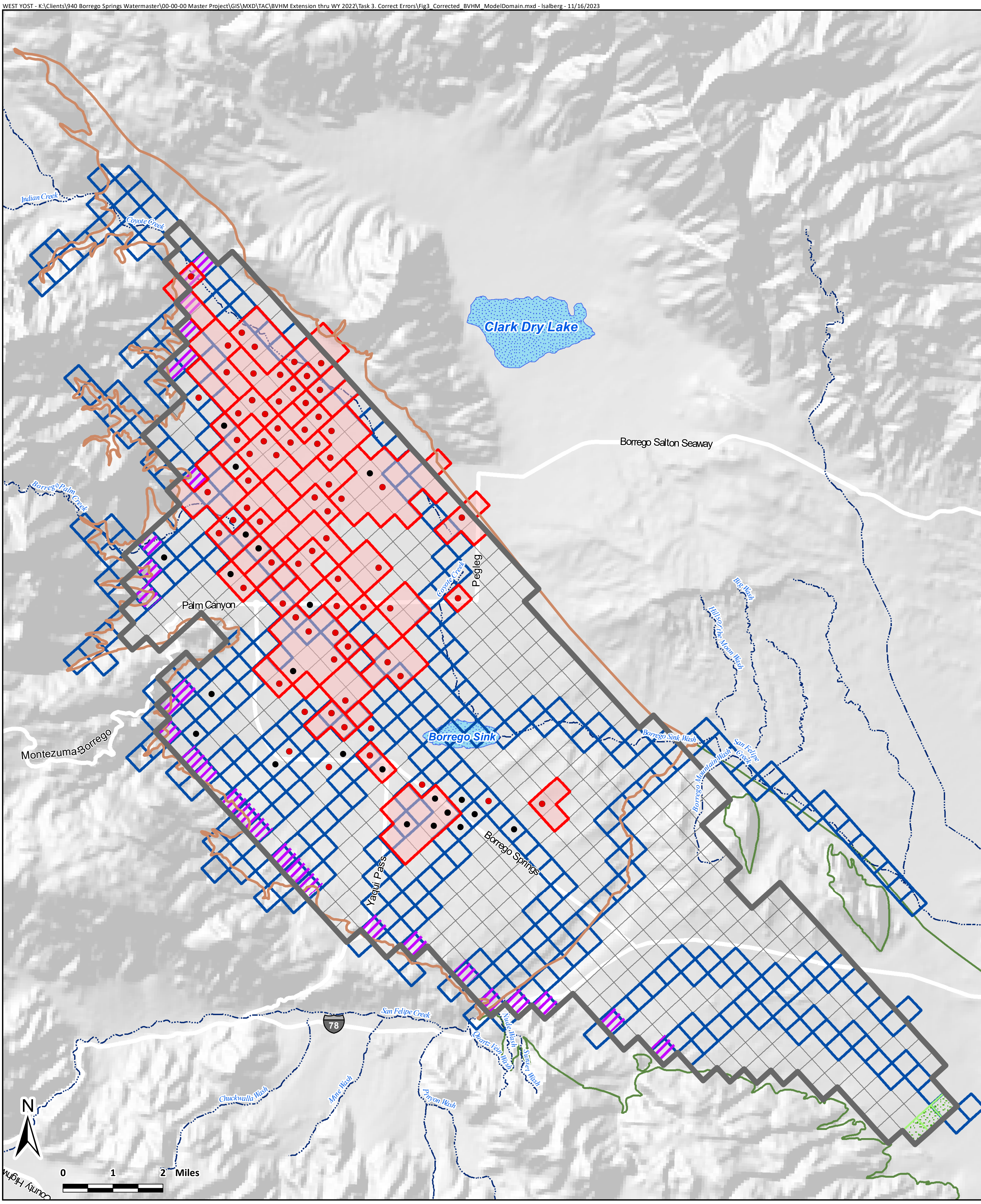


BVHM Packages

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

Farm Process Features

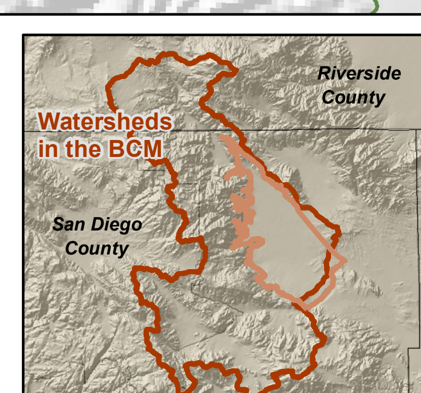
- Water Budget Subregion in the FMP
- FMP Well in MNW2 Package

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
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."

