Borrego Springs Watermaster
Technical Advisory Committee Ad-Hoc Meeting
March 29, 2024 @ 10:00 a.m.
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AGENDA

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

I. **Roll Call**

II. **Public Comments**
This is an opportunity for members of the public to address the TAC on items included on the agenda. Comments will be limited to three minutes per commenter. Comments will be limited to 10 minutes total.

III. **Preparatory Work for Task 4 of the 2025 Redetermination of the Sustainable Yield -– *Model Recalibration*.........Page 2**

IV. **Future Meetings**

V. **Adjournment**

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Preparatory Work for Task 4 – *Model Recalibration*
2025 Redetermination of the Sustainable Yield

DATE: March 15, 2024

TO: Technical Advisory Committee
Borrego Springs Watermaster

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

SUBJECT: Preparatory Work for Task 4 – Model Recalibration
2025 Redetermination of the Sustainable Yield

BACKGROUND AND OBJECTIVES

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

- Task 1 – Compare FMP-estimated Pumping to Actual Pumping for WY 2022
- Task 2 – Update Water-Use Factors in the FMP
- Task 3 – Correct Errors Identified in the 2021 BVHM
- Task 4 – Model Recalibration
- Task 5 – Determine the Sustainable Yield

To-date, West Yost has completed Tasks 1 through 3 of the scope of work and has begun work on Task 4 – *Model Recalibration*. Most of the Task 4 work has been preparing the BVHM for recalibration. The TAC has asked to review the preparatory work prior to West Yost performing the recalibration.

The purpose of this memorandum is to describe the preparatory work that has been performed by West Yost for BVHM recalibration. Through TAC review of this memorandum, West Yost hopes to solicit TAC input and suggestions before proceeding with the recalibration. This memo includes the following sections and attachments to describe the preparatory work:

- **Version of the BVHM to Recalibrate**. This section describes the version of the BVHM that West Yost has prepared and tested prior to recalibration, which incorporates West Yost's prior work to extend and improve the model in Task 1, Task 2, and Task 3. This section also includes a historical water budget for the Basin that was generated by running this "pre-calibrated" version of the BVHM over the historical period of WY 1945-2022.
- **Model Calibration Targets and Data**. This section describes the selected calibration targets and data that will be used during model recalibration.
- **Pilot Points and Adjustable Model Parameters**. This section describes the selected pilot points and parameters that will be adjusted during model recalibration.

- **Historical On-Farm Efficiencies**. This section describes the effort to develop and constrain historical On-Farm Efficiencies (OFE) values to use in the FMP during model recalibration. This effort included performing a literature review of historical irrigation practices in the Borrego Valley and interviewing agricultural pumpers.

VERSION OF THE BVHM TO RECALIBRATE

West Yost has prepared and tested the version of the BVHM to calibrate in Task 4. This most recent version of the BVHM is termed the "*Task 4 Pre-Calibrated BVHM*" and includes ***all*** updates and improvements to the BVHM implemented in Task 1, Task 2, and Task 3. A historical water budget for the Basin was generated by running *Task 4 Pre-Calibrated BVHM* over the historical period WY 1945-2022, which was then compared to the water budgets from prior BVHM versions. These water budgets and comparisons are described below:

- **Table 1. Water Budget from Task 4 Pre-Calibrated BVHM**. This table describes the annual historical water budget for the Basin generated from running the *Task 4 Pre-Calibrated BVHM* over the historical period WY 1945-2022.
- **Table 2. Comparison of Average Annual BVHM Water Budgets.** This table compares the annual average water budget generated from the *Task 4 Pre-Calibrated BVHM* to water budgets generated from prior versions of the BVHM, including the BVHM versions generated in Task 1, Task 2, and Task 3 of the current scope-of-work. The columns in this table include water budgets for the:
    - **Task 1 2022 BVHM**. This is the version of the BVHM that was extended through WY 2022 and used to perform Task 1 to compare FMP-estimated pumping to Actual pumping in WY 2021 and WY 2022.
    - **Task 2 BVHM—*Updated Water-Use Factors*.** Water-use factors used in the FMP were evaluated and updated to more realistic/defensible values to improve the ability of the FMP to estimate groundwater pumping in WY 2021 and 2022. The two water-use factors that were updated were: crop coefficient (KC) and OFE, or irrigation efficiency. The scaling factors applied to the KC and OFE values were removed, which resulted in more realistic values of KC and OFE values and a more accurate FMP estimate of pumping in WY 2021 and 2022 (when groundwater pumping was metered for the first time).
    - **Task 3 BVHM—*Corrected Errors in 2022 BVHM.*** In this task, several errors and discrepancies that were identified in the 2022 BVHM were corrected, including errors in the Streamflow Routing (SFR), Multi-Node Well (MNW2), and Flow and Head Boundary (FHB) packages and the FMP. The errors corrected were from input errors, such as the assignment of model inputs to inactive cells, discretization, cell geometry, depth distribution of pumping, etc. The results were presented as the column representing the "Final Corrected BVHM" in Table 7 of the Task 3 technical memorandum (TM).[1] The updated water-use factors from Task 2 were not included in Task 3.
    - ***Task 4 Pre-Calibrated BVHM***. This is the version of the BVHM that will be recalibrated in Task 4. This BVHM version includes all updates and improvements made to the BVHM in Task 1, Task 2, and Task 3.

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[1] Available on the Watermaster's website at: https://borregospringswatermaster.com/wp-content/uploads/2023/12/BVHM-Task-3-TM-Final.pdf

Table 2 shows the impacts to the simulated water budget that resulted from the updates and improvements to the BVHM made in Tasks 1, 2, and 3 (see last column in Table 2 under *% Difference* for *Task 4 Pre-Calibrated BVHM*):

- *Increase in total inflows by 28%.* Total inflows increased by 2,144 acre-feet per year (afy) from the improvements made to the BVHM in Task 2 and Task 3. All components of inflow to the model domain increased, including streambed recharge, unsaturated zone recharge, and subsurface inflow. The increased inflows are due to corrections made to the SFR and FHB packages made during Task 3 and increased return flows generated from updating the OFE values in Task 2.
- *Increase in total outflows by 16%.* Total outflows increased by 2,480 afy from the improvements made to the BVHM in Task 2 and Task 3. The increase in total outflow is driven by a 26% increase in the average annual groundwater pumping from FMP wells due to adjusting the water-use factors in Task 2, which ultimately resulted in a better match between FMP-estimated pumping and metered pumping data collected by the Watermaster in WY 2021 and WY 2022.
- *Increase in the average annual decline in storage by 5%.* The estimated annual storage decline increased from 7,163 afy 7,500 afy – an increase in the annual reduction of storage of 336 afy. The increase in the annual decline in groundwater storage was because the increase in total outflows was greater than the increase in total inflows that resulted from the improvements made to the BVHM in Task 2 and Task 3.

MODEL CALIBRATION TARGETS AND DATA

West Yost has selected calibration targets (wells) and data (groundwater-elevations) for Task 4 BVHM recalibration, which are displayed the following attachments:

- **Figure 1. Wells used to Recalibrate the BVHM by Aquifer Layer**. This is a map of the wells with groundwater-elevation data to use during recalibration—a total of 85 wells. 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 A. Calibration Data Hydrographs.** Appendix A contains time-series charts of groundwater-elevation data for the 85 wells identified in Figure 1 that will serve as calibration targets. These time-series charts display: (i) measured groundwater elevation data; (ii) the calibration targets selected from the groundwater-elevation measurements; and (iii) the model-estimated groundwater elevations that were generated from running the Task 4 Pre-Calibrated BVHM.

PILOT POINTS AND ADJUSTABLE MODEL PARAMETERS

West Yost has selected pilot points and initial model parameters to recalibrate, which are summarized in the following attachments:

- **Table 3. Aquifer Parameters used in USGS Calibration.** This table identifies the aquifer parameters that will be calibrated during Task 4 and the initial parameter values, which are based on the USGS final calibrated parameter values. Parameters that will be calibrated include: hydraulic properties (horizontal and vertical hydraulic conductivity), storage properties (specific yield and specific storage), and unsaturated zone properties (saturated water content, initial water content). These parameters are assigned to each of the three model layers, as identified in Table 3.

- **Table 4. Scalar Multipliers used in USGS Calibration.** This table identifies the scalars that will be calibrated during Task 4 and scaler values used by the USGS during the original BVHM calibration. Scalars that will be calibrated include: stream runoff (SFR package), underflow from upstream portions of the watershed (FHB package), OFE and KC values (FMP). **Figure 2** and **Figure 3** show the spatial distribution of the scalars applied to the SFR and FHB packages, respectively.
- **Figures 4a – 4c. Map of Pilot Points in Layers 1, 2, and 3.** These figures identify the location of pilot points in Layers 1, 2, and 3 that will be used during model recalibration. Generally, pilot points are evenly spaced (horizontal and vertical) across each model layer. Additional pilot points are assigned in areas or to wells where specific hydrogeologic data is available (such as estimates of conductivity and storativity from aquifer stress tests).

HISTORICAL ON-FARM EFFICIENCIES

As described in the memo documenting Task 2 – *Update Water-Use Factors,*[2] the scaling factors applied to historical OFE values in the BVHM simulate nearly 100% irrigation efficiencies, which is unrealistic. West Yost staff recommended, and the TAC agreed, that the OFE values should be revised historically to reflect the evolution of crop types grown and irrigation methods used in the Basin since WY 1945. West Yost staff performed a literature review, conducted interviews with farmers in the Basin, and identified evidence of historical irrigation infrastructure, and from these efforts, developed recommendations for historical OFE values and a range of defensible values to use during Task 4 – *Model Recalibration*. The recommended OFE values are documented in the attached memo titled: ***Assumptions for Historical On-Farm Efficiencies in the BVHM***.

NEXT STEPS

TAC members are requested to review this the memo and its attachments and provide comments to Andy Malone (amalone@westyost.com) and Lauren Salberg (lsalberg@westyost.com) by March 22, 2024. At the request of the TAC and/or the discretion of the Technical Consultant (Andy Malone), an Ad-Hoc TAC meeting be held to discuss the contents of this memo.

Following TAC review and input, West Yost will proceed with model recalibration.

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[2] Available on the Watermaster's website at: https://borregospringswatermaster.com/wp-content/uploads/2023/08/III_BVHM-Task-2.pdf

ATTACHMENTS

Figure 1. Wells used to Recalibrate the BVHM by Aquifer Layer

Figure 2. Runoff Scalars applied to Streamflow Routing Package used in USGS BVHM Calibration

Figure 3. Underflow Scalars applied to Flow and Head Boundary Package used in USGS BVHM Calibration

Figures 4a – 4c. Map of Pilot Points in Layers 1, 2, and 3

Table 1. Water Budget from *Task 4 Pre-Calibrated BVHM*

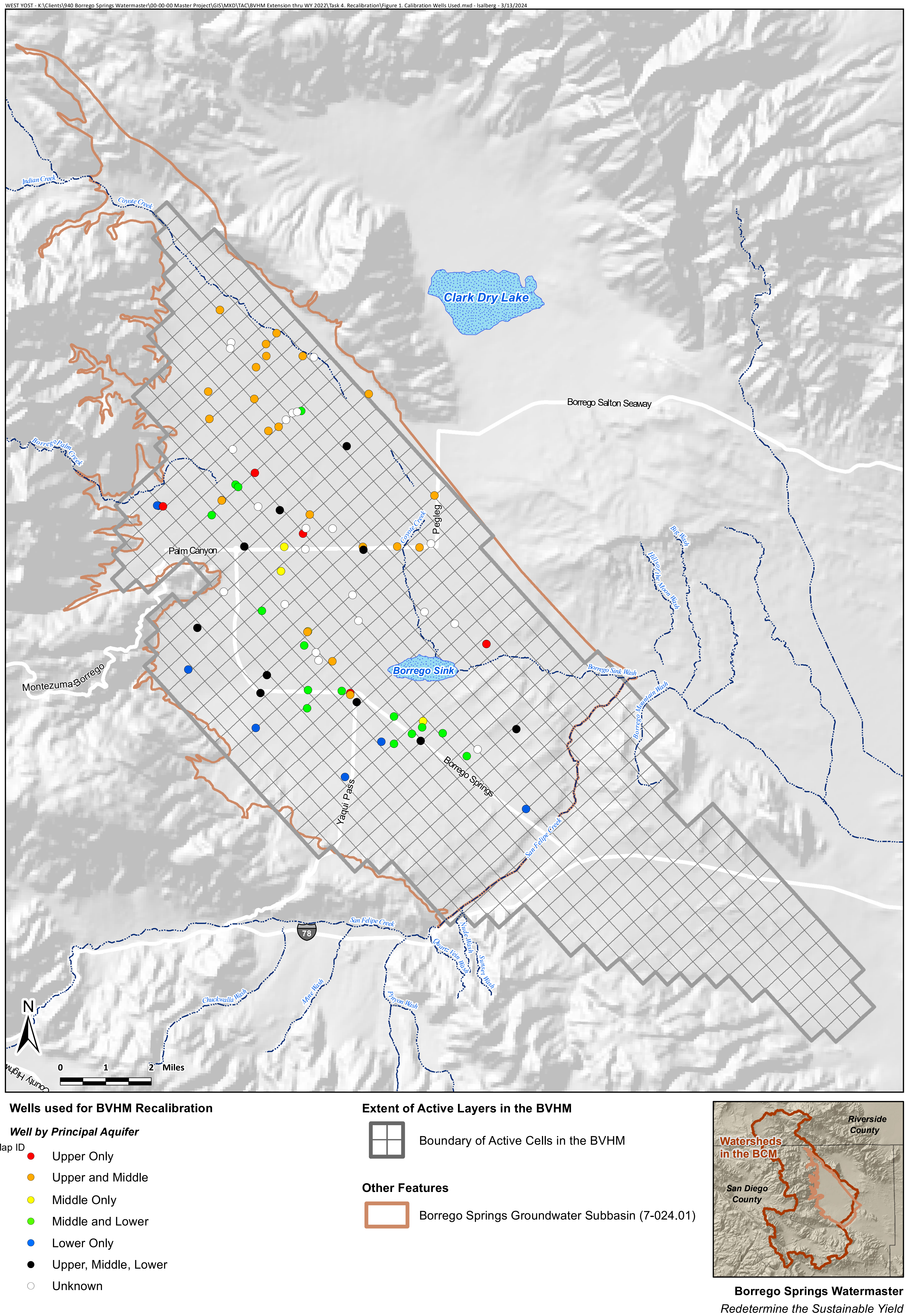
Table 2. Comparison of Average Annual BVHM Water Budgets

Table 3. Aquifer Parameters used in USGS Calibration

Table 4. Scalar Multipliers used in USGS Calibration

Appendix A. Calibration Data Hydrographs

Memo titled: *Assumptions for Historical On-Farm Efficiencies in the BVHM*



Borrego Springs Watermaster

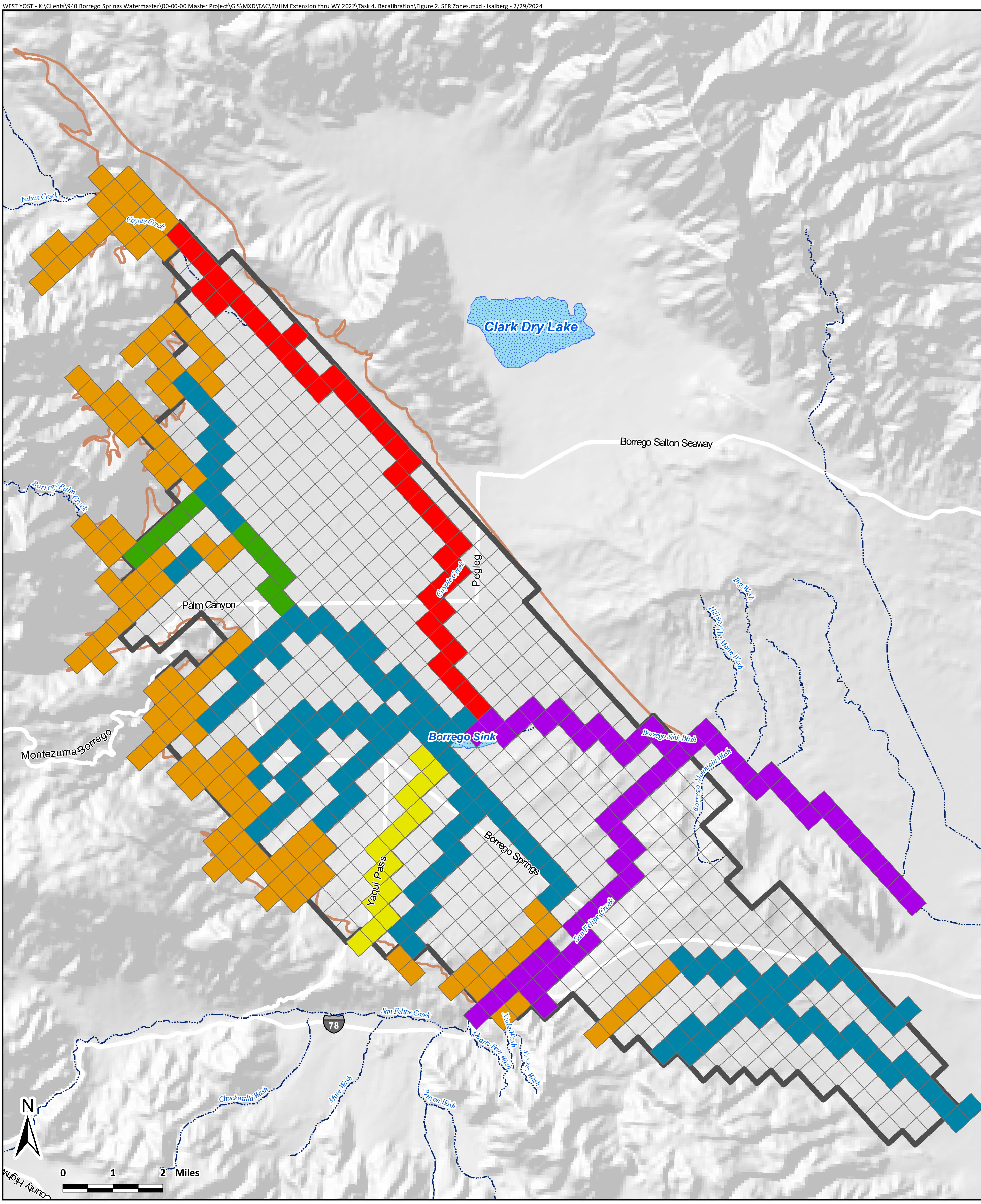
Redetermine the Sustainable Yield

Prepared by:

WEST YOST

Figure 1

Wells used to Recalibrate BVHM by Aquifer Layer



Streamflow Routing (SFR) Cells by Creek
(Runoff Scalar used in USGS Calibration in *Italic*)

- Coyote Creek *(Runoff Scalar = 1.01)*
- San Felipe Creek *(Runoff Scalar = 0.92)*
- Borrego Palm Creek *(Runoff Scalar = 0.90)*
- Yaqui Creek *(Runoff Scalar = 0.80)*
- Unidentified Tributary Streams *(Runoff Scalar = 0.80)*
- Upper Portions of Unidentified Tributary Streams *(Runoff Scalar = 0.80)*

BVHM Cells

Boundary of Active Cells in the BVHM

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

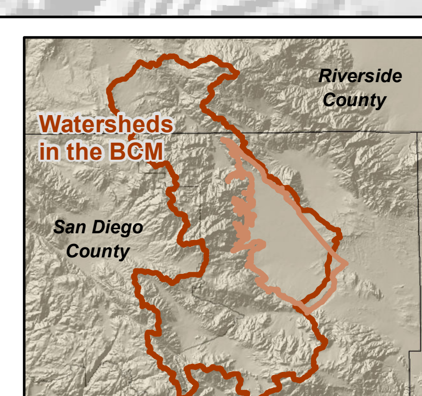


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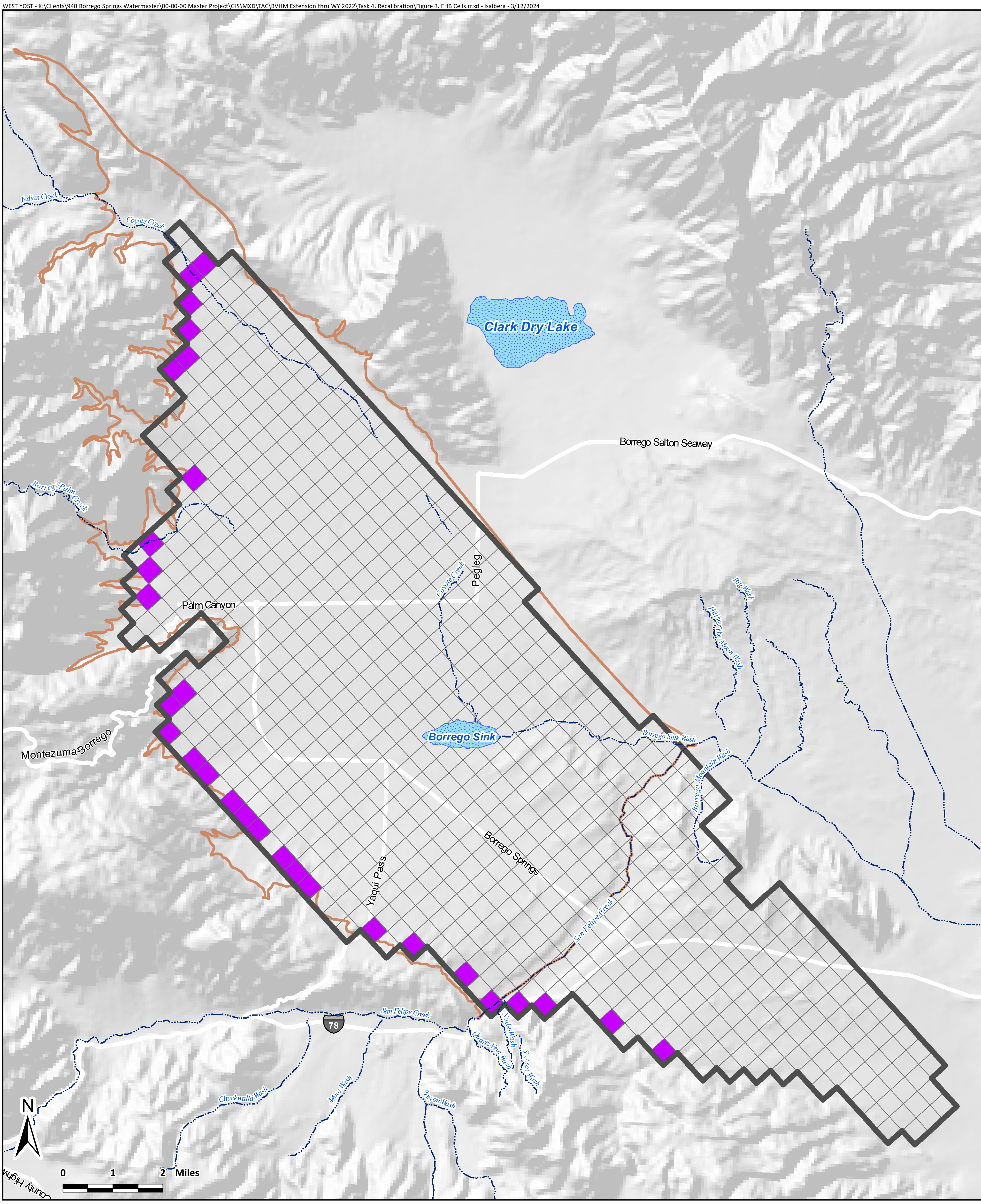
Figure 2

Runoff Scalars applied to Streamflow Routing Package used in USGS BVHM Calibration



Flow and Head Boundary (FHB) Cells (underflow scalar varies by cell)

BVHM Cells

Boundary of Active Cells in the BVHM

Other Features

Borrego Springs Groundwater Subbasin (7-024.01)

