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TASK 4 – *MODEL CALIBRATION AND REDETERMINATION OF THE 2025 SUSTAINABLE YIELD*

DATE: October 29, 2024

TO: Technical Advisory Committee
Borrego Springs Watermaster

FROM: Andy Malone, PG; Eric Chiang, PhD; Lauren Salberg (West Yost)

SUBJECT: Task 4 – Model Calibration and Redetermination of the 2025 Sustainable Yield

EXECUTIVE SUMMARY

Sections II.E and III.F of the Judgment require the Sustainable Yield of the Borrego Springs Subbasin (Basin) to be redetermined by January 1, 2025 through a process that includes: collecting additional data, refining the Borrego Valley Hydrologic Model (BVHM), and using model runs to update the Sustainable Yield. This task has been performed by the Watermaster's Technical Consultant in collaboration with the Technical Advisory Committee (TAC).

The process to redetermine the 2025 Sustainable Yield involved updating and calibrating BVHM using historical and newly collected data—most importantly, metered groundwater pumping and measured groundwater elevations at wells. The BVHM was calibrated over the historical period of 1945-2022 and included a model sensitivity analysis. This update and calibration of the BVHM was performed successfully and represents an improvement to the BVHM and its ability to simulate the hydrology of the Basin. The final recalibrated model is referred to herein as the *Calibrated BVHM.*

The simulated water budgets for the Basin produced from the model calibration and sensitivity analysis were used to redetermine the 2025 Sustainable Yield, which is intended to represent the average annual volume of groundwater that can be pumped from the Basin without causing chronic overdraft conditions. The main conclusions from this work are:

- The *Calibrated BVHM* is a good simulator of the hydrology of the Basin and can confidently be used to redetermine the 2025 Sustainable Yield.
- The 2025 Sustainable Yield should be set based on the method described herein and should range between 7,568 afy and 8,078 afy based on the 10 model realizations used in the uncertainty analysis. The most defensible model realization is the *Calibrated BVHM,* which yielded a Sustainable Yield estimate of 7,952 afy.
- *The Calibrated BVHM* can and should be used to predict future groundwater conditions in the Basin under future groundwater pumping plans and climatic conditions to: (i) assess the sustainability of future groundwater conditions under a Rampdown to the final 2025 Sustainable Yield established by the Watermaster; (ii) evaluate Watermaster's current Carryover rules; and (iii) support the 2025 Groundwater Management Plan Assessment Report.

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 United States Geological Survey (USGS)[1] and were used by the USGS to improve the hydrogeologic understanding of the Borrego Springs Subbasin (Basin) and evaluate future management scenarios that would eliminate conditions of overdraft (*Initial BVHM*)[2].

The *Initial BVHM* was updated and extended by Dudek and used to simulate historical groundwater conditions from October 1929 through September 2016 (*2016 BVHM*).[3] 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) (referred to herein as the "Original Sustainable Yield").

Sections II.E and III.F of the Judgment require the Sustainable Yield to be redetermined by January 1, 2025 through a process that includes: collecting additional data, refining the BVHM, using the best available science, and using model runs to update the Sustainable Yield. As a first step, and based on the Technical Advisory Committee (TAC) recommendations, the Watermaster Board approved a technical scope of work to extend the BVHM from WY 2016 through WY 2021 and 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)[4] 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.

Based on this work, and in consideration of a TAC-majority recommendation, the Watermaster Board approved a scope of work and budget for WYs 2023 and 2024 to update the BVHM and Redetermine the Sustainable Yield by 2025.[5] Table 1 below summarizes the Board-approved scope of work with a cost estimate of $348,204.

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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] The *Initial BVHM* simulated the historical period of 1929 through 2011 and a projection period of 2011 through 2060.

[3] Dudek. 2019. Update to USGS Borrego Valley Hydrologic Model for the Borrego Valley GSA (draft final).

[4] 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.

[5] Scope of Work to Redetermine the Sustainable Yield by 2025.

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

Task No.	Task	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, Task 2, and Task 3. This memorandum describes the methods and results for ***Task 4 – Model Calibration and Redetermination of the 2025 Sustainable Yield.***[6] The objective of Task 4 is to improve the ability of the BVHM to simulate the hydrology of the groundwater basin, including groundwater pumping, groundwater elevations, groundwater-flow directions, and the water budget. The water budget from Task 4 is used herein to redetermine the 2025 Sustainable Yield of the Basin.

Task 4 has been performed in an iterative process whereby the TAC provided feedback on the methods for BVHM calibration and the results. This memorandum summarizes the information previously distributed to the TAC.[7] TAC comments on this memorandum and the Technical Consultant's responses to TAC comments are included in Appendix C.

Organization of Task 4 Memorandum

This Task 4 Memorandum includes the following sections:

- **Original Calibration/Validation of the BVHM.** This section summarizes the previous efforts by the USGS[1] and Dudek[2] to prepare, calibrate, and validate the BVHM, including the use of the calibration results to characterize the water budget for the Basin and estimate the Original Sustainable Yield at 5,700 afy.
- **Version of the BVHM to Recalibrate in Task 4**. This section describes the version of the BVHM that West Yost prepared and tested for calibration in Task 4, which incorporates West Yost's prior work to extend and improve the BVHM in Task 1, Task 2, and Task 3.
- **Model Calibration Methods and Results**. This section describes methods that were employed to calibrate the FMP and BVHM and presents the calibration results.

[6] At its September 2024 meeting, the Board determined that the 2025 Sustainable Yield should be based on the historical water budget derived from Task 4 – Model Recalibration. Hence, Task 5 was not performed as part of this effort.

[7] Information and memorandums on Task 4 previously distributed to the TAC for review/feedback are on the Borrego Springs Watermaster TAC webpage:

1. Task 4 to Redetermine the Sustainable Yield by 2025— Model Recalibration Methods
2. Preparatory Work for Task 4 – Model Recalibration
3. Methodology for using OpenET as a validation check on the FMP
4. Email distributed to the TAC on June 11, 2025 on the results of FMP calibration.

- **Redetermination of the 2025 Sustainable Yield.** This section describes the water budget for the Basin as estimated by the *Calibrated BVHM*, and then interprets the water budget to redetermine the 2025 Sustainable Yield.
- **Uncertainty Analysis.** This section describes the methods and results of an uncertainty analysis that was performed on the model calibration to understand the potential ranges in the water budget and the estimate of the 2025 Sustainable Yield.

ORIGINAL CALIBRATION/VALIDATION OF THE BVHM

The *Initial BVHM* was a three-layer, finite-difference, numerical, groundwater-flow model of the Borrego Valley. The *Initial BVHM* used the MODFLOW numerical modeling code One-Water Hydrologic Flow Model (MODFLOW-OWHM v1.0.0).

The *Initial BVHM* was calibrated by the USGS 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 1930-1945 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 observed 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 streambeds; and vertical hydraulic conductivity of 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 estimated was large and many parameters varied 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 ft and +20 ft (+/- 6 m), and more than 50 percent were between −5 and +5 ft (+/- 1.5 m). The comparison showed little bias, as indicated by an average residual of 0.1 ft (0.03 m) and the relatively small magnitude of most residuals. Overall, the residuals tended to underestimate groundwater levels slightly (positive residuals). The residuals ranged from −100 ft to +53 ft (-30 to 16 m) and the standard deviation and root mean square error (RMSE) were both approximately 11 ft (3 m).

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.

VERSION OF THE BVHM TO CALIBRATE IN TASK 4

West Yost completed Task 1, Task 2, and Task 3 of the scope of work to prepare and test the version of the BVHM to be calibrated in Task 4 (*Pre-Calibrated BVHM*). The work included:

- **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-run 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 underestimated groundwater pumping, which indicated that the water-use factors used in the FMP to estimate actual evapotranspiration (ET) and groundwater pumping are inaccurate, and hence, the BVHM needs to be improved and calibrated.
- **Task 2 – Update Water-Use Factors in the FMP**. In this task, the water-use factors used in the FMP were evaluated and updated[8] 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 were probably not reflective of historical irrigation methods in the Basin—historical irrigation methods (e.g., flood and furrow irrigation) were likely less efficient than current irrigation methods. West Yost recommended that during model calibration, historical OFE values should be revised to reflect the evolution of irrigation methods used in the Basin since 1945. In addition, adjustments to KC and OFE values during model calibration, if any, should be constrained to defensible ranges.
- **Task 3 – Correct Errors Identified in the BVHM**. In this task, several errors and discrepancies identified in the BVHM were corrected, and the model was re-run from WY 1930 through WY 2022 to quantify the influence of the errors on the BVHM results.

Table 2 is a water budget for the Basin was generated by running *Pre-Calibrated BVHM* over the historical period WY 1945-2022. Figure 1 is a map that displays the domain of the *Pre-Calibrated BVHM* and the model cells that were used to simulate the boundary conditions (*e.g.,* mountain front recharge). The

[8] The scaling factors that were applied to KC and OFE by the USGS during the original model calibration were removed (*i.e.,* set to 1).

model geometry, layering, spatial resolution, and temporal resolution were retained from the *Initial BVHM* and were not modified in this calibration.

MODEL CALIBRATION METHODS AND RESULTS

Model calibration is the process of adjusting model parameters of a historical model to produce the best match between simulated and observed system responses, such as time series of simulated and 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.

Model calibration was performed in a two-step process:

1. Calibration of the FMP
2. Calibration of the BVHM

Both the FMP and BVHM were calibrated over the historical period of October 1945 through September 2022. However, the total simulation period was from October 1929 through September 2022, with the years 1930-1945 used as a model "spin-up" period.

The detailed methods, results, and conclusions of model calibration are summarized below:

Calibration of the FMP

The first step in model calibration involved iterative manual adjustments to FMP parameters to match recently measured groundwater pumping used for irrigation in WY 2021 and 2022. The objectives of FMP calibration were to:

- **Improve the ability of the FMP to estimate groundwater pumping.** During the calibration process, FMP-estimated pumping was compared to the metered groundwater pumping data from WY 2021 and 2022 (referred to as "Actual pumping")—the period when Watermaster established and implemented its well metering program.
- **Validate the ability of the FMP to estimate ET.** This was accomplished by comparing the FMP-estimated ET with the OpenET-estimated ET during 2016-2022.

FMP Calibration Methods

The following FMP model parameters were manually adjusted during the calibration of the FMP:

- **On-Farm Efficiency.** As described in the memo documenting Task 2 – *Update Water-Use Factors*,[9] unrealistic historical OFE values of nearly 100% were used in the *Initial BVHM*. West Yost staff recommended, and the TAC agreed, that the OFE values should be revised to reflect the evolution of crop types grown and irrigation methods used in the Basin since 1945. West Yost staff performed a literature review, conducted interviews with farmers in the Basin, and identified evidence of historical irrigation infrastructure in the Basin, and from these efforts, developed recommendations for historical OFE values and a range of

[9] West Yost. 2023. Task 2 to Redetermine the Sustainable Yield by 2025 – Update Water-Use Factors in the Farm Process. August 23, 2023.

defensible values to use during Task 4. The recommended OFE values and acceptable ranges are documented in Appendix A, a memorandum titled*: Assumptions for Historical On-Farm Efficiencies in the BVHM*.

- **Crop Coefficient.** Monthly KC values for selected irrigated crops in the FMP (row crops, citrus, palms, potatoes) were adjusted to better match seasonal patterns in crop demands and values of KC recommended by the USGS[10] based on crop stage (early, mid, or late).
- **KC scaling factors.** Monthly KC scaling factors in the FMP were adjusted to better match monthly FMP-estimated pumping with monthly Actual pumping in WY 2021 and 2022.
- **Transpiration Fraction of Consumptive Use (FTR).** FTR values for two crop types in the FMP (golf courses and potatoes) were increased to match USGS-recommended values more closely and to better match monthly FMP-estimated pumping with monthly Actual pumping in WY 2021 and 2022.[9]

The FMP was calibrated via iterative steps:

1. Run the FMP from WY 1930 through WY 2022 and produce tables and time-series charts of estimated groundwater pumping and ET.
2. Compare FMP-estimated groundwater pumping to Actual pumping in WY 2021 and 2022. An 'acceptable' calibration result was defined as FMP-estimated pumping within +/-10% of Actual pumping.
3. Make manual adjustments to the FMP parameters and repeat Steps 1 and 2 until achieving the best possible match between FMP-estimated groundwater pumping to Actual pumping in WY 2021 and 2022 (within +/-10%).
4. Compare FMP-estimated ET to the estimated ET of the OpenET models geeSEBAL and eeMETRIC, which were selected by the TAC as the most appropriate for Borrego Springs. No metric was established as an 'acceptable' calibration result, as this comparison was meant to be a validation check on the FMP-estimated ET.

The final calibrated version of the FMP is referred to herein as the *Calibrated FMP*.

FMP Calibration Results and Conclusions

As shown in Table 3 below, the results of the *Calibrated FMP* show that the percent difference between FMP-estimated pumping and Actual pumping is -1.7% (underestimated) in WY 2021 and 0.5% (overestimated) in WY 2022:

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[10] Boyce, S.E., Hanson, R.T., Ferguson, I., Schmid, W., Henson, W., Reimann, T., Mehl, S.M., and Earll, M.M., 2020, One-Water Hydrologic Flow Model: A MODFLOW based conjunctive-use simulation software: U.S. Geological Survey Techniques and Methods 6–A60, 435 p., https://doi.org/10.3133/tm6A60.

Table 3. FMP-Estimated Pumping vs. Actual Pumping *WY 2021 - 2022*				
WY	Actual Pumping (af)	FMP-Estimated Pumping (af)	Difference (af)	% Difference
	(a)	*(b)*	*(c) = (b) - (a)*	*(d) = (c)/ ([(a)+(b)]/2)*
2021	12,124	11,920	-204	-1.7%
2022	10,848	10,902	54	0.5%

The following OFE values were derived through the FMP calibration and are within the reasonable ranges for irrigation methods known to have been used in the Basin:

- Flood and furrow: 0.50
- Broadcast sprinkler: 0.70
- Micro-drip: 0.74

The following figures further describe the results and conclusions of the FMP calibration:

Figure 2. Precipitation vs. FMP-Estimated Evapotranspiration and Groundwater Pumping – This figure explains how explains how the FMP estimates ET (by its individual components: evaporation and transpiration) and groundwater pumping on a monthly time step from 2020-2022. The figure shows: (i) monthly precipitation measured at the CIMIS station in Borrego Springs; (ii) monthly precipitation from the BCM, which is input to the FMP; (iii) monthly FMP-estimated ET terms for irrigated farms; and (iv) monthly FMP-estimated groundwater pumping. The main takeaway from this figure is that the FMP is reasonably simulating precipitation, ET, and groundwater pumping, which is based on the following observations:

- Monthly precipitation input data from the BCM matches the monthly patterns of precipitation measured at the CIMIS station. This comparison was performed as a validation check on the precipitation inputs to the FMP.
- During wet months, most crop transpiration demands are satisfied by precipitation. As a result, FMP-estimated groundwater pumping is reduced, and the evaporation and transpiration components of irrigation water are also reduced.
- During dry months, crop transpiration demands must be satisfied by irrigation water sourced from groundwater pumping as it is the only reliable water supply. Consequently, FMP-estimated groundwater pumping is increased.
- Monthly FMP-estimated groundwater pumping varies on a reasonable seasonal pattern in response to seasonal crop demands and precipitation.
- Due to deep groundwater levels, evaporation and transpiration of shallow groundwater play an insignificant role in fulfilling crop transpiration demands.

Figure 3. Comparison of Monthly FMP-Estimated Pumping vs. Actual Pumping (WY 2021 and 2022) – This figure compares monthly FMP-estimated pumping from the *Calibrated FMP* and Pre-Calibrated FMP with Actual pumping for WYs 2021 and 2022. FMP-estimated pumping from the *Calibrated FMP* is 2% lower than Actual pumping in WY 2021 and nearly the equal to Actual pumping in WY 2022. This represents an improvement in the calibration of the FMP and its ability to estimate groundwater pumping.

Figure 4. Comparison of Total Monthly ET from Farms in the FMP: FMP vs. OpenET Models – This figure compares the FMP estimates of ET to OpenET models (geeSEBAL and eeMETRIC) as a validation check. This figure includes four charts that compare ET estimated by the *Calibrated FMP* to: (A) ET estimated by the Pre-calibrated FMP; (B) ET estimated by eeMETRIC; (C) ET estimated by geeSEBAL; and (D) the mean and range of ET estimated by the geeSEBAL and eeMETRIC models. These charts indicate that ET estimates by eeMETRIC and geeSEBAL are lower than ET estimates of the *Calibrated FMP*, especially during the early period of 2016-2019. OpenET has acknowledged that its models (specifically geeSEBAL) underestimate ET in agricultural regions in very arid environments (such as Borrego Springs). Specially, the geeSEBAL model tends to yield lower ET estimates in desert and arid regions and the eeMETRIC model has uncertainty associated with atmospheric interference, particularly during cloudy conditions. These observations made by OpenET might explain why FMP-estimated ET is higher than the selected OpenET models. OpenET- and FMP-estimated ET match more closely during the more recent period of 2020-2022. An exception occurred in March 2020 when the FMP estimated relatively high ET. Figure 2 showed that most of the FMP-estimated ET in March 2020 was due to evaporation of the high volumes of precipitation. In general, the FMP generates ET estimates that are similar in the seasonal pattern and magnitudes as OpenET.

CONCLUSION: The *Calibrated FMP* produces reasonable results and is well calibrated. This conclusion is demonstrated by comparing FMP results to measured precipitation, metered pumping in WYs 2021 and 2022, and OpenET data sets during 2016-2022.

Calibration of the BVHM

The second step in model calibration involved iterative manual and automated adjustments to BVHM parameters to match measured groundwater elevations at wells. The objectives of BVHM calibration were to:

1. Improve the ability of the BVHM to simulate the hydrology of the Basin (e.g., water budget, groundwater levels, and groundwater-flow directions).
2. Produce a water budget that can be used to redetermine the Sustainable Yield.

BVHM Calibration Methods

BVHM calibration was accomplished by using the open-source computer code PESTPP-IES[11,12] to generate several calibrated realizations. A calibrated realization in the context of hydrologic models refers to a specific set of model parameters that have been adjusted so that the model outputs closely match observed data. Multiple calibrated realizations exist because there are often many different sets of model parameters that can produce a good fit between the model outputs and the observed data. This phenomenon is known as non-uniqueness in model calibration.

The model parameters were adjusted via two approaches:

- The "Pilot Points" approach was used to adjust the hydraulic and storage properties of the aquifer-system sediments. Pilot Points were chosen to represent locations in the model

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[11] White, J. T., Hunt, R. J., Fienen, M. N., & Doherty, J. E. (2020). Approaches to Highly Parameterized Inversion: PEST++ Version 5, a Software Suite for Parameter Estimation, Uncertainty Analysis, Management Optimization and Sensitivity Analysis. U. S. Geological Survey.

[12] White, J. T. (2018). A model-independent iterative ensemble smoother for efficient history-matching and uncertainty quantification in very high dimensions. Enviromental Modelling and Software, 109.

domain where the parameters were allowed to vary. The parameter values of Pilot Points were interpolated to model cells during the calibration process.

- "Scalar Multipliers" were used to adjust all other model parameters, such as rates of subsurface inflow.

The steps to recalibrate the BVHM included the following:

1. **Select adjustable model parameters and reasonable ranges for parameter values**. 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 this past work performed by the USGS and Dudek, the results of Tasks 1-3, and the calibration of the FMP, the following model parameters were selected for adjustment (within defined reasonable bounds) during BVHM calibration:
   - Aquifer parameters by model layer, including hydraulic conductivity, specific yield, and specific storage.
   - Subsurface inflows to the model domain.

   Table 4 identifies the aquifer parameters that were adjusted during the calibration process and the acceptable ranges for parameter values. Upper and lower bounds were set for the aquifer parameters to constrain the final calibrated aquifer properties to a reasonable range. These bounds were carefully chosen based on past modeling studies, results of aquifer tests, and published literature.

   Table 5 lists the cells where subsurface inflow to the BVHM domain were adjusted during the calibration process. Scalar multipliers of the *Initial BVHM* were used and then adjusted within reasonable ranges (constrained between 0.80 to 1.20).

2. **Assign pilot points and initial model parameter values and acceptable ranges.** Figures 5Ai through 5Diii show the location of pilot points in Layers 1, 2, and 3 used to adjust the aquifer parameters during the calibration process within the acceptable ranges defined in Table 4. Generally, the pilot points are evenly spaced across each model layer. The aquifer properties from the *Initial BVHM* were used as the initial parameter values for the pilot points. Additional pilot points were assigned to areas or well locations where hydrogeologic data were available (e.g., estimates of aquifer properties derived from aquifer stress tests).

3. **Select calibration targets/data.** Measured groundwater elevations at wells were used as the calibration targets, which were selected based on the following criteria:
   - Wells used in calibration are spatially distributed across the model domain by model layer.
   - Wells used in calibration are geographically distributed to evenly weight the calibration across the model domain.
   - Groundwater-elevation measurements at wells are 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 was selected.

Figure 6 is a map of 83 wells with groundwater-elevation data used during calibration. This figure shows the spatial distribution of the wells across the Basin, along with the vertical distribution of well screens across the upper, middle, and lower aquifers layers. Appendix B contains time-series charts of the groundwater-elevation data at each of the 83 wells. Each chart displays (i) all measured groundwater-elevation data and (ii) the calibration targets selected from the measured groundwater-elevation data.

4. **Configured settings and prepared input files for PESTPP-IES**. In this step, several input files were prepared for PESTPP-IES and the supporting codes that enabled the interpolation of pilot point values to model cells. PESTPP-IES was configured to generate 200 calibrated realizations.
5. **Performed model calibration with PESTPP-IES**. In this step, PESTPP-IES was used to adjust all adjustable model parameters (*i.e.,* aquifer parameters and subsurface inflows). Through a series of successive iterations, PESTPP-IES modifies parameter realizations such that they all conform with calibration constraints. The outcome of PESTPP-IES is thus an ensemble of calibrated realizations. After the fifth iteration, the parameter realization with the smallest residuals between the calibration targets and the model calculated counterparts was chosen as the calibrated realization.
6. **Reviewed calibration results**. The model calibration results were displayed and analyzed with the following:
   - Table and maps of final model parameters.
   - Map of mean residual by well.
   - Table of the annual water budget over the calibration period.
   - Scatter plots and time-series charts that compare simulated versus observed groundwater elevations at wells.

If the analysis of the calibration results was unsatisfactory, adjustments were made to the PEST settings, the model parameters, scalers, and/or other input values, and model calibration was executed again until an acceptable calibration was achieved. Calibration concluded when the objective function could no longer be practically minimized. The final calibrated version of the BVHM is referred to herein as the *Calibrated BVHM*.

BVHM Calibration Results and Conclusions

The following describe the results of BVHM calibration:

- **Appendix B. Hydrographs**. Appendix B contains time-series charts of the groundwater-elevation data at each of the 83 wells selected as calibration targets. Each chart displays the following information over the calibration period WY 1945-2022:
  - All measured groundwater elevations at the well.
  - The calibration targets selected from the measured groundwater elevations.
  - The simulated groundwater elevations from the final *Calibrated BVHM*.
  - The simulated groundwater elevations from the *Initial BVHM* (developed by the USGS, extended by Dudek through WY 2016, and used to estimate the Original Sustainable Yield).
  - An inset map with the location of the well in the Basin and Management Area.
  - A set of calibration statistics for the mean residual (difference between measured and simulated groundwater levels) and RMSE.

- **Calibration Results and Statistics**. The figures and tables below describe the results of BVHM calibration:
  - **Figure 7. Observed vs. Model-Simulated Groundwater Elevation**. Figure 7 is a scatterplot of observed vs. simulated groundwater elevations. Each point on the figure corresponds to a specific measured groundwater elevation versus its corresponding model-simulated groundwater elevation. Also shown on this figure are:
    - Trend Line, which represents the linear relationship between all observed vs. model-simulated groundwater elevations. The slope of 1.02 indicates that, on average, the model slightly overestimates groundwater elevations.
    - RMSE, which is a statistical measure of the average magnitude of the errors between observed vs. simulated groundwater elevations. The RMSE is calculated as the square root of the average of the squared differences between the observed and simulated groundwater elevations. A low RMSE indicates that the simulated elevations are close to observed elevations, suggesting a good performance of the model. The RMSE shows that, on average, the model-simulated groundwater elevations are approximately 3.70 m (or 12.1 feet) higher than the observed groundwater elevations.
    - R^2, the coefficient of determination, is a measure of how well observed values are replicated by the model. The R^2 value is approximately 86%, which indicates there is a strong correlation between observed and simulated groundwater elevations.

    Overall, Figure 7 demonstrates that the BVHM is generally a good simulator of observed groundwater elevations with a slight bias towards overestimating groundwater elevations.
  - **Figure 8. RMSE of Observation Wells – Calibrated BVHM**. Figure 8 is a map of RMSE for all wells used in model calibration and classifies the fit of each well as "good" (0 – 5 m), "fair" (5 – 10 m), and "poor" (> 10 m). Most wells (88%) exhibit a good fit and wells with a good fit are evenly distributed across the Basin. Only one well (Triangle) exhibits a "poor" fit with several nearby wells with "fair" fits. As shown on Appendix Figure B-68 for the Triangle well, measured groundwater elevations show an increasing trend, while the simulated elevations show a decreasing trend. This well is in an area of the Basin with complicated geology that is likely not well characterized in the model. However, based on TAC feedback, wells in this area, including Triangle, were kept as calibration targets.
  - **Figure 9. Residuals from Observation Targets – Calibrated BVHM.** A residual close to 0 indicates that the model-simulated groundwater elevation closely matches the observed groundwater elevation. A negative residual indicates the model under-predicted the observed groundwater elevation and a positive residual indicates the model over-predicted the observed groundwater elevation. Figure 9 is a map of the spatial distribution of residuals across the Basin for all wells used in the calibration, and assigns a "fit" to the residuals, ranging from good to poor. Overall, Figure 9 shows that residuals with a "good" fit are evenly distributed across the Basin. However, there are a handful of residuals on the western side of the South Management Area that exhibit "fair" fits.
  - **Figure 10. Under vs. Over-Predicted Groundwater-Elevations – Calibrated BVHM.** Figure 10 is a map that displays the spatial distribution of under-predicted vs. over-predicted groundwater elevations for all wells used in model calibration. Generally, Figure 10 shows that the model both over-predicts and under-predicts groundwater elevations with no apparent spatial bias.

- **Figure 11Ai – 11Aiii. Horizontal Hydraulic Conductivity Values used in BVHM Calibration**. These figures show the spatial distribution of horizontal hydraulic conductivity in model layers 1 through 3 in the *Calibrated BVHM*.
- **Figures 11Bi – 11Biii. Vertical Hydraulic Conductivity Values used in BVHM Calibration**. These figures show the spatial distribution of vertical hydraulic conductivity in model layers 1 through 3 in the *Calibrated BVHM*.
- **Figures 11Ci – 11Ciii. Specific Yield Values used in BVHM Calibration**. These figures show the spatial distribution of specific yield in model layers 1 through 3 in the *Calibrated BVHM*.
- **Figures 11Di – 11Diii. Specific Storage Values used in BVHM Calibration**. These figures show the spatial distribution of specific storage in model layers 1 through 3 in the *Calibrated BVHM*.
- **Figure 12 – Measured Groundwater Elevation vs. BVHM-Estimated Groundwater Flowpaths.** Figure 12 is a map showing: (i) groundwater-elevations measured at monitoring wells in the Basin in fall 2022 and (ii) BVHM-estimated directions of groundwater flow from September 2022. Groundwater-levels were generally measured at shallow wells in the Basin representing the upper aquifer; therefore, BVHM-estimated groundwater-flow directions are shown for layer 1 in the model (also representing the upper aquifer). Both the measured groundwater-elevation data and BVHM-estimated groundwater-flow directions show groundwater moving from the North and South Management Areas towards the pumping centers in the Central Management Area.

CONCLUSION: The *Calibrated BVHM* produces reasonable results and is well calibrated. This has mainly been demonstrated with statistical comparisons of measured versus simulated groundwater elevations at 83 target wells horizontally and vertically distributed across the Basin.

REDETERMINATION OF THE 2025 SUSTAINABLE YIELD

This section describes the water budget for the Basin as estimated by the BVHM calibration over WY 1945-2022, and then interprets the water budget to redetermine the 2025 Sustainable Yield.

Table 6 lists the annual water budget from the *Calibrated BVHM* for the Basin. This water budget pertains only the portion of the BVHM domain that covers the Basin, and hence, excludes the area overlying the Ocotillo Wells Subbasin. Figure 13 is a map that shows the portion of the BVHM domain that overlies the Basin. Average annual inflows to the Basin were about 9,400 afy; average annual outflows from the Basin were about 17,200 afy; and the average annual change is storage was about -7,800 afy; and total change in storage from WY 1945-2022 was about -609,000 af.

Table 7 shows how the 2025 Sustainable Yield has been redetermined using the water budget from shown in Table 6. The formula used to redetermine the Sustainable Yield is based on the hydrologic concept of “net recharge” to a groundwater basin, which excludes the anthropogenic impacts to the basin from pumping and artificial recharge of imported waters. The basic formula to calculate Net Recharge is:

Natural Inflows – Natural Outflows = Net Recharge (Sustainable Yield)

In this analysis, Net Recharge is intended to represent the average annual volume of groundwater that can be pumped from a groundwater basin without causing chronic overdraft conditions. It is important to calculate Net Recharge over a long-term period to account for the hydrologic variability, particularly in desert regions where natural inflows can be highly variable. Table 7 shows how Table 6 was interpreted to compute Net Recharge:

- Natural Inflows include the following water budget terms:
  - Average annual inflows from streambed recharge and mountain front recharge computed over the long-term period 1945-2022. The long-term period of analysis is important given the highly variable precipitation, stormwater runoff, and streambed recharge that occurs in desert groundwater basins.
  - Average annual unsaturated zone recharge (return flows) that resulted from irrigation and precipitation overlying the Basin over the long-term period 1980-2022. This period of analysis is shorter because the irrigation methods utilized in the Basin changed around 1980. Prior to 1980, the model simulates return flows from flood and furrow irrigation, which is an inefficient irrigation method that results in higher return flows compared to more recent irrigation practices, such as drip irrigation and micro sprinklers. Hence, the post-1980 estimates of unsaturated zone recharge are utilized to calculate Net Recharge because they are more representative of current and future recharge that is expected to occur from return flows under modern irrigation practices.
- Natural Outflows include the following water budget terms:
  - Annual average outflows from ET of shallow groundwater and subsurface outflow from the Basin over the short-term recent period 2007 – 2022. This short-term recent period of analysis is utilized because groundwater levels have declined significantly over the calibration period, which has reduced the volume of shallow groundwater that can be consumed by natural vegetation and/or lost to evaporation. Hence, the 2007-2022 estimates of groundwater ET are utilized to calculate Net Recharge because they are more representative of current and future natural outflows that are expected to occur.

Table 7 presents the 2025 Sustainable Yield as the calculation of Net Recharge, which is estimated at **7,952 afy** for the Borrego Springs Subbasin.

Table 8 compares the 2025 Sustainable Yield (shown in Table 7) to the Original Sustainable Yield as published in the 2020 Groundwater Management Plan (GMP). The table compares the average annual volumes of inflows, outflows, and Sustainable Yield, and presents the difference (in afy) and percent difference for each term. As shown in Table 8, the percent difference between the 2025 Sustainable Yield and the Original Sustainable Yield is approximately 32% (or, a 38% increase from the Original Sustainable Yield) which is driven by an increase in the simulated inflows and a decrease in the simulated outflows.

UNCERTAINTY ANALYSIS

At the suggestion of the TAC, an uncertainty analysis was performed on the model calibration to understand the potential ranges in the water budget and the estimate of the 2025 Sustainable Yield. The sensitivity analysis was performed as follows:

1. Selected the ten "best" model realizations from the calibration runs produced with PESTPP-IES. The top ten realizations include the realization selected as the *Calibrated BVHM*, meaning an additional nine models were analyzed. The "best" models selected were those with the lowest total sum of squared residuals (phi) values. Although thousands of model realizations were run, many did not produce 'reasonable' results and were therefore excluded from the sensitivity analysis.

2. Processed the model results and calculated the water budget for the Basin for each model realization.
3. Calculated the Sustainable Yield for each model realization using the water budgets generated in Step 2.
4. Prepared tables and figures to summarize the (i) calibration statistics; (ii) water budgets; (iii) estimates of Sustainable Yield; and (iv). These tables are described below:
   - **Table 9. Model Calibration Statistics.** This table presents a summary of the calibration statistics for the ten model realizations analyzed for the sensitivity analysis, including the realization selected as the *Calibrated BVHM*. The table compares the following statistics for each realization: sum of squared residuals (phi), correlation coefficient, RMSE, and the mean, minimum, maximum, standard error, and variance of residuals. The *Calibrated BVHM* has the lowest sum of squared residuals, but all model realizations have a correlation coefficient of 0.93 (meaning that 93% of the variance in the observed groundwater elevations is explained by the model) and generally have similar residual statistics. This indicates that any of these models could be considered a good fit and generate a reliable water budget. The *Calibrated BVHM* was selected as the best fit because it:
     - Has the lowest sum of squared residuals (phi) value.
     - Has calibration statistics, including residuals and RMSE, that are on the lower end of the distribution of statistics.
     - Has a reasonable distribution of aquifer parameters (Figures 11Ai – 11Diii).
   - **Figures 14-a - 14-l – Observed vs. Model-Simulated Groundwater Elevation** for each of the nine model realizations analyzed. This series of figures contain scatterplots of observed vs. simulated groundwater elevations to visualize the relationship between the two datasets. A scatterplot for the selected realization, the *Calibrated BVHM,* is shown on Figure 7. Similar to Figure 7, Figures 14-a to 14-I also show the trend line, RMSE, and R^2 value for each model realization, and show that the additional nine realizations:
     - Either slightly under-estimate or over-estimate groundwater elevations, as indicated by the slope of linear trend lines which range from 0.99 to 1.04.
     - Show good performance of the model as evidenced by low RMSE values ranging from 3.66 m to 3.76 m.
     - Have a strong correlation between observed and simulated groundwater elevations with R^2 values ranging from 0.86 to 0.87.
   - **Table 10. Water Budget Comparison – Model Calibration Realizations.** This table presents and compares the water budget terms and estimates of Sustainable Yield for each of the ten model realizations. The Sustainable Yield estimates range from 7,568 afy to 8,078 afy. The 2025 Sustainable Yield from the selected model realization (*i.e.*, the *Calibrated BVHM*) is 7,952 afy.
   - **Table 11. Sustainable Yield Comparison – Model Calibration Realizations.** This table shows the minimum, maximum, average, and standard deviation of the estimates of Sustainable Yield from the realizations presented in Table 10. The difference between the minimum and maximum Sustainable Yield is 510 afy. The 2025 Sustainable Yield of 7,952 afy is 149 afy greater than the average of 7,803 afy but is within the standard deviation of 186 afy.

Overall, these tables and figures demonstrate that:

- The 10 "best" model realizations derived from the sensitivity analysis are good simulators of the hydrology of the Basin.
- The 2025 Sustainable Yield is likely within the range of about 7,600 afy to 8,100 afy with an average of about 7,800 afy.
- The most defensible estimate of the 2025 Sustainable Yield is 7,952 afy as estimated by the *Calibrated BVHM*.

CONCLUSIONS

Based on the results and interpretations from this work, the main conclusions are:

- The *Calibrated BVHM* is a good simulator of the hydrology of the Basin and can confidently be used to redetermine the 2025 Sustainable Yield.
- The 2025 Sustainable Yield should be set based on the method described herein and should range between 7,600 afy to 8,100 afy based on the 10 model realizations used in the uncertainty analysis. The most defensible model realization is the *Calibrated BVHM* which yielded a Sustainable Yield estimate of 7,952 afy.
- The *Calibrated BVHM* can and should be used to predict future groundwater conditions in the Basin under future groundwater pumping plans and climatic conditions to:
  - Assess the sustainability of future groundwater conditions under a Rampdown to the final 2025 Sustainable Yield established by the Watermaster.
  - Evaluate Watermaster's current Carryover rules.
  - Support the 2025 GMP Assessment Report.

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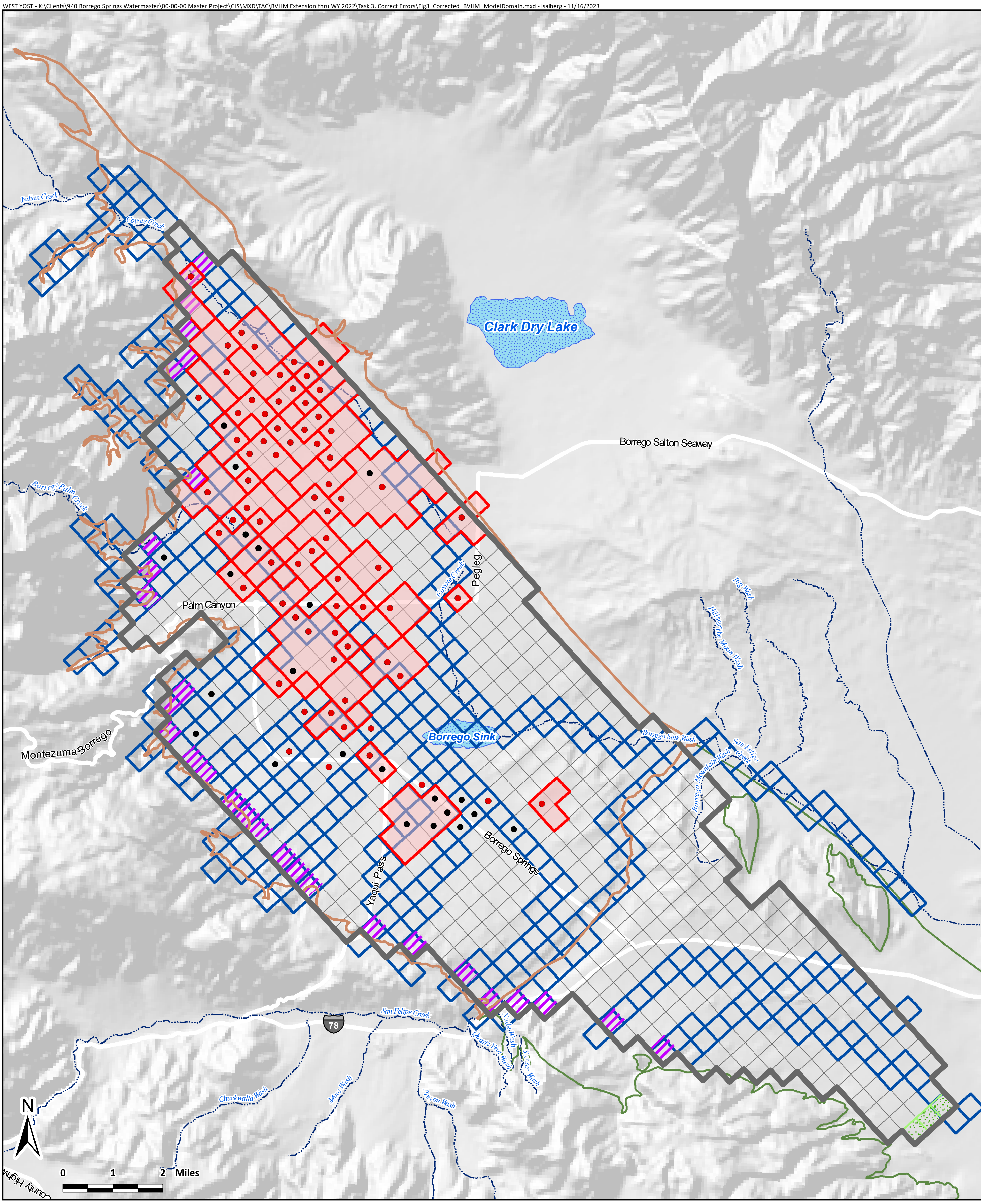


BVHM Packages

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

Farm Process Features

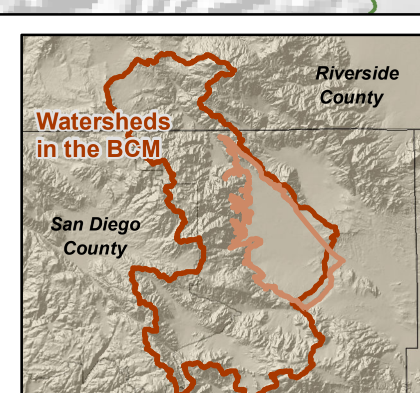
- Water Budget Subregion in the FMP
- FMP Well in MNW2 Package

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

Redetermine the Sustainable Yield

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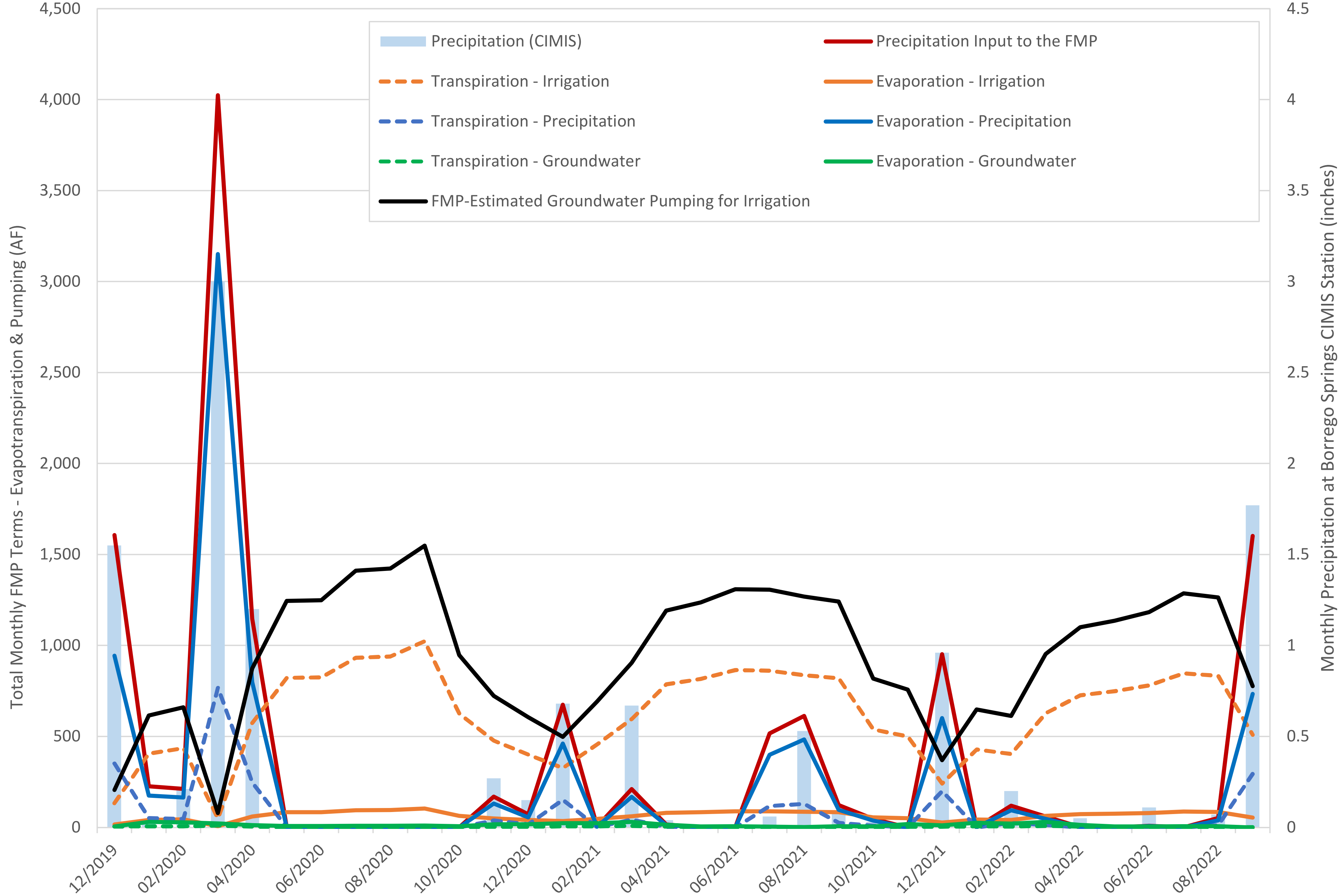
Figure 1

Pre-Calibrated

Borrego Valley Hydrologic Model (BVHM) Domain

Figure 2. Precipitation vs. FMP-Estimated Evapotranspiration and Groundwater Pumping



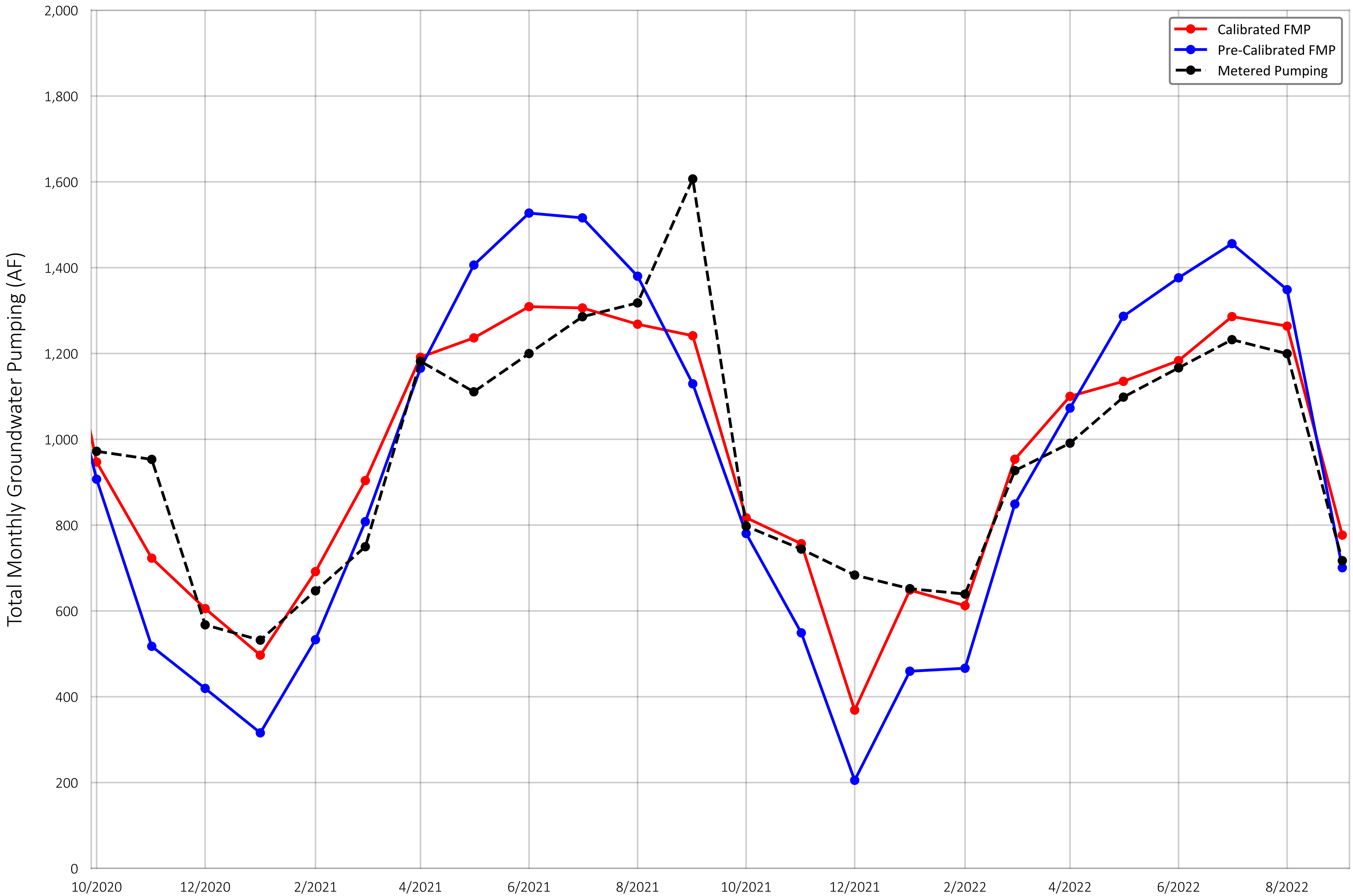


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Figure 3. Comparison of Monthly
FMP-Estimated Pumping vs. Actual Pumping
WY 2021 - 2022

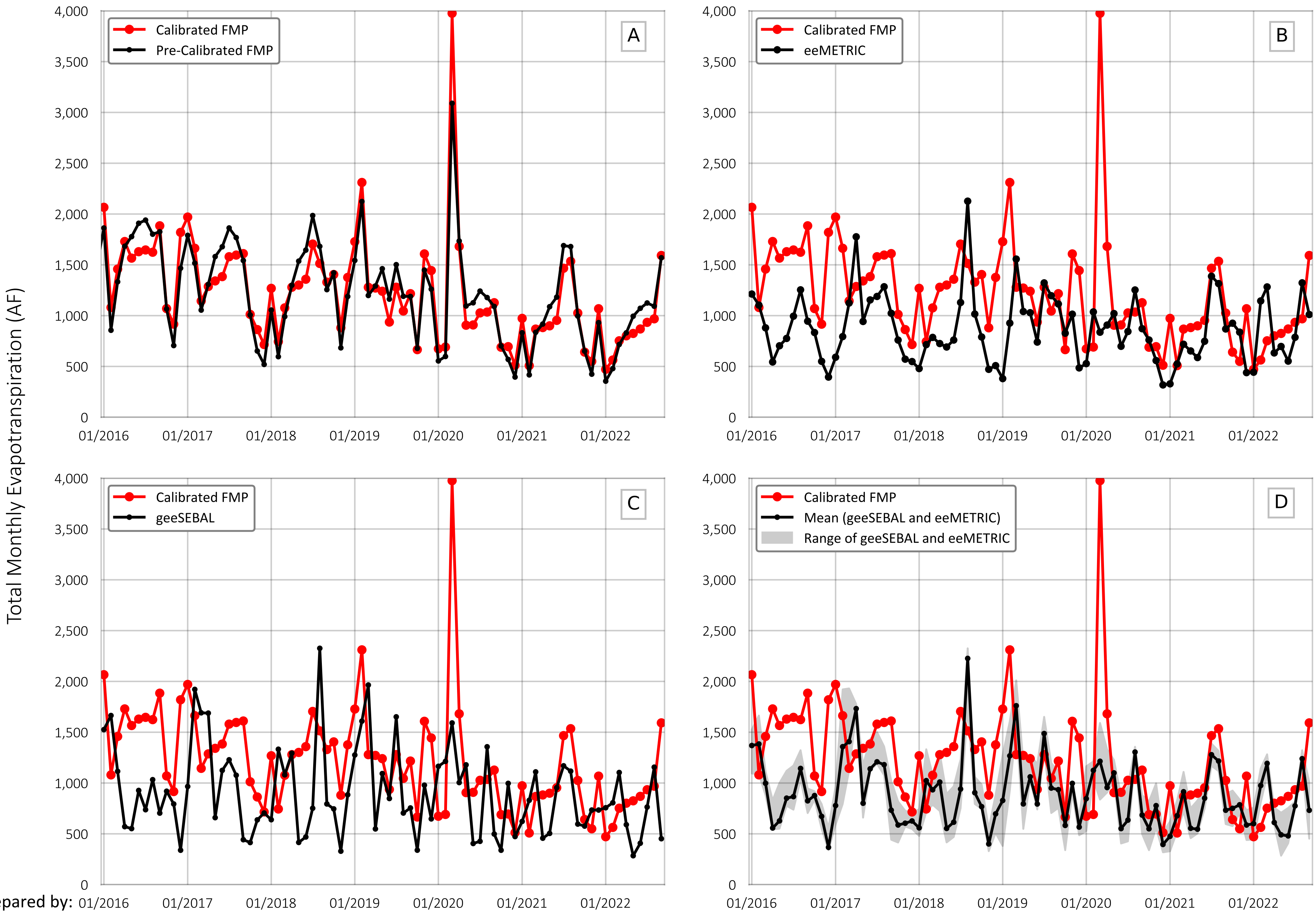

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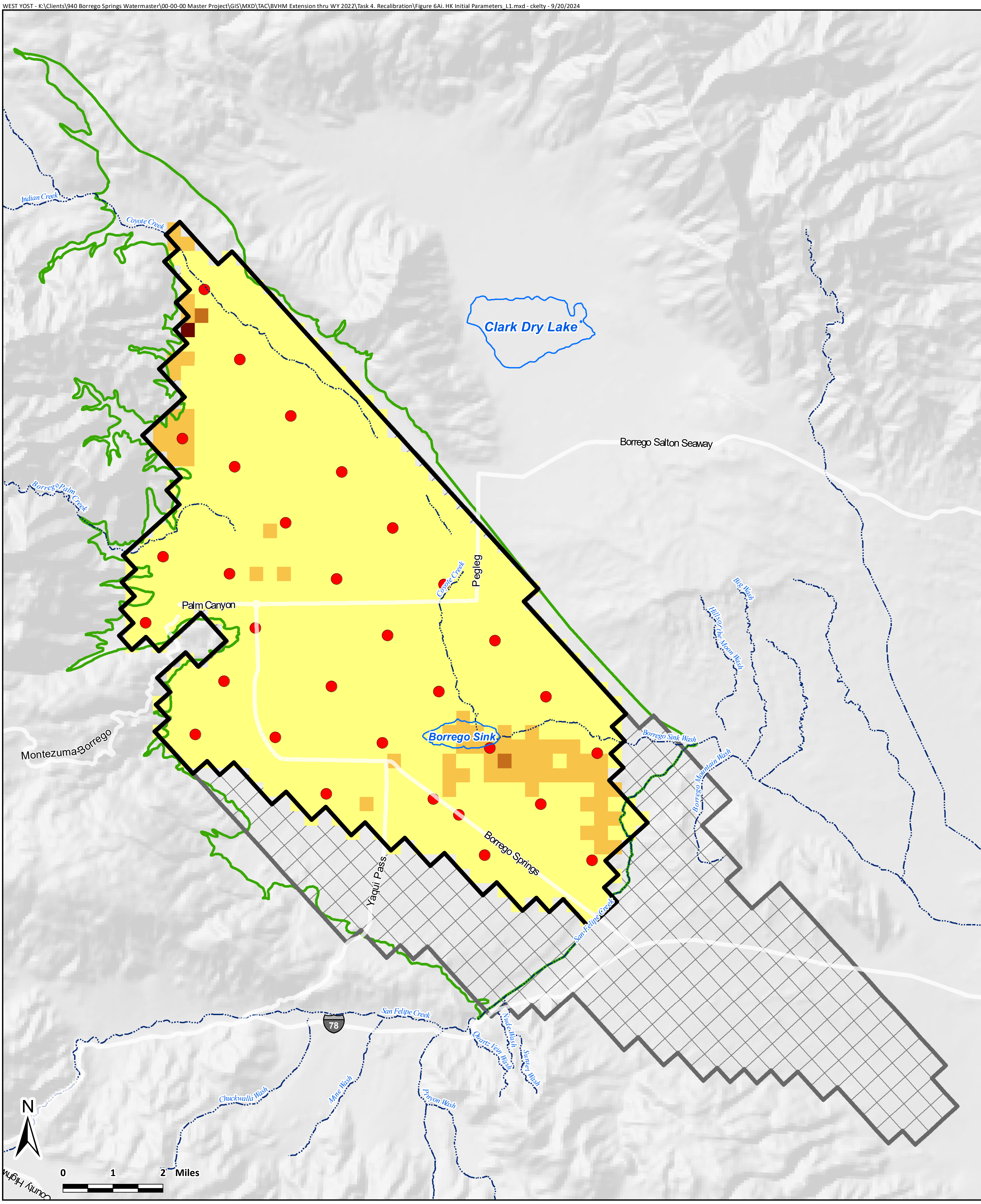
Figure 4. Comparison of Total Monthly ET from Farms in the FMP: FMP vs. OpenET Models



Horizontal Conductivity Values (m/day)

- 10 - 100
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

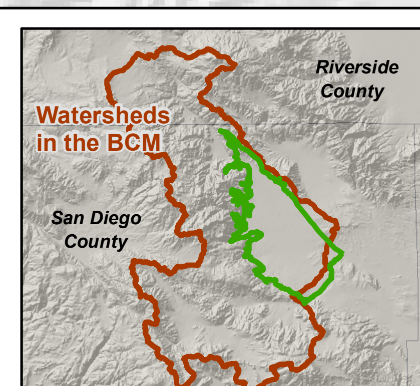
Pilot Points used in Calibration
Layer 1

Extent of Active Layers in the BVHM

- Layer 1
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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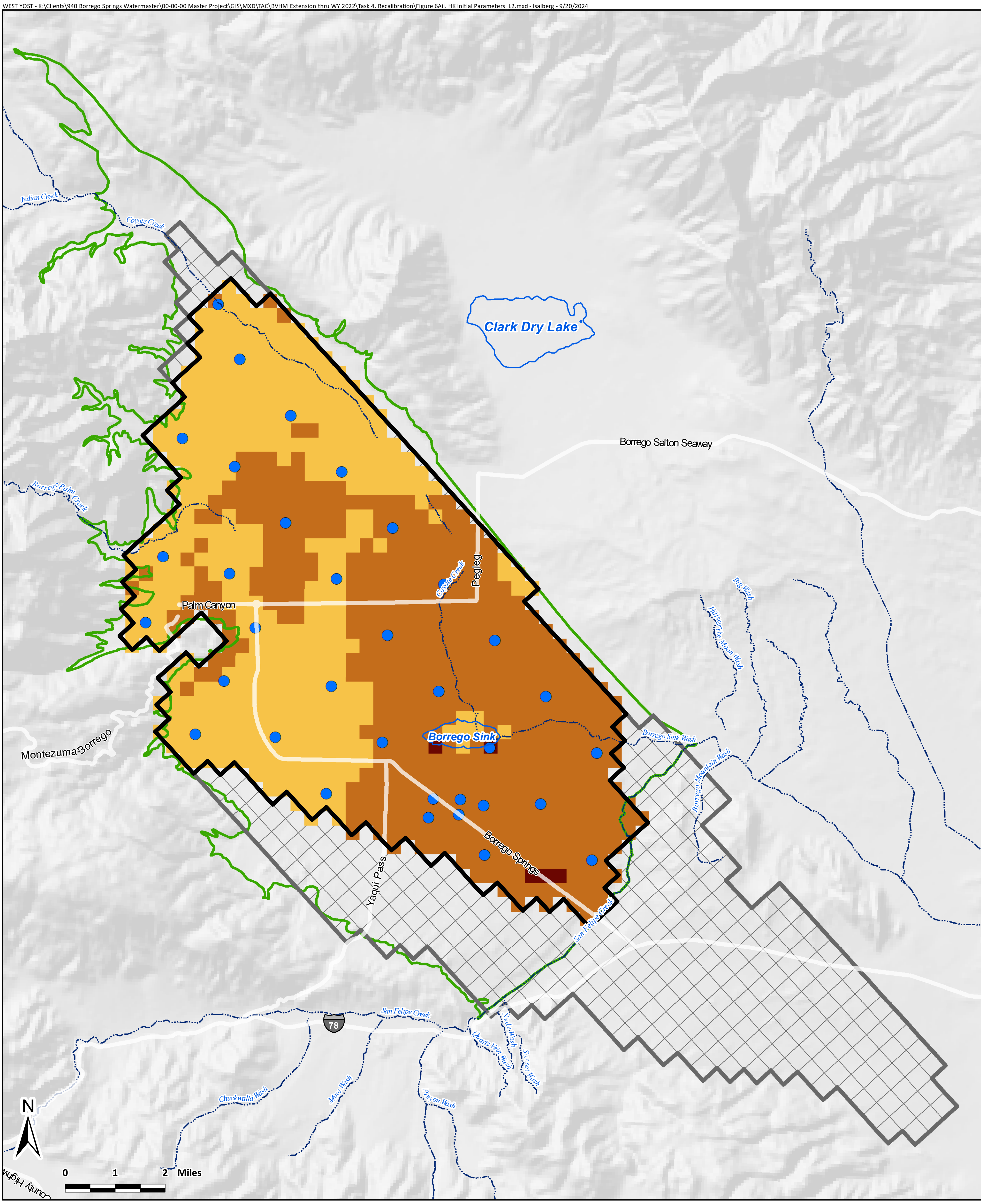
Figure 5Ai

Horizontal Conductivity Values used in Initial BVHM
Layer 1

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Aii. HK Initial Parameters_L2.mxd - lsalberg - 9/20/2024



Horizontal Conductivity Values (m/day)

- 10 - 100
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

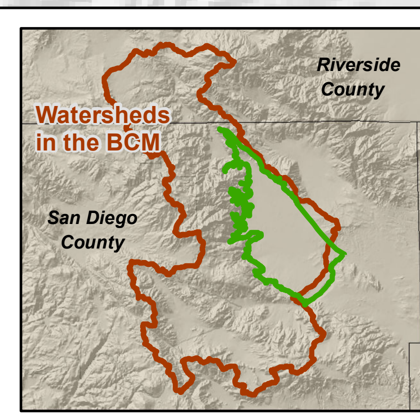
Pilot Points used in Calibration
Layer 2

Extent of Active Layers in the BVHM

- Layer 2
- Boundary of Active Cells in the BVHM
  All Layers

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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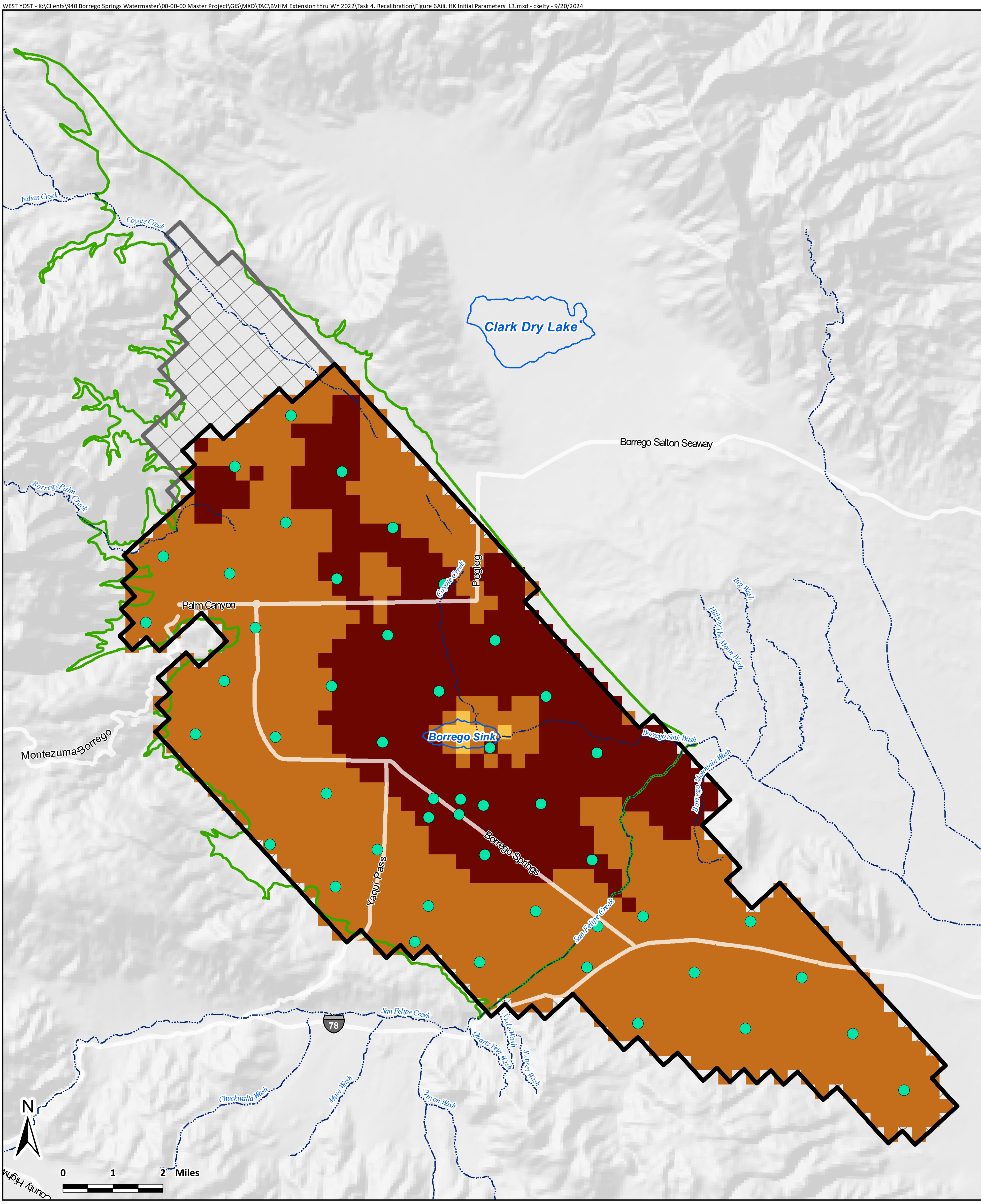
Figure 5Aii

Horizontal Conductivity Values used in Initial BVHM
Layer 2

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Aiii. HK Initial Parameters_L3.mxd - ckelty - 9/20/2024



Horizontal Conductivity Values (m/day)

- 10 - 100
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 3

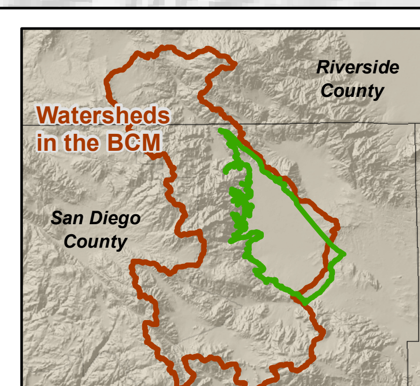
Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

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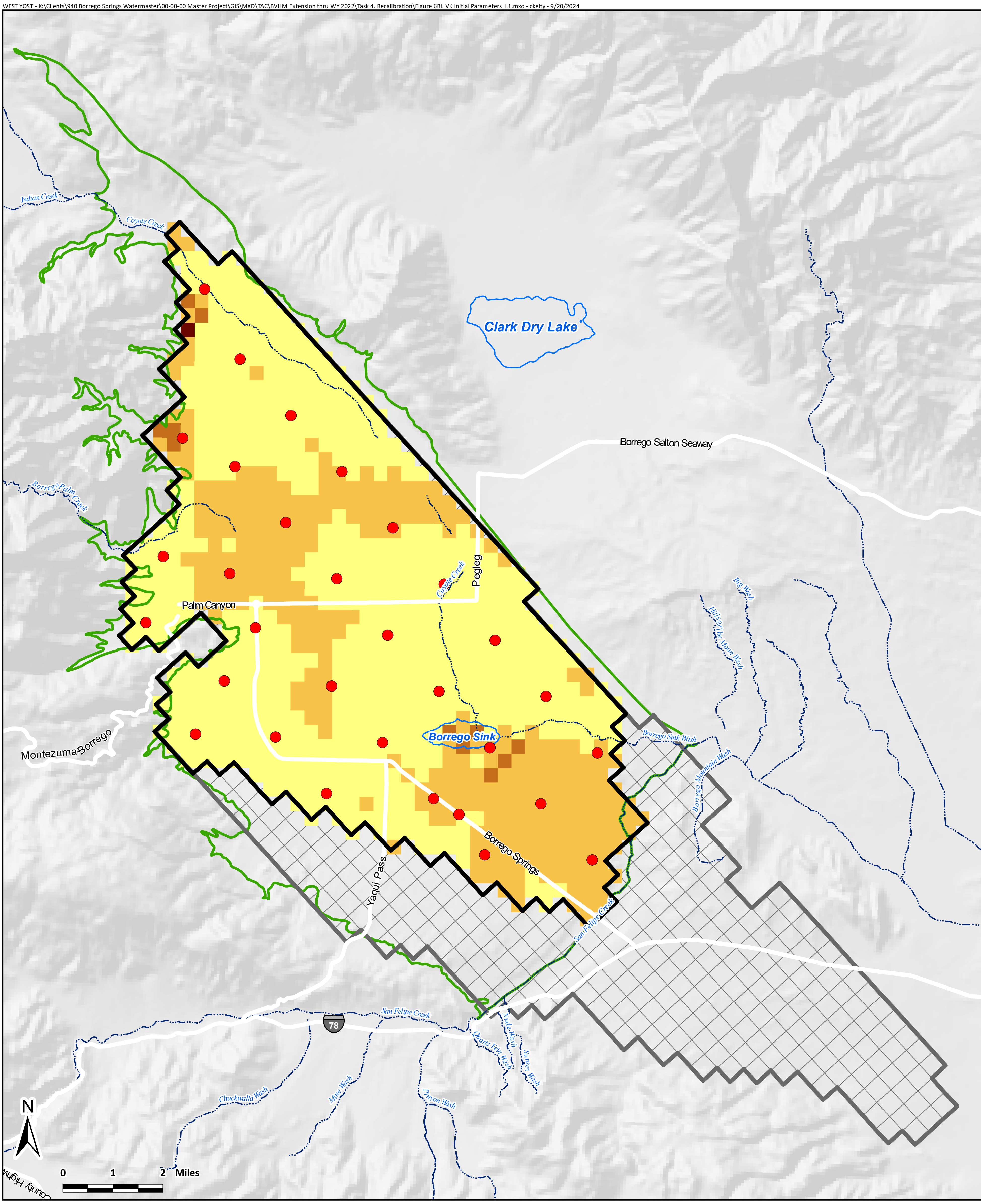
Figure 5Aiii

Horizontal Conductivity Values used in Initial BVHM
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Bi. VK Initial Parameters_L1.mxd - ckelty - 9/20/2024



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

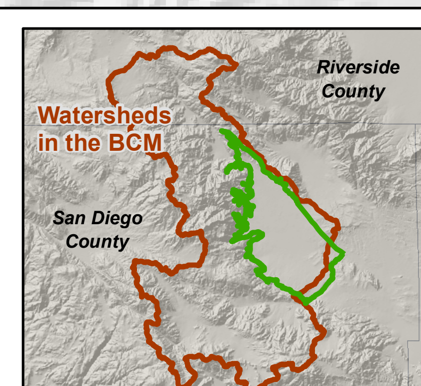
Pilot Points used in Calibration
Layer 1

Extent of Active Layers in the BVHM

- Layer 1
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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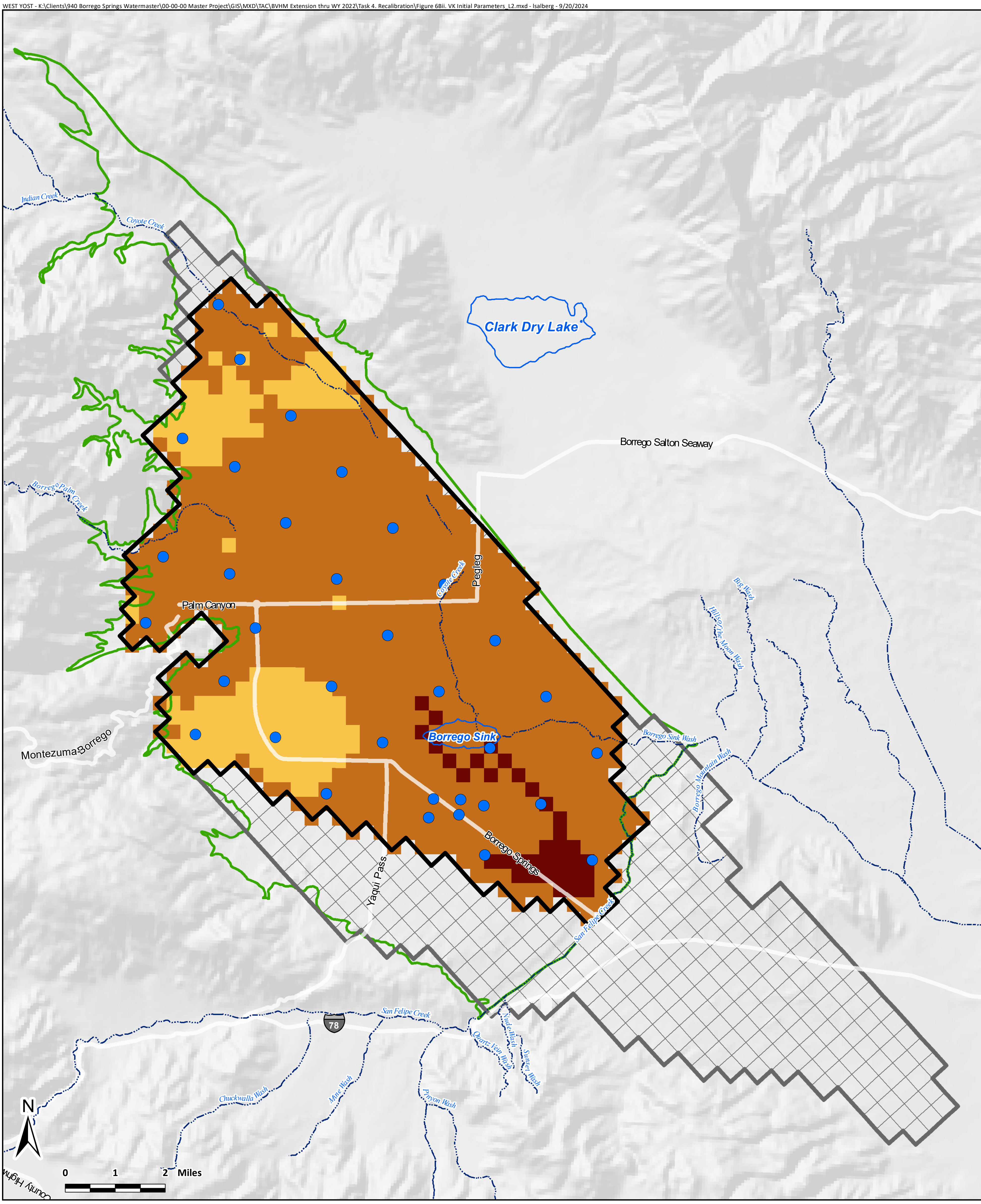
Figure 5Bi

Vertical Conductivity Values used in Initial BVHM
Layer 1

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Bii. VK Initial Parameters_L2.mxd - lsalberg - 9/20/2024



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 2

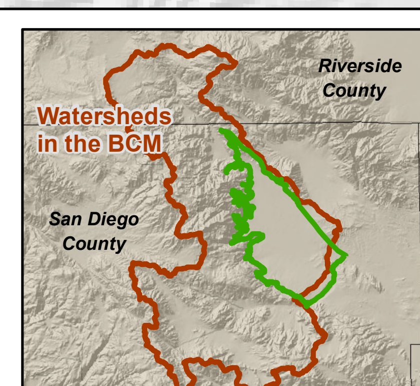
Extent of Active Layers in the BVHM

Layer 2

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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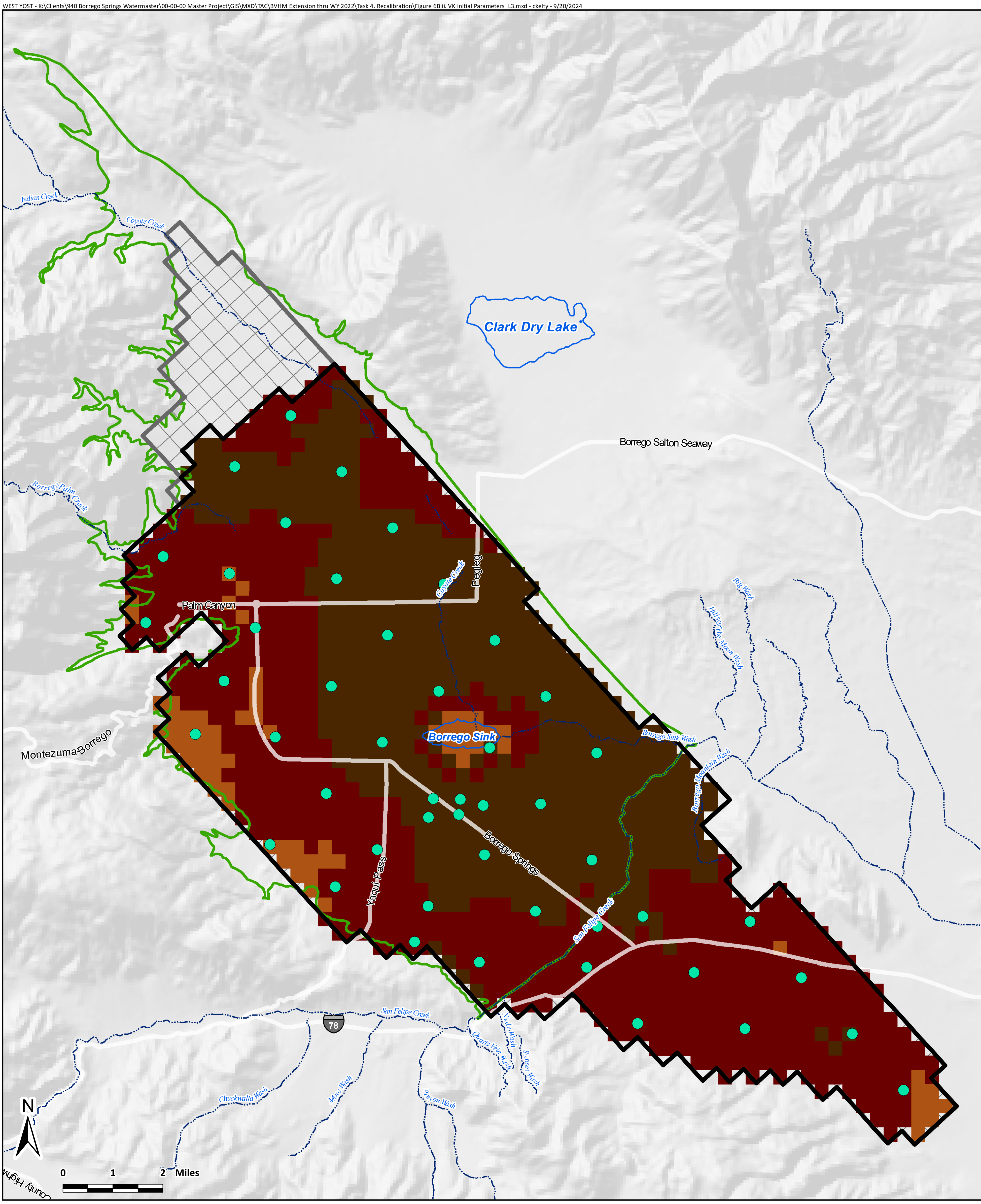
Figure 5Bii

Vertical Conductivity Values used in Initial BVHM
Layer 2



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

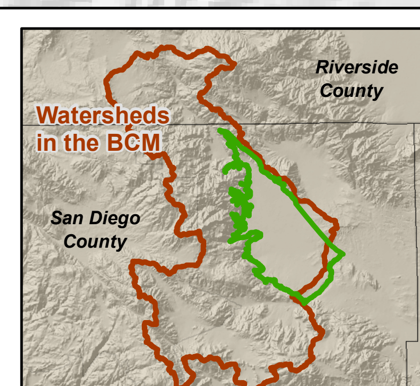
Pilot Points used in Calibration
Layer 3