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

To: Technical Advisory Committee (TAC)

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

Date: December 11, 2023

Subject: Discuss Potential Methods for Task 5 to Redetermine the Sustainable Yield – *Determine the Sustainable Yield*

Background

The Judgment defines the Sustainable Yield of the Borrego Springs Subbasin (Basin) consistent with SGMA (Water Code, § 10721(w)) as: "The maximum quantity of water, calculated over a base period representative of long-term conditions in the Basin, that can be cumulatively pumped on an annual basis from the Basin without causing an Undesirable Result." The Judgment also requires the Sustainable Yield be redetermined by January 1, 2025, and every five years thereafter through 2035. If the redetermination results in a changed Sustainable Yield, then the Rampdown rate is adjusted accordingly to bring pumping in the Basin within the Sustainable Yield by 2040.

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 United States Geological Survey (USGS) and were used to improve the hydrogeologic understanding of the Basin and evaluate future management scenarios that would eliminate conditions of overdraft (initial BVHM).[1]

The initial BVHM was updated and extended by Dudek and used to simulate historical groundwater conditions in the Basin from October 1929 through September 2016 (2016 BVHM).[2] Dudek estimated average inflows of 6,770 acre-feet per year (afy) from 1945–2016 and determined that this was a reasonable estimate of inflows because it captured a wide range of climatic conditions. Dudek estimated average outflows (besides pumping) to be 1,021 afy for the most recent 10 years (2007–2016) and determined that this was representative of current outflows because the change in land use (i.e., loss of native phreatophytes) had decreased outflow from evapotranspiration in the Basin over the model period. Using these assumptions, the difference between inflows over outflows for the Basin was estimated to be approximately 5,750 afy.

Based on these studies, Section II.E of the Judgment established the initial Sustainable Yield at 5,700 afy. The studies also included future projections of groundwater conditions under various future land

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[1] USGS. 2015. *Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California*. Scientific Investigations Report 2015–5150.
[2] DUDEK. 2019. *Update to USGS Borrego Valley Hydrologic Model for the Borrego Valley GSA (draft final)*. Prepared for the County of San Diego, Planning and Development Services.

use, water use, and climatic conditions, which were used to set sustainable management criteria in the Groundwater Management Plan (GMP) (*e.g.,* Minimum Thresholds for groundwater elevations).

During the August 29, 2023 TAC meeting, the TAC began to discuss the appropriate period to redetermine the Sustainable Yield in 2025, noting that the period should be multi-year to multi-decadal because (i) a long time-period is required by the Sustainable Management Groundwater Act (SGMA) and (ii) desert environments, such as Borrego Springs, experience infrequent but significant storm events and a longer period is required to capture the important effect of these storm events on recharge.

For the November 1, 2023 TAC meeting, West Yost prepared a technical memorandum (TM) and facilitated continued discussion on this topic. Following the November 1, 2023, some TAC member submitted written comments and feedback, which are summarized in Exhibit 1. Below is a summary of the topics discussed and TAC feedback:

1. What domain of the BVHM should be used to estimate water budget of the Basin, and hence, form the basis of redetermined Sustainable Yield? The BVHM domain currently covers an area containing both the Borrego Valley Subbasin and the Ocotillo Wells Subbasin.

   TAC Feedback: The model domain containing only the Borrego Springs Subbasin should be used to calculate the water budget of the Basin. The model domain overlying the Ocotillo Wells Subbasin should be excluded from the calculation of the water budget and Sustainable Yield.

2. Should the Sustainable Yield be based on the long-term annual average recharge to the Basin or long-term annual average *net* recharge (accounting for natural discharge) as estimated by the BVHM?