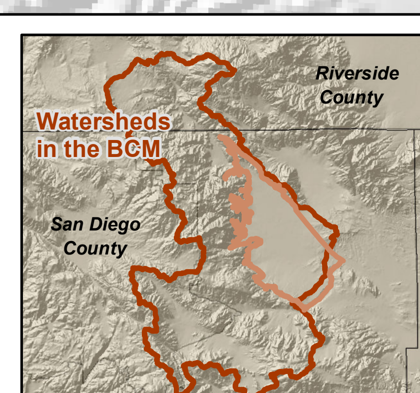


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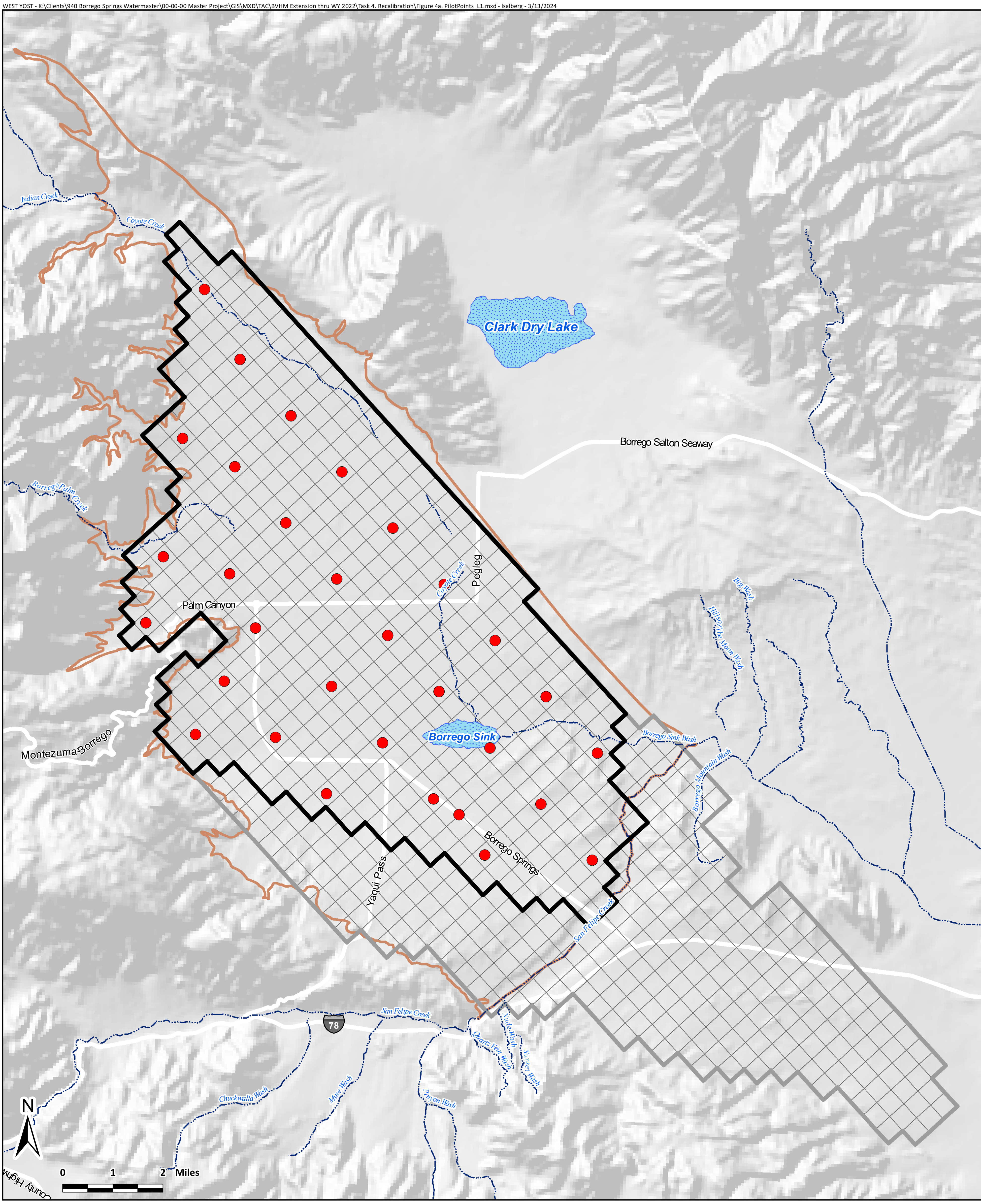
Figure 3

Underflow Scalars applied to the Flow and Head Boundary Package in USGS BVHM Calibration

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 4a. PilotPoints_L1.mxd - Isalberg - 3/13/2024



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)

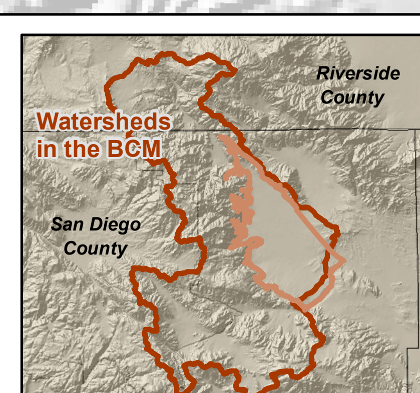


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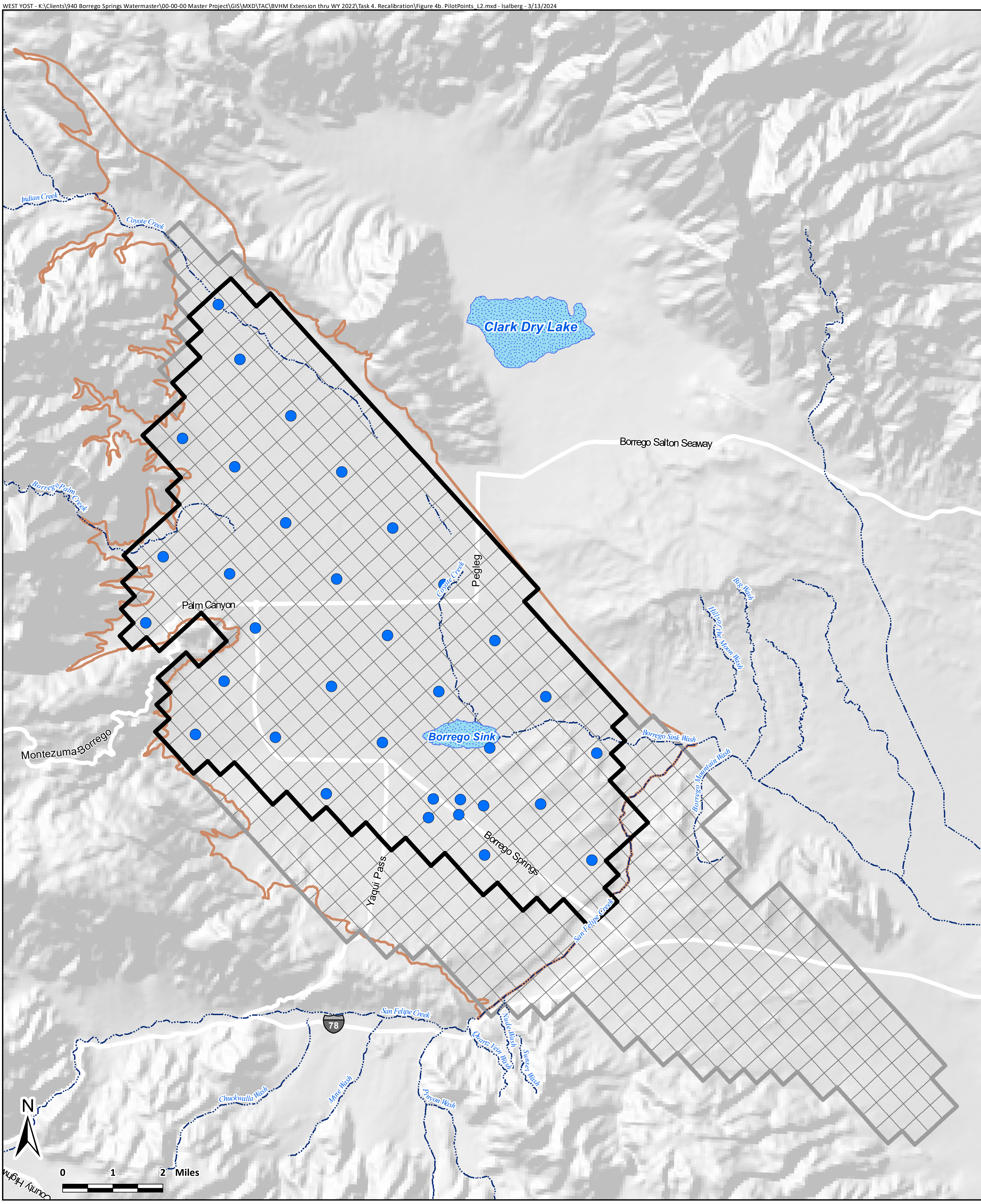
Figure 4a

Pilot Points used in BVHM Calibration
Layer 1



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)

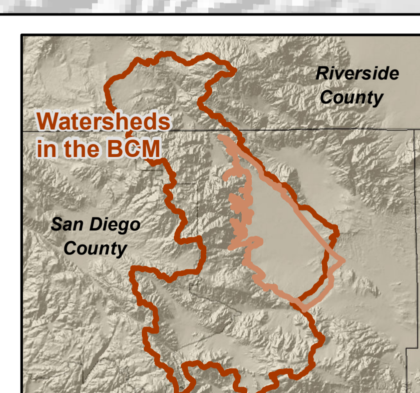


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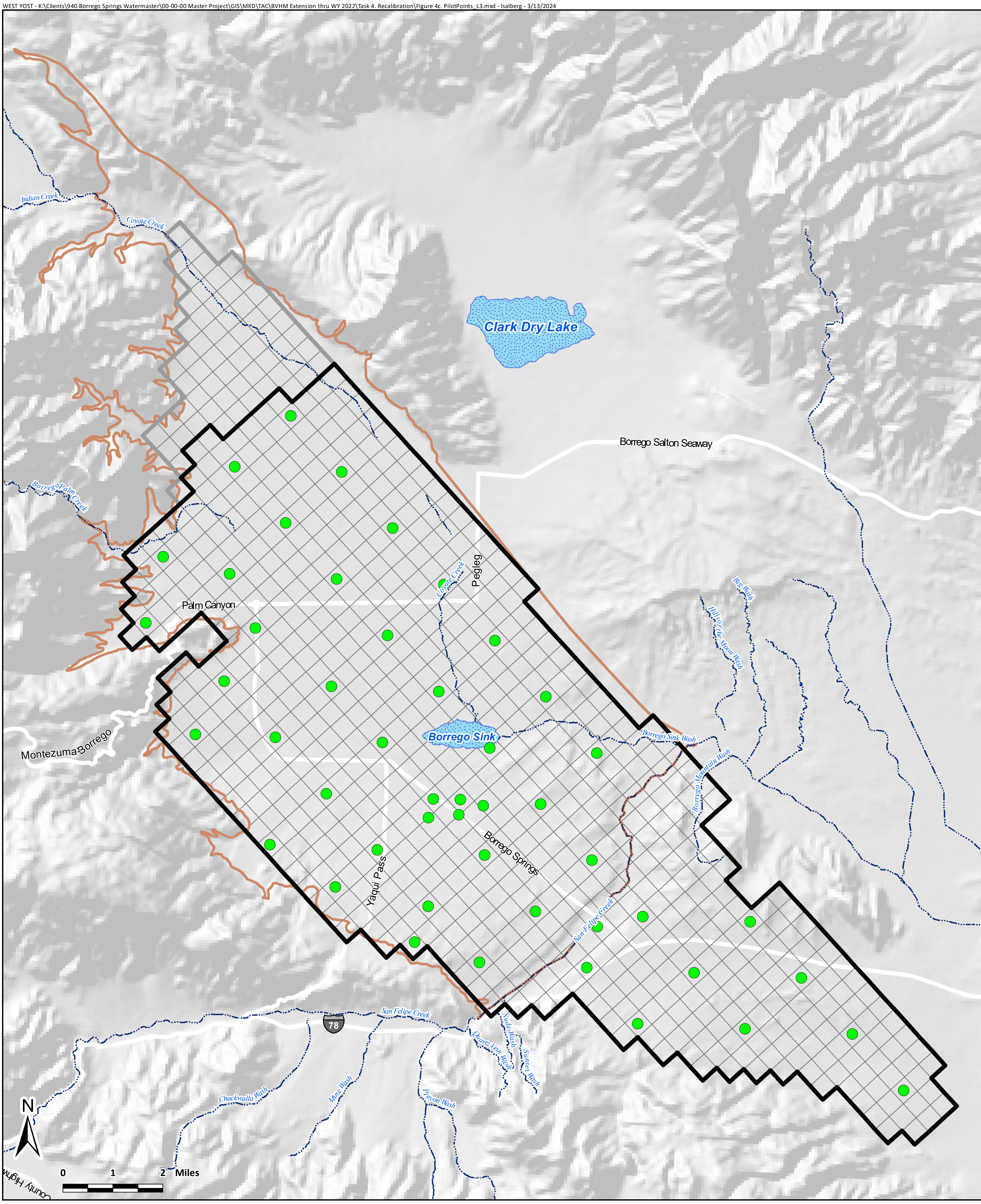
Figure 4b

Pilot Points used in BVHM Calibration
Layer 2



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)

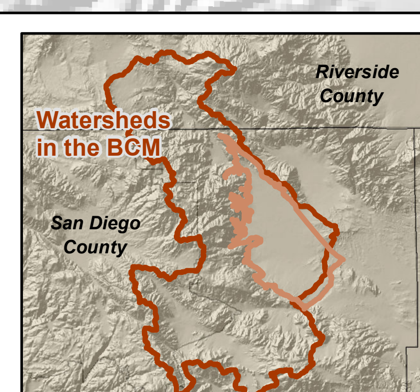


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Figure 4c

Pilot Points used in BVHM Calibration
Layer 3

Table 1. Water Budget for the *Task 4 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	Unsaturated Zone Recharge	Subsurface Inflow	Total Inflows	Groundwater Pumping: FMP Wells	Groundwater Pumping: Non-FMP Wells	ET	Subsurface Outflow	Total Outflows		
1945	8,493	2,905	2,120	13,518	0	87	7,728	532	8,347	5,171	5,171
1946	4,656	2,954	2,120	9,730	931	149	10,081	552	11,713	-1,983	3,189
1947	221	1,849	2,120	4,190	1,489	193	8,985	551	11,219	-7,029	-3,840
1948	150	1,197	2,126	3,473	3,041	237	8,704	549	12,531	-9,059	-12,899
1949	6,151	1,572	2,120	9,843	3,952	280	8,115	554	12,902	-3,059	-15,958
1950	154	1,082	2,120	3,355	5,258	324	8,313	546	14,441	-11,085	-27,043
1951	7,903	1,049	2,120	11,073	6,415	366	7,483	540	14,804	-3,731	-30,774
1952	655	1,112	2,126	3,892	8,242	410	6,121	541	15,315	-11,423	-42,197
1953	4,220	1,377	2,120	7,717	10,667	454	7,174	539	18,834	-11,117	-53,314
1954	779	1,095	2,120	3,993	11,323	496	5,869	530	18,218	-14,225	-67,539
1955	298	1,111	2,120	3,528	11,054	540	5,320	524	17,438	-13,910	-81,449
1956	2,138	1,002	2,126	5,266	12,740	583	5,582	521	19,427	-14,161	-95,609
1957	3,874	1,020	2,120	7,014	13,040	627	4,918	516	19,100	-12,086	-107,695
1958	771	1,057	2,120	3,948	11,998	671	4,321	513	17,503	-13,554	-121,250
1959	1,217	993	2,120	4,330	12,765	714	4,392	508	18,378	-14,048	-135,297
1960	868	1,060	2,126	4,053	12,086	757	3,796	508	17,147	-13,094	-148,392
1961	918	1,165	2,120	4,203	12,724	800	3,718	505	17,746	-13,544	-161,936
1962	271	1,180	2,120	3,571	12,492	844	3,334	502	17,172	-13,602	-175,537
1963	1,808	1,389	2,120	5,317	11,735	962	2,869	500	16,066	-10,749	-186,287
1964	3,463	2,153	2,126	7,742	10,933	1,030	3,172	515	15,651	-7,909	-194,195
1965	9,313	1,997	2,120	13,429	10,972	1,075	2,759	509	15,315	-1,886	-196,081
1966	7,297	2,686	2,120	12,102	6,002	1,119	2,627	516	10,264	1,839	-194,243
1967	1,114	2,559	2,120	5,793	5,796	1,161	2,429	515	9,901	-4,109	-198,351
1968	14,431	3,642	2,126	20,199	6,405	1,206	2,347	516	10,474	9,724	-188,627
1969	589	2,546	2,120	5,255	5,865	1,248	2,195	512	9,821	-4,566	-193,193
1970	372	2,493	2,120	4,985	5,726	1,291	2,090	510	9,616	-4,631	-197,823
1971	395	2,369	2,120	4,884	5,565	1,335	2,011	507	9,417	-4,534	-202,357
1972	2,249	2,344	2,126	6,719	5,795	1,712	2,038	505	10,050	-3,331	-205,688
1973	1,380	2,374	2,120	5,874	4,966	1,665	1,814	503	8,949	-3,075	-208,763
1974	963	2,213	2,120	5,296	5,422	1,694	1,847	503	9,465	-4,169	-212,933
1975	2,212	2,144	2,120	6,476	5,222	1,825	1,746	502	9,295	-2,819	-215,752
1976	4,275	2,520	2,126	8,921	5,297	1,953	1,697	503	9,449	-529	-216,281
1977	21,906	4,347	2,120	28,373	5,608	2,093	1,963	513	10,177	18,197	-198,084
1978	9,227	2,872	2,120	14,219	5,860	2,236	2,008	521	10,625	3,594	-194,490
1979	25,654	5,356	2,120	33,131	6,003	2,357	1,918	520	10,798	22,332	-172,158
1980	3,881	2,596	2,126	8,603	7,609	2,514	2,296	527	12,947	-4,344	-176,502
1981	2,129	1,738	2,120	5,987	8,483	2,645	2,391	523	14,042	-8,055	-184,557
1982	10,282	2,255	2,120	14,657	7,978	2,766	2,122	519	13,384	1,273	-183,284
1983	8,137	3,295	2,120	13,552	6,084	2,902	1,910	530	11,425	2,127	-181,157
1984	1,540	2,346	2,126	6,011	8,480	3,002	2,611	538	14,630	-8,619	-189,776
1985	3,316	2,308	2,120	7,744	8,096	3,141	2,257	534	14,028	-6,284	-196,060
1986	1,562	2,263	2,120	5,945	7,863	3,152	2,166	534	13,715	-7,771	-203,831
1987	958	2,160	2,120	5,238	8,578	3,437	2,149	530	14,695	-9,456	-213,287
1988	1,836	2,474	2,126	6,436	8,512	4,137	1,921	531	15,102	-8,666	-221,953
1989	397	2,126	2,120	4,643	8,952	3,956	1,928	525	15,360	-10,717	-232,670
1990	7,570	2,665	2,120	12,355	9,231	3,848	1,769	522	15,371	-3,016	-235,686
1991	2,692	2,325	2,120	7,136	8,435	4,065	1,550	519	14,569	-7,433	-243,119
1992	24,713	5,162	2,126	32,001	8,349	4,356	1,599	516	14,820	17,180	-225,938
1993	6,253	3,751	2,120	12,125	11,035	4,195	1,936	523	17,689	-5,564	-231,503
1994	8,662	2,811	2,120	13,593	13,438	3,997	1,903	520	19,857	-6,265	-237,767
1995	1,363	2,365	2,120	5,848	15,157	3,867	1,661	518	21,203	-15,354	-253,122
1996	1,090	1,992	2,126	5,208	17,566	4,127	1,662	517	23,873	-18,665	-271,786
1997	9,481	2,825	2,120	14,426	15,032	4,270	1,377	513	21,193	-6,767	-278,553
1998	2,862	2,811	2,120	7,793	13,342	4,043	1,395	524	19,304	-11,511	-290,064
1999	686	2,355	2,120	5,161	14,808	4,071	1,358	521	20,757	-15,597	-305,661
2000	950	2,293	2,126	5,369	16,326	4,288	1,197	521	22,332	-16,963	-322,624
2001	817	2,555	2,120	5,492	15,552	3,759	984	517	20,812	-15,320	-337,944
2002	931	2,236	2,120	5,288	17,179	4,216	939	515	22,849	-17,562	-355,506
2003	1,432	2,411	2,120	5,963	15,903	4,021	767	514	21,206	-15,243	-370,748
2004	10,944	2,896	2,126	15,966	16,992	4,018	743	514	22,266	-6,300	-377,048
2005	9,433	4,266	2,120	15,819	15,031	3,650	930	530	20,141	-4,322	-381,370
2006	2,812	2,726	2,120	7,658	18,562	3,855	977	533	23,926	-16,268	-397,638
2007	848	2,349	2,120	5,317	20,217	4,631	776	529	26,153	-20,836	-418,474
2008	1,878	2,875	2,126	6,880	18,773	3,992	599	527	23,891	-17,012	-435,486
2009	2,267	2,904	2,120	7,291	19,321	4,110	618	526	24,576	-17,285	-452,771
2010	877	2,672	2,120	5,669	19,589	3,195	532	524	23,840	-18,172	-470,942
2011	1,852	2,925	2,120	6,897	19,038	2,664	467	521	22,691	-15,794	-486,736
2012	6,830	3,658	2,126	12,614	17,775	1,746	554	533	20,609	-7,995	-494,731
2013	2,425	3,253	2,120	7,798	18,900	1,748	535	529	21,712	-13,914	-508,645
2014	2,158	2,950	2,120	7,228	19,140	1,641	503	525	21,809	-14,581	-523,226
2015	3,007	3,126	2,120	8,253	18,423	1,899	402	522	21,246	-12,993	-536,219
2016	2,184	3,222	2,126	7,532	17,901	1,984	423	524	20,832	-13,300	-549,519
2017	4,266	3,353	2,120	9,739	15,975	1,648	396	521	18,540	-8,800	-558,319
2018	3,227	2,988	2,120	8,335	17,379	1,430	372	518	19,700	-11,365	-569,684
2019	3,794	4,175	2,120	10,088	12,648	1,532	293	516	14,990	-4,901	-574,585
2020	4,126	4,426	2,126	10,677	10,410	1,701	292	517	12,920	-2,243	-576,828
2021	3,022	3,600	2,120	8,742	11,625	1,720	288	512	14,145	-5,404	-582,231
2022	3,896	4,092	2,120	10,109	10,551	1,518	263	509	12,841	-2,732	-584,964
Average	**4,151**	**2,505**	**2,121**	**8,777**	**10,944**	**2,205**	**2,606**	**522**	**16,276**	**-7,500**	-
Minimum	**150**	**993**	**2,120**	**3,355**	**0**	**87**	**263**	**500**	**8,347**	**-20,836**	
Maximum	**25,654**	**5,356**	**2,126**	**33,131**	**20,217**	**4,631**	**10,081**	**554**	**26,153**	**22,332**	

Table 2. Comparison of Average Annual BVHM Water Budgets

Water Budget Component -- Annual Average	Annual Average Water Budget over the Simulation Period October 1944 - September 2022						
	Task 1 2022 BVHM	*Task 2 BVHM - Updated Water-Use Factors*		*Task 3 BVHM - Corrected Errors in 2022 BVHM*		*Task 4 Pre-Calibrated BVHM*	
	afy	*afy*	*% Difference*	*afy*	*% Difference*	*afy*	*% Difference*
Total Inflows	**6,633**	**7,772**	**16%**	**7,632**	**14%**	**8,777**	**28%**
Streambed Recharge	3,775	4,038	7%	3,888	3%	4,151	9%
Unsaturated Zone Recharge	1,490	2,368	46%	1,622	8%	2,505	51%
Subsurface Inflow	1,367	1,366	0%	2,121	43%	2,121	43%
Total Outflows	**13,796**	**15,968**	**15%**	**14,057**	**2%**	**16,276**	**16%**
Groundwater Pumping	10,630	13,026	20%	10,693	1%	13,149	21%
Non-FMP Wells	2,226	2,074	-7%	2,299	3%	2,205	-1%
FMP Wells	8,404	10,952	26%	8,394	0%	10,944	26%
Evapotranspiration	2,644	2,422	-9%	2,841	7%	2,606	-1%
Subsurface Outflow	521	520	0%	523	0%	522	0%
Total Change in Storage	**-7,163**	**-8,196**	**-13%**	**-6,425**	**11%**	**-7,500**	**-5%**

Description of Model Versions

Task 1 2022 BVHM. This is the version of the BVHM that was extended through WY 2022 and used to perform Task 1 to compare FMP-estimated pumping to Actual pumping in WY 2021 and WY 2022.

Task 2. Update - Water Use Factors . Water-use factors used in the FMP were evaluated and updated to more realistic/defensible values to improve the ability of the FMP to estimate groundwater pumping in WY 2021 and 2022. The two water-use factors that were updated were: crop coefficient (KC) and on-farm efficiency (OFE), or irrigation efficiency. The scaling factors applied to the KC and OFE values were removed, which resulted in more realistic values of KC and OFE values and a more accurate FMP estimate of pumping in WY 2021 and 2022 (when groundwater pumping was metered for the first time).