Extent of Active Layers in the BVHM

- Layer 3
- Boundary of Active Cells in the BVHM
  All Layers

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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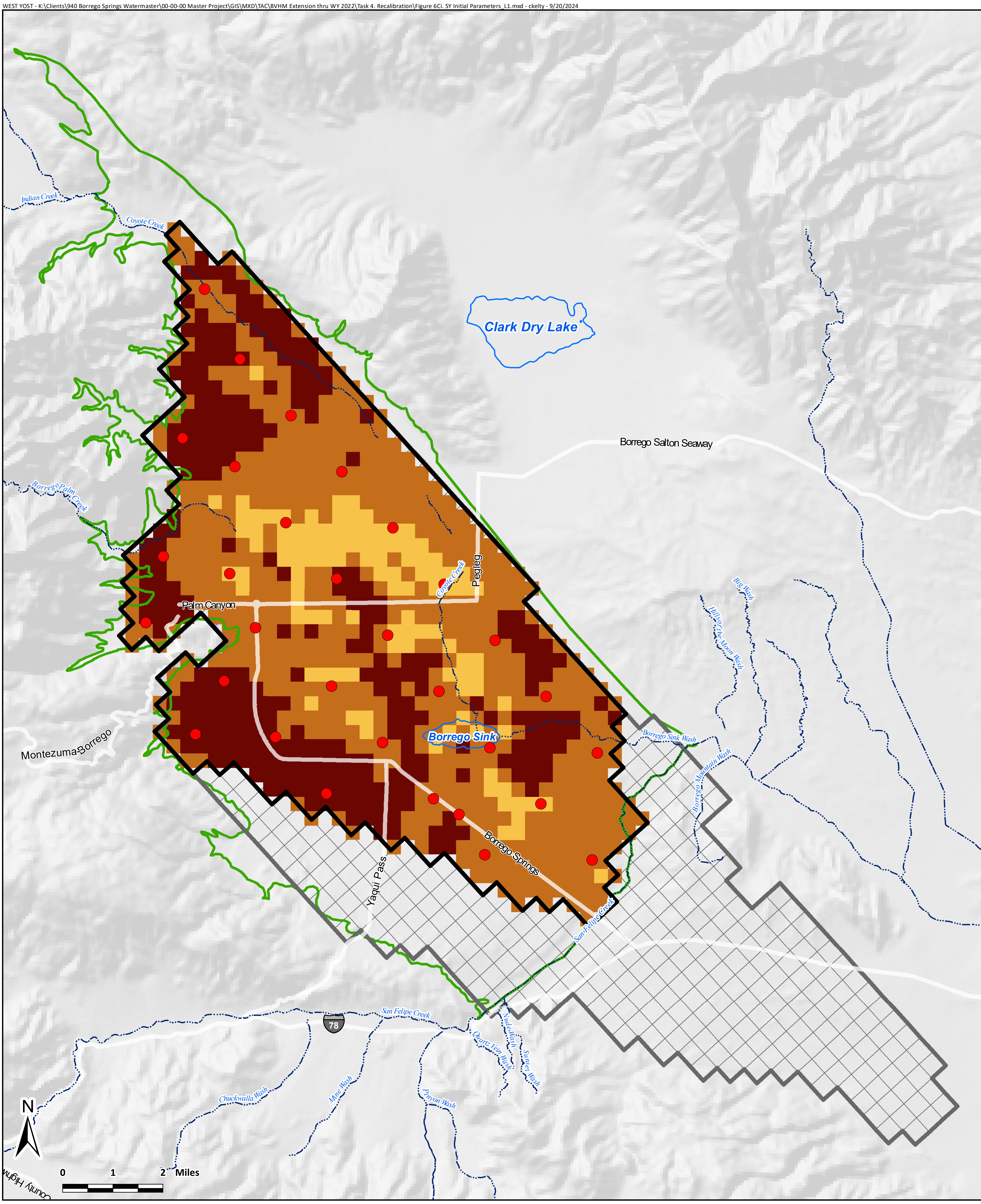
Figure 5Biii

Vertical Conductivity Values used in Initial BVHM
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Ci. SY Initial Parameters_L1.mxd - ckelty - 9/20/2024



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

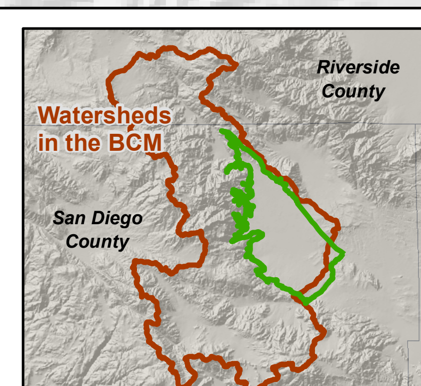
Pilot Points used in Calibration
Layer 1

Extent of Active Layers in the BVHM

- Layer 1
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

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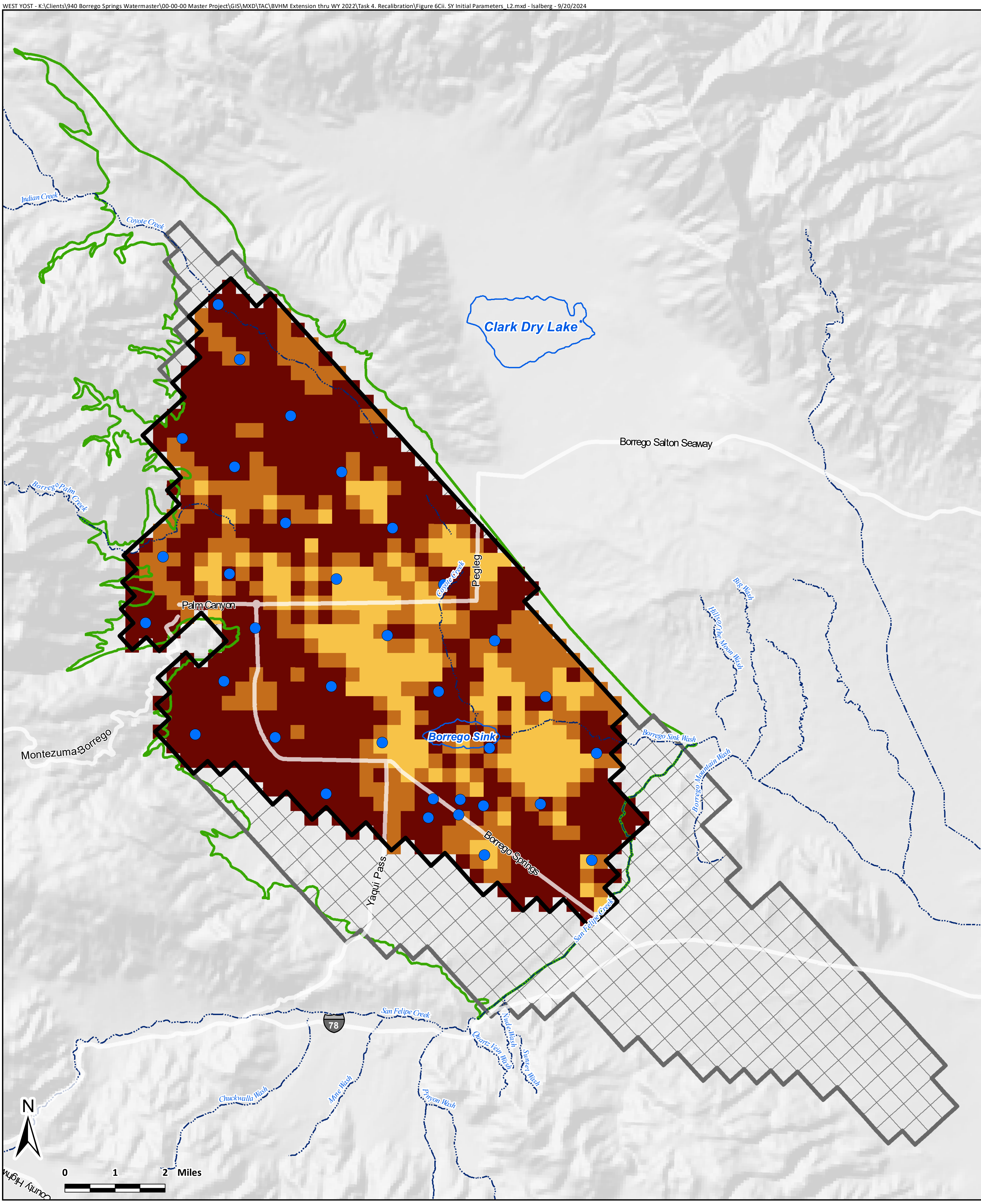
Figure 5Ci

Specific Yield Values used in Initial BVHM
Layer 1

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Cii. SY Initial Parameters_L2.mxd - Isalberg - 9/20/2024



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

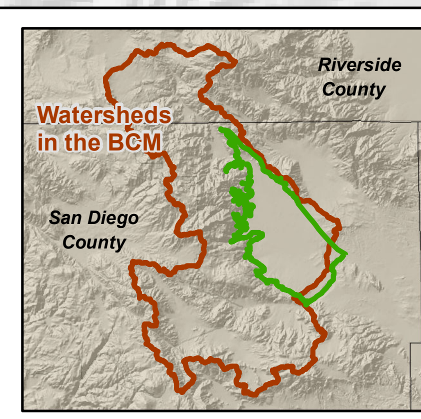
Pilot Points used in Calibration
Layer 2

Extent of Active Layers in the BVHM

- Layer 2
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)

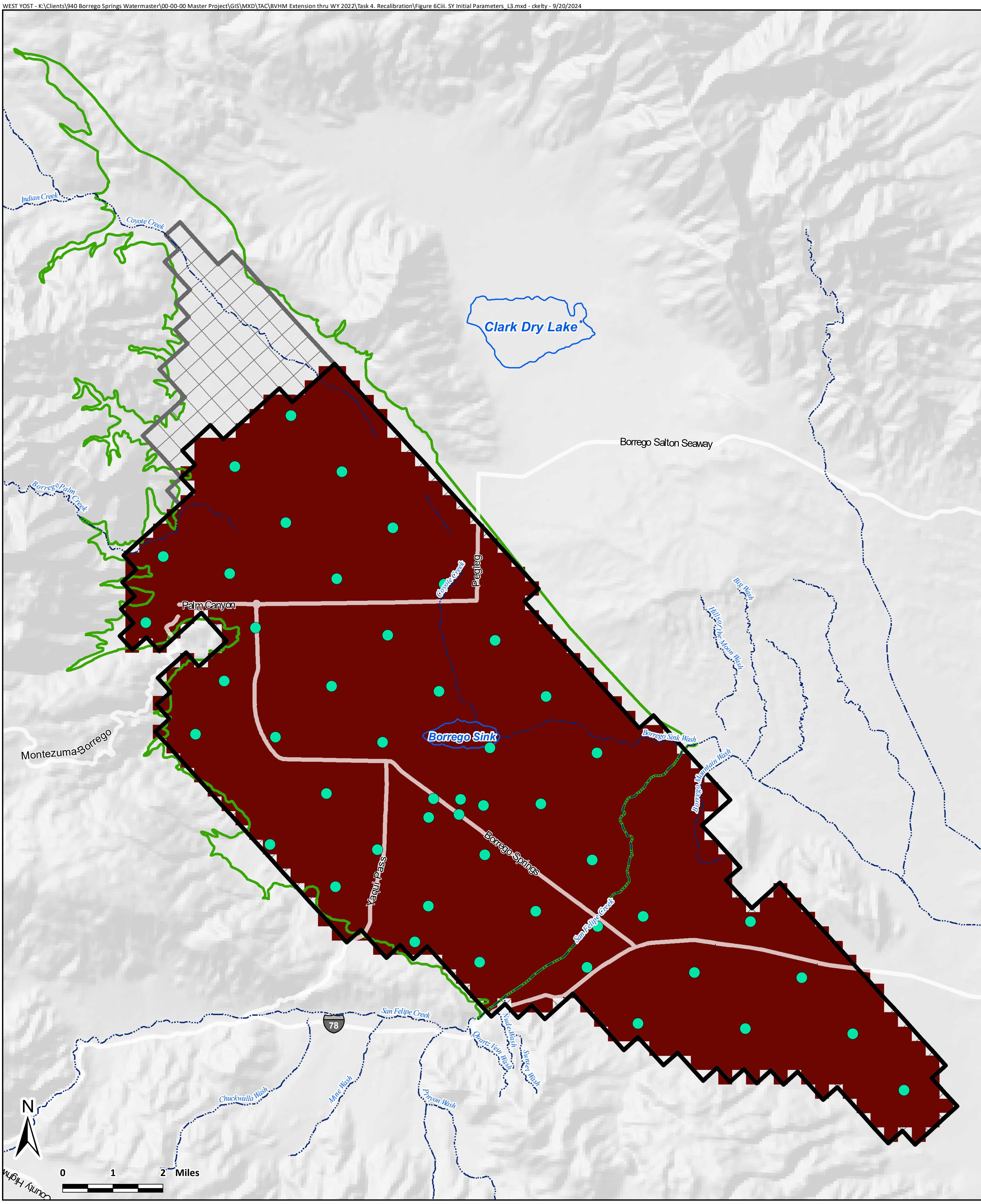


Borrego Springs Watermaster
Redetermine the Sustainable Yield

Prepared by:
WEST YOST

Figure 5Cii

Specific Yield Values used in Initial BVHM
Layer 2



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

Pilot Points used in Calibration
Layer 3

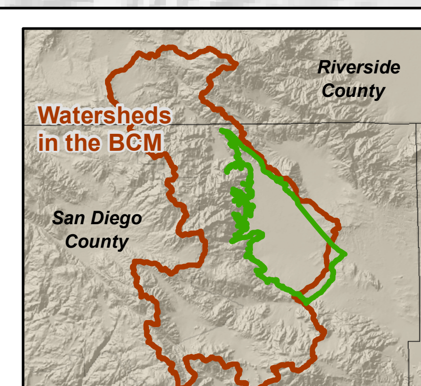
Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



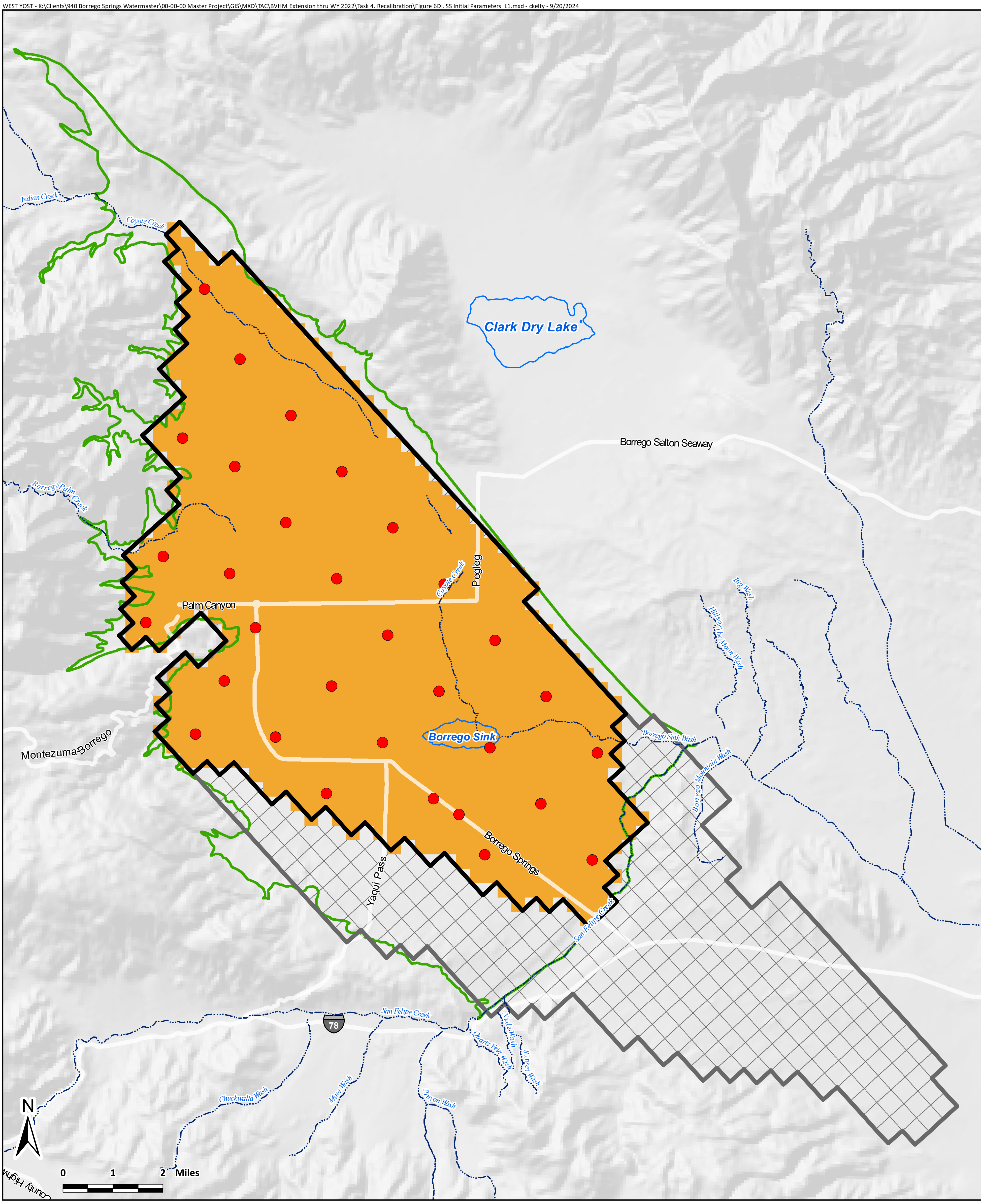
Borrego Springs Watermaster
Redetermine the Sustainable Yield

Prepared by:

WEST YOST

Figure 5Ciii

Specific Yield Values used in Initial BVHM
Layer 3



Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 1

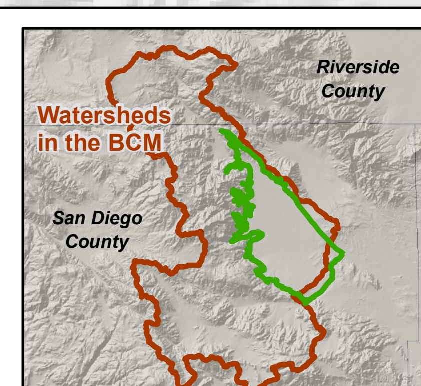
Extent of Active Layers in the BVHM

Layer 1

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



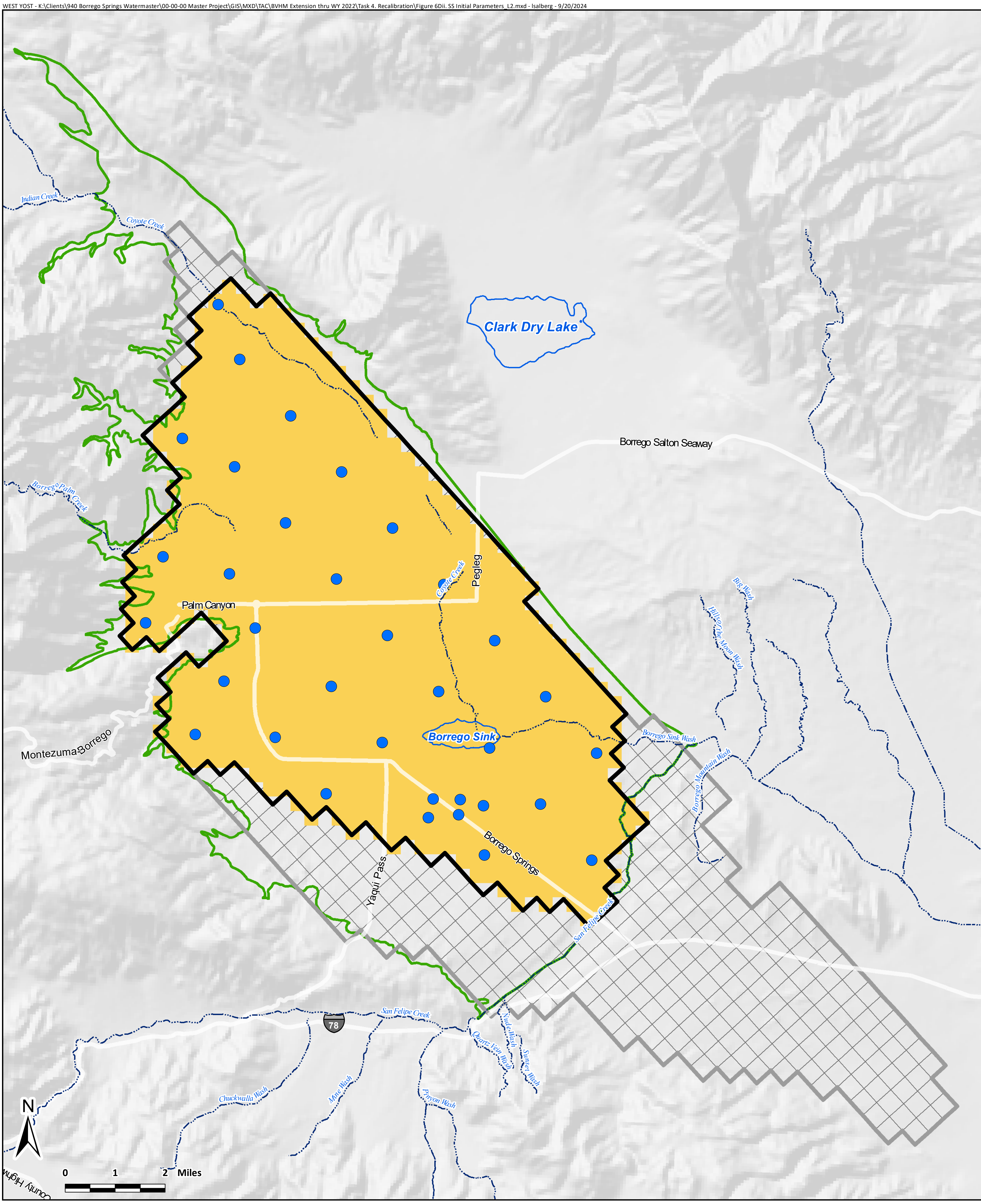
Borrego Springs Watermaster
Redetermine the Sustainable Yield

Prepared by:

WEST YOST

Figure 5Di

Specific Storage Values used in Initial BVHM
Layer 1



Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 2

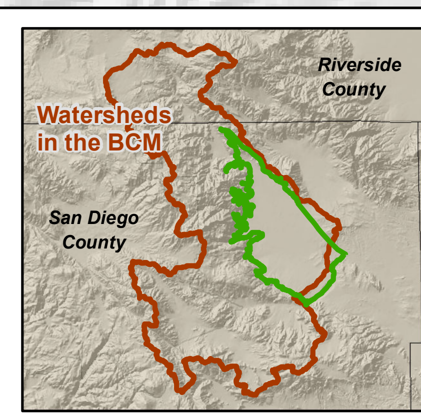
Extent of Active Layers in the BVHM

Layer 2

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

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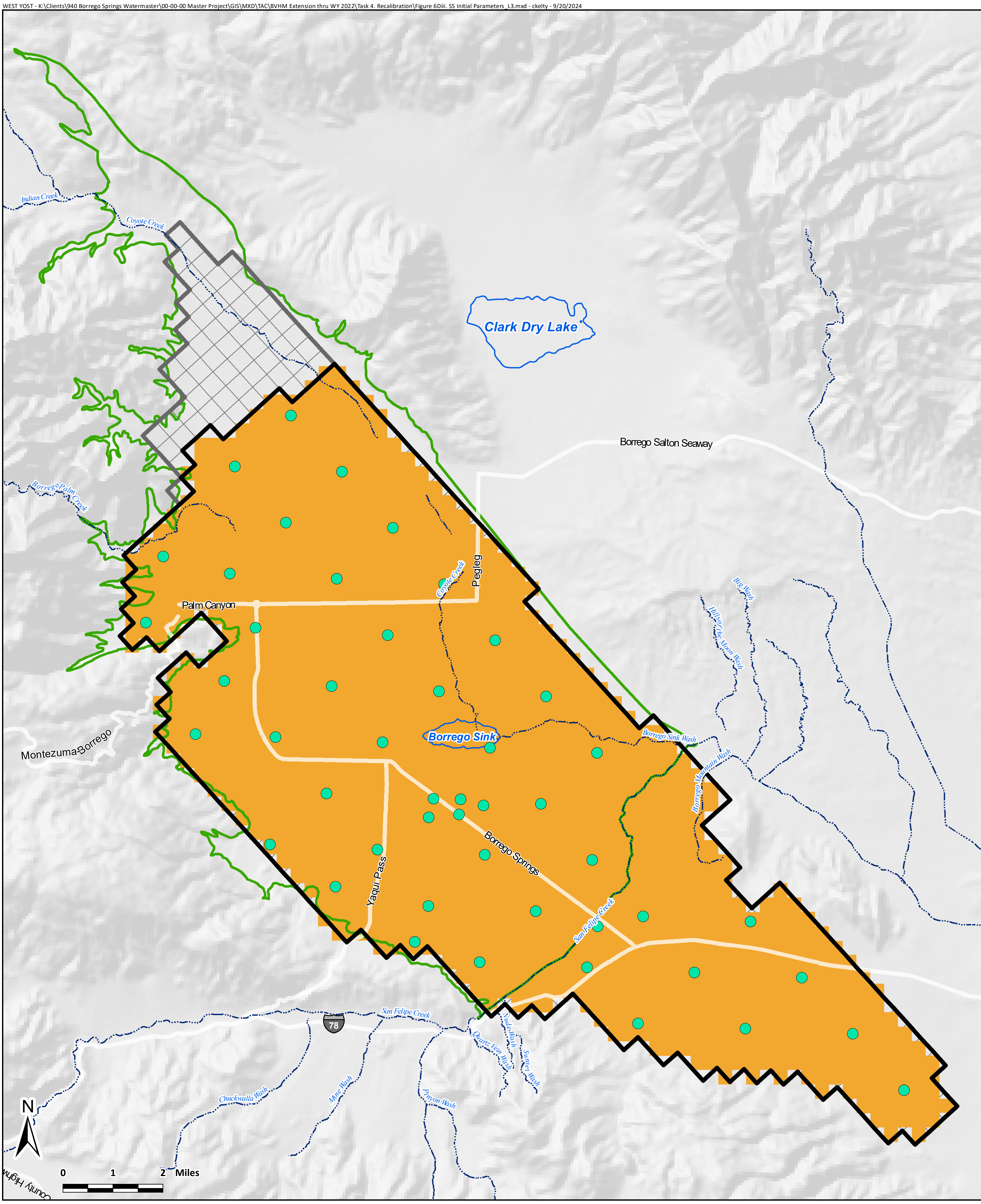
WEST YOST

Figure 5Dii

Specific Storage Values used in Initial BVHM
Layer 2

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 6Diii. SS Initial Parameters_L3.mxd - ckelty - 9/20/2024



Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 3

Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

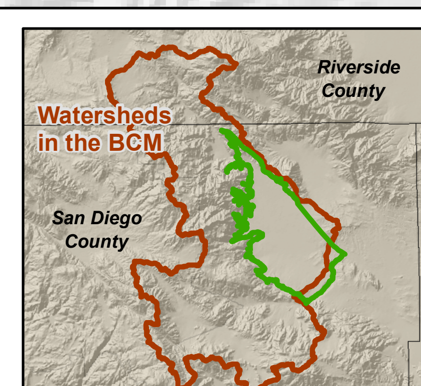


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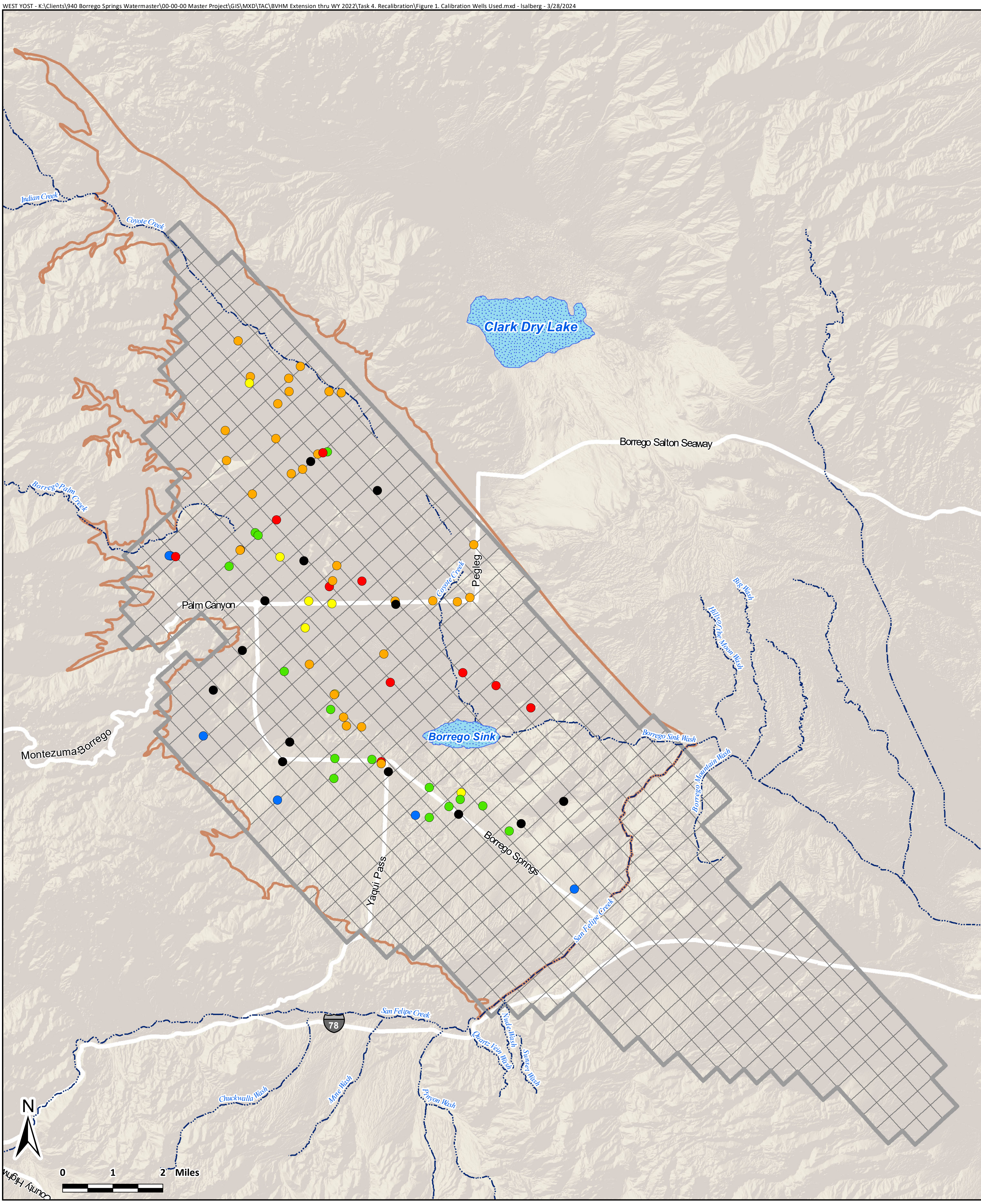
Figure 5Diii

Specific Storage Values used in Initial BVHM
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 1. Calibration Wells Used.mxd - lsalberg - 3/28/2024



Wells used for BVHM Calibration

Well by Principal Aquifer

Map ID

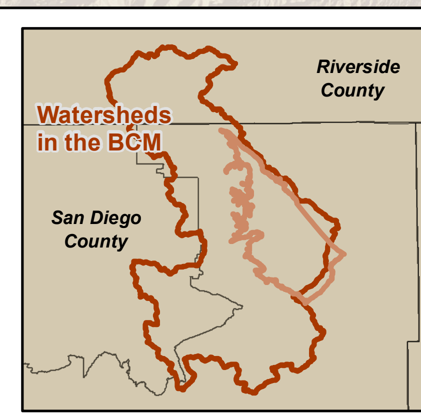
- Upper Only
- Upper and Middle
- Middle Only
- Middle and Lower
- Lower Only
- Upper, Middle, Lower

Extent of Active Layers in the BVHM

Boundary of Active Cells in the BVHM

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



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Redetermine the Sustainable Yield

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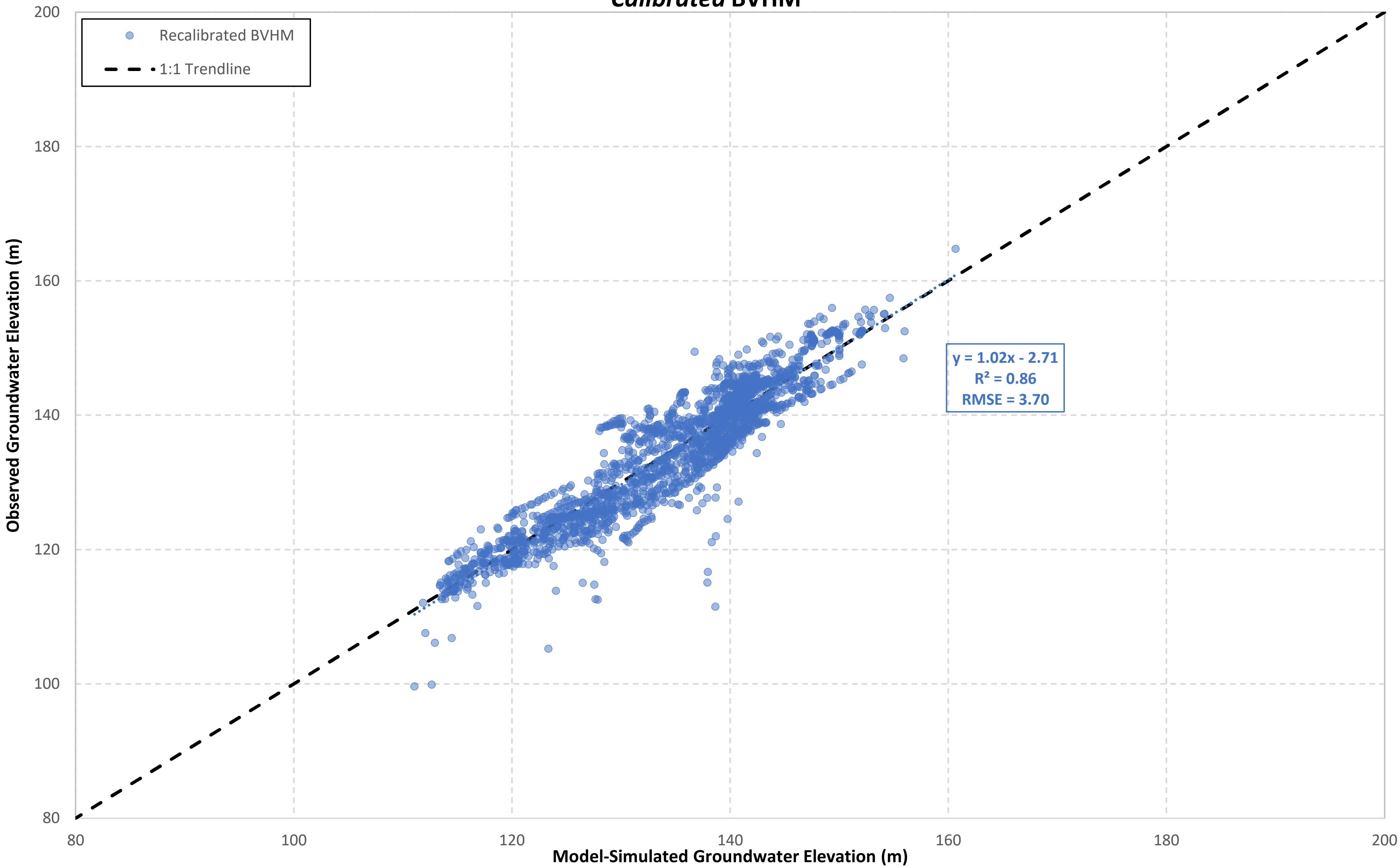
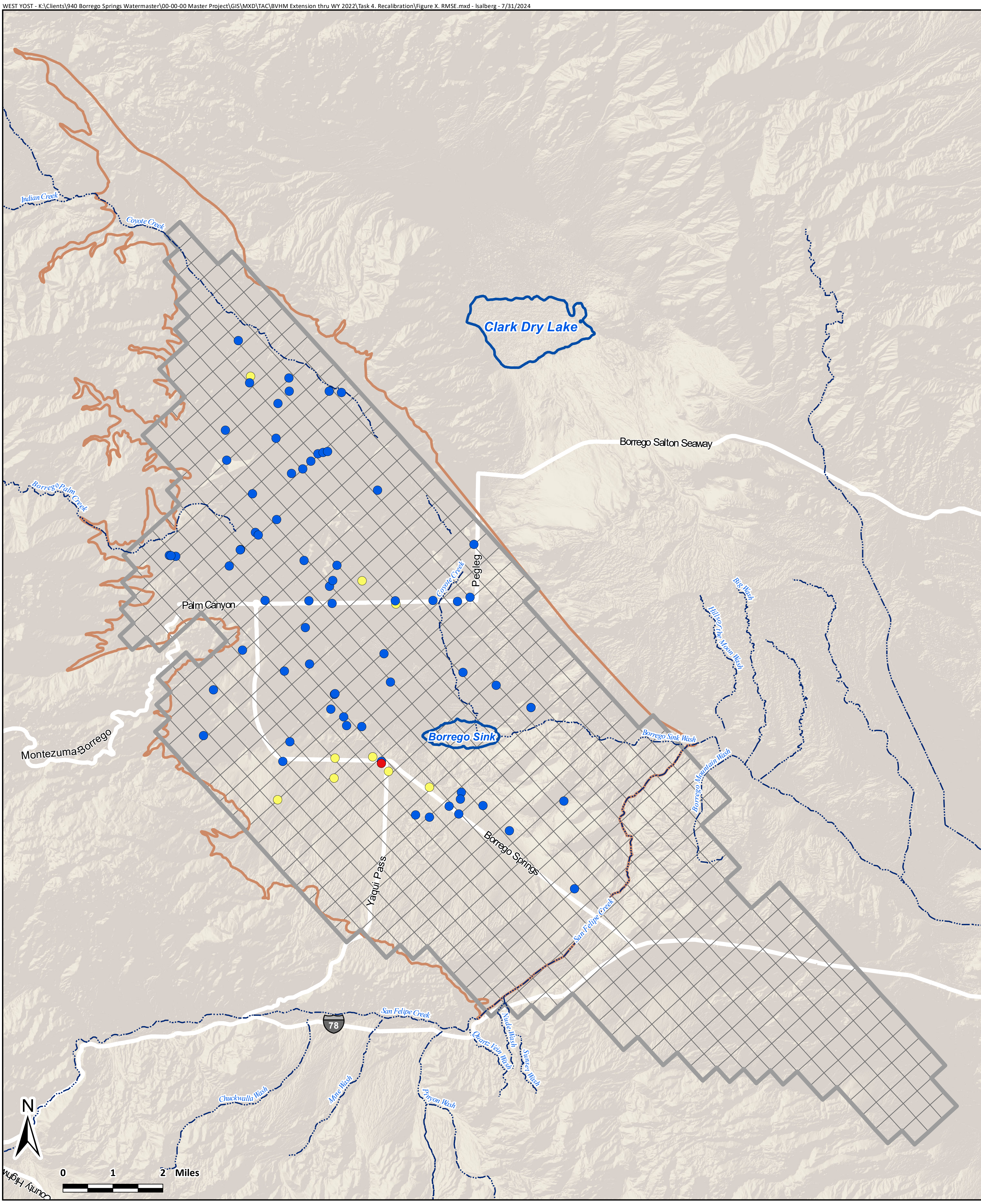
WEST YOST

Figure 6

Wells used to Calibrate BVHM by Aquifer Layer

Figure 7. Observed vs. Model-Simulated Groundwater Elevation
***Calibrated* BVHM**



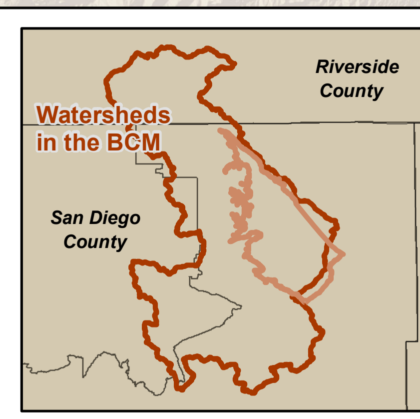


RMSE (m)

- Good (0 - 5)
- Fair (5 - 10)
- Poor (> 10)

Other Features

- Boundary of Active Cells in the BVHM *All Layers*
- Borrego Springs Groundwater Subbasin (7-024.01)



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Redetermine the Sustainable Yield

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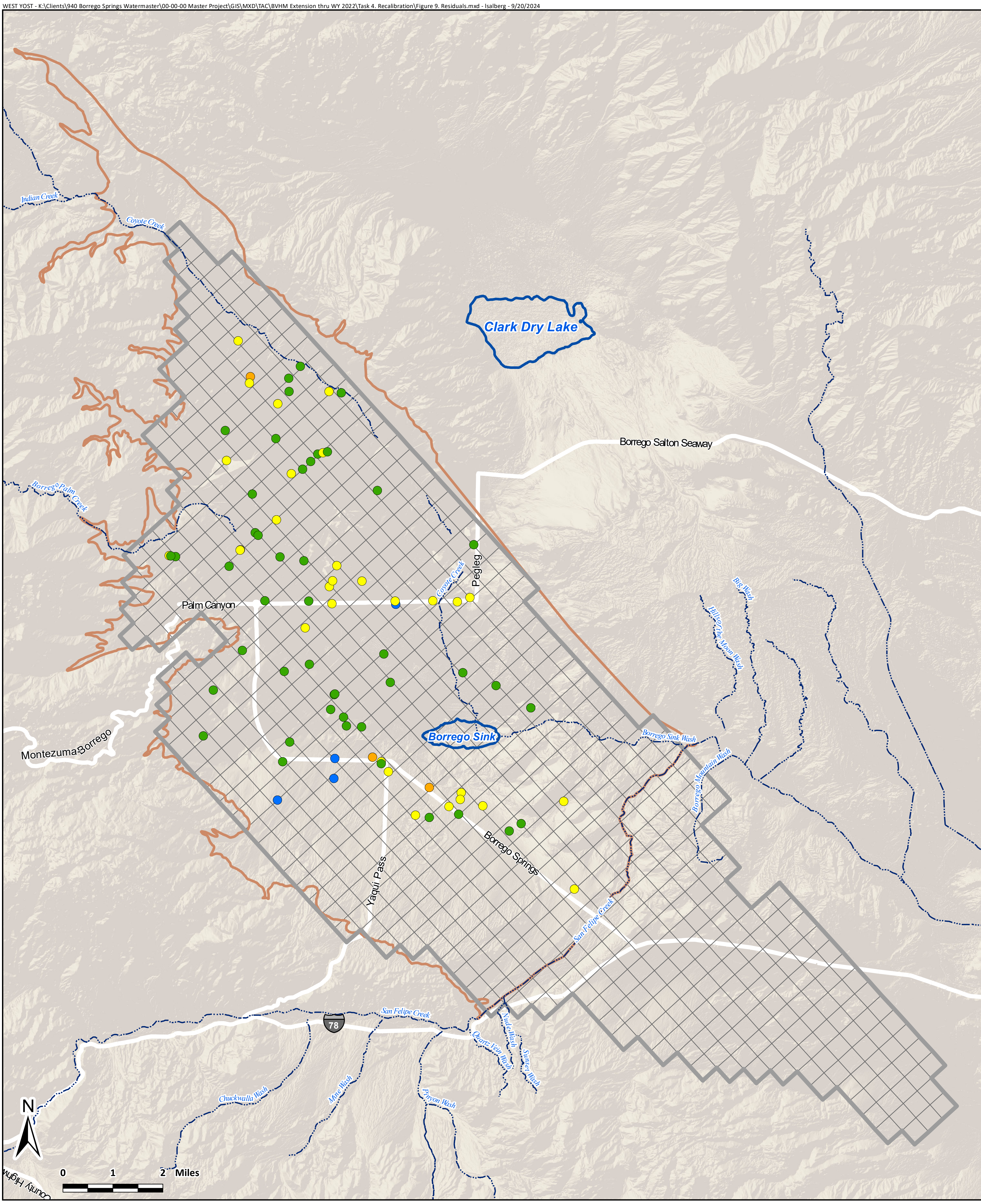
Figure 8

RMSE of Observation Wells
Calibrated BVHM



Residuals (m)

- Poor (< -10)
- Fair (-10 to -5)
- Good (-5 to 0)
- Good (0 to 5)
- Fair (5 to 10)
- Poor (> 10)

Other Features

- Boundary of Active Cells in the BVHM *All Layers*
- Borrego Springs Groundwater Subbasin (7-024.01)

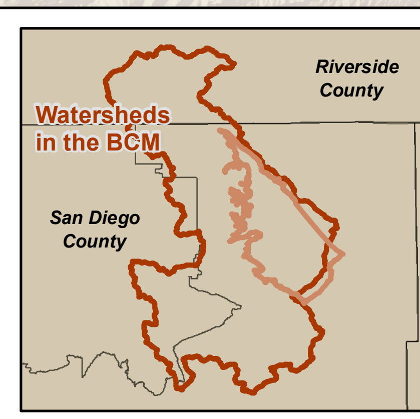


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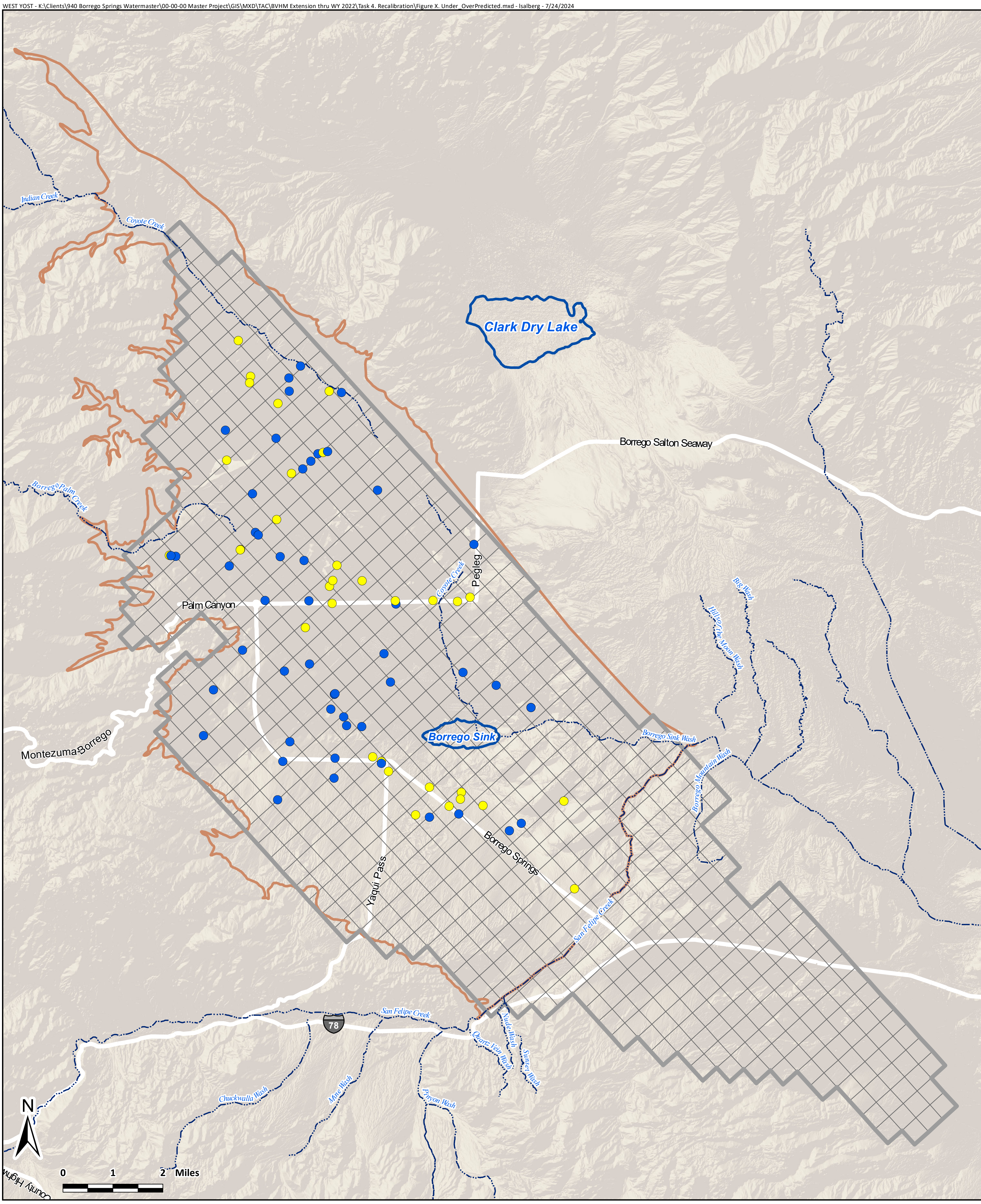
Figure 9

Residuals from Observation Targets
Calibrated BVHM

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure X. Under_OverPredicted.mxd - lsalberg - 7/24/2024



Residuals (m)

- Underpredicted (< 0)
- Overpredicted (> 0)

Other Features

- Boundary of Active Cells in the BVHM *All Layers*
- Borrego Springs Groundwater Subbasin (7-024.01)

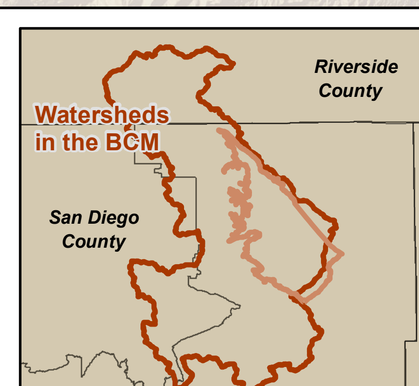


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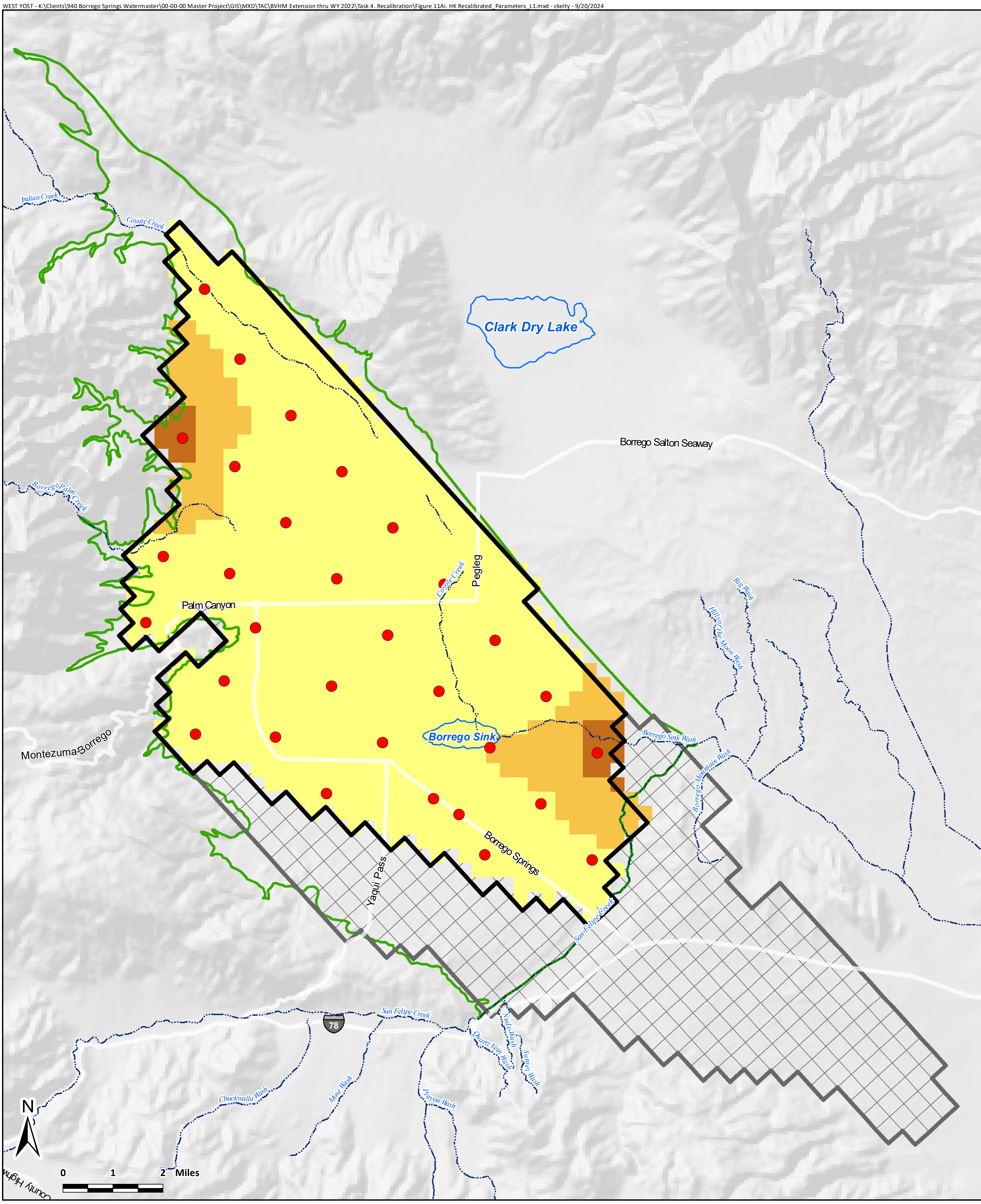
Figure 10

Under vs. Over-Predicted Groundwater-Elevations

Calibrated BVHM

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Ai. HK Recalibrated_Parameters_L1.mxd - ckelty - 9/20/2024



Horizontal Conductivity Values (m/day)

- 10 - 102
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

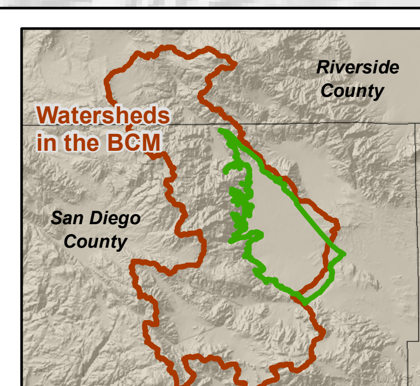
Pilot Points used in Calibration
Layer 1

Extent of Active Layers in the BVHM

- Layer 1
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



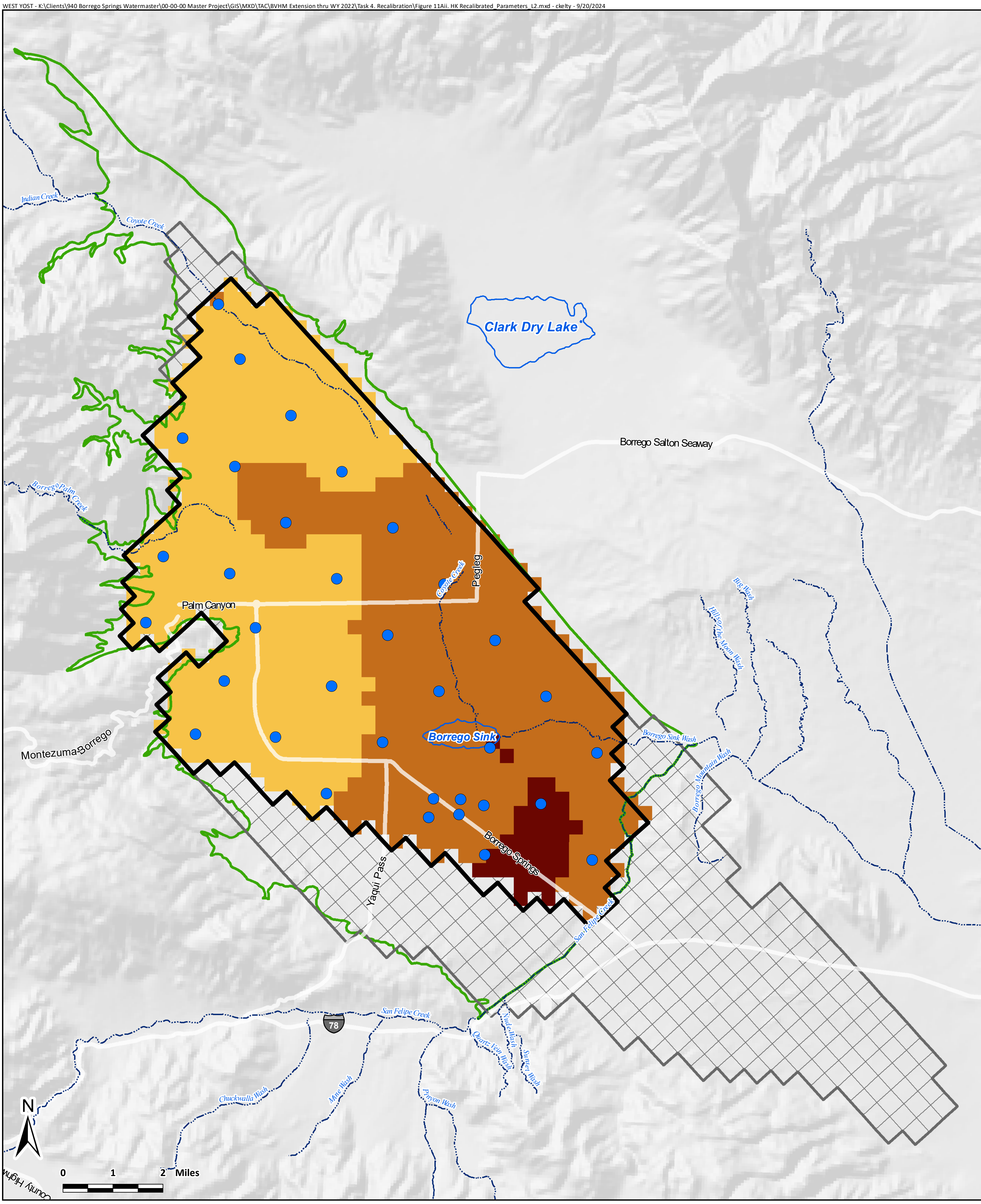
Borrego Springs Watermaster
Redetermine the Sustainable Yield

Figure 11Ai

Horizontal Conductivity Values used in BVHM Calibration
Layer 1

Prepared by:

WEST YOST



Horizontal Conductivity Values (m/day)

- 10 - 100
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

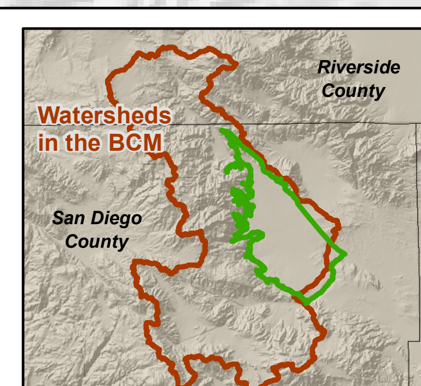
Pilot Points used in Calibration
Layer 2

Extent of Active Layers in the BVHM

- Layer 2
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

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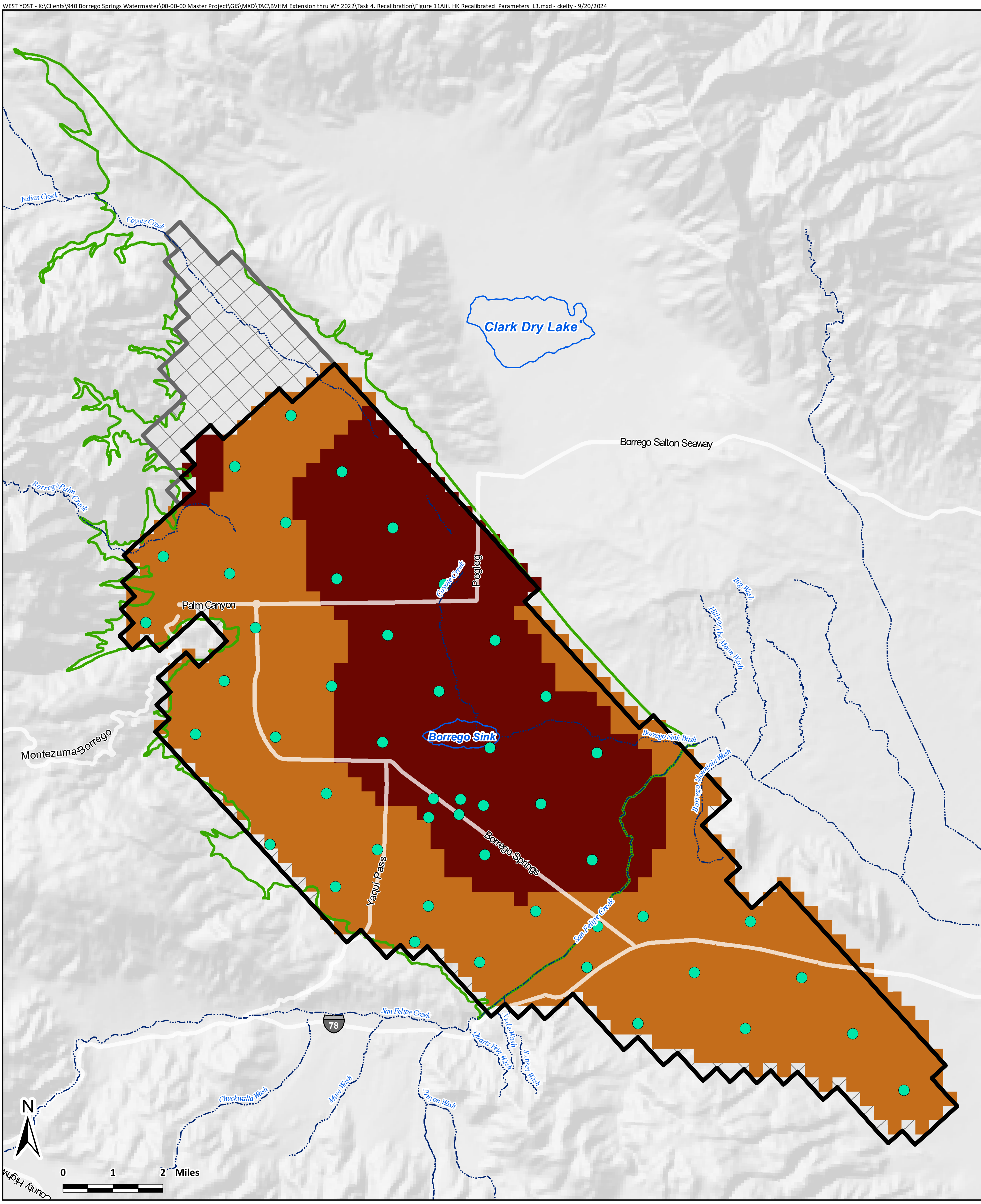
Figure 11Aii

Horizontal Conductivity Values used in BVHM Calibration
Layer 2

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Aiii. HK Recalibrated_Parameters_L3.mxd - ckelty - 9/20/2024



Horizontal Conductivity Values (m/day)

- 10 - 102
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 3

Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

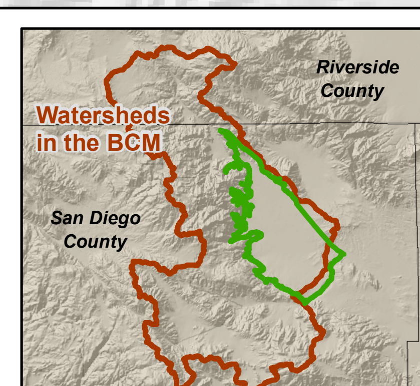


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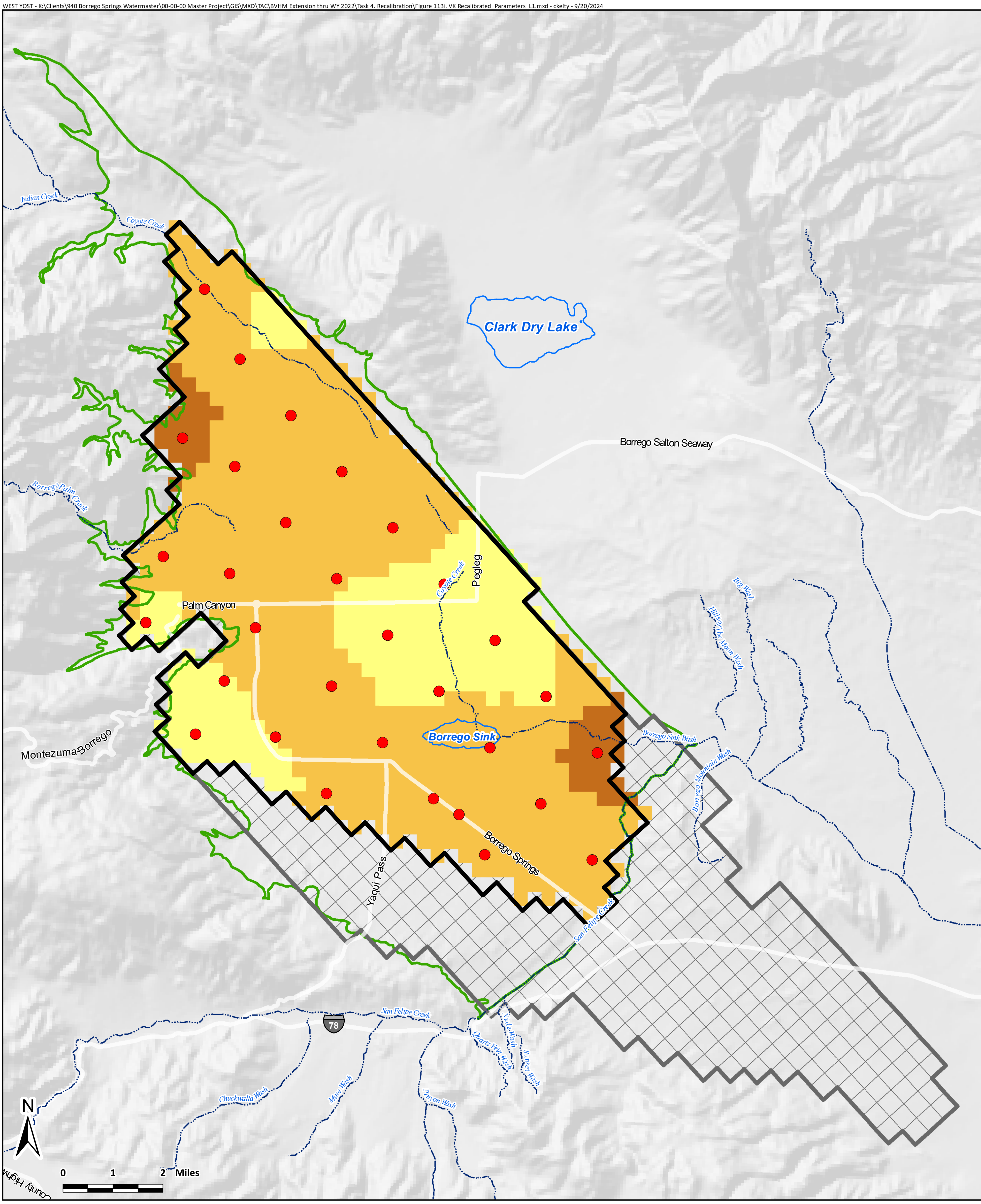
Figure 11Aiii

Horizontal Conductivity Values used in BVHM Calibration
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Bi. VK Recalibrated_Parameters_L1.mxd - ckelty - 9/20/2024



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 1

Extent of Active Layers in the BVHM

Layer 1

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

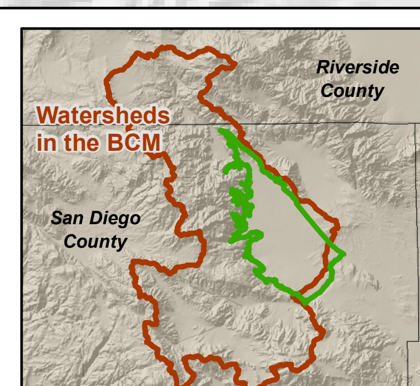


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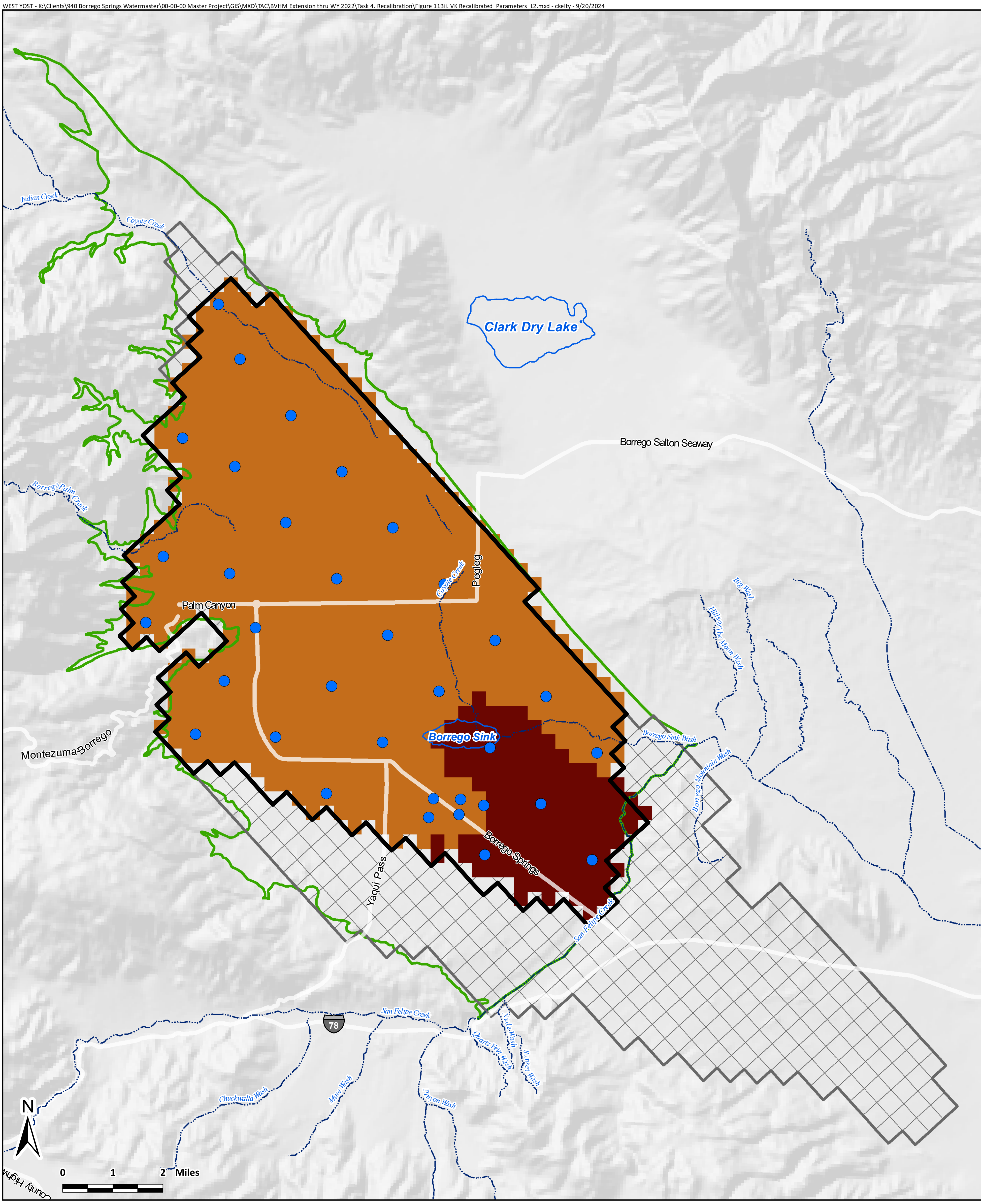
Figure 11Bi

Vertical Conductivity Values used in BVHM Calibration
Layer 1

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Bii. VK Recalibrated_Parameters_L2.mxd - ckelty - 9/20/2024



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 2

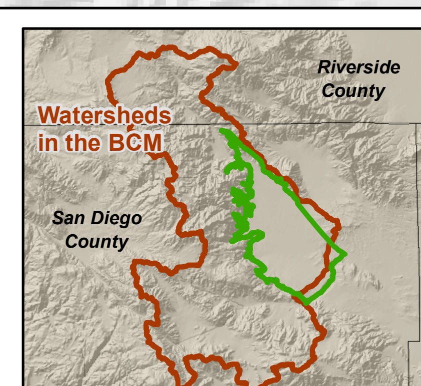
Extent of Active Layers in the BVHM

Layer 2

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

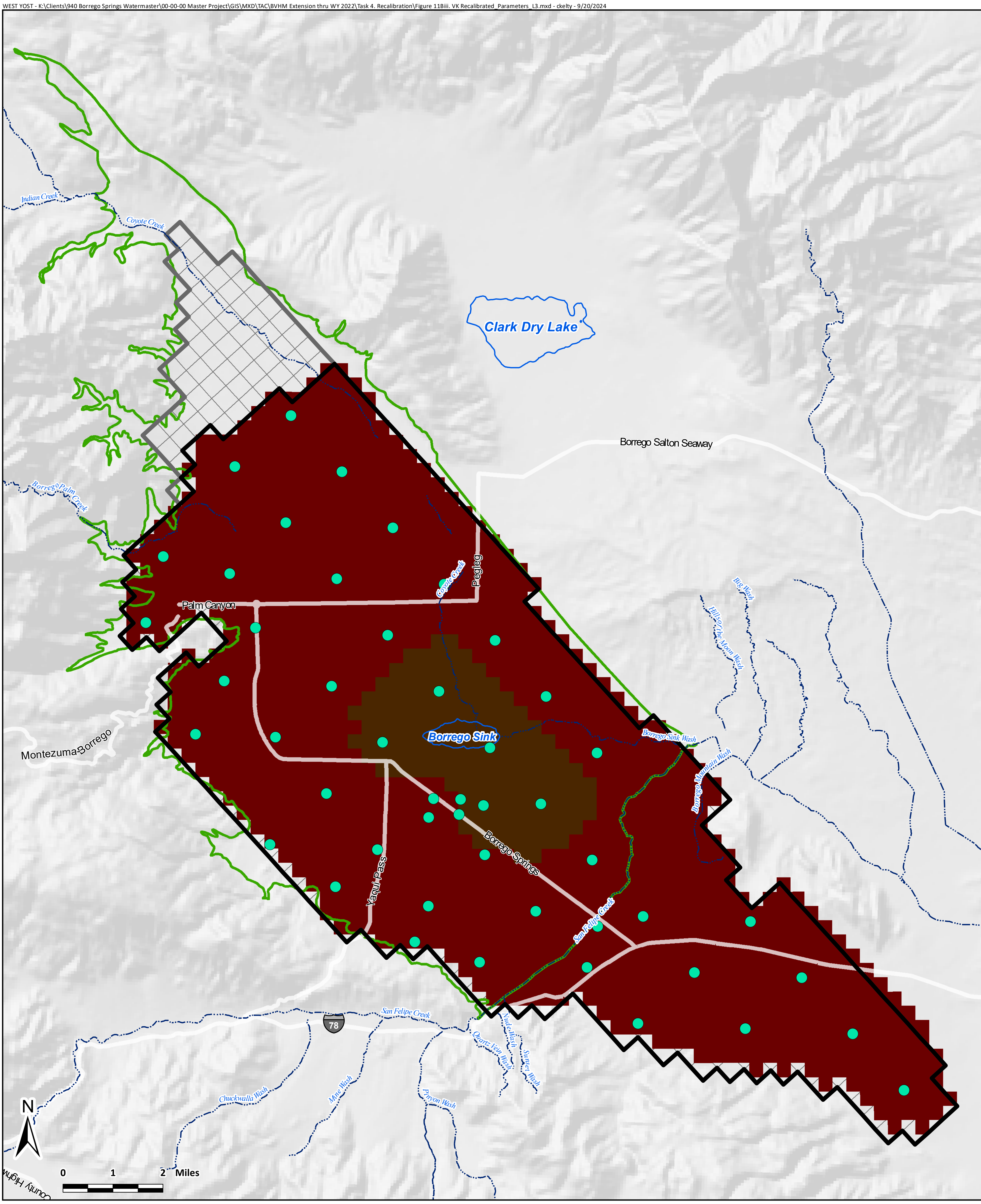
Figure 11Bii

Vertical Conductivity Values used in BVHM Calibration
Layer 2

Prepared by:

WEST YOST

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Biii. VK Recalibrated_Parameters_L3.mxd - ckelty - 9/20/2024



Vertical Conductivity Values (m/day)

- 10 - 50
- 1 - 10
- 0.1 - 1
- 0.01 - 0.1
- < 0.01

Pilot Points used in Calibration
Layer 3

Extent of Active Layers in the BVHM

- Layer 3
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)

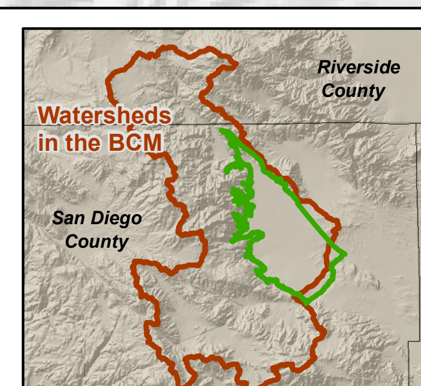


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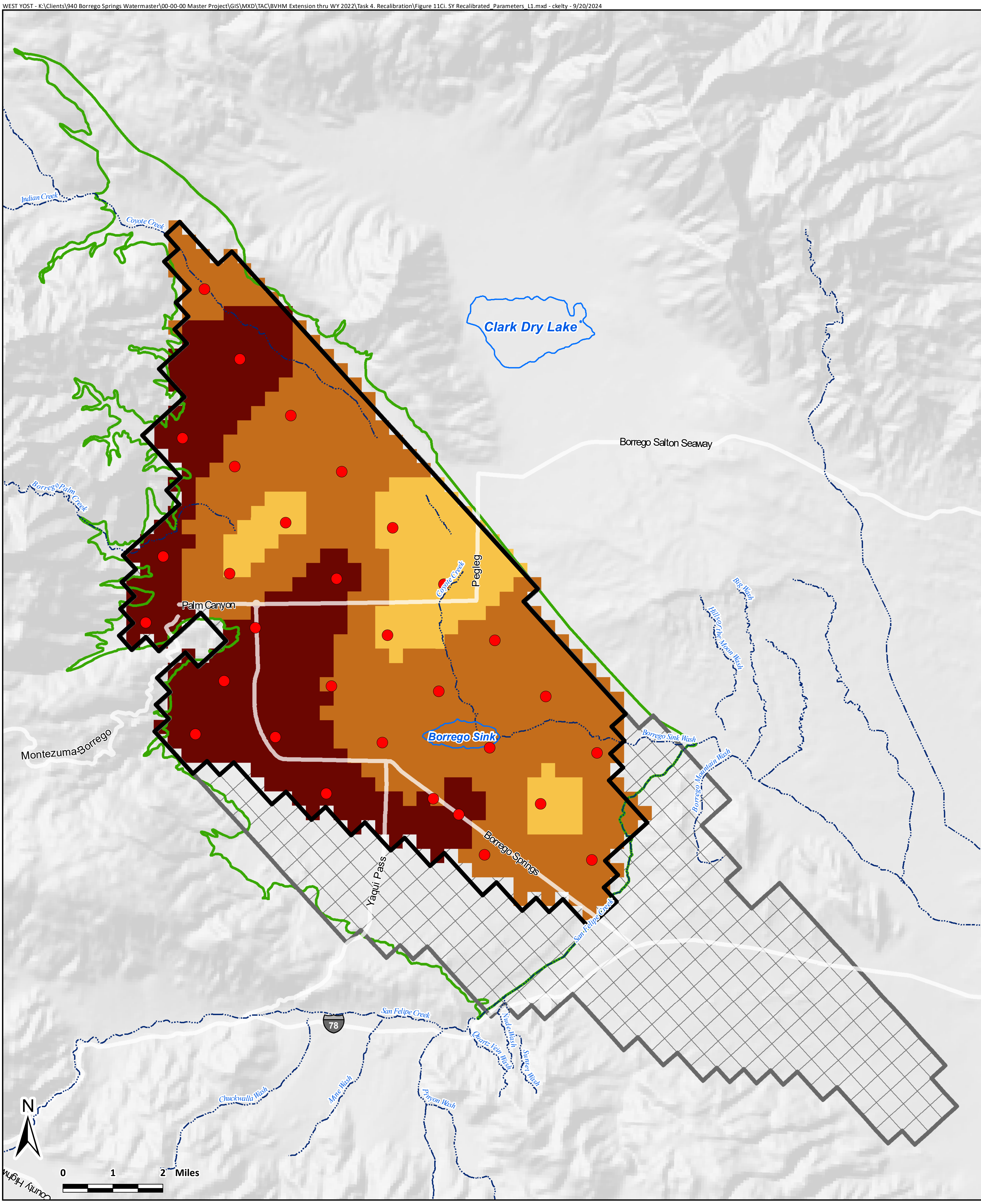
Figure 11Biii

Vertical Conductivity Values used in BVHM Calibration
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Ci. SY Recalibrated_Parameters_L1.mxd - ckelty - 9/20/2024