   TAC Feedback: The Sustainable Yield should be based on the long-term annual average *net* recharge, where outflows from the model domain (evapotranspiration of shallow groundwater and subsurface outflow) are subtracted from inflows (stream recharge, unsaturated zone recharge, and subsurface inflow). These water budget components are consistent with those listed in Table 2.2-9 *Estimated Surplus of Inflows Over Outflows* in the GMP, which was used to establish the current Sustainable Yield of 5,700 afy. Table 1 is an excerpt of Table 2.2-9 from the GMP and identifies the annual average inflows and outflows calculated by the BVHM.

Table 1. Excerpt from GMP Table 2.2-9 *Estimated Surplus of Inflows Over Outflows*

Water Budget Components	Acre-Feet/Year
INFLOWS (Model Update 1945- 2016)	
Stream Recharge	3,905
Unsaturated Zone Recharge	1,497
Underflow (Inflow from Adjacent Basins)	1,367
Total Inflows	**6,770**
OUTFLOWS BESIDES PUMPING (Most Recent 10 Years, 2007-2016)	
Evapotranspiration	498
Underflow (Flow out of Southern End)	523
Total Outflows	**1,021**

3. Should the period used to estimate the Sustainable Yield be the historical calibration period of the BVHM (e.g., 1945-2022) or a future BVHM projection that accounts for the effects of climate change and future land/water uses that could affect natural recharge?

   TAC Feedback: The historical calibration period should be used to redetermine the Sustainable Yield. Specifically, the entire calibration period (1945-2022) should be used to estimate inflows. A more recent historical period (2007-2022) should be used to estimate outflows because it is more representative of current and future conditions.

All TAC discussion and feedback were considered when preparing the proposed methods to perform Task 5 – *Determine the Sustainable Yield.*

Proposed Methods to Redetermine the Sustainable Yield

This section describes a proposed approach for redetermining the Sustainable Yield by 2025. Some of these steps describe various options, which are meant to facilitate TAC feedback and recommendations.

1. **Compute the water budget of the Basin using the recalibrated BVHM.** As described in the Task 4 memorandum – *Model Recalibration,*[3] the final calibration of the BVHM will result in an annual water budget table for the period 1945-2022. The water budget will be calculated for the portion of the BVHM domain that overlies the Basin (*i.e.,* ignores the portion of the BVHM that overlies the Ocotillo Wells Subbasin).
2. **Estimate the long-term average annual *net recharge* to the Basin to establish the *Preliminary* Sustainable Yield.** Using the water budget estimated by the recalibrated BVHM, the long-term average annual *net* recharge is calculated as the difference between the long-term average annual inflow to the model domain (stream recharge, unsaturated zone recharge, and subsurface inflow) and the long-term average annual outflow (ET of shallow groundwater and subsurface outflow) from the model domain. The long-term average annual inflow is calculated for the entire model simulation period (1945-2022) to capture the variability of climatic conditions. The long-term average annual outflow is calculated for a recent period (2007-2022), which should be more reflective of current/future conditions of lower groundwater levels and lesser outflow by ET of shallow groundwater. This is a similar approach that was used to estimate the current Sustainable Yield of 5,700 afy.
3. **Develop a future groundwater pumping scenario to simulate the Rampdown of pumping to the *Preliminary* Sustainable Yield by 2040 and beyond.** The objective of this task is to develop the requisite information to prepare the input file(s) for future pumping that: (i) will comply with a Rampdown of pumping to the *Preliminary* Sustainable Yield by 2040 and (ii) will be used in BVHM projection simulations for the period 2024-2070.

   The following are options and considerations for the execution of this step:

[3] Refer to the memo included in this TAC Agenda Package for Agenda Item V. Task 4 – *Model Recalibration*.

a. The Rampdown of pumping could be implemented by linear reductions in pumping at all active pumping wells across the Basin to achieve a basin-wide pumping rate at the *Preliminary* Sustainable Yield by 2040 and thereafter. This is a similar approach that was used to estimate the current Sustainable Yield of 5,700 afy. This is a straightforward approach but would not likely result in a probable spatial distribution of future pumping in the Basin.

b. The Rampdown of pumping could be implemented by collecting information on future land use and water supply plans of the BPA holders and using the information to develop a future pumping scenario that achieves a Basin-wide pumping rate at the *Preliminary* Sustainable Yield by 2040 and thereafter. This is a more labor-intensive approach but would likely result in a more probable spatial distribution of future pumping in the Basin.