Task 3. Correct Errors identified in the 2022 BVHM. In this task, several errors and discrepancies that were identified in the 2022 BVHM were corrected, including errors in the SFR, MNW2, FHB packages and the FMP. The errors corrected were from input errors, such as the assignment of model inputs to inactive cells, discretization, cell geometry, depth distribution of pumping, etc. The results were presented as the column representing the "Final Corrected BVHM" in Table 7 of the Task 3 technical memorandum. The updated water-use factors from Task 2 were not included in Task 3.

Task 4. - Model Recalibration. This is the version of the BVHM that will be recalibrated in Task 4. This BVHM version includes all updates and improvements made to the BVHM in Task 1, Task 2, and Task 3.

Table 3. Aquifer Parameters used in USGS Calibration[1]

Parameter Calibrated	Model Layer[2]	Value	Unit	Sensitivity
Hydraulic Properties - Horizontal Hydraulic Conductivity				
Coarse-grained sediments in aquifer	Layer 1	98.40	ft/d	0.142
	Layer 2	6.56	ft/d	0.0556
	Layer 3	1.05	ft/d	0.19
Fine-grained sediments in aquifer	Layer 1	7.08	ft/d	0.0111
	Layer 2	0.20	ft/d	0.00439
	Layer 3	0.01	ft/d	0.0274
Coarse-grained sediments of upper aquifer—sand rich area	Layer 1	216.00	ft/d	0.0876
Fine-grained sediments of upper aquifer—sand rich area	Layer 1	76.00	ft/d	0.0481
Horizontal hydraulic conductivity of sink	Layers 1 - 3	5.37	ft/d	0.00304
Horizontal hydraulic conductivity of older alluvium		0.30	ft/d	0.00645
Hydraulic Properties - Vertical Hydraulic Conductivity				
Vertical hydraulic conductivity of sink	Layers 1 - 3	2.05	ft/d	0.000872
Vertical hydraulic conductivity of older alluvium		0.30	ft/d	0.00324
Vertical hydraulic conductivity of small tributary streambeds		3.28	ft/d	0.0326
Vertical hydraulic conductivity of upper tributary streambeds		12.90	ft/d	0.045
Vertical hydraulic conductivity of Coyote Canyon streambed		65.60	ft/d	0.0894
Vertical hydraulic conductivity of Palm Canyon streambed		16.40	ft/d	0.0458
Vertical hydraulic conductivity of Yaqui Canyon streambed		2.93	ft/d	0.0111
Vertical hydraulic conductivity of San Felipe streambed		0.66	ft/d	0.0174
Storage Properties - Specific Storage				
Specific storage	Layer 1	0.000000508	na	0.00419
	Layer 2	0.00000159	na	0.00263
	Layer 3	0.000000853	na	0.00477
Storage Properties - Specific Yield				
Zone 1	Layer 1	0.155	na	0.00165
	Layer 2	0.074	na	0
	Layer 3	0.030	na	9.35×10^{-15}
Zone 2	Layer 1	0.134	na	0.0166
	Layer 2	0.066	na	0
	Layer 3	0.030	na	1.40×10^{-14}
Zone 3	Layer 1	0.050	na	0.0167
	Layer 2	0.300	na	7.73×10^{-15}
	Layer 3	0.030	na	1.40×10^{-14}
Zone 4	Layer 1	0.300	na	0.345
	Layer 2	0.032	na	0.000458
	Layer 3	0.027	na	0
Zone 5	Layer 1	0.151	na	0.161
	Layer 2	0.300	na	0.0139
	Layer 3	0.027	na	0
Zone 6	Layer 1	0.106	na	0.106
	Layer 2	0.029	na	0.00183
	Layer 3	0.038	na	0.0000574
Zone 7	Layer 1	0.152	na	0.249
	Layer 2	0.029	na	0.00537
	Layer 3	0.077	na	0.000996
Zone 8	Layer 1	0.050	na	0.0349
	Layer 2	0.200	na	0.0134
	Layer 3	0.031	na	0.00441
Zone 9	Layer 1	0.071	na	0.0051
	Layer 2	0.029	na	0.00854
	Layer 3	0.040	na	0.0013
Zone 10	Layer 1	0.089	na	0.0815
	Layer 2	0.041	na	0.0219
	Layer 3	0.085	na	0.016
Zone 11	Layer 1	0.140	na	0
	Layer 2	0.070	na	0
	Layer 3	0.062	na	0.000825
Zone 12	Layer 1	0.140	na	0
	Layer 2	0.070	na	0
	Layer 3	0.029	na	0.0314
Zone 13	Layer 1	0.140	na	0
	Layer 2	0.070	na	0
	Layer 3	0.029	na	0.0542
Zone 14	Layer 1	0.150	na	0
	Layer 2	0.070	na	0
	Layer 3	0.051	na	0.0238
Unsaturated Zone Properties				
Hydraulic conductivity of unsaturated zone	Unsaturated Layer(s)	0.023	ft/d	0.08
Maximum fraction of saturation of unsaturated zone in stream channels		0.0566	ft	0.00
Initial fraction of saturation of unsaturated zone in stream channels		0.0245	ft	0.00
Maximum fraction of saturation of unsaturated zone		0.463	ft	0.25
Initial fraction of saturation of unsaturated zone		0.00881	ft	0.01

Notes:

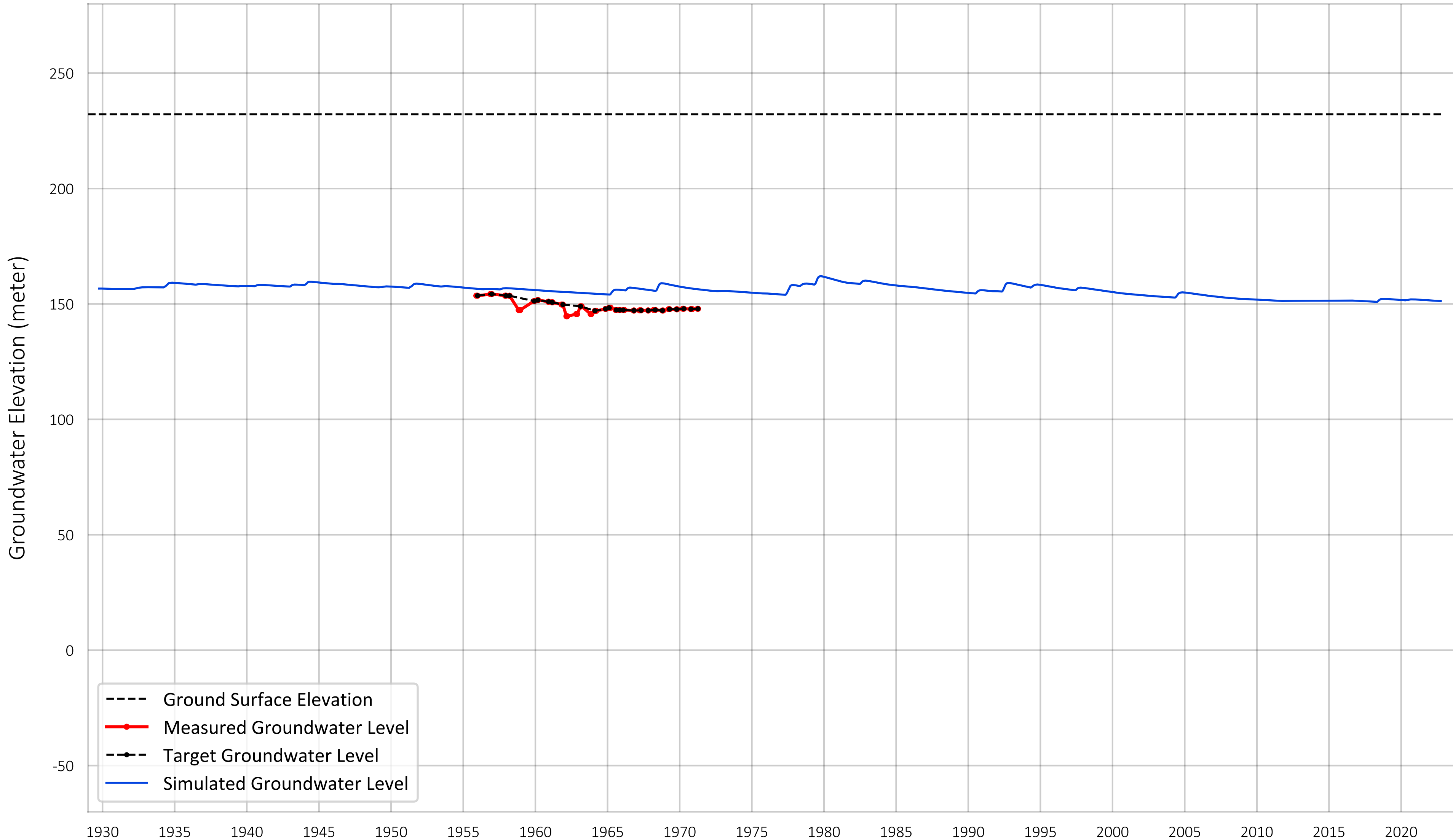
1) Parameters defined in Table 18. *Parameter values estimated for the BVVHM* of the Faunt et. al, 2015 Report.
Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed M., Brandt J., Martin P., and Coes, A.L. 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California: U.S. Accessed at https://pubs.er.usgs.gov/publication/sir20155150.

2) Upper aquifer (Layer 1), middle aquifer (Layer 2), and lower aquifer (Layer 3)

Table 4. Scalar Multipliers used in USGS Calibration[1]

Scalar Multiplier Calibrated	Model Package	Scalar Multiplier	Sensitivity
Scalar applied to Stream Runoff			
Runoff from northern small Basins	SFR	0.80	0.06
Runoff from southern small Basins		0.80	0.09
Runoff from Henderson Canyon Basin		0.80	0.04
Runoff from Palm Canyon Basin		0.90	0.07
Runoff from San Felipe Basin		0.92	0.05
Runoff from Coyote Creek Basin		1.01	0.03
Scalar applied to Underflow from Adjacent Basins			
Underflow from FHB cell 4	FHB	8.88	0.04
Underflow from FHB cell 5		0.87	0.04
Underflow from FHB cell 6		1.26	0.04
Underflow from FHB cell 7		0.10	0.05
Underflow from FHB cell 8		0.12	0.04
Underflow from FHB cell 9		0.12	0.04
Underflow from FHB cell 10		0.33	0.04
Underflow from FHB cell 11		0.29	0.04
Underflow from FHB cell 12		0.12	0.00
Underflow from FHB cell 13		0.82	0.04
Underflow from FHB cell 14		1.73	0.04
Underflow from FHB cell 15		1.01	0.04
Underflow from FHB cell 17		0.52	0.02
Underflow from FHB cell 18		4.17	0.05
Underflow from FHB cell 19		0.24	0.04
Underflow from FHB cell 20		0.15	0.04
Underflow from FHB cell 21		0.15	0.04
Underflow from FHB cell 22		0.10	0.05
Underflow from FHB cell 23		1.78	0.04
Underflow from FHB cell 24		0.13	0.04
Underflow from FHB cell 25		9.75	0.08
Underflow from FHB cell 27		9.75	0.08
Underflow from FHB cell 28		0.11	0.04
Underflow from FHB cell 30		9.75	0.03
Underflow from FHB cell 32		9.75	0.12
Underflow from FHB cell 33		9.75	0.07
Underflow from FHB cell 34		9.75	0.07
Underflow from all other FHB cells		3.5	0.00
Scalar applied to On-Farm Efficiency (OFE), by Water Year			
WY 1930 - WY 1949	FMP	1.00	0.95
WY 1950 - WY 1959		1.10	0.65
WY 1960 - WY 1989		1.15	0.92 - 2.99
WY 1990 - WY 1999		1.17	0.40
10/1/1999 - 11/1/1999		1.25	NR[2]
11/1/1999 - WY 2009		1.20	0.33
WY 2010 - WY 2022		1.25	0.01
Scalar applied to Crop Coefficients (KC), by Month of WY			
October	FMP	0.85	0.49
November		0.85	0.49
December		1.08	0.53
January		1.08	0.53
February		1.08	0.53
March		0.90	0.60
April		0.90	0.60
May		0.90	0.60
June		0.90	0.63
July		0.90	0.63
August		0.90	0.63
September		0.85	0.49

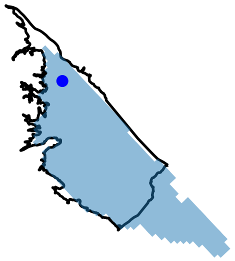
Notes:
1) Scalar values defined in Table 18. *Parameter values estimated for the BVVHM* of the Faunt et. al, 2015 Report. Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed M., Brandt J., Martin P., and Coes, A.L. 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California: U.S. Accessed at https://pubs.er.usgs.gov/publication/sir20155150.
2) NR = "Not Reported" in Table 18 of USGS Report. The scalar of 1.25 listed in the FMP input file for the period of October 1999 to November 1999 appears to be a mistake in the input file. Table 18 of the USGS reports that a scalar of 1.17 was applied to the 1990s and a scalar of 1.2 was applied to the 2000s. The table only reports that a scalar of 1.25 was applied to the 2010s. The scalar value reported in this table represents the value listed in the FMP input file.



Prepared by:

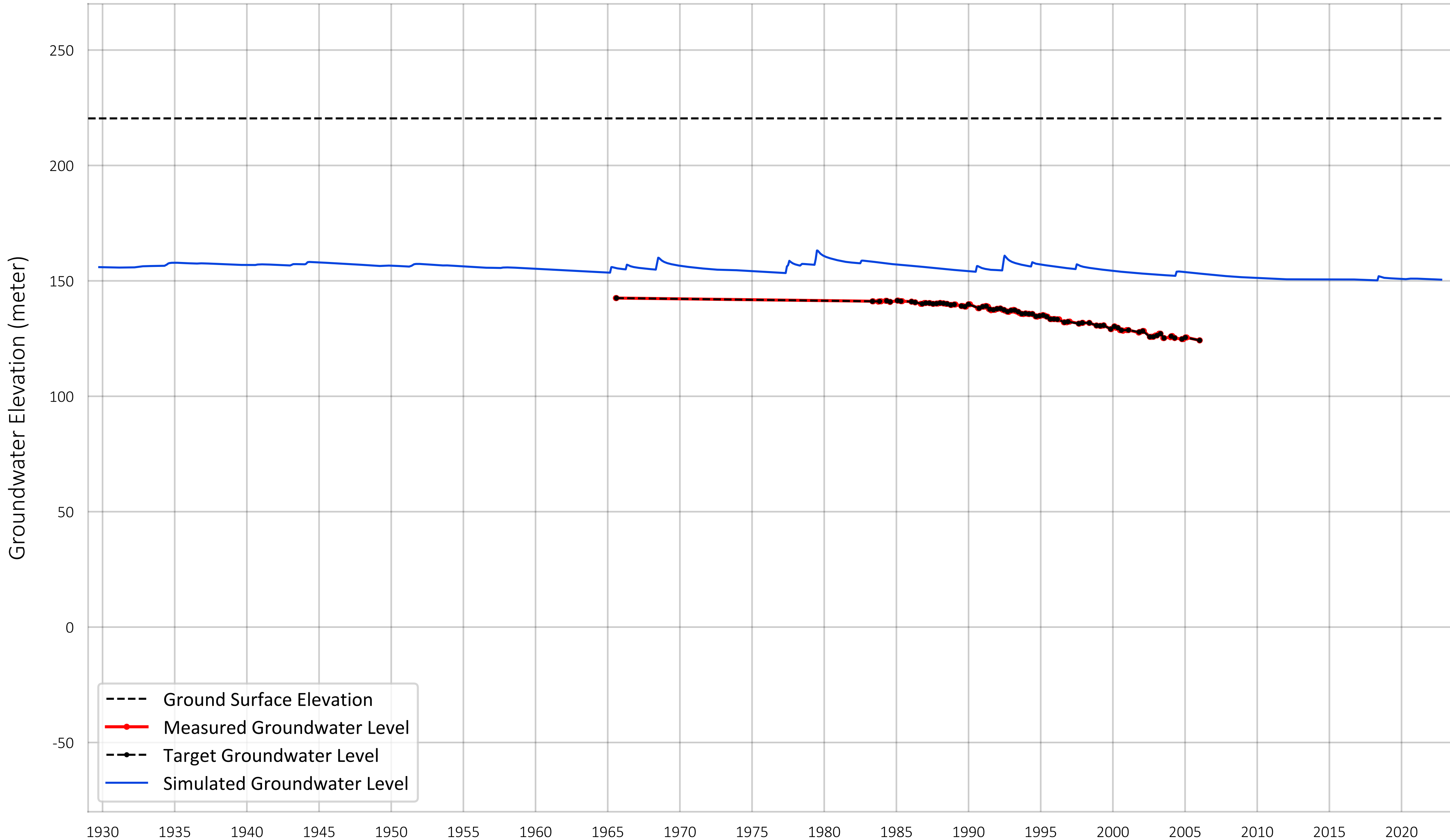
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E08B001S

Figure A-1



Prepared by:

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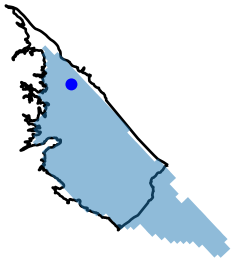
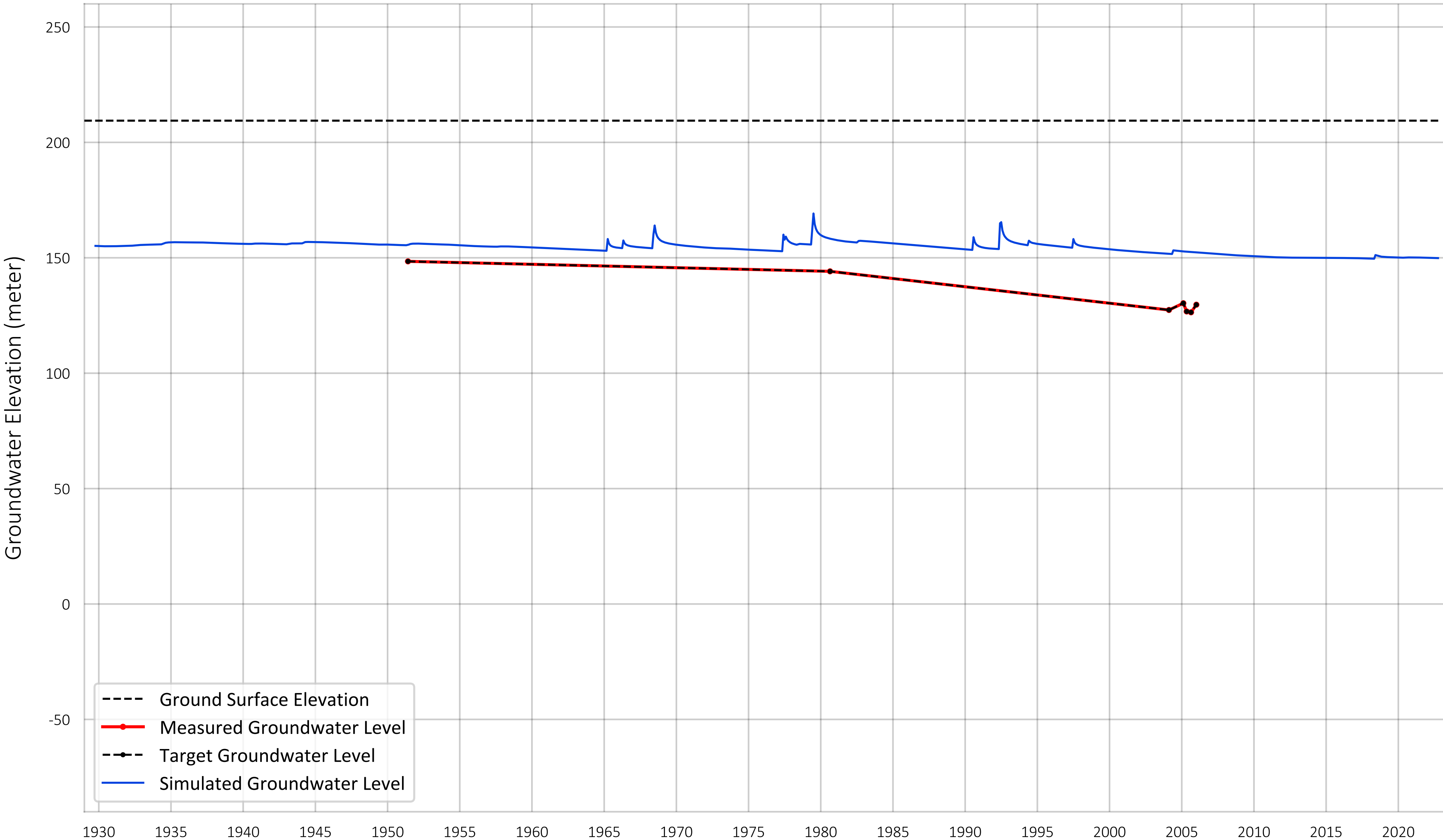
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E09L001S

Figure A-2



Prepared by:

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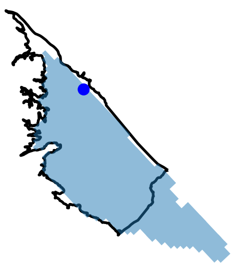
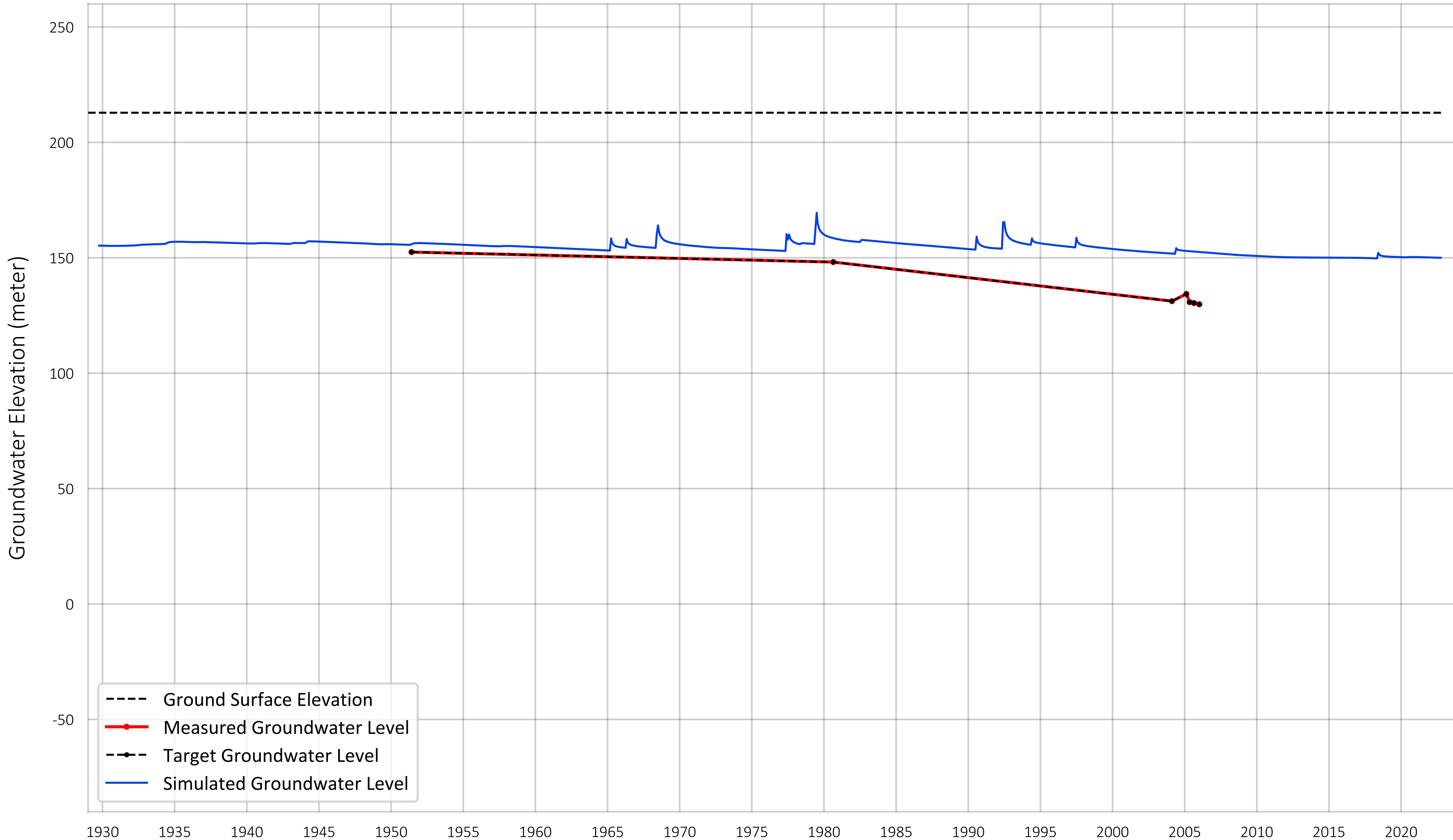
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E10L001S