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

Pilot Points used in Calibration
Layer 1

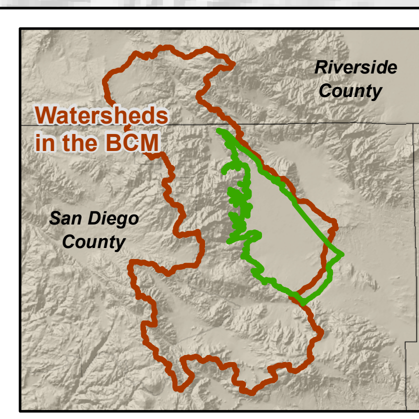
Extent of Active Layers in the BVHM

Layer 1

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

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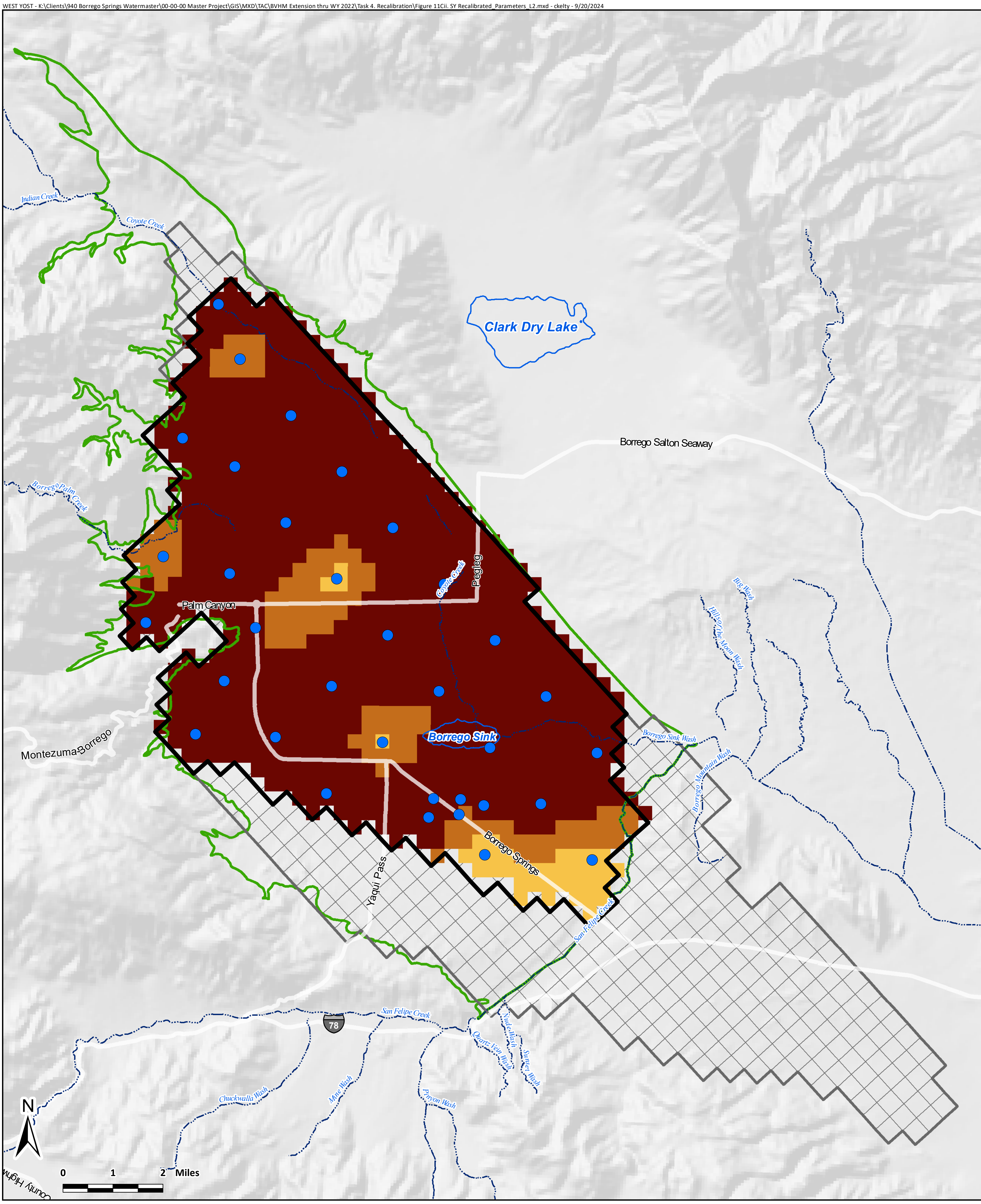
WEST YOST

Figure 11Ci

Specific Yield Values used in BVHM Calibration
Layer 1



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

Pilot Points used in Calibration
Layer 2

Extent of Active Layers in the BVHM

- Layer 2
- Boundary of Active Cells in the BVHM *All Layers*

Other Features

- Borrego Springs Groundwater Subbasin (7-024.01)

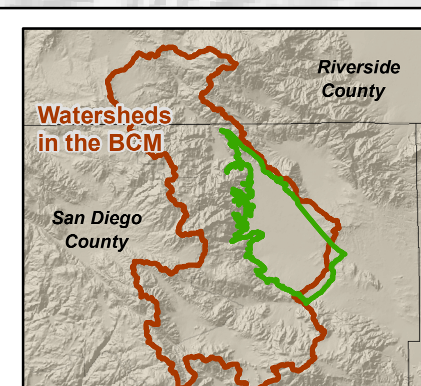


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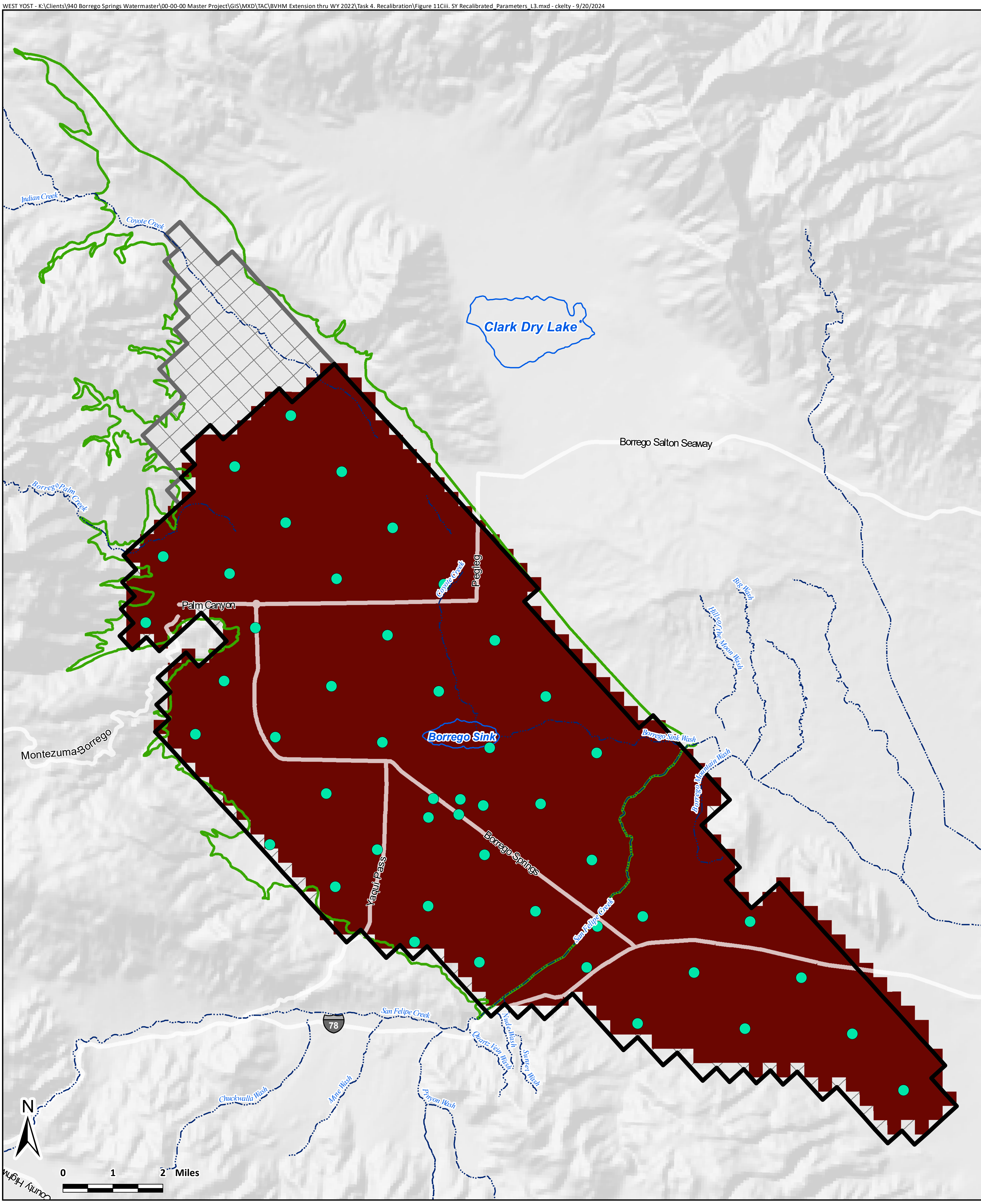
Figure 11Cii

Specific Yield Values used in BVHM Calibration
Layer 2

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Ciii. SY Recalibrated_Parameters_L3.mxd - ckelty - 9/20/2024



Specific Yield Values

- 0.30 - 0.35
- 0.20 - 0.30
- 0.10 - 0.20
- 0.01 - 0.10

Pilot Points used in Calibration
Layer 3

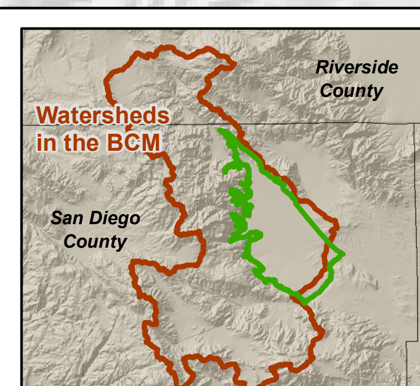
Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
Redetermine the Sustainable Yield

Figure 11Ciii

Specific Yield Values used in BVHM Calibration
Layer 3

Prepared by:

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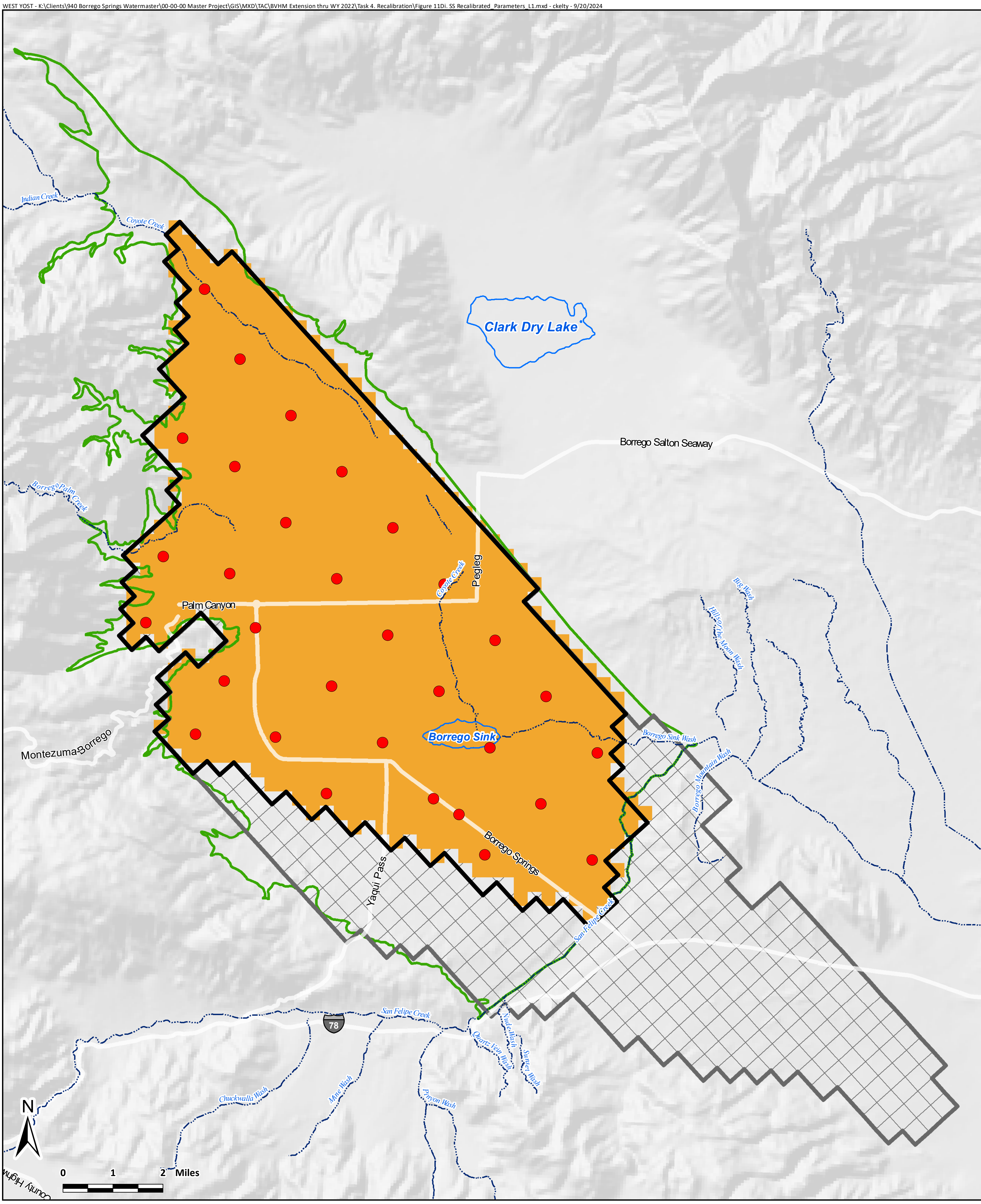


Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 1

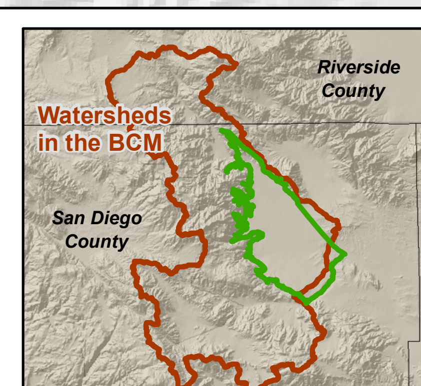
Extent of Active Layers in the BVHM

Layer 1

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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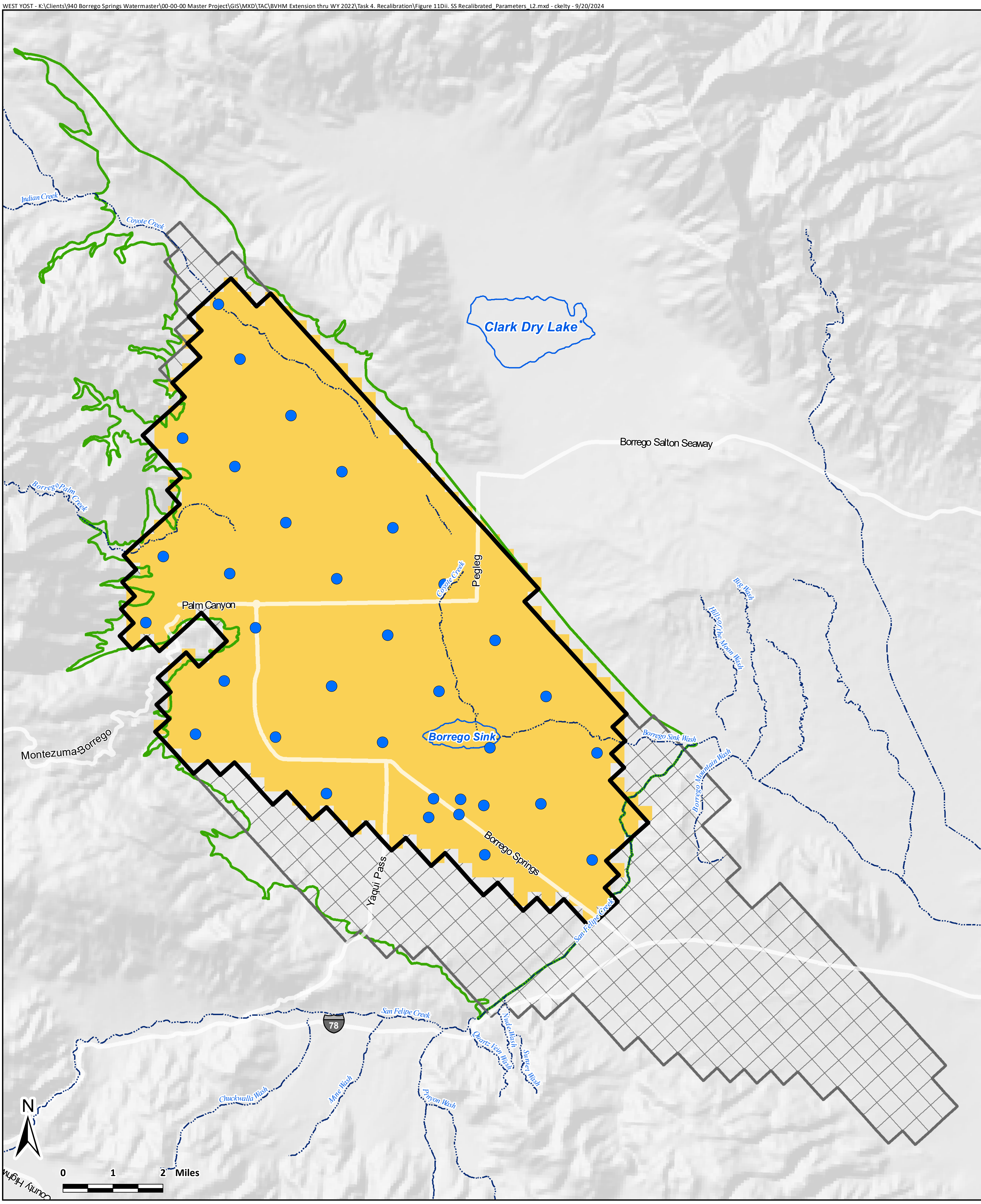
Figure 11Di

Specific Storage Values used in BVHM Calibration
Layer 1



Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 2

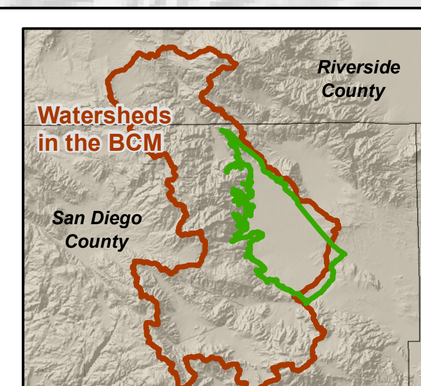
Extent of Active Layers in the BVHM

Layer 2

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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Figure 11Dii

Specific Storage Values used in BVHM Calibration
Layer 2

Prepared by:

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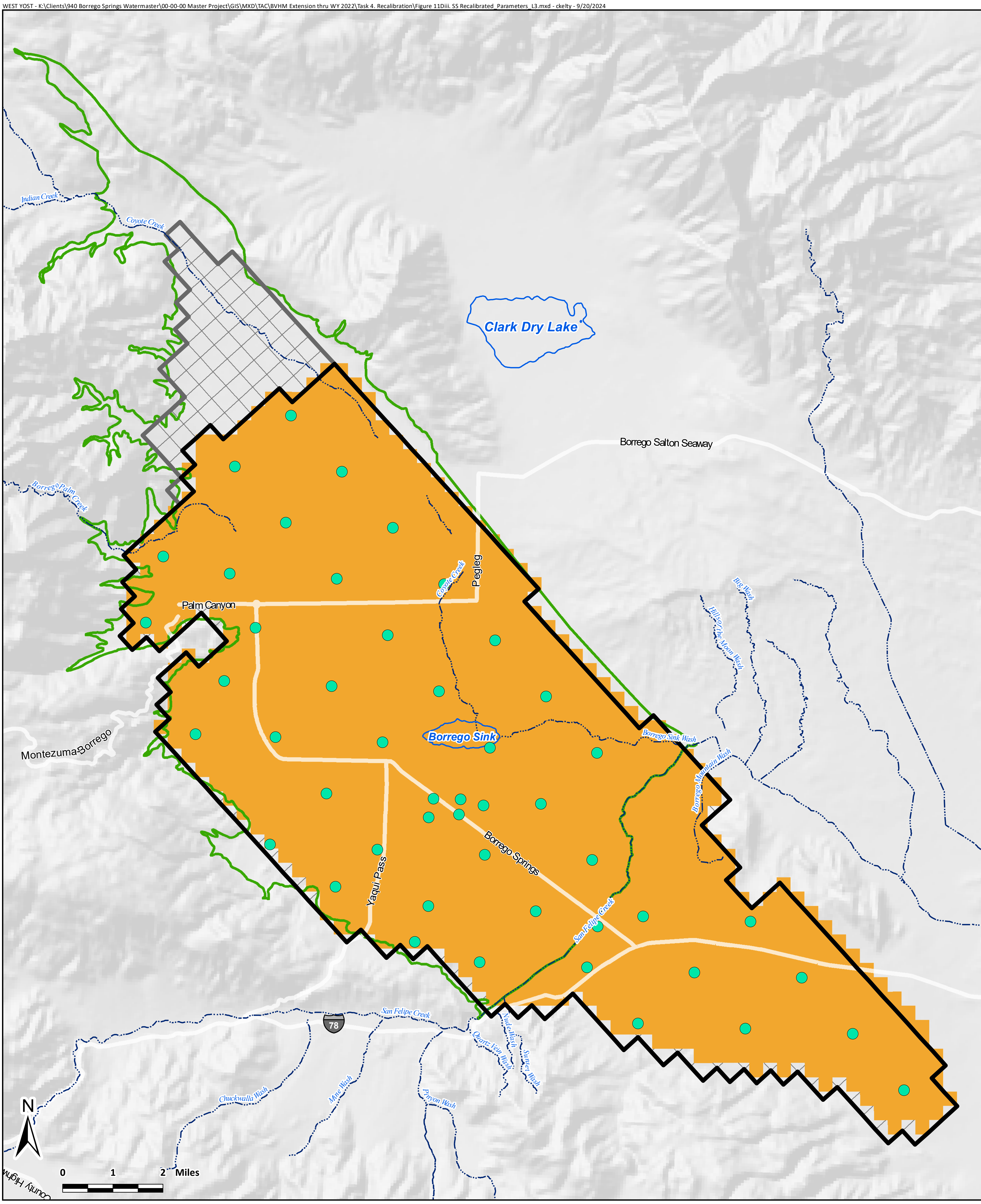
WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 11Diii. SS Recalibrated_Parameters_L3.mxd - ckelty - 9/20/2024



Specific Storage Values

- > 1e-5
- 1e-6 - 1e-5
- 1e-7 - 1e-6
- 1e-8 - 1e-7
- < 1e-8

Pilot Points used in Calibration
Layer 3

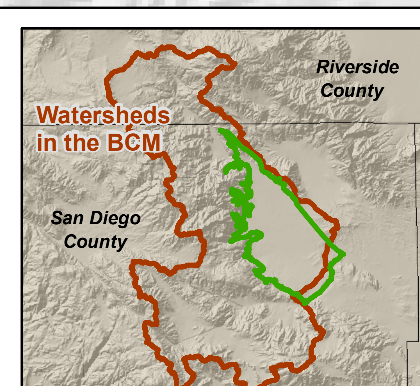
Extent of Active Layers in the BVHM

Layer 3

Boundary of Active Cells in the BVHM
All Layers

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)



Borrego Springs Watermaster
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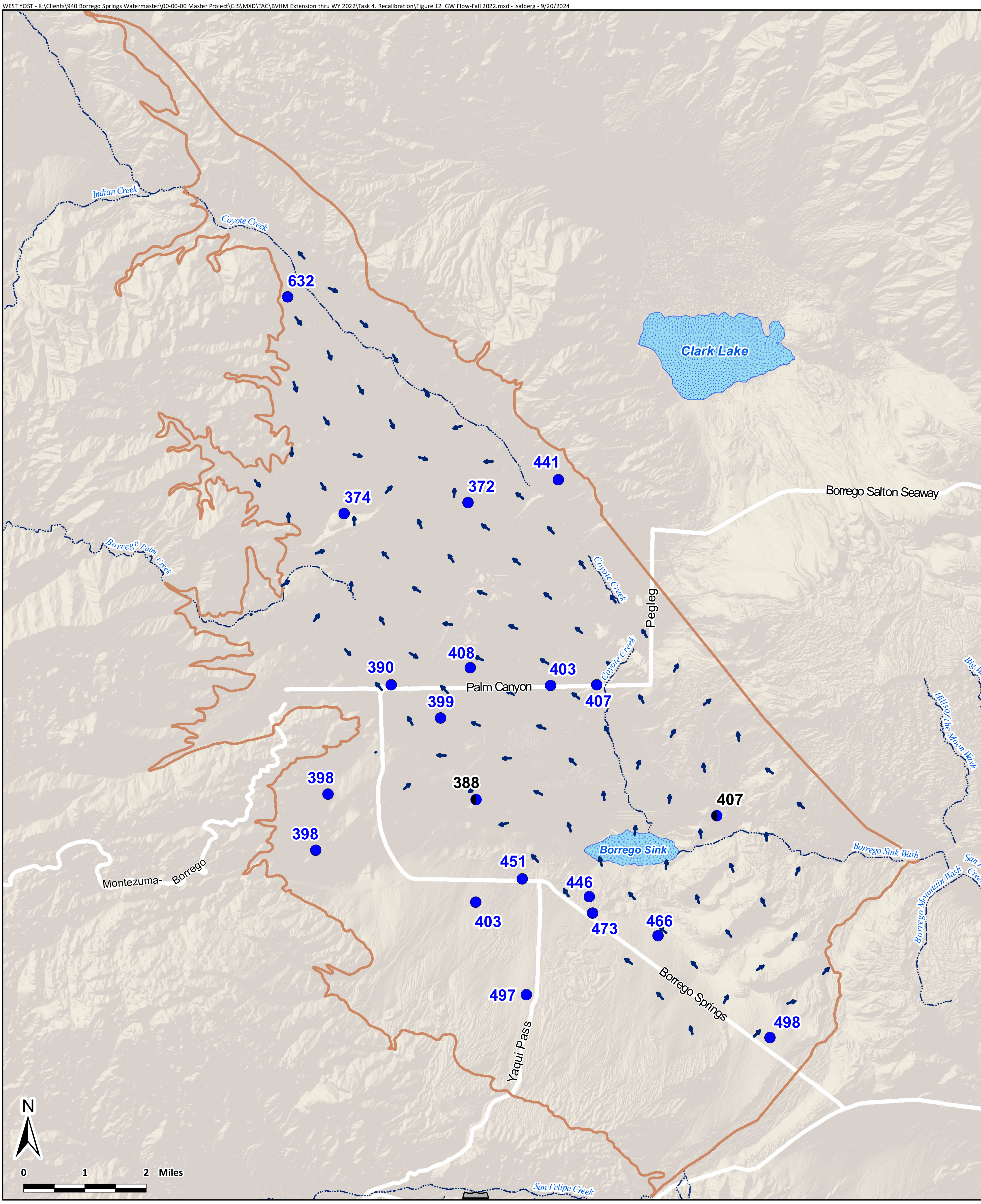
WEST YOST

Figure 11Diii

Specific Storage Values used in BVHM Calibration
Layer 3

WEST YOST - K:\Clients\940 Borrego Springs Watermaster\00-00-00 Master Project\GIS\MXD\TAC\BVHM Extension thru WY 2022\Task 4. Recalibration\Figure 12_GW Flow-Fall 2022.mxd - lsalberg - 9/20/2024



BVHM-simulated Groundwater Flowpath (Fall 2022)

Groundwater Monitoring Wells with Groundwater Elevation Measurements in Fall 2022

350 True static groundwater elevation (ft-amsl)

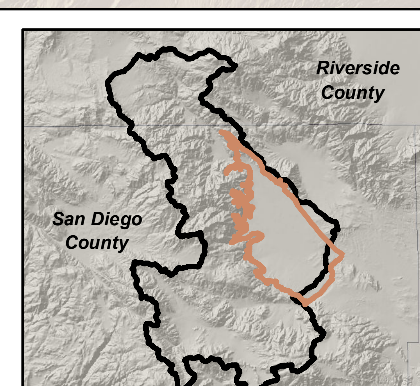
350 Estimated static groundwater elevation (ft-amsl)

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

Stream Channel

Dry Lake



Borrego Springs Watermaster

Redetermine the Sustainable Yield

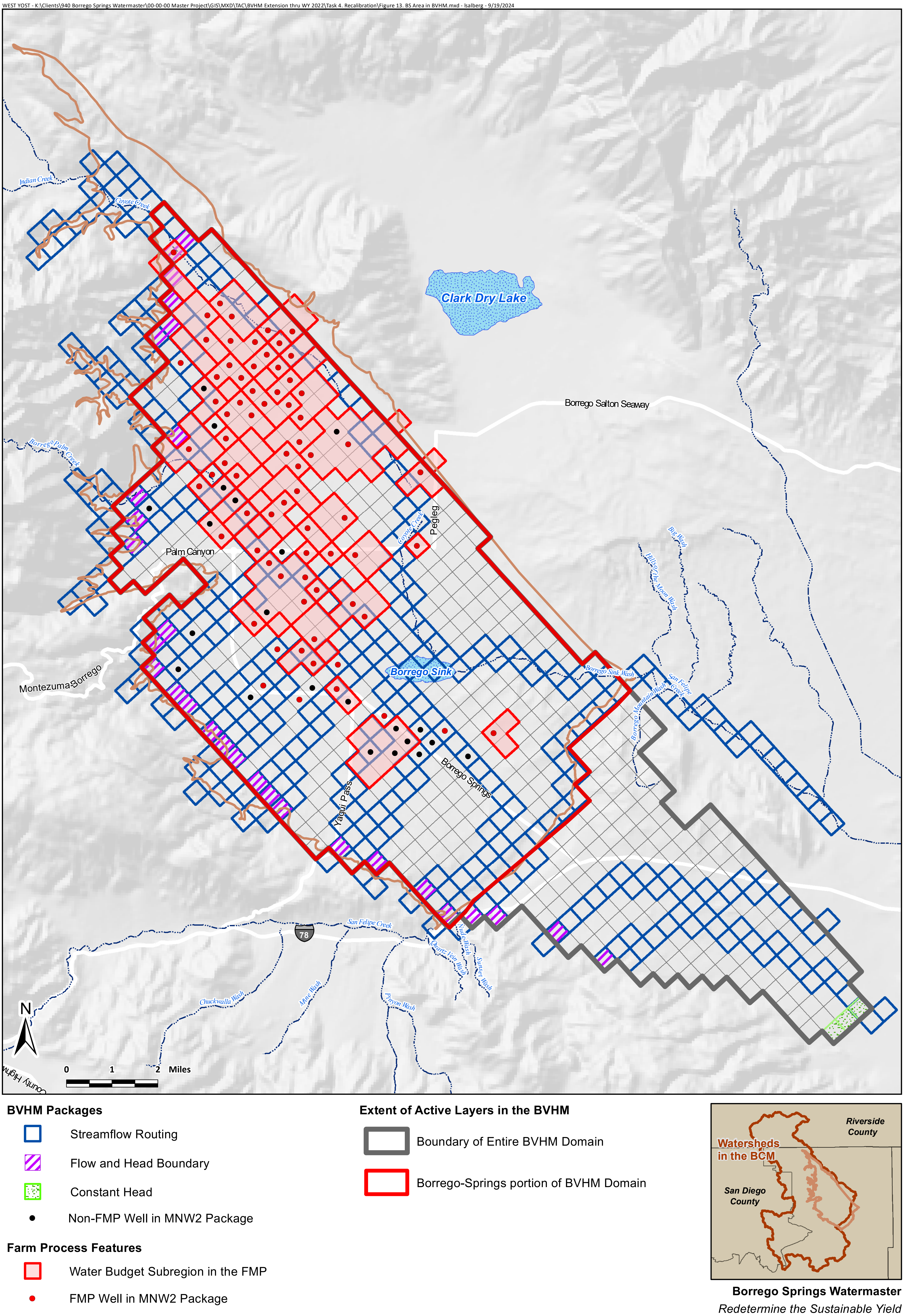
Prepared by:

WEST YOST

Figure 12

Measured Groundwater Elevation vs. BVHM-Estimated Groundwater Flowpaths

Fall 2022



Borrego Springs Watermaster
Redetermine the Sustainable Yield

Prepared by:

WEST YOST

Figure 13

Portion of the BVHM Domain overlying the Borrego Springs Subbasin

Figure 14-A. Observed vs. Model-Simulated Groundwater Elevation
Realization #1

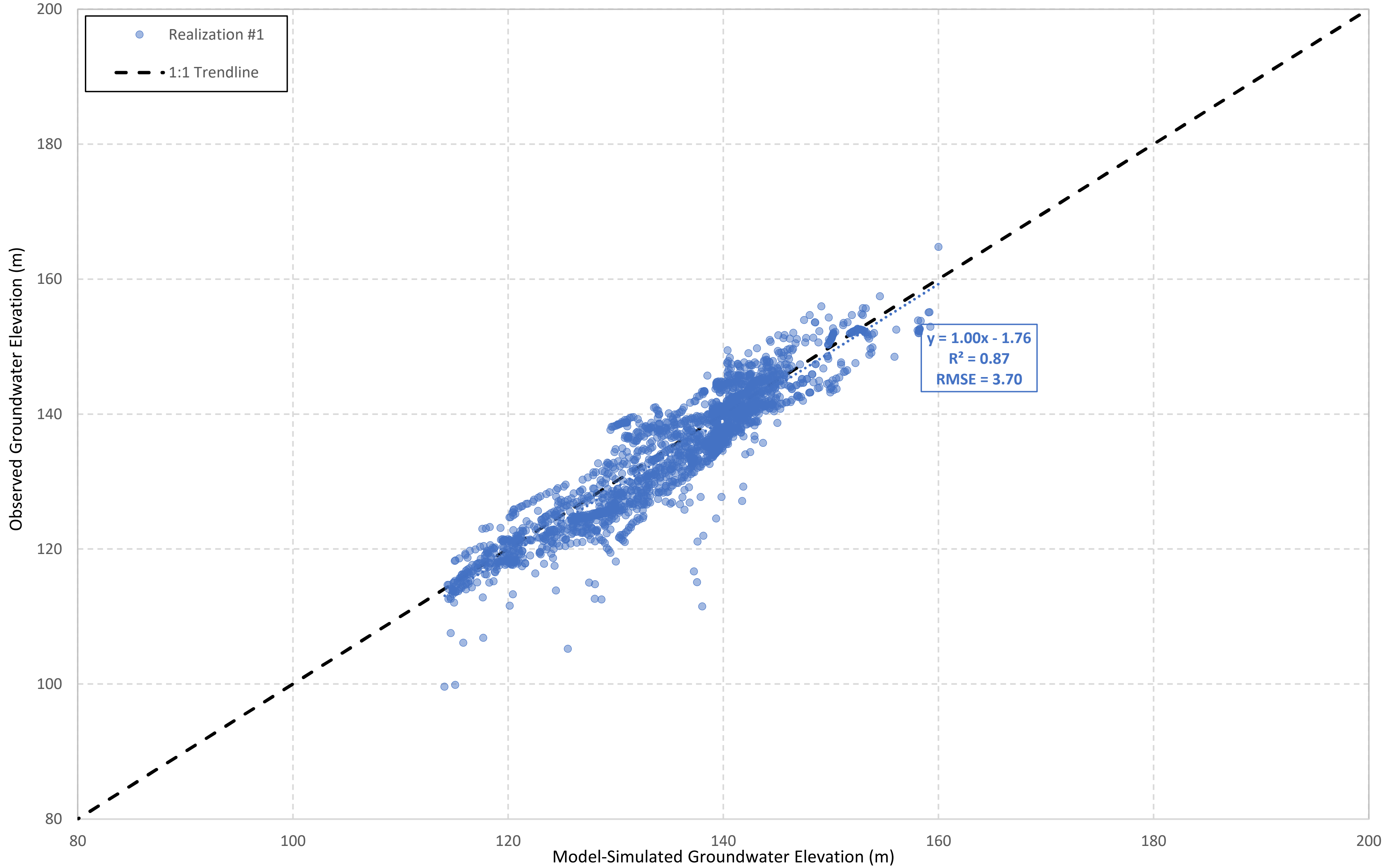


Figure 14-B. Observed vs. Model-Simulated Groundwater Elevation
Realization #2

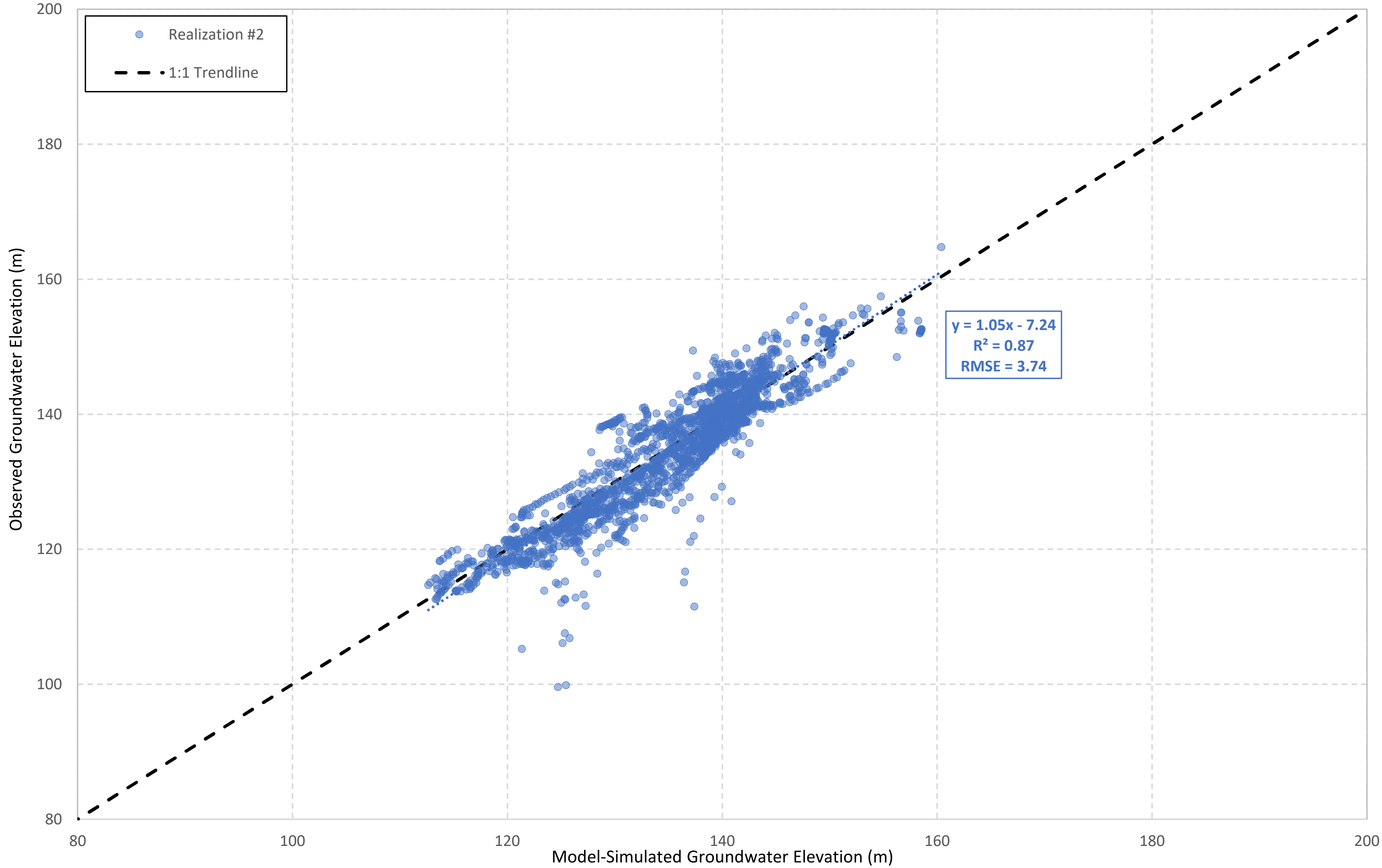


Figure 14-C. Observed vs. Model-Simulated Groundwater Elevation
Realization #3

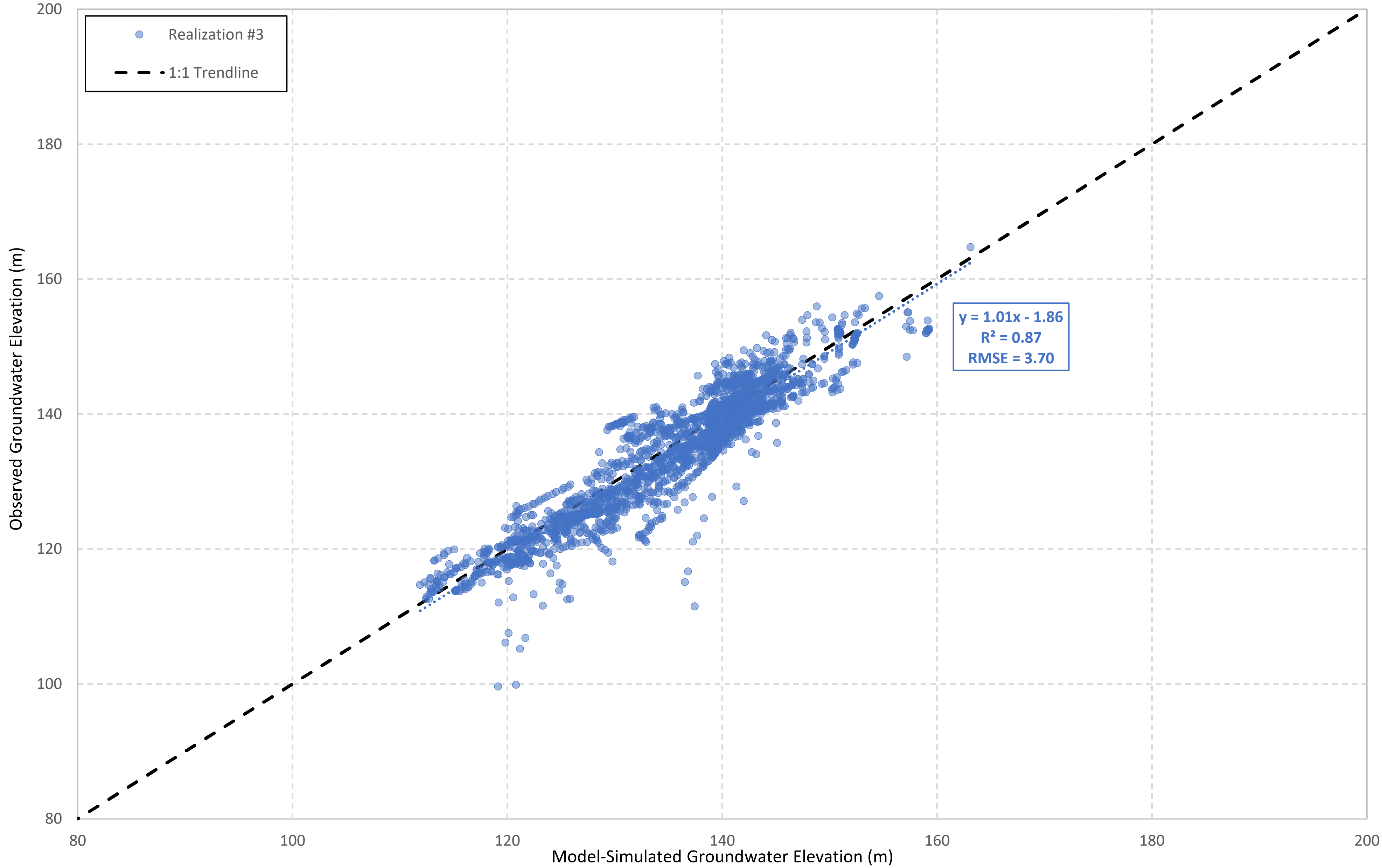


Figure 14-D. Observed vs. Model-Simulated Groundwater Elevation
Realization #4

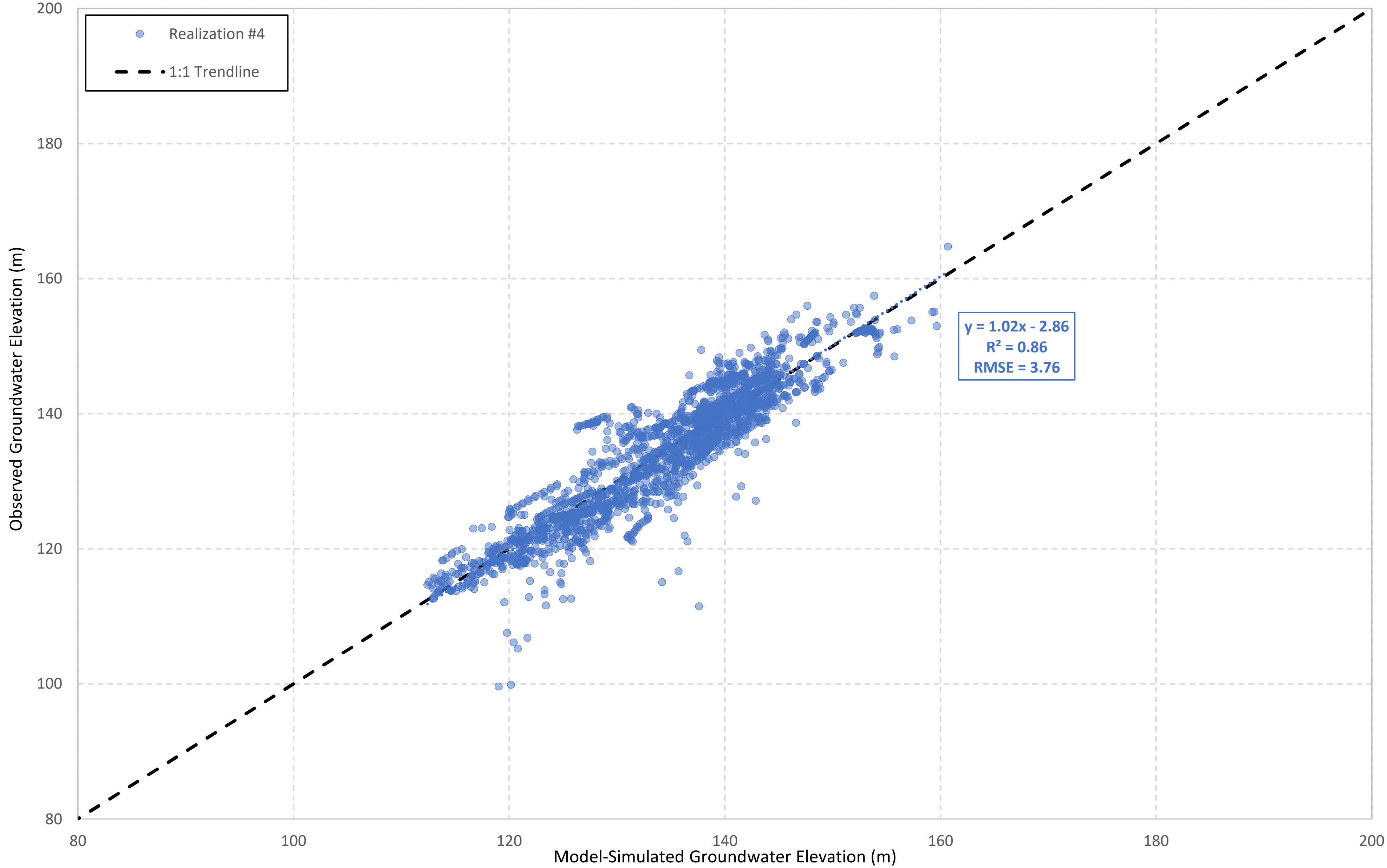


Figure 14-E. Observed vs. Model-Simulated Groundwater Elevation
Realization #5

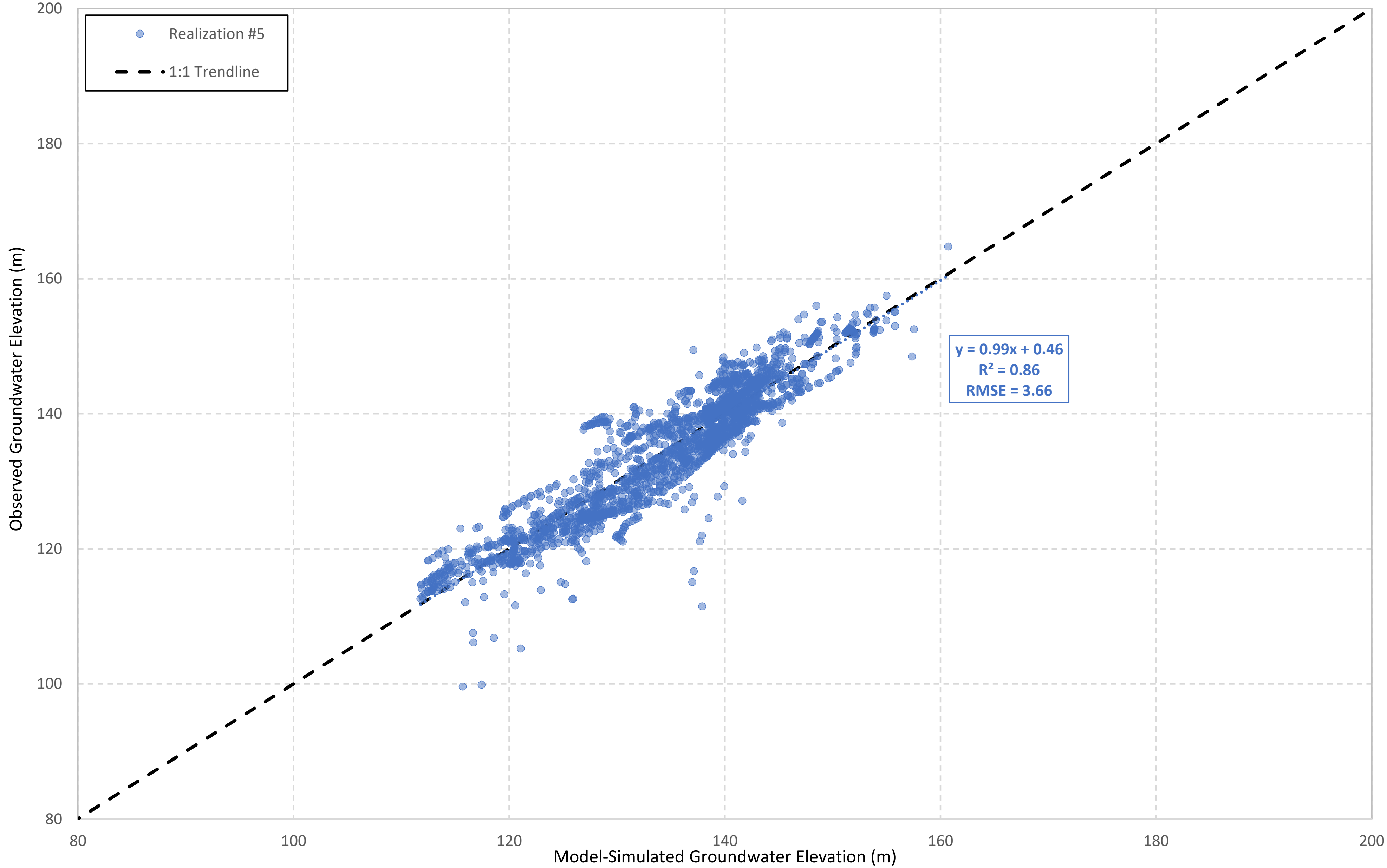


Figure 14-F. Observed vs. Model-Simulated Groundwater Elevation
Realization #6

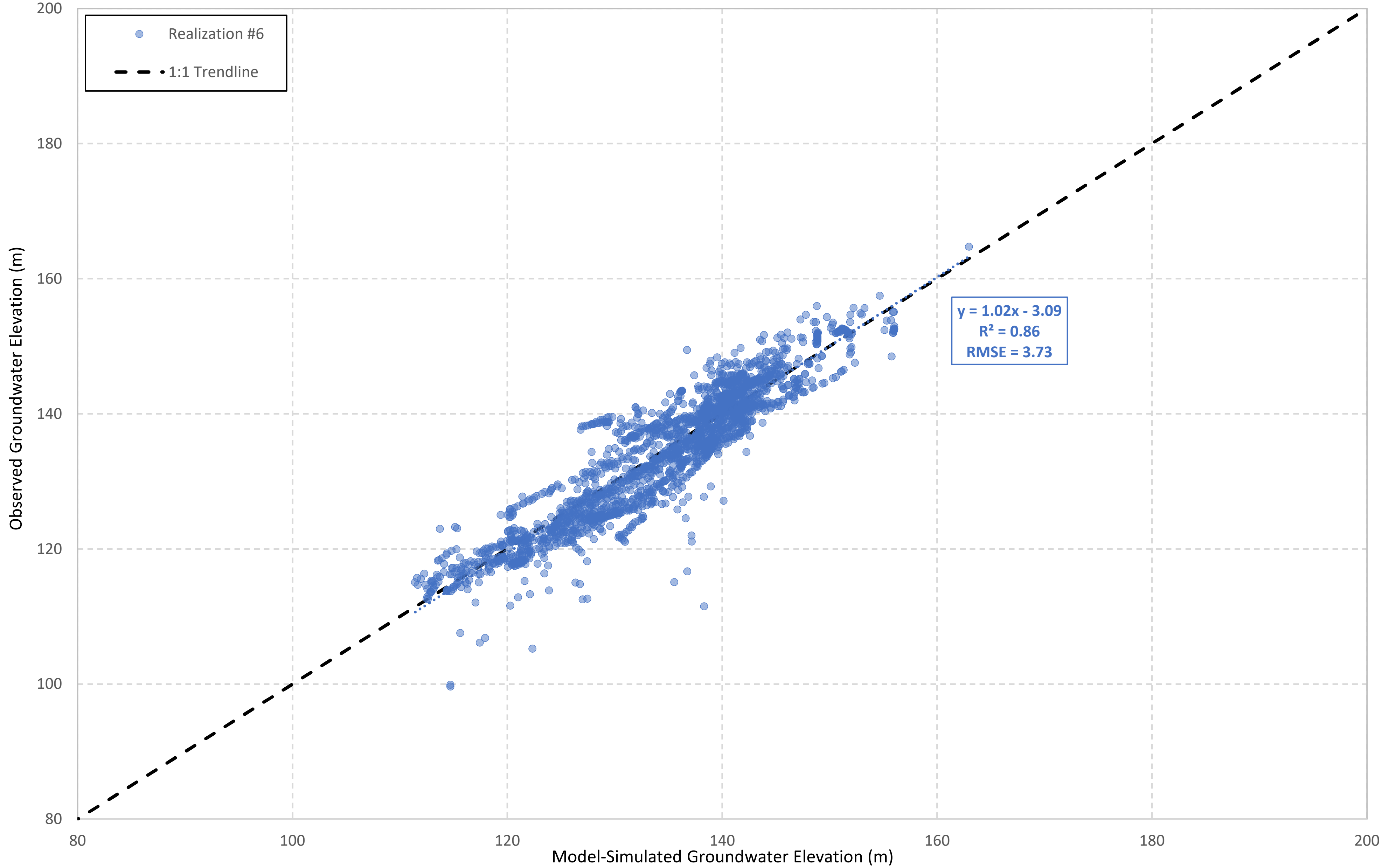


Figure 14-G. Observed vs. Model-Simulated Groundwater Elevation
Realization #7

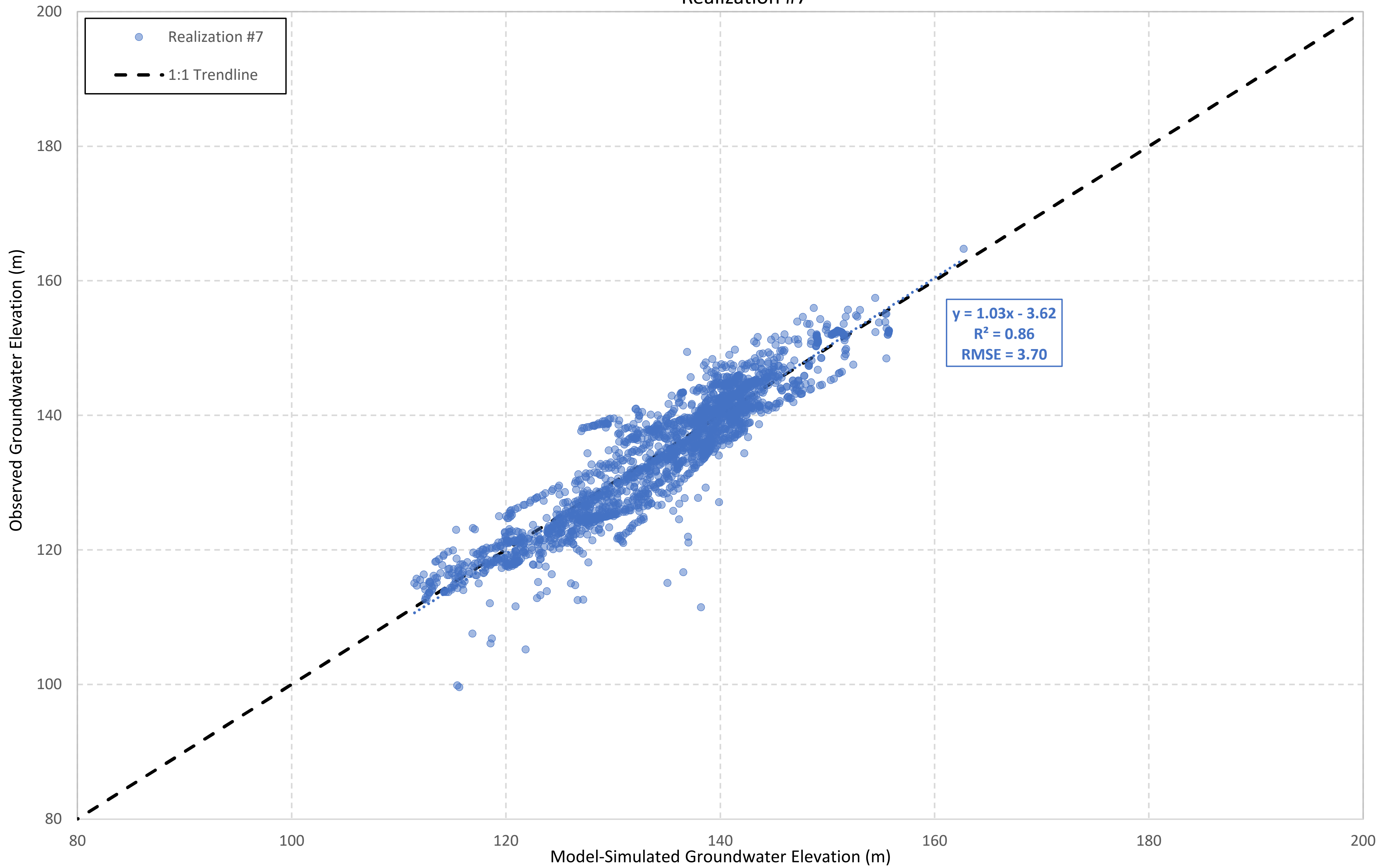


Figure 14-H. Observed vs. Model-Simulated Groundwater Elevation
Realization #8

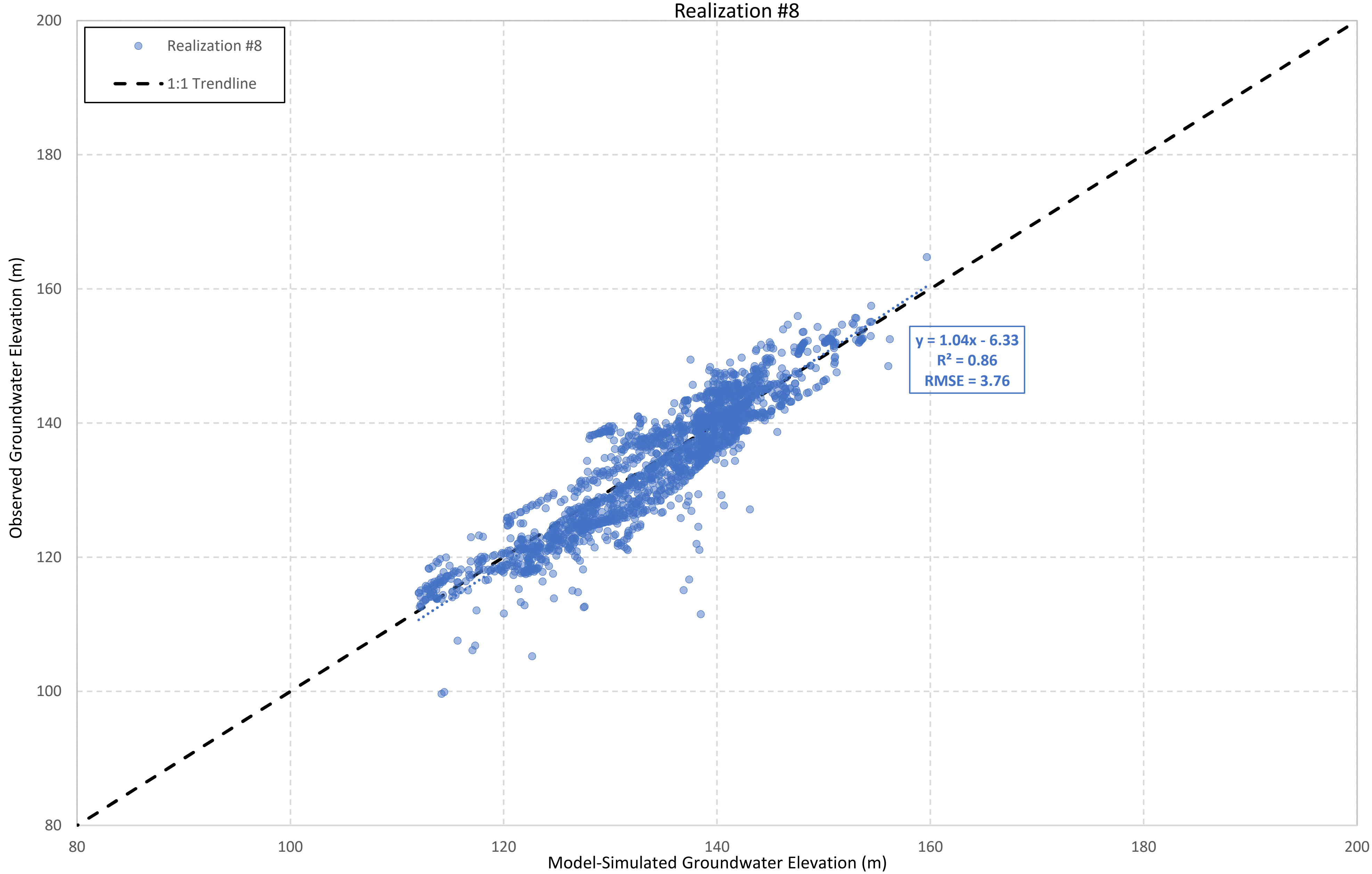


Figure 14-l. Observed vs. Model-Simulated Groundwater Elevation
Realization #9

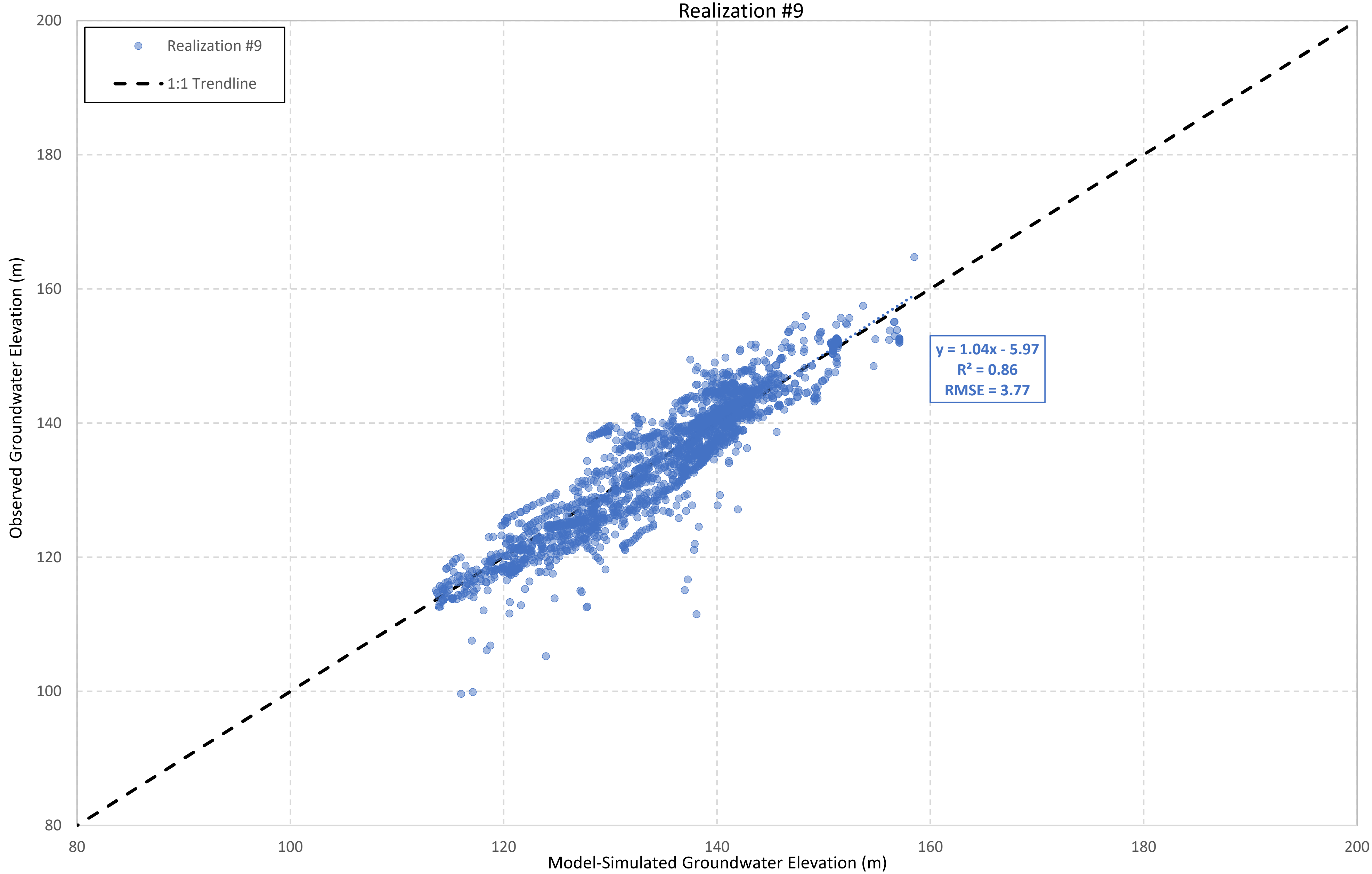


Table 2. Water Budget for the *Pre-Calibrated* BVHM

Water Year 1945 to 2022

Water Year	Inflows *afy*				Outflows *afy*					Annual Change in Storage *afy*	Cumulative Change in Storage *af*
	Streamed Recharge	Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping		ET	Subsurface Outflow	Total Outflows		
					FMPWells	Non-FMP Wells					
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**	

Table 4. Range of Acceptable Values for Model Parameters Assigned to Pilot Points								
	Horizontal Conductivity(m/d)		Vertical Conductivity(m/d)		Specific Storage		Specific Yield	
Predominant Sediment Types by Model Layer	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Upper Aquifer - Layer 1								
Gravel	10	180	1	36	$1x10^{-9}$	$1x10^{-4}$	0.05	0.35
Coarse Sand	10	100	1	22			0.01	0.35
Medium Sand	5	50	0.5	15			0.05	0.30
Fine-grained sediments (sand and silt)	0.01	55	0.001	22			0.10	0.30
Palm Springs Fm	0.01	50	0.001	22			0.01	0.30
Middle Aquifer - Layer 2								
Coarse Sand	0.75	100	0.075	20	$1x10^{-9}$	$1x10^{-4}$	0.01	0.35
Medium Sand	0.5	20	0.05	4			0.01	0.30
Fine-grained sediments (sand and silt)	0.01	5	0.001	1			0.01	0.25
Palm Springs Fm	0.01	12	0.001	2.4			0.01	0.10
Lower Aquifer - Layer 3								
Older Alluvium	0.001	10	0.0001	2	$1x10^{-9}$	$1x10^{-4}$	0.01	0.10

Table 5. Initial, Final, and Range of Subsurface Inflow Rates Allowed in Model Calibration				
FHB Cell ID	Initial Subsurface Inflow Rate (m/d)	Range of Subsurface Inflow Rates Allowed in Calibration		Final Calibrated Subsurface Inflow Rate (m/d)
		Minimum (m/d)	Maximum (m/d)	
101	41.1	32.9	49.3	41.1
102	1,210.7	968.5	1,452.8	1,188.9
103	56.4	45.1	67.6	51.6
104	131.7	105.3	158.0	146.0
105	46.5	37.2	55.8	46.2
106	44.9	35.9	53.9	46.6
107	263.3	210.6	316.0	257.5
108	647.4	517.9	776.8	625.5
109	49.5	39.6	59.4	40.0
110	115.1	92.1	138.1	101.0
111	2.1	1.7	2.5	1.9
112	3.6	2.9	4.3	3.5
113	16.8	13.5	20.2	16.7
114	5.6	4.5	6.7	5.6
201	21.4	17.1	25.6	21.9
201	828.8	663.0	994.6	773.0
202	149.7	119.8	179.7	164.0
202	159.5	127.6	191.4	151.1
205	5.4	4.3	6.5	5.5
206	2.9	2.3	3.4	2.9
207	9.0	7.2	10.8	9.2
208	2.5	2.0	3.0	2.6
301	2.7	2.1	3.2	2.4
302	22.3	17.8	26.7	22.8
303	10.1	8.1	12.1	9.1
304	1.7	1.4	2.1	1.6
305	1.2	0.9	1.4	1.1
306	12.6	10.1	15.1	13.0
307	2.2	1.8	2.7	2.5
308	33.5	26.8	40.2	36.0
309	4.6	3.7	5.5	4.6
310	914.3	731.4	1,097.1	883.6
311	63.2	50.5	75.8	61.2
312	78.5	62.8	94.2	72.3
313	354.4	283.5	425.2	342.1
314	22.2	17.7	26.6	23.3
315	60.2	48.2	72.2	61.6
316	4.4	3.5	5.3	4.3
317	8.0	6.4	9.6	8.5
318	1,313.9	1,051.1	1,576.7	1,397.4
319	330.8	264.6	397.0	383.0
320	19.4	15.5	23.3	19.5
321	14.2	11.4	17.0	13.3
322	11.5	9.2	13.7	12.0

Table 6. Water Budget for the *Calibrated 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	Mountain Front Recharge	Total Inflows	Groundwater Pumping: FMP Wells	Groundwater Pumping: Non-FMP Wells	ET of Groundwater	Sursurface Outflow	Total Outflows		
1945	7,413	3,982	2,087	13,482	0	87	7,664	270	8,021	5,462	5,462
1946	4,000	3,908	2,087	9,996	1,099	149	9,862	306	11,416	-1,420	4,042
1947	497	1,720	2,087	4,305	2,115	193	8,936	241	11,484	-7,180	-3,138
1948	357	961	2,093	3,412	4,136	236	8,721	197	13,290	-9,878	-13,016
1949	5,421	1,770	2,087	9,278	5,452	279	8,057	205	13,994	-4,715	-17,732
1950	385	996	2,087	3,468	7,276	324	8,170	207	15,977	-12,509	-30,240
1951	8,090	1,575	2,087	11,753	9,051	366	7,462	216	17,095	-5,342	-35,583
1952	753	1,194	2,093	4,040	11,522	410	6,661	229	18,822	-14,782	-50,364
1953	3,448	1,276	2,087	6,811	15,506	454	7,042	230	23,232	-16,421	-66,785
1954	1,141	1,281	2,087	4,510	16,410	496	6,267	239	23,413	-18,903	-85,688
1955	664	1,093	2,087	3,845	15,918	540	5,802	247	22,507	-18,662	-104,350
1956	2,513	941	2,093	5,547	18,617	583	5,907	256	25,362	-19,816	-124,166
1957	3,867	1,163	2,087	7,118	18,751	627	5,192	264	24,834	-17,716	-141,881
1958	1,150	1,756	2,087	4,993	17,229	670	4,604	274	22,777	-17,784	-159,666
1959	1,607	2,591	2,087	6,285	18,585	713	4,483	281	24,063	-17,777	-177,443
1960	804	4,144	2,093	7,041	17,449	757	3,880	287	22,373	-15,332	-192,775
1961	1,341	4,818	2,087	8,247	18,579	800	3,692	286	23,357	-15,110	-207,885
1962	674	5,092	2,087	7,854	18,194	843	3,300	291	22,629	-14,775	-222,660
1963	2,059	5,397	2,087	9,543	17,076	963	2,832	299	21,170	-11,627	-234,287
1964	3,340	5,945	2,093	11,377	15,802	1,030	3,197	318	20,348	-8,970	-243,257
1965	9,709	6,828	2,087	18,624	15,910	1,075	2,599	328	19,913	-1,288	-244,545
1966	6,549	9,310	2,087	17,947	6,815	1,121	2,528	335	10,798	7,149	-237,396
1967	1,477	7,372	2,087	10,937	6,542	1,163	2,308	326	10,339	598	-236,798
1968	14,443	8,605	2,093	25,140	7,209	1,207	2,251	325	10,991	14,149	-222,649
1969	600	6,249	2,087	8,936	6,603	1,249	2,093	324	10,269	-1,333	-223,982
1970	753	5,302	2,087	8,143	6,722	1,291	2,006	328	10,347	-2,204	-226,186
1971	739	4,686	2,087	7,512	6,607	1,334	1,955	331	10,227	-2,715	-228,901
1972	2,547	4,381	2,093	9,021	6,880	1,706	1,974	333	10,892	-1,871	-230,772
1973	1,673	4,164	2,087	7,925	5,855	1,672	1,828	334	9,689	-1,764	-232,536
1974	672	3,778	2,087	6,537	6,297	1,704	1,820	333	10,155	-3,618	-236,154
1975	2,434	3,589	2,087	8,111	6,200	1,850	1,759	334	10,143	-2,032	-238,186
1976	4,087	4,010	2,093	10,190	6,185	1,966	1,741	335	10,227	-37	-238,222
1977	21,839	7,226	2,087	31,153	6,695	2,066	2,214	346	11,322	19,831	-218,392
1978	8,645	3,930	2,087	14,662	6,867	2,160	2,111	360	11,498	3,164	-215,227
1979	24,464	8,089	2,087	34,640	6,913	2,219	2,092	361	11,585	23,055	-192,172
1980	2,332	3,515	2,093	7,940	7,620	2,306	2,412	350	12,687	-4,747	-196,919
1981	2,342	2,146	2,087	6,575	8,497	2,382	2,371	321	13,571	-6,996	-203,915
1982	10,367	2,992	2,087	15,446	7,909	2,442	2,191	307	12,849	2,597	-201,318
1983	6,828	3,461	2,087	12,377	5,930	2,496	2,161	306	10,892	1,485	-199,833
1984	1,933	2,078	2,093	6,104	8,488	2,523	2,803	328	14,142	-8,038	-207,871
1985	2,987	2,138	2,087	7,212	7,979	2,740	2,366	329	13,414	-6,201	-214,072
1986	1,144	1,944	2,087	5,176	7,769	2,808	2,304	311	13,191	-8,015	-222,088
1987	1,159	1,580	2,087	4,827	8,586	2,864	2,265	289	14,004	-9,177	-231,265
1988	1,875	1,805	2,093	5,773	8,438	3,365	2,103	286	14,193	-8,420	-239,685
1989	672	1,480	2,087	4,239	9,147	3,279	2,027	288	14,742	-10,502	-250,187
1990	7,793	2,110	2,087	11,991	9,408	3,408	1,892	290	14,999	-3,008	-253,195
1991	2,901	1,695	2,087	6,684	8,527	3,630	1,691	295	14,143	-7,459	-260,654
1992	24,082	4,279	2,093	30,454	8,409	4,079	1,928	303	14,718	15,735	-244,919
1993	4,969	2,799	2,087	9,856	10,731	4,098	2,229	306	17,364	-7,509	-252,428
1994	8,898	1,781	2,087	12,767	13,462	3,911	1,929	302	19,605	-6,838	-259,266
1995	1,066	1,521	2,087	4,674	14,756	3,915	1,697	301	20,669	-15,995	-275,261
1996	1,409	1,217	2,093	4,719	17,594	4,087	1,662	285	23,628	-18,909	-294,170
1997	9,313	2,023	2,087	13,424	15,162	4,204	1,418	283	21,067	-7,643	-301,813
1998	2,410	2,048	2,087	6,545	13,267	4,030	1,506	298	19,101	-12,556	-314,368
1999	1,041	1,849	2,087	4,977	14,575	4,013	1,322	301	20,211	-15,234	-329,602
2000	1,344	1,883	2,093	5,320	16,238	4,234	1,173	305	21,950	-16,630	-346,232
2001	1,106	2,060	2,087	5,254	15,579	3,587	985	310	20,460	-15,206	-361,438
2002	1,302	2,021	2,087	5,410	17,665	4,045	937	311	22,958	-17,547	-378,985
2003	1,837	2,706	2,087	6,630	15,728	3,865	784	311	20,688	-14,058	-393,043
2004	11,249	3,178	2,093	16,520	16,669	3,964	774	312	21,720	-5,199	-398,243
2005	7,685	4,821	2,087	14,593	13,807	3,514	1,117	338	18,775	-4,182	-402,424
2006	2,919	2,993	2,087	8,000	18,107	3,792	943	338	23,180	-15,180	-417,604
2007	1,274	2,474	2,087	5,835	20,287	4,354	712	320	25,672	-19,837	-437,441
2008	2,114	2,625	2,093	6,833	18,174	3,742	591	299	22,806	-15,973	-453,414
2009	2,022	2,438	2,087	6,548	19,044	3,894	606	286	23,831	-17,283	-470,698
2010	1,295	2,509	2,087	5,891	19,329	3,138	528	277	23,271	-17,380	-488,078
2011	2,265	2,581	2,087	6,933	18,751	2,731	476	279	22,236	-15,303	-503,381
2012	6,311	3,048	2,093	11,452	17,206	1,862	582	284	19,933	-8,481	-511,862
2013	2,935	2,563	2,087	7,586	19,267	1,885	552	298	22,001	-14,416	-526,278
2014	2,574	2,687	2,087	7,349	18,720	2,025	538	309	21,592	-14,243	-540,521
2015	3,262	2,993	2,087	8,343	17,958	2,177	446	316	20,898	-12,555	-553,076
2016	2,353	2,937	2,093	7,383	17,573	2,304	463	319	20,659	-13,276	-566,352
2017	4,000	3,061	2,087	9,149	15,468	2,037	391	316	18,212	-9,063	-575,415
2018	3,612	2,751	2,087	8,451	17,650	1,885	416	308	20,259	-11,808	-587,224
2019	3,905	3,876	2,087	9,868	12,469	1,929	331	312	15,041	-5,173	-592,397
2020	3,650	3,028	2,093	8,772	10,504	2,000	322	317	13,143	-4,371	-596,768
2021	3,342	2,166	2,087	7,595	11,799	2,092	359	316	14,566	-6,971	-603,738
2022	4,022	2,416	2,087	8,526	10,778	1,910	355	322	13,365	-4,839	-608,577
Average	**4,129**	**3,172**	**2,089**	**9,390**	**12,078**	**2,152**	**2,662**	**299**	**17,192**	**-7,802**	
Minimum	**357**	**941**	**2,087**	**3,412**	**0**	**87**	**322**	**197**	**8,021**	**-19,837**	
Maximum	**24,464**	**9,310**	**2,093**	**34,640**	**20,287**	**4,354**	**9,862**	**361**	**25,672**	**23,055**	

Table 7. 2025 Sustainable Yield ***Borrego Springs Subbasin***	
Water Budget Component	Annual Average (afy)
Long-Term Natural Inflows (1945-2022)	**6,218**
Streambed Recharge	4,129
Mountain Front Recharge (subsurface inflow)	2,089
Return Flows under Modern Irrigation Methods (1980-2022)	**2,518**
Unsaturated Zone Recharge	2,518
Short-Term Natural Outflows (2007-2022)	**784**
Evapotranspiration of Groundwater	479
Subsurface Outflow	305
2025 Sustainable Yield	**7,952**

Table 8. Water Budget Comparison

(Annual Average in afy)

Water Budget Component	2025 Sustainable Yield	Original Sustainable Yield	Difference	Percent Difference
Total Natural Inflows	**8,736**	**6,770**	**1,966**	**25%**
Streambed Recharge	4,129	3,905	224	6%
Mountain Front Recharge (subsurface inflow)	2,089	1,497	592	33%
Unsaturated Zone Recharge	2,518	1,367	1,151	59%
Total Natural Outflows	**784**	**1,021**	**-237**	**-26%**
Evapotranspiration of Groundwater	479	498	-19	-4%
Subsurface Outflow	305	523	-218	-53%
Sustainable Yield	**7,952**	**5,749**	**2,203**	**32%**

Table 9. Model Calibration Statistics								
Model Realization	Sum of Squared Residuals (m)	Correlation Coefficient	Mean Residual (m)	Minimum Residual (m)	Maximum Residual (m)	Standard Error of Residuals (m)	Variance of Residuals (m)	Root Mean Square Error (m)
Calibrated BVHM (Selected Realization)	28,903	0.93	-0.28	-27.19	12.66	4.23	17.85	3.70
Realization #1	29,529	0.93	-0.90	-26.59	8.99	4.23	17.90	3.70
Realization #2	29,868	0.93	-0.55	-25.94	12.12	4.28	18.28	3.74
Realization #3	29,722	0.93	-0.89	-25.98	8.67	4.23	17.86	3.70
Realization #4	30,030	0.93	-0.18	-26.16	11.72	4.30	18.45	3.76
Realization #5	29,299	0.93	-0.16	-26.45	12.31	4.18	17.50	3.66
Realization #6	29,733	0.93	-0.29	-26.85	12.68	4.27	18.21	3.73
Realization #7	29,075	0.93	-0.22	-26.75	12.49	4.22	17.83	3.70
Realization #8	29,794	0.93	-0.37	-27.03	11.88	4.29	18.44	3.76
Realization #9	29,950	0.93	-0.39	-26.62	11.90	4.31	18.57	3.77

Table 10. Water Budget Comparison - Model Calibration Realizations

(Annual Average in afy)

Water Budget Component	*Calibrated* BVHM (Selected Realization)	Model Realization									Minimum	Maximum	Average	Standard Deviation
		#1	#2	#3	#4	#5	#6	#7	#8	#9				
Long-Term Natural Inflows (1945-2022)	**6,218**	**6,023**	**6,267**	**6,253**	**6,059**	**6,128**	**6,038**	**6,036**	**6,030**	**6,248**	**6,023**	**6,267**	**6,130**	**100**
Streambed Recharge	4,129	3,949	4,185	4,156	3,968	4,111	3,960	3,955	3,953	4,141	3,949	4,185	4,051	95
Mountain Front Recharge (subsurface inflow)	2,089	2,074	2,082	2,097	2,091	2,016	2,079	2,081	2,076	2,107	2,016	2,107	2,079	23
Return Flows under Modern Irrigation Methods (1980-2022)	**2,518**	**2,446**	**2,417**	**2,645**	**2,420**	**2,468**	**2,555**	**2,583**	**2,497**	**2,485**	**2,417**	**2,645**	**2,503**	**70**
Unsaturated Zone Recharge	2,518	2,446	2,417	2,645	2,420	2,468	2,555	2,583	2,497	2,485	2,417	2,645	2,503	70
Short-Term Natural Outflows (2007-2022)	**784**	**718**	**711**	**821**	**910**	**933**	**905**	**902**	**914**	**704**	**704**	**933**	**830**	**89**
Evapotranspiration of Groundwater	479	627	794	828	491	610	574	463	495	706	463	828	607	126
Subsurface Outflow[1]	305	91	-84	-8	419	323	331	439	419	-2	-84	439	223	192
Sustainable Yield	**7,952**	**7,751**	**7,973**	**8,078**	**7,568**	**7,663**	**7,689**	**7,717**	**7,612**	**8,029**	**7,568**	**8,078**	**7,803**	**186**

1. Negative values of subsurface outflow indicate water flowing into the Basin from the Ocotillo Wells Subbasin to the south.