c. If (b.) is executed, more than one scenario may need to be developed and simulated to characterize the uncertainty in future pumping.

d. During recalibration of the BVHM over the period 1945-2022, the FMP will be used to estimate pumping for agricultural irrigation. The use of the FMP to simulate future agricultural pumping is challenging because (i) the future of land uses, crop types, and irrigation efficiencies is uncertain and (ii) a specific Rampdown of agricultural pumping will need to be implemented to achieve a basin-wide pumping rate at the *Preliminary* Sustainable Yield by 2040 and thereafter. If the FMP is used to project agricultural pumping, this would likely be an iterative step to ensure the Rampdown achieves the *Preliminary* Sustainable Yield by 2040 and thereafter. If the FMP is not used to project agricultural pumping (*e.g.,* pumping is assigned to wells instead), it could still be used to simulate irrigation return flows and other processes; or alternative methods could be developed and used to simulate these processes.

These options and considerations should be discussed by the TAC to assist in the development of the most prudent strategy to develop the future pumping scenario(s).

4. **Perform uncertainty analysis for future climate change and climate variability**. The modeling work performed to establish the current Sustainable Yield recognized the important influence of long-term climate change and the shorter-term climatic variability on the future recharge to the Basin. Hence, that modeling work included multiple projection scenarios of the pumping Rampdown paired with various climatic futures, including:

   a. Repeat of the historical climate from 1960-2010 for the period 2020-2070. [see attached Figure 3.3-2 from the GMP]

   b. Application of DWR change factors for 2030 and 2070 to the historical climate from 1960-2010 as outlined in the DWR climate guidance for GSPs.[4] This analysis indicated

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[4]https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance_Final_ay_19.pdf

that the DWR climate change factors had a relatively small influence on the long-term recharge and change-in-storage. [see attached Figure 3.3-2 from the GMP]

c. A Monte Carlo Simulation (MCS) uncertainty analysis of the Rampdown period 2020-2040 using 53 random 20-year periods of the historical climate time series from 1945-2010. This analysis indicated that shorter-term climatic variability had a relatively large influence on the long-term recharge and change-in-storage. The 20th percentile change-in-storage scenario was used to set Minimum Thresholds for groundwater elevations at most Representative Monitoring Sites in the Basin. [see attached Figure 3.3-3 from the GMP]

West Yost concurs that long-term climate change and shorter-term climatic variability are crucial factors to consider when evaluating the update to the Sustainable Yield and the potential for Undesirable Results (e.g., potential exceedance of Minimum Thresholds in the future). There are two general approaches to implement this evaluation for this redetermination of the Sustainable Yield:

a. Use the same (or similar) procedures listed in the bullet points a, b, and c above for the uncertainty analysis of the current Sustainable Yield.

b. Use different procedures and/or datasets to perform the uncertainty analysis. For example, newly published climate projections for downscaled precipitation and temperature are now available for use in model projections, such as: NASA Earth Exchange (NEX) Downscaled Climate Projections (NEX-DCP30)[5], NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)[6], and CMIP6 Downscaling Using the Weather Research and Forecasting model (WRF-CMIP6)[7].

These options and considerations should be discussed by the TAC to assist in the development of the most prudent strategy to include climatic uncertainty in the redetermination of the Sustainable Yield.

5. **Analyze the BVHM results from the future scenario(s).** The BVHM results of the future scenario(s) should be analyzed against the Sustainable Management Criteria in the GMP (e.g., Minimum Thresholds, Measurable Objectives, and Interim Milestones) to determine the potential for Undesirable Results that could occur under the *Preliminary* Sustainable Yield. The types of analyses that could be performed are described below for the applicable Sustainability Indicators:

- *Chronic lowering of Groundwater Levels*. Projected heads should be compared to the Minimum Thresholds established for Representative Monitoring Wells to identify if groundwater levels are projected to decline below the Minimum Thresholds established in the GMP.

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[5] https://ds.nccs.nasa.gov/thredds/catalog/bypass/NEX-CP30/bcsd/catalog.html
[6] https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6
[7] https://dept.atmos.ucla.edu/alexhall/downscaling-cmip6

- *Reduction in Groundwater Storage*. Projected cumulative change in groundwater storage should be compared to the Minimum Threshold established for the Basin to identify if storage is projected to decline below the Minimum Threshold established in the GMP.
- *Degradation of groundwater quality*. Model results will not be used to assess Undesirable Results for groundwater quality because the BVHM does not simulate solute concentrations and/or transport.