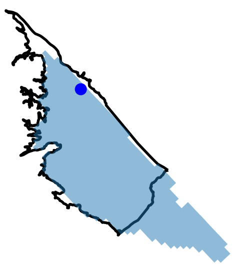
Figure A-3



Prepared by:

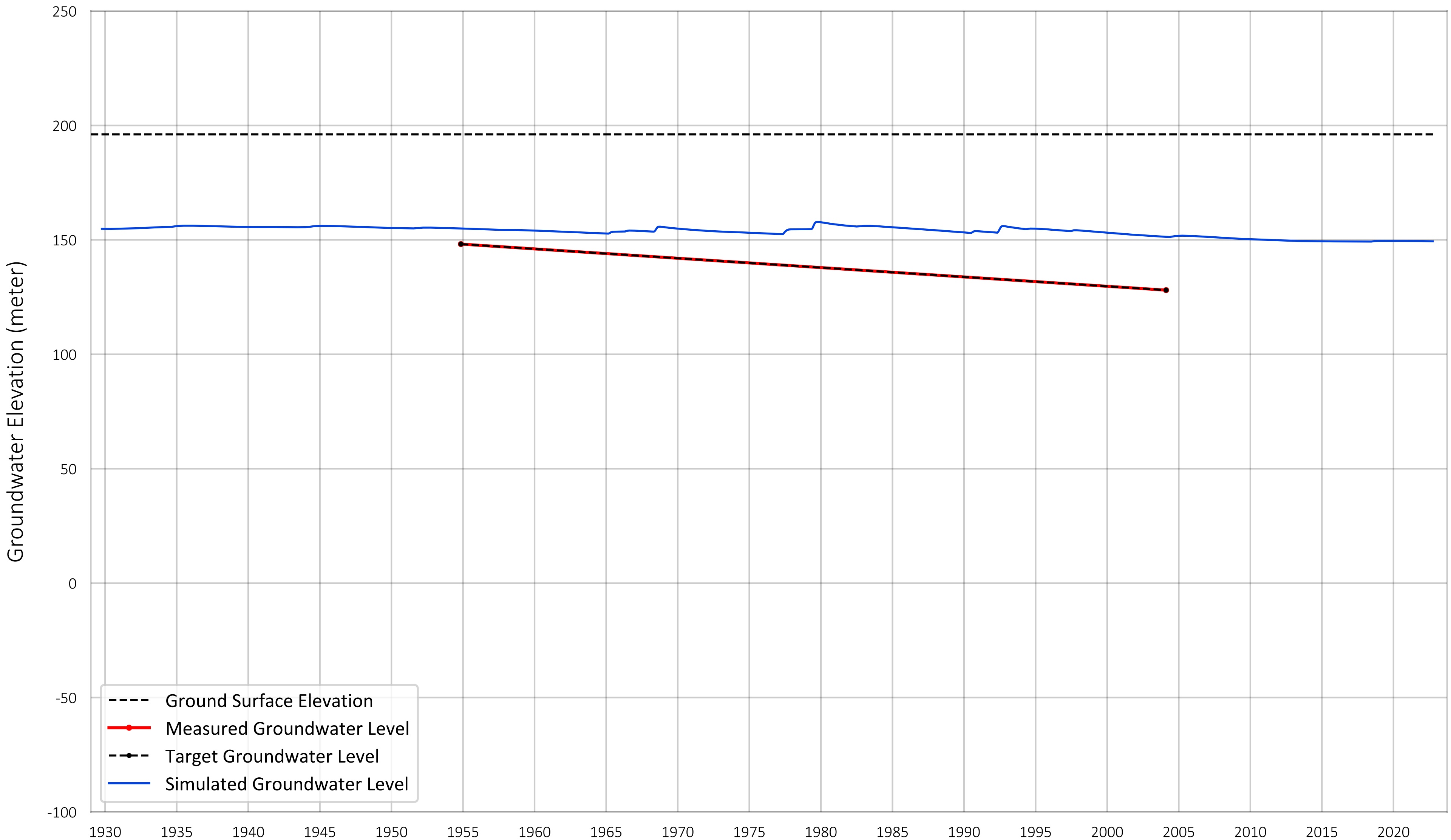
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E10M001S

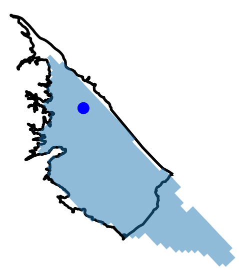
Figure A-4



Prepared by:

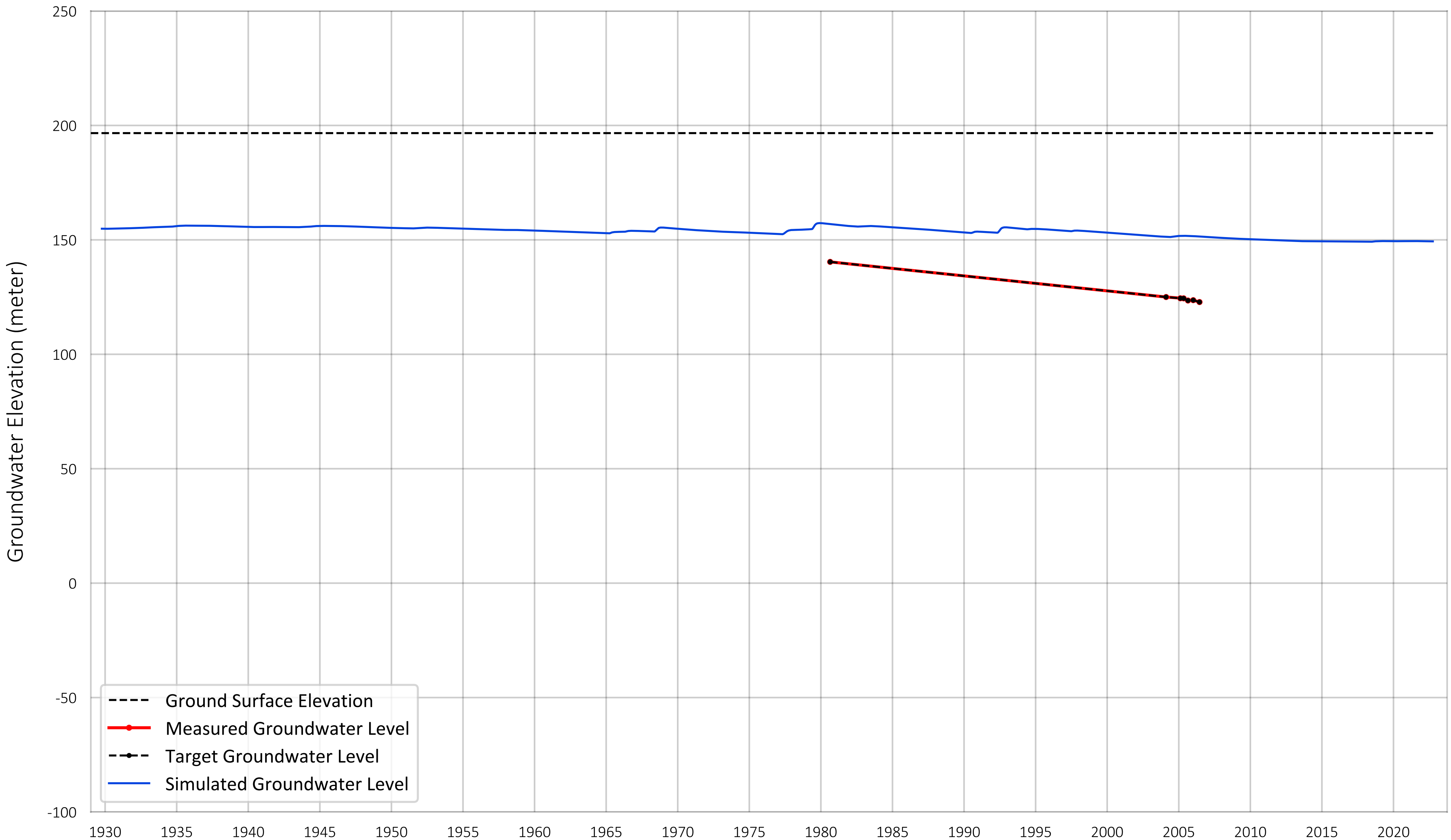
WEST YOST
Water. Engineered.

Well Location



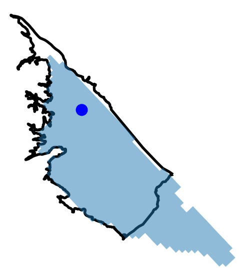
Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E21B001S

Figure A-5



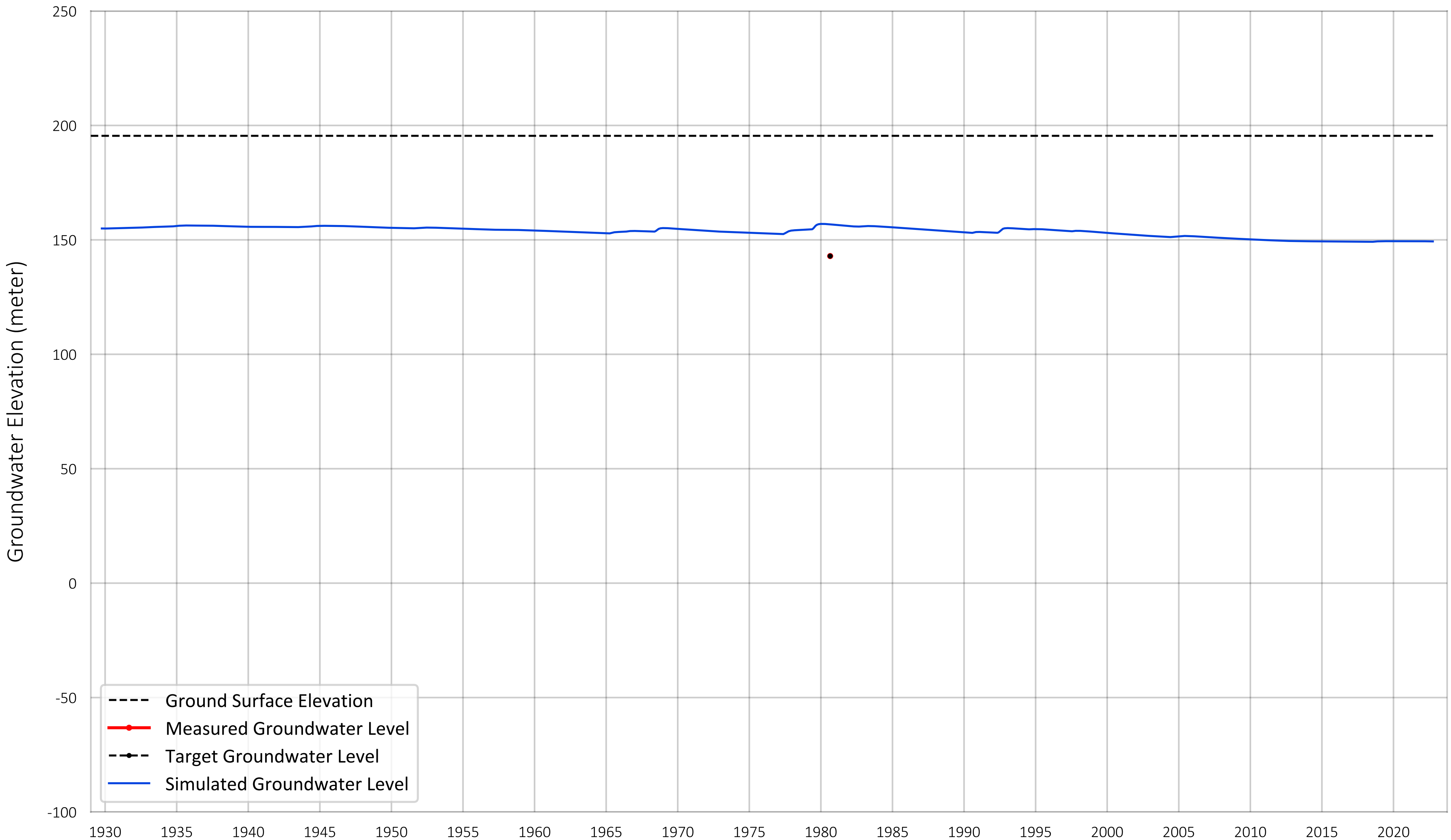
Prepared by:

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E21B002S

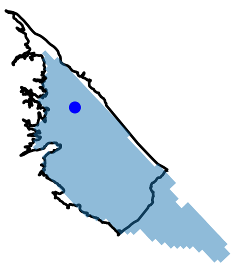
Figure A-6



Prepared by:

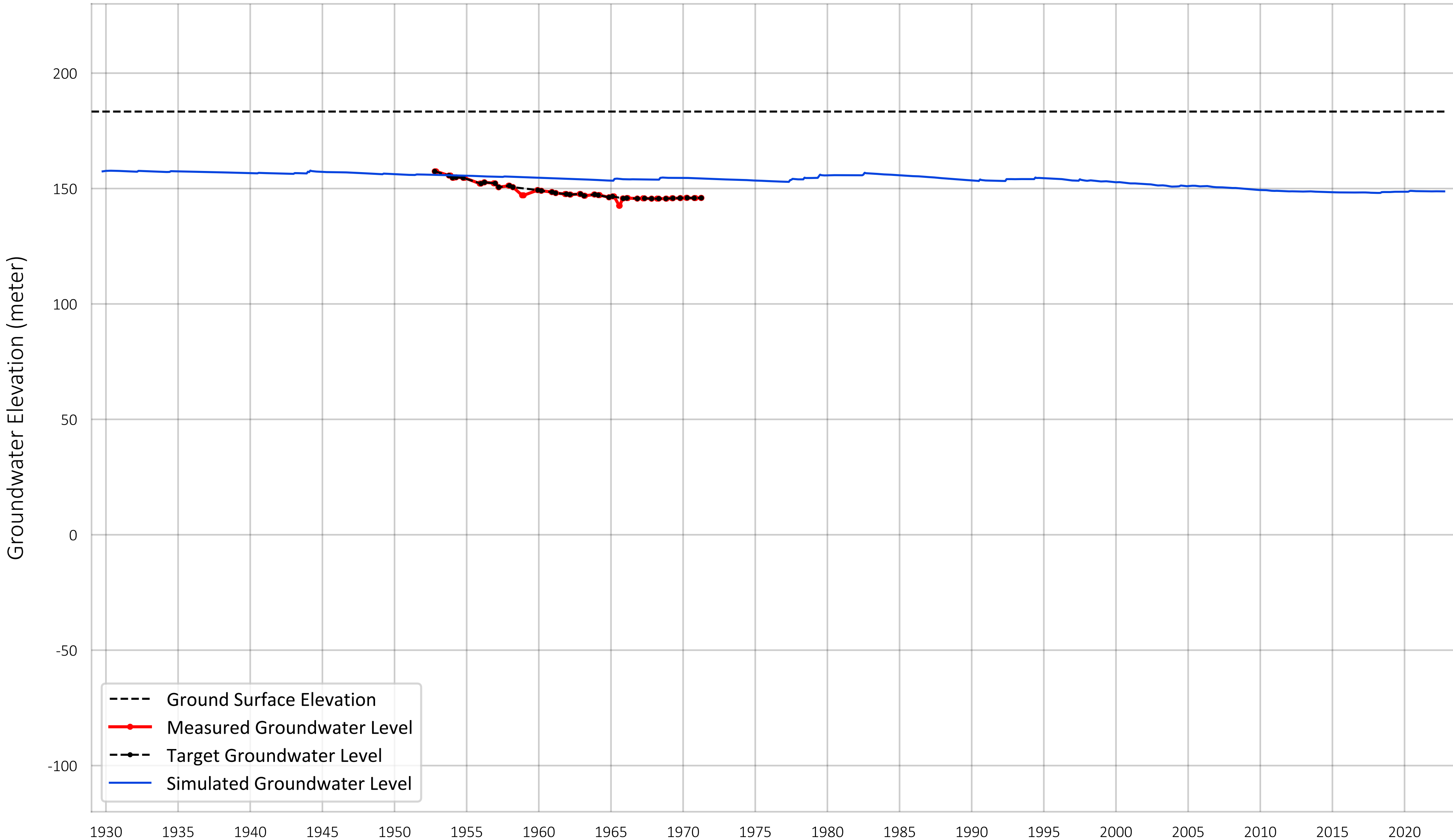
WEST YOST
Water. Engineered.

Well Location



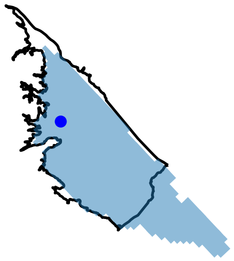
Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E21F001S

Figure A-7



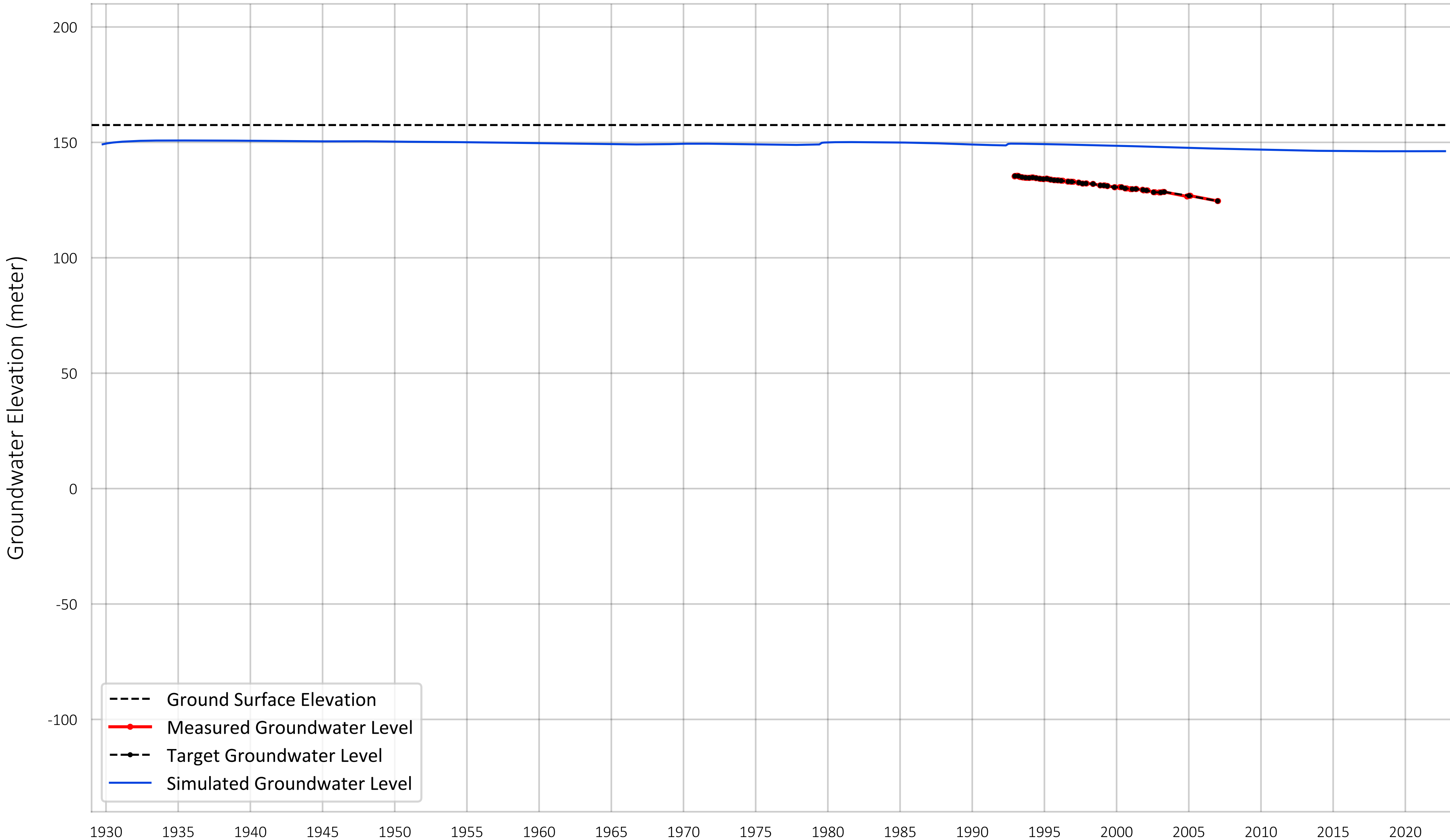
Prepared by:

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 010S006E29N001S

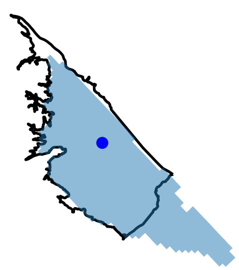
Figure A-8



Prepared by:

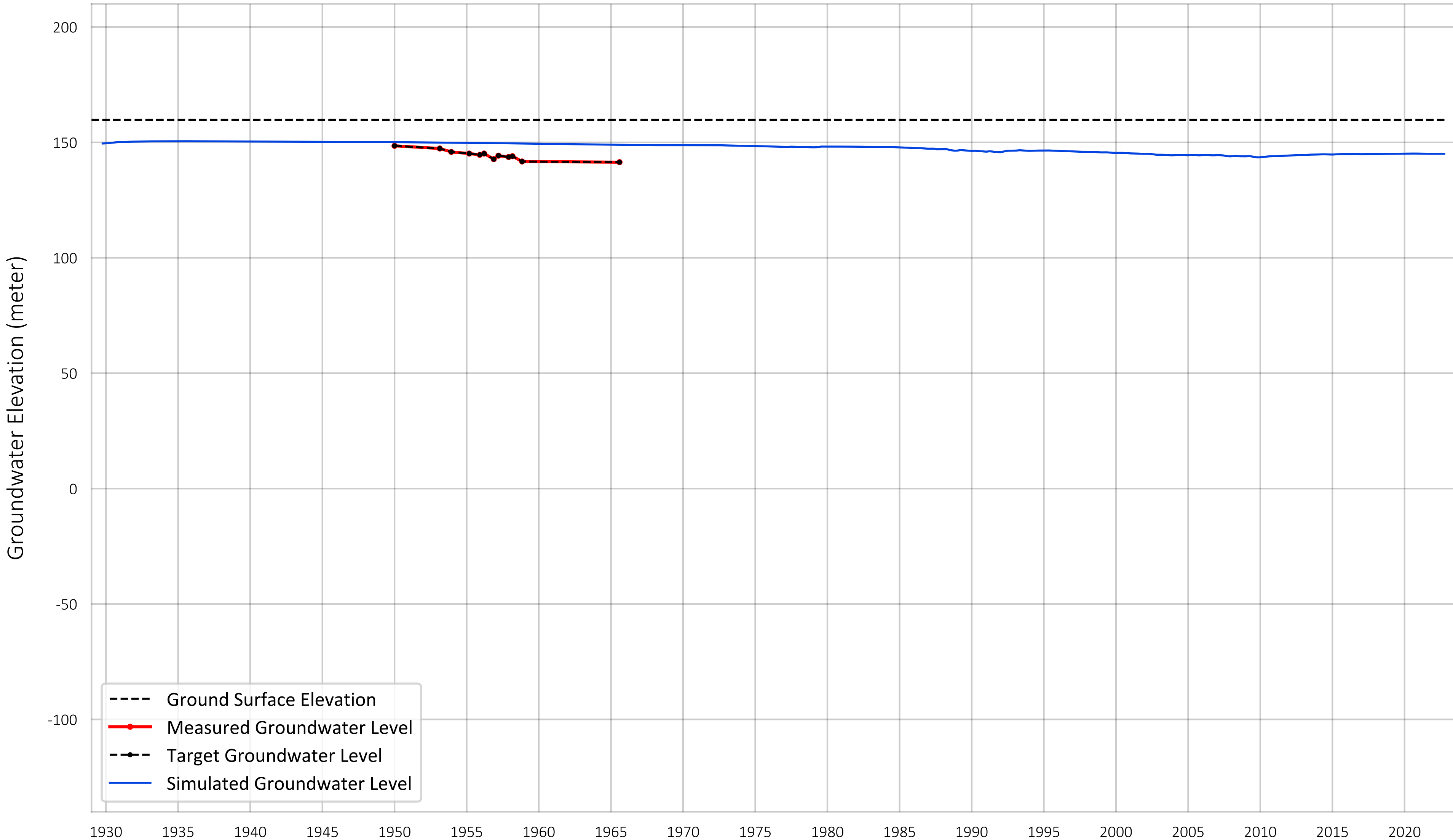
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 011S006E02C003S