Table 11. Sustainable Yield Comparison - Model Calibration Realizations	
Sustainable Yield	**Estimate of Sustainable Yield(afy)**
Minimum	7,568
Maximum	8,078
Average	7,803
2025 Sustainable Yield	7,952
Standard Deviation	186

Appendix A

Assumptions for Historical On-Farm Efficiencies in the BVHM

TECHNICAL MEMORANDUM

DATE: March 15, 2024

TO: Technical Advisory Committee (TAC)
Borrego Springs Watermaster

FROM: Andy Malone, PG; Lauren Salberg; Clay Kelty (West Yost)
Watermaster Technical Consultant

SUBJECT: Assumptions for Historical On-Farm Efficiencies in the BVHM

BACKGROUND AND OBJECTIVES

The Farm Process (FMP) is used in the Borrego Valley Hydrologic Model (BVHM) to estimate the irrigation demand for different land uses and crop types in the Borrego Springs Subbasin (Basin) to estimate pumping at historically unmetered at wells that were used to irrigate these lands. The FMP estimates groundwater pumping using Equation 1 below:

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

where,

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

ET_o is the reference evapotranspiration (ET)

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

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

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

P is precipitation available to meet the actual ET

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

The FMP in the BVHM estimates groundwater pumping based on irrigated land use classifications including: citrus, dates, golf courses, nurseries, palms, potatoes, row crops, semiagricultural, and grapes. Figure 1 identifies the irrigated and non-irrigated[1] land use classifications simulated by the FMP at selected periods over the simulation period of 1945-2022.

As part of the scope-of-work of Task 2 to Redetermine the Sustainable Yield – *Update Water Use Factors in the FMP,* the KC and OFE values used in the FMP were reviewed. During this evaluation, it was discovered that the scaling factors applied to the KC and OFE values during the original model calibration performed by the United States Geological Survey (Faunt et. al, 2015)[2] resulted in unrealistic values of KC and OFE, such that:

- KC scaling factors produced unrealistic seasonal crop demands, where the greatest crop demands occur during winter months instead of during the growing season.
- OFE scaling factors simulated nearly 100% irrigation efficiency by the end of the BVHM simulation (WY 2009 through WY 2022), which is not a valid assumption based on the known irrigation practices in the Basin.

As documented in a technical memorandum describing Task 2,[3] West Yost removed the scaling factors applied to the KC and OFE values (*initial* values), ran the BVHM, and compared the FMP-estimated pumping to actual pumping for WY 2021 and WY 2022. The result of this comparison was that FMP-estimated pumping was underestimated using either the *scaled* or *initial* values, but the difference was less significant using the *initial* (unscaled) values, as shown in Table 1.

Table 1. Comparison of Actual Pumping to FMP-Estimated Pumping using *Scaled* and *Initial* Values

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

Based on the analysis of *scaled* and *initial* KC and OFE values in the 2022 BVHM, West Yost recommended, and the TAC agreed, that:

- The *initial* KC values should be used in *Task 4 – Perform Model Recalibration*. Adjustments to KC values during model recalibration, if any, should be constrained to a defensible range.

[1] A non-irrigated land use classification is any land use that does not require groundwater pumping to meet irrigation demands (*i.e.* phreatophytes or native vegetation). Groundwater pumping is not estimated by the FMP for non-irrigated land use classifications.

[2] Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed M., Brandt J., Martin P., and Coes, A.L. 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California: U.S. Accessed at https://pubs.er.usgs.gov/publication/sir20155150.

[3] https://borregospringswatermaster.com/wp-content/uploads/2023/08/III_BVHM-Task-2.pdf

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

This memorandum proposes historical OFE values that are representative of the historical irrigation practices utilized on specific crop types within the Basin. These OFE values will be used as the initial OFE values and adjusted during Task 4 – *Model Calibration.* A description of the methodology, findings, and recommendations for historical OFE values are described below.

Methods of Estimating Historical On-Farm Efficiency

To develop initial estimates and defensible ranges of historical OFE values in the Basin (prior to WY 2021-2022), historical land use and irrigation practices were investigated by:

- Reviewing published literature.
- Interviewing local farmers with knowledge of the long-term history of irrigation practices and agricultural production in the Basin.[4]
- Identifying abandoned irrigation infrastructure still present in the Basin, from field visits and review of aerial photographs, as evidence of historical irrigation practices.

History of Crop Types and Irrigation Methods in the Basin

Changes in land use, crop types, and irrigation methods are the primary drivers of changes in groundwater demands in the Basin. Table 2 summarizes the key events in the history of land use in the Basin, such as the primary crop type and associated irrigation method. A more detailed description of the history of agriculture and irrigation methods in the Basin is included in Appendix A.

Figure 1 illustrates how the FMP spatially simulates the evolution of land use in the Basin throughout the simulation period for key times in the Basin (1950s, 1970s, 1980s, and 2022). Figure 2 (from Dudek, 2020)[5] shows historical FMP-estimated pumping for agriculture and recreation over the simulation period of WY 1945 through 2016. Figure 2 illustrates the trends in land use classifications described in Table 2. Groundwater pumping for agricultural irrigation represented most of the groundwater pumping in the Basin until the decline in agricultural pumping in 1966 due to the labor disputes. Groundwater pumping for agriculture began to increase again in the 1980s with the expansion of citrus farming.

[4]West Yost staff interviewed David Bauer and Tyler Bilyk to discuss the history of agriculture in the Basin in March 2024. Their interviews are documented in Appendix A.

[5] Dudek. 2020. Groundwater Management Plan for the Borrego Springs Subbasin. Exhibit 1. https://borregospringswatermaster.com/wp-content/uploads/2021/06/stipulated-judgment-04-08-2021_bookmarked.pdf

Table 2. Key Events in the Agricultural History of the Borrego Valley

Year	Description of Event(s)
1913	• Irrigated agriculture begins following the 1912 amendment of the Homestead Act. • Alfalfa was the initial crop, which used diverted surface water from Coyote Creek for irrigation.
1926-1927	• Dates planted and irrigated via the first deep well in the Basin at Ensign Ranch.
1945[a]	• Agricultural expansion. Prior to 1945, groundwater production for irrigation was estimated to be less than 100 acre-feet per year (afy).[6] • Primary crops were table grapes and alfalfa. Both crops are assumed to be irrigated via flood and furrow methods.
1953-1954	• De Anza Country Club golf course opens in 1953 – the first recreational water use (Figure 2).
1956-1960	• 1958 - peak irrigated acreage in the Basin of 5,000 acres.[7] • Grapes are the primary crop, irrigated via flood and furrow.
1966[b]	• End of grape irrigation in the Basin following a labor dispute led by César Chávez.
1966-1979	• Decline in agricultural production in the Basin following the labor disputes. • Remaining crops grown during this period include row crops and some citrus groves.
1979-2024	• Citrus production expands and becomes the primary crop grown in the Basin. This expansion is partly attributed to the adoption of relatively cost-efficient drip irrigation methods. • Additional crops grown during this period include ornamental tree farms, nurseries, and alfalfa, all assumed to be grown via drip or similar irrigation methods. The exception are potatoes grown from the early 2000s to late 2010s that were irrigated via flood and furrow methods.

a) Irrigation is first simulated in the BVHM in 1945.

b) The BVHM uses two different land use classifications for table grapes: 1) grapes, and 2) non-irrigated grapes. The "grape" classification represents active irrigation of grapes. "Non-irrigated grapes" the production of grapes that remained after irrigation ended and the vineyards were left to fallow following the labor disputes.

[6] Moyle, Jr., W.R. 1982. *Water Resources of Borrego Valley and Vicinity, California, Phase 1-- Definition of Geologic and Hydrologic Characteristics of Basin*. U.S. Geological Survey Open-File Report 82-855, 39 pp. https://pubs.usgs.gov/publication/ofr82855

[7] California Department of Water Resources (DWR). 1984. *Borrego Valley Water Management Plan*. https://www.borregowd.org/wp-content/uploads/2020/05/BWD_Report-DWR-June-1984.pdf

As described in Table 2, four primary irrigation methods appear throughout the history of agriculture in the Basin:

- **Flood and furrow (1945 to 1966 and January 2000 to October 2016).** Flood and furrow irrigation is a method of supplying water to crops through shallow, evenly spaced trenches. An example of this irrigation method in shown in Figure 3a. In addition to the literature review, early agriculture in the Basin is assumed to be irrigated via flood and furrow based on evidence from:
    - An interview with Tyler Bilyk[4] where he cited antidotal evidence that flood and furrow was the preferred method of irrigation for grapes based on the observation that he has not seen any above grade poly (PVC) or drip irrigation equipment in historic vineyards.
    - Remnants of flood and furrow infrastructure in the Basin, such as concrete mainlines and standpipes, which are observed in aerial photographs at abandoned vineyards, for example, along Di Giorgio Road (see Figure 3b).

  Although flood and furrow methods were most prominent before the 1970s on vineyards, this irrigation method also was used seasonally to grow potatoes at the Agri-Empire Farm. The potatoes harvested here were a seasonal crop that grew from approximately late winter to early summer. The most recent harvest was 2019.

  Flood and furrow irrigation is the least efficient irrigation method that was used within the Basin.

- **Broadcast sprinklers (1953 to present).** Broadcast sprinklers irrigate a relatively wide area via a water distribution system of control lines, pipes, and valves connected to a central pump station. An example of this irrigation method in shown in Figure 3c. Broadcast sprinklers have been used predominantly at golf courses in Borrego Springs.[8] Additionally, it was likely used at semi-agricultural areas (*e.g.,* livestock, feedlots, dairies, and/or poultry farms) where livestock would graze.
- **Micro-irrigation (late 1970s to present).** Micro-irrigation systems drip or spray water to the roots of plants, either from above the soil surface or buried below the surface. An example of this irrigation method in shown in Figure 3d. The rebound in agriculture during the late 1970s to early 1980s was partly due to the increasingly popular use of micro-irrigation systems that conserve water and reduce operating costs. This irrigation method allowed Borrego Valley farmers to compete with Imperial and Coachella Valley farmers that had access to relatively inexpensive imported water from the Colorado River.[6] Based on communications with David Bauer and Tyler Bilyk,[5] most citrus farms in Borrego Valley have been using above grade poly (PVC) and micro-irrigation since the 1980s. Mr. Bilyk also noted that micro-irrigation methods were also likely used for ornamental tree farms and nurseries during this period. Micro-irrigation can be more efficient than other types of irrigation systems, such as flood and

[8] Netto, S.P. 2001. Water Resources of Borrego Valley, San Diego, California. San Diego State University. https://ca.water.usgs.gov/projects/borrego/documents/Netto_Masters_2001.pdf

furrow or sprinkler irrigation, because evaporation is reduced due to water being targeted directly to the root zone.

- **Center Pivot (1970s to present).** Center-pivot irrigation involves overhead sprinklers attached to a water-wheel that rotates around a pivot (Figure 3e). A circular area centered on the pivot is irrigated, often creating a circular pattern in crops when viewed from above. Most center pivots were initially water-powered, however today most are propelled by electric motors. This irrigation method was used intermittently at one location in the Basin, the "Center Pivot Farm." This farm has historically grown alfalfa and converted to growing ornamentals in 2012 using an overhead center pivot sprinkling system to irrigate.

Recommendations for Historical OFE Values for Use in the FMP

Based on the history of land use and irrigation methods described above and summarized in Table 2, OFE values were identified for each irrigation method and assigned to the irrigated land use classifications simulated in the FMP (Figure 1).

For each irrigated land use classification in the FMP, Table 3 identifies:

- The primary irrigation method(s) used to irrigate the crop type.
- The recommended initial OFE value to use at the start of Task 4 – *Model Recalibration.*
- A range of acceptable OFE values that could be used during model recalibration. During Task 4, these recommended ranges will be used to constrain calibrated values.

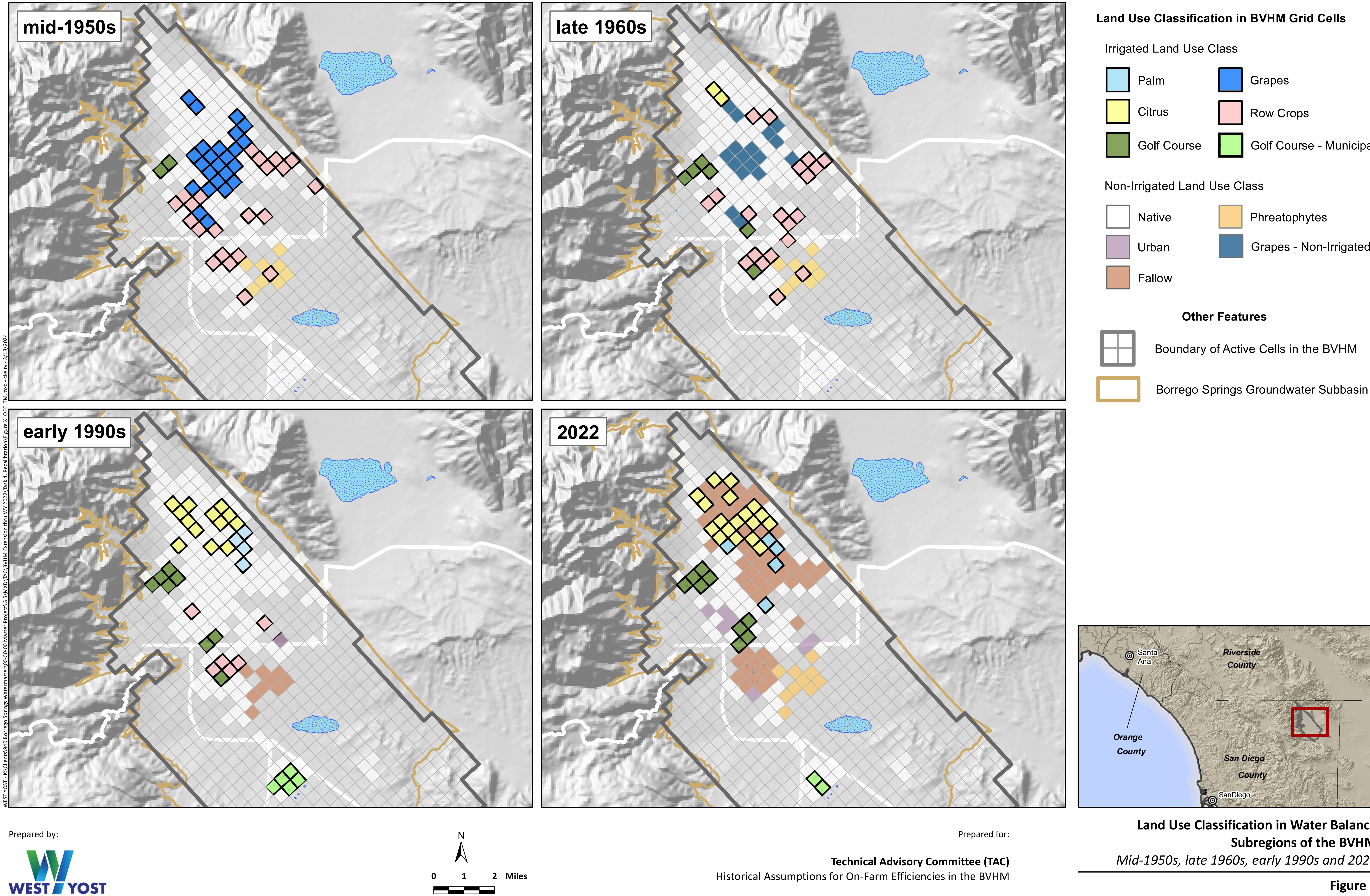
Table 3. Proposed Historical OFEs for Irrigated BVHM Grid Cells in Task 4

Crop Type	Irrigation Method(s)	OFE	Range of OFE[c]
Citrus	flood and furrow (pre-1980)	0.6	0.4 - 0.7
	micro-irrigation (1980-present)	0.78[a]	0.7-0.95
Dates	flood and furrow	0.6	0.4 - 0.7
Golf Courses	broadcast sprinkler	0.86[b]	0.6 - 0.9
Nursery	micro-irrigation	0.78[a]	0.7-0.95
Palm	micro-irrigation	0.78[a]	0.7-0.95
Potatoes	flood and furrow	0.6	0.4 - 0.7
Row Crops	flood and furrow (pre-1980)	0.6	0.4 - 0.7
	micro-irrigation (1980-present)	0.78[a]	0.7-0.95
Semiagricultural	broadcast sprinkler	0.86[b]	0.6 - 0.9
Grapes	flood and furrow (1945-1966)	0.6	0.4 - 0.7

Notes:
a) Micro sprinklers are defined as a single sprinkler under the canopy of a tree and are typically used for the irrigation of citrus (Netto, 2001).
b) Broadcast sprinklers are defined as a "wide area broadcast type of water sprinkler", commonly used at golf courses in Borrego Springs (Netto, 2001).
c) General OFE range for a given irrigation method. These ranges are from Table 1 in Howell (2003).

During the performance of Task 4 – *Model Recalibration* West Yost recommends to:

- Use the recommended initial OFE for each crop type shown in Table 3 as the initial OFE value.
- Use the recommended range of OFE values for each crop type to constrain OFE to a reasonable range of values during calibration.



Prepared by:

WEST YOST

Prepared for:

Technical Advisory Committee (TAC)
Historical Assumptions for On-Farm Efficiencies in the BVHM

Land Use Classification in Water Balance Subregions of the BVHM
Mid-1950s, late 1960s, early 1990s and 2022

Figure 1

Figure 2. BVHM Simulated Groundwater Pumping by Sector from 1945 to 2016

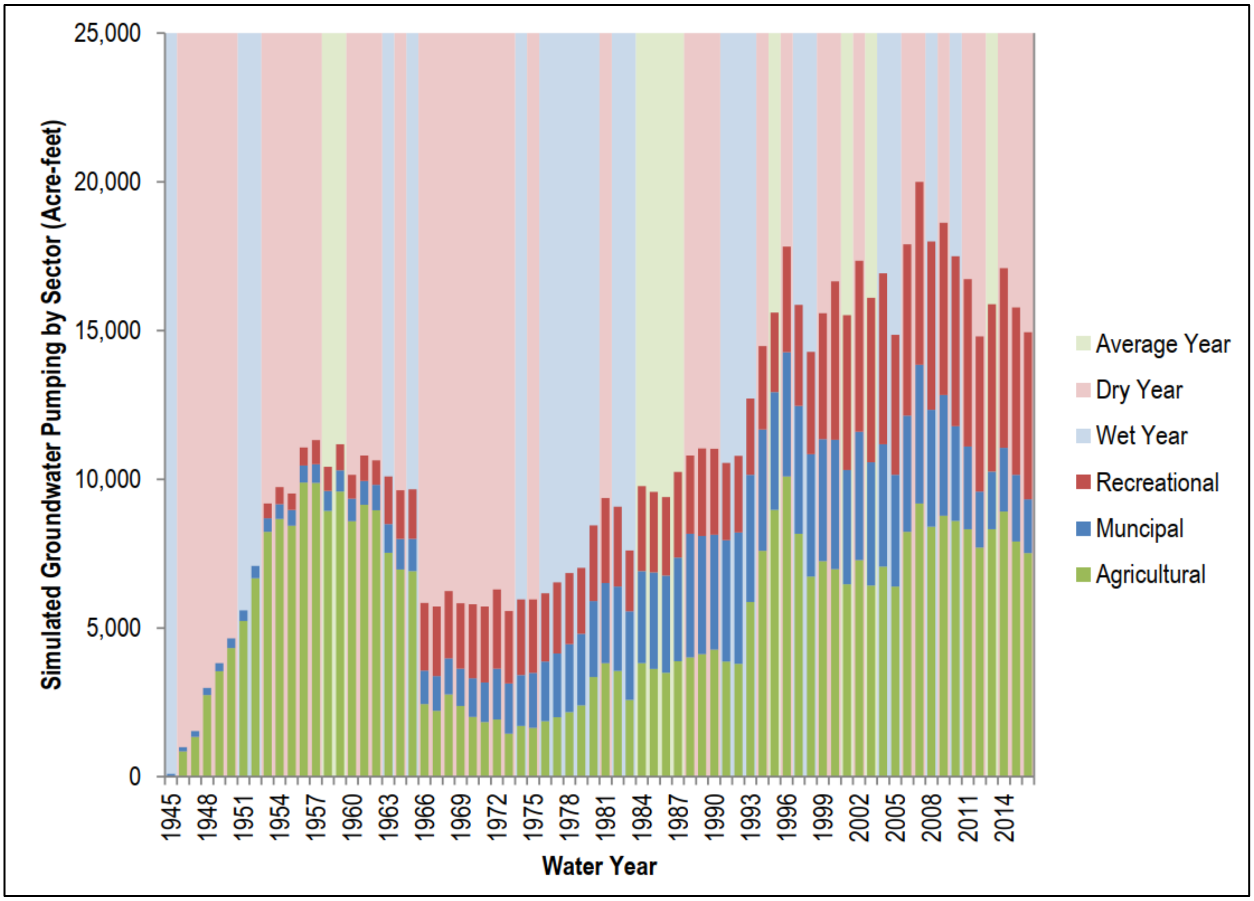
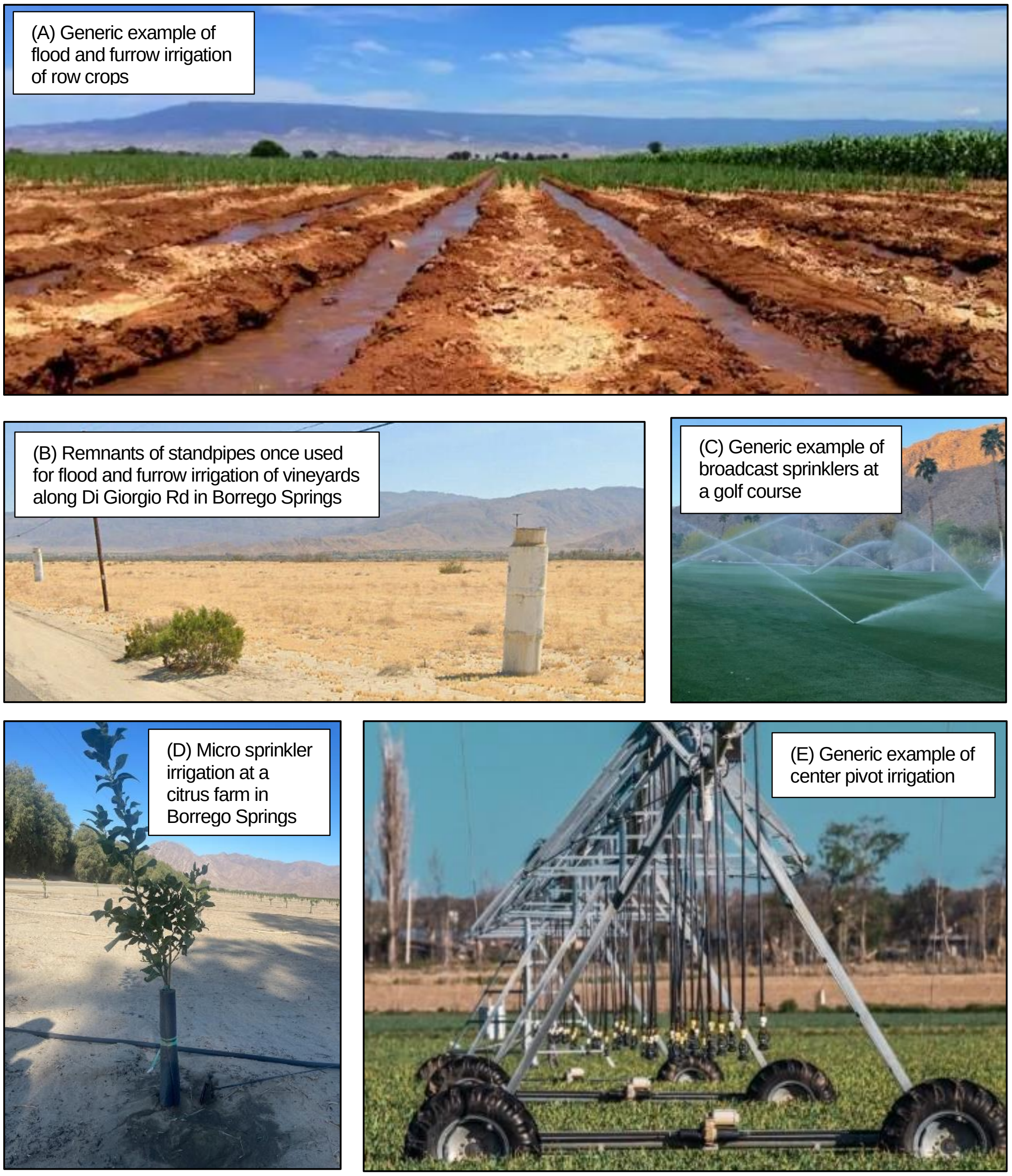


Figure 3. Irrigation Methods Employed in Borrego Springs



APPENDIX A

HISTORY OF AGRICULTURE AND IRRIGATION METHODS IN BORREGO VALLEY

- Pre-1945 — Early Agricultural
  - Irrigated agriculture in Borrego Valley started shortly after the 1912 amendment of the Homestead Act, with alfalfa first grown in 1913 at Doc Beaty's Coyote Creek Homestead (Brigandi, 1959). The irrigation source for these fields was diverted surface water from Coyote Creek.
  - During 1926-27, following the completion of the first deep well (160 feet and 1,000 GPM production rate) at Ensign Ranch, approximately 40 acres of dates were planted in Borrego Valley (Moyle, 1982).
  - By 1928, 200 acres of alfalfa was planted in the Borrego Valley (Brigandi, 1959).
  - The overall groundwater extraction during this period was minimal and estimated to be less than 100 af in 1945 (Moyle, 1982). Thus, groundwater extraction prior to 1945 is expected to have been approximately equal to average annual recharge to the Basin (Netto, 2001).

- Mid-1940s to mid-1960s — Grapes Agricultural Expansion
  - Agricultural expansion after World War II dramatically increased the volume of groundwater extracted from the Basin. This increased groundwater demand is evident in well records that document about 100 wells were drilled throughout the Basin from 1946 to 1953 (Burnham, 1954; Moyle, 1982).
  - By 1953, agricultural water use became the main source of discharge from the Basin, with recreational and municipal water use only accounting for a relatively small but growing percentage of the estimated pumping (Figure 1; Dudek, 2020).
  - Irrigated acreage in the Borrego Valley peaked in 1958 at 5,000 acres and thereafter declined until to about 2,000 acres in 1965 (DWR, 1984). The sharp decline in irrigated acreage in the mid-1960s was due to a labor dispute led by César Chávez, director of the National Farm Workers Association, which resulted in table grapes to no longer be irrigated in Borrego Valley after 1966 (Moyle, 1982).
  - Table grapes were the main crop farmed and irrigated in the late 1950s to early 1960s. Based on personal communication with local farmer Tyler Bilyk on March 1, 2024, it is inferred that these grapes were irrigated by inefficient flood and furrow irrigation methods because no above grade poly (PVC) or drip irrigation equipment were found in historic vineyards. This observation is supplemented by the remnants of infrastructure, such as concrete mainlines and standpipes, that are observed in aerial photographs at abandoned vineyards along Di Giorgio Road.

- Mid-1960s and late 1970s — Decline in Agricultural Production
    - Agricultural water use dropped off substantially from the mid-1960s to the late 1970s following the end of table grapes production (see Figure 1).
    - Citrus in 1968 only occupied about 220 acres in Borrego Valley (Netto, 2001). This area accounts for a relatively small amount of the total agricultural land use because undifferentiated row crops occupied about 2,500 acres in 1968 (Netto, 2001).
    - The undifferentiated row crops and early citrus farms in the mid-1960s to late 1970s were likely irrigated by flood and furrow methods.

- Late 1970s to Present — Citrus Agricultural Expansion
    - By 1979, citrus had become the primary agricultural product grown in Borrego Valley and occupied an area of about 1,040 acres (Netto, 2001). Citrus continued to expand over the decades, and by 1995, it occupied an area of approximately 2,600 acres (Netto, 2001). This accounted for approximately 60 percent of the agriculture acreage in 1995 because other crops, such as ornamental tree farms and nurseries, alfalfa, and potatoes, only occupied about 1700 acres.
    - The agriculture rebound in the late 1970s to early 1980s was partly due to the increasingly popular use of drip and trickle irrigation systems that conserve water and reduce operating costs. This irrigation method allowed Borrego Valley farmers to compete with Imperial and Coachella Valley farmers that had access to relatively inexpensive imported water from the Colorado River (DWR, 1984).
    - Based on personal communication with local farmer Tyler Bilyk on March 1, 2024, he inferred that most citrus farms in Borrego Valley have been using above grade poly (PVC) and micro-irrigation methods since the 1980s. He also noted that micro-irrigation methods were also likely used for ornamental tree farms and nurseries during this period. Two exceptions he noted are:
        - Center Pivot Farm, which is located about 1 mile northeast from the intersection of Palm Canyon Road and Borrego Valley Rd, has been irrigated using an overhead sprinkling system to grow alfalfa for most of its existence. The farm only recently converted from growing alfalfa to ornamentals in 2012.
        - Potato Field Farm, which is located about 1.2 miles southeast from the intersection of Henderson Canyon Road and Borrego Valley Rd, has been irrigated using flood and furrow methods for the entire time of production. The potatoes harvested here are a seasonal crop that grow from approximately late winter to early summer. The most recent harvest was 2019.

- Based on personal communication with local farmer David Bauer on March 28, 2024:
  - The citrus farms in the northern portion of the North Management Area have used micro-irrigation methods since their inception.
  - These irrigation methods became more efficient on his farms in the 1990s as soil moisture sensors were employed to better control irrigation timing based on soil moisture.

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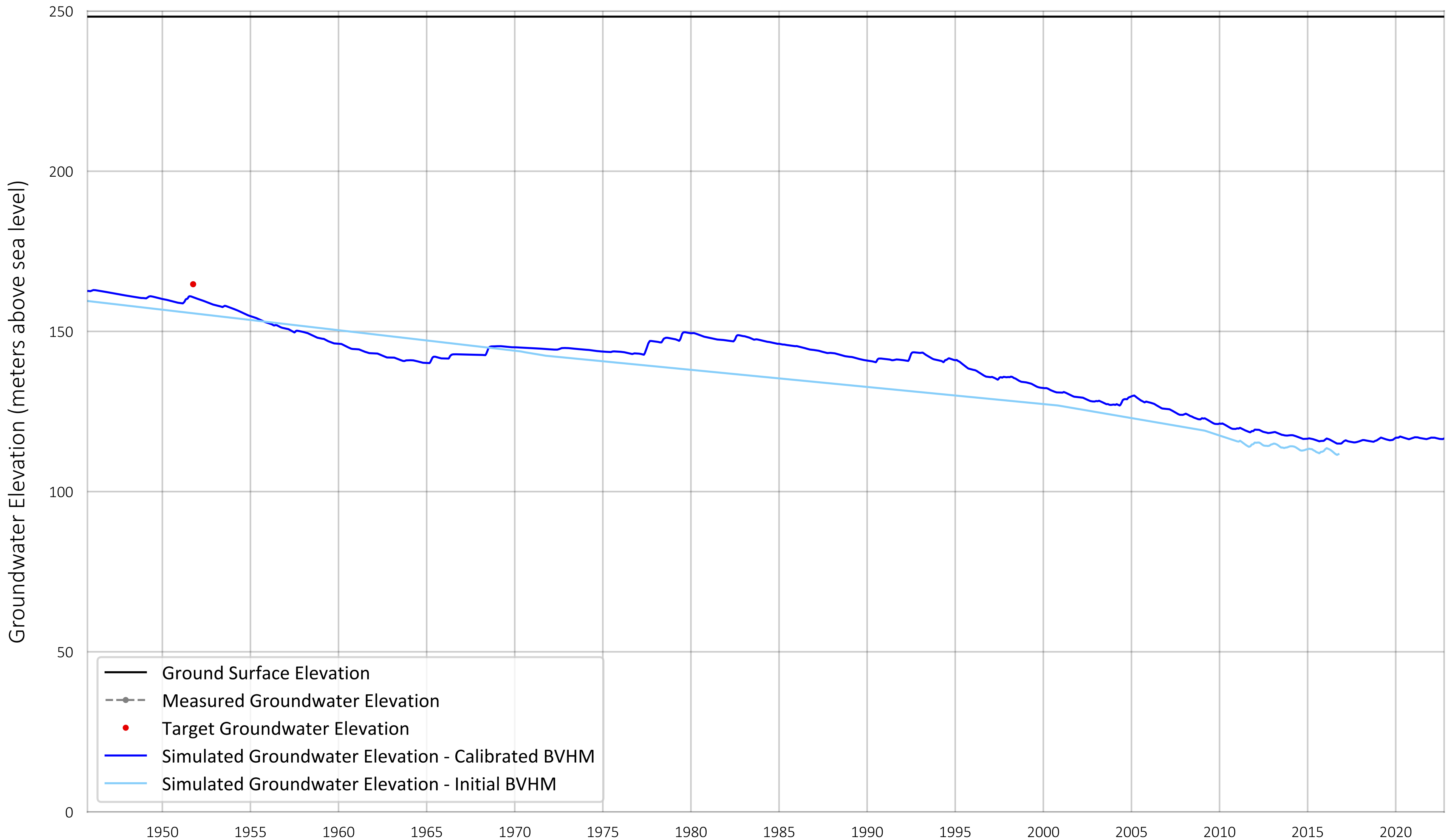
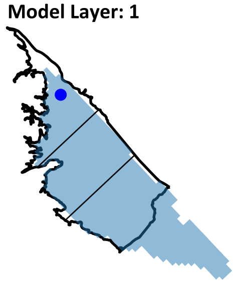
- Snyder, R.L., Lamina, B.J., Shaw, D.A., and Pruitt, W.O. 1987b. *Using reference evapotranspiration (ETo) and crop coefficients to estimate crop evapotranspiration (ETc) for trees and vines*. https://calisphere.org/item/fbc9dc78-de6e-4d99-a561-0028370f8107/.
- United States Geological Survey (USGS). 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California.

Appendix B

Hydrographs



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 164.73
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 160.68
Standard Deviation = 0.00

Mean Residual (m) = -4.05
RMSE (m) = 4.05

Prepared by:

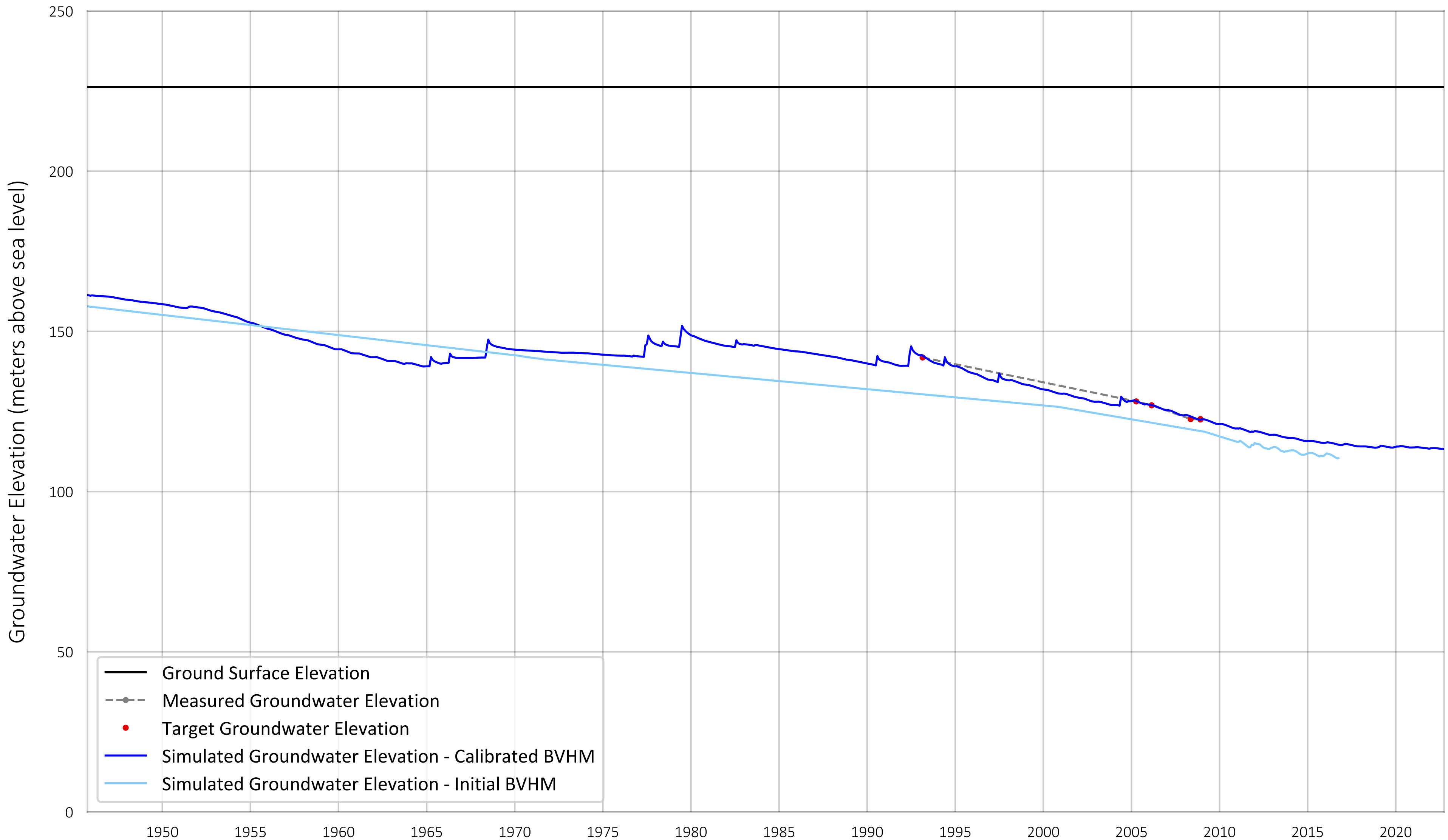
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

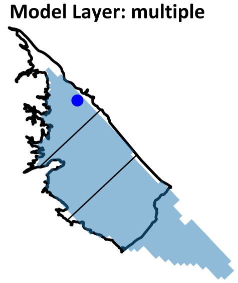
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245848
Well Name: 5F1

Figure B-1



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 127.45
Standard Deviation = 7.47

Simulated Groundwater Elevation (m)
Mean = 127.68
Standard Deviation = 7.65

Mean Residual (m) = 0.22
RMSE (m) = 0.44

Calibrated BVHM Groundwater Elevation

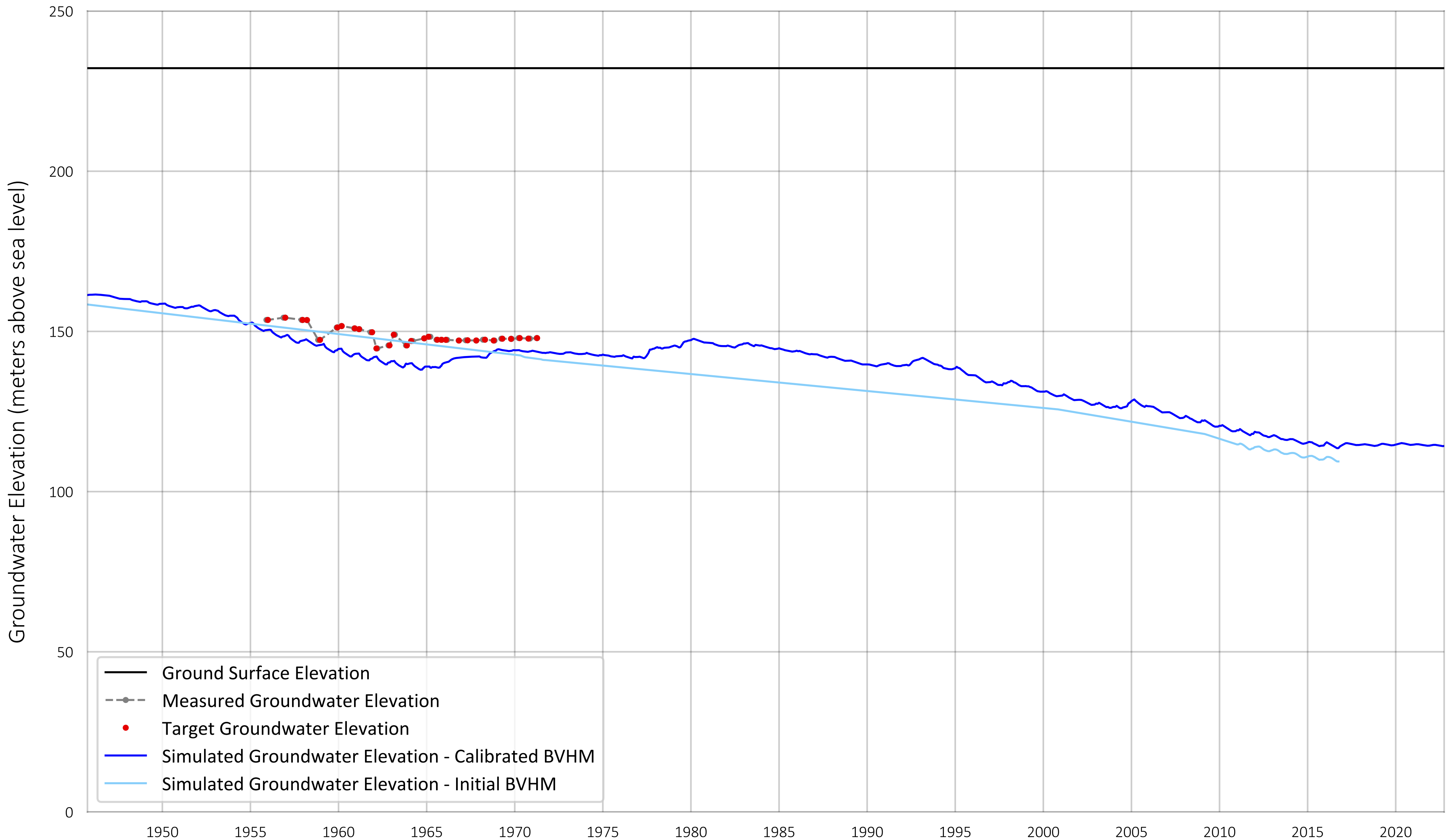
HydroDaVE Well ID: 1245929
Well Name: Viking

Figure B-2

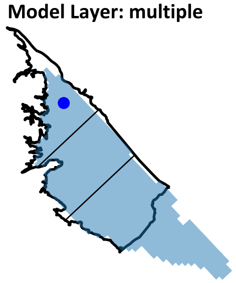
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 148.73
Standard Deviation = 2.55

Simulated Groundwater Elevation (m)
Mean = 142.87
Standard Deviation = 2.94

Mean Residual (m) = -5.86
RMSE (m) = 6.20

Prepared by:

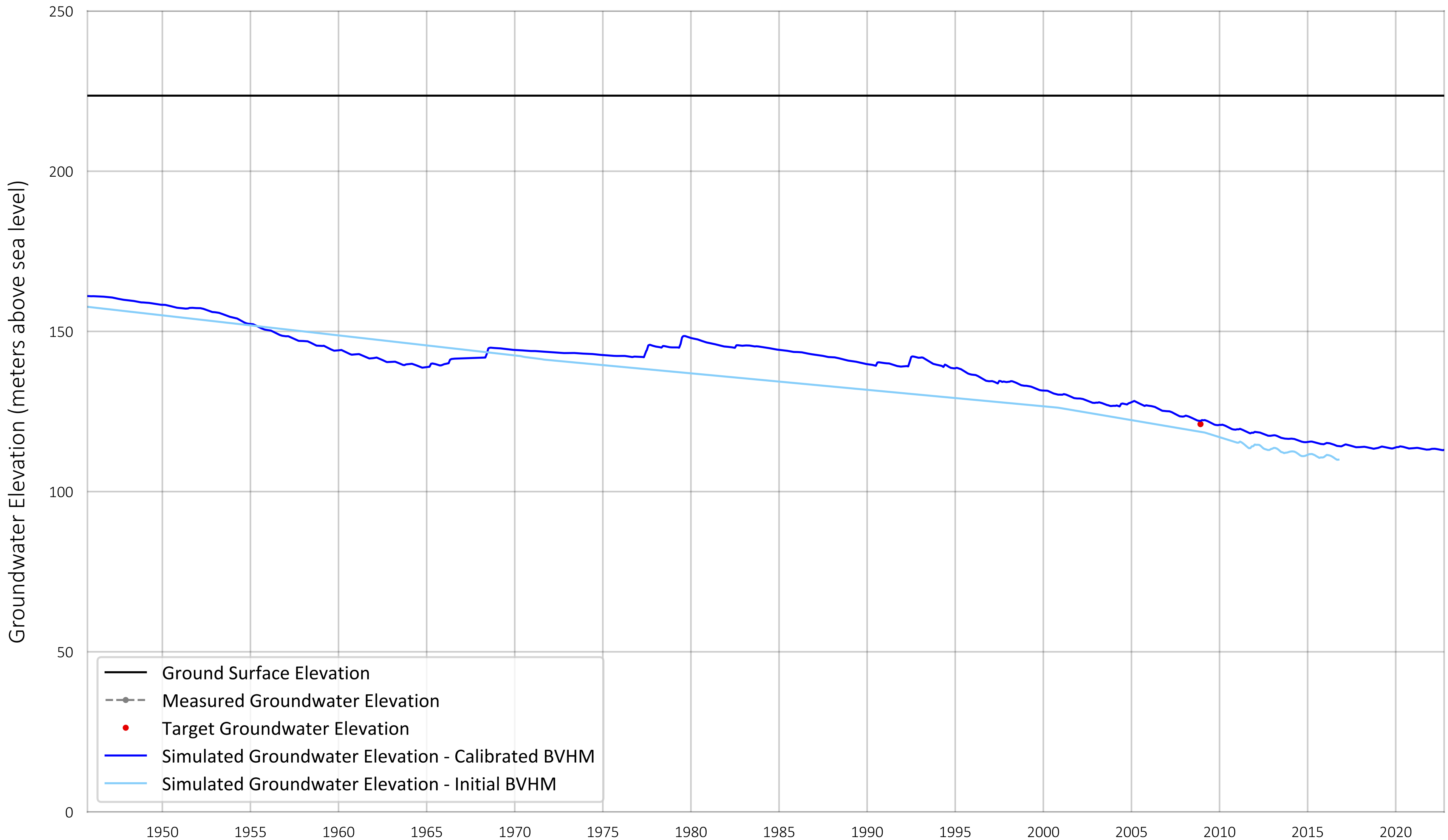
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

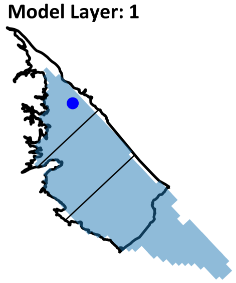
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245806
Well Name: 010S006E08B001S

Figure B-3



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 121.07
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 122.06
Standard Deviation = 0.00

Mean Residual (m) = 0.99
RMSE (m) = 0.99

Calibrated BVHM Groundwater Elevation

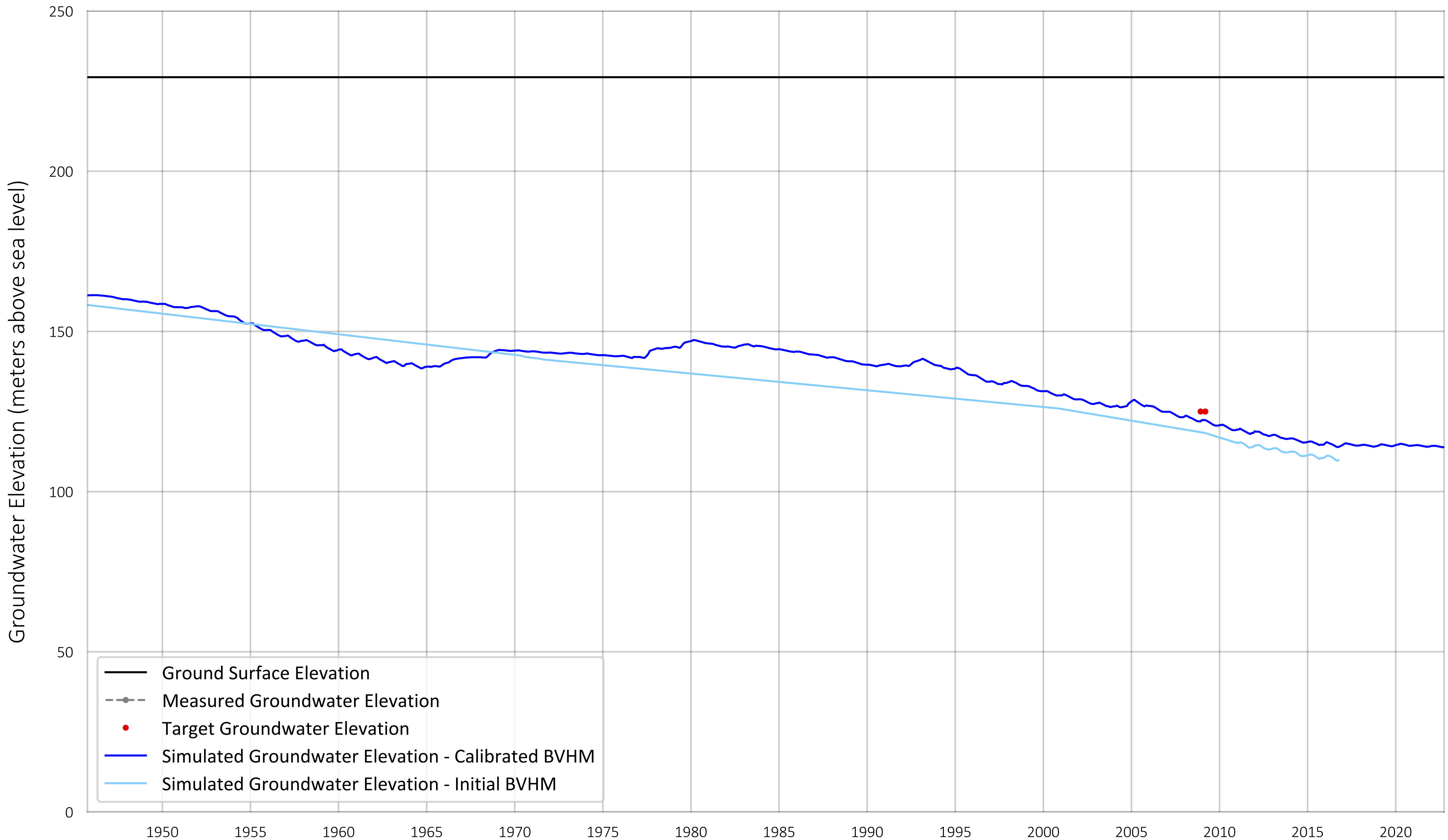
HydroDaVE Well ID: 1245807
Well Name: T2 Farms

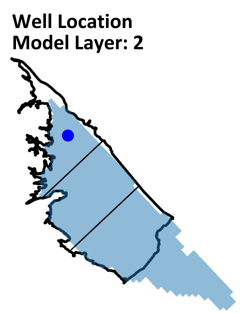
Figure B-4

Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster





Statistics

Target Groundwater Elevation (m)
Mean = 124.99
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 122.14
Standard Deviation = 0.27

Mean Residual (m) = -2.85
RMSE (m) = 2.86

Prepared by:

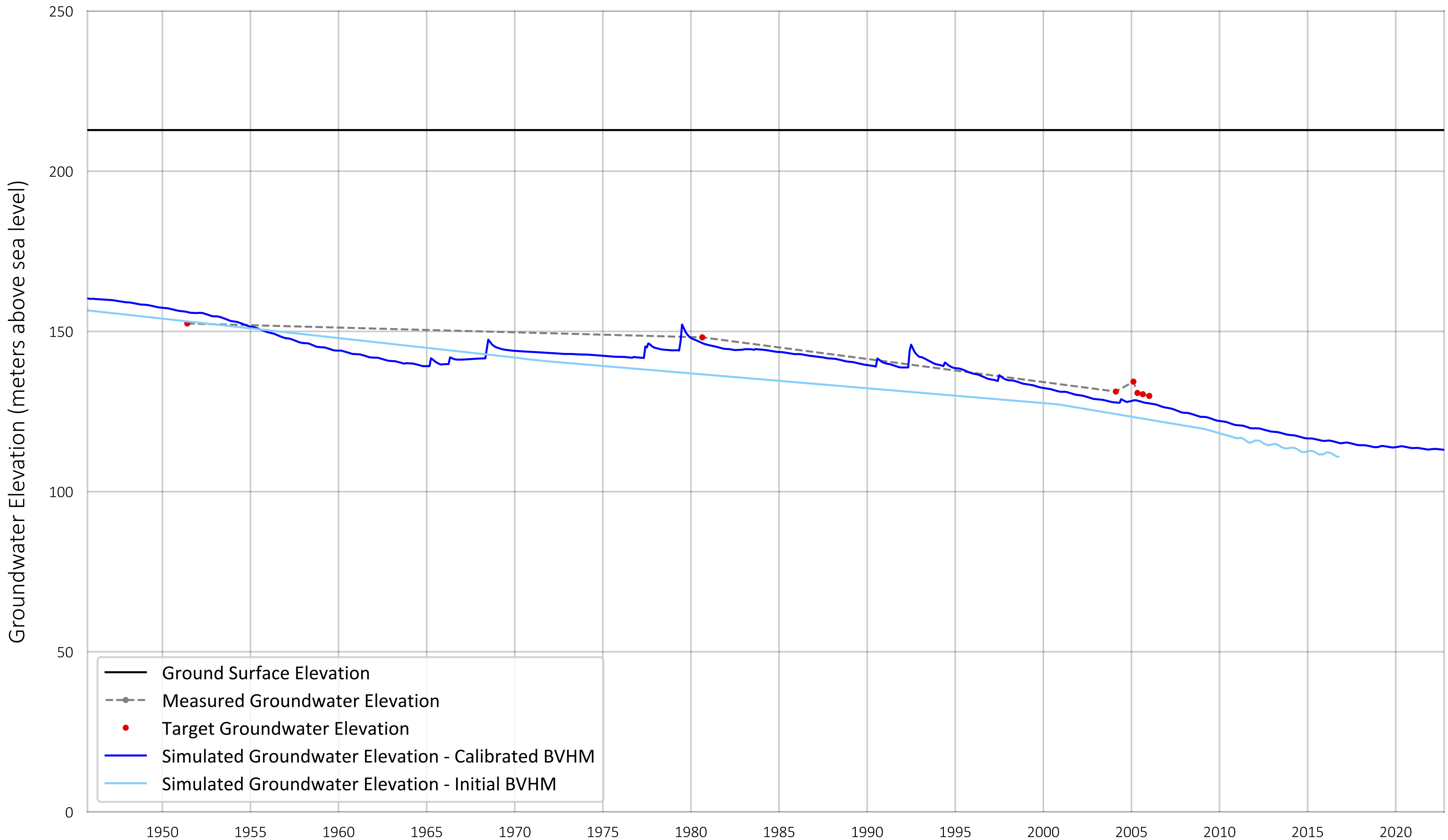
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

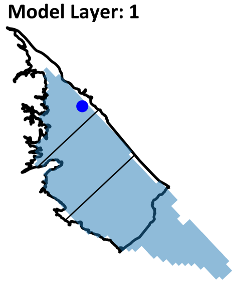
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245864
Well Name: Charmer 2

Figure B-5



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 136.74
Standard Deviation = 9.46

Simulated Groundwater Elevation (m)
Mean = 134.65
Standard Deviation = 11.64

Mean Residual (m) = -2.09
RMSE (m) = 3.36

Prepared by:

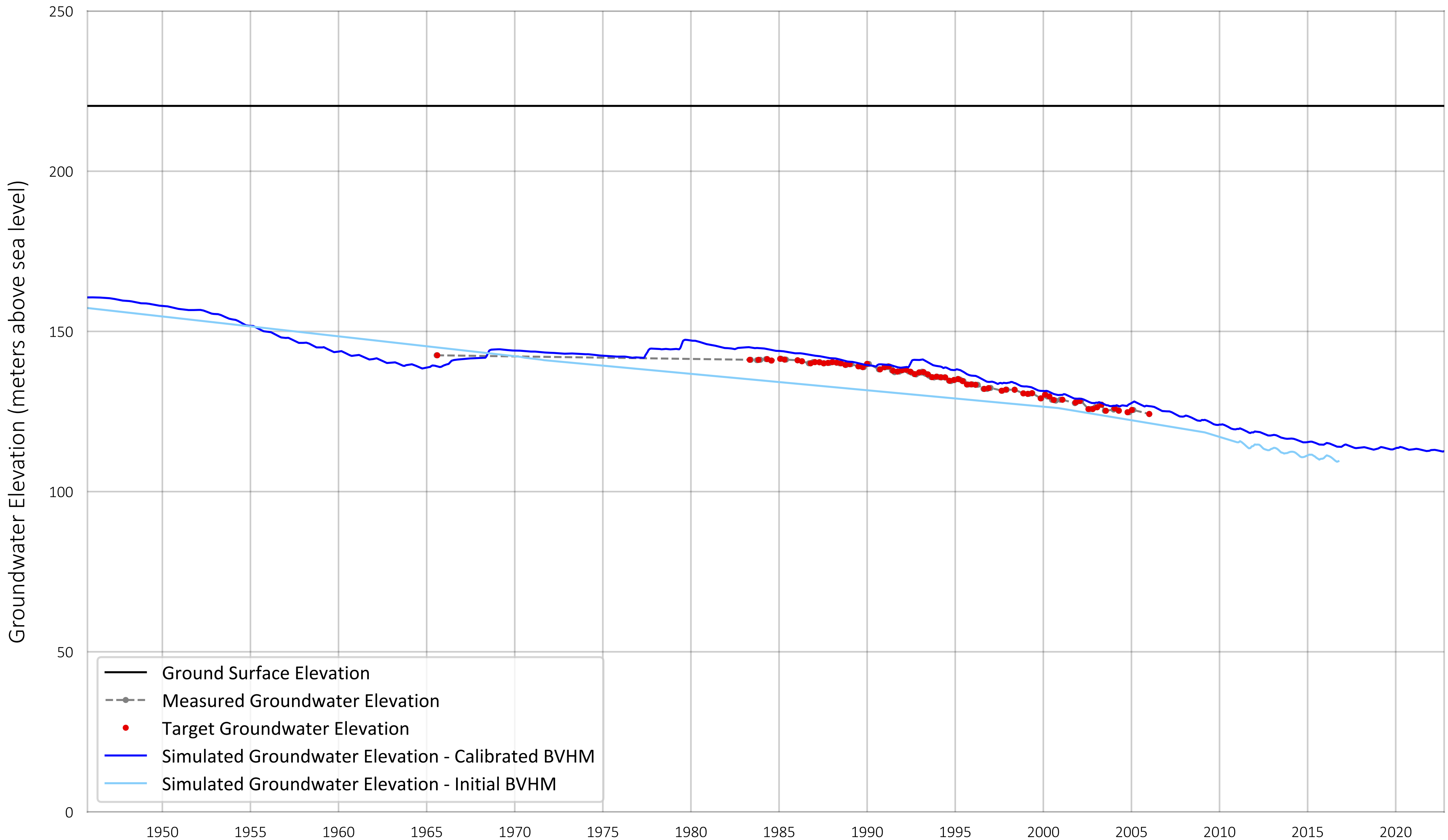
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

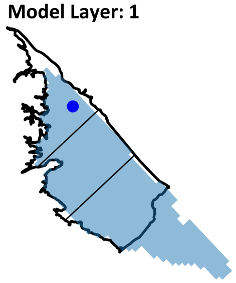
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245810
Well Name: 010S006E10M001S

Figure B-6



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 134.78
Standard Deviation = 5.43

Simulated Groundwater Elevation (m)
Mean = 136.82
Standard Deviation = 5.56

Mean Residual (m) = 2.04
RMSE (m) = 2.37

Prepared by:

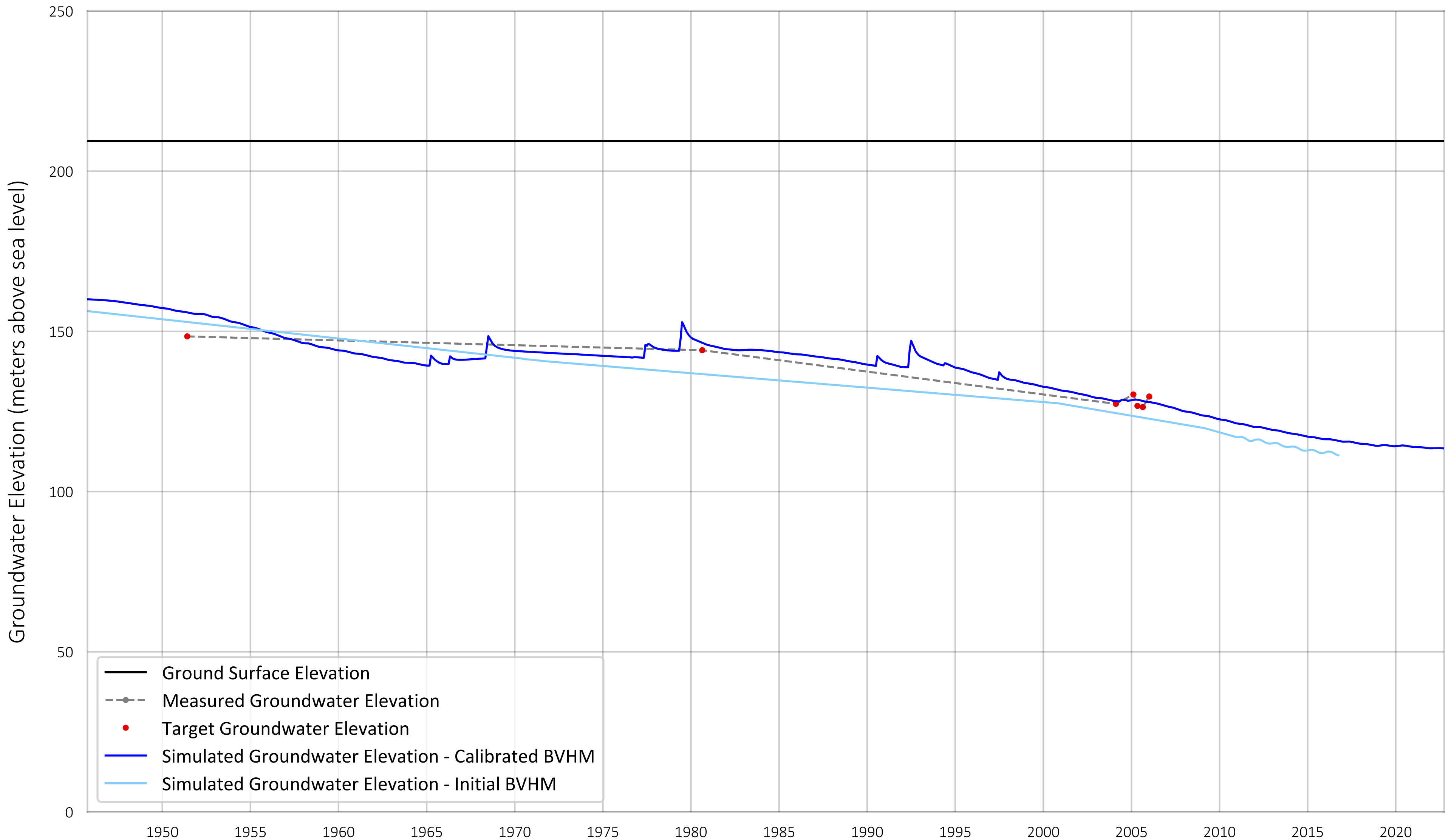
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

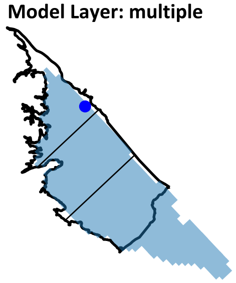
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245808
Well Name: 010S006E09L001S

Figure B-7



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 133.29
Standard Deviation = 9.08

Simulated Groundwater Elevation (m)
Mean = 134.87
Standard Deviation = 11.45

Mean Residual (m) = 1.57
RMSE (m) = 3.27

Prepared by:

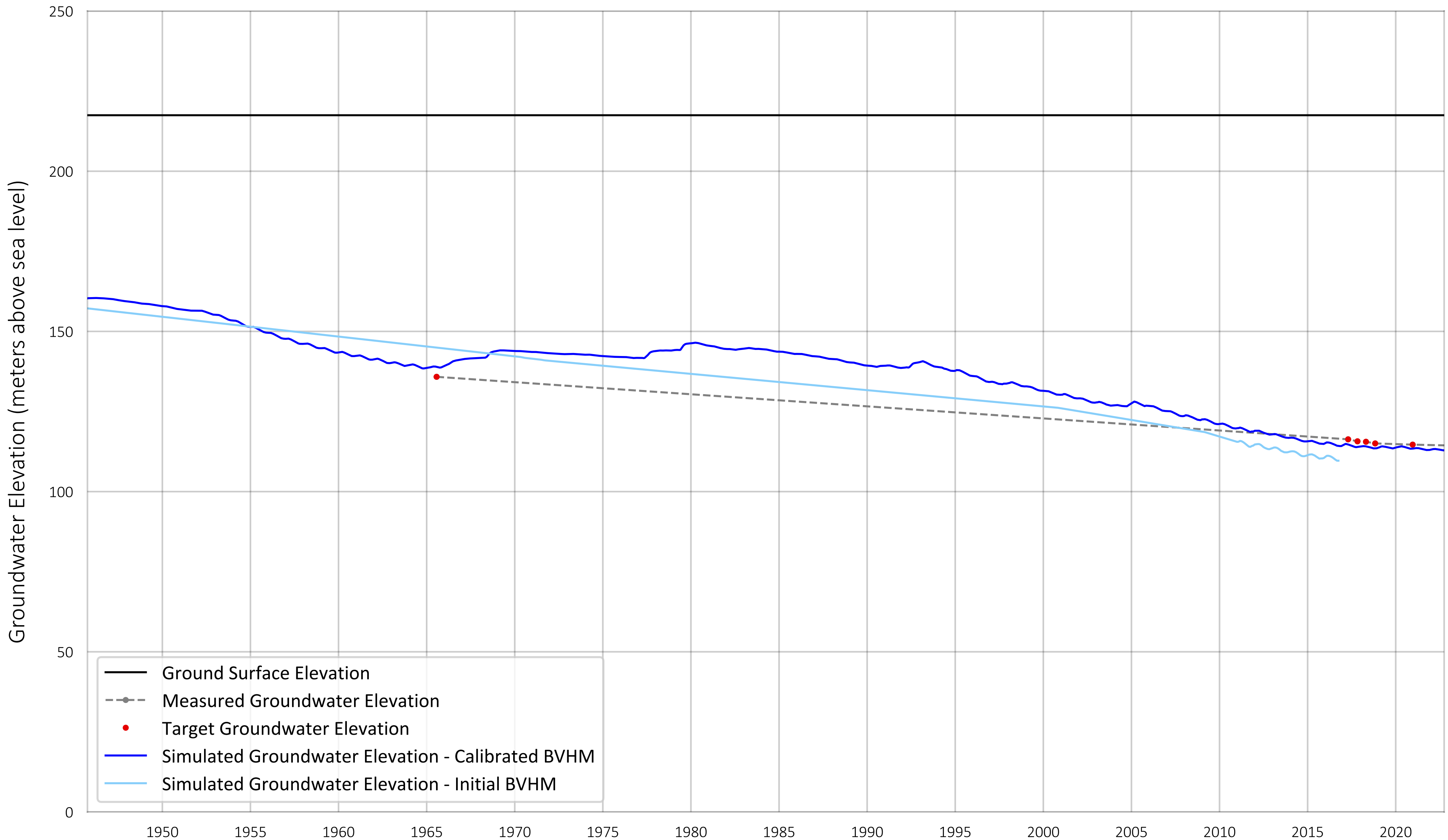
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

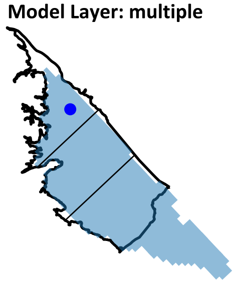
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245809
Well Name: 010S006E10L001S

Figure B-8



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 118.85
Standard Deviation = 8.34

Simulated Groundwater Elevation (m)
Mean = 118.11
Standard Deviation = 10.22

Mean Residual (m) = -0.74
RMSE (m) = 1.89

Prepared by:

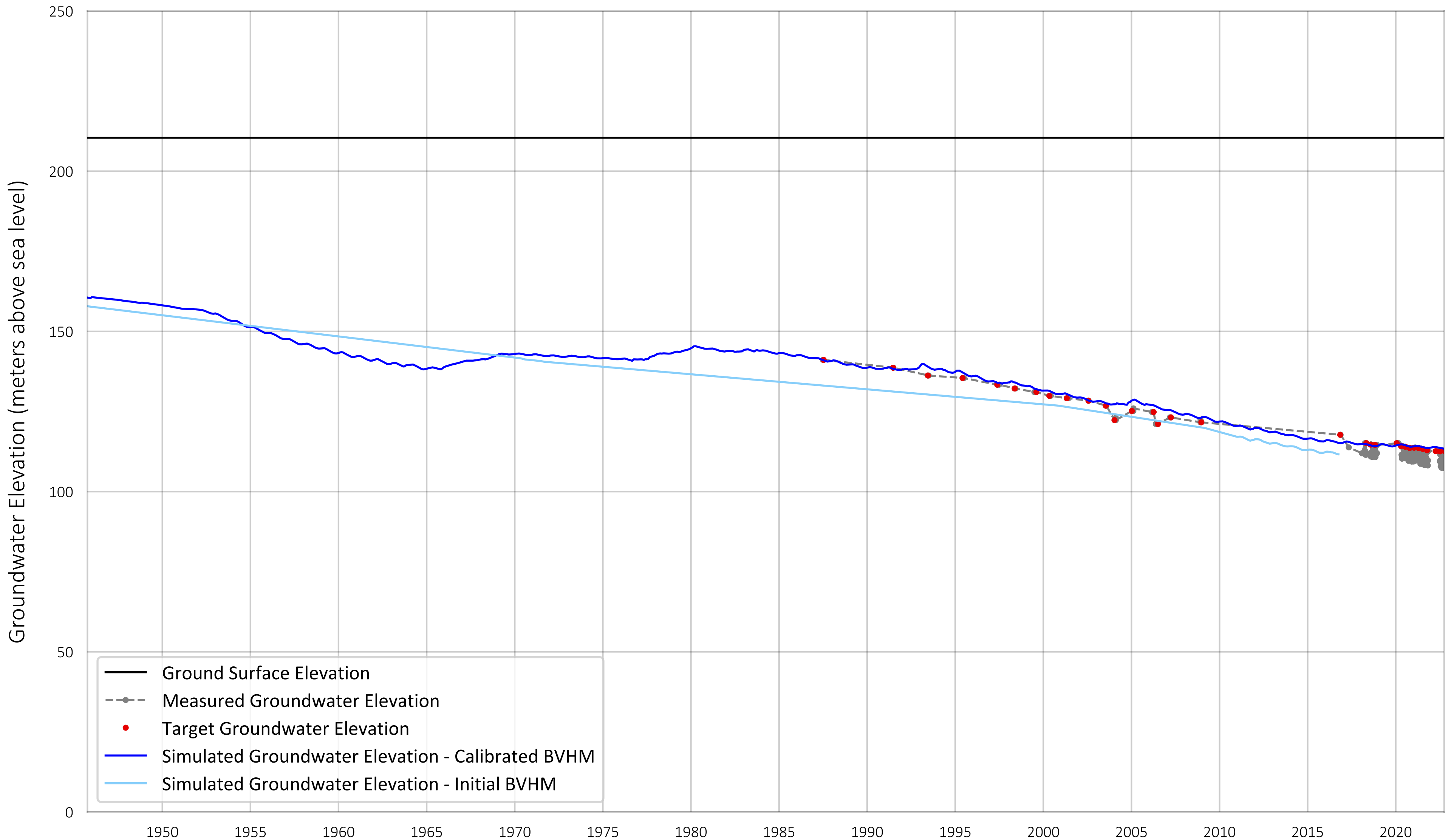
WEST YOST
Water. Engineered.