6. **Adjust the Sustainable Yield based on the analysis of the future scenarios, if necessary.** If the BVHM results of the future scenario(s) show that Minimum Thresholds are projected to be exceeded, then the *Preliminary* Sustainable Yield would need to be reduced, and then steps 3-5 would be repeated until the Minimum Thresholds are not exceeded. At this point, the Sustainable Yield would be redetermined for 2025-2030.

   Alternatively, the Sustainable Management Criteria could be adjusted, if such adjustments are substantiated with defensible reasoning and/or new data and information.

Next Steps

At the December 18, 2023 TAC meeting, West Yost will provide an overview of the methods proposed in this Task 5 TM 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**. West Yost will present the preliminary methodology to perform Task 5 – *Determine the Sustainable Yield* and the associated TAC feedback to the Watermaster Board during its February 8, 2024 regular meeting.

Enclosures

Exhibit 1. TAC Comments received on November 1, 2023 TAC Memo on Task 5

Figure 3.3-2 from the GMP – *BVHM Model Runs Addressing Future Climate and Pumping Reductions*

Figure 3.3-3 from the GMP – *Monte Carlo Simulation Time Varying Recharge 1945 to 2010 and Forecasted Cumulative Overdraft*

Exhibit 1. Responses to TAC Comments/Recommendations on Task 5 - Redetermine the Sustainable Yield

	TAC Members					
TAC Comments/Recommendations	**AAWARE** *Bob Wagner*	**BWD** *Trey Driscoll*	**County of San Diego** *Jim Bennett*	**T2 Borrego** *Tom Watson*	**Roadrunner Club** *John Peterson*	**Technical Consultant Responses**
Water-budget components to use to redetermine the Sustainable Yield						
Long-term annual average recharge as estimated by the BVHM				X		We agree with the majority TAC opinion that net recharge to the Basin will be calculated as the difference between long-term annual average recharge and discharge. The water budget terms defined in Table 2.2-9 of the GMP should be used to redetermine the Sustainable Yield.
Long-term annual average recharge minus discharge (subsurface outflow and evapotranspiration [ET] of groundwater)	X	X[1]	X[1]			
Time period to use to redetermine the Sustainable Yield						
Historical calibration period (1945-2022)		X[2]	X[3]	X		We agree with the majority TAC opinion that the historical calibration period should be used to redetermine the Sustainable Yield. Specifically, the entire calibration period (1945-2022) should be used to estimate inflows. A more recent historical period (2007-2022) should be used to estimate outflows because it is more representative of current and future conditions.
Future BVHM projection that accounts for the effects of climate change and future land/water uses that could affect natural recharge	X					
Model Domain to use to calculate the water budget						
Entire BVHM domain (Borrego Springs Subbasin and Ocotillo Wells Subbasin)						We agree with the majority TAC opinion that the BVHM domain used to estimate the water budget and redetermine the Sustainable Yield should include only the portion of the domain that overlies the Borrego Springs Subbasin (*i.e.,* exclude the portion of the domain overlying the Ocotillo Wells Subbasin).
Portion of the BVHM domain that contains only the Borrego Springs Subbasin		X[4]	X	X	X[5]	
More discussion is needed	X					

Notes:

1. Recommendation to use the inflow and outflow components listed in Table 2.2-9 of the GMP to estimate the Sustainable Yield. Table 2.2-9 identifies inflows as stream recharge, unsaturated zone recharge, and underflow, and outflows as evapotranspiration of groundwater and underflow.

2. Recommendation to use a more recent historical time period for calibration which better reflects current land use and, therefore, ET from native and non-native vegetation (*e.g.* loss of native phreatophytes which has decreased ET). ET estimates from external sources, such as OpenET could be used to check the model estimate.