Figure A-9



Prepared by:

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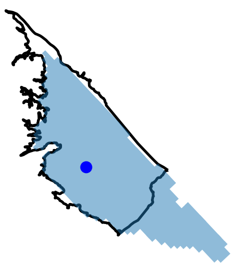
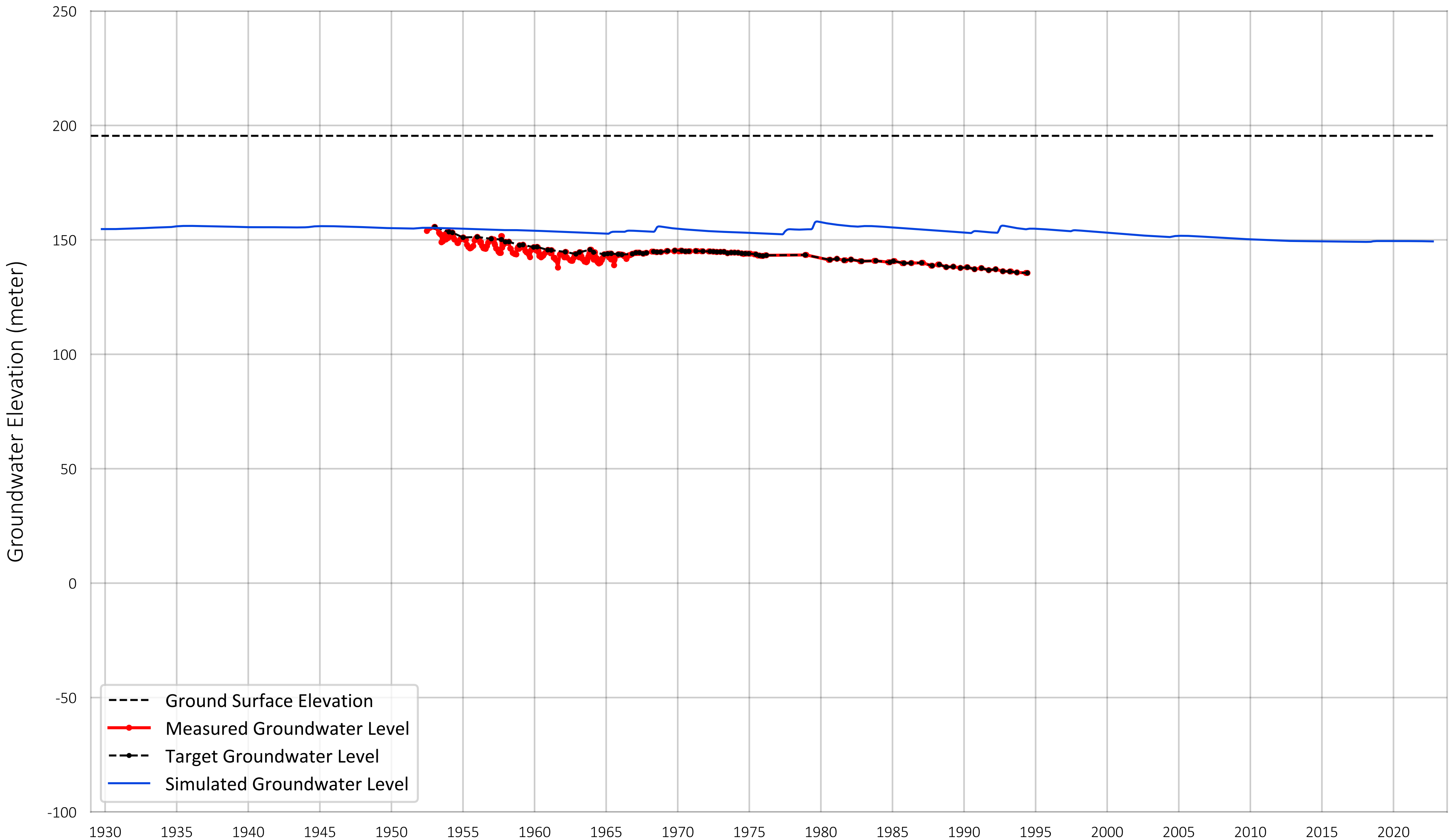
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 011S006E15F001S

Figure A-10



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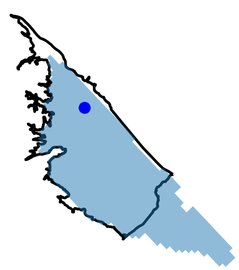
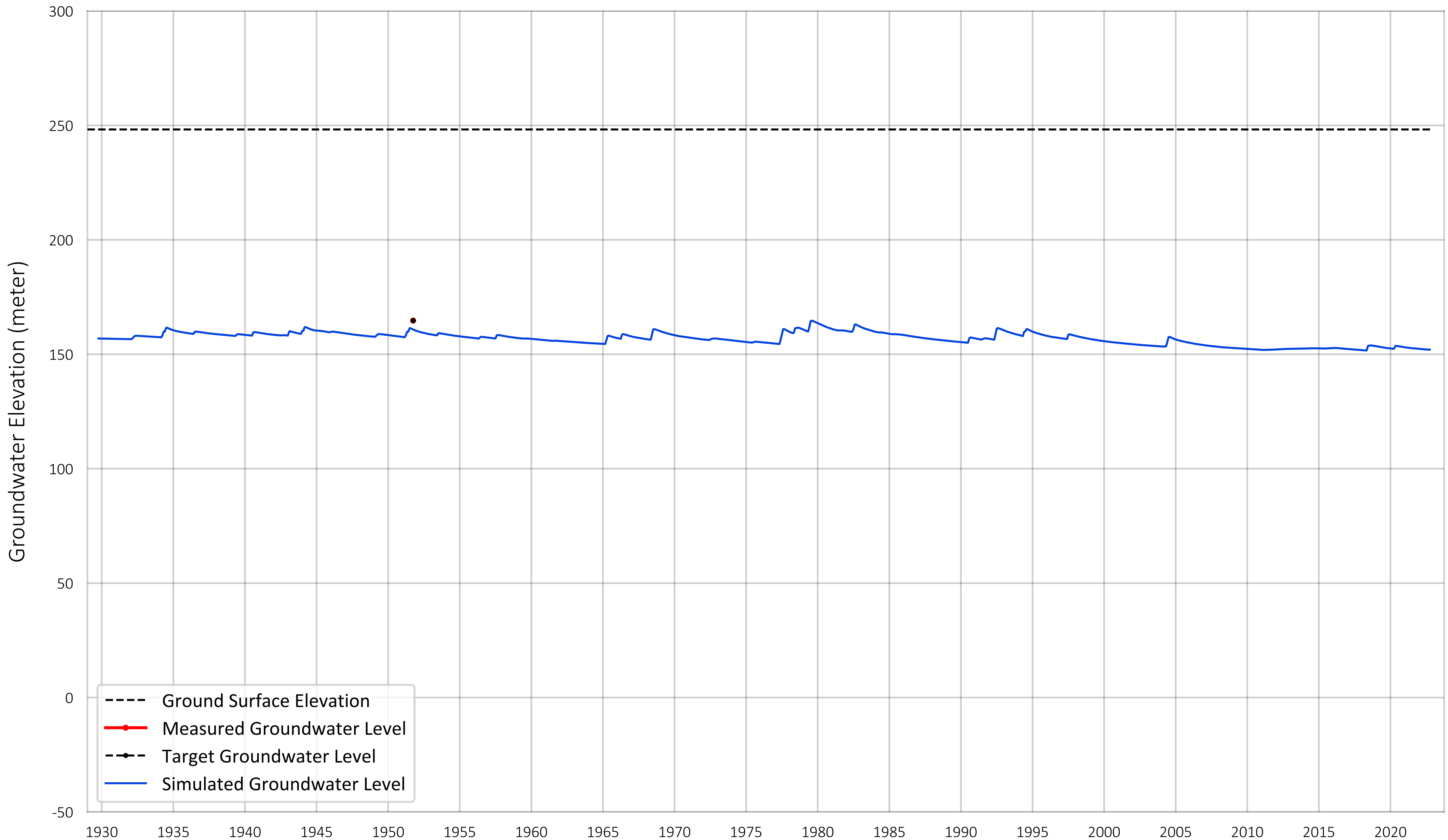
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 21A1

Figure A-11



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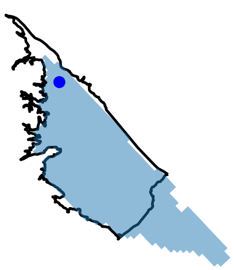
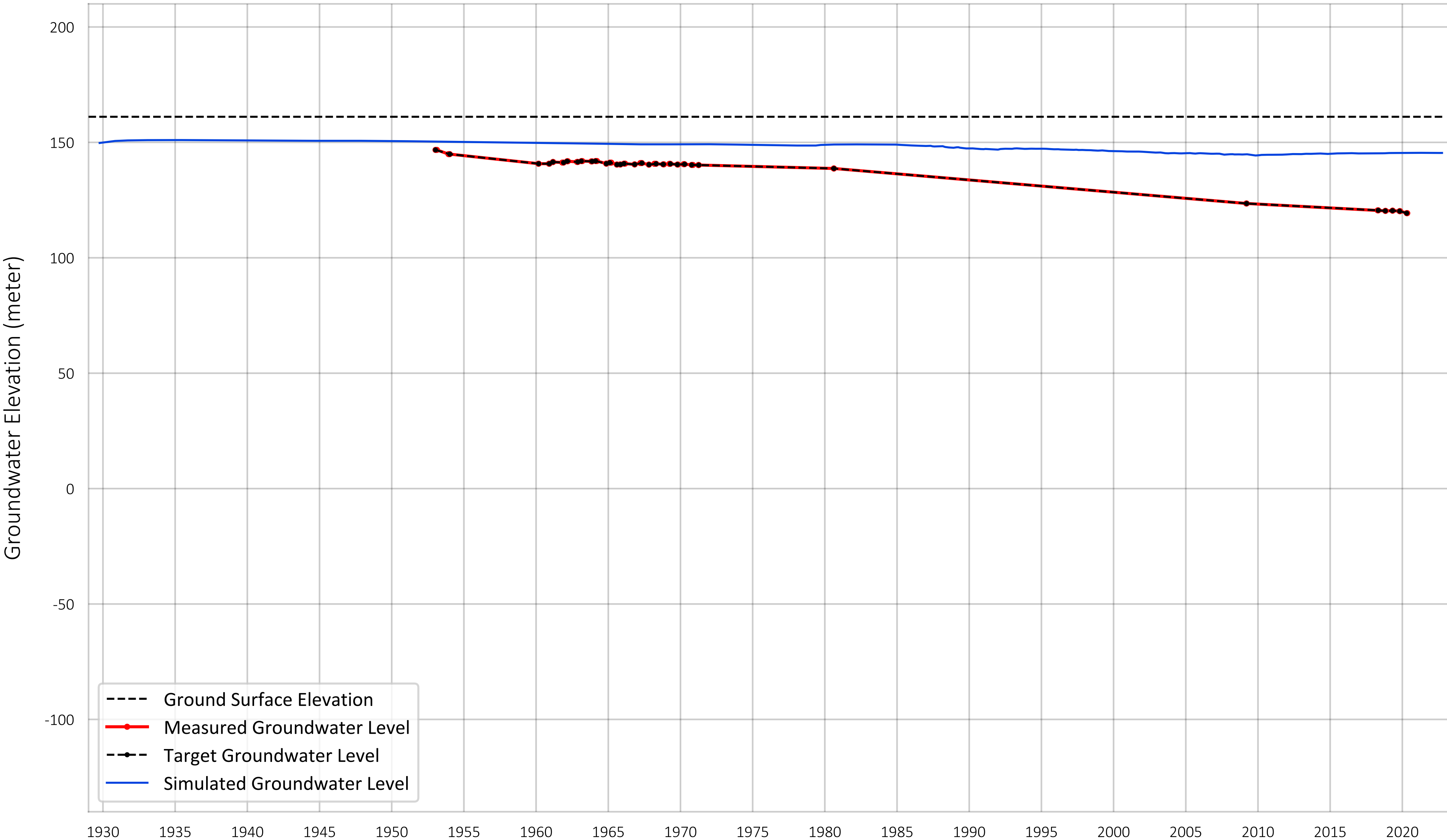
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: 5F1

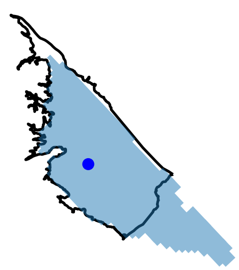
Figure A-12



Prepared by:

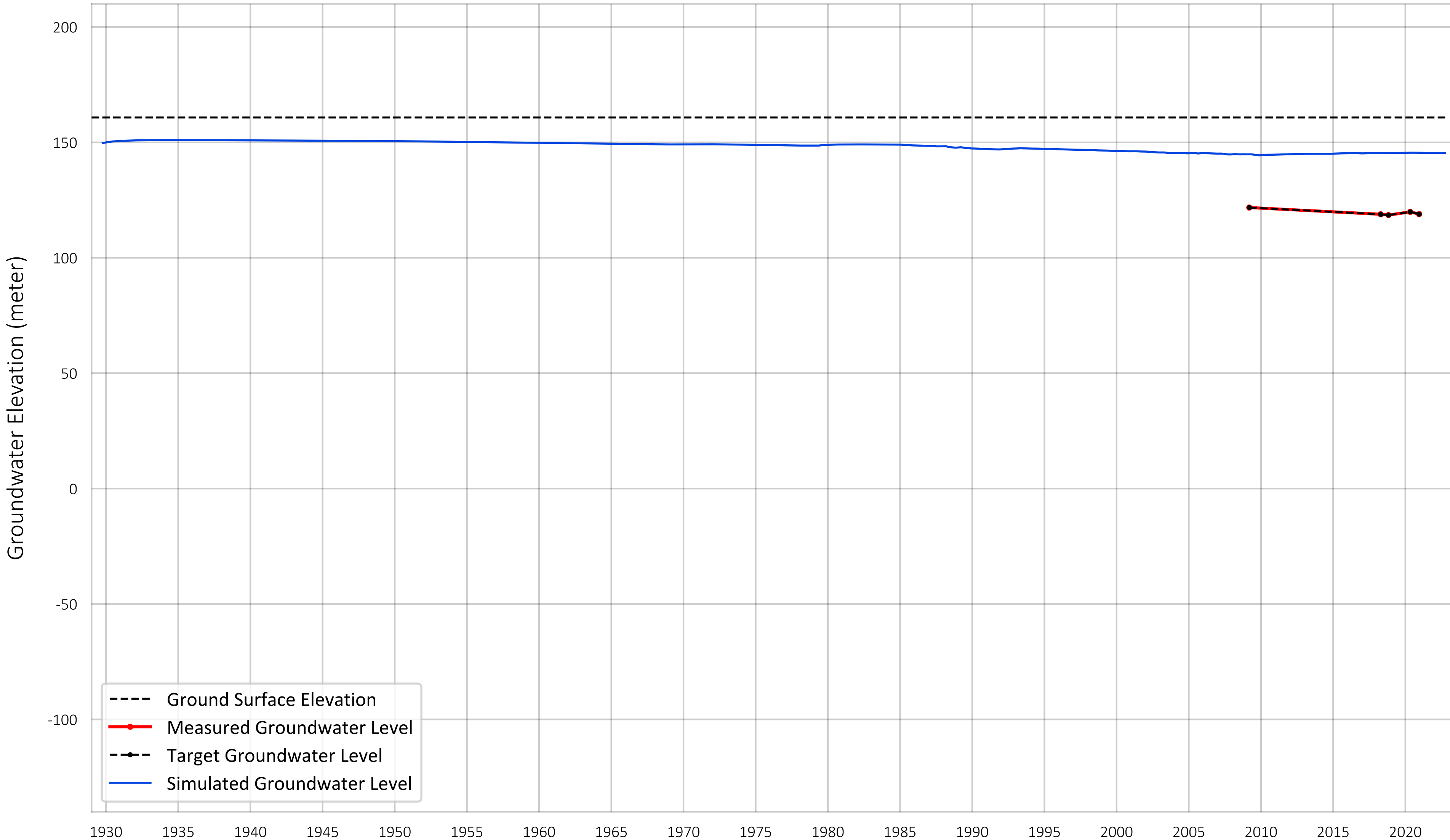
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Abandoned Motel-1

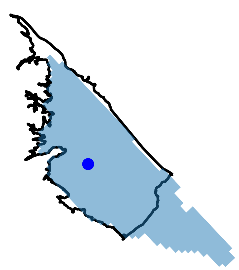
Figure A-13



Prepared by:

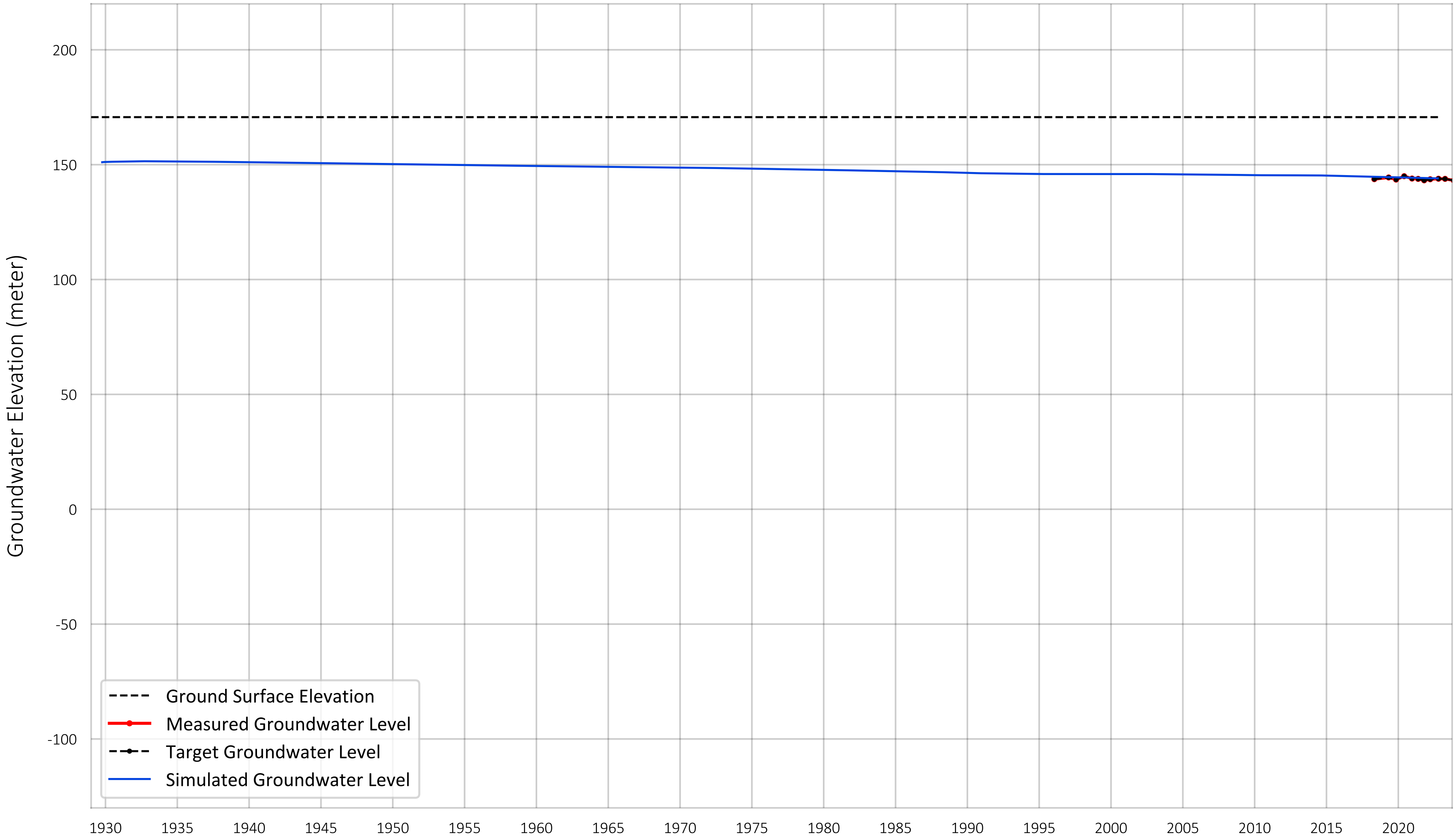
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Abandoned Motel-2

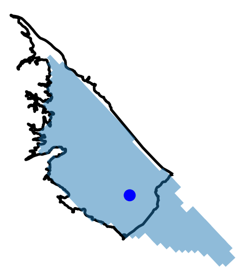
Figure A-14



Prepared by:

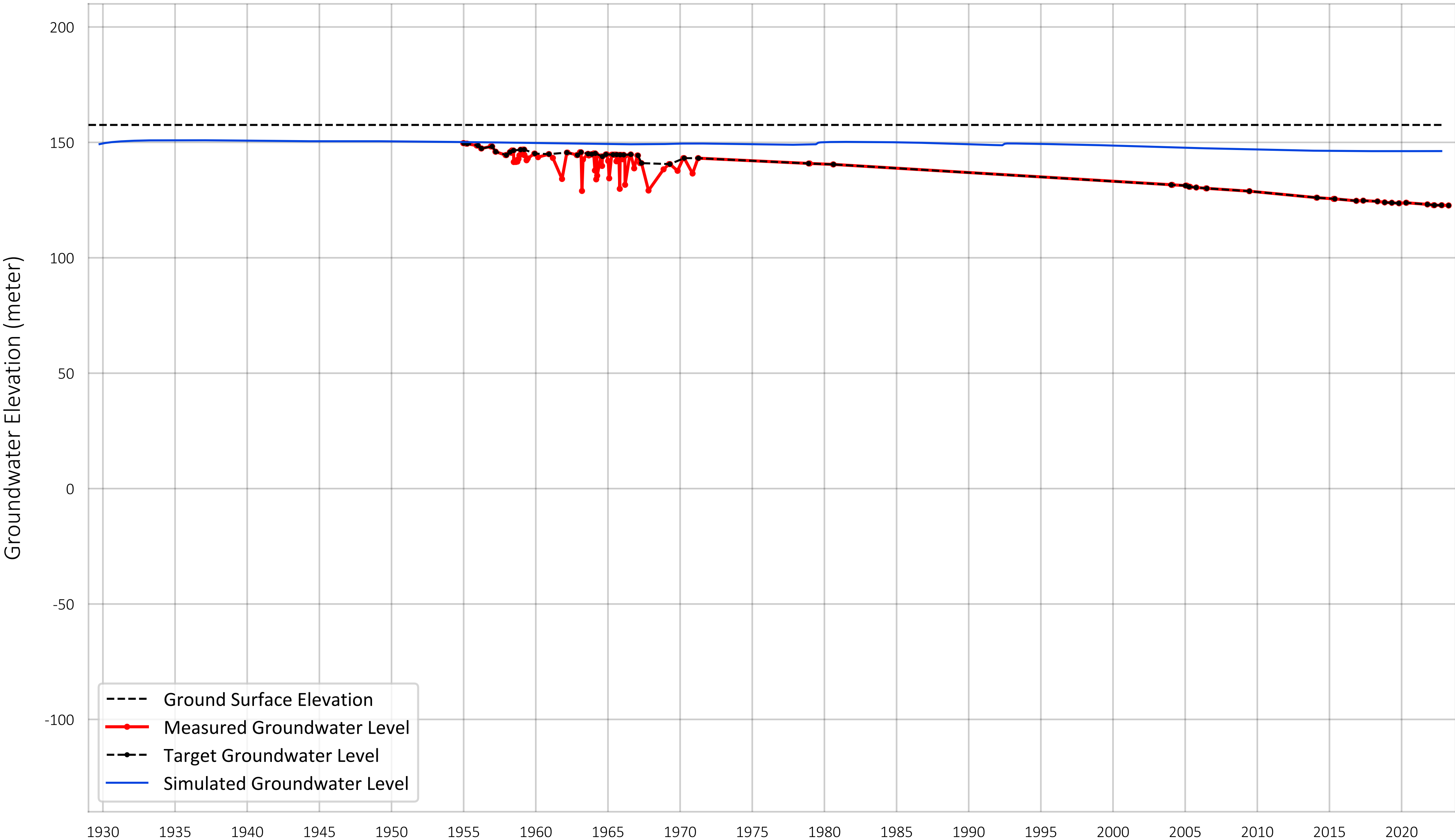
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Air Ranch Well 4