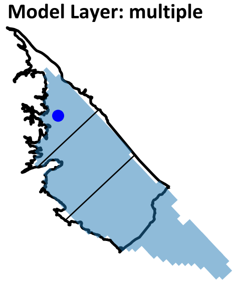
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245869
Well Name: Fortiner #1

Figure B-9





Statistics

Target Groundwater Elevation (m)
Mean = 122.52
Standard Deviation = 8.99

Simulated Groundwater Elevation (m)
Mean = 123.57
Standard Deviation = 9.42

Mean Residual (m) = 1.04
RMSE (m) = 1.85

Calibrated BVHM Groundwater Elevation

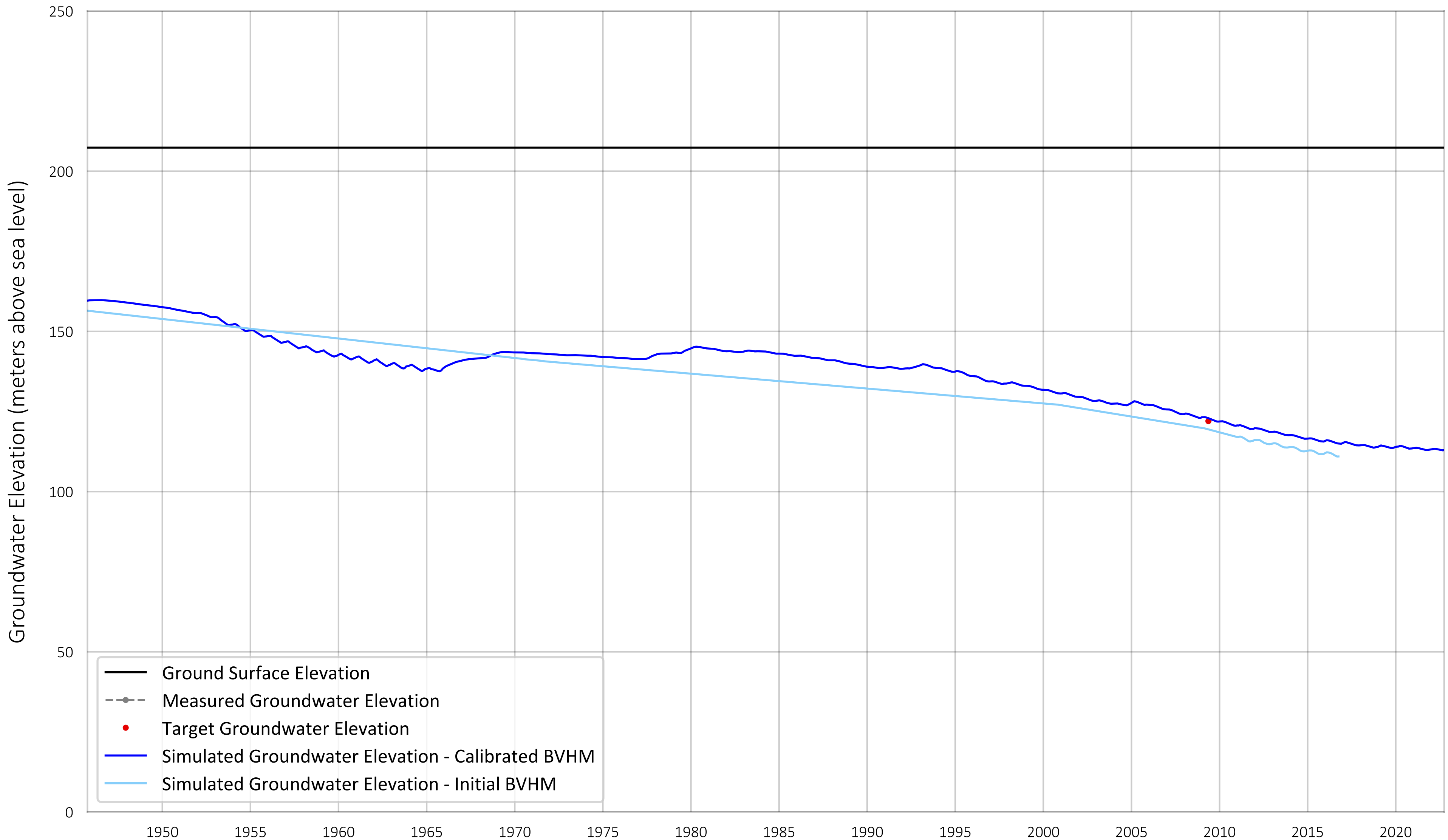
HydroDaVE Well ID: 1245886
Well Name: ID4-18

Figure B-10

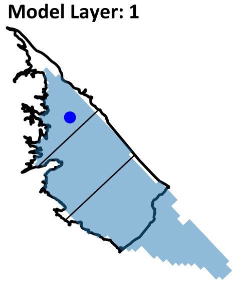
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 122.01
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 122.91
Standard Deviation = 0.00

Mean Residual (m) = 0.91
RMSE (m) = 0.91

Prepared by:

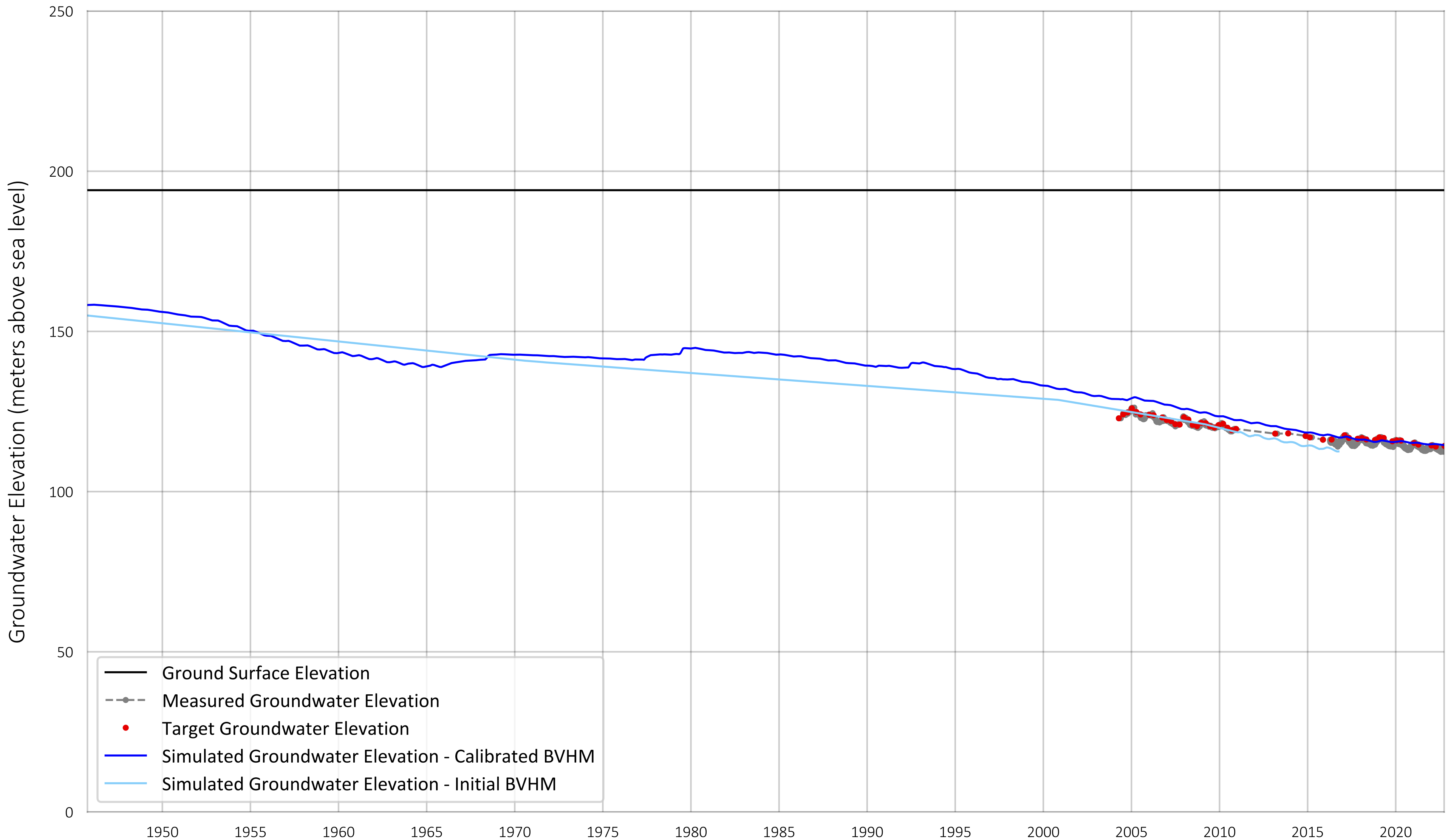
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

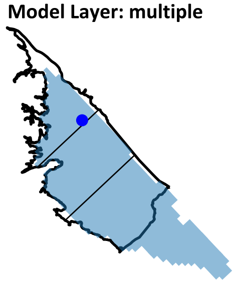
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245814
Well Name: MSO Well 1

Figure B-11



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 119.51
Standard Deviation = 3.29

Simulated Groundwater Elevation (m)
Mean = 121.85
Standard Deviation = 5.14

Mean Residual (m) = 2.34
RMSE (m) = 3.11

Prepared by:

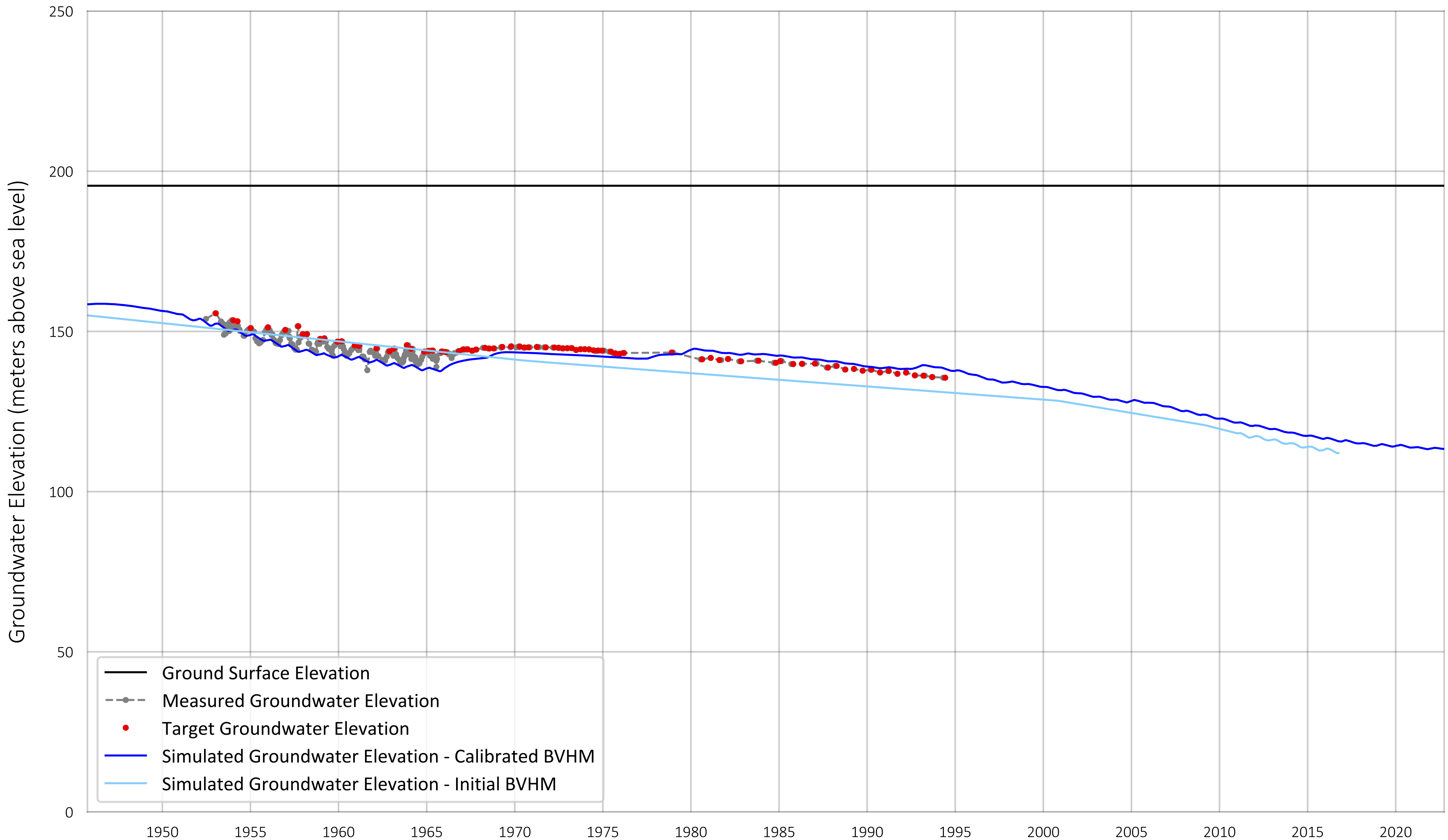
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

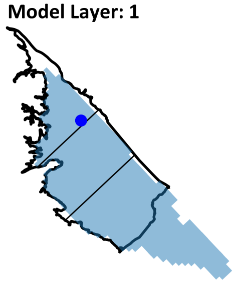
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245897
Well Name: MW-1

Figure B-12



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 143.65
Standard Deviation = 4.14

Simulated Groundwater Elevation (m)
Mean = 142.03
Standard Deviation = 2.73

Mean Residual (m) = -1.61
RMSE (m) = 3.17

Prepared by:

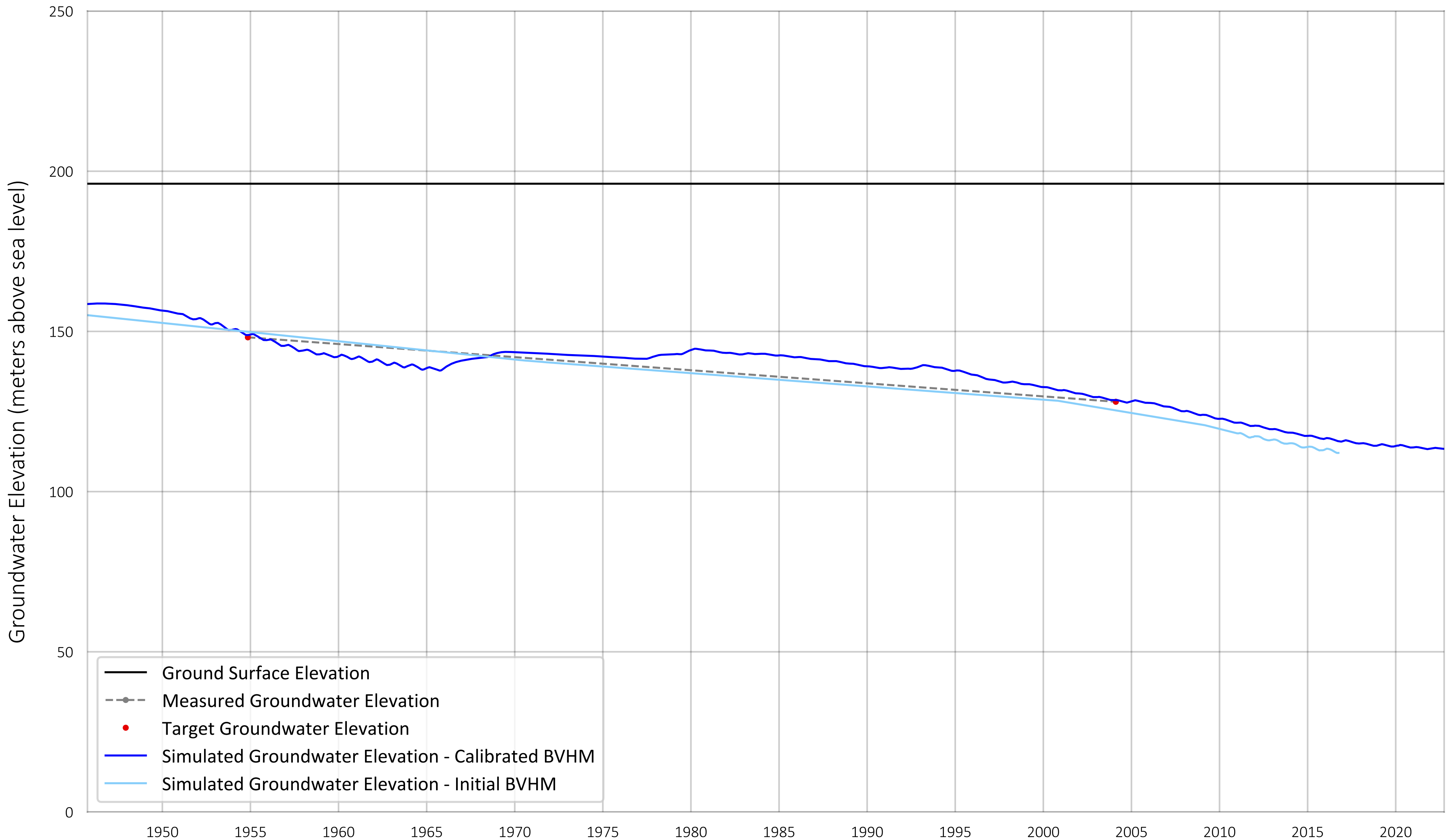
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

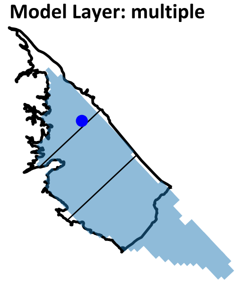
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245847
Well Name: 21A1

Figure B-13



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 138.10
Standard Deviation = 14.22

Simulated Groundwater Elevation (m)
Mean = 138.72
Standard Deviation = 14.34

Mean Residual (m) = 0.62
RMSE (m) = 0.63

Prepared by:

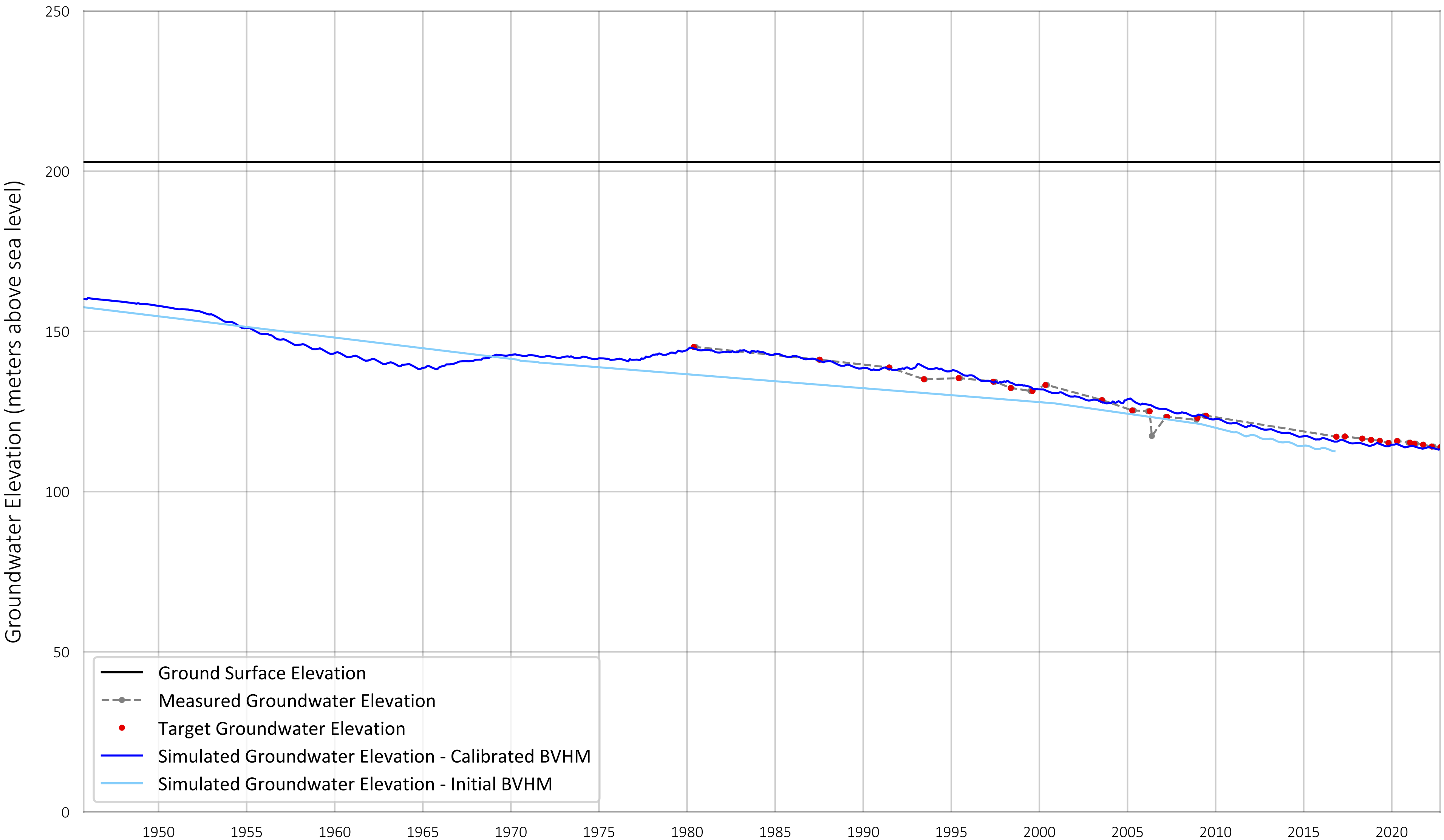
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

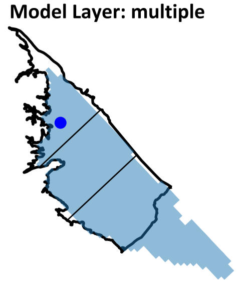
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245817
Well Name: 010S006E21B001S

Figure B-14



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 124.94
Standard Deviation = 9.59

Simulated Groundwater Elevation (m)
Mean = 124.93
Standard Deviation = 10.31

Mean Residual (m) = -0.02
RMSE (m) = 1.57

Prepared by:

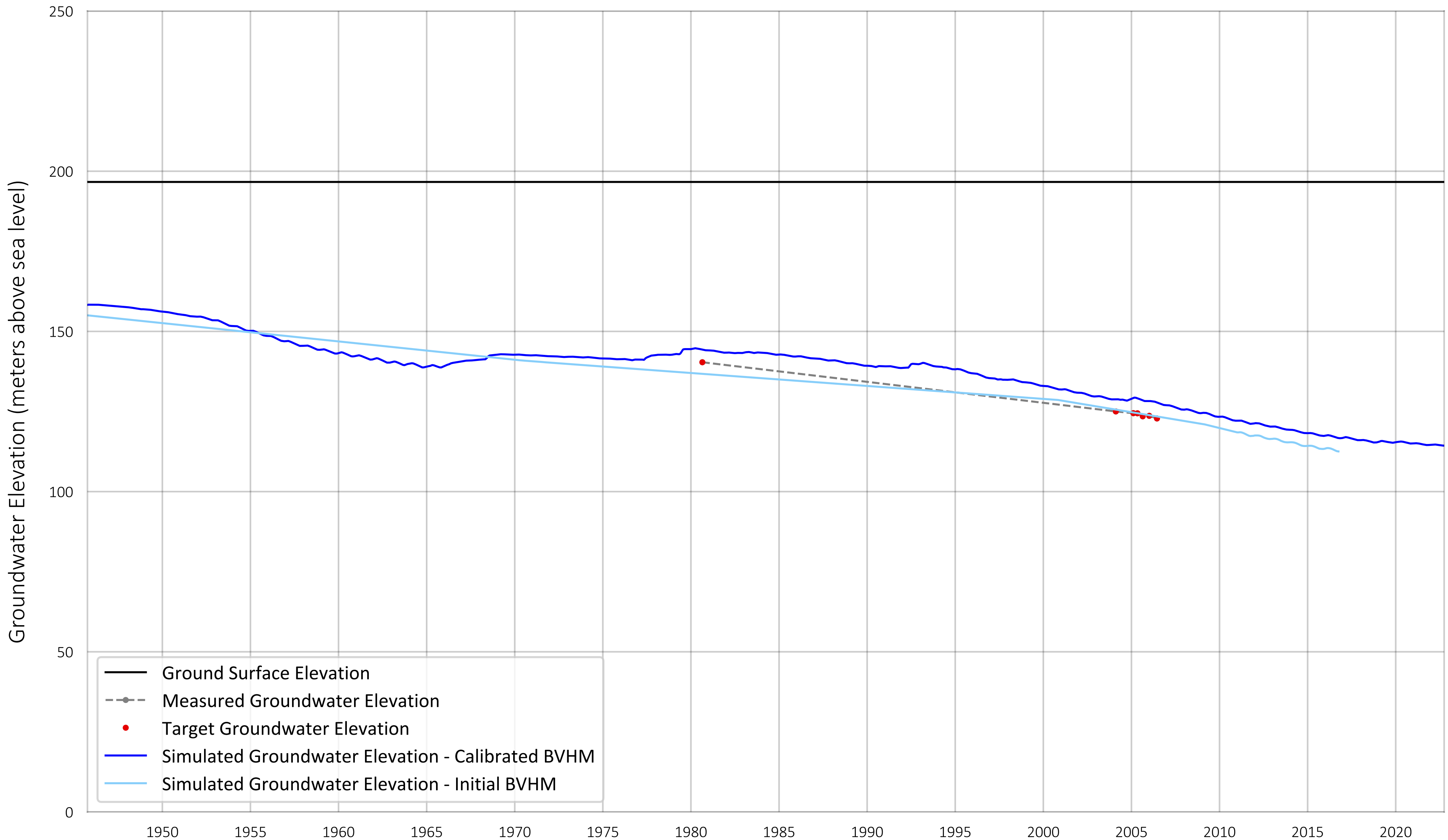
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

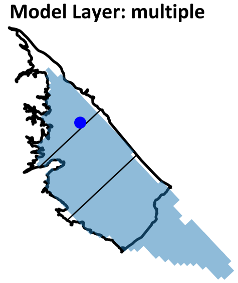
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245888
Well Name: ID4-3

Figure B-15



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 126.33
Standard Deviation = 6.24

Simulated Groundwater Elevation (m)
Mean = 130.86
Standard Deviation = 5.94

Mean Residual (m) = 4.54
RMSE (m) = 4.56

Prepared by:

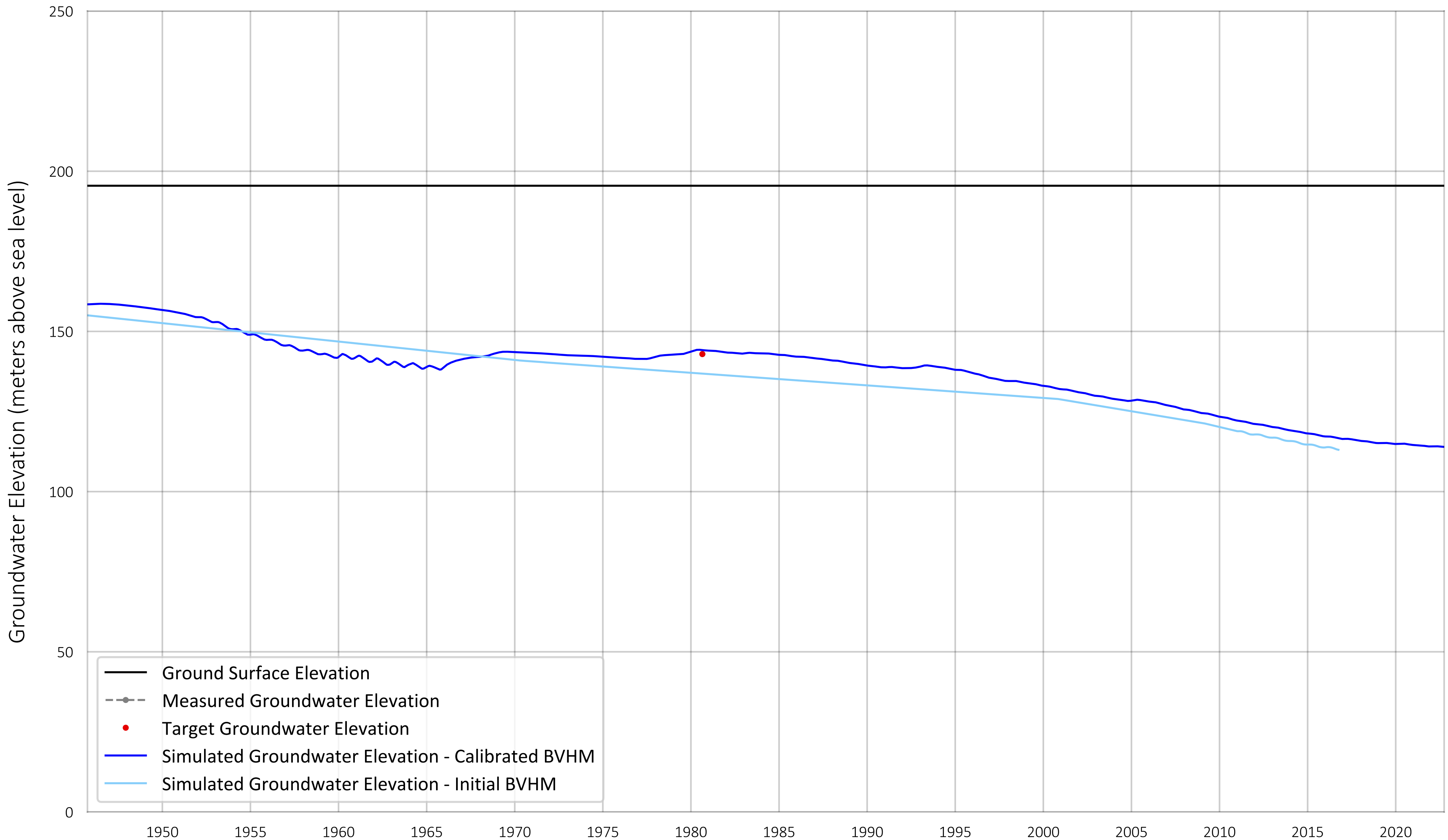
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

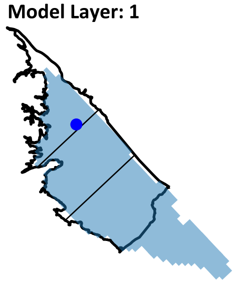
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245818
Well Name: 010S006E21B002S

Figure B-16



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 142.92
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 144.19
Standard Deviation = 0.00

Mean Residual (m) = 1.26
RMSE (m) = 1.26

Prepared by:

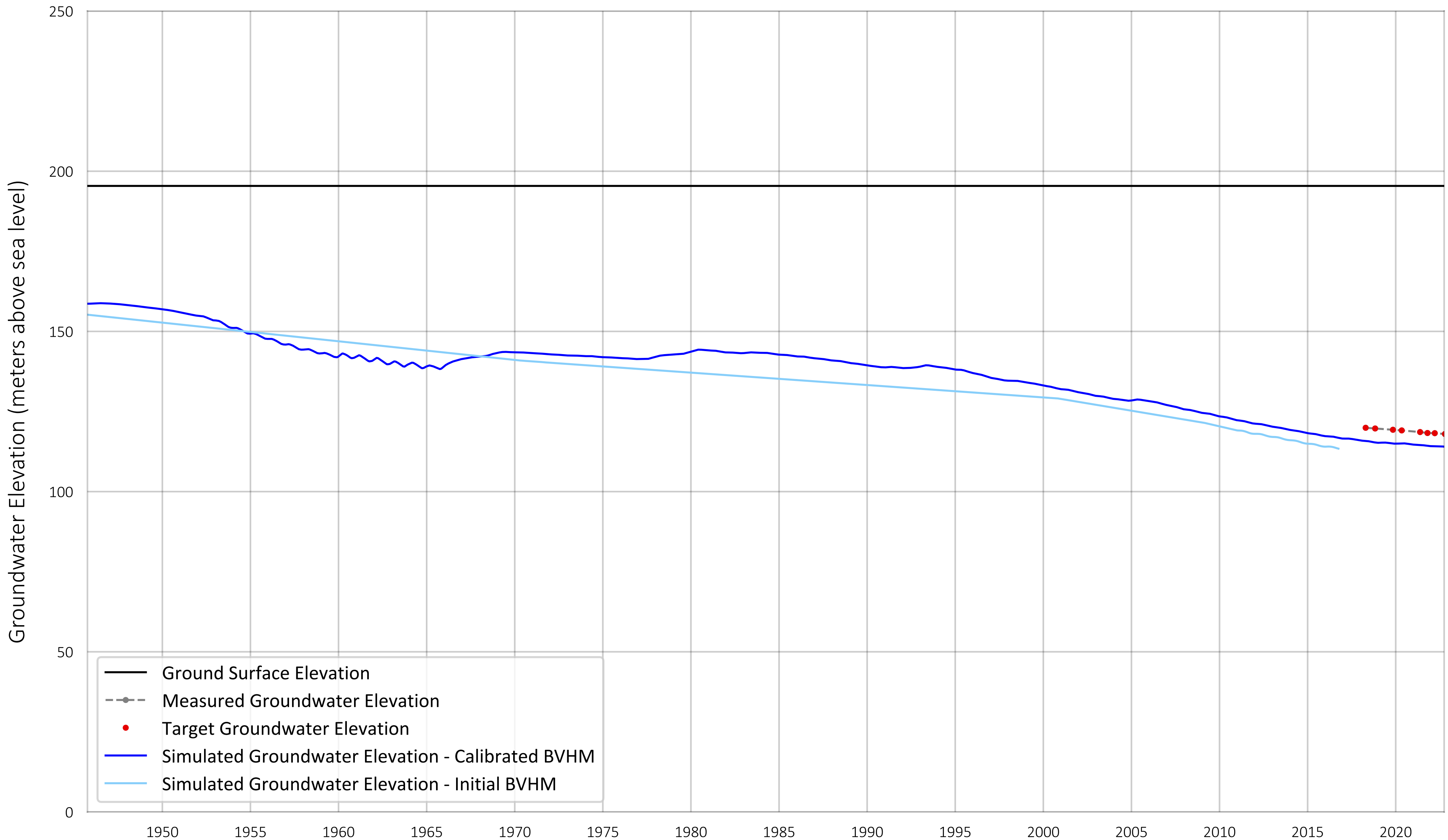
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

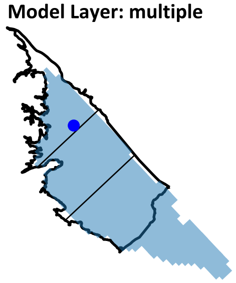
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245819
Well Name: 010S006E21F001S

Figure B-17



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 119.02
Standard Deviation = 0.67

Simulated Groundwater Elevation (m)
Mean = 114.90
Standard Deviation = 0.58

Mean Residual (m) = -4.12
RMSE (m) = 4.12

Prepared by:

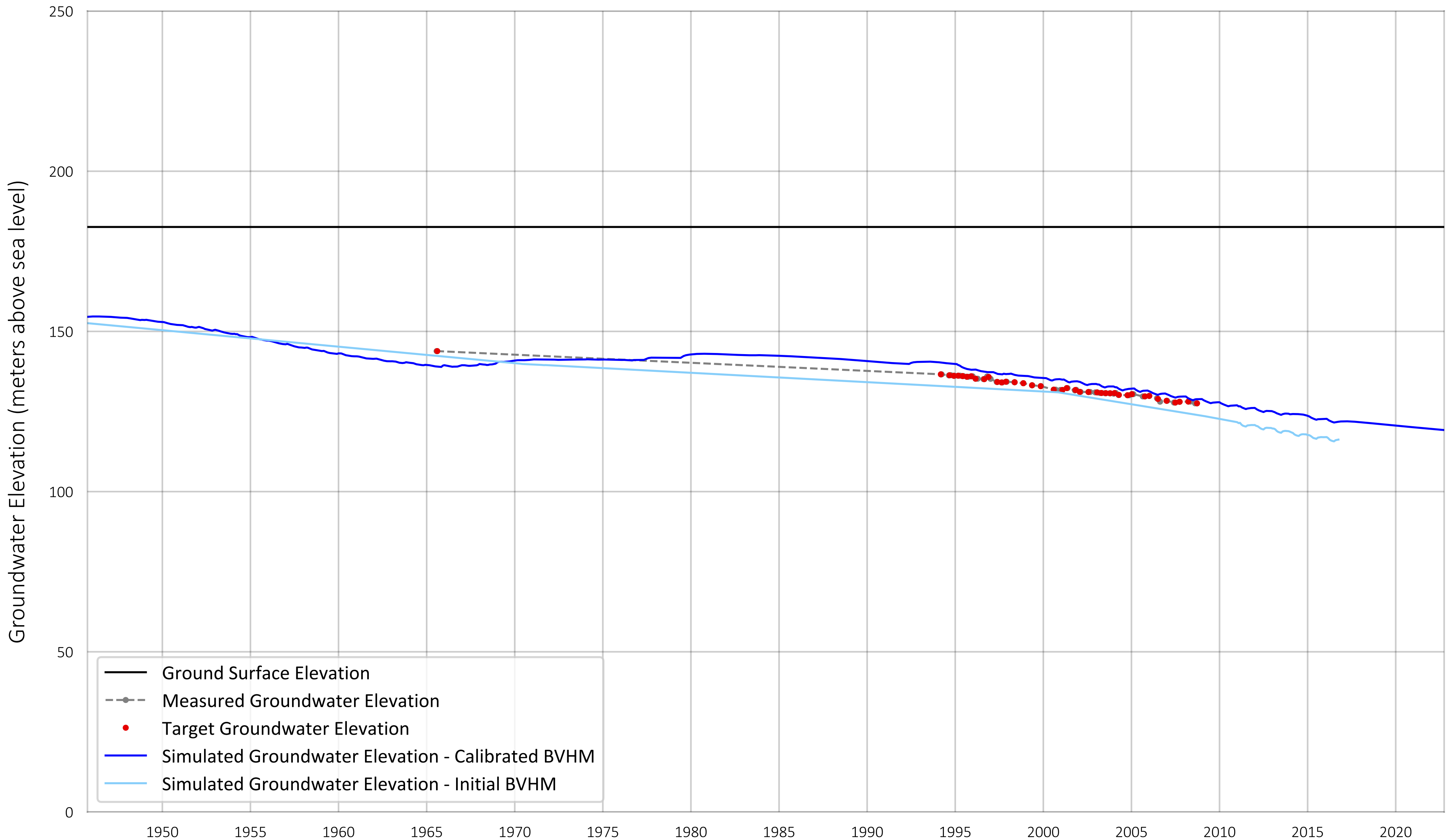
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

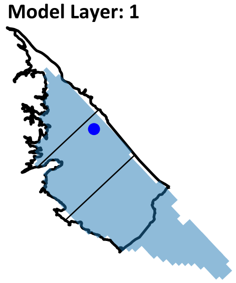
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245868
Well Name: Evans

Figure B-18



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 132.56
Standard Deviation = 3.31

Simulated Groundwater Elevation (m)
Mean = 134.70
Standard Deviation = 3.32

Mean Residual (m) = 2.14
RMSE (m) = 2.50

Prepared by:

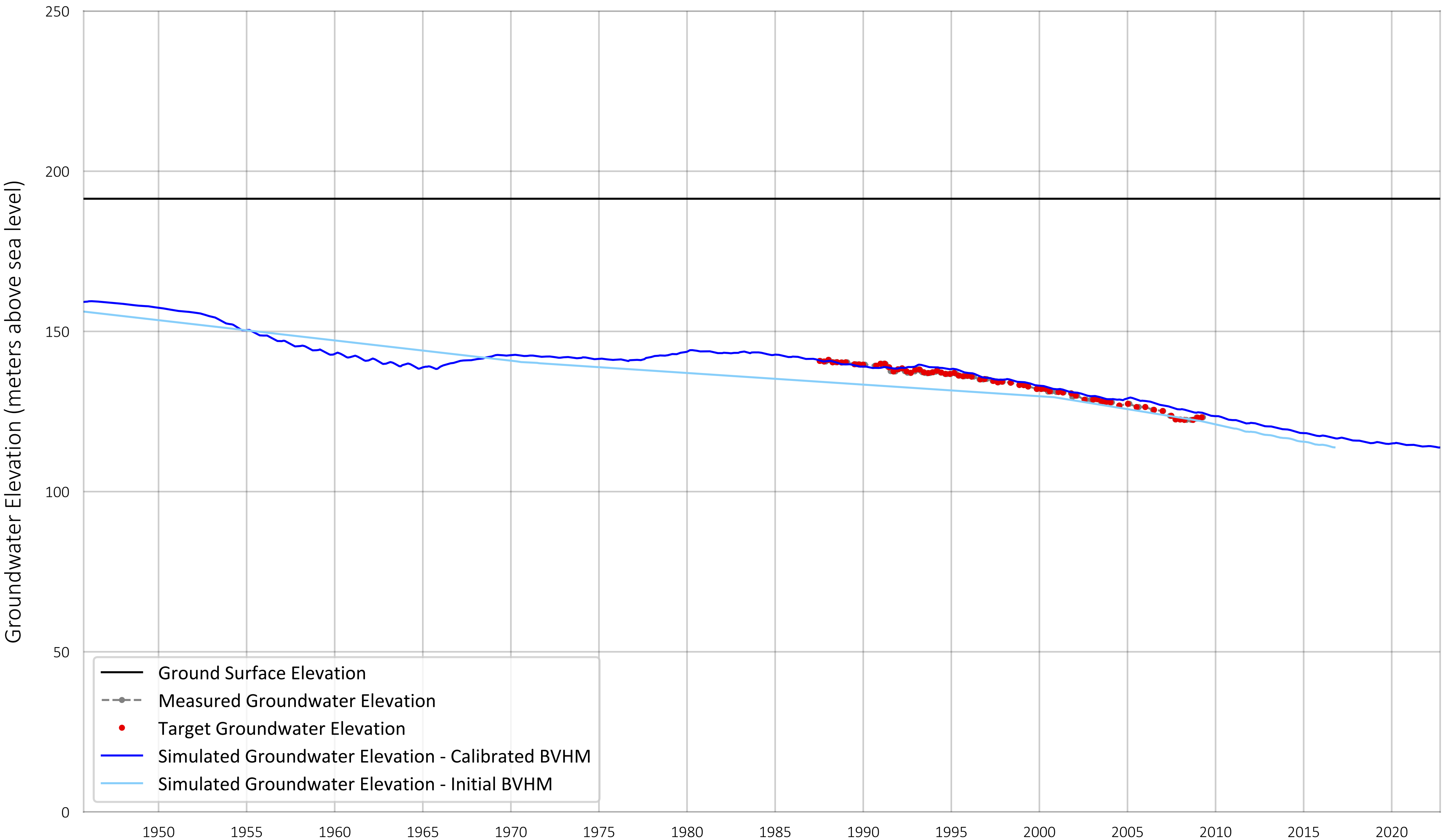
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

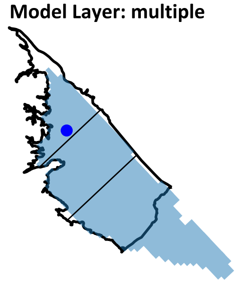
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245906
Well Name: Potato Field

Figure B-19



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 133.49
Standard Deviation = 5.69

Simulated Groundwater Elevation (m)
Mean = 134.49
Standard Deviation = 5.03

Mean Residual (m) = 1.00
RMSE (m) = 1.39

Prepared by:

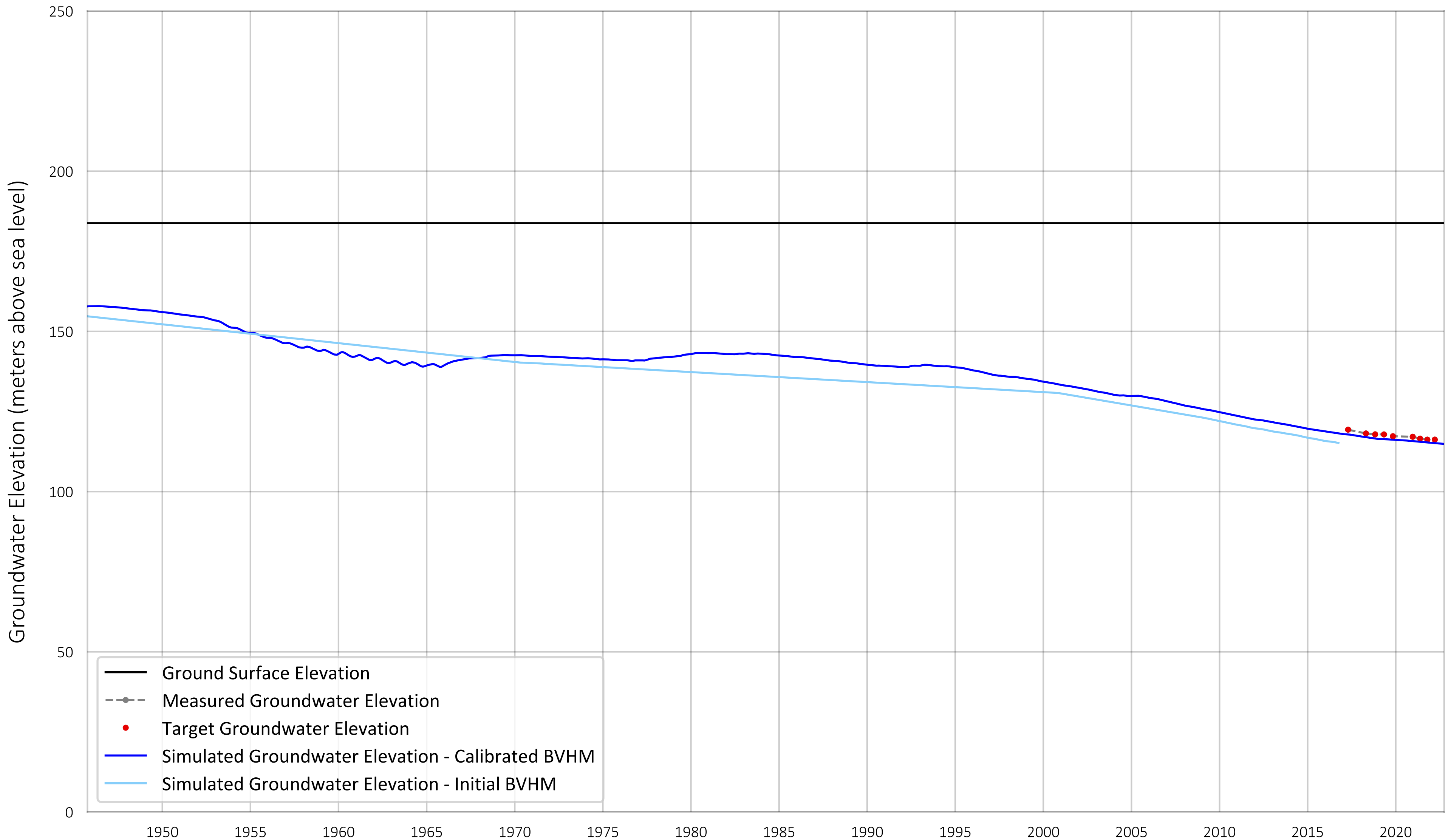
WEST YOST
Water. Engineered.

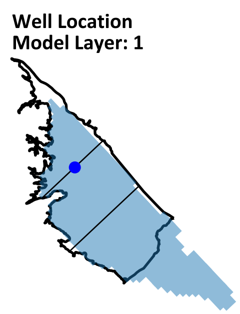
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245867
Well Name: Empty Irrigation

Figure B-20





Statistics

Target Groundwater Elevation (m)
Mean = 117.40
Standard Deviation = 1.02

Simulated Groundwater Elevation (m)
Mean = 116.17
Standard Deviation = 0.89

Mean Residual (m) = -1.22
RMSE (m) = 1.24

Prepared by:

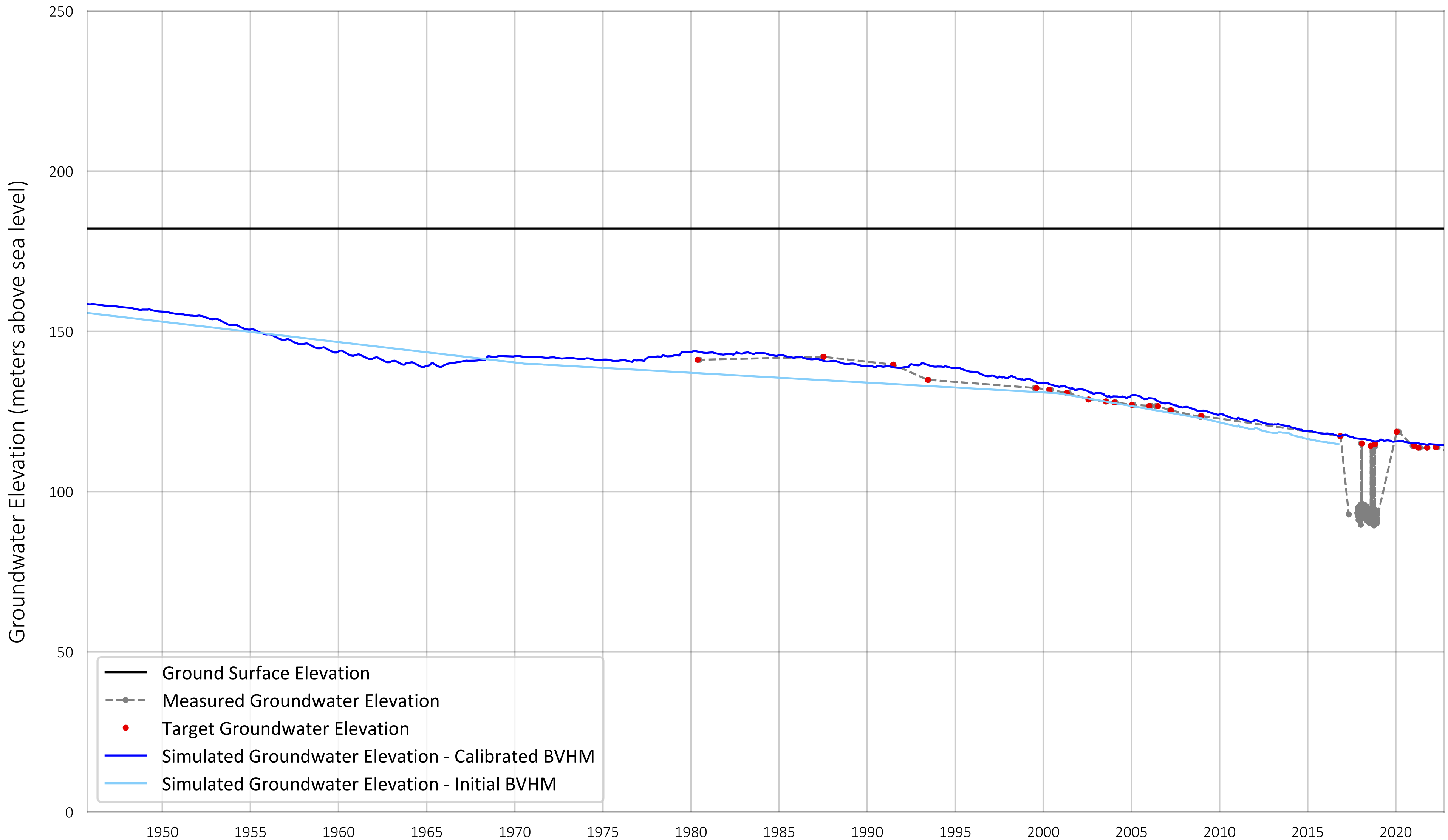
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

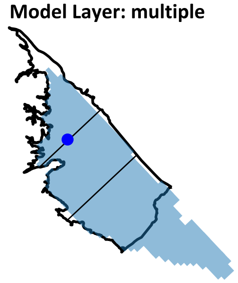
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245930
Well Name: White Well

Figure B-21



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 125.11
Standard Deviation = 9.21

Simulated Groundwater Elevation (m)
Mean = 126.44
Standard Deviation = 9.56

Mean Residual (m) = 1.33
RMSE (m) = 1.98

Prepared by:

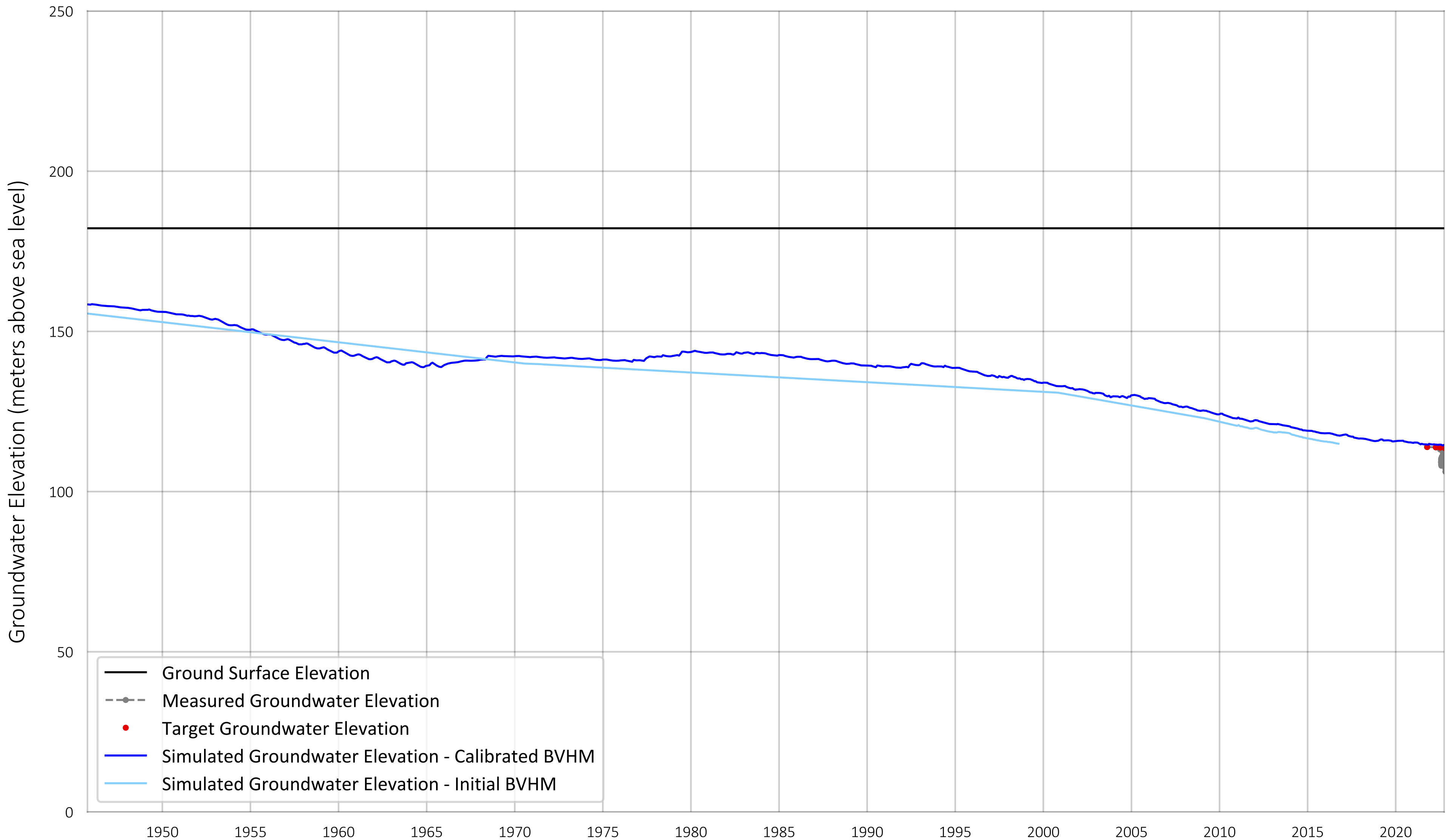
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245889
Well Name: ID4-4

Figure B-22

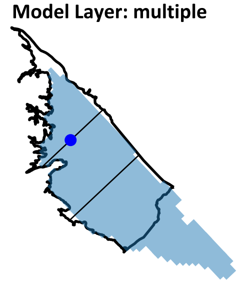


Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 113.81
Standard Deviation = 0.10

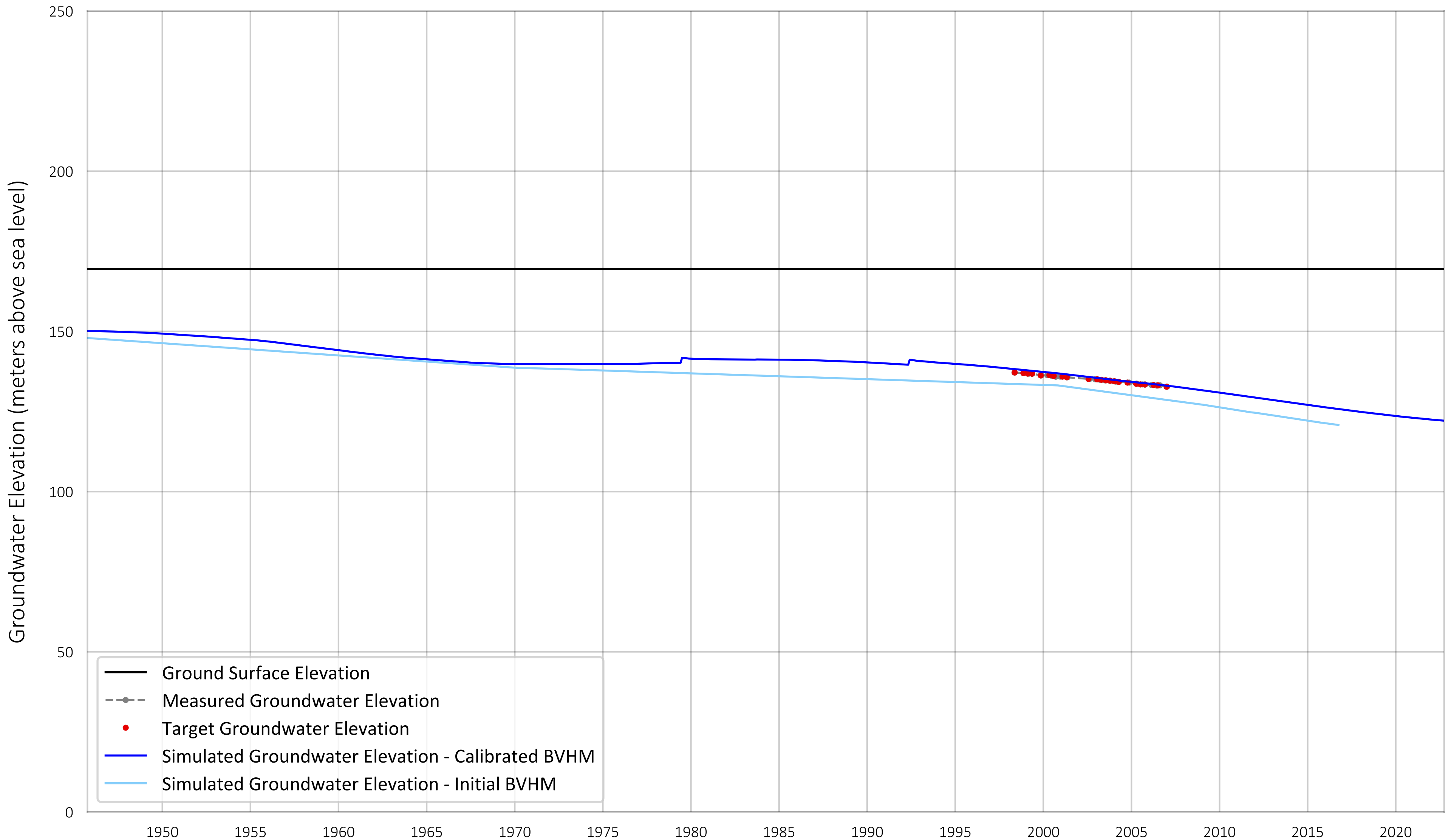
Simulated Groundwater Elevation (m)
Mean = 114.67
Standard Deviation = 0.01

Mean Residual (m) = 0.85
RMSE (m) = 0.86

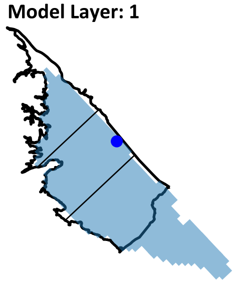
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245891
Well Name: ID4-9

Figure B-23



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 134.99
Standard Deviation = 1.37

Simulated Groundwater Elevation (m)
Mean = 135.63
Standard Deviation = 1.66

Mean Residual (m) = 0.64
RMSE (m) = 0.71

Prepared by:

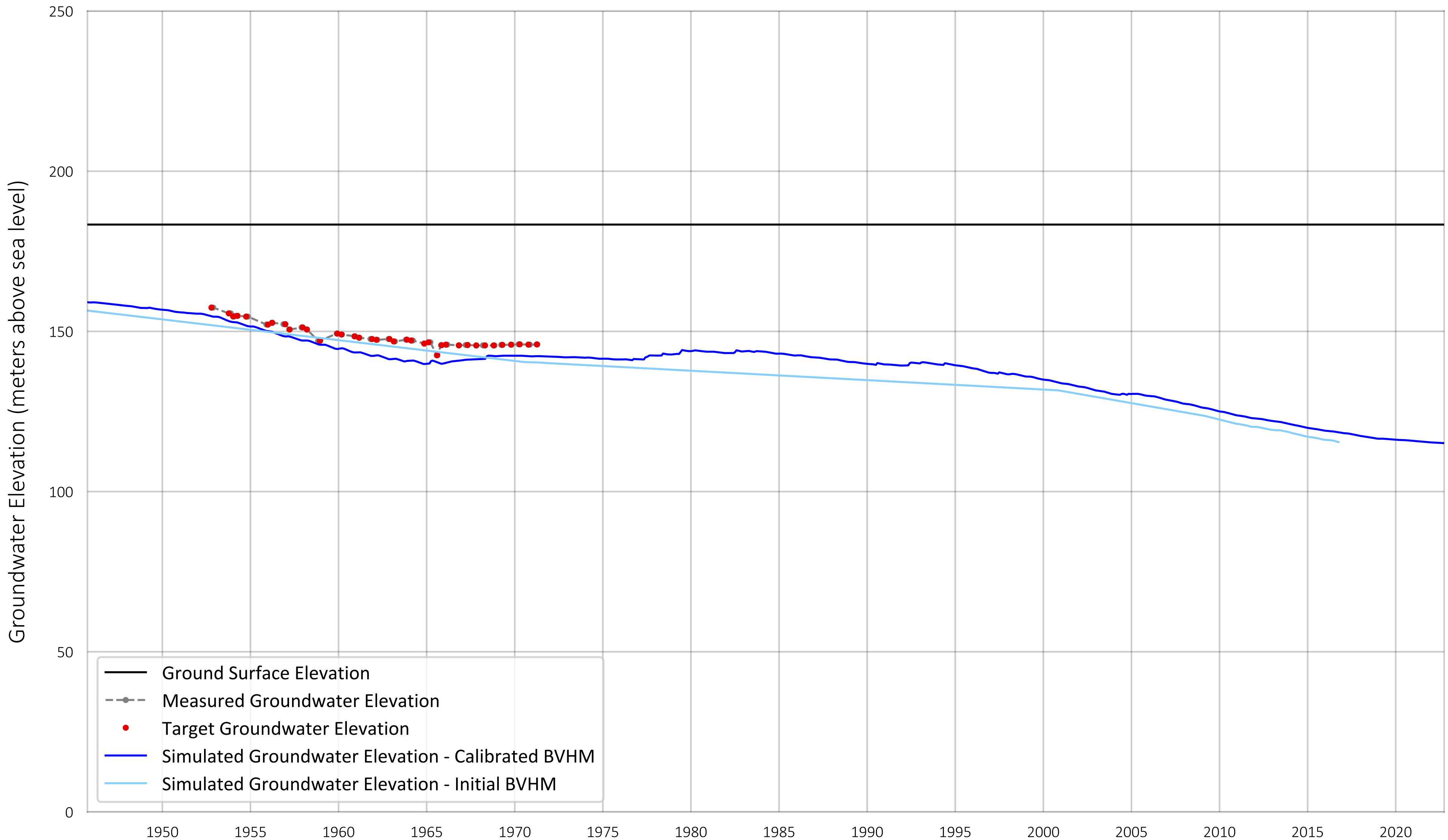
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

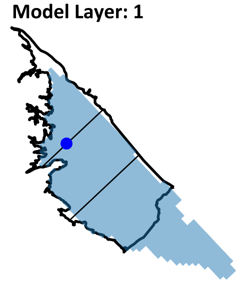
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245872
Well Name: Gray Irrigation

Figure B-24



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 148.58
Standard Deviation = 3.55

Simulated Groundwater Elevation (m)
Mean = 144.51
Standard Deviation = 4.43

Mean Residual (m) = -4.07
RMSE (m) = 4.32

Prepared by:

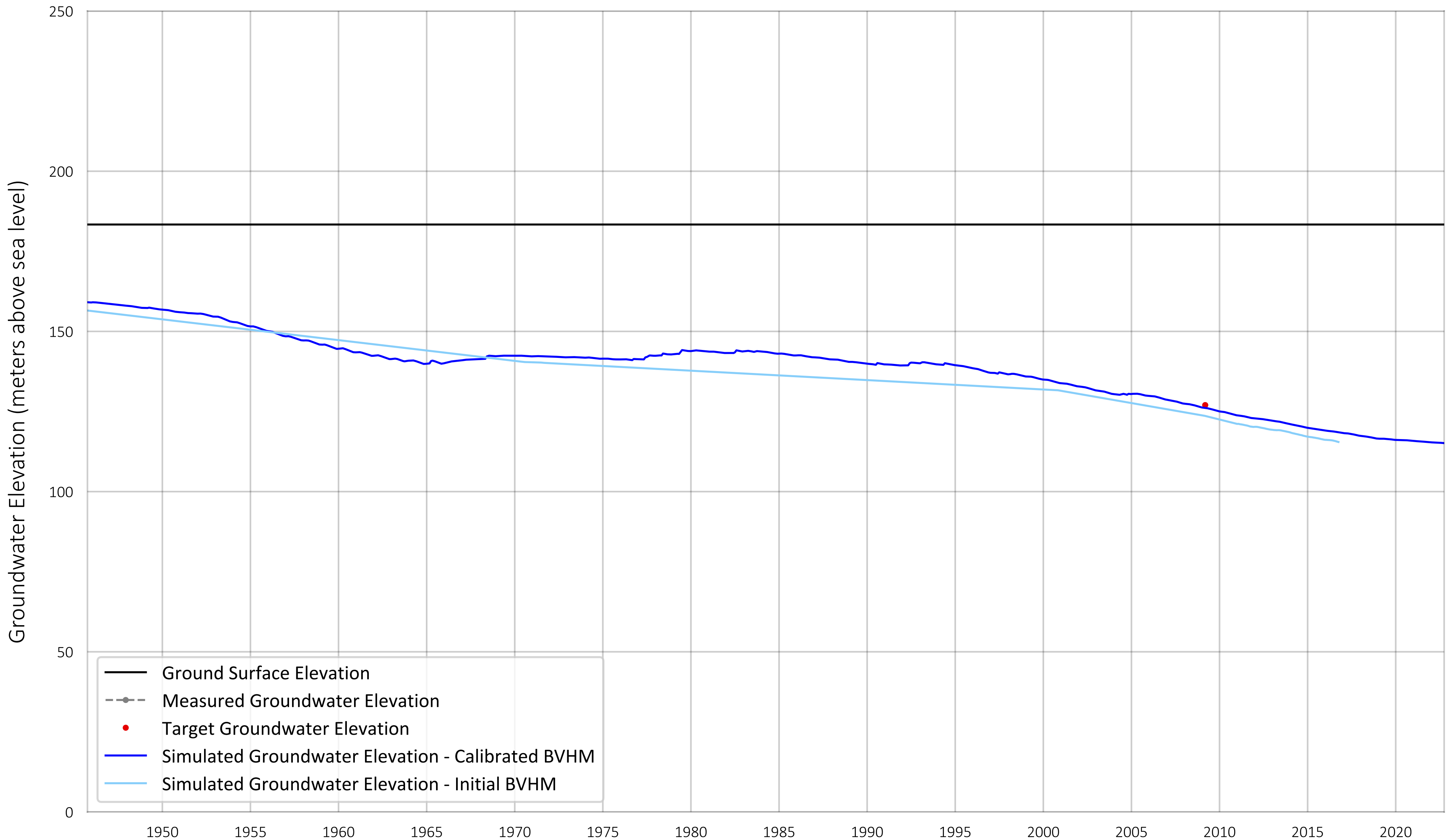
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

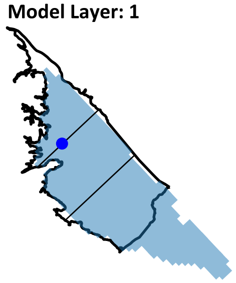
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245824
Well Name: 010S006E29N001S

Figure B-25



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 127.00
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 126.13
Standard Deviation = 0.00

Mean Residual (m) = -0.87
RMSE (m) = 0.87

Prepared by:

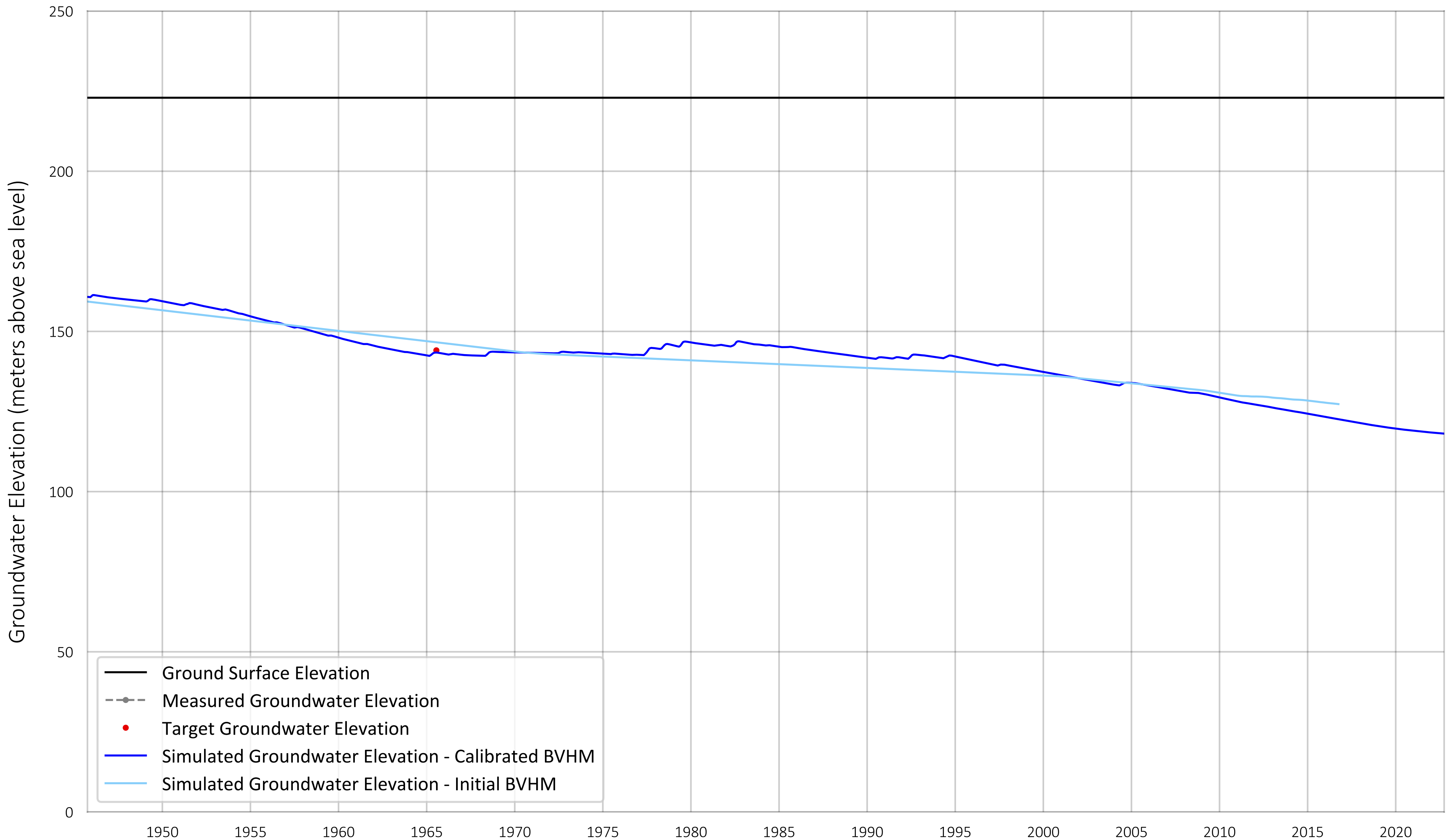
WEST YOST Water. Engineered.