3. This approach is consistent with the existing GMP and indirectly addresses climate change and future land/water uses by coupling the change in storage threshold to the chronic lowering of groundwater levels threshold. Natural recharge to Borrego Springs is highly variable and there is much greater uncertainty associated with precipitation and recharge than climate change projections. The Monte Carlo Simulation uncertainty analysis performed to redetermine the Sustainable Yield established the minimum threshold for the chronic lowering of groundwater levels using the variability in recharge to the Basin.

4. Recommendation that if the model domain is revised, underflow from the southern end of the of the model should be evaluated in terms of the outflows used in the provisional estimate of Sustainable Yield.

5. Verbal comment from the November 1, 2023 TAC meeting.

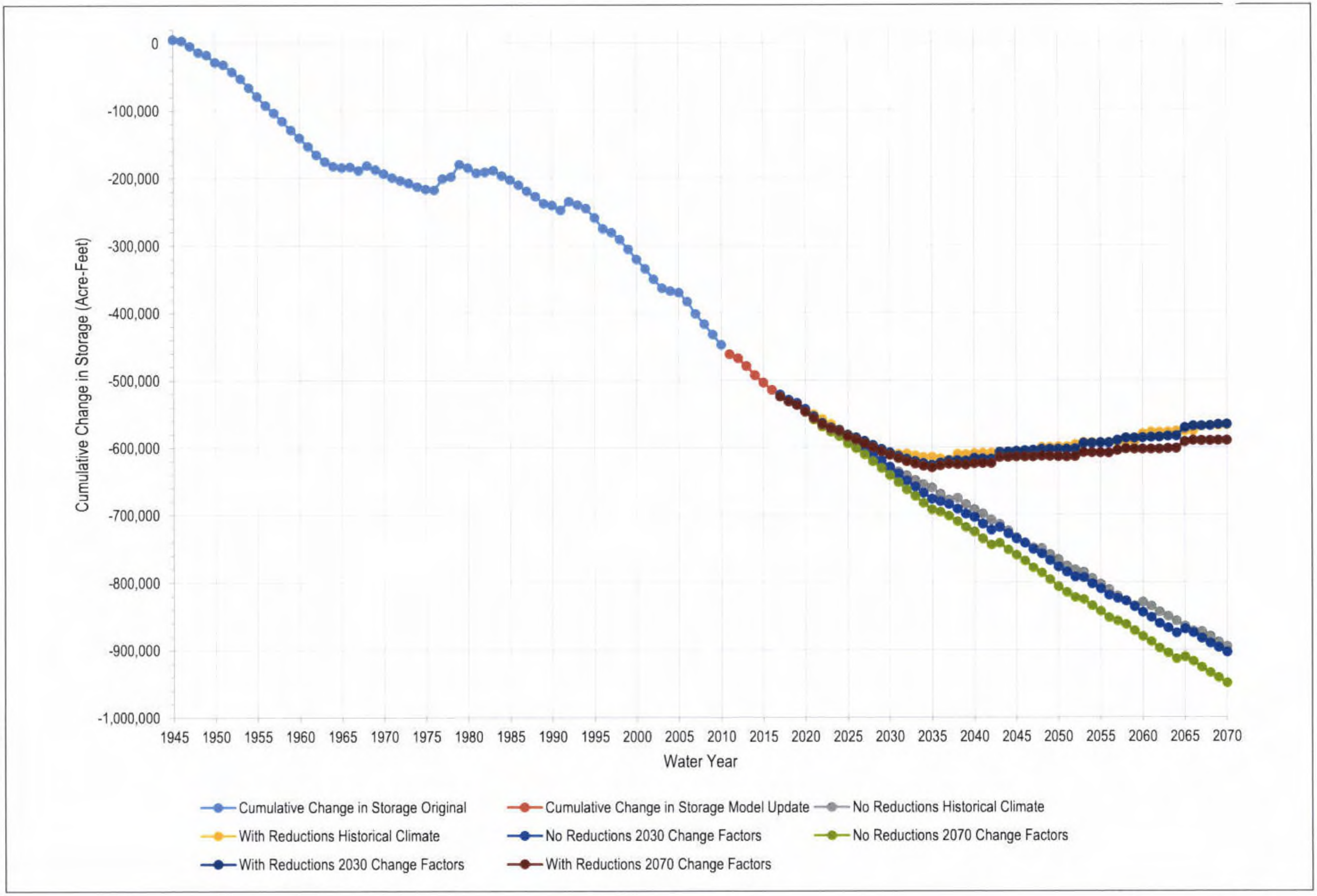
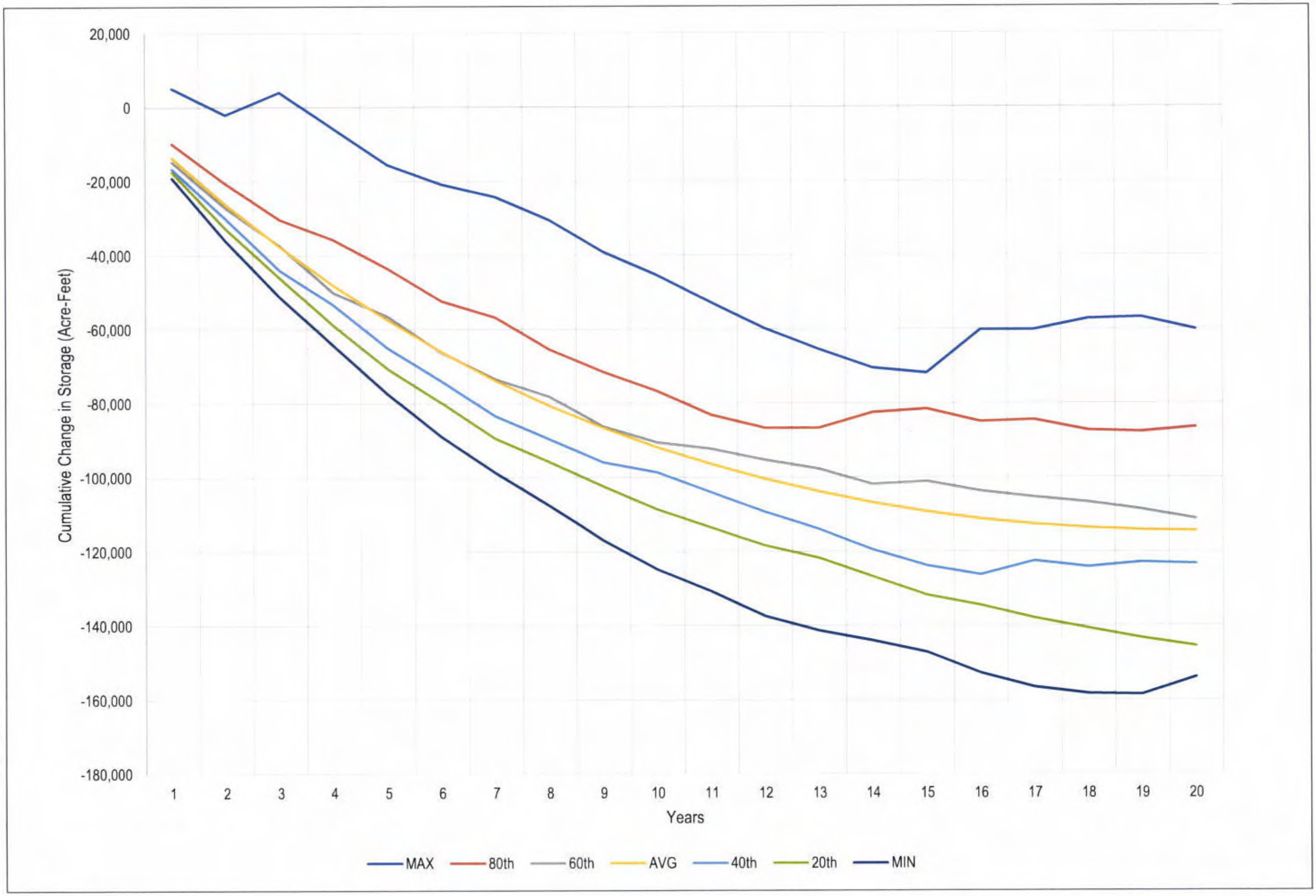


FIGURE 3.3-2

BVHM Model Runs Addressing Future Climate and Pumping Reductions

Groundwater Management Plan for the Borrego Springs Groundwater Subbasin



SOURCE: ENSI 2018

FIGURE 3.3-3

Monte Carlo Simulation Time Varying Recharge 1945 to 2010 and Forcasted Cumulative Overdraft