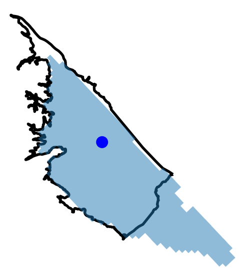
Figure A-15



Prepared by:

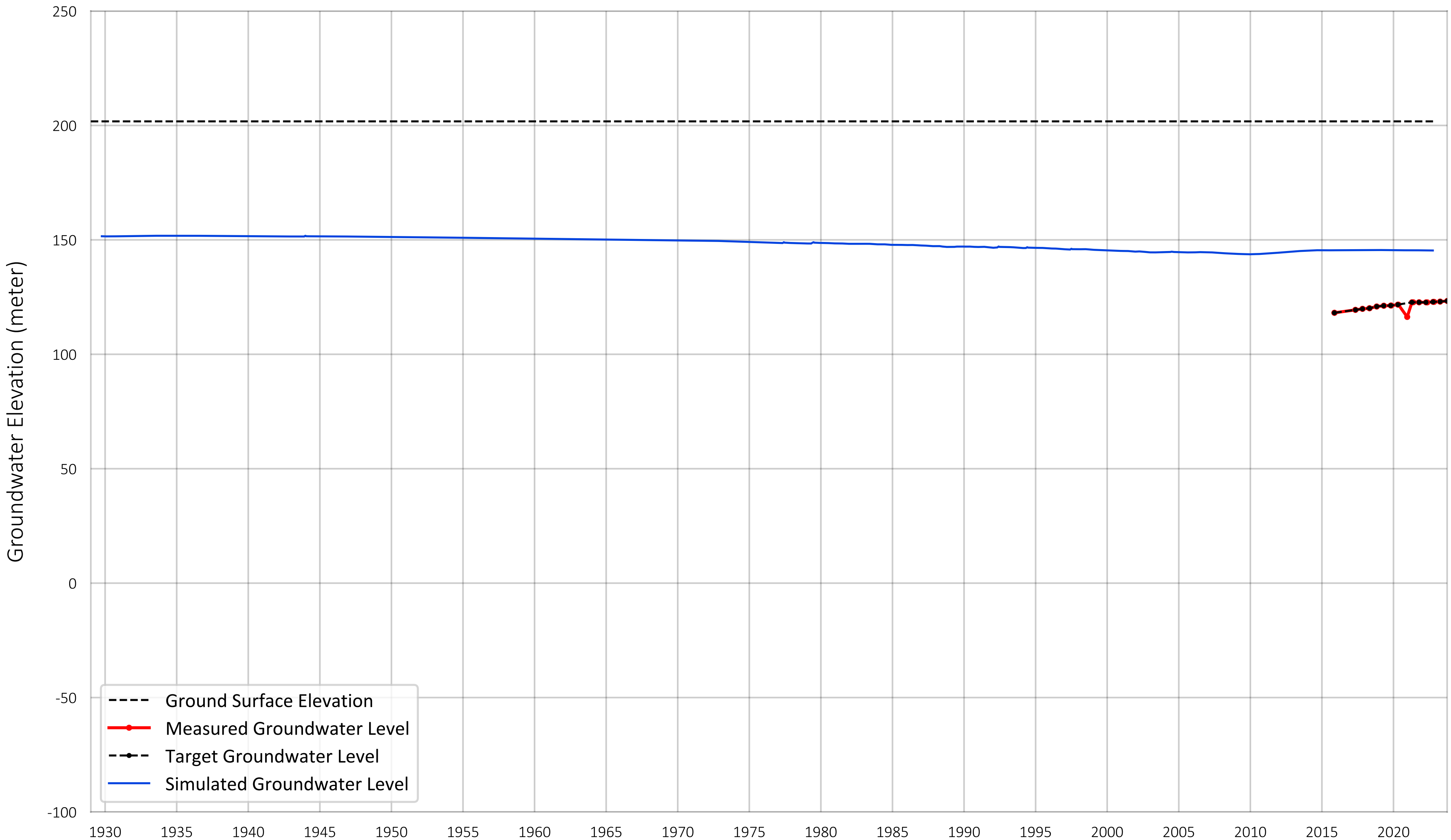
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Airport 2

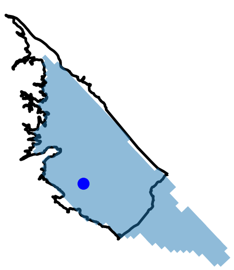
Figure A-16



Prepared by:

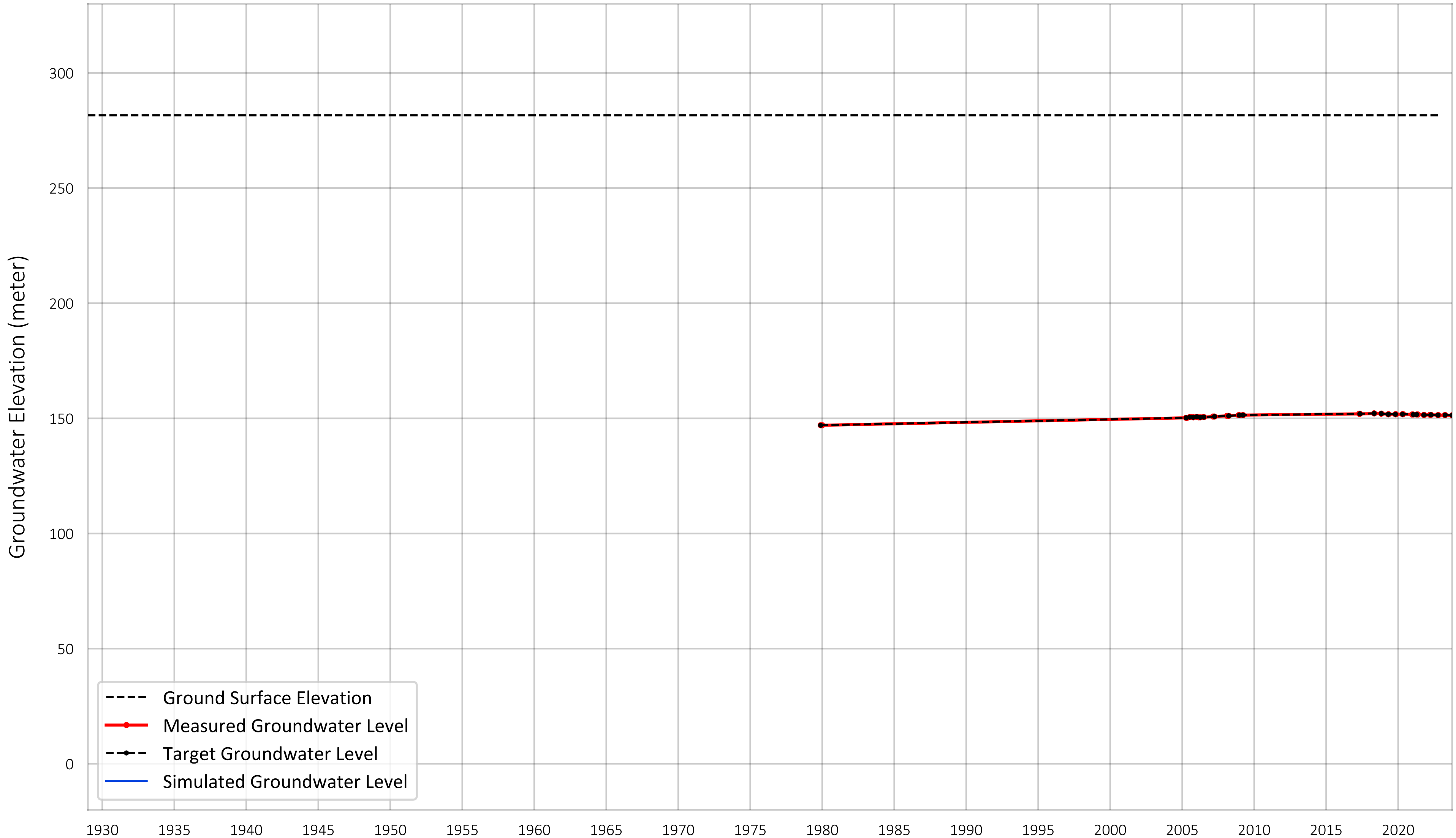
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Anzio/Yaqui Pass

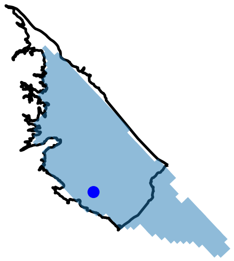
Figure A-17



Prepared by:

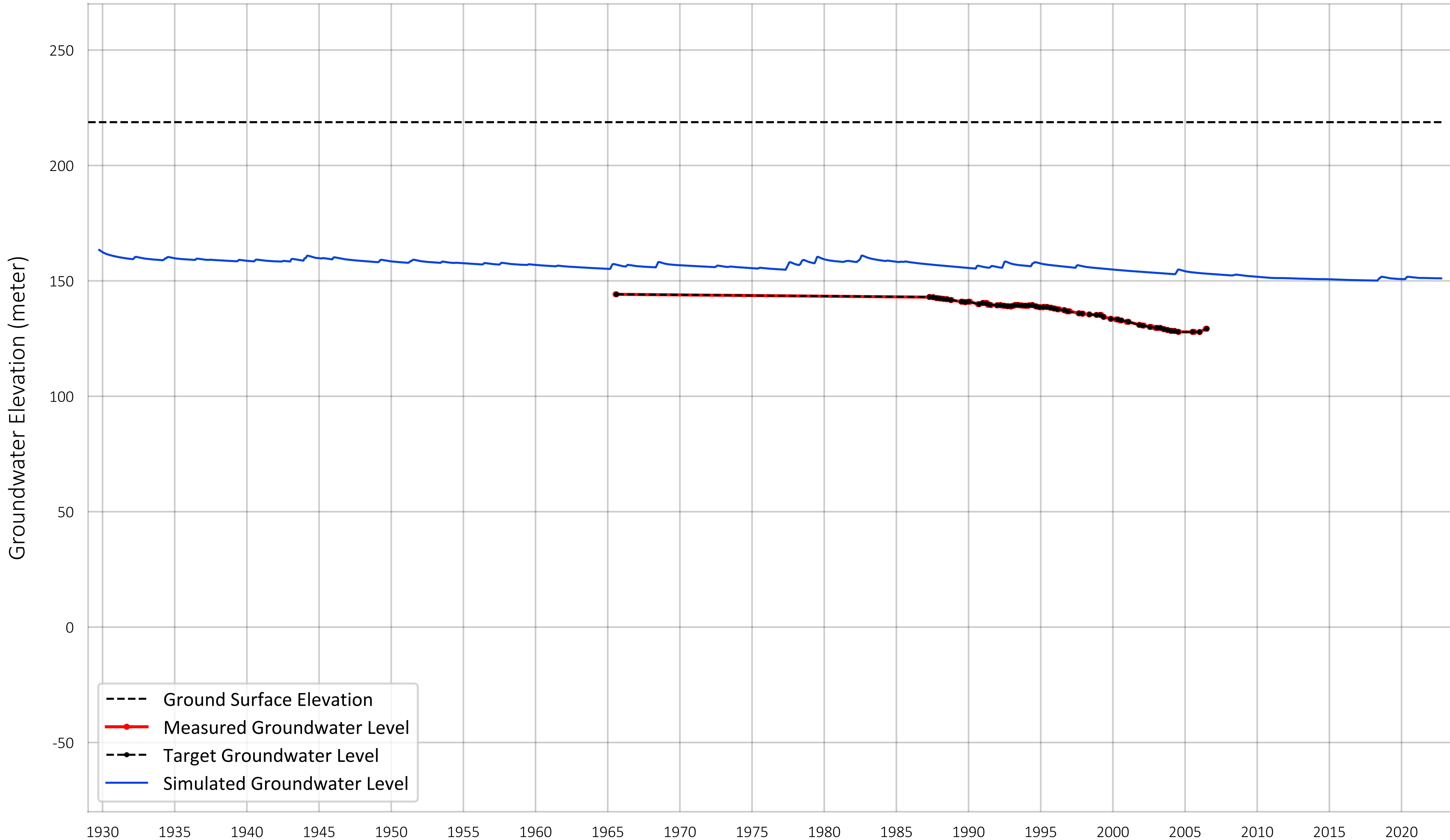
West Yost Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Army Well

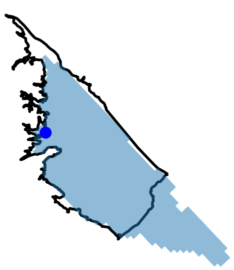
Figure A-18



Prepared by:

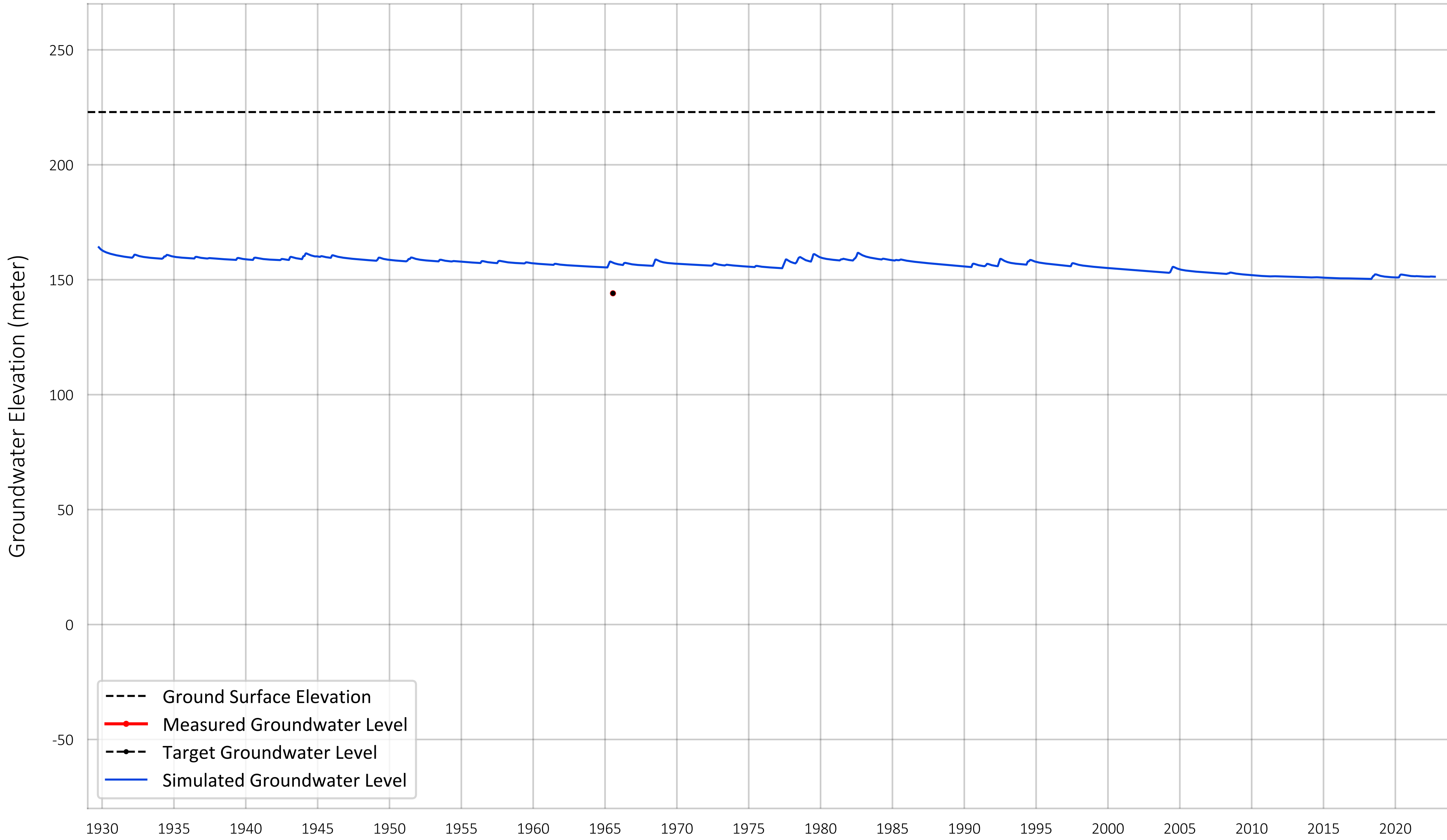
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Auxiliary 1

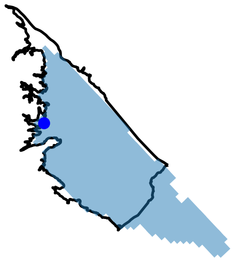
Figure A-19



Prepared by:

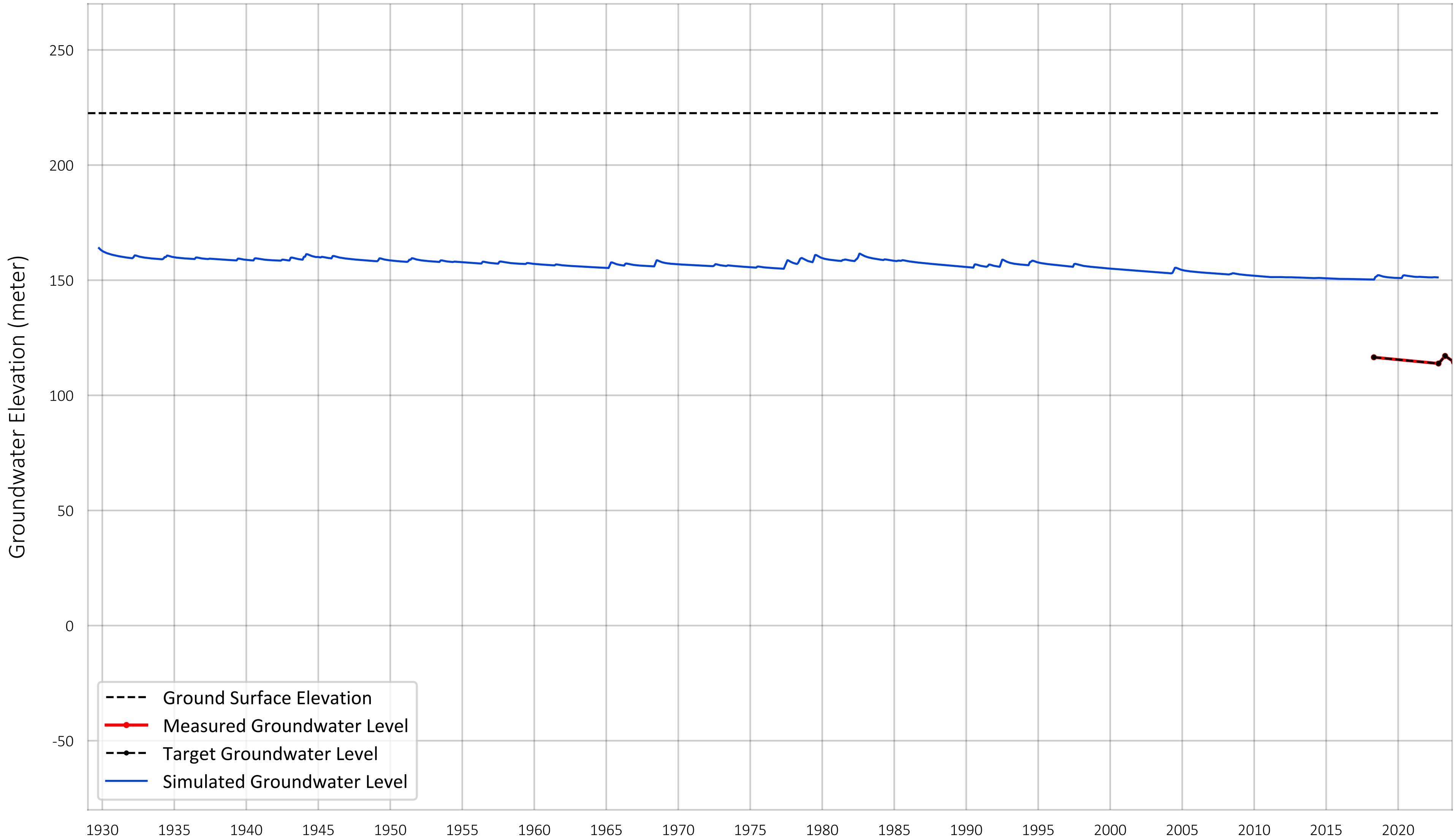
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Auxiliary 2

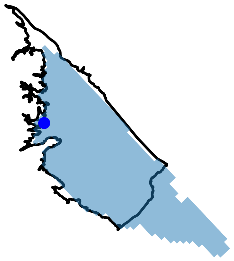
Figure A-20



Prepared by:

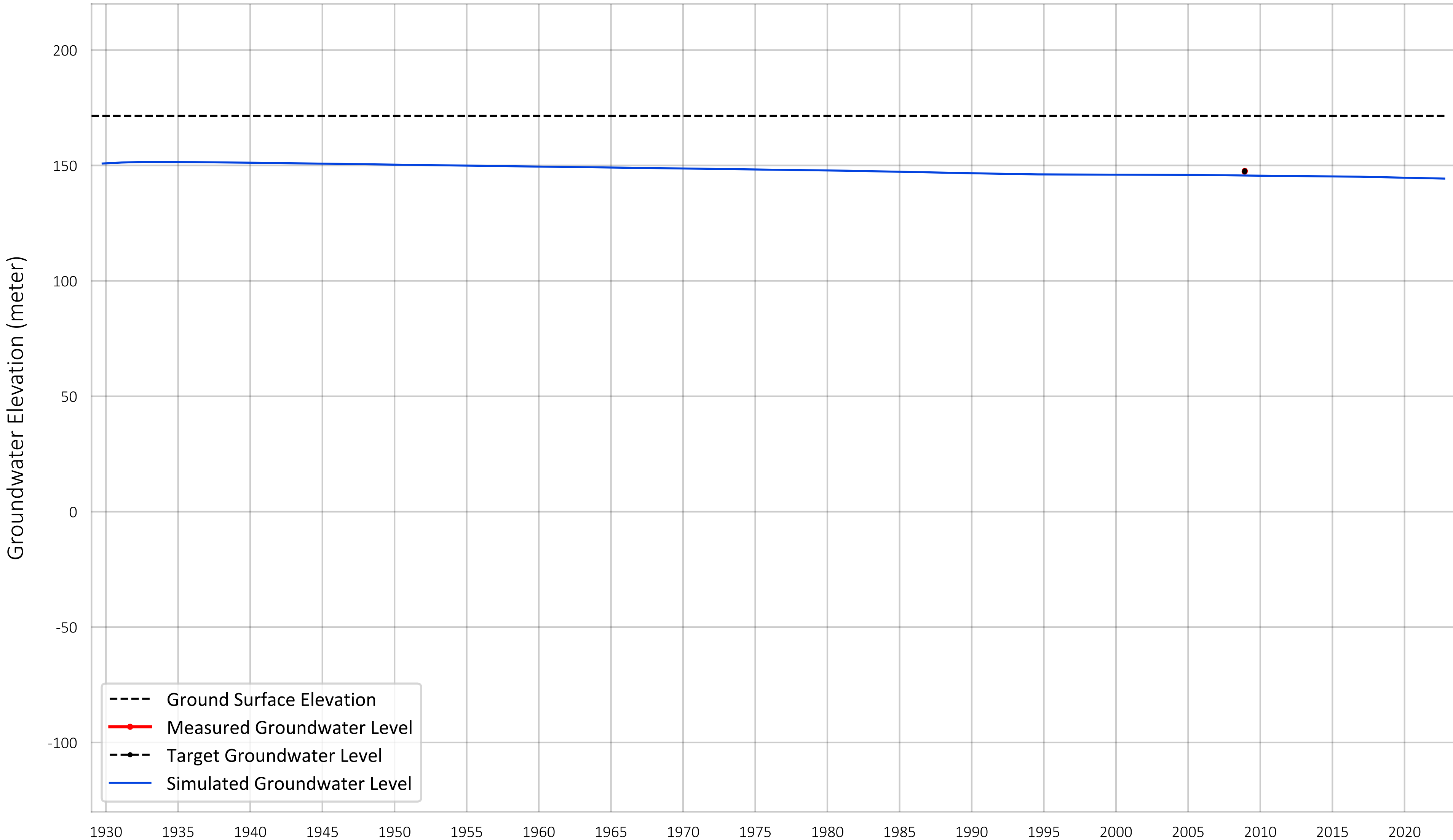
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Auxiliary 3