Prepared for: Borrego Springs Watermaster

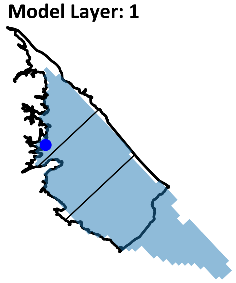
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245905
Well Name: Pecoff 2

Figure B-26



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 144.09
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 143.40
Standard Deviation = 0.00

Mean Residual (m) = -0.68
RMSE (m) = 0.68

Prepared by:

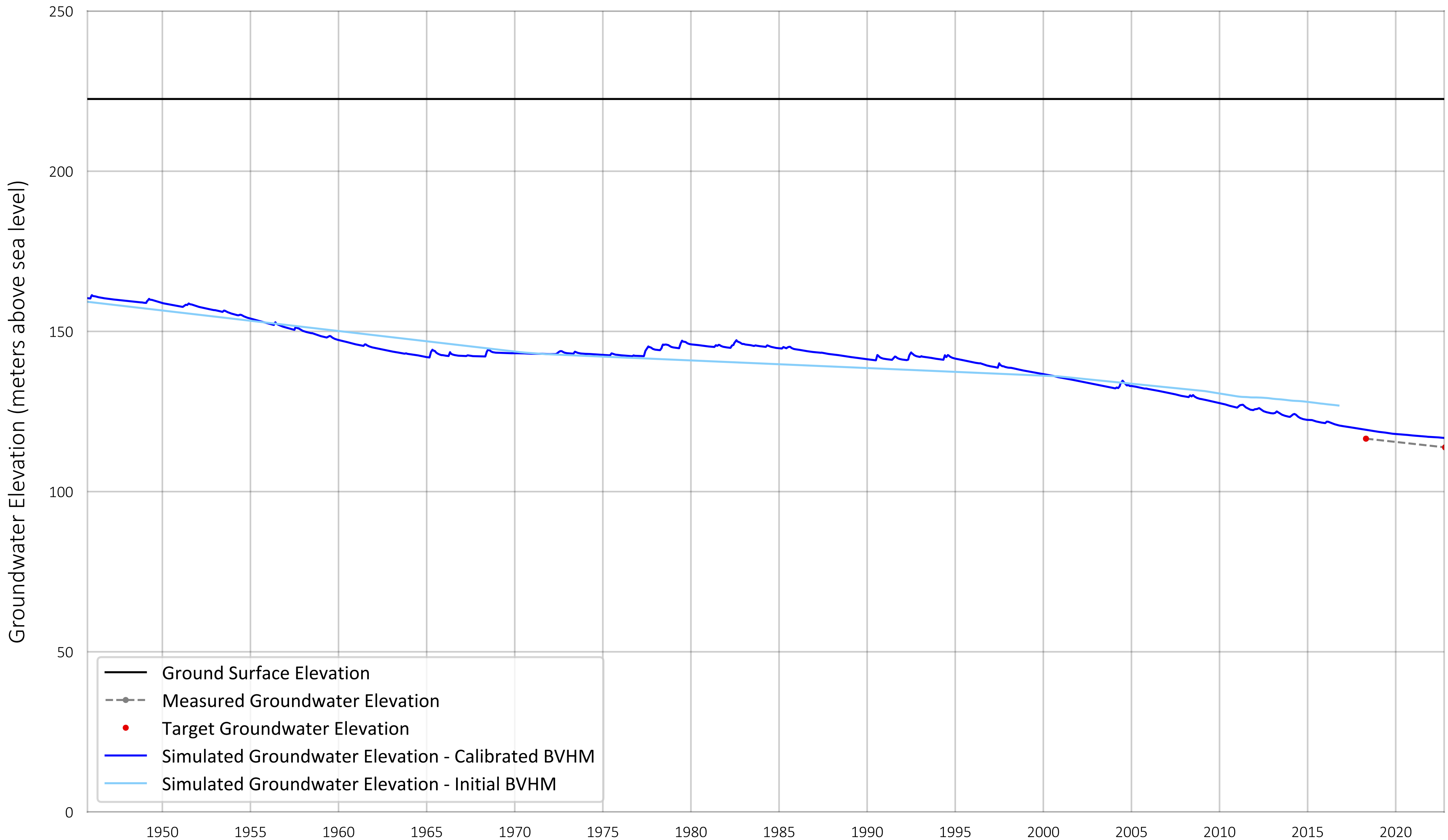
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

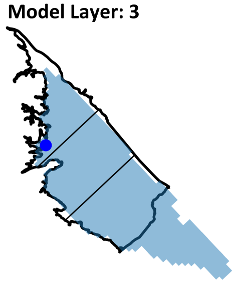
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245922
Well Name: Auxiliary 2

Figure B-27



Well Location
Model Layer: 3



Statistics

Target Groundwater Elevation (m)
Mean = 116.52
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 119.28
Standard Deviation = 0.00

Mean Residual (m) = 2.76
RMSE (m) = 2.76

Prepared by:

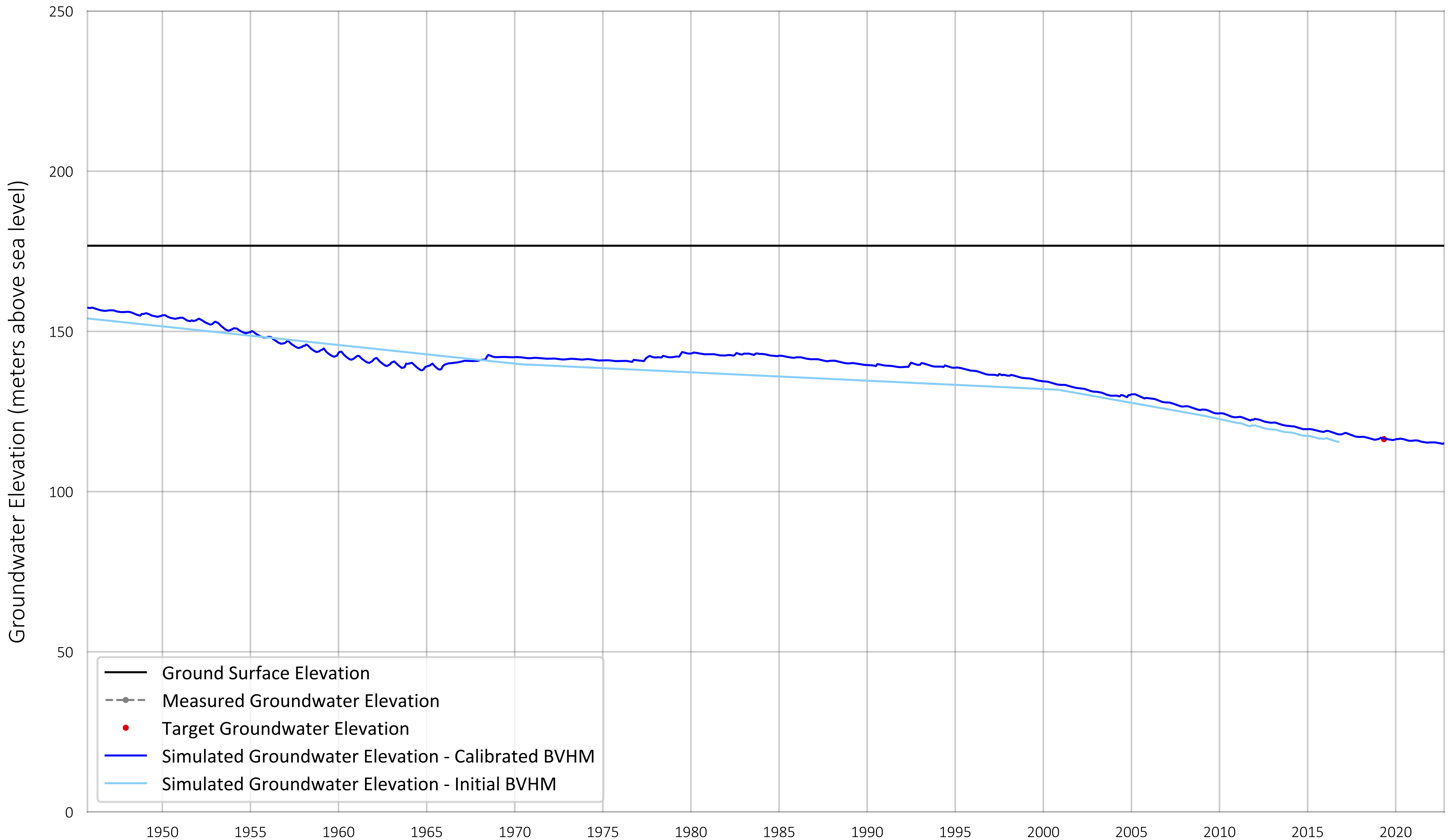
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

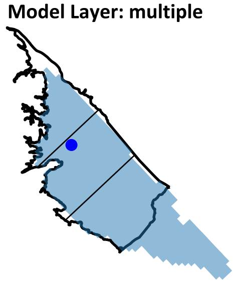
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245924
Well Name: Auxiliary 3

Figure B-28



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 116.39
Standard Deviation = 0.00

Simulated Groundwater Elevation (m)
Mean = 116.57
Standard Deviation = 0.00

Mean Residual (m) = 0.18
RMSE (m) = 0.18

Calibrated BVHM Groundwater Elevation

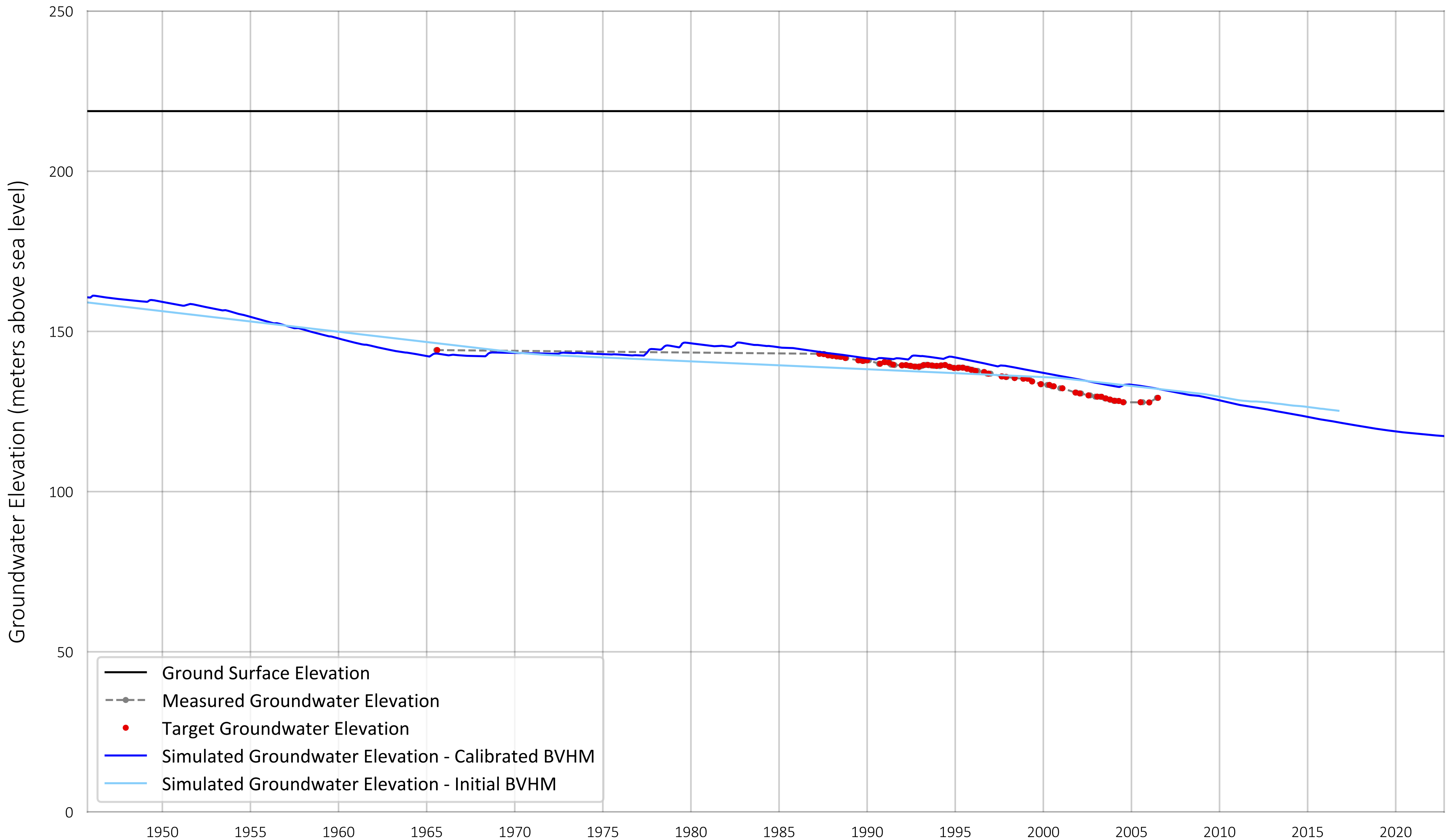
HydroDaVE Well ID: 1245948
Well Name: The Springs

Figure B-29

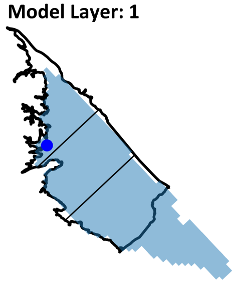
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 136.58
Standard Deviation = 4.81

Simulated Groundwater Elevation (m)
Mean = 139.29
Standard Deviation = 3.63

Mean Residual (m) = 2.71
RMSE (m) = 3.04

Prepared by:

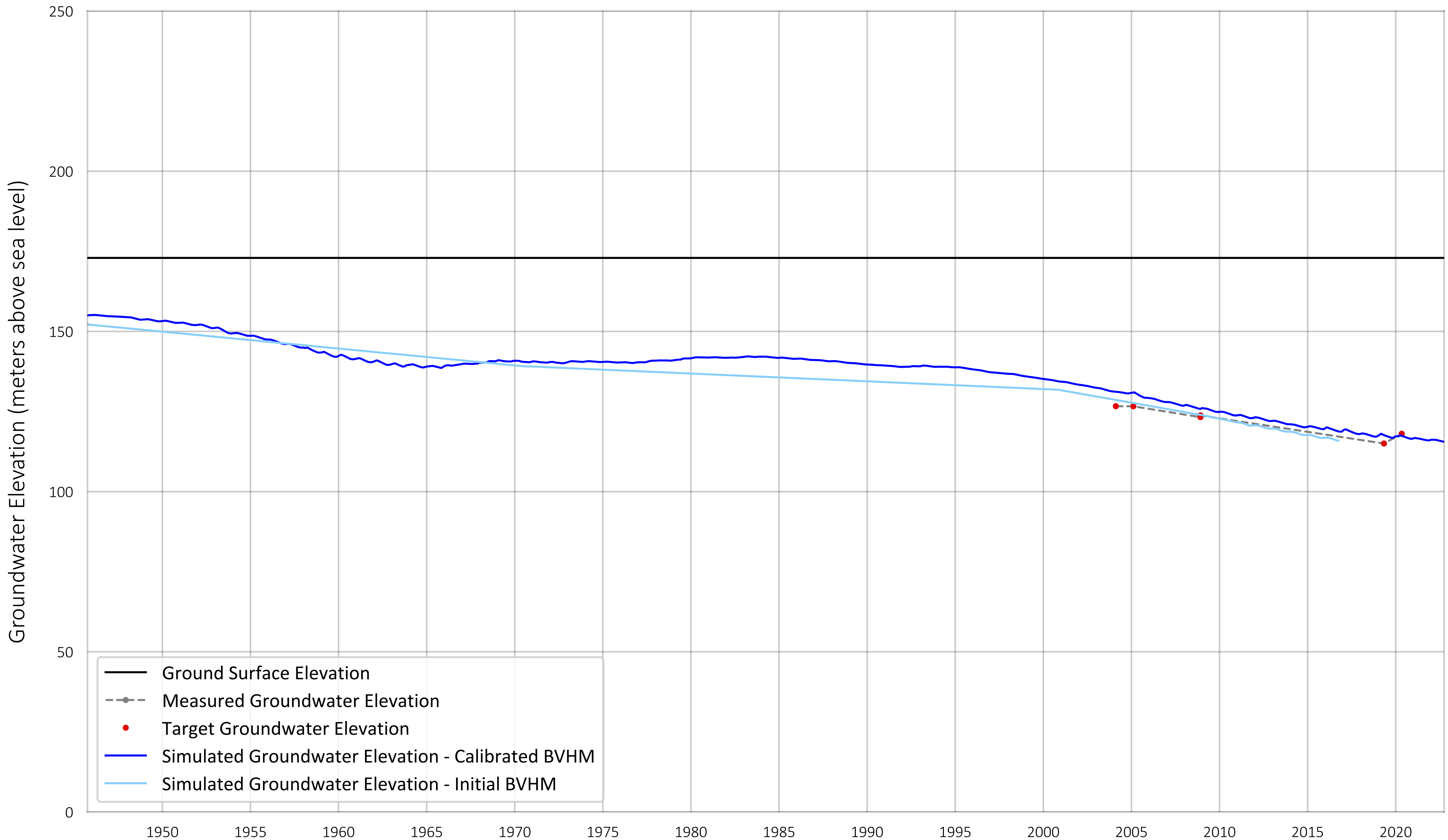
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

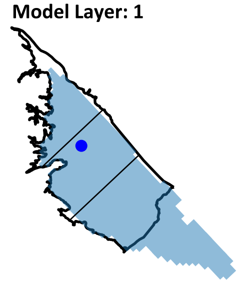
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245923
Well Name: Auxiliary 1

Figure B-30



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 122.22
Standard Deviation = 4.73

Simulated Groundwater Elevation (m)
Mean = 124.79
Standard Deviation = 6.11

Mean Residual (m) = 2.57
RMSE (m) = 3.09

Prepared by:

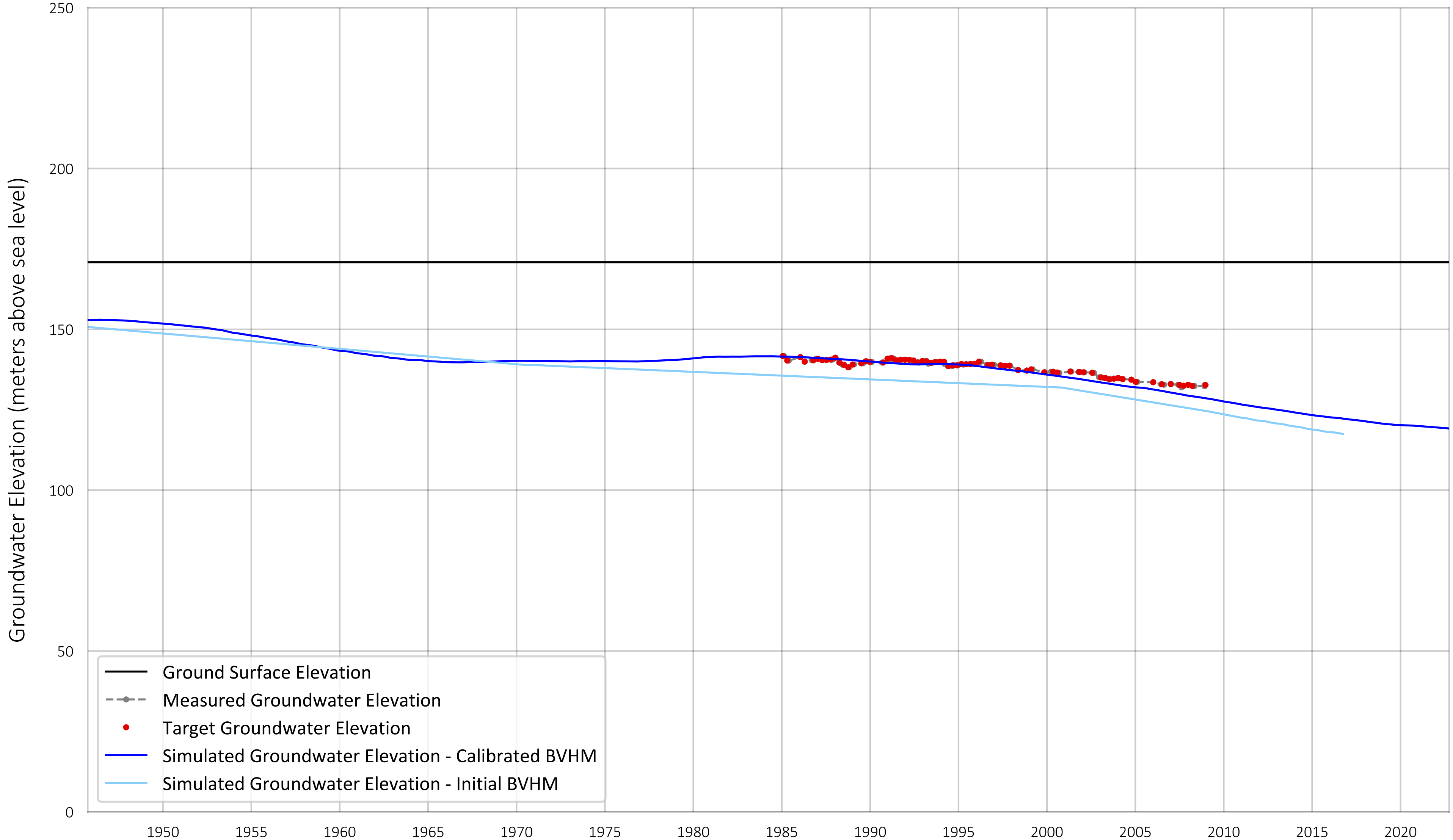
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

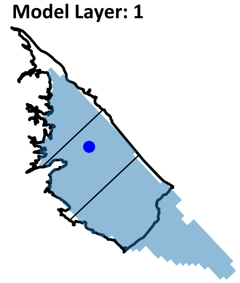
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245921
Well Name: Springs 2

Figure B-31



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 138.04
Standard Deviation = 2.69

Simulated Groundwater Elevation (m)
Mean = 137.18
Standard Deviation = 3.69

Mean Residual (m) = -0.86
RMSE (m) = 1.52

Prepared by:

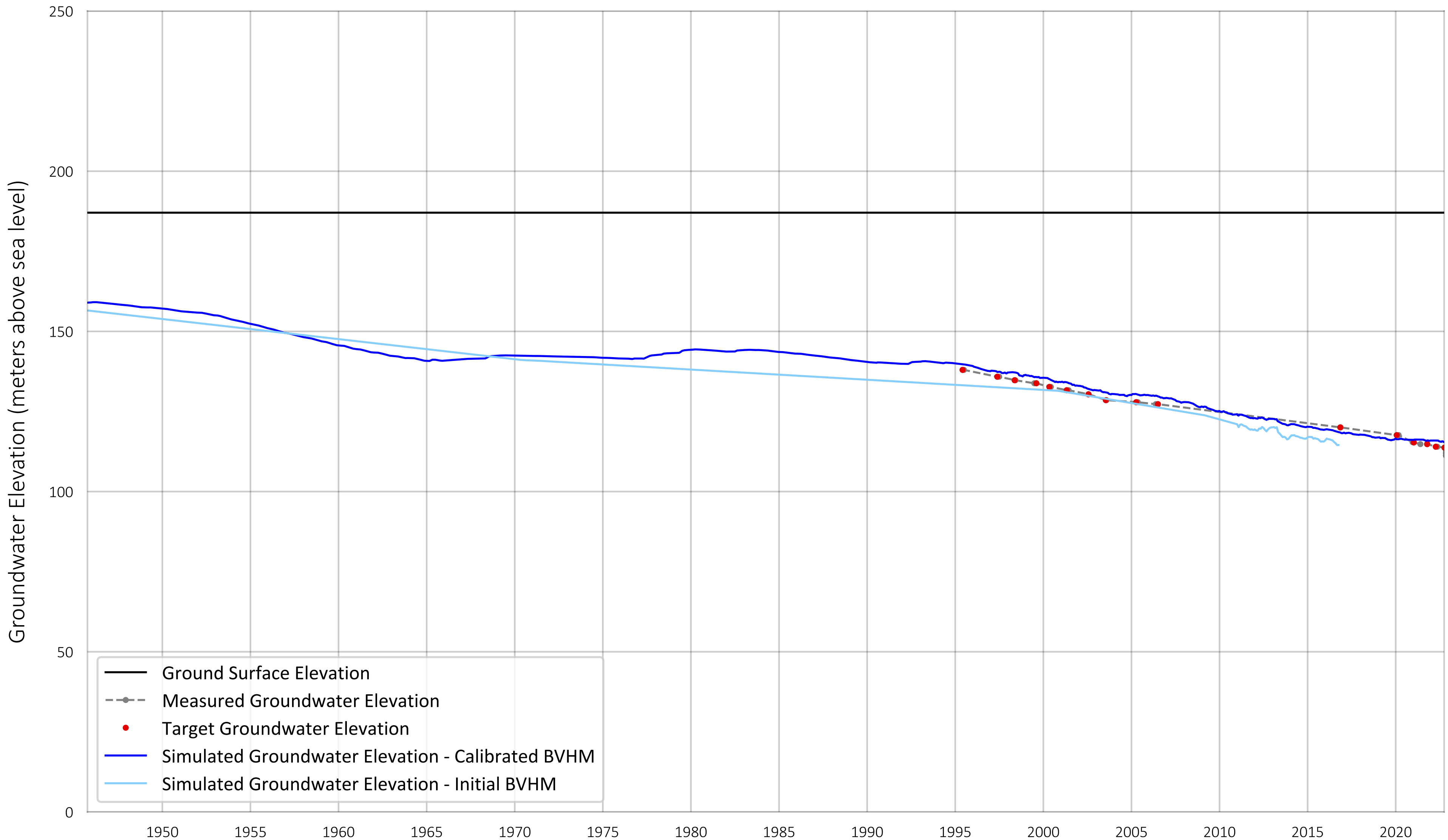
WEST YOST
Water. Engineered.

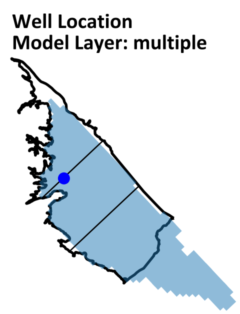
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245927
Well Name: UEC North

Figure B-32





Statistics

Target Groundwater Elevation (m)
Mean = 126.85
Standard Deviation = 8.30

Simulated Groundwater Elevation (m)
Mean = 128.36
Standard Deviation = 9.06

Mean Residual (m) = 1.51
RMSE (m) = 1.97

Prepared by:

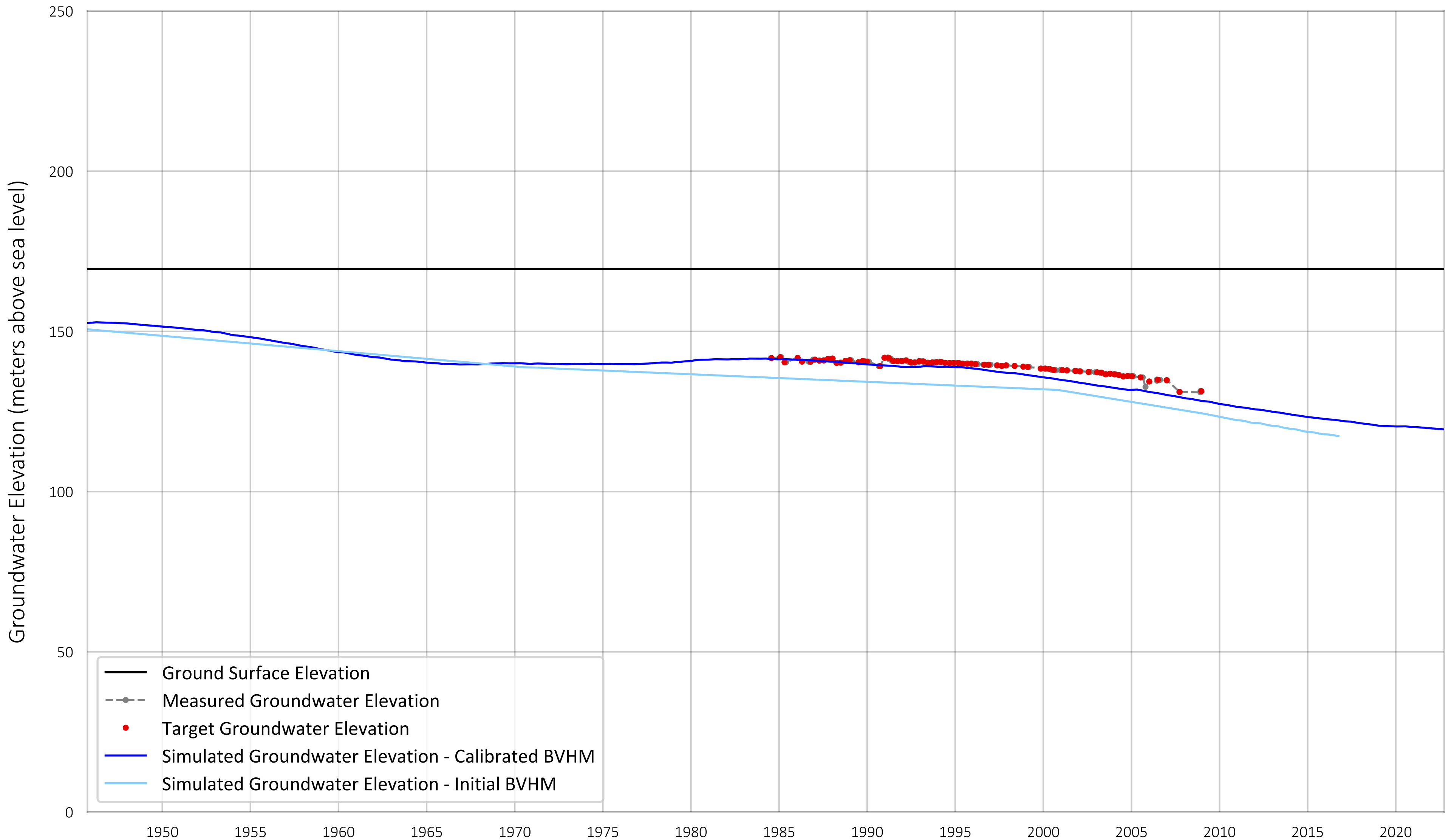
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

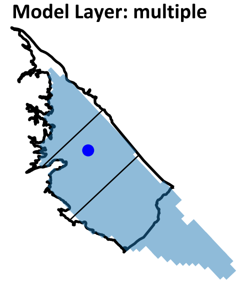
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245885
Well Name: ID4-11

Figure B-33



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 139.09
Standard Deviation = 2.31

Simulated Groundwater Elevation (m)
Mean = 137.14
Standard Deviation = 3.46

Mean Residual (m) = -1.95
RMSE (m) = 2.41

Calibrated BVHM Groundwater Elevation

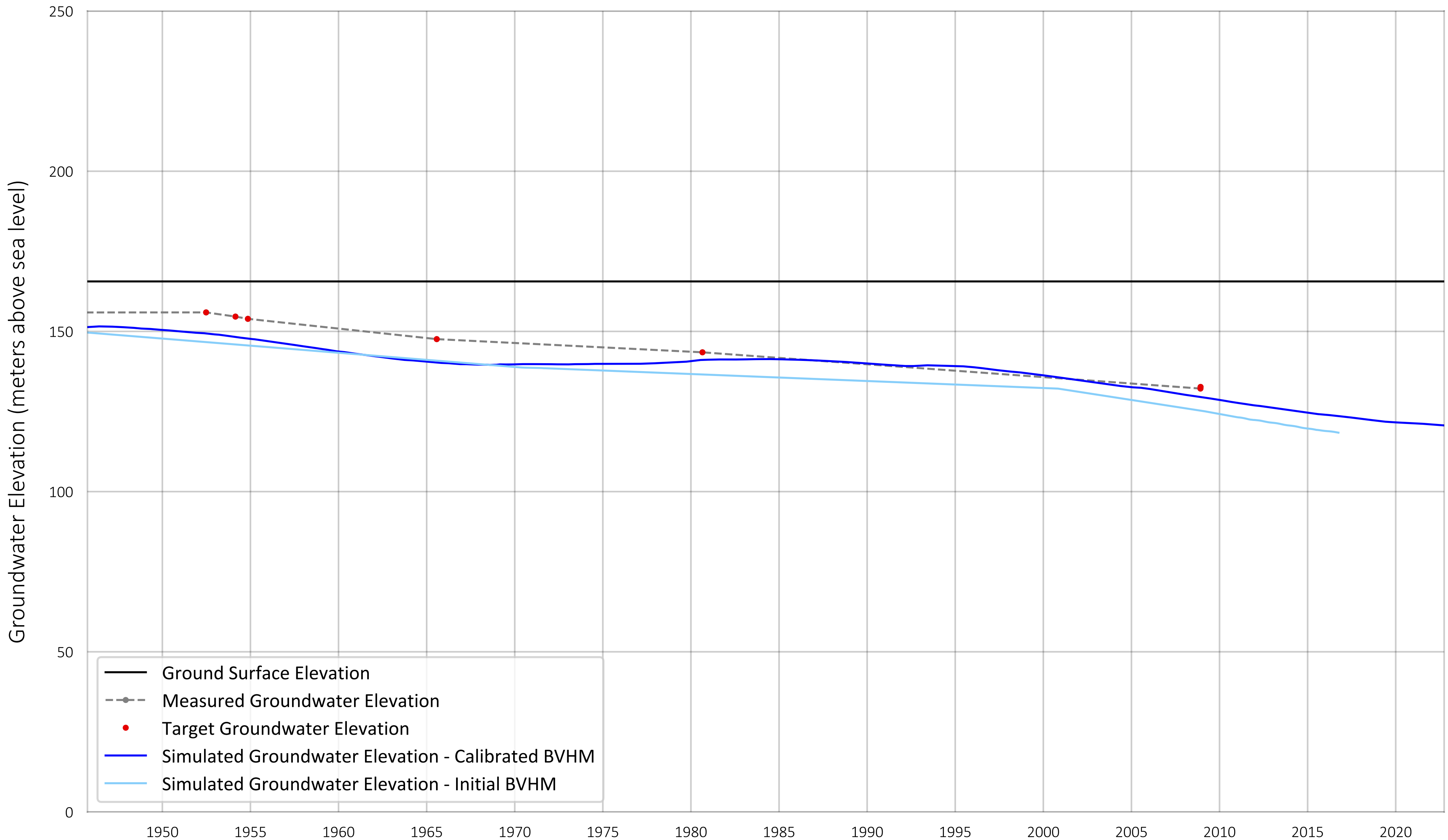
HydroDaVE Well ID: 1245928
Well Name: UEC South

Figure B-34

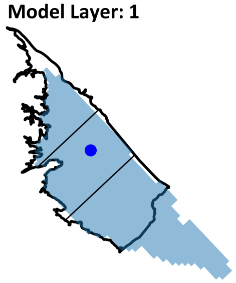
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 145.77
Standard Deviation = 10.11

Simulated Groundwater Elevation (m)
Mean = 140.82
Standard Deviation = 8.50

Mean Residual (m) = -4.95
RMSE (m) = 5.32

Prepared by:

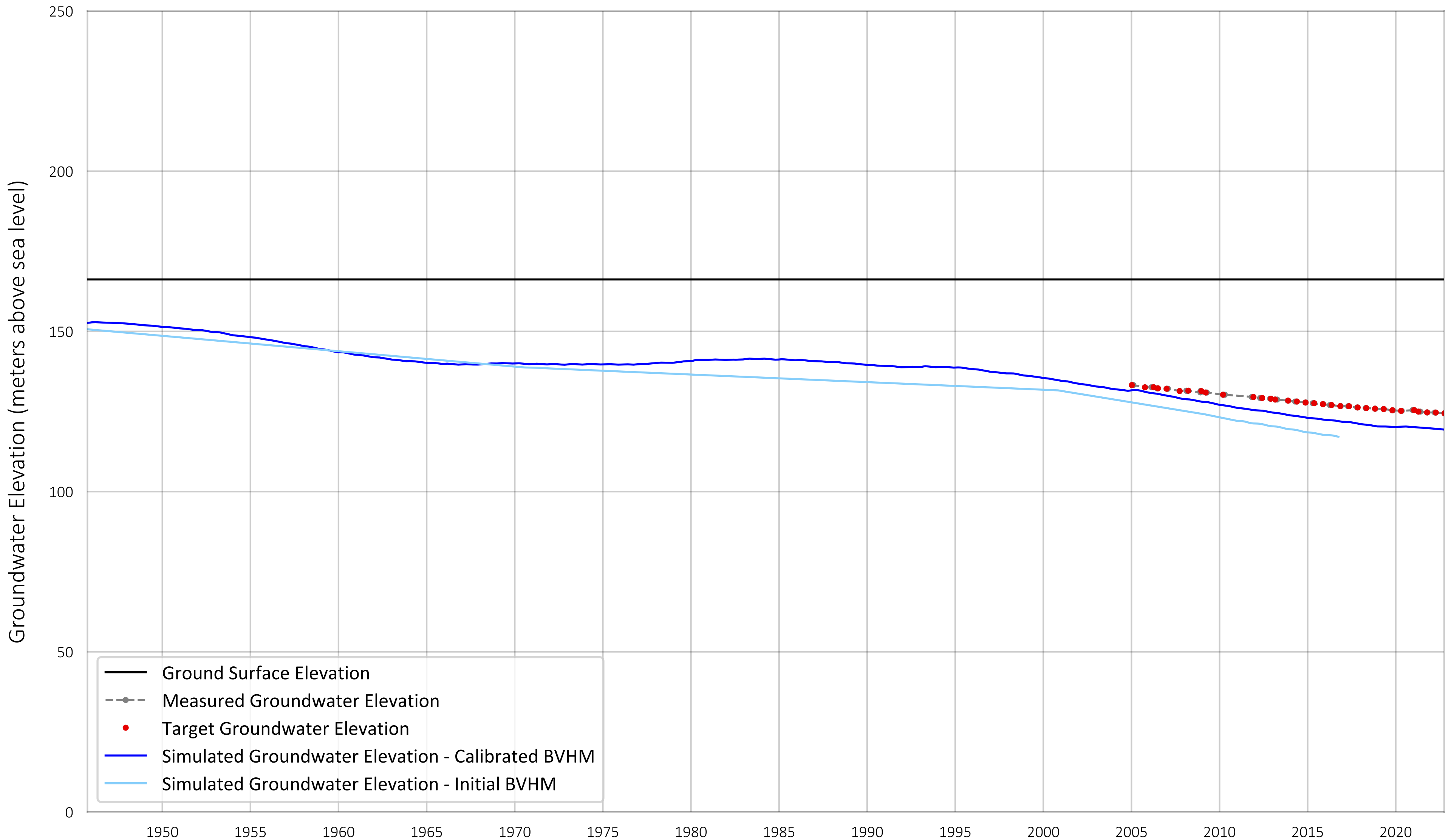
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

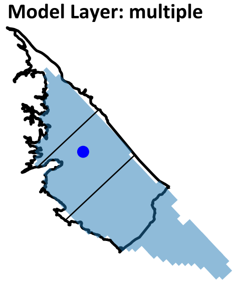
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245907
Well Name: Redimix Plant

Figure B-35



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 128.39
Standard Deviation = 2.71

Simulated Groundwater Elevation (m)
Mean = 124.36
Standard Deviation = 3.93

Mean Residual (m) = -4.03
RMSE (m) = 4.21

Prepared by:

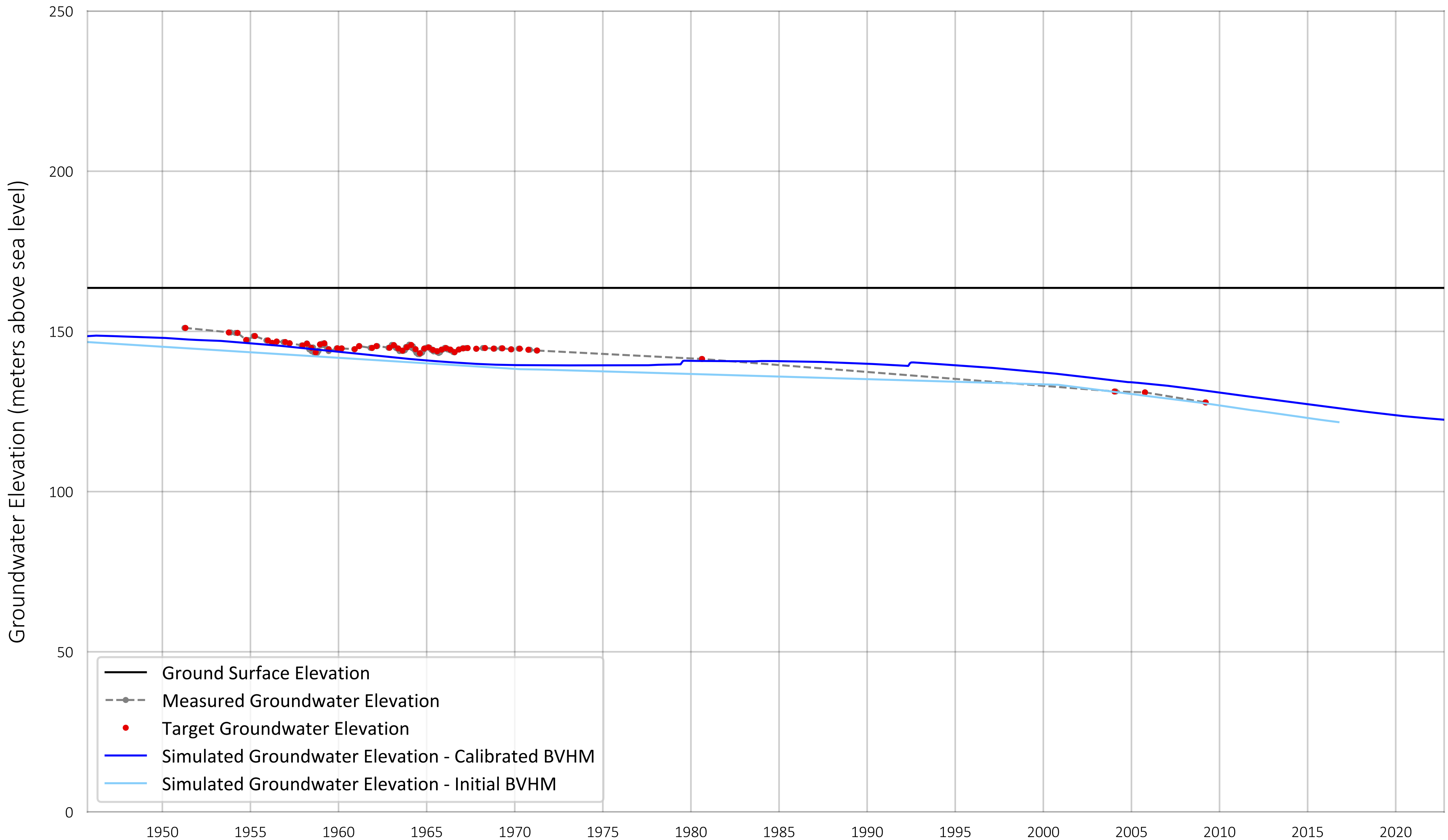
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

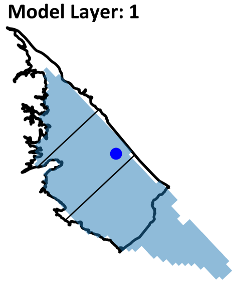
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245904
Well Name: Palleson

Figure B-36



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 144.44
Standard Deviation = 3.91

Simulated Groundwater Elevation (m)
Mean = 141.94
Standard Deviation = 3.17

Mean Residual (m) = -2.50
RMSE (m) = 3.24

Calibrated BVHM Groundwater Elevation

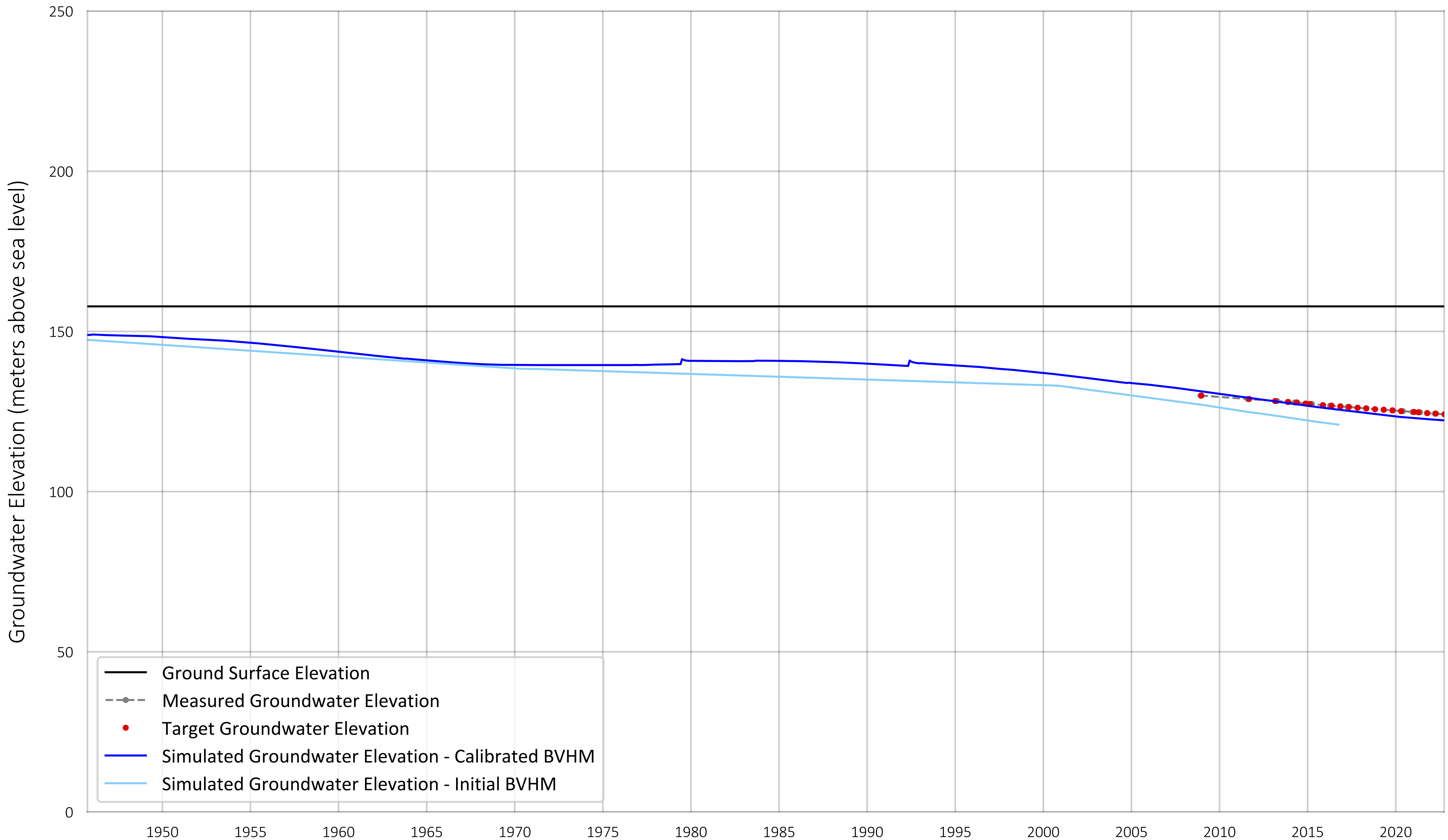
HydroDaVE Well ID: 1245874
Well Name: Hawkins

Figure B-37

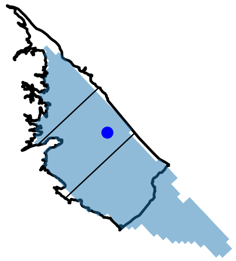
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 126.51
Standard Deviation = 1.52

Simulated Groundwater Elevation (m)
Mean = 125.47
Standard Deviation = 2.36

Mean Residual (m) = -1.05
RMSE (m) = 1.34

Prepared by:

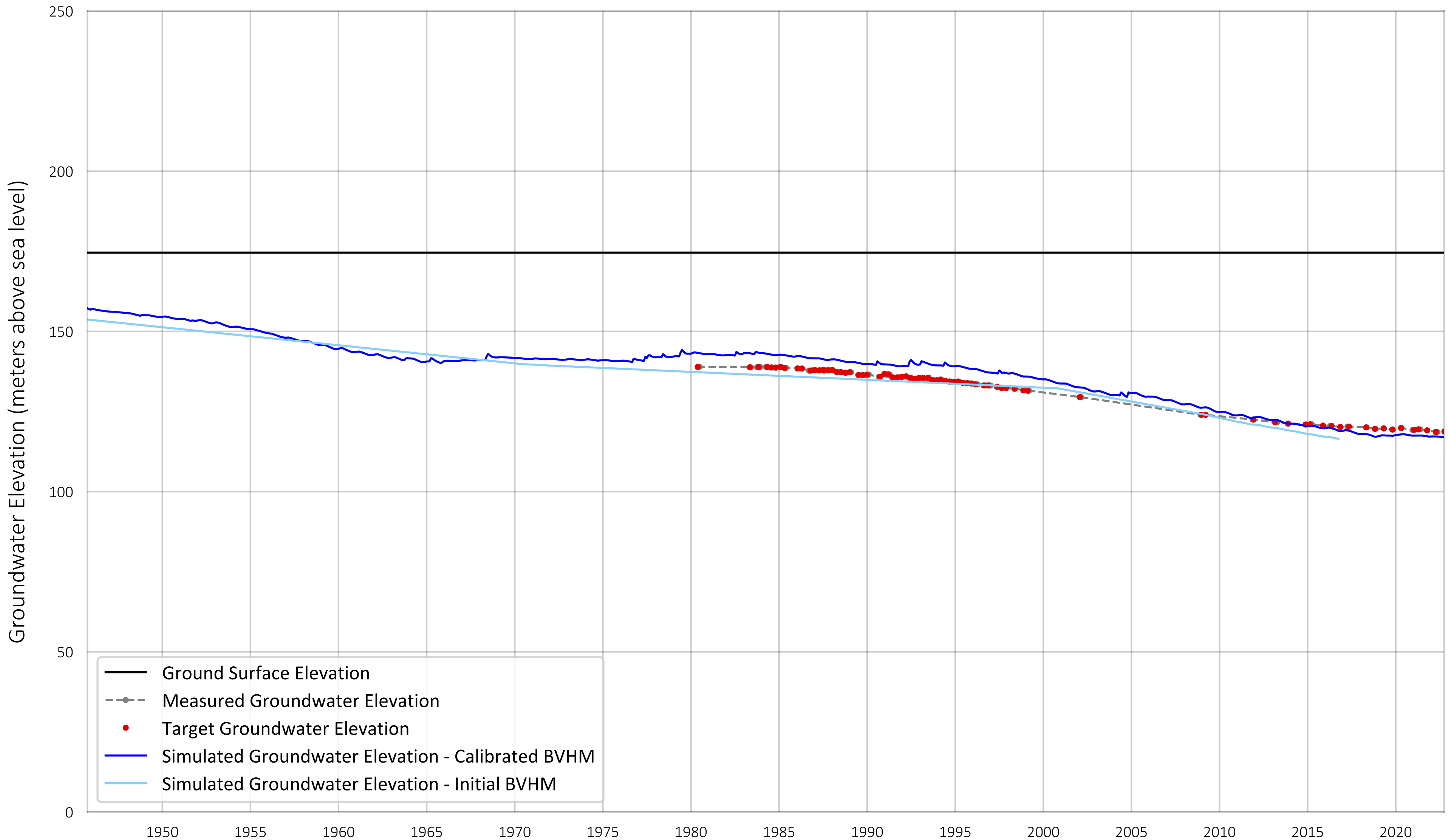
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

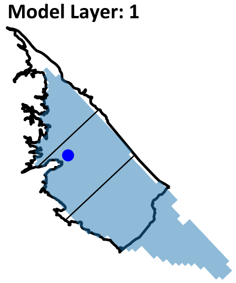
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245899
Well Name: MW-4

Figure B-38



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 131.73
Standard Deviation = 7.08

Simulated Groundwater Elevation (m)
Mean = 134.52
Standard Deviation = 9.26

Mean Residual (m) = 2.79
RMSE (m) = 3.65

Calibrated BVHM Groundwater Elevation

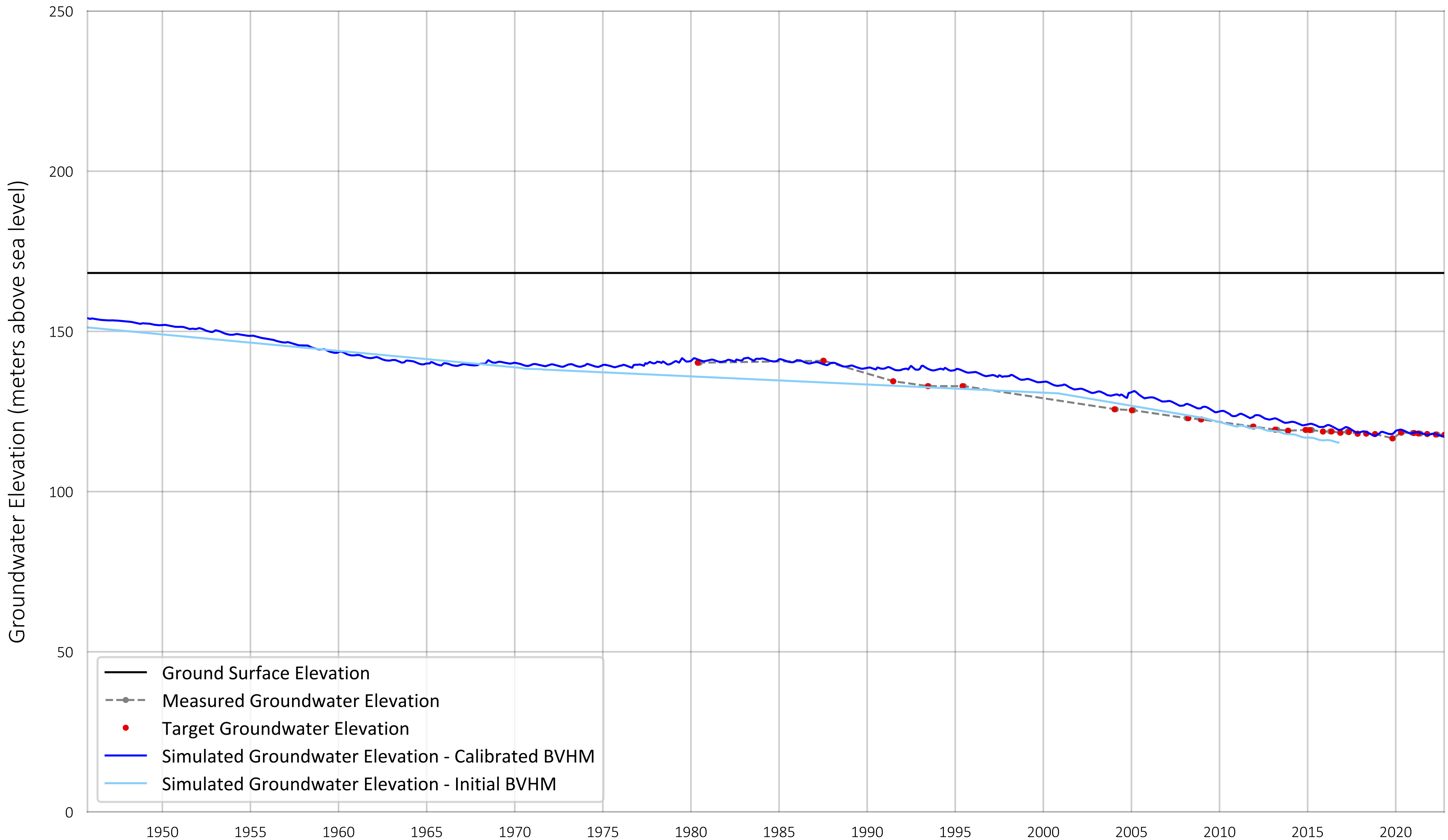
HydroDaVE Well ID: 1245883
Well Name: ID4-1

Figure B-39

Prepared by:

WEST YOST
Water. Engineered.

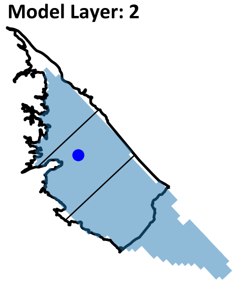
Prepared for: Borrego Springs Watermaster



Prepared by:

WEST YOST Water. Engineered.

Prepared for: Borrego Springs Watermaster



Statistics

Target Groundwater Elevation (m)
Mean = 122.63
Standard Deviation = 7.14

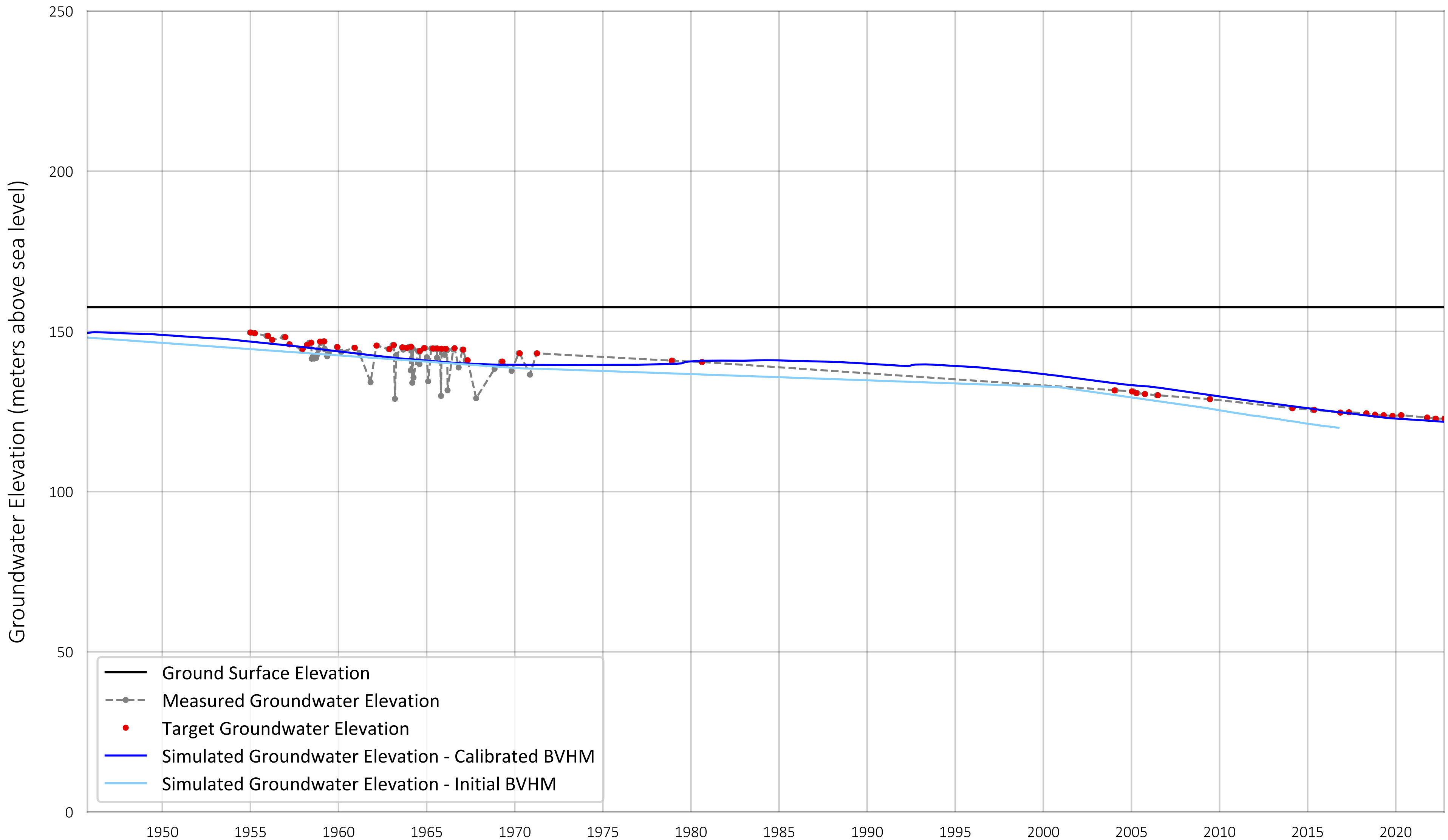
Simulated Groundwater Elevation (m)
Mean = 124.59
Standard Deviation = 7.91

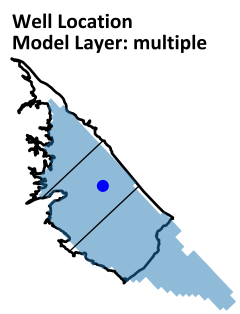
Mean Residual (m) = 1.96
RMSE (m) = 2.72

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245890
Well Name: ID4-5

Figure B-40





Statistics

Target Groundwater Elevation (m)
Mean = 138.71
Standard Deviation = 9.27

Simulated Groundwater Elevation (m)
Mean = 137.19
Standard Deviation = 8.15

Mean Residual (m) = -1.52
RMSE (m) = 2.49

Prepared by:

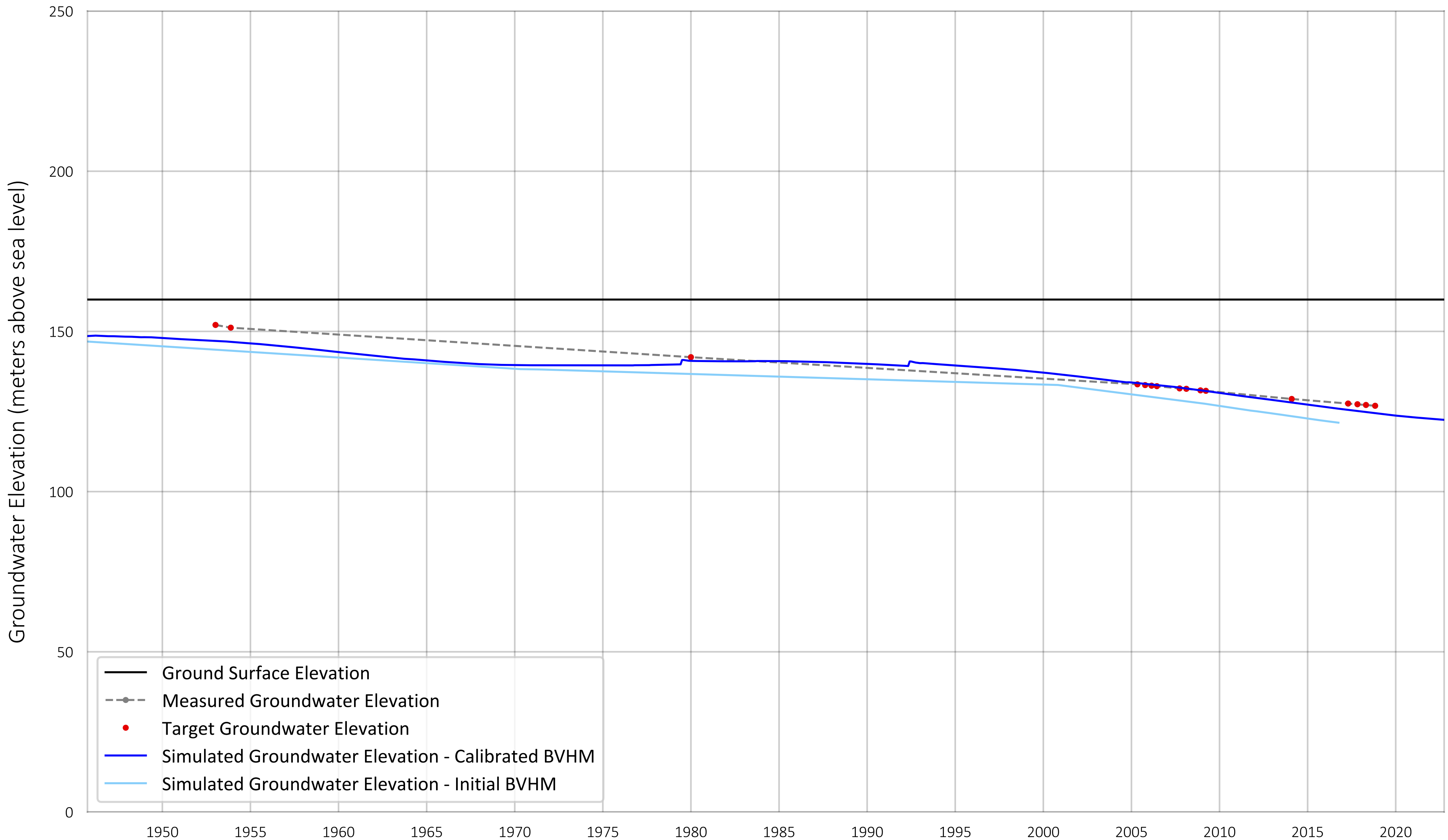
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

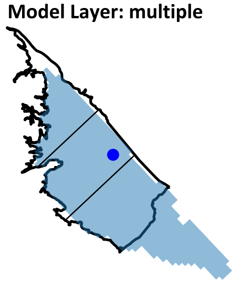
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245851
Well Name: Airport 2

Figure B-41



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 133.92
Standard Deviation = 7.83

Simulated Groundwater Elevation (m)
Mean = 132.77
Standard Deviation = 7.02

Mean Residual (m) = -1.15
RMSE (m) = 2.03

Prepared by:

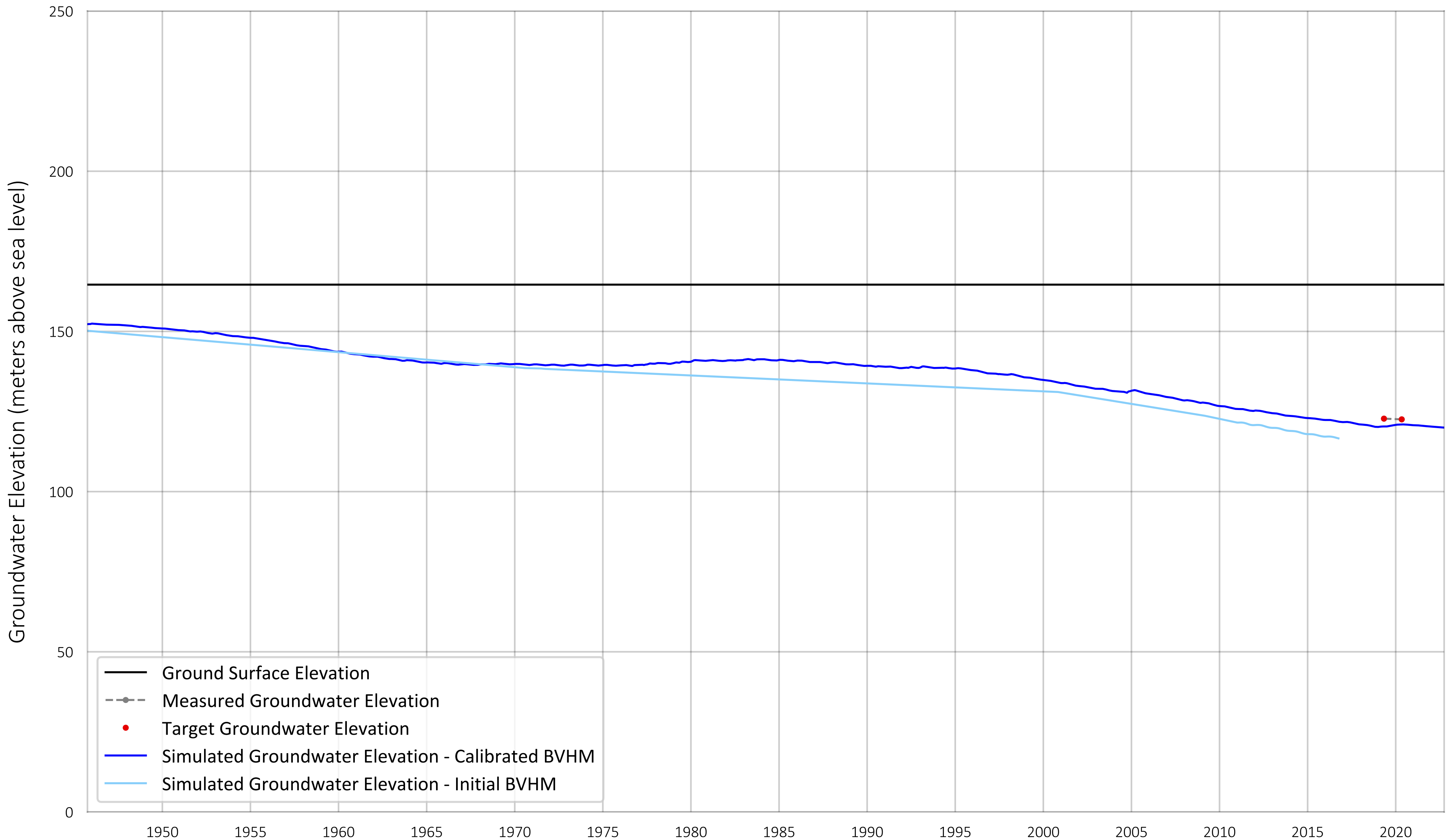
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

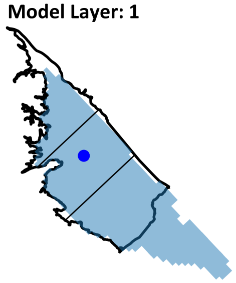
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245870
Well Name: Gabrych #2

Figure B-42



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 122.66
Standard Deviation = 0.16

Simulated Groundwater Elevation (m)
Mean = 120.64
Standard Deviation = 0.46

Mean Residual (m) = -2.02
RMSE (m) = 2.06

Prepared by:

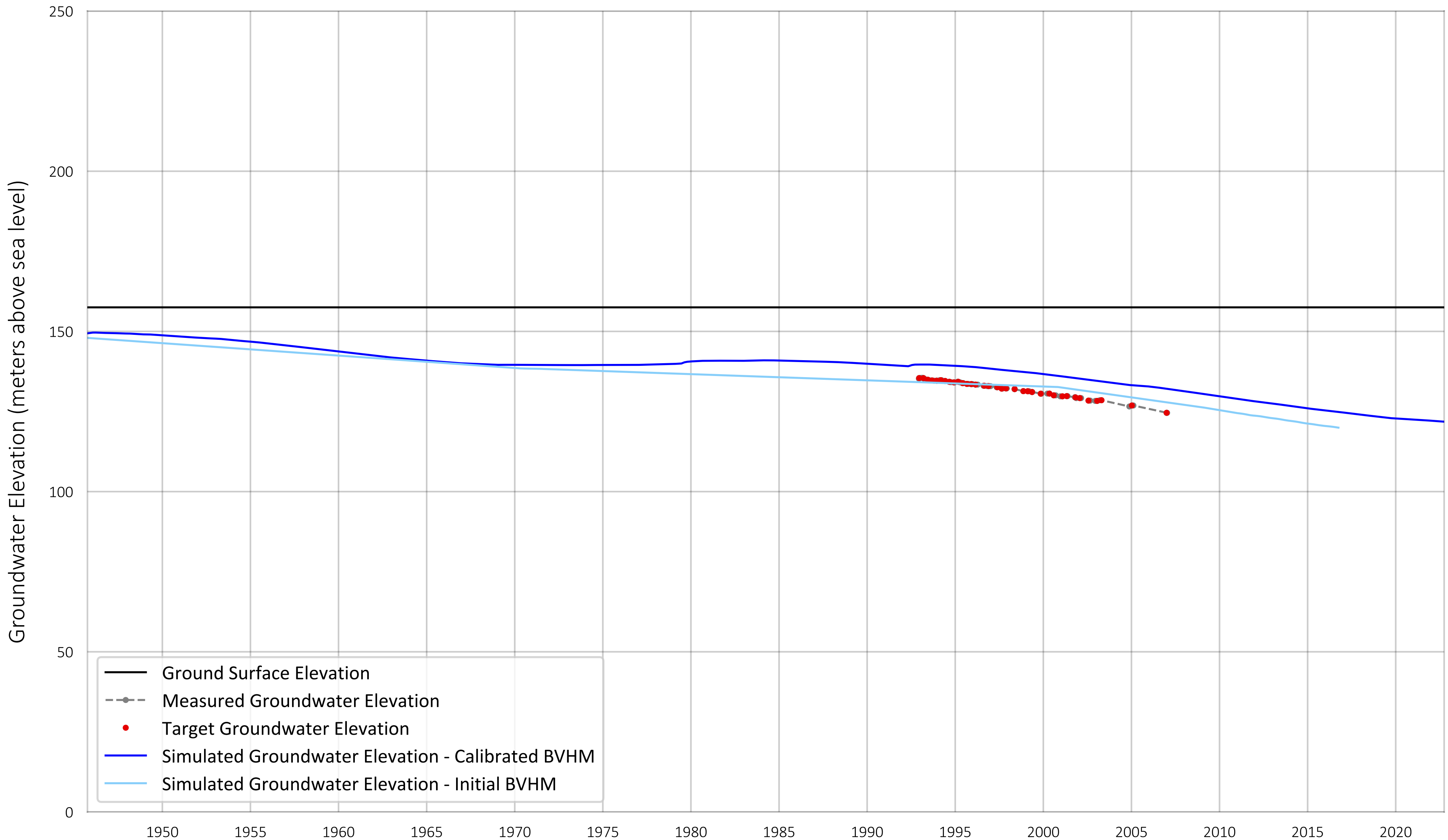
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

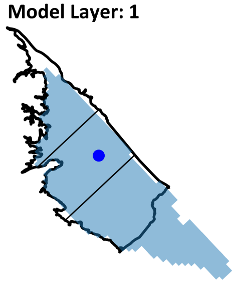
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245945
Well Name: Elementary School

Figure B-43



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 131.89
Standard Deviation = 2.66

Simulated Groundwater Elevation (m)
Mean = 137.50
Standard Deviation = 2.05

Mean Residual (m) = 5.61
RMSE (m) = 5.65

Calibrated BVHM Groundwater Elevation

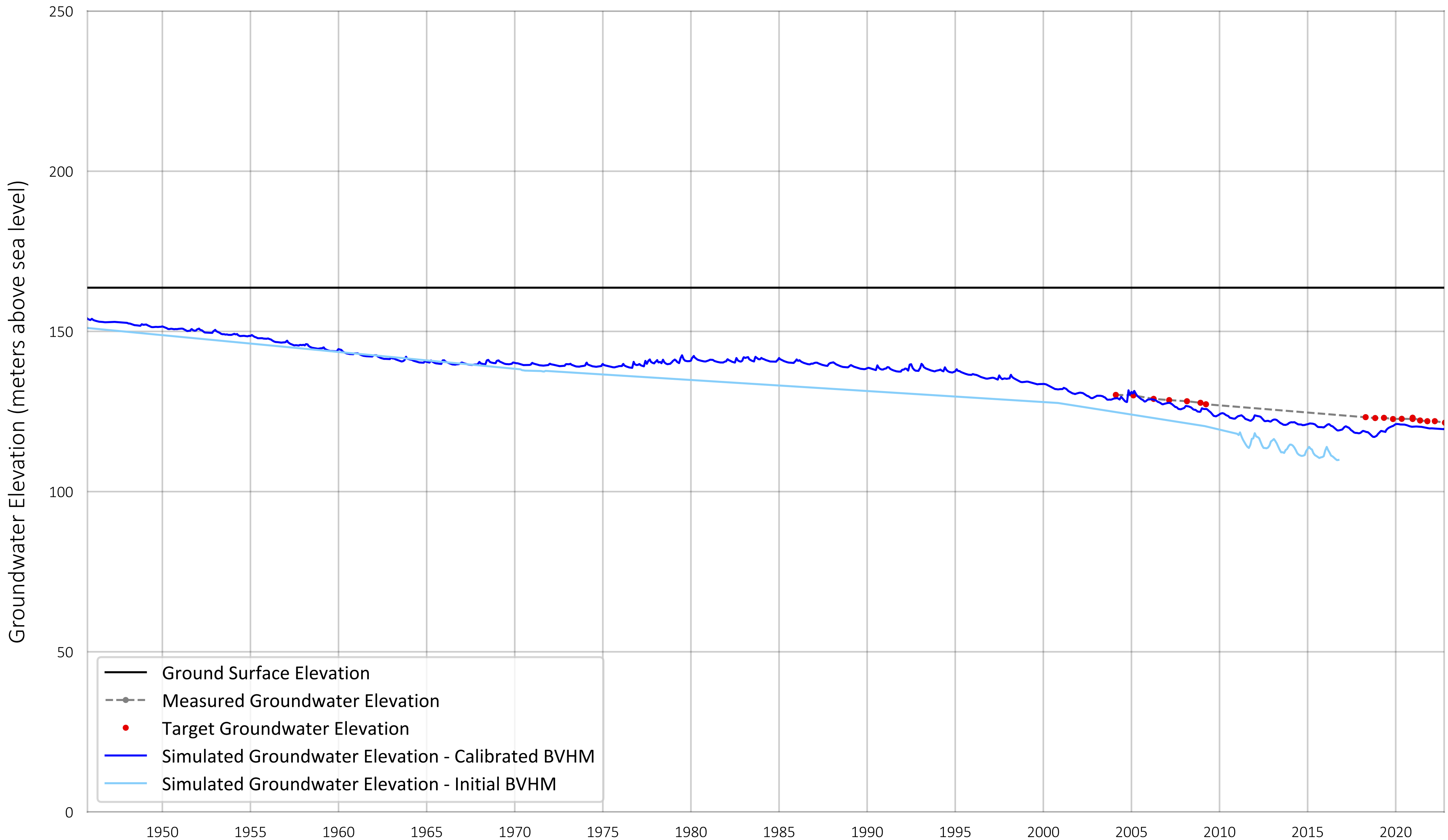
HydroDaVE Well ID: 1245826
Well Name: 011S006E02C003S

Figure B-44

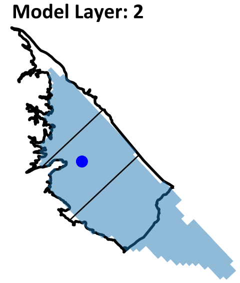
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 2



Statistics

Target Groundwater Elevation (m)
Mean = 125.14
Standard Deviation = 3.16

Simulated Groundwater Elevation (m)
Mean = 122.96
Standard Deviation = 4.37

Mean Residual (m) = -2.18
RMSE (m) = 2.68

Prepared by:

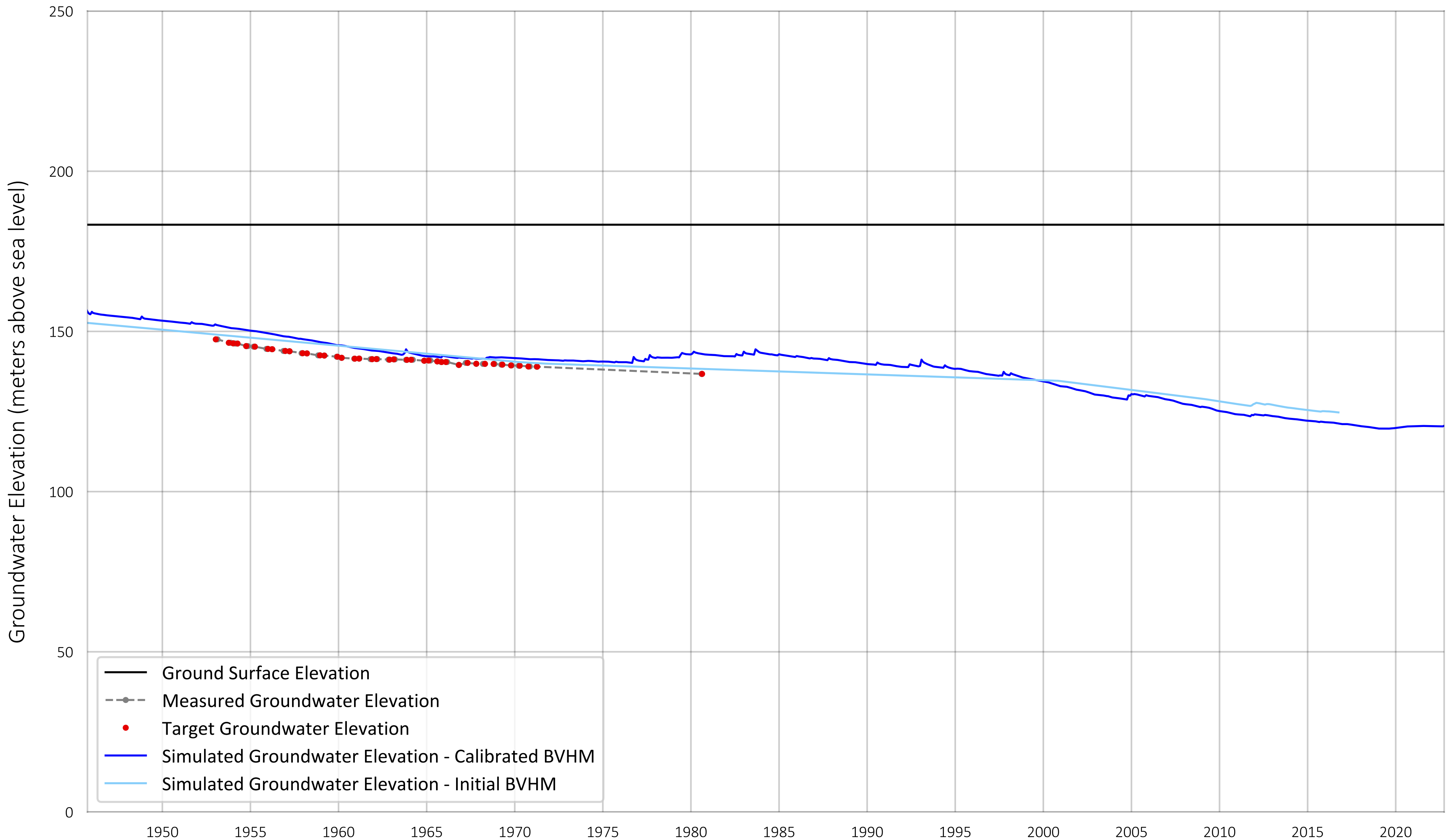
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

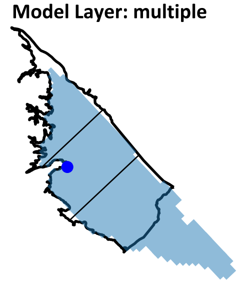
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245862
Well Name: Cameron 2

Figure B-45



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 141.88
Standard Deviation = 2.44

Simulated Groundwater Elevation (m)
Mean = 145.04
Standard Deviation = 3.45

Mean Residual (m) = 3.16
RMSE (m) = 3.43

Prepared by:

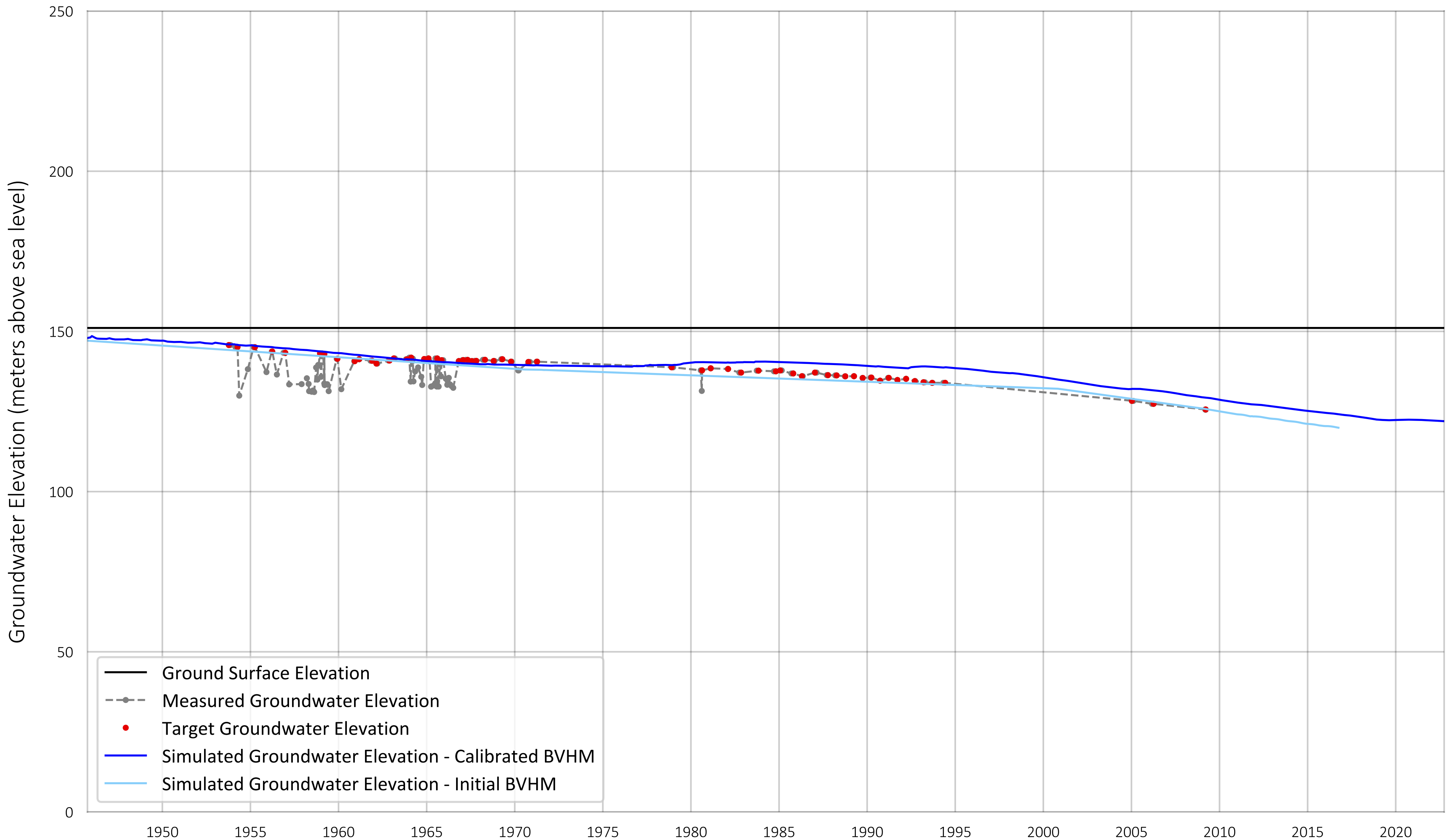
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245857
Well Name: Bending Elbow

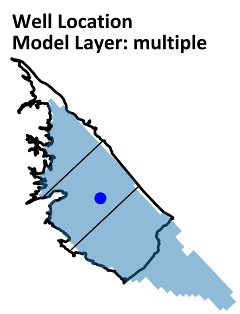
Figure B-46



Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Statistics

Target Groundwater Elevation (m)
Mean = 138.66
Standard Deviation = 4.07

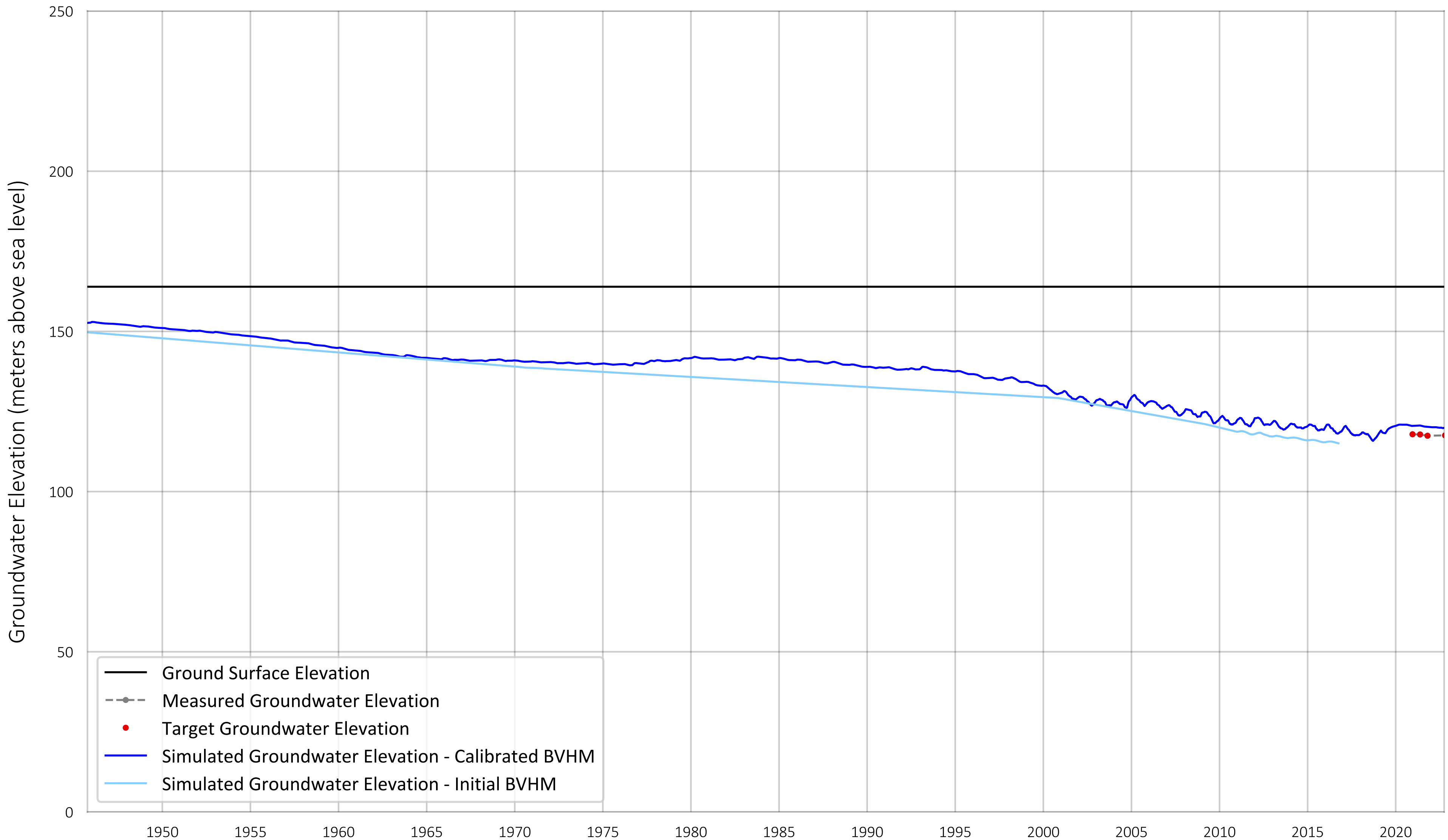
Simulated Groundwater Elevation (m)
Mean = 140.29
Standard Deviation = 2.86

Mean Residual (m) = 1.62
RMSE (m) = 2.59

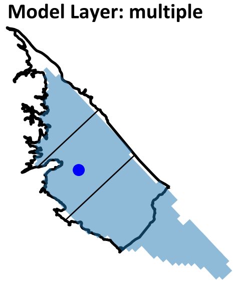
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245858
Well Name: Berkovitch

Figure B-47



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 117.72
Standard Deviation = 0.25