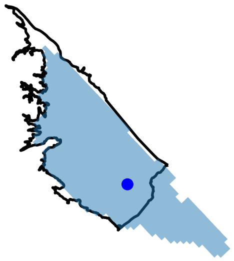
Figure A-21



Prepared by:

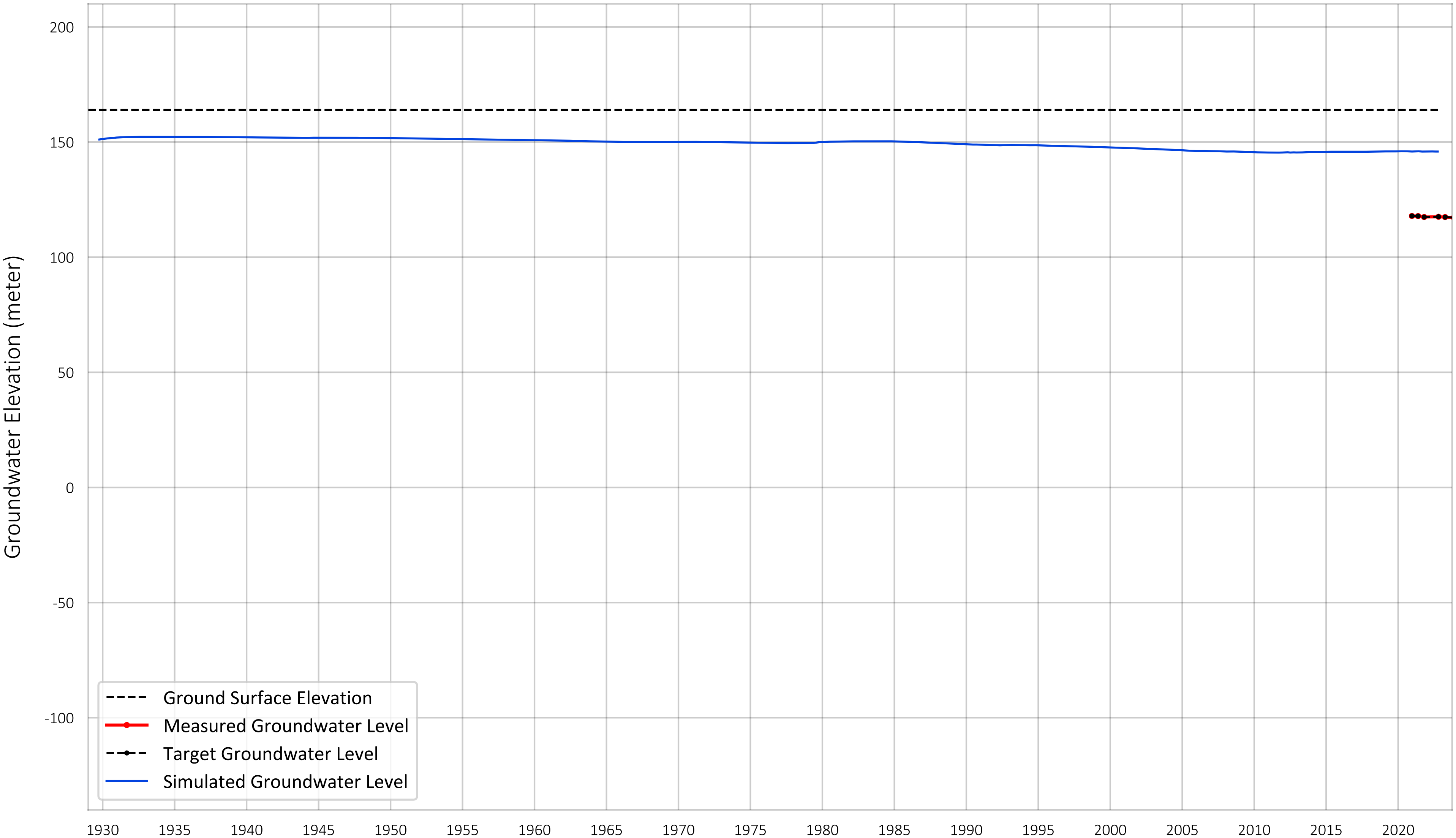
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: BAR #3

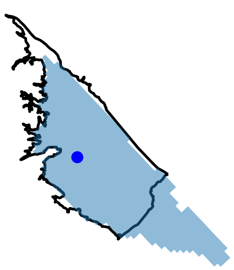
Figure A-22



Prepared by:

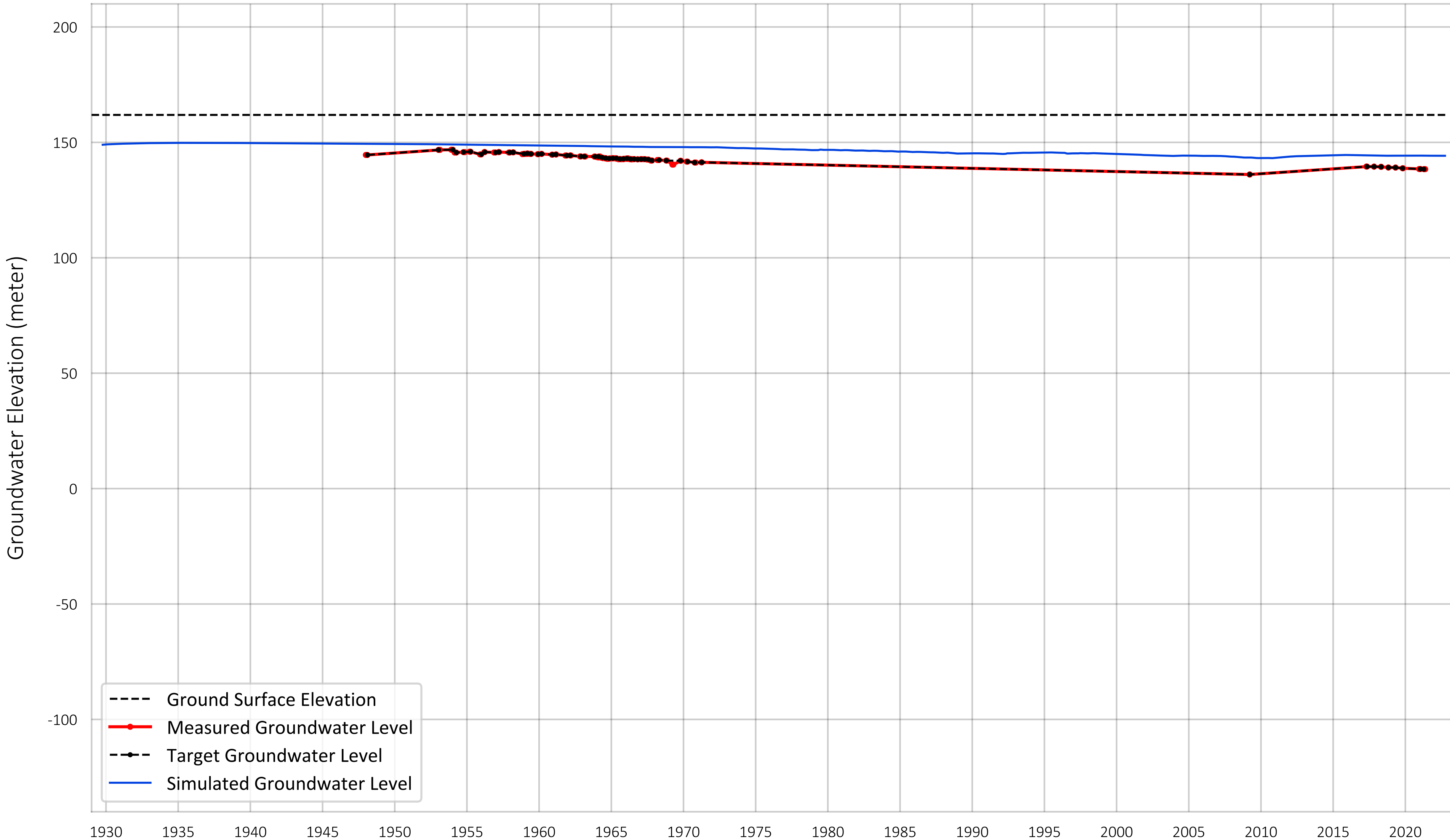
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: BSR Well 6

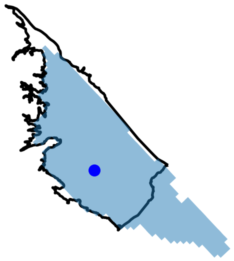
Figure A-23



Prepared by:

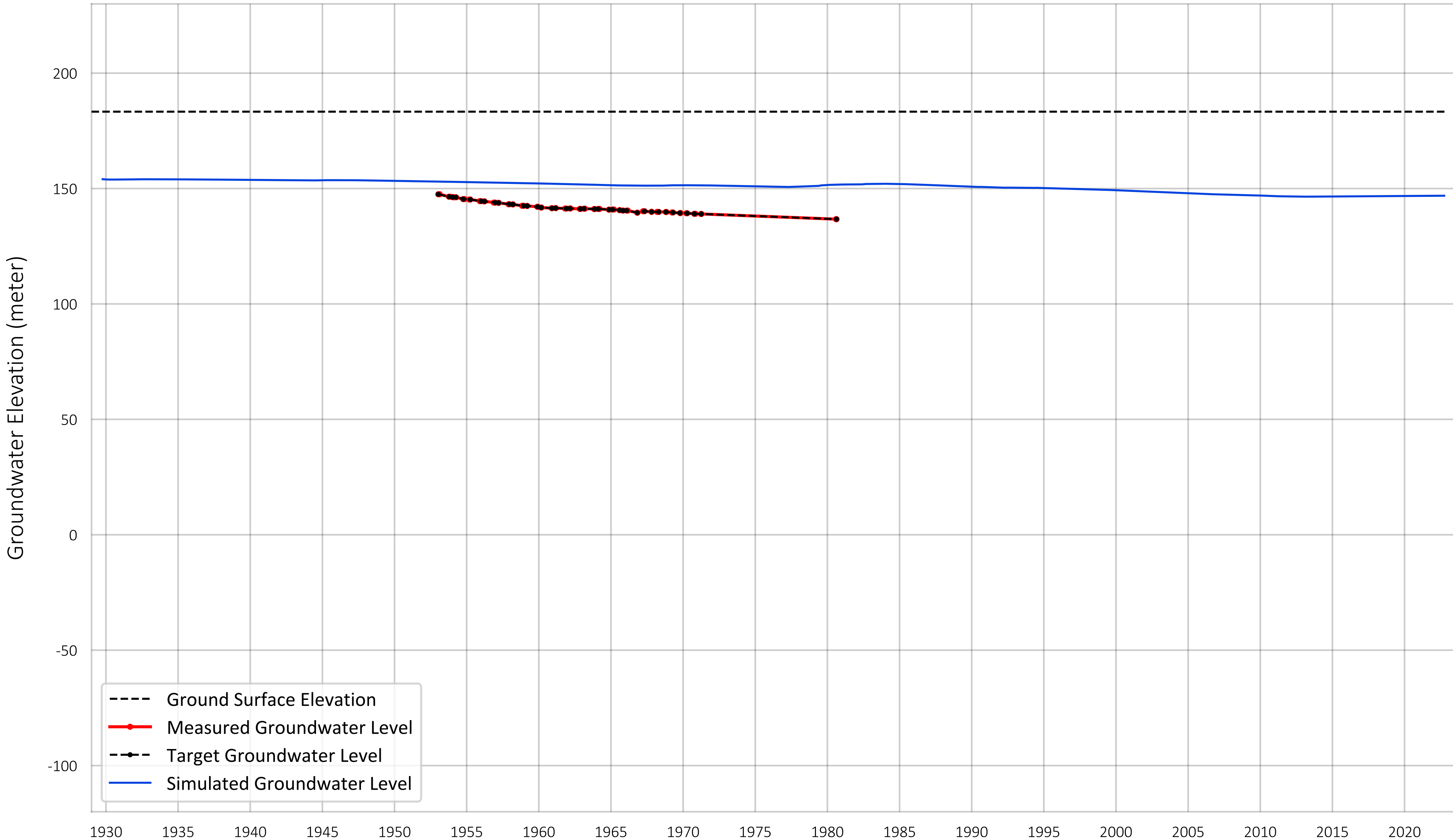
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Bakko

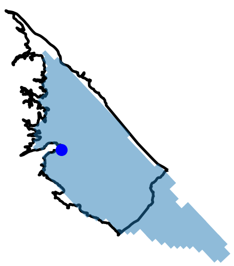
Figure A-24



Prepared by:

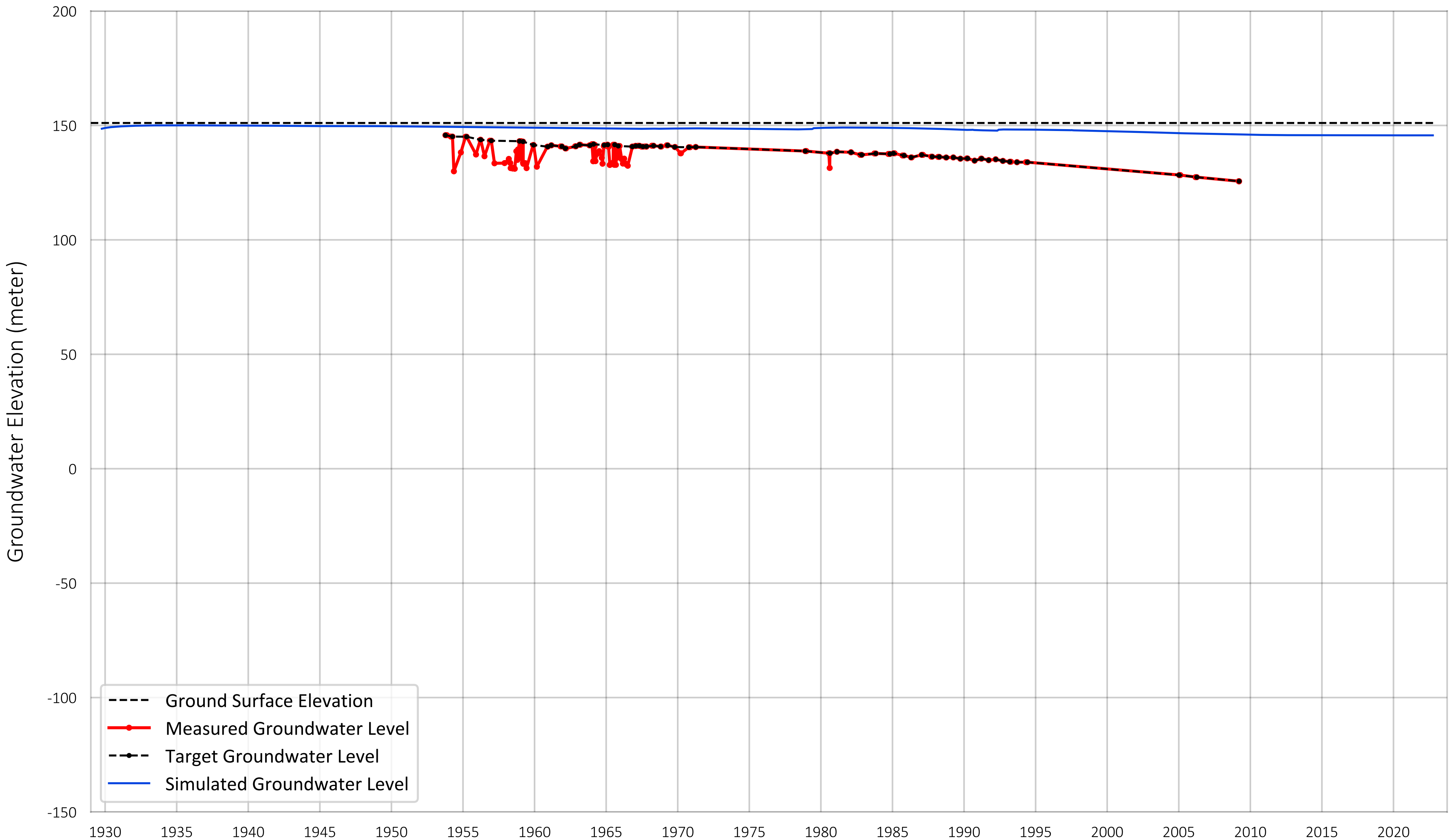
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Bending Elbow

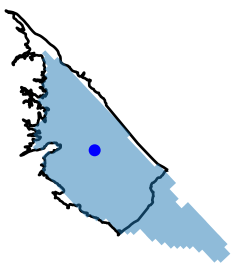
Figure A-25



Prepared by:

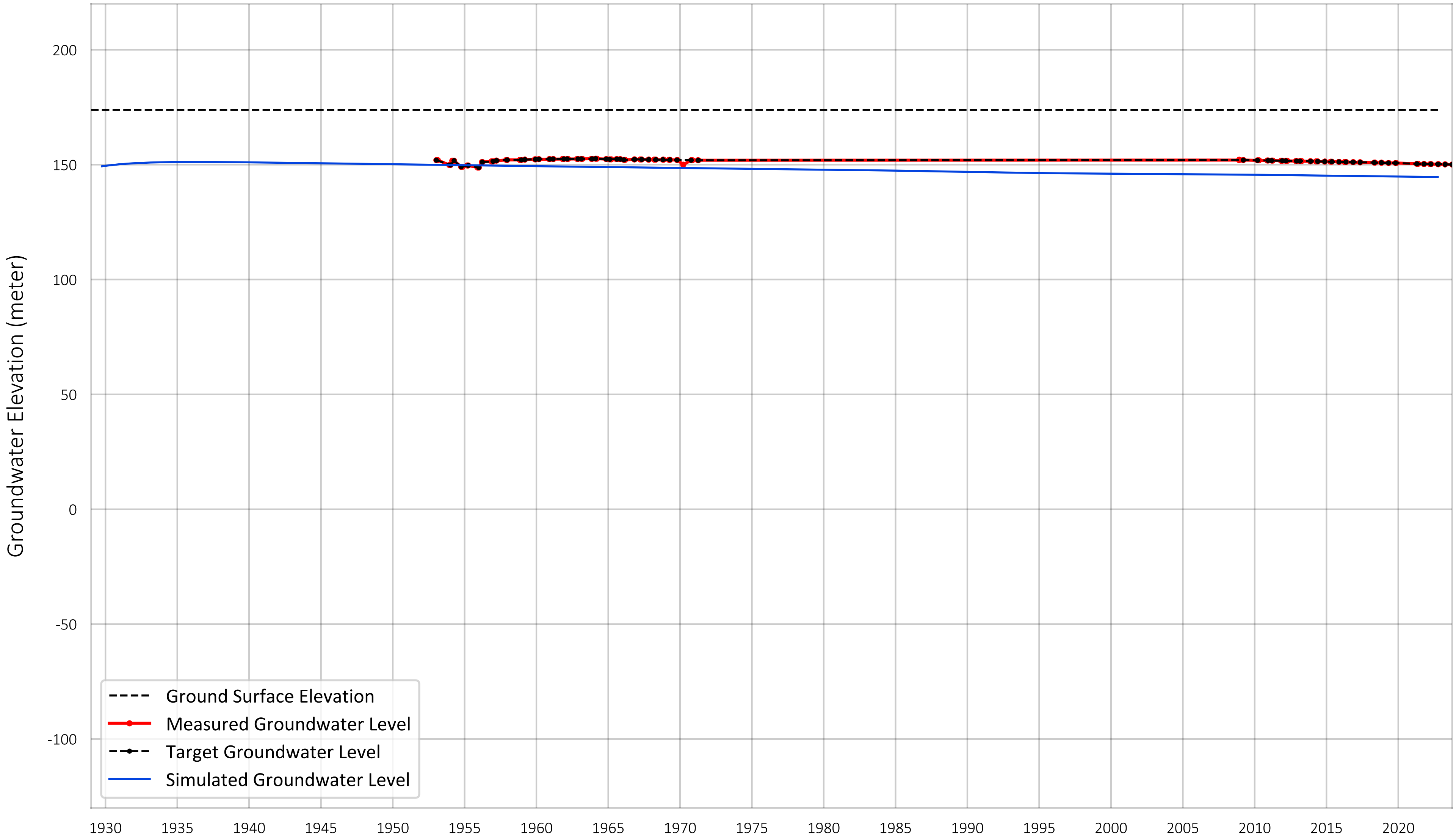
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Berkovitch

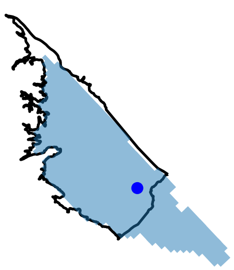
Figure A-26



Prepared by:

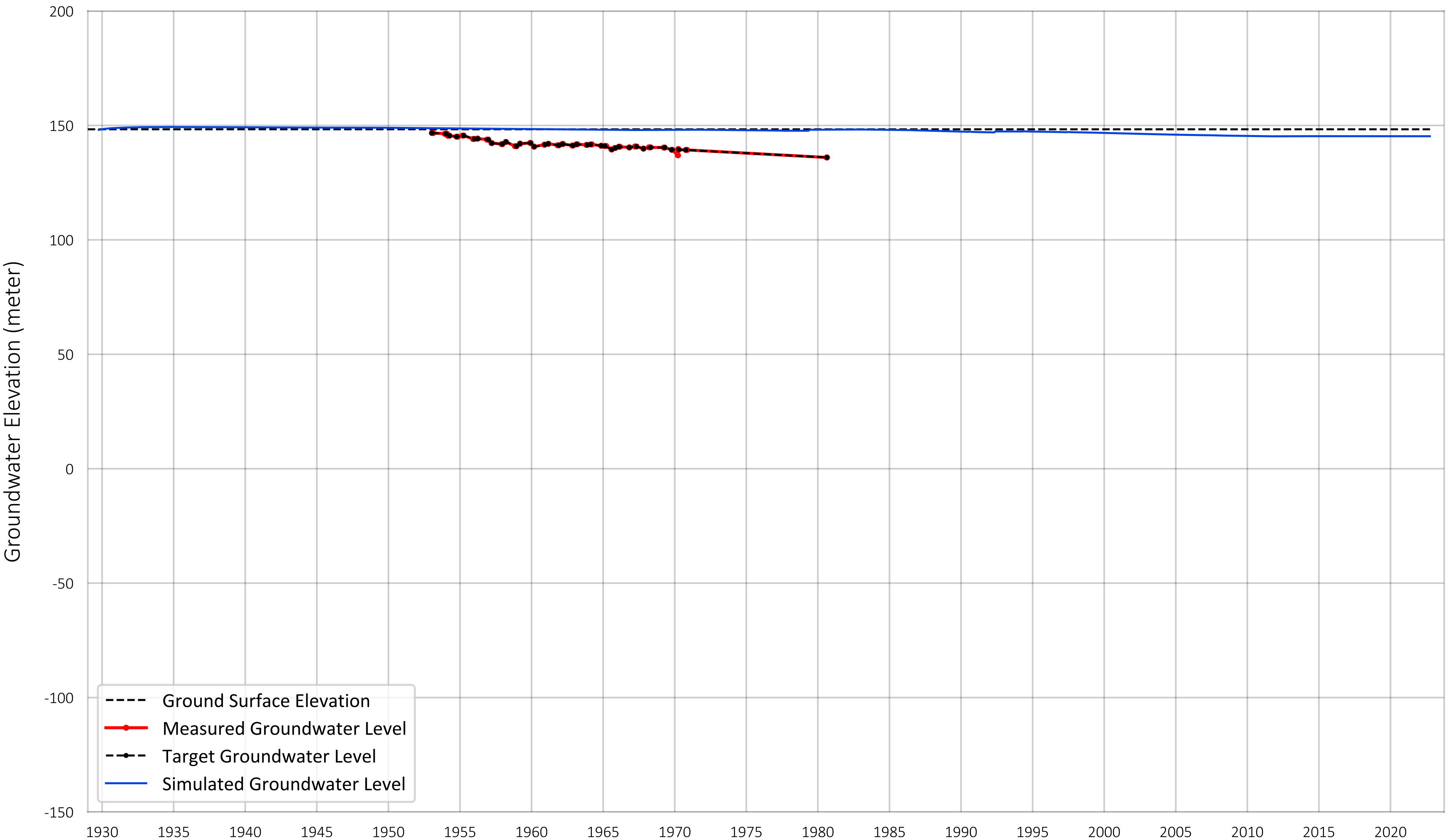
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Bing Crosby Well (Sky Ranch)