Simulated Groundwater Elevation (m)
Mean = 120.44
Standard Deviation = 0.24

Mean Residual (m) = 2.72
RMSE (m) = 2.72

Calibrated BVHM Groundwater Elevation

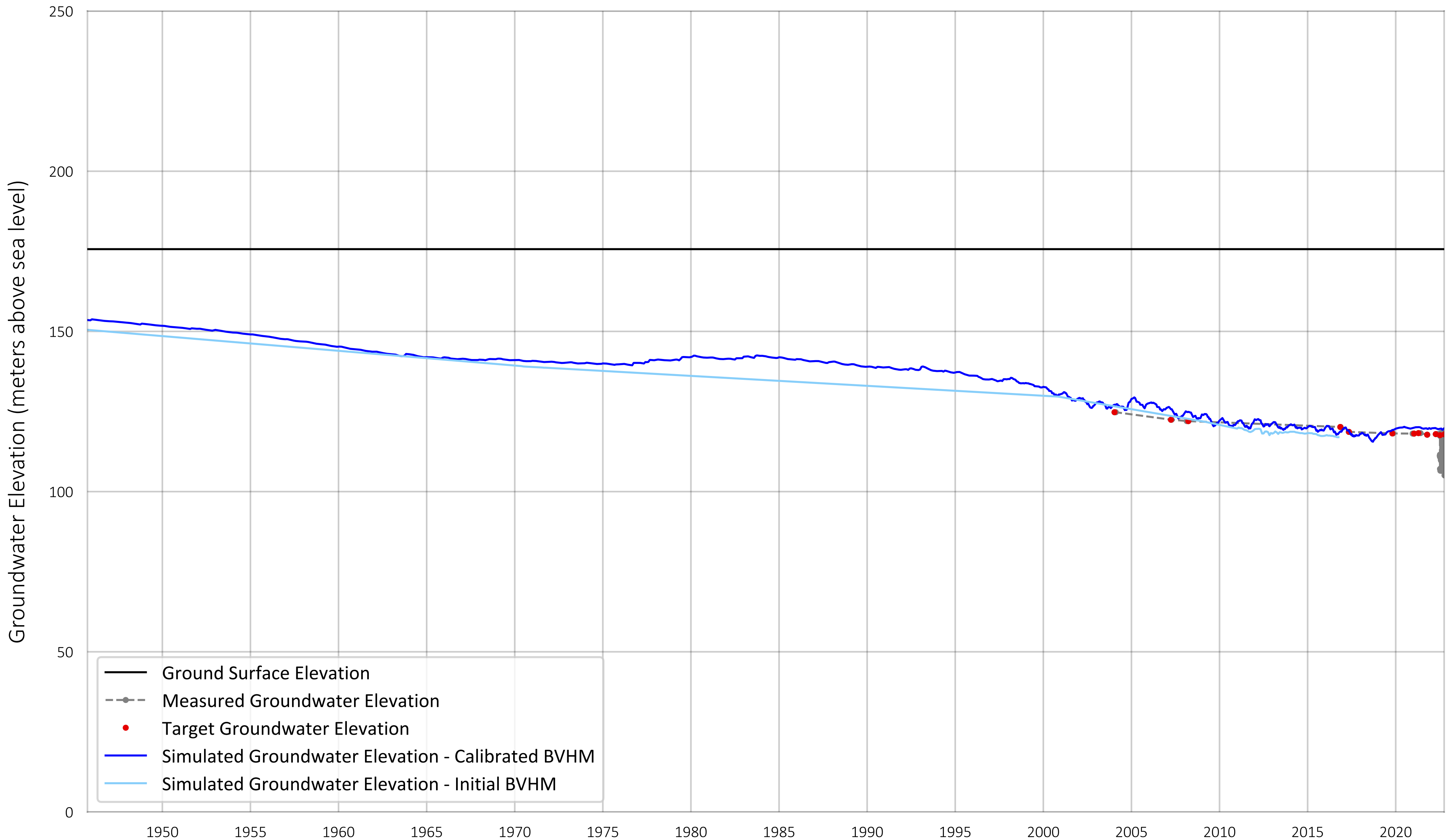
HydroDaVE Well ID: 1245860
Well Name: BSR Well 6

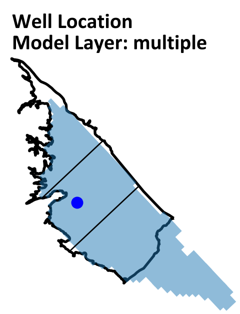
Figure B-48

Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster





Statistics

Target Groundwater Elevation (m)
Mean = 119.62
Standard Deviation = 2.41

Simulated Groundwater Elevation (m)
Mean = 121.25
Standard Deviation = 3.06

Mean Residual (m) = 1.62
RMSE (m) = 2.04

Prepared by:

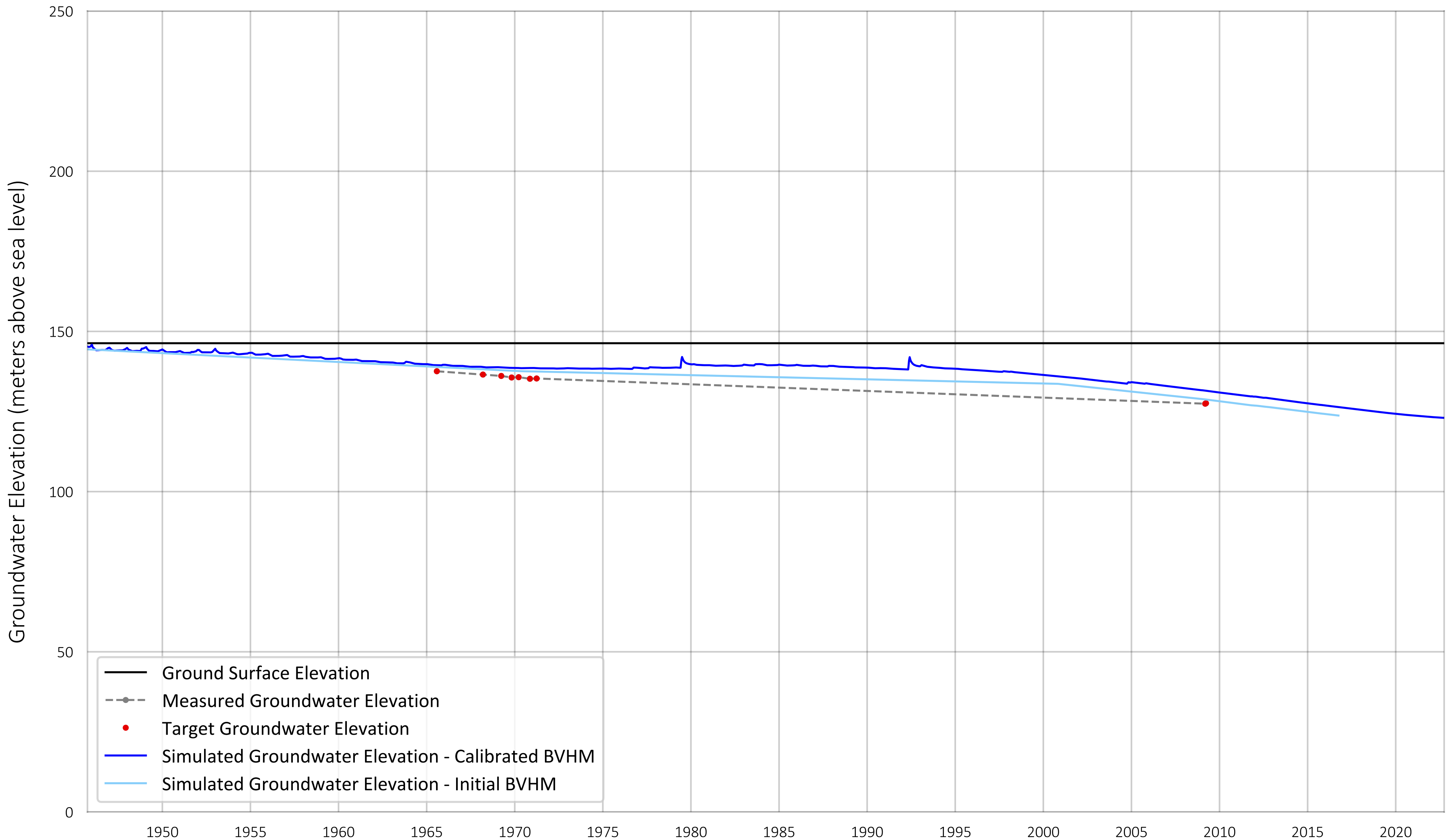
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

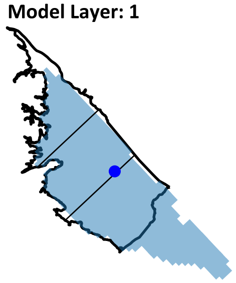
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245893
Well Name: ID5-5

Figure B-49



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 134.12
Standard Deviation = 3.82

Simulated Groundwater Elevation (m)
Mean = 137.14
Standard Deviation = 3.21

Mean Residual (m) = 3.02
RMSE (m) = 3.10

Calibrated BVHM Groundwater Elevation

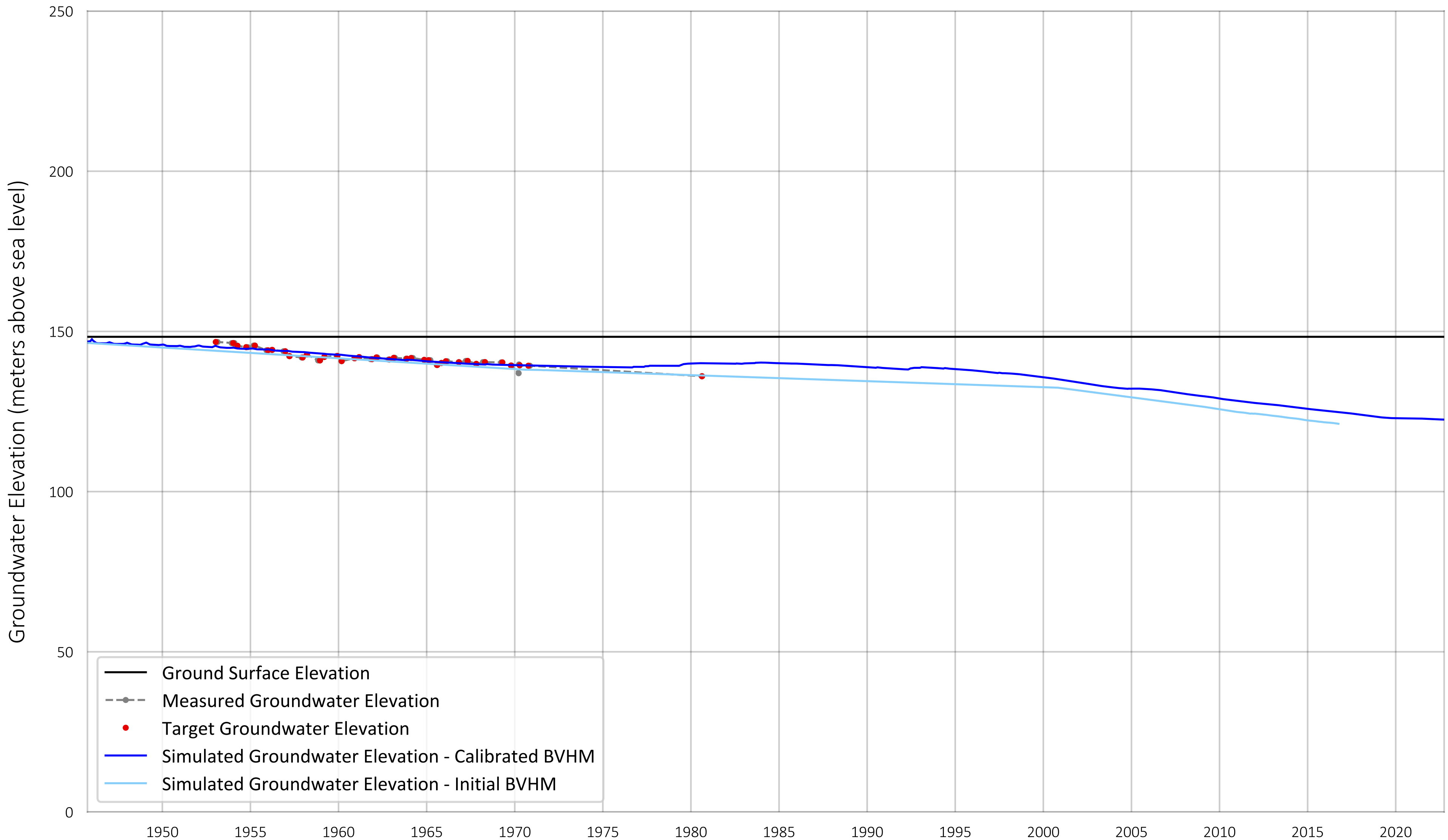
HydroDaVE Well ID: 1245913
Well Name: Sink - 12G1

Figure B-50

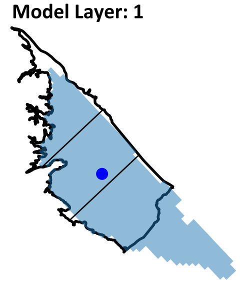
Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 141.78
Standard Deviation = 2.21

Simulated Groundwater Elevation (m)
Mean = 141.93
Standard Deviation = 1.89

Mean Residual (m) = 0.16
RMSE (m) = 1.07

Prepared by:

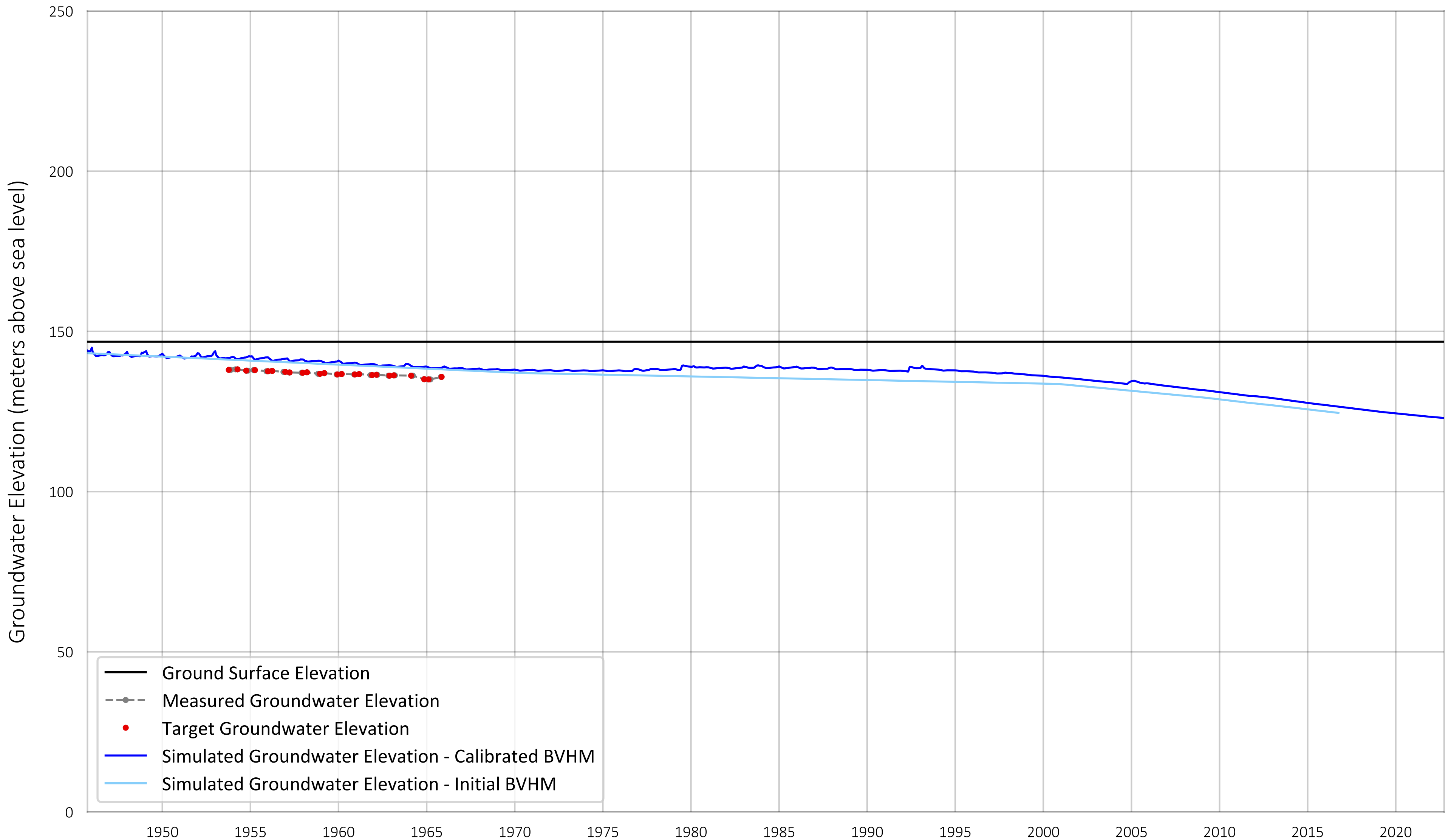
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

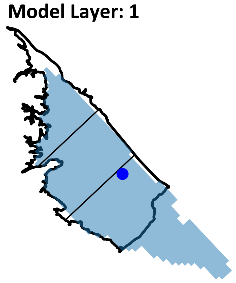
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245861
Well Name: Burned House 1

Figure B-51



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 136.82
Standard Deviation = 0.84

Simulated Groundwater Elevation (m)
Mean = 140.35
Standard Deviation = 1.00

Mean Residual (m) = 3.53
RMSE (m) = 3.56

Prepared by:

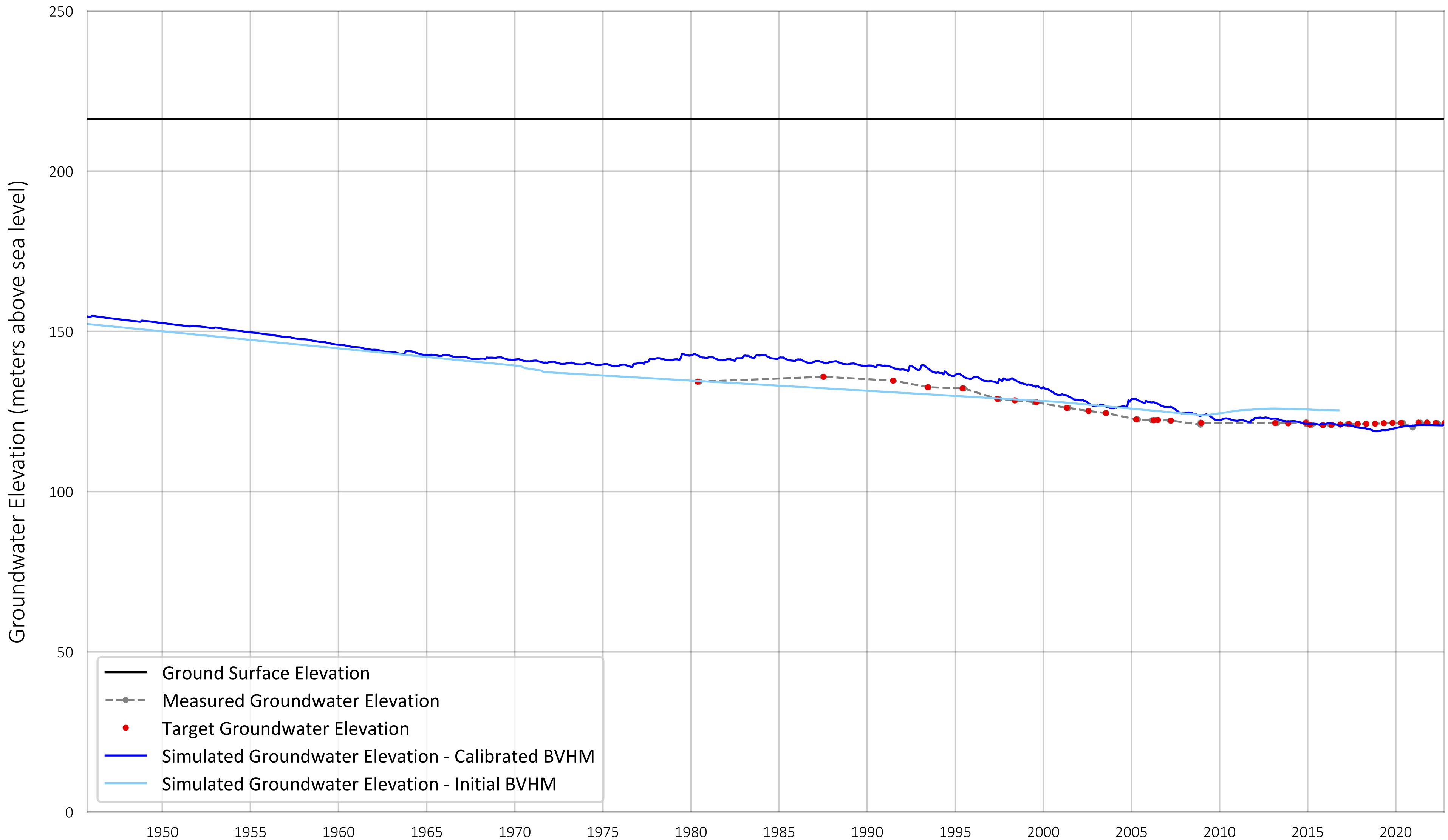
WEST YOST
Water. Engineered.

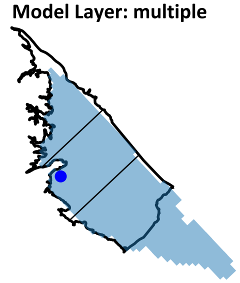
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245914
Well Name: Sink - 7N1

Figure B-52





Statistics

Target Groundwater Elevation (m)
Mean = 124.31
Standard Deviation = 4.72

Simulated Groundwater Elevation (m)
Mean = 126.26
Standard Deviation = 7.12

Mean Residual (m) = 1.95
RMSE (m) = 3.54

Prepared by:

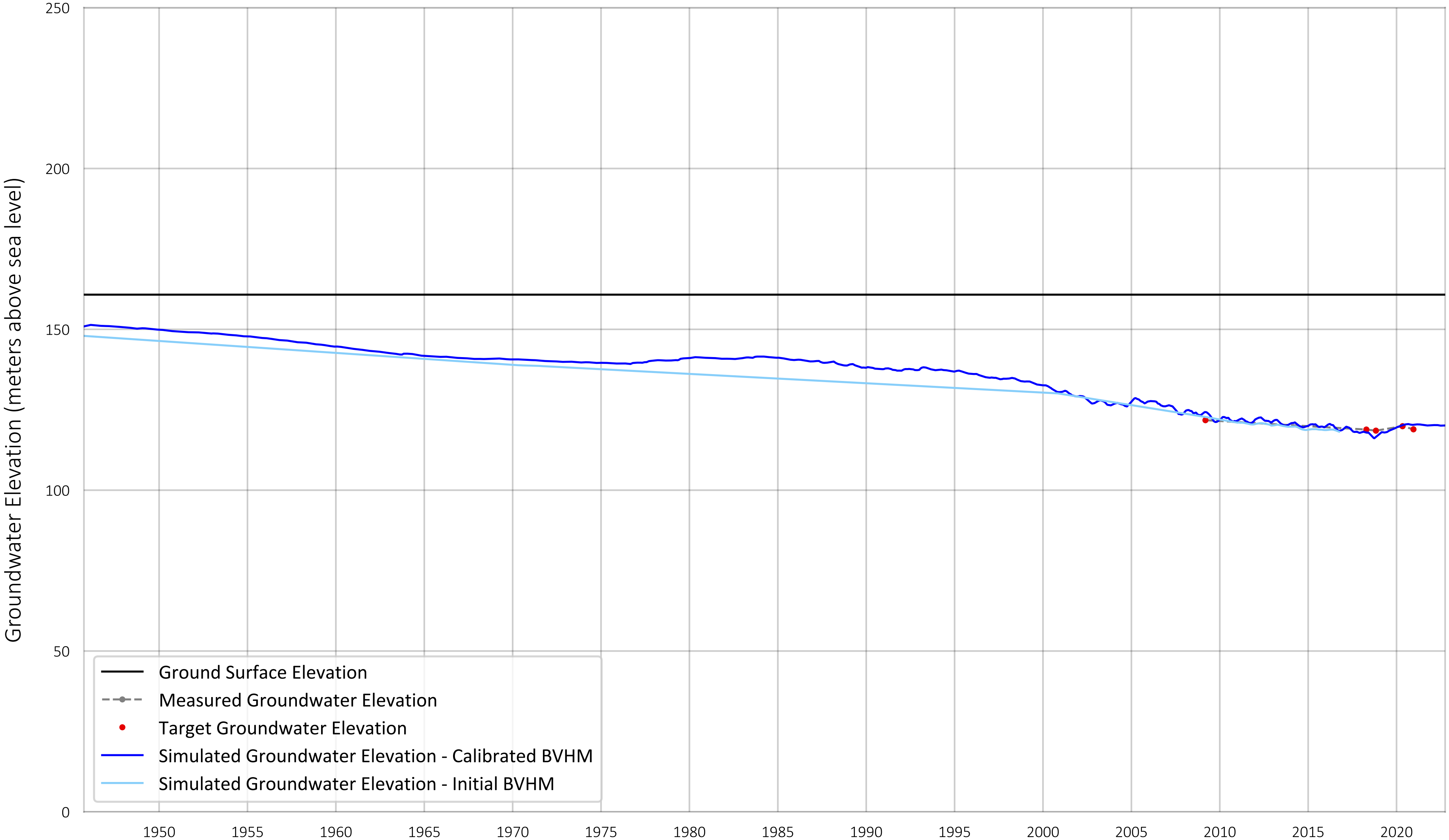
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

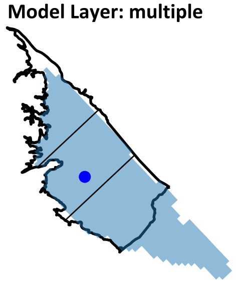
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245887
Well Name: ID4-2

Figure B-53



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 119.59
Standard Deviation = 1.32

Simulated Groundwater Elevation (m)
Mean = 119.87
Standard Deviation = 2.91

Mean Residual (m) = 0.29
RMSE (m) = 1.59

Prepared by:

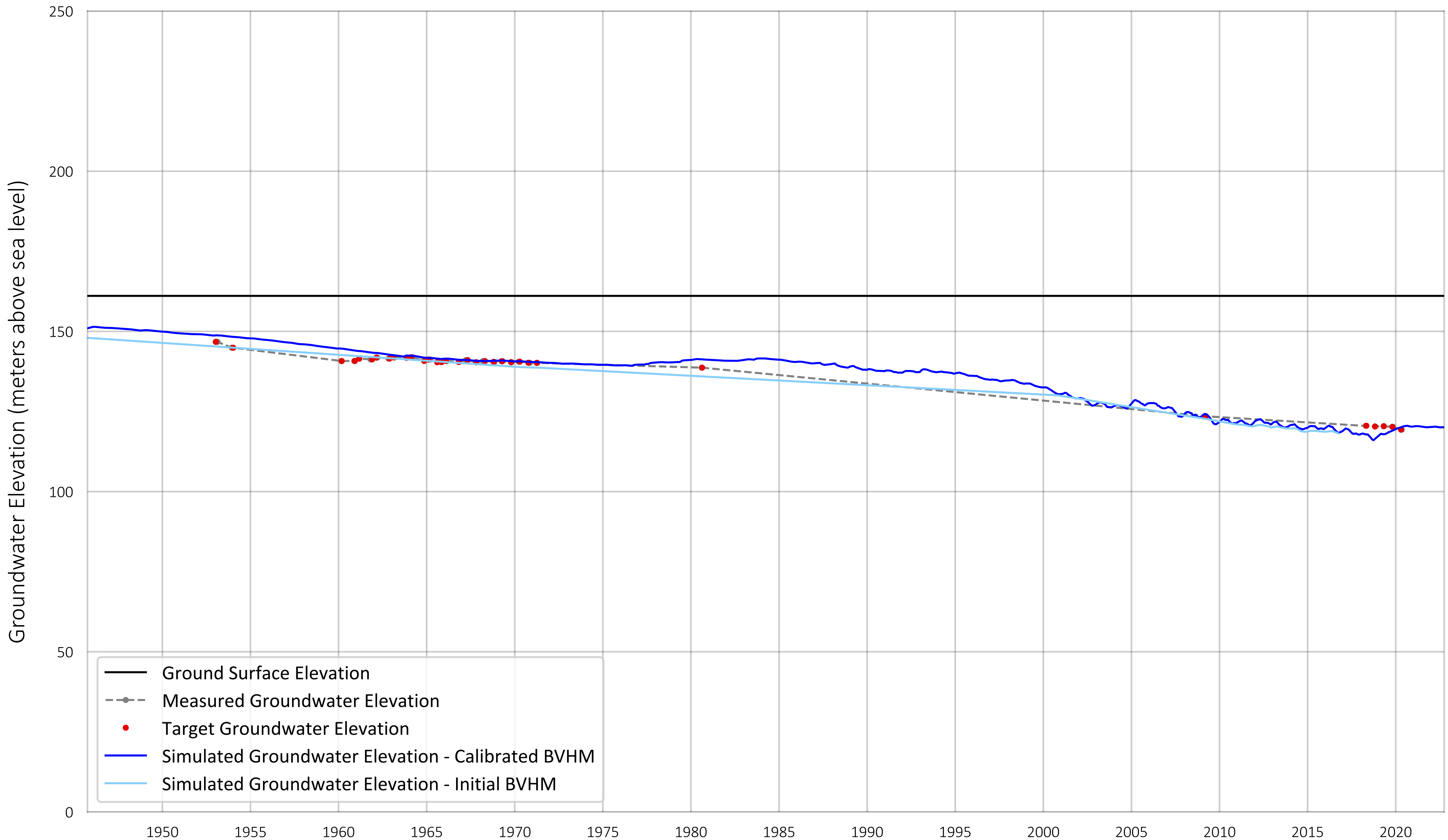
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

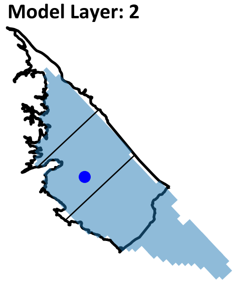
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245850
Well Name: Abandoned Motel-2

Figure B-54



Well Location
Model Layer: 2



Statistics

Target Groundwater Elevation (m)
Mean = 137.47
Standard Deviation = 8.15

Simulated Groundwater Elevation (m)
Mean = 138.15
Standard Deviation = 9.31

Mean Residual (m) = 0.68
RMSE (m) = 1.73

Prepared by:

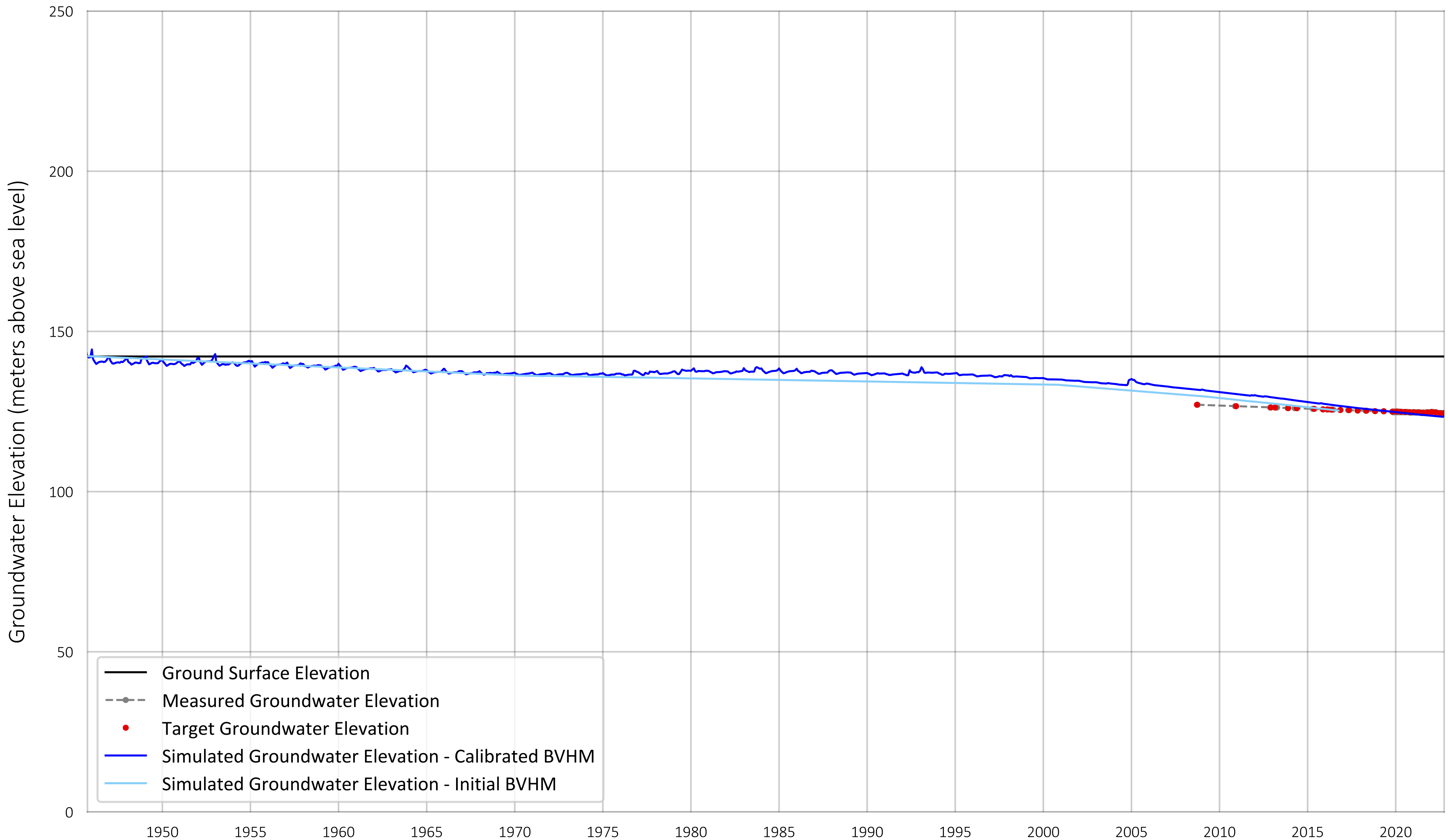
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245849
Well Name: Abandoned Motel-1

Figure B-55

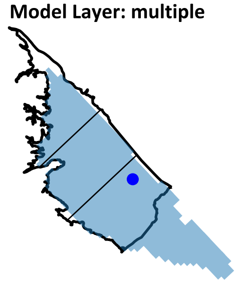


Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 125.36
Standard Deviation = 0.66

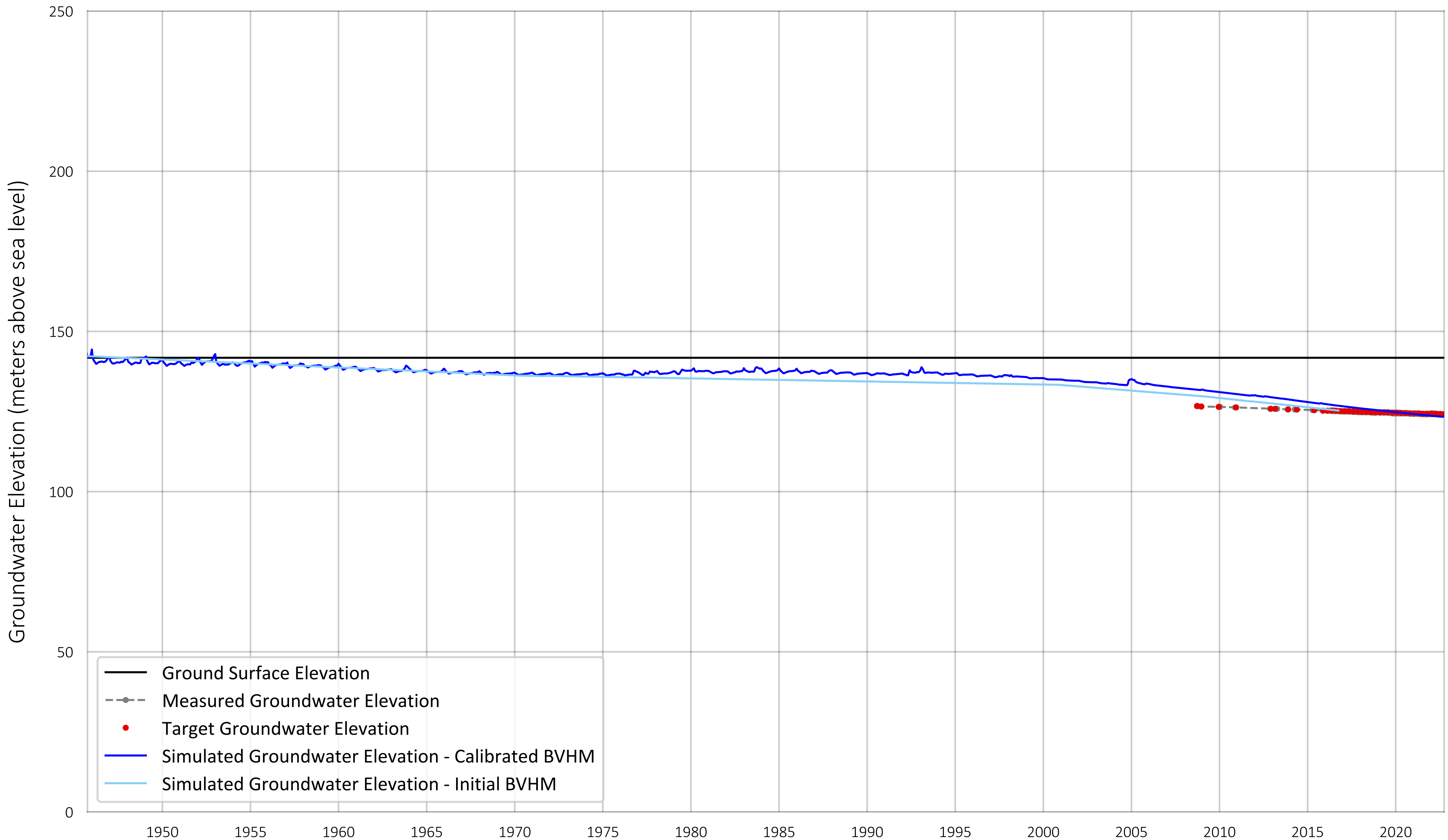
Simulated Groundwater Elevation (m)
Mean = 126.17
Standard Deviation = 2.30

Mean Residual (m) = 0.81
RMSE (m) = 1.80

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245900
Well Name: MW-5A

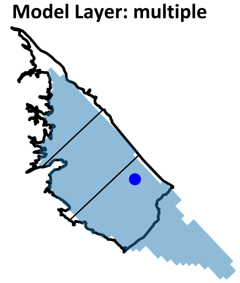
Figure B-56



Prepared by:

WEST YOST Water. Engineered.

Prepared for: Borrego Springs Watermaster



Statistics

Target Groundwater Elevation (m)
Mean = 125.05
Standard Deviation = 0.67

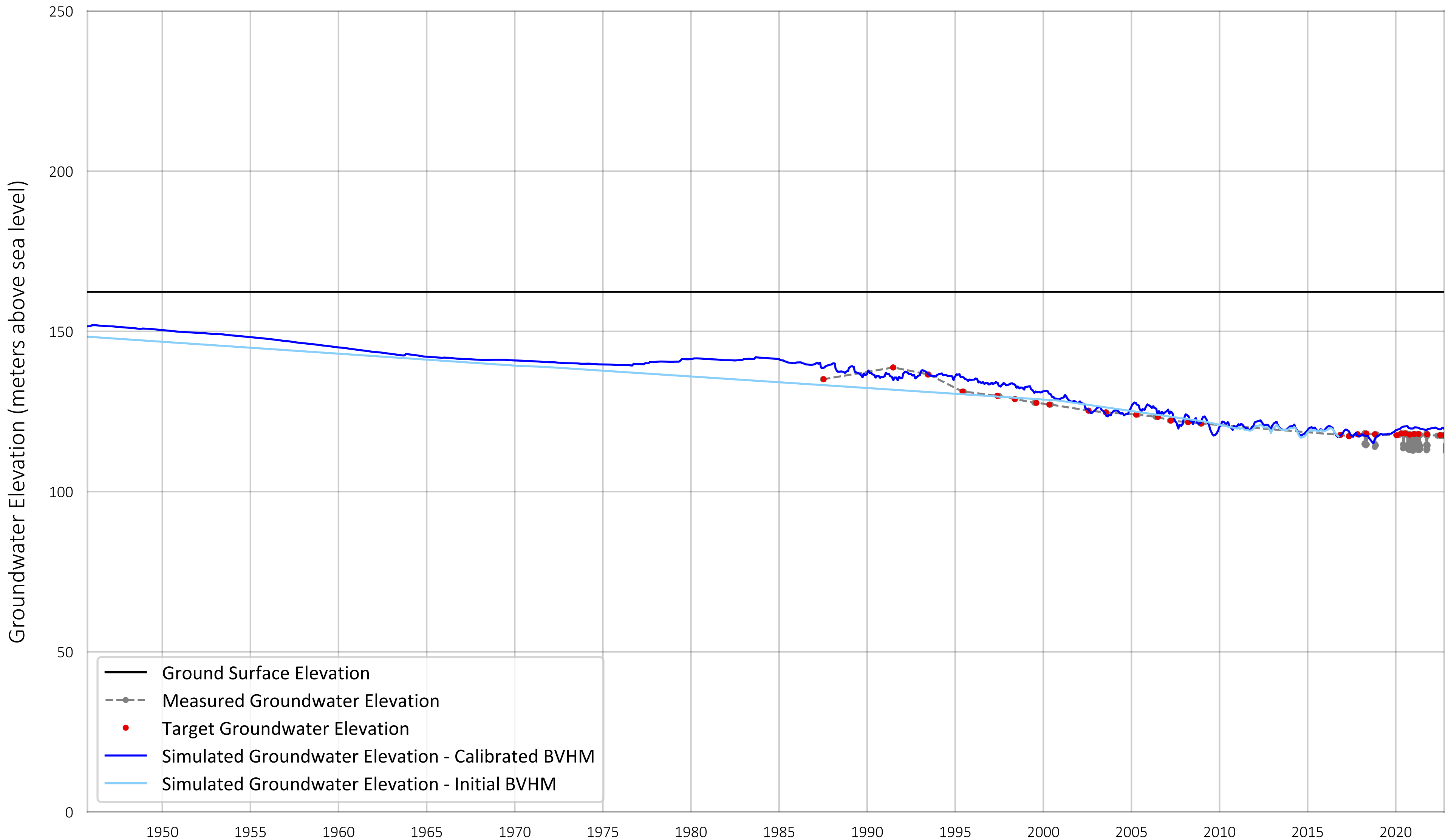
Simulated Groundwater Elevation (m)
Mean = 126.41
Standard Deviation = 2.36

Mean Residual (m) = 1.36
RMSE (m) = 2.15

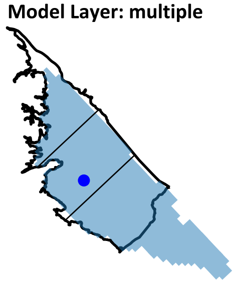
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245901
Well Name: MW-5B

Figure B-57



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 123.20
Standard Deviation = 6.46

Simulated Groundwater Elevation (m)
Mean = 124.72
Standard Deviation = 6.89

Mean Residual (m) = 1.52
RMSE (m) = 2.43

Prepared by:

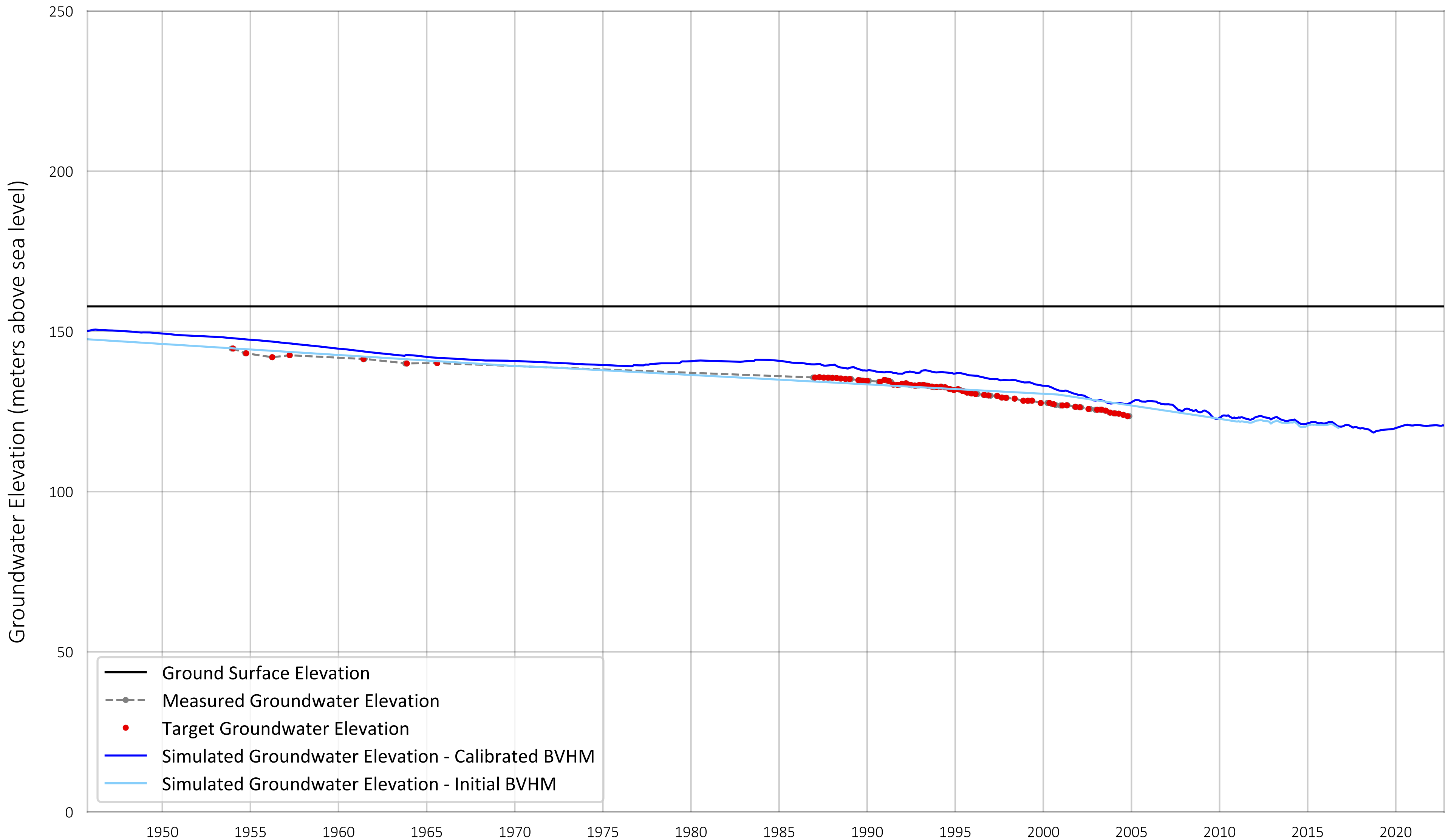
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

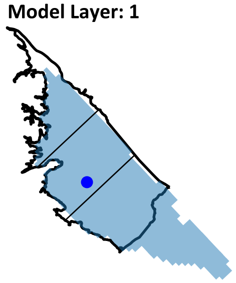
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245879
Well Name: ID1-12

Figure B-58



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 132.02
Standard Deviation = 4.94

Simulated Groundwater Elevation (m)
Mean = 136.15
Standard Deviation = 4.78

Mean Residual (m) = 4.12
RMSE (m) = 4.25

Prepared by:

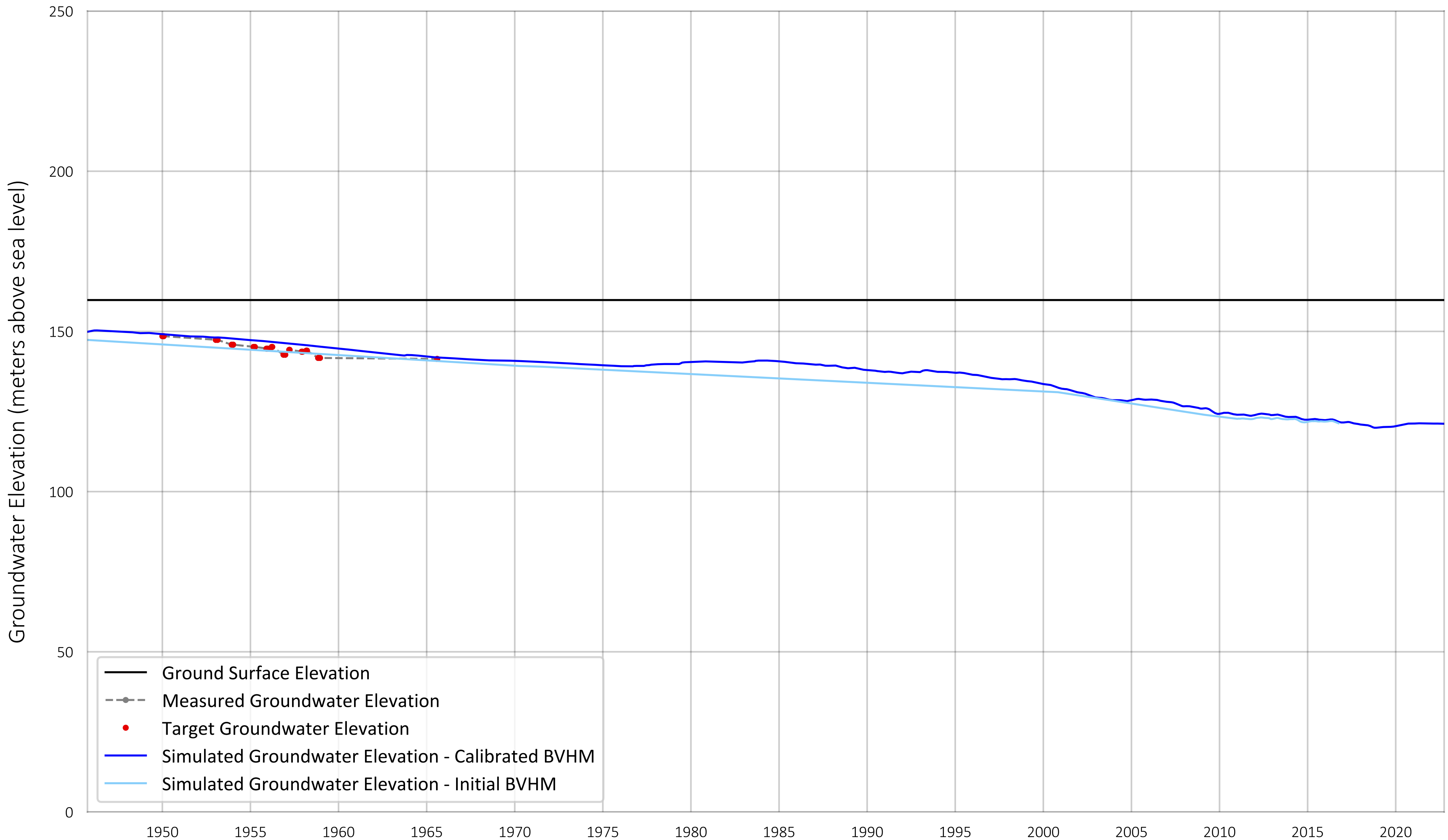
WEST YOST
Water. Engineered.

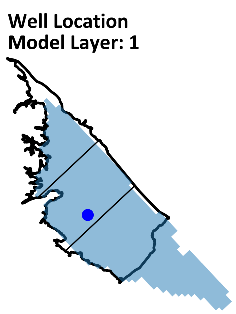
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245896
Well Name: Levie Well

Figure B-59





Statistics

Target Groundwater Elevation (m)
Mean = 144.53
Standard Deviation = 2.05

Simulated Groundwater Elevation (m)
Mean = 146.42
Standard Deviation = 1.78

Mean Residual (m) = 1.88
RMSE (m) = 2.11

Calibrated BVHM Groundwater Elevation

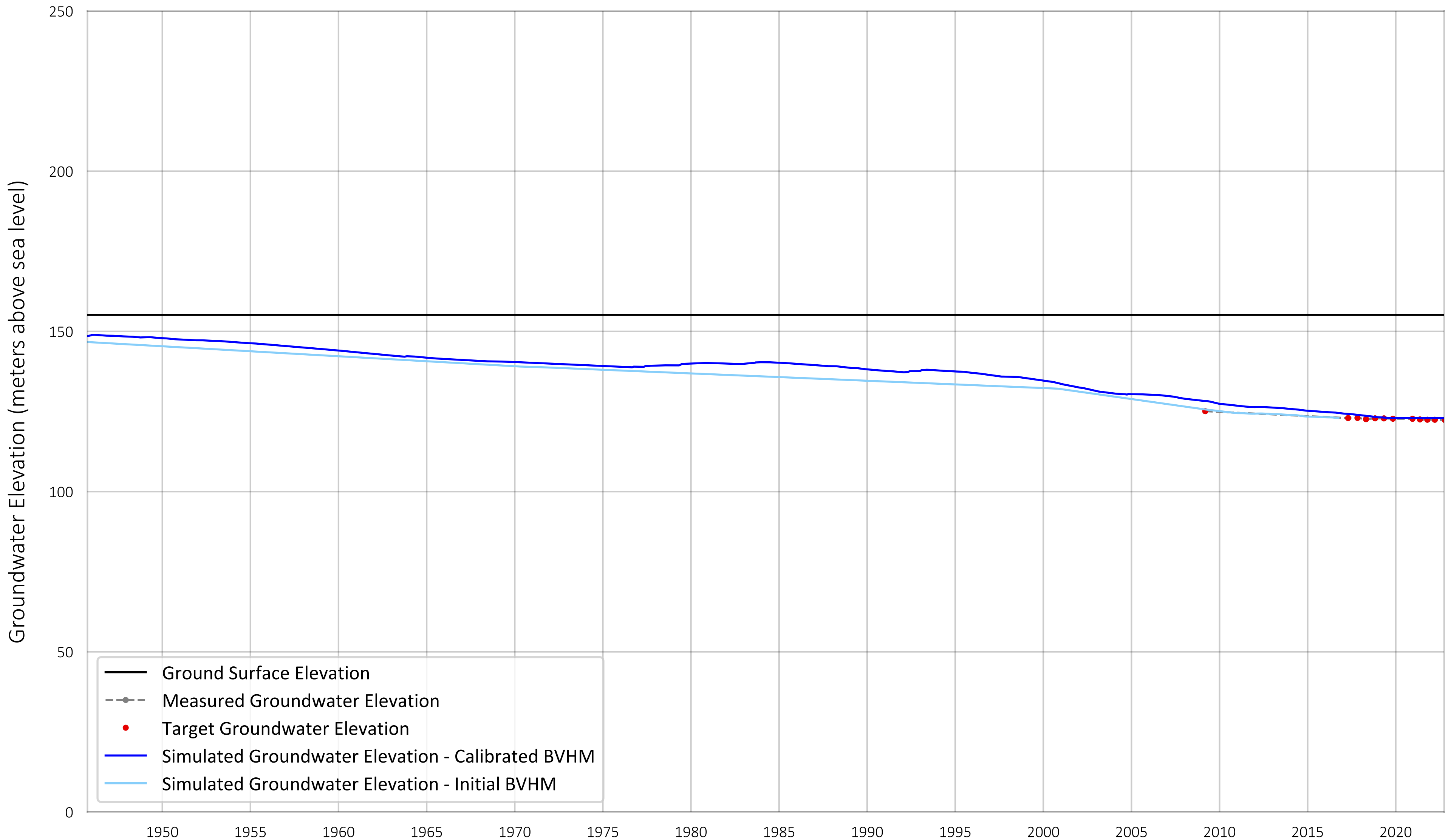
HydroDaVE Well ID: 1245833
Well Name: 011S006E15F001S

Figure B-60

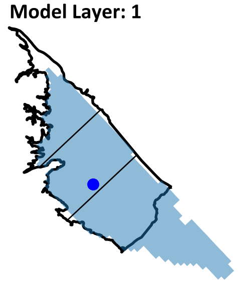
Prepared by:

WEST YOST Water. Engineered.

Prepared for: Borrego Springs Watermaster



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 122.93
Standard Deviation = 0.74

Simulated Groundwater Elevation (m)
Mean = 123.79
Standard Deviation = 1.57

Mean Residual (m) = 0.86
RMSE (m) = 1.19

Prepared by:

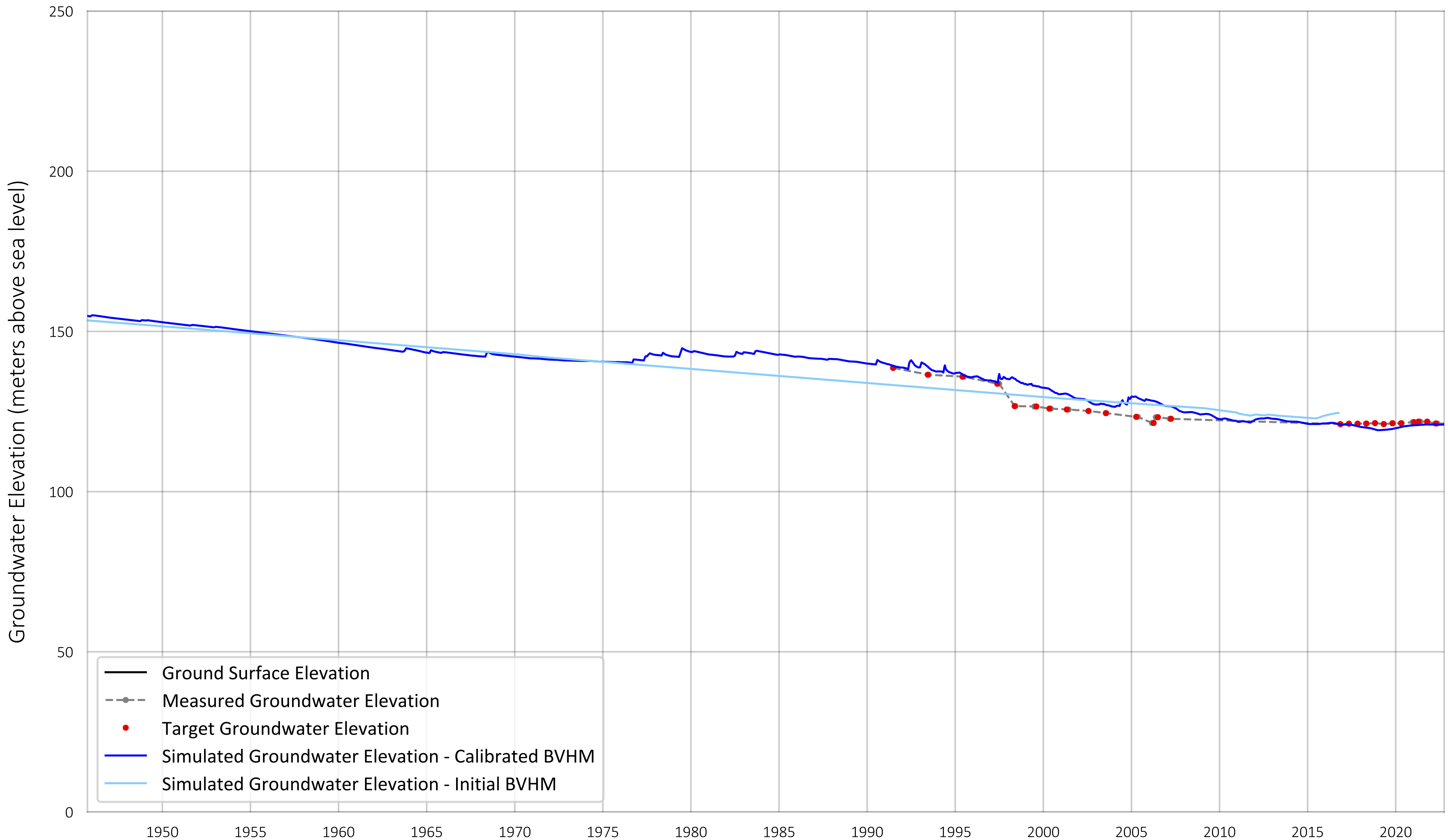
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

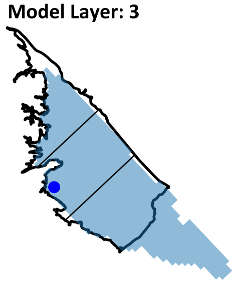
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245865
Well Name: County Yard

Figure B-61



Well Location
Model Layer: 3



Statistics

Target Groundwater Elevation (m)
Mean = 124.85
Standard Deviation = 5.29

Simulated Groundwater Elevation (m)
Mean = 126.59
Standard Deviation = 6.69

Mean Residual (m) = 1.74
RMSE (m) = 3.61

Prepared by:

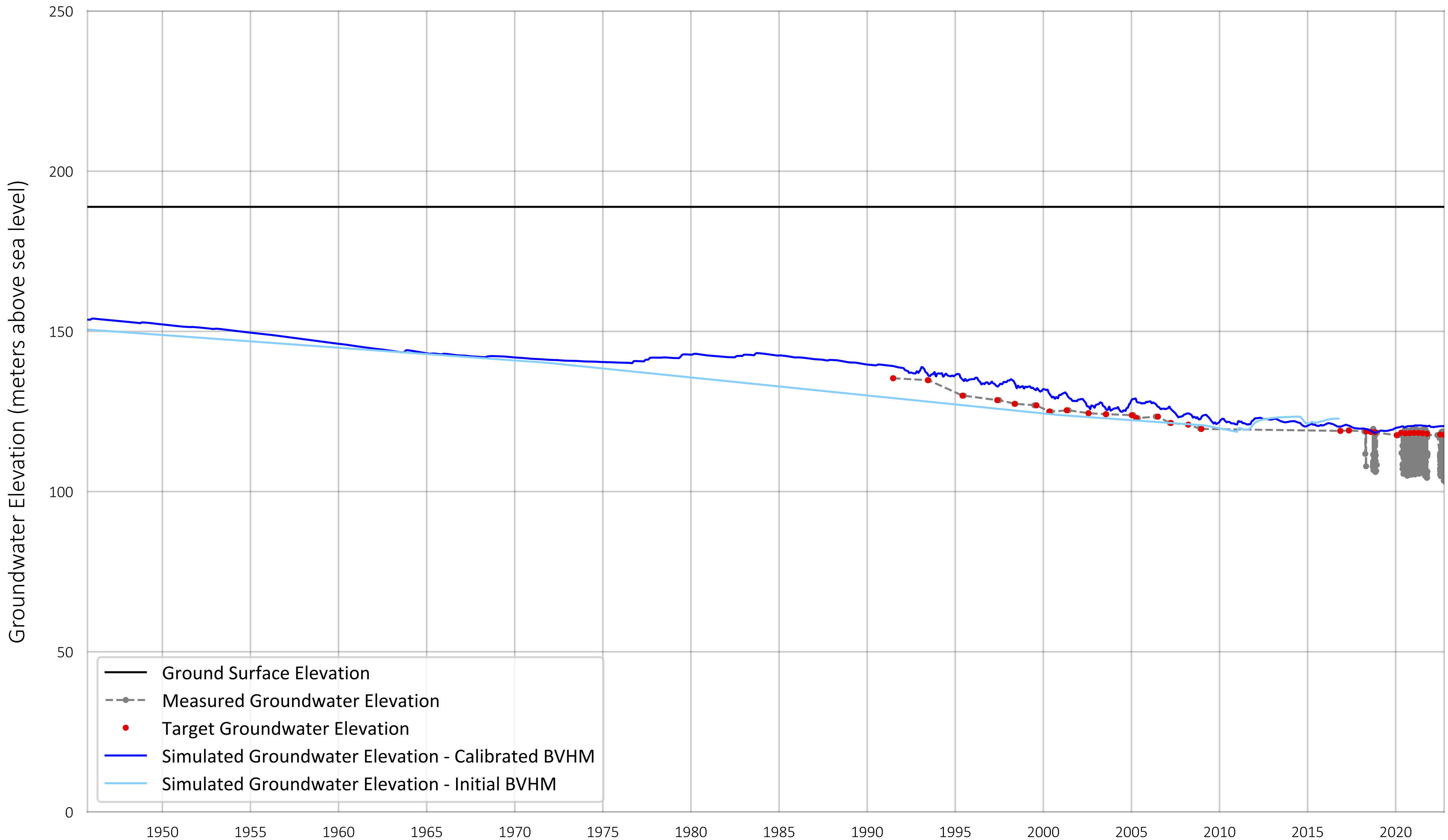
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

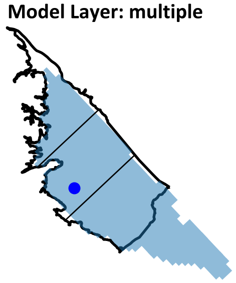
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245884
Well Name: ID4-10

Figure B-62



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 122.37
Standard Deviation = 5.01

Simulated Groundwater Elevation (m)
Mean = 125.37
Standard Deviation = 6.04

Mean Residual (m) = 2.99
RMSE (m) = 3.42

Prepared by:

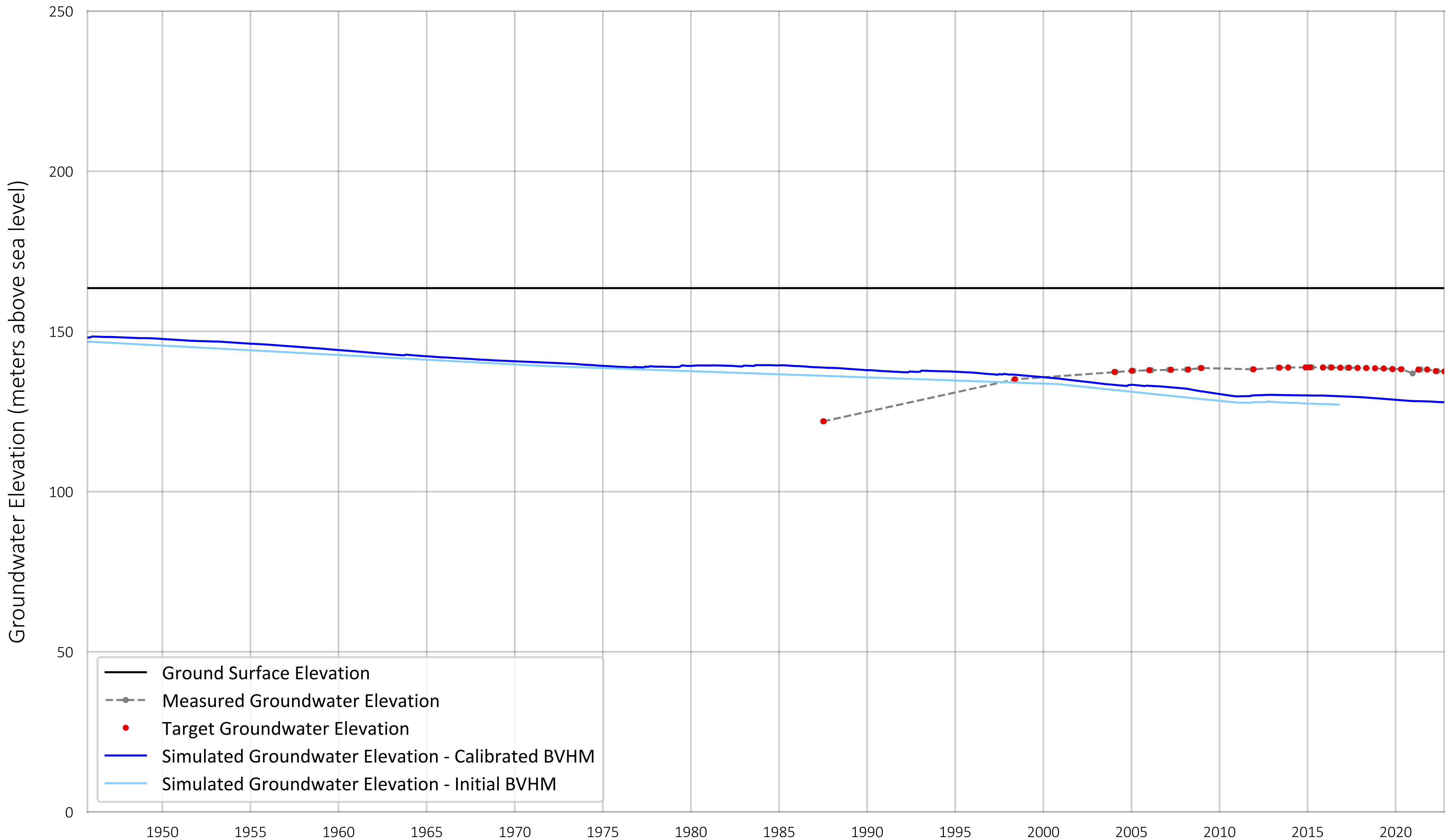
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

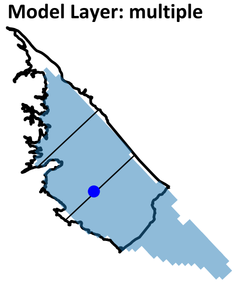
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245880
Well Name: ID1-16

Figure B-63



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 137.58
Standard Deviation = 3.28

Simulated Groundwater Elevation (m)
Mean = 130.74
Standard Deviation = 2.56

Mean Residual (m) = -6.84
RMSE (m) = 8.68

Prepared by:

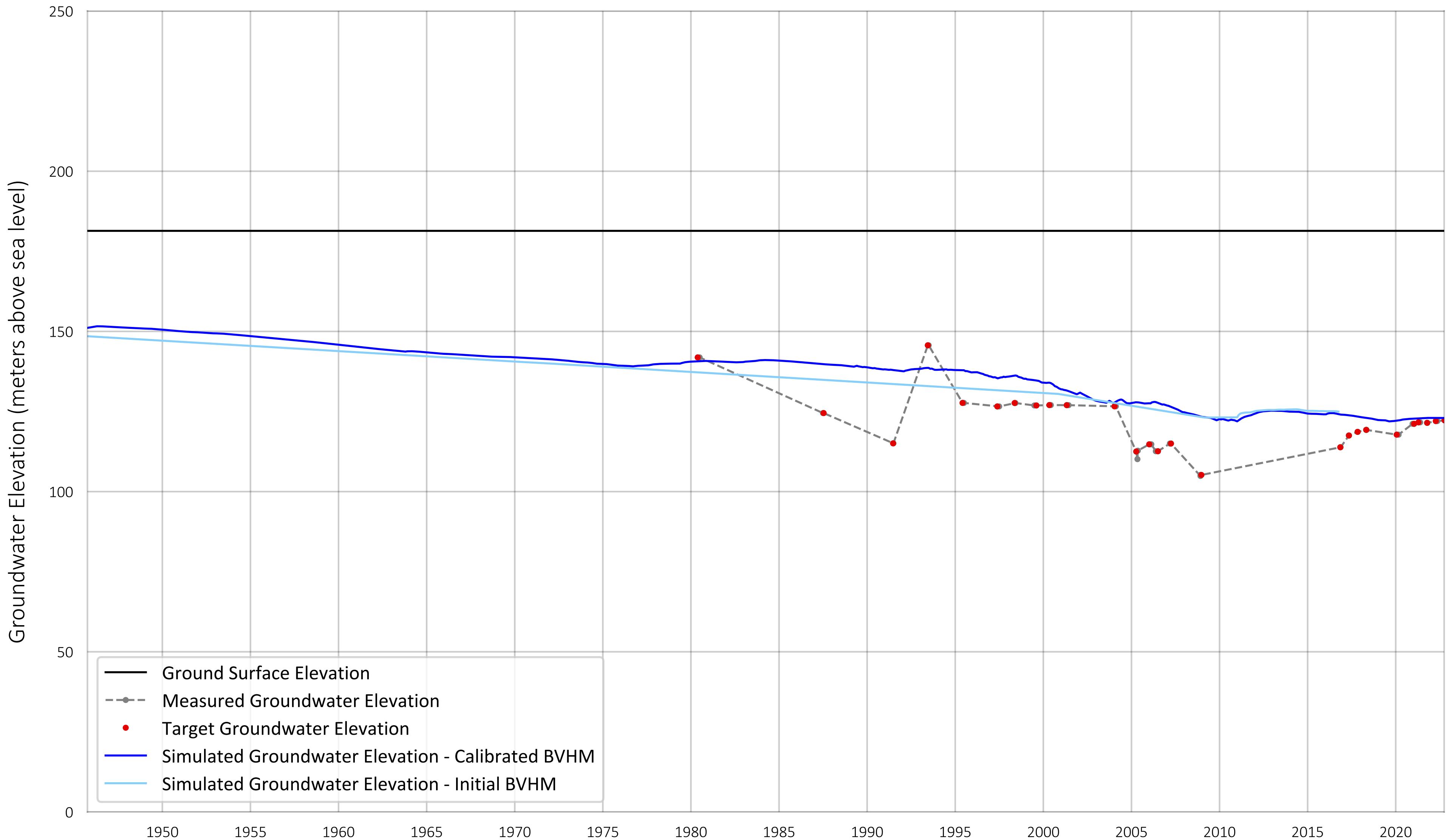
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

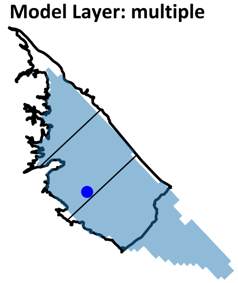
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245903
Well Name: Paddock

Figure B-64



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 121.99
Standard Deviation = 8.84

Simulated Groundwater Elevation (m)
Mean = 129.43
Standard Deviation = 6.51

Mean Residual (m) = 7.44
RMSE (m) = 9.99

Prepared by:

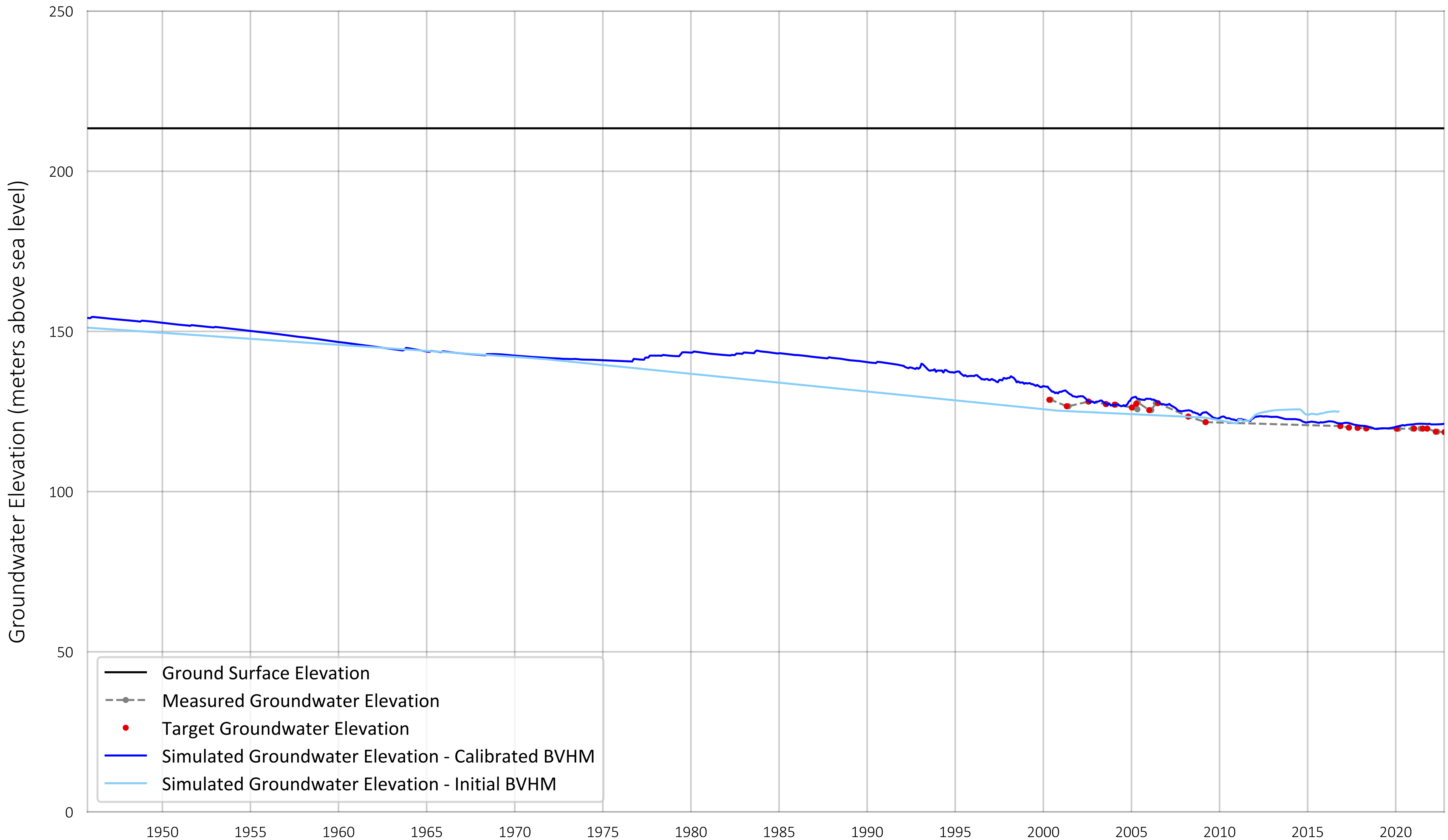
WEST YOST
Water. Engineered.

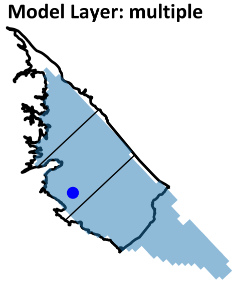
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245878
Well Name: ID1-10

Figure B-65





Statistics

Target Groundwater Elevation (m)
Mean = 123.35
Standard Deviation = 3.72

Simulated Groundwater Elevation (m)
Mean = 125.00
Standard Deviation = 4.11

Mean Residual (m) = 1.65
RMSE (m) = 2.09

Prepared by:

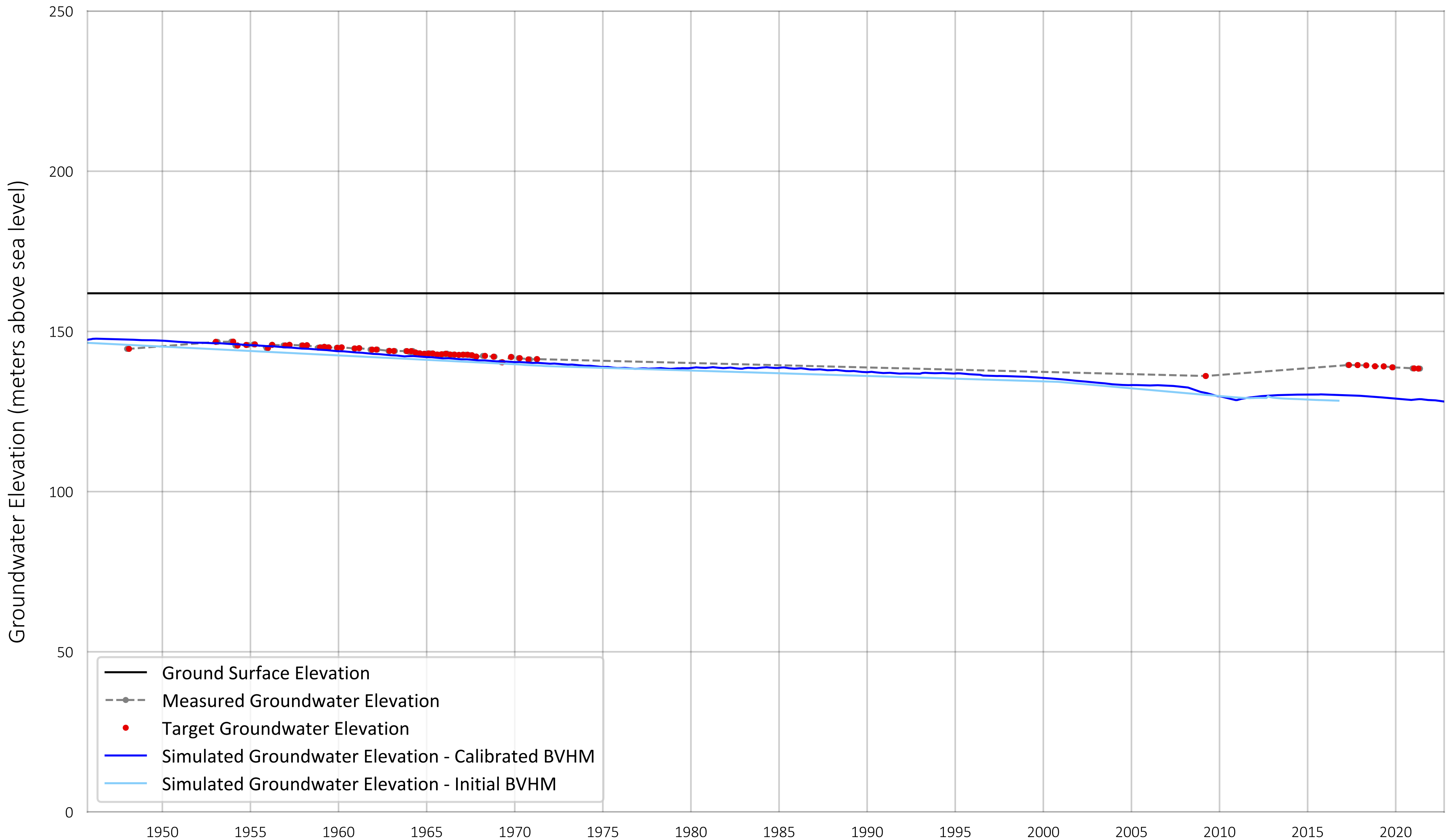
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245931
Well Name: ID4-20 (Wilcox)

Figure B-66

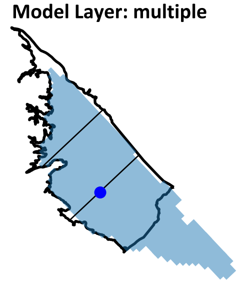


Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 143.03
Standard Deviation = 2.41

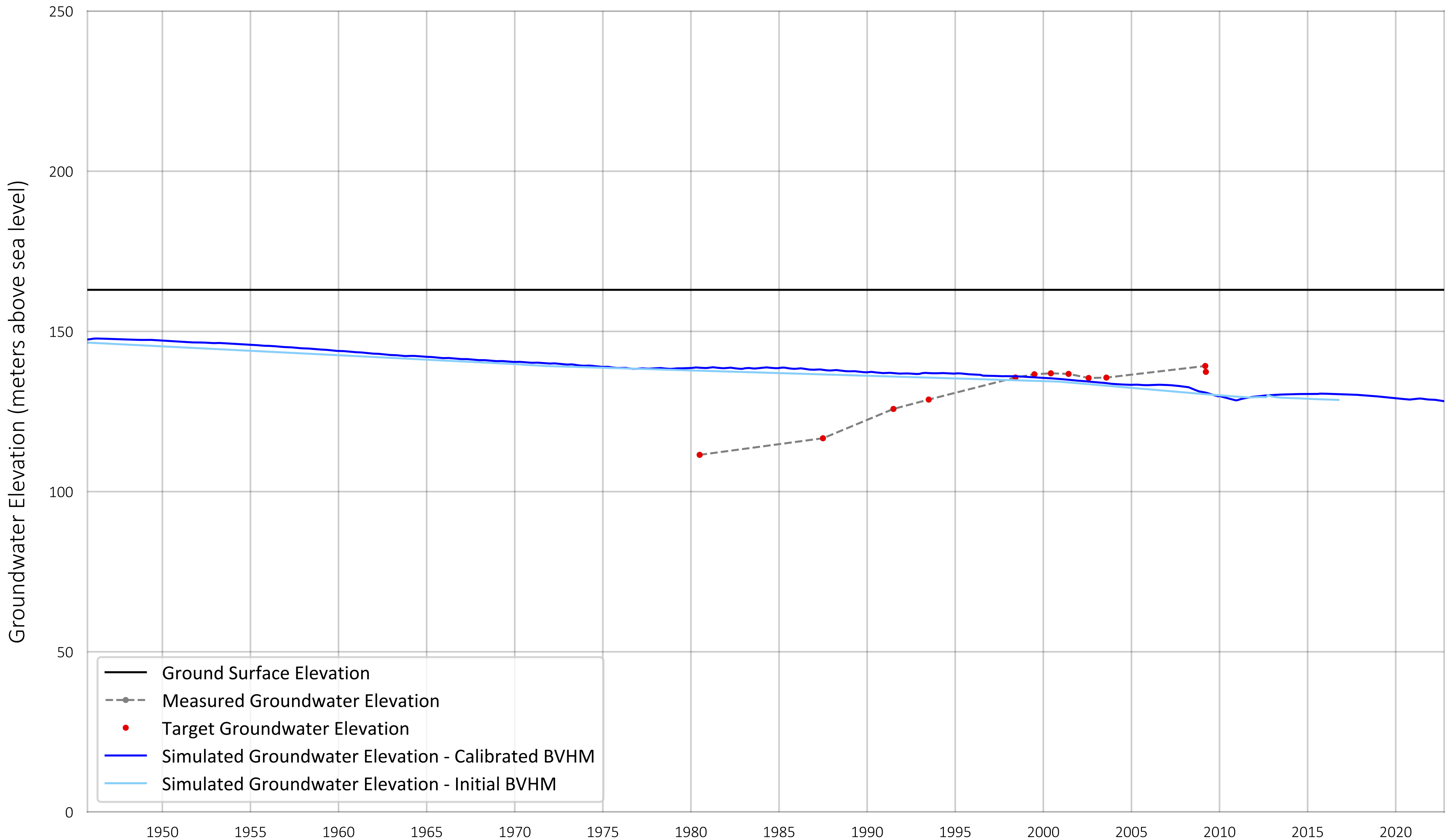
Simulated Groundwater Elevation (m)
Mean = 140.78
Standard Deviation = 5.26

Mean Residual (m) = -2.25
RMSE (m) = 3.86

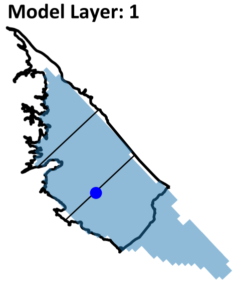
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245856
Well Name: Bakko

Figure B-67



Well Location
Model Layer: 1



Statistics

Target Groundwater Elevation (m)
Mean = 131.35
Standard Deviation = 8.98

Simulated Groundwater Elevation (m)
Mean = 135.21
Standard Deviation = 2.47

Mean Residual (m) = 3.87
RMSE (m) = 11.22

Prepared by:

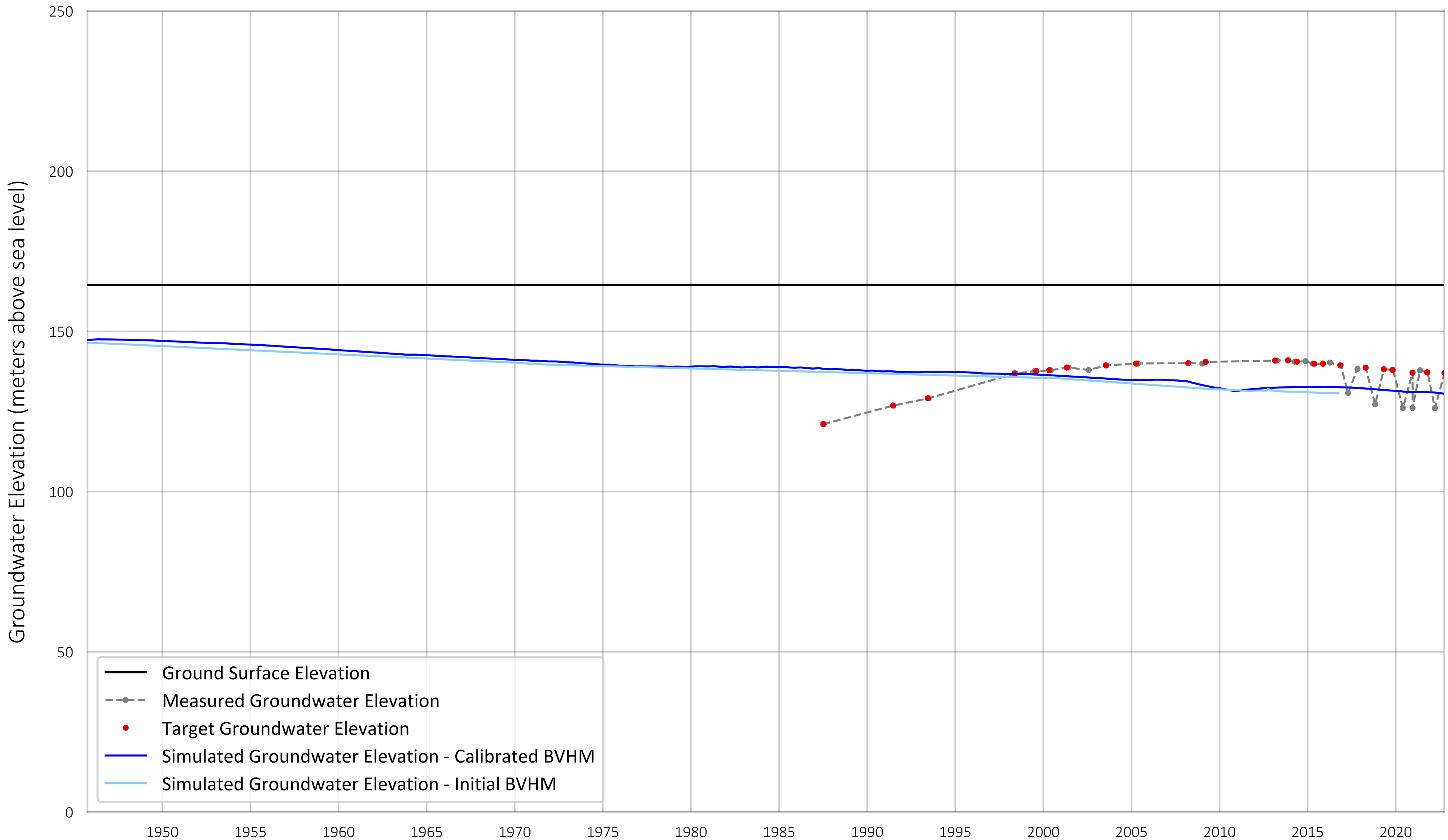
WEST YOST
Water. Engineered.

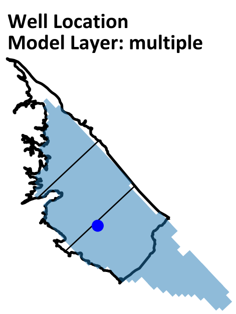
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245926
Well Name: Triangle

Figure B-68





Statistics

Target Groundwater Elevation (m)
Mean = 137.23
Standard Deviation = 5.02

Simulated Groundwater Elevation (m)
Mean = 134.08
Standard Deviation = 2.32

Mean Residual (m) = -3.15
RMSE (m) = 7.31

Prepared by:

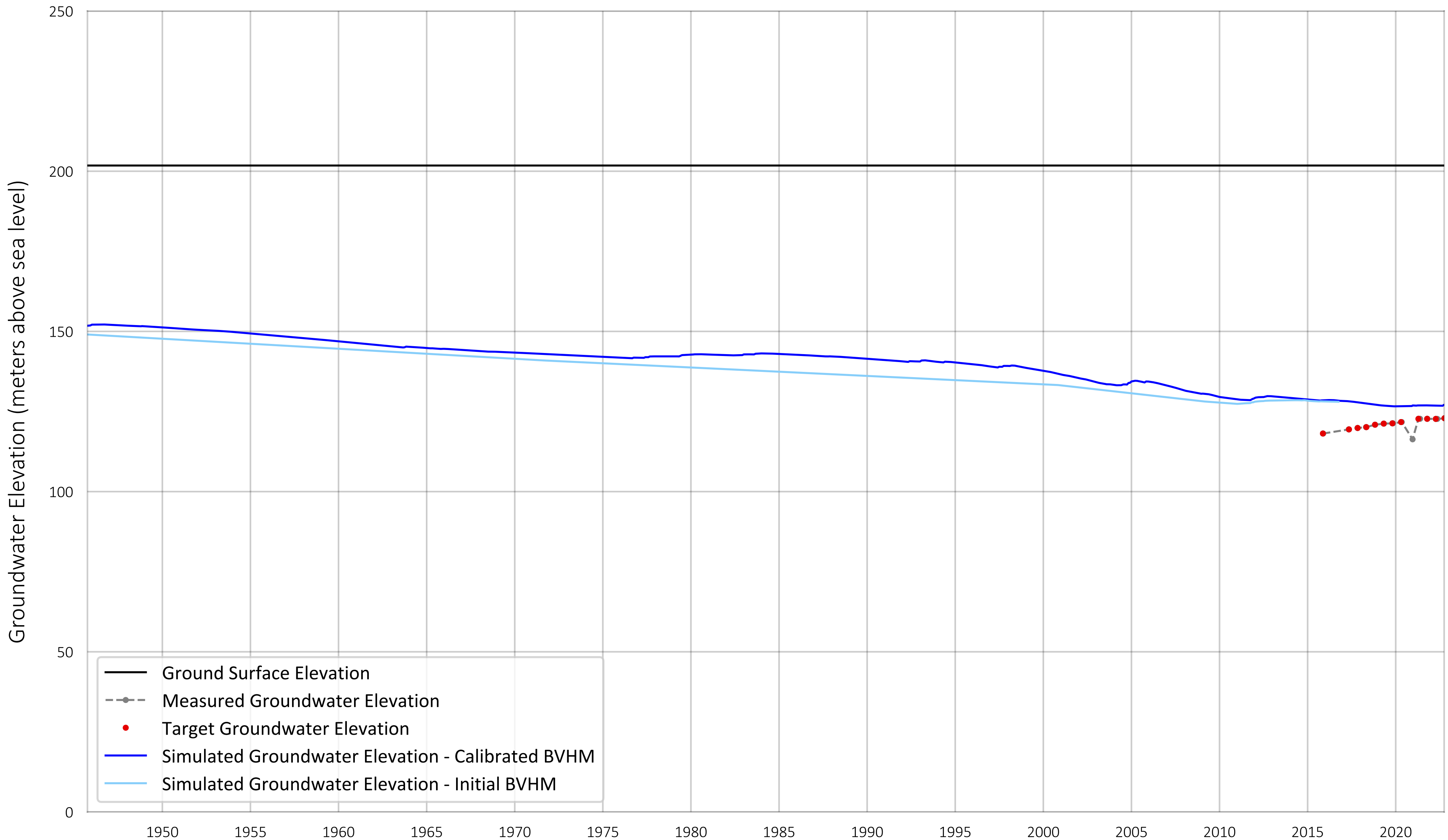
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

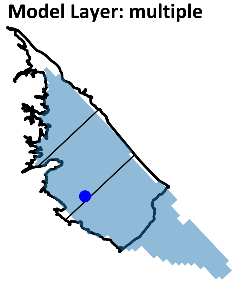
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245895
Well Name: La Casa

Figure B-69



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 120.98
Standard Deviation = 1.49

Simulated Groundwater Elevation (m)
Mean = 127.27
Standard Deviation = 0.65

Mean Residual (m) = 6.29
RMSE (m) = 6.60

Prepared by:

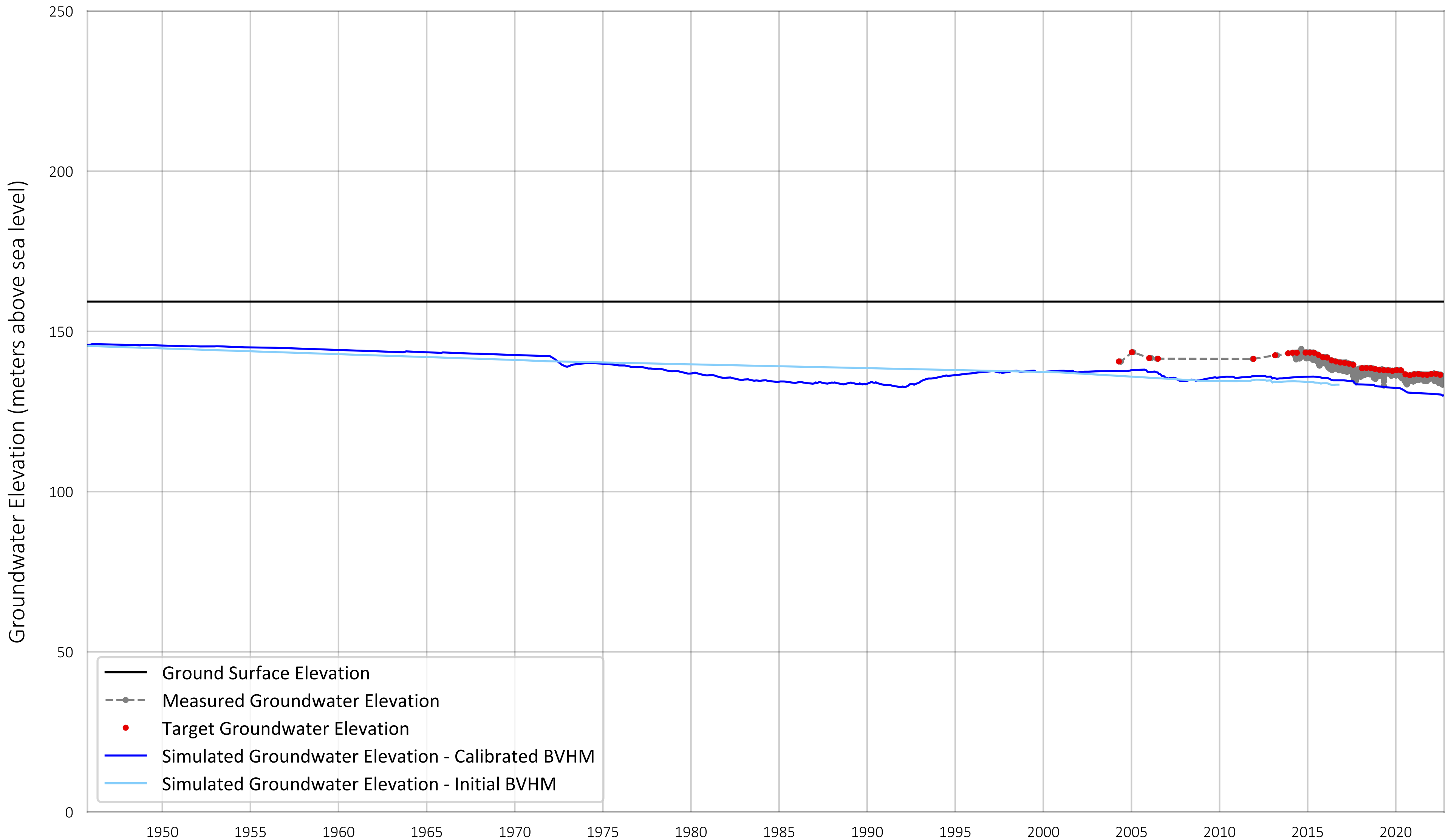
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

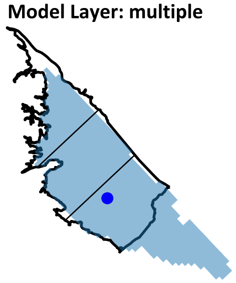
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245853
Well Name: Anzio Yaqui Pass

Figure B-70



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 139.73
Standard Deviation = 2.52

Simulated Groundwater Elevation (m)
Mean = 133.87
Standard Deviation = 2.26

Mean Residual (m) = -5.86
RMSE (m) = 5.94

Prepared by:

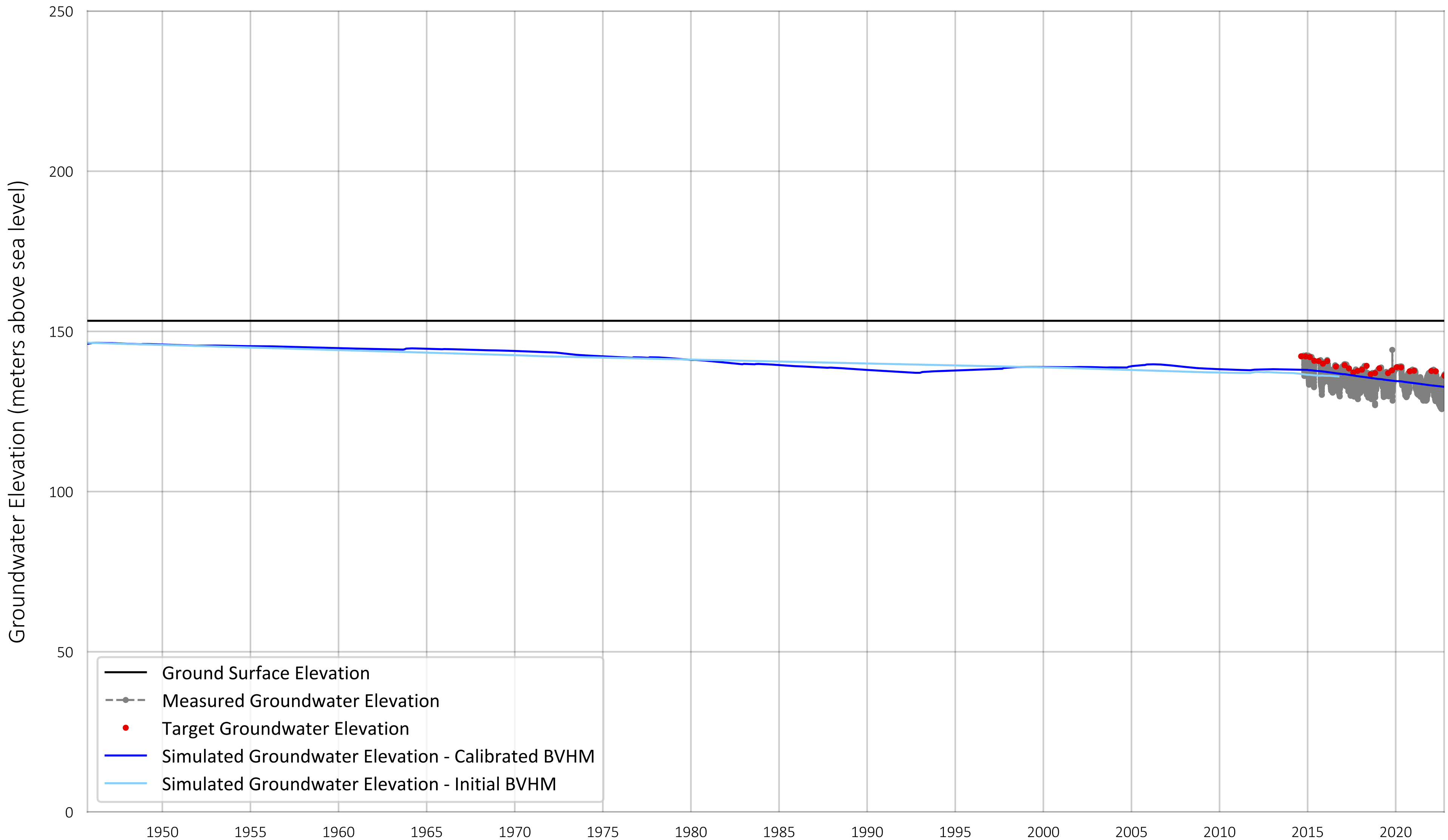
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

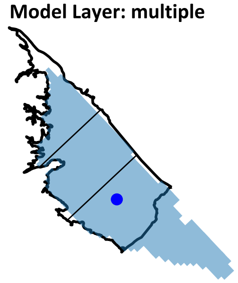
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245898
Well Name: MW-3

Figure B-71



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 138.91
Standard Deviation = 1.70

Simulated Groundwater Elevation (m)
Mean = 135.84
Standard Deviation = 1.56

Mean Residual (m) = -3.06
RMSE (m) = 3.24

Prepared by:

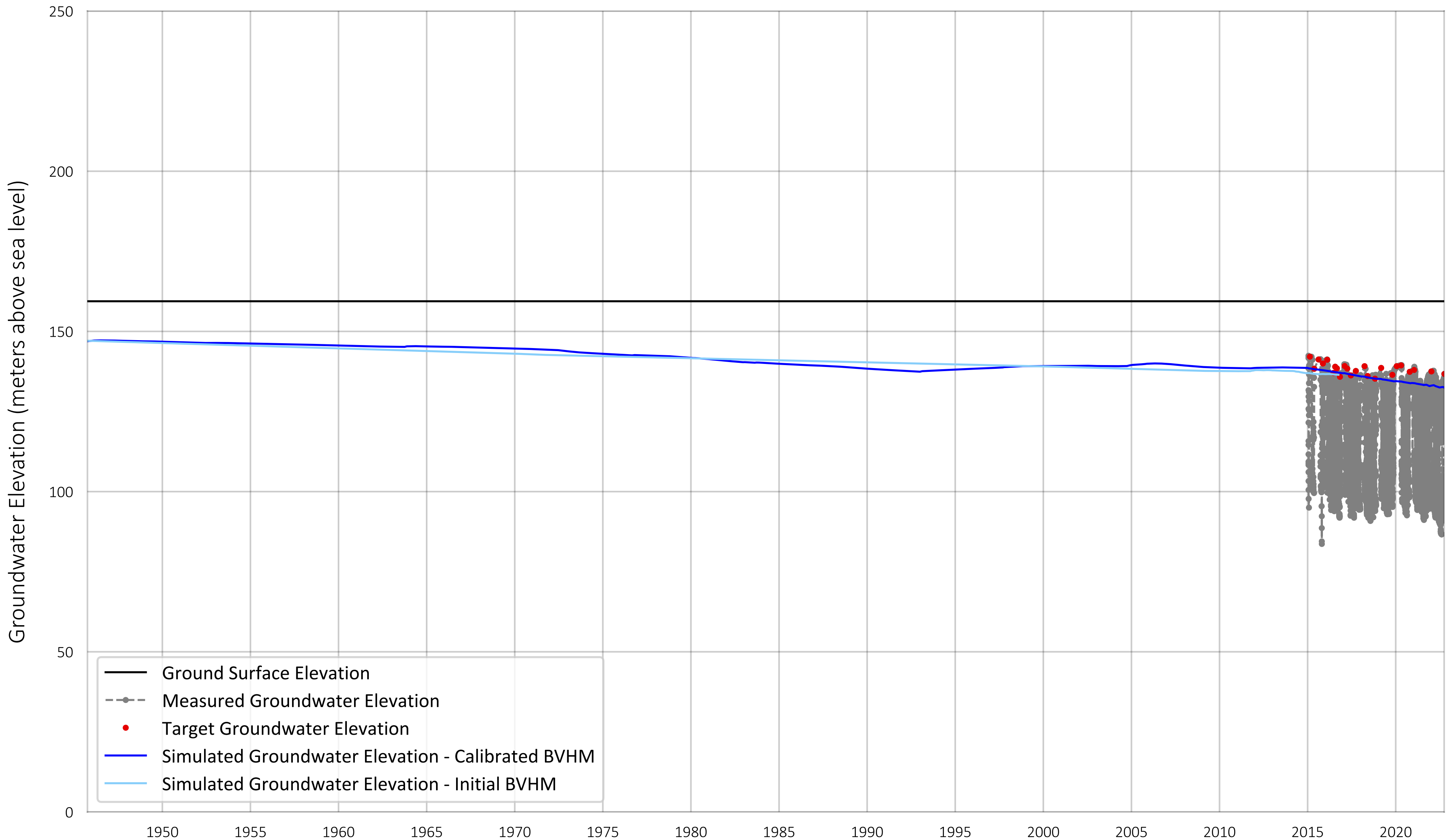
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

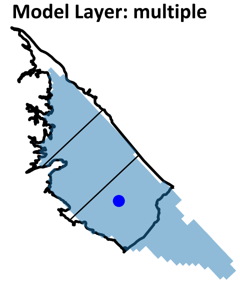
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245894
Well Name: JC Well

Figure B-72



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 138.33
Standard Deviation = 1.78

Simulated Groundwater Elevation (m)
Mean = 136.17
Standard Deviation = 1.59

Mean Residual (m) = -2.15
RMSE (m) = 2.78

Prepared by:

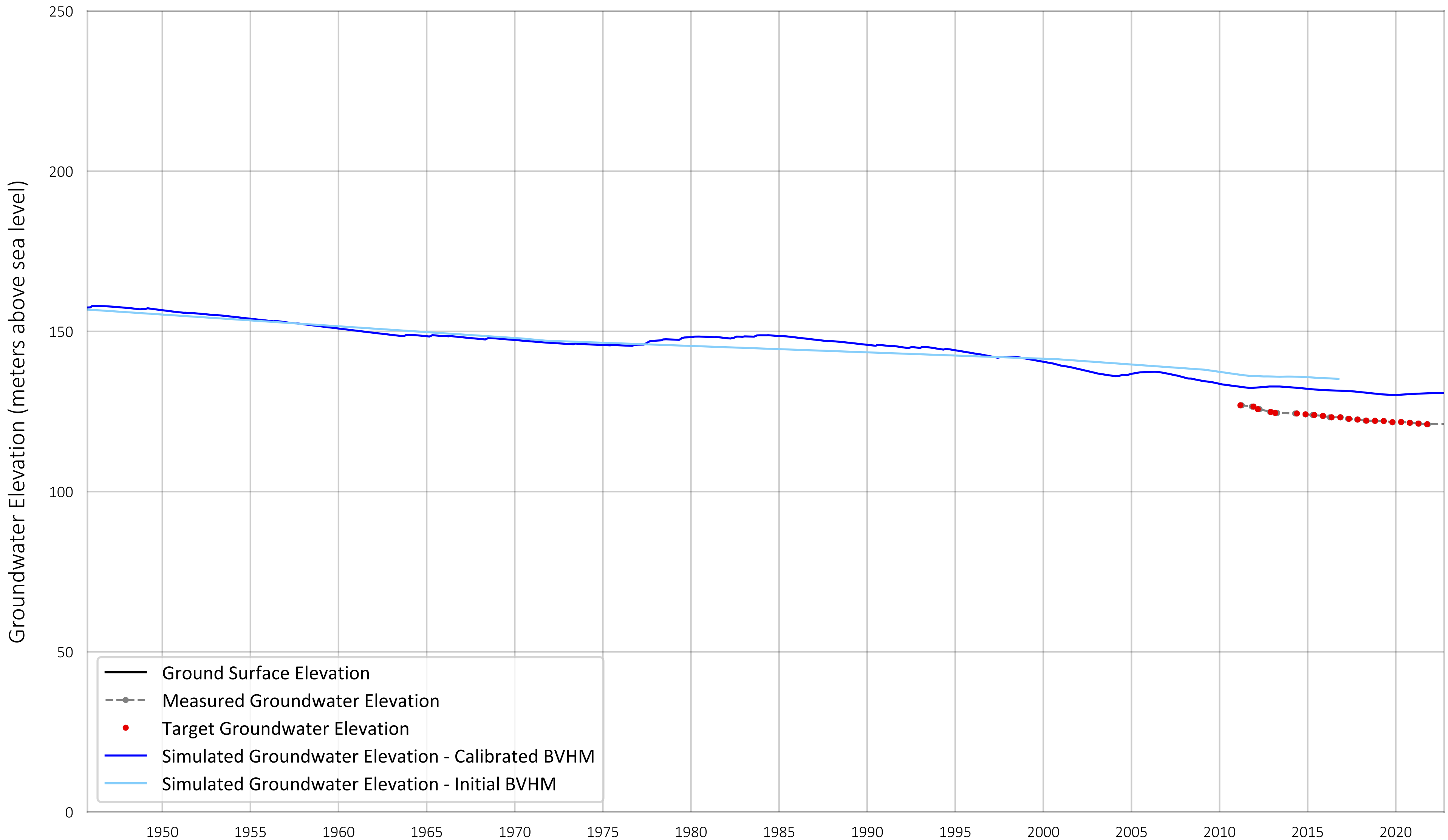
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

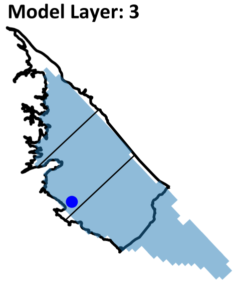
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245910
Well Name: RH-4

Figure B-73



Well Location
Model Layer: 3



Statistics

Target Groundwater Elevation (m)
Mean = 123.32
Standard Deviation = 1.72

Simulated Groundwater Elevation (m)
Mean = 131.47
Standard Deviation = 0.92

Mean Residual (m) = 8.16
RMSE (m) = 8.21

Prepared by:

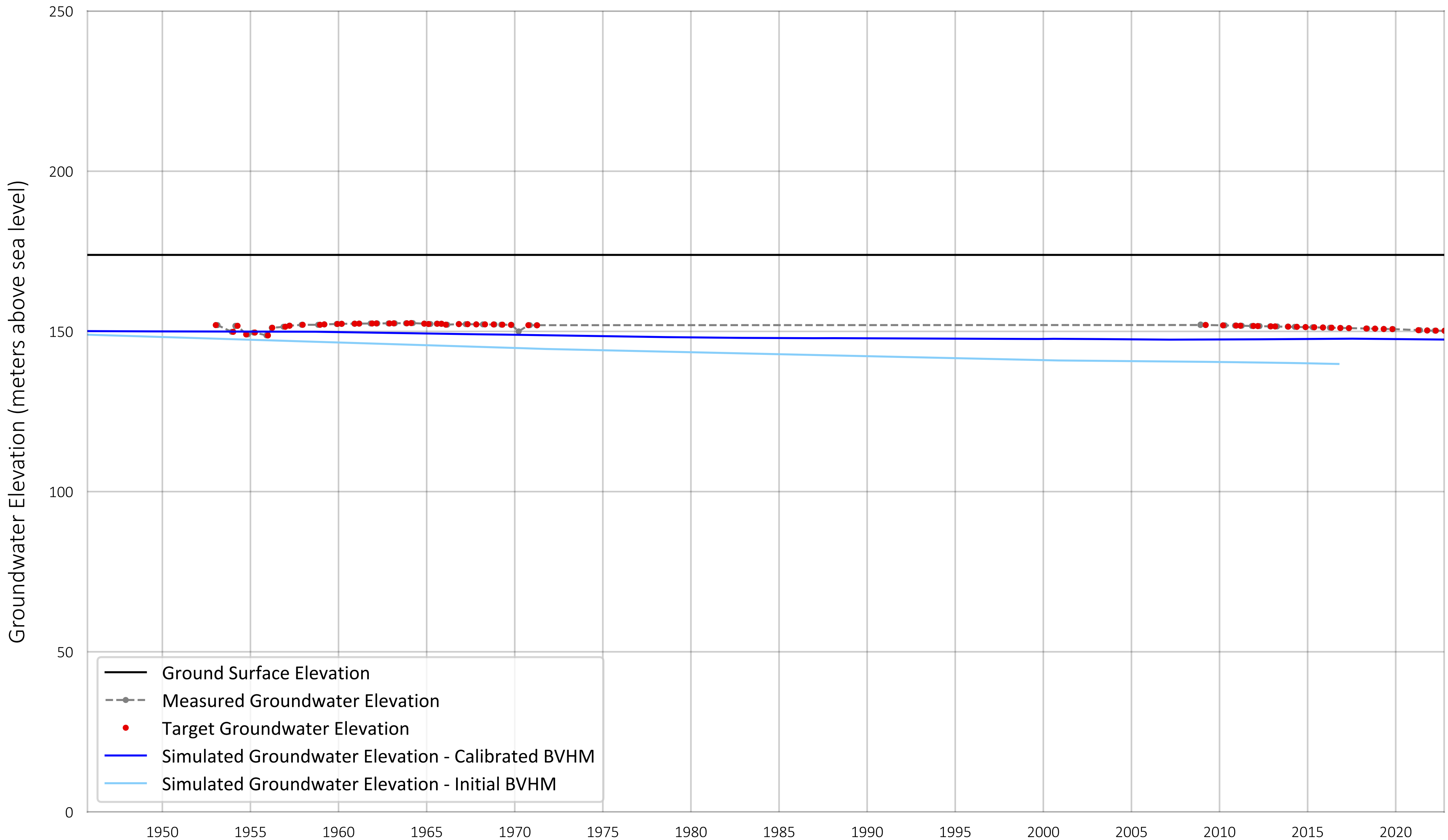
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245836
Well Name: Terry Well

Figure B-74

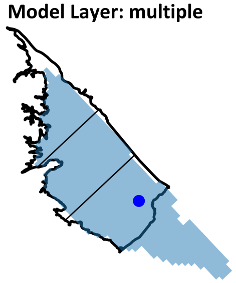


Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 151.61
Standard Deviation = 0.88

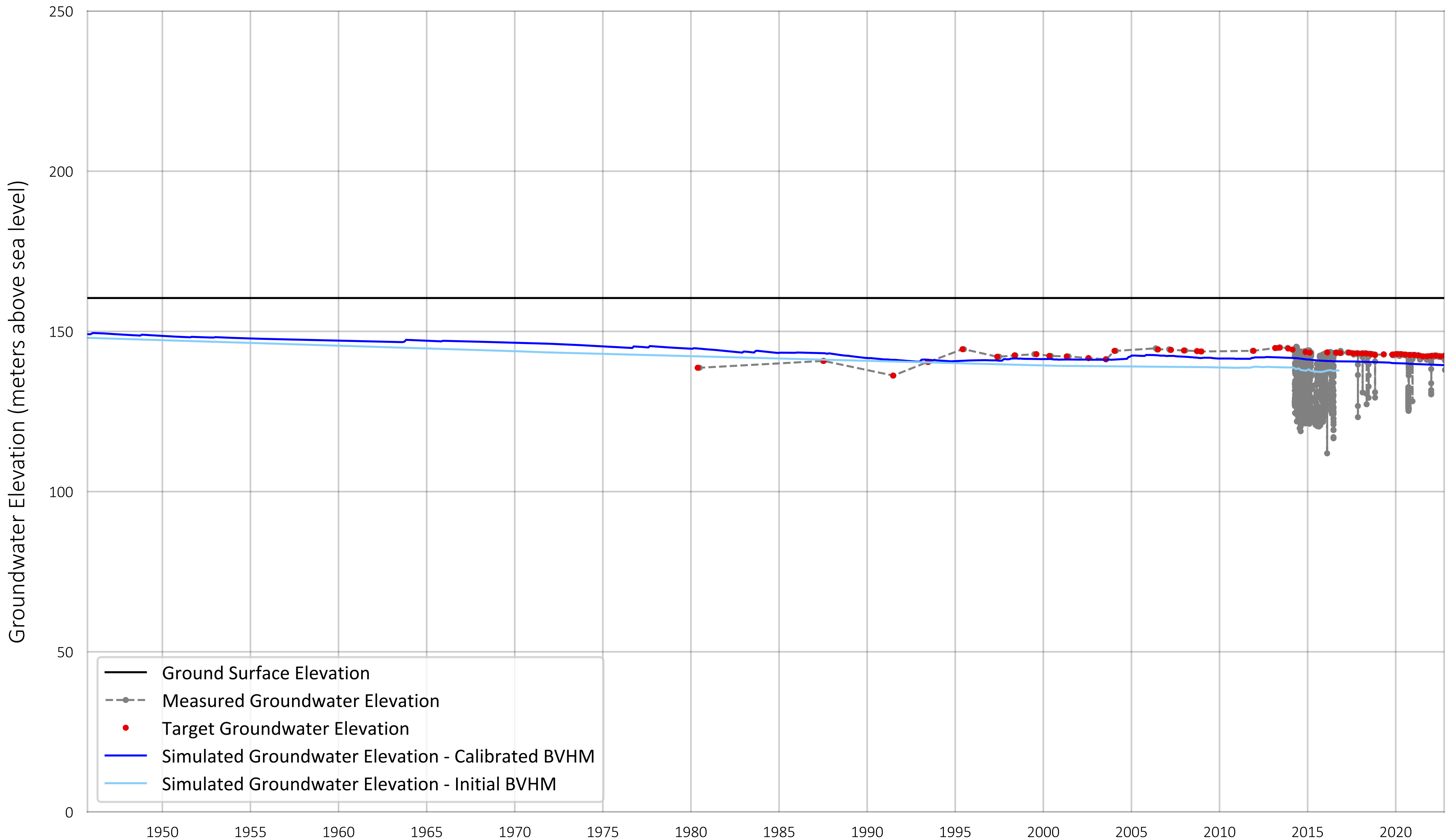
Simulated Groundwater Elevation (m)
Mean = 148.78
Standard Deviation = 1.01

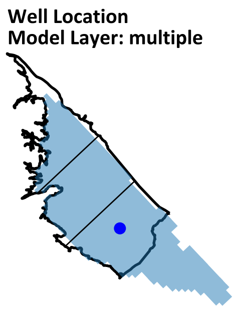
Mean Residual (m) = -2.83
RMSE (m) = 3.07

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245859
Well Name: Bing Crosby Well

Figure B-75





Statistics

Target Groundwater Elevation (m)
Mean = 142.80
Standard Deviation = 1.51

Simulated Groundwater Elevation (m)
Mean = 140.98
Standard Deviation = 1.03

Mean Residual (m) = -1.82
RMSE (m) = 2.59

Prepared by:

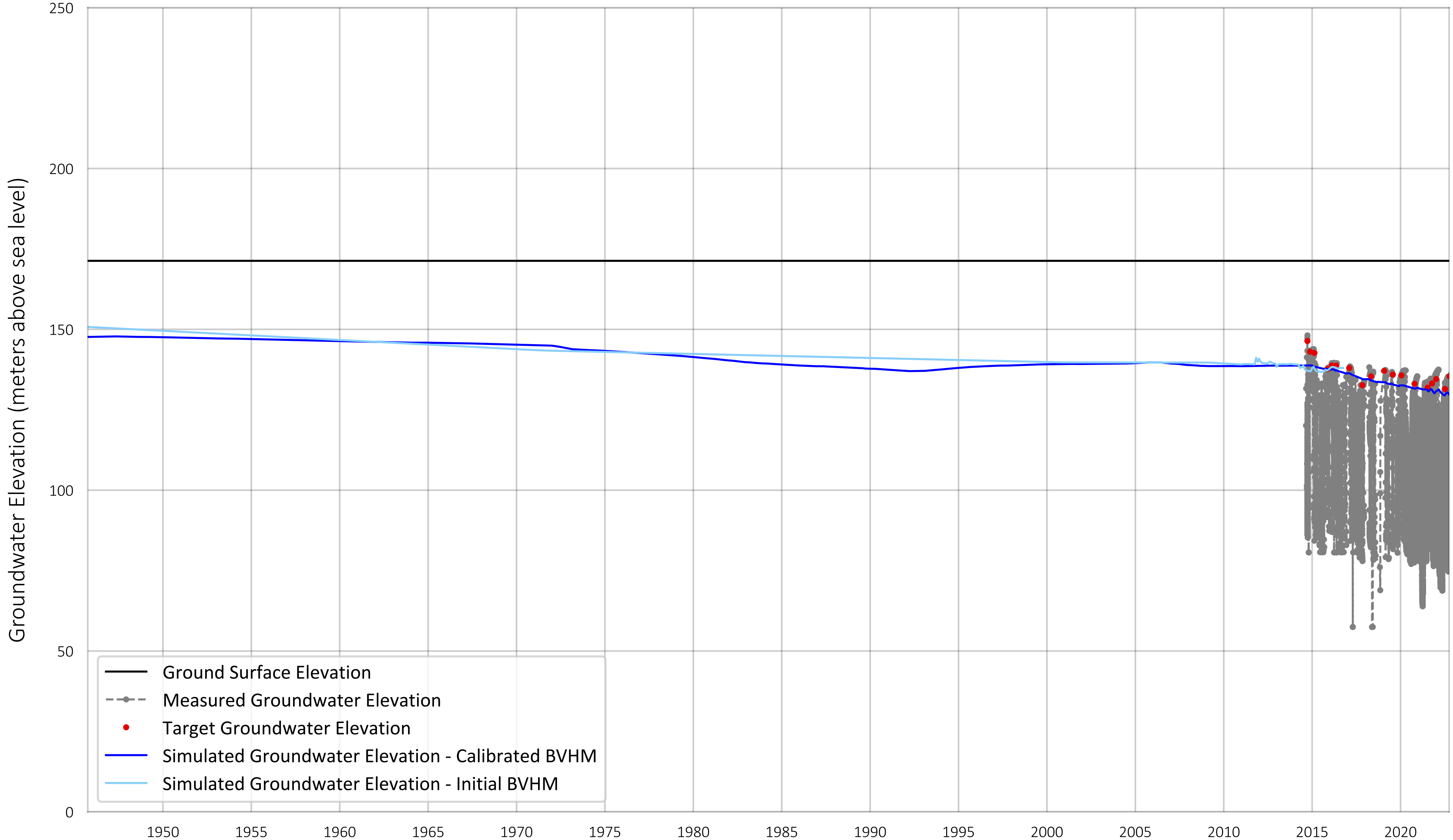
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

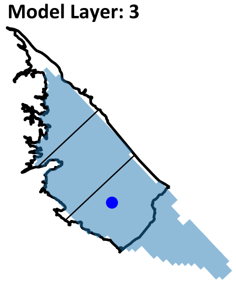
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245877
Well Name: RH-1 (ID1-1)

Figure B-76



Well Location
Model Layer: 3



Statistics

Target Groundwater Elevation (m)
Mean = 136.83
Standard Deviation = 4.19

Simulated Groundwater Elevation (m)
Mean = 134.50
Standard Deviation = 3.15

Mean Residual (m) = -2.33
RMSE (m) = 3.09

Prepared by:

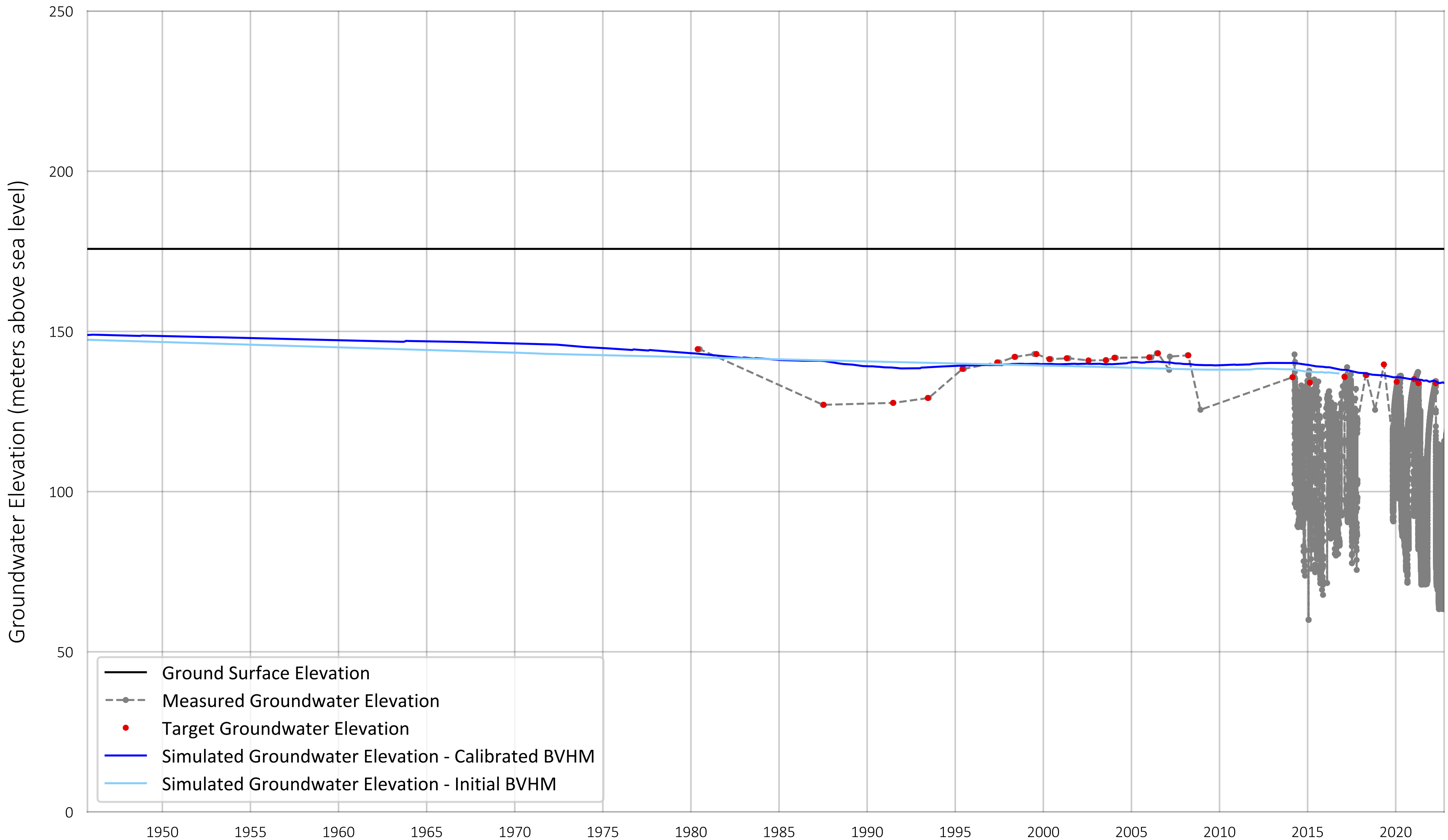
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

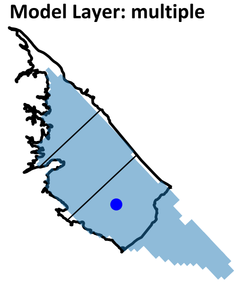
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245909
Well Name: RH-3

Figure B-77



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 137.80
Standard Deviation = 4.99

Simulated Groundwater Elevation (m)
Mean = 138.84
Standard Deviation = 2.12

Mean Residual (m) = 1.04
RMSE (m) = 4.55

Prepared by:

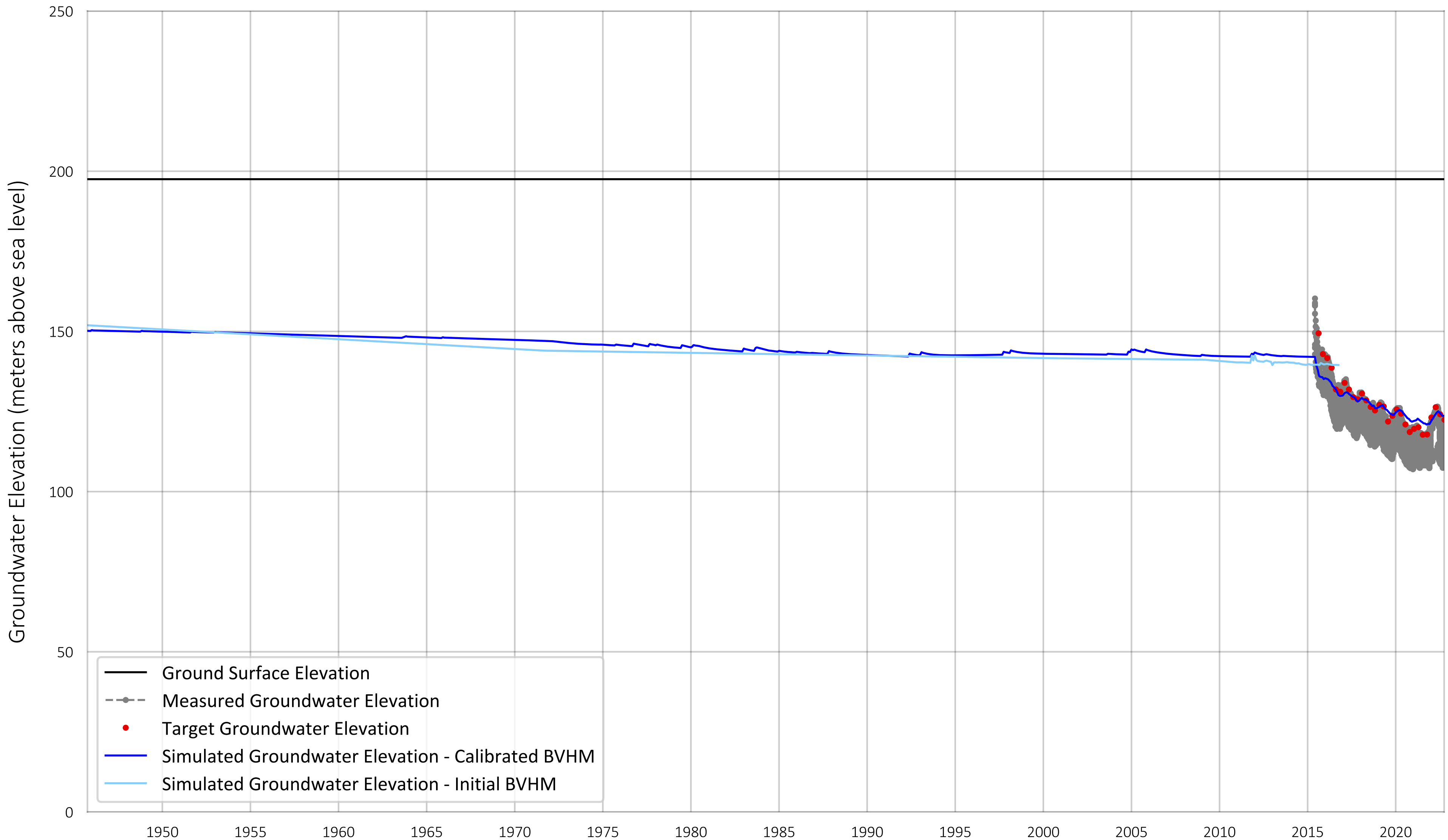
WEST YOST
Water. Engineered.

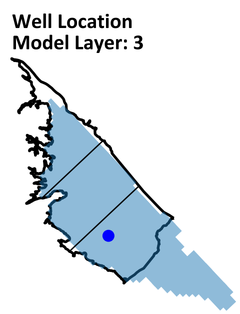
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245881
Well Name: RH-2 (ID1-2)

Figure B-78





Statistics

Target Groundwater Elevation (m)
Mean = 127.86
Standard Deviation = 7.74

Simulated Groundwater Elevation (m)
Mean = 127.22
Standard Deviation = 4.43

Mean Residual (m) = -0.64
RMSE (m) = 3.60

Prepared by:

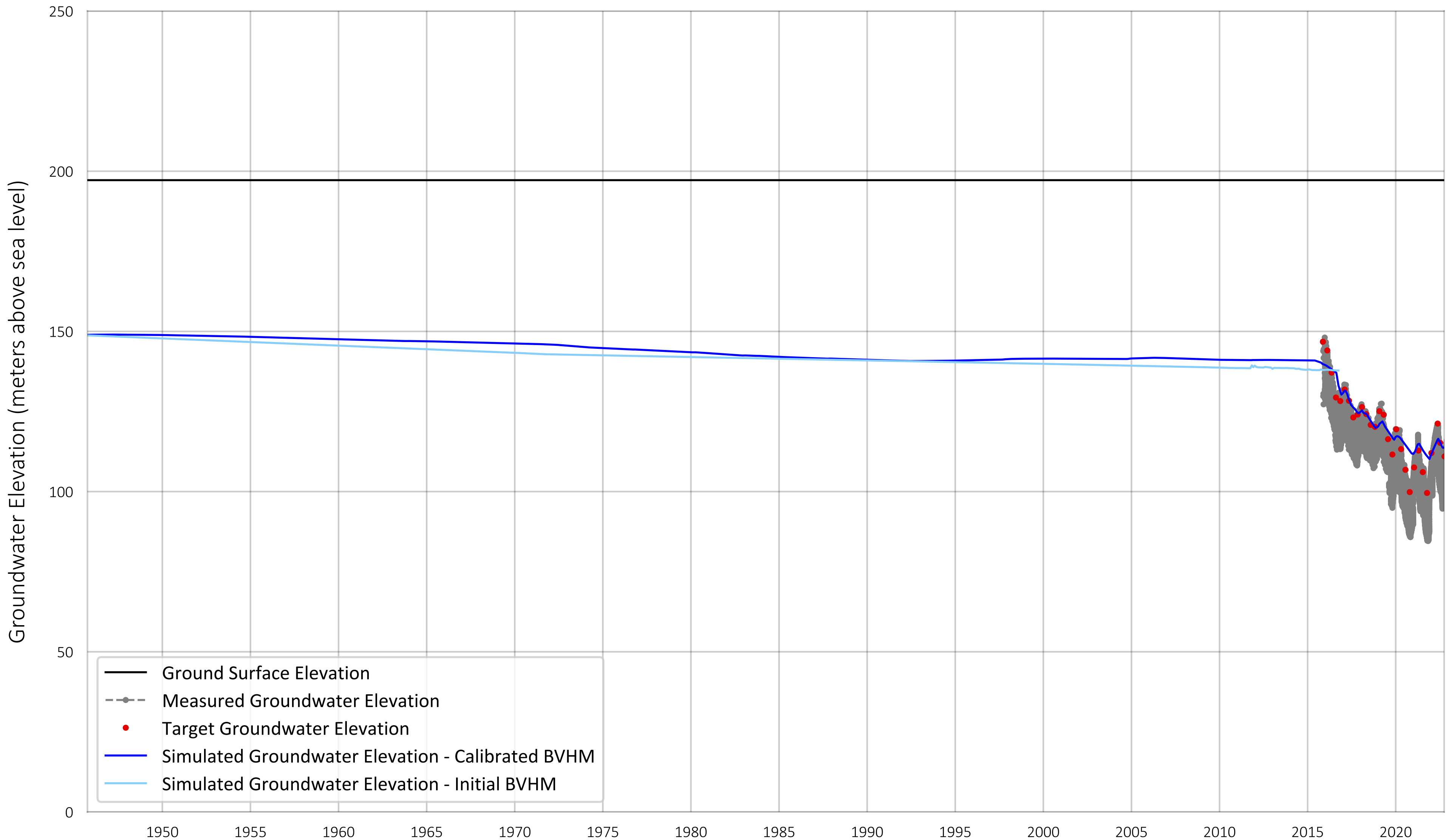
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

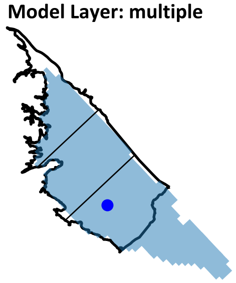
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245911
Well Name: RH-5

Figure B-79



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 120.55
Standard Deviation = 11.69

Simulated Groundwater Elevation (m)
Mean = 122.18
Standard Deviation = 8.89

Mean Residual (m) = 1.62
RMSE (m) = 4.93

Prepared by:

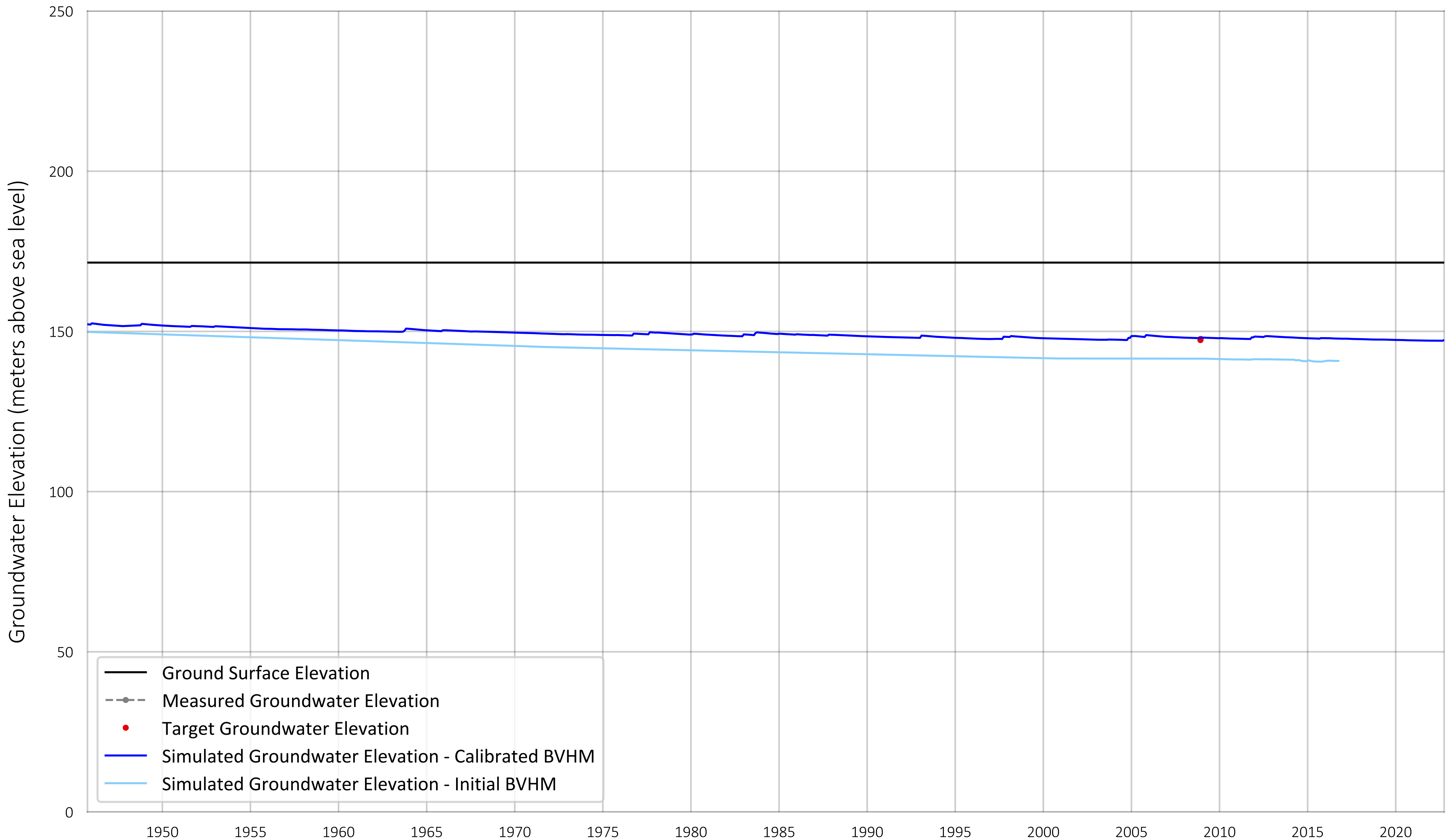
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

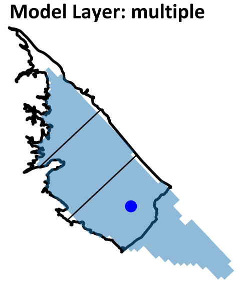
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245912
Well Name: RH-6

Figure B-80



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 147.47
Standard Deviation = 0.23

Simulated Groundwater Elevation (m)
Mean = 147.90
Standard Deviation = 0.01

Mean Residual (m) = 0.43
RMSE (m) = 0.46

Prepared by:

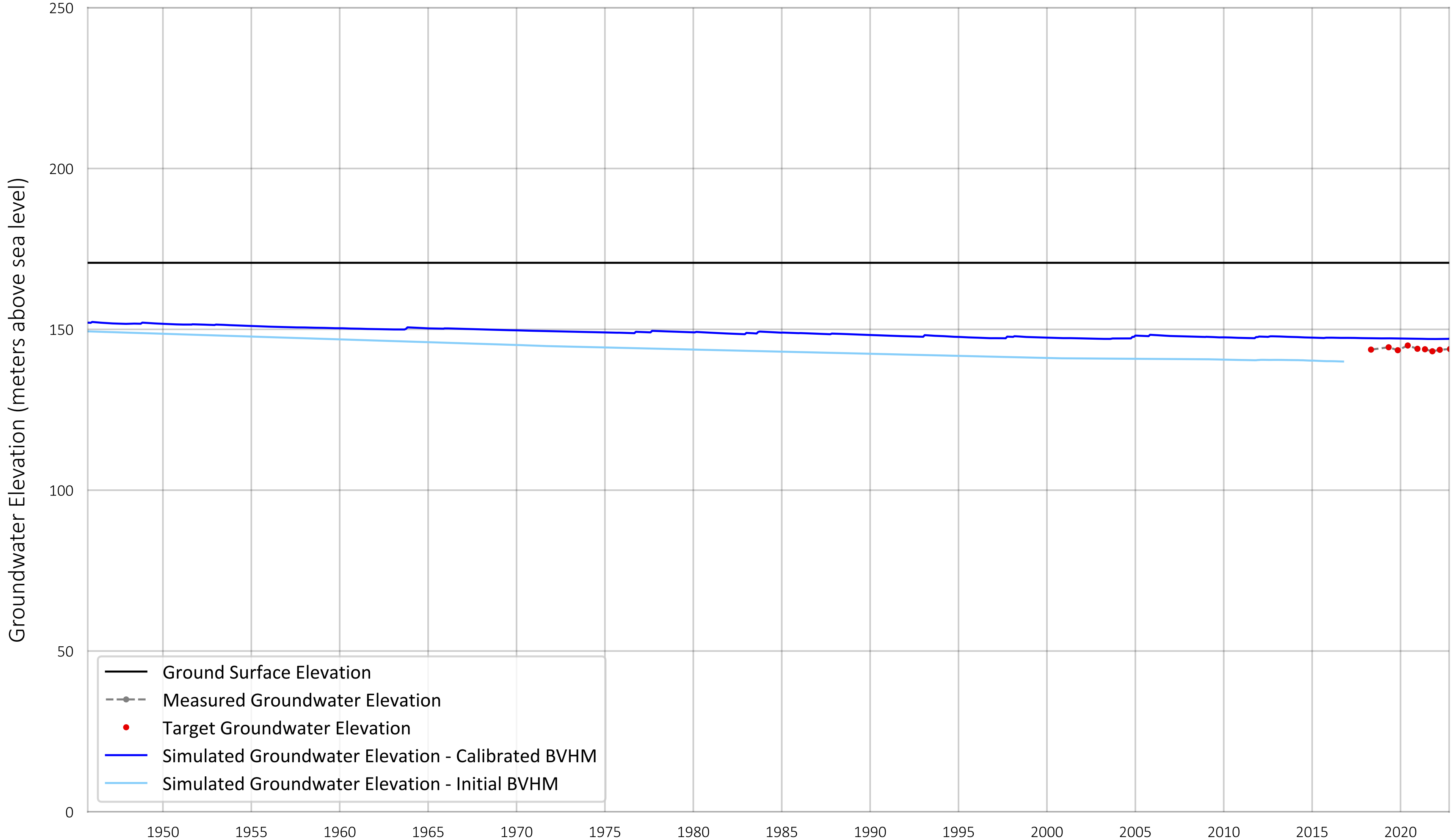
WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

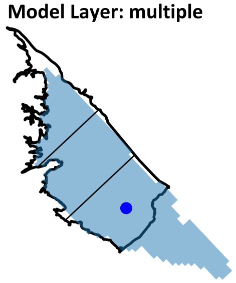
Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245915
Well Name: BAR #3

Figure B-81



Well Location
Model Layer: multiple



Statistics

Target Groundwater Elevation (m)
Mean = 143.90
Standard Deviation = 0.56

Simulated Groundwater Elevation (m)
Mean = 147.10
Standard Deviation = 0.10

Mean Residual (m) = 3.20
RMSE (m) = 3.24

Prepared by:

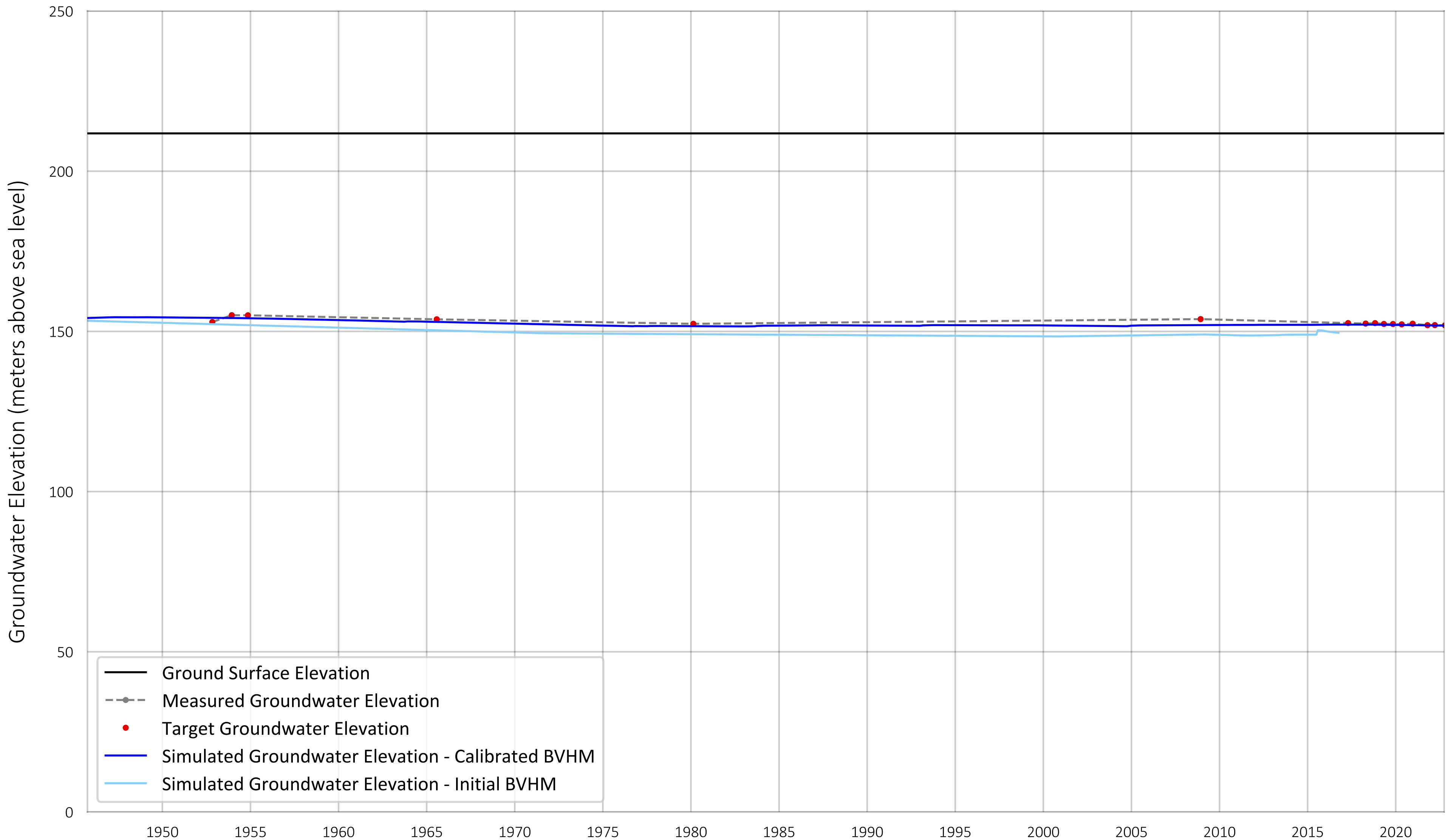
WEST YOST
Water. Engineered.

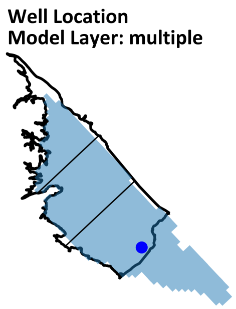
Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245852
Well Name: Air Ranch Well 4

Figure B-82





Statistics

Target Groundwater Elevation (m)
Mean = 152.92
Standard Deviation = 1.02

Simulated Groundwater Elevation (m)
Mean = 152.49
Standard Deviation = 0.92

Mean Residual (m) = -0.43
RMSE (m) = 0.77

Prepared by:

WEST YOST
Water. Engineered.

Prepared for: Borrego Springs Watermaster

Calibrated BVHM Groundwater Elevation

HydroDaVE Well ID: 1245875
Well Name: Hayden

Figure B-83

Appendix C

Response to Comments

RESPONSE TO COMMENTS ON THE DRAFT TASK 4 TM – *MODEL CALIBRATION AND REDETERMINATION OF THE 2025 SUSTAINABLE YIELD*

Comments from Wagner & Bonsignore on behalf of AAWARE

Comments were provided on October 4, 2024 as a red-line document of the draft report. Grammatical edits were added and accepted. The following shows how the comments and suggestions by Wagner & Bonsignore were addressed.

1) **Comment – [FMP Calibration Results and Conclusions]:** *"Should we have another table similar to this one but with the results from Table 6. Water Budget for the Calibrated BVHM?"* [in reference to Table 3 – FMP-Estimated Pumping vs. Actual Pumping WY 2021-2022]

   Response*:* The percent difference between FMP-estimated pumping and Actual pumping for the *Calibrated BVHM* is the same as the *Calibrated FMP* (-1.7% [underestimated] in WY 2021 and 0.5% [overestimated] in WY 2022). Therefore, no additional table is necessary.

2) **Comment – [FMP Calibration Results and Conclusions]:** *"Why did the total metered pumping numbers change? According to Technical Memorandum dated March 15, 2024 Table 1, actual pumping was 12,857 AF in 2021 and 10,863 AF in 2022? See Appendix A."* [in reference to Table 3 – FMP-Estimated Pumping vs. Actual Pumping WY 2021-2022]

   Response: Actual Pumping reported in the draft Task 4 TM was updated to reflect changes to estimates of groundwater pumping in WY 2021 and WY 2022, which include:

   - Pumping from the Anza Borrego Desert State Park well is removed from Actual Pumping. In Task 3 of the scope of work, the State Park well was added to the MNW2 package and pumping was assigned. Therefore, pumping from the State Park well in WYs 2021 and 2022 is no longer compared to pumping estimated by the FMP, since the pumping is assigned.
   - Pumping from two wells in WY 2021 was updated to reflect updates to estimated pumping, based on newly available metered data. These two wells lacked metered data, so pumping was initially estimated for WY 2021 using the water duty method. In WY 2022, these wells were metered and the metered data was used to calculate total pumping. In comparing metered pumping data to estimated pumping from the water duty method, it was discovered that water duty method overestimated metered pumping for these wells. The estimated pumping for WY 2021 was revised and based on the metered pumping data for WY 2022. This change in estimated pumping in WY 2021 was also incorporated in the calculation of Actual Pumping in this TM.

   A footnote was added to the text to document the changes made to the calculation of Actual Pumping.

3) **Comment – [FMP Calibration Results and Conclusions]:** *"This statement seems incorrect because it assumes that the monthly ET values from the Calibrated FMP have more credibility than the ET estimated from the two Open ET models."* [in reference to the statement "These charts indicate that eeMETRIC and geeSEBAL generally underestimate ET compared to the *Calibrated FMP*, especially during the early period of 2016-2019."]

   Response: The text was revised to remove the use of terms such as "over-estimated" and "under-estimated".

4) **Comment – [FMP Calibration Results and Conclusions]:** "*This should not be the reason for the eeMETRIC uncertainty in Borrego Springs given that it is less likely to have cloudy conditions which greatly reduces the atmospheric interference*." [in reference to the statement "Specially, the geeSEBAL model tends to yield lower ET estimates in desert and arid regions and the eeMETRIC model has uncertainty associated with atmospheric influence, particularly during cloudy conditions."]

 Response: No changes were made to the text. Cloudy conditions do occur in Borrego Springs on occasion, and should be considered when evaluating differences between FMP- and eeMETRIC-estimated ET. An example of the influence of cloudy conditions on eeMETRIC's estimate of ET is provided in the TM. Different estimates of ET by the FMP vs. eeMETRIC are shown in March 2020, which aligns with a precipitation event (*i.e.* cloudy conditions). Around the time of this precipitation event, ET estimated by the FMP is larger than ET estimated by eeMETRIC.

5) **Comment – [BVHM Calibration Methods]:** "*Please add the source for the scalar mutlipliers.*" And, in reference to the scalar multipliers, "*Are these from the USGS study?*

 Response: The text was updated to identify that the initial scalar multipliers (that were adjusted during model calibration) were sourced from the *Initial BVHM*. The sentence now reads "Scalar multipliers of the *Initial BVHM* were used and then adjusted within reasonable ranges (constrained between 0.80 to 1.20)."

6) **Comment – [Redetermination of the 2025 Sustainable Yield]:** "*Why did outflows from the model stay the same after excluding the portion of the model overlying the Ocotillo Subbasin? Average inflows were reduced by about 500 af, should outflows be also reduced?"*

 Response: Outflows are different for the water budget calculated for the entire model domain (Table 2, for the *Pre-Calibrated BVHM*) and the water budget calculated for the Basin-only portion of the model domain (Table 6, for *Calibrated BVHM*). Table 2 shows that average annual outflows are 14,057 afy from the *Pre-Calibrated BVHM* for the entire model domain. Table 6 shows that the average annual outflows are 17,192 afy from the *Calibrated BVHM* for the Basin-only portion of the model domain. The cause of the increase in annual average outflows in the *Calibrated BVHM* is the increase in estimated pumping by the FMP.

7) **Comment – [Uncertainty Analysis]:** Recommendation to revise sentence to "Selected the ten "best" model realizations from the calibration runs **produced with PESTPP-IES***"*

 Response*:* The text was updated to implement this recommendation.

Comments from Aquilogic on behalf of Rams Hill

Comments were provided on October 4, 2024 as a red-line document of the draft report. Grammatical edits were added and accepted. The following shows how the comments and suggestions by Aquilogic were addressed.

1) **Comment – [Executive Summary]:** Recommendation to modify the sentence "The simulated water budgets for the Basin produced from the model calibration and sensitivity analysis were used to redetermine the 2025 Sustainable Yield, which is intended to represent the average annual volume of groundwater that can be pumped from the Basin without causing ~~chronic overdraft conditions~~ **undesirable results**."

 Response: The text was not revised as suggested. This is because the Rampdown of groundwater pumping to the 2025 Sustainable Yield has not yet been evaluated for the potential to cause Undesirable Results. This evaluation would require running the *Calibrated BVHM* in projection mode to simulate the Rampdown of pumping to the 2025 Sustainable Yield by 2040, and then assessing groundwater conditions for significant and unreasonable impacts to beneficial uses/users in the Basin [Note: Such an evaluation is a recommendation in this TM]. Instead, the

2025 Sustainable Yield was calculated as the long-term "net recharge" to the Basin, which is intended to represent the average annual volume of groundwater that can be pumped from the Basin without depleting groundwater in storage.

2) **Comment – [Background and Objectives]:** "*Simulation Period"* [of the Initial BVHM]

   Response*:* The simulation period of the *Initial BVHM* was WY 1930 through 2011. Additionally, projection scenarios were run using the *Initial BVHM* over a 50-year period from 2011 to 2060. A footnote was added to the text to identify the simulation period of the *Initial BVHM*.

3) **Comment – [Calibration of the FMP]:** *"Recommended for the original BVHM, or recommended in some other study?"* [in reference to the statement that "values of KC recommended by the USGS based on crop stage (early, mid, or late)."]

   Response*:* The USGS-recommended values of crop coefficients are referenced in Appendix 6. Farm Process Version 4 (FMP) of the *One-Water Hydrologic Flow Model: A MODFLOW Based Conjunctive-Use Simulation Software* (Boyce et al., 2020).[1] A reference to this source was added to the text.

4) **Comment – [Calibration of the FMP]:** *"Recommended for the original BVHM, or recommended in some other study?"* [in reference to the statement that "FTR values for two crop types in the FMP (golf courses and potatoes) were increased to match USGS-recommended values more closely and to better match monthly FMP-estimated pumping with monthly Actual pumping in WY 2021 and 2022."]

   Response*:* The USGS-recommended values of FTR are referenced in Appendix 6. Farm Process Version 4 (FMP) of the *One-Water Hydrologic Flow Model: A MODFLOW Based Conjunctive-Use Simulation Software* (Boyce et al., 2020). A reference to this source was added to the text.

5) **Comment** – **[Redetermination of the 2025 Sustainable Yield]:** *"What is the change in storage when pumping is limited to 7,952 AFY?"*

   Response: The change in storage under a Sustainable Yield of 7,952 afy has not yet been calculated and is not part of the scope of Task 4. The change in storage will be calculated using projection scenarios in the BVHM, which will occur under Task 5. Following the Watermaster Board's direction, Task 5 will be performed in parallel to Redetermining the 2025 Sustainable Yield. Therefore, the projection of future changes in groundwater storage will not be available for this report.

6) **Comment** – **[Uncertainty Analysis]:** *"Table 2 shows year by year water budgets, not realizations."*

   Response*:* The sentence was updated to reference Table 11, which summarizes the range of estimates of the Sustainable Yield from the uncertainty analysis.

No Comments Received from:

- Trey Driscoll (Intera) on behalf of the Borrego Water District
- Jim Bennett on behalf of the County of San Diego
- John Peterson on behalf of the Roadrunner Club
- Russell Detwiler (University of California, Irvine) on behalf of the Borrego Springs Community

[1] Boyce, S.E., Hanson, R.T., Ferguson, I., Schmid, W., Henson, W., Reimann, T., Mehl, S.M., and Earll, M.M., 2020, One-Water Hydrologic Flow Model: A MODFLOW based conjunctive-use simulation software: U.S. Geological Survey Techniques and Methods 6–A60, 435 p., https://doi.org/10.3133/tm6A60.