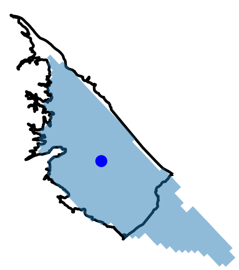
Figure A-27



Prepared by:

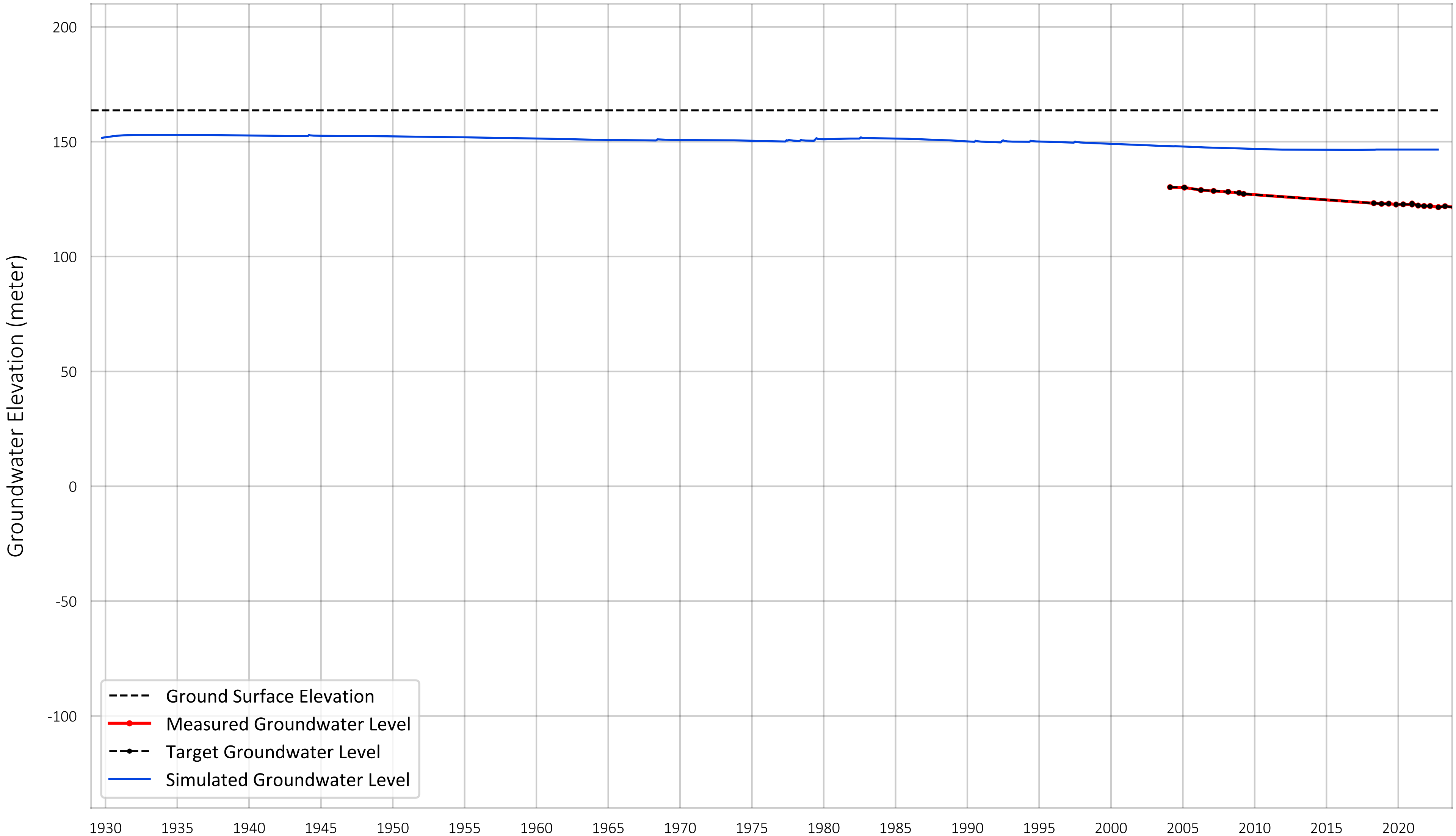
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Burned House 1

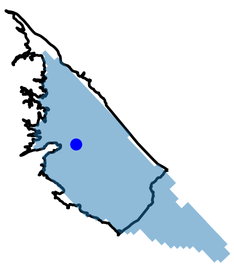
Figure A-28



Prepared by:

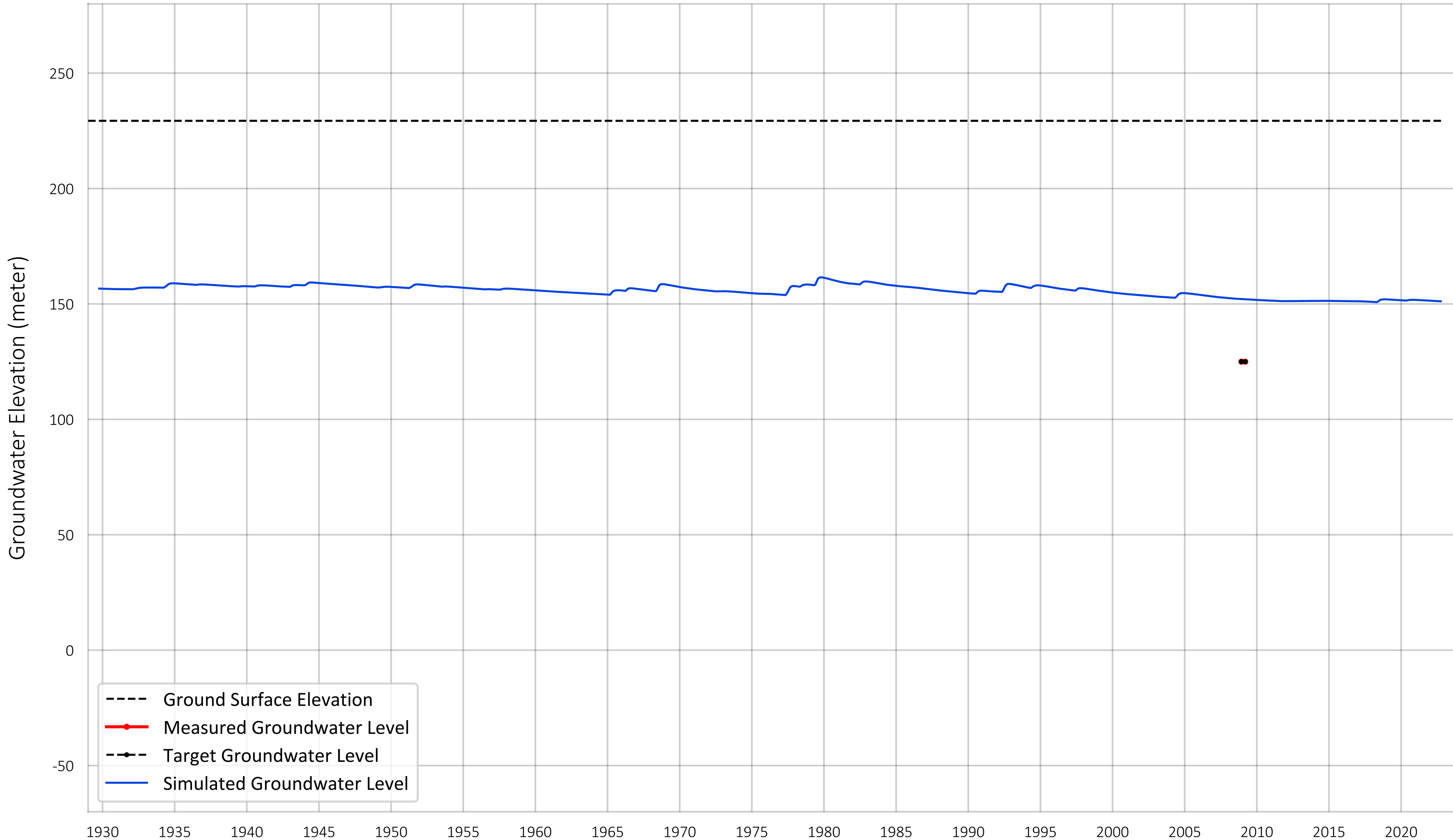
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Cameron 2

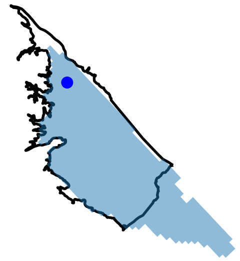
Figure A-29



Prepared by:

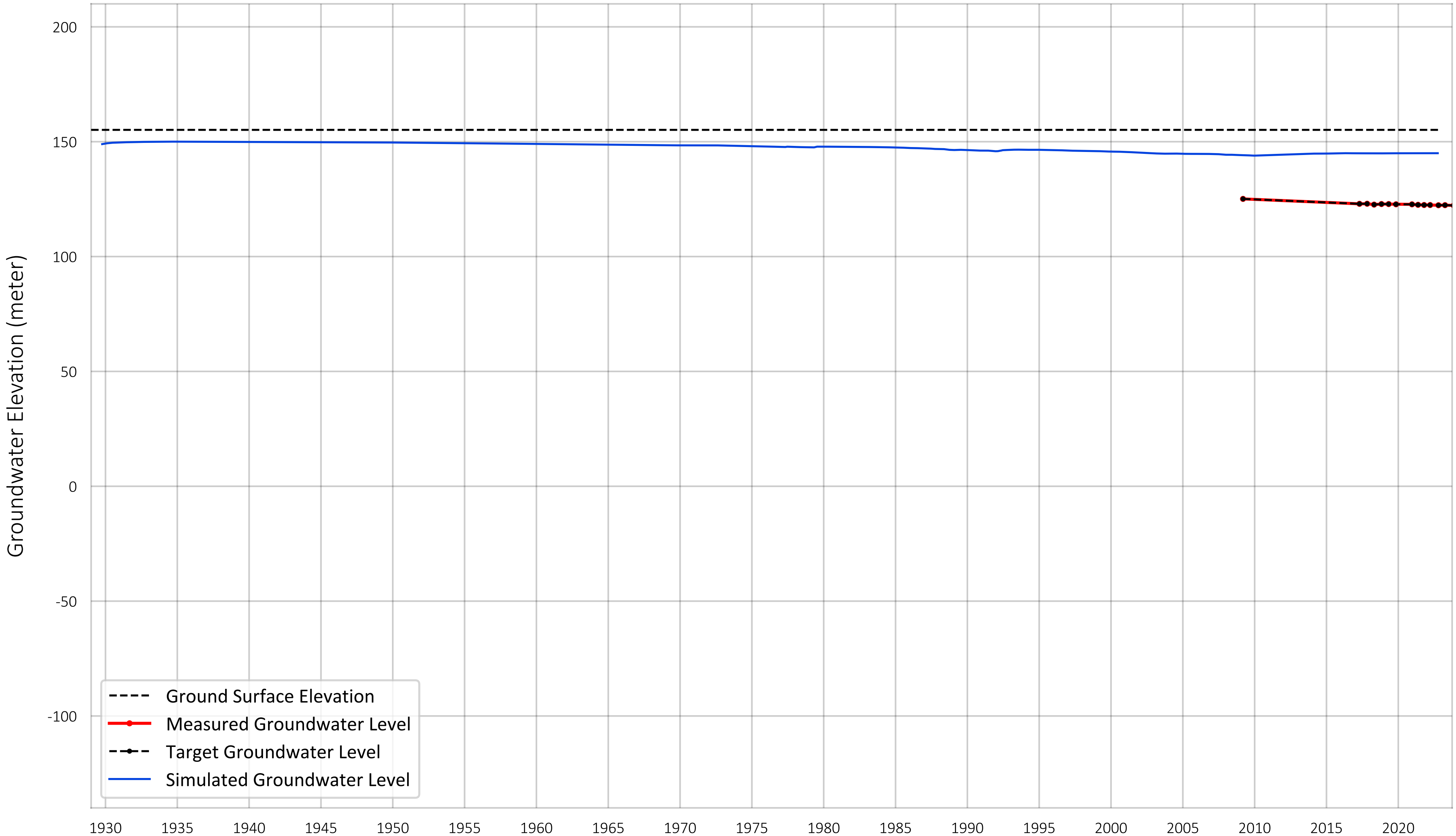
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Charmer 2

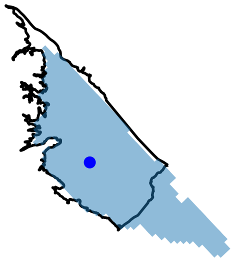
Figure A-30



Prepared by:

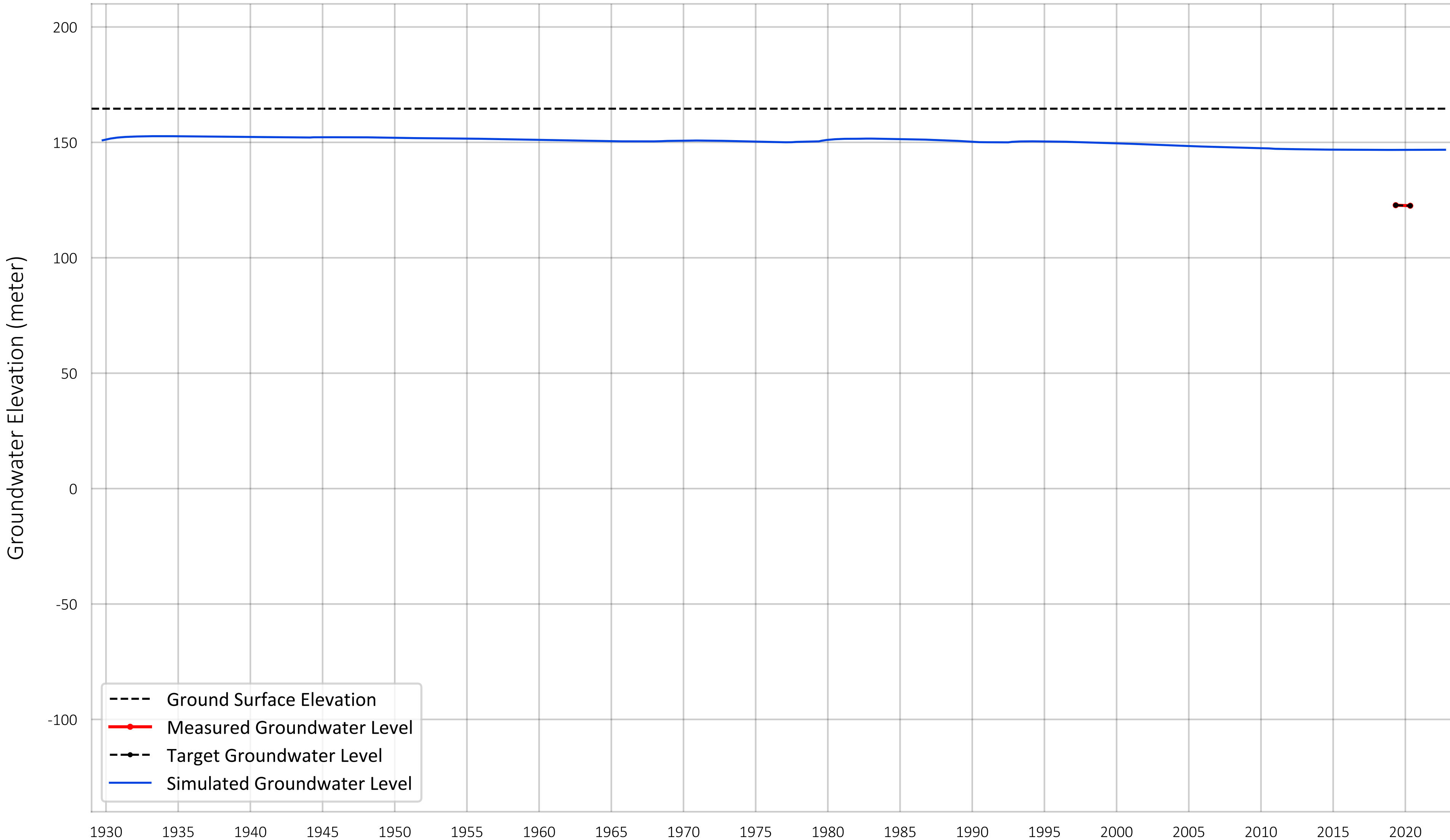
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: County Yard (SD DOT)

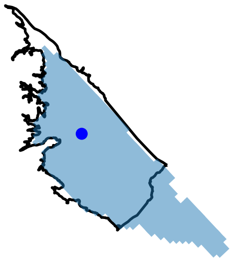
Figure A-31



Prepared by:

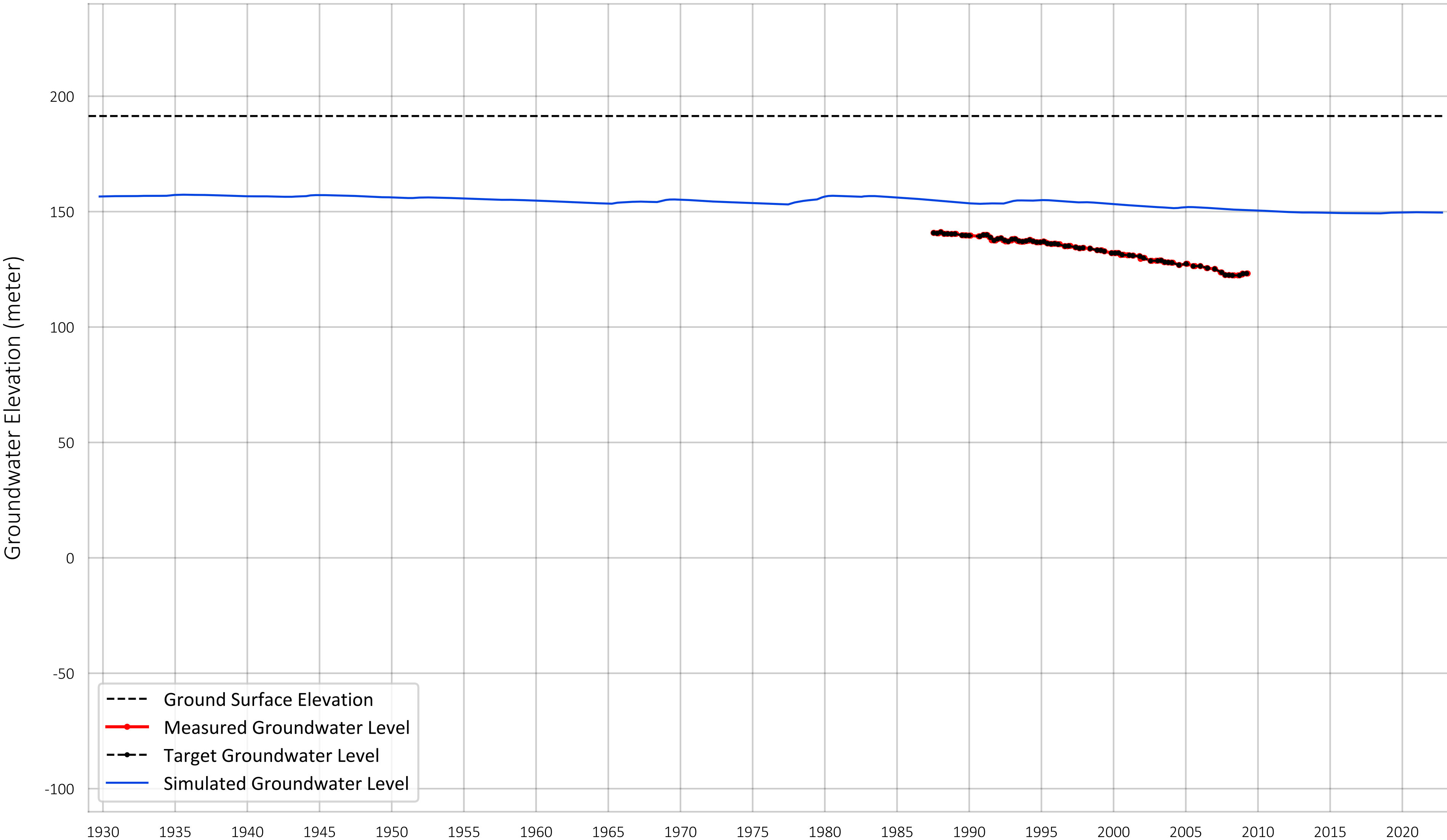
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Elementary School

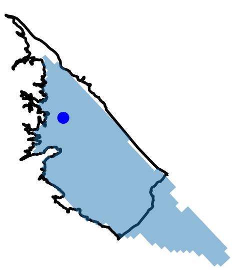
Figure A-32



Prepared by:

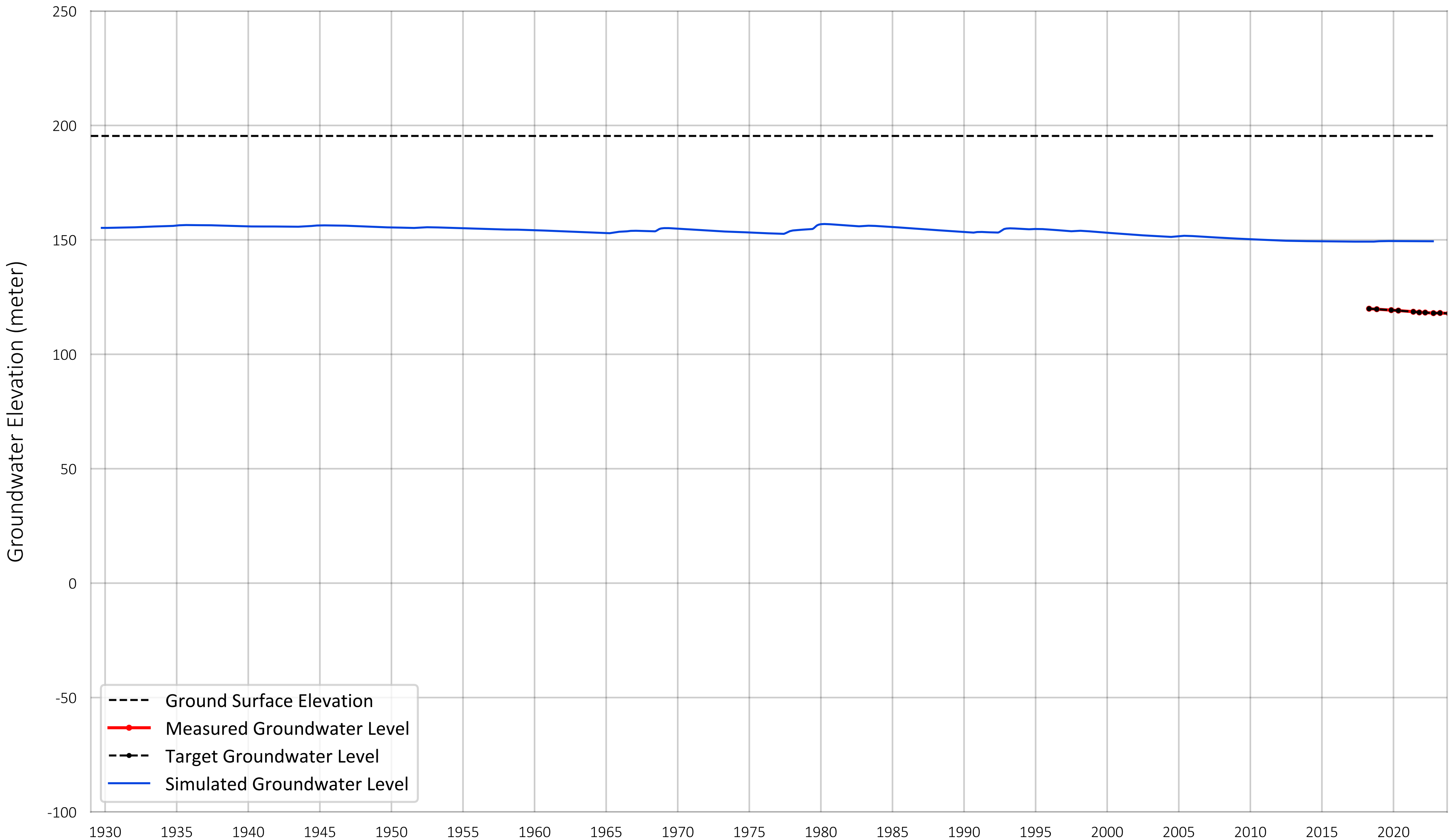
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Empty Irrigation

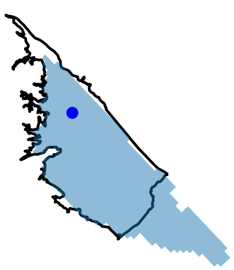
Figure A-33



Prepared by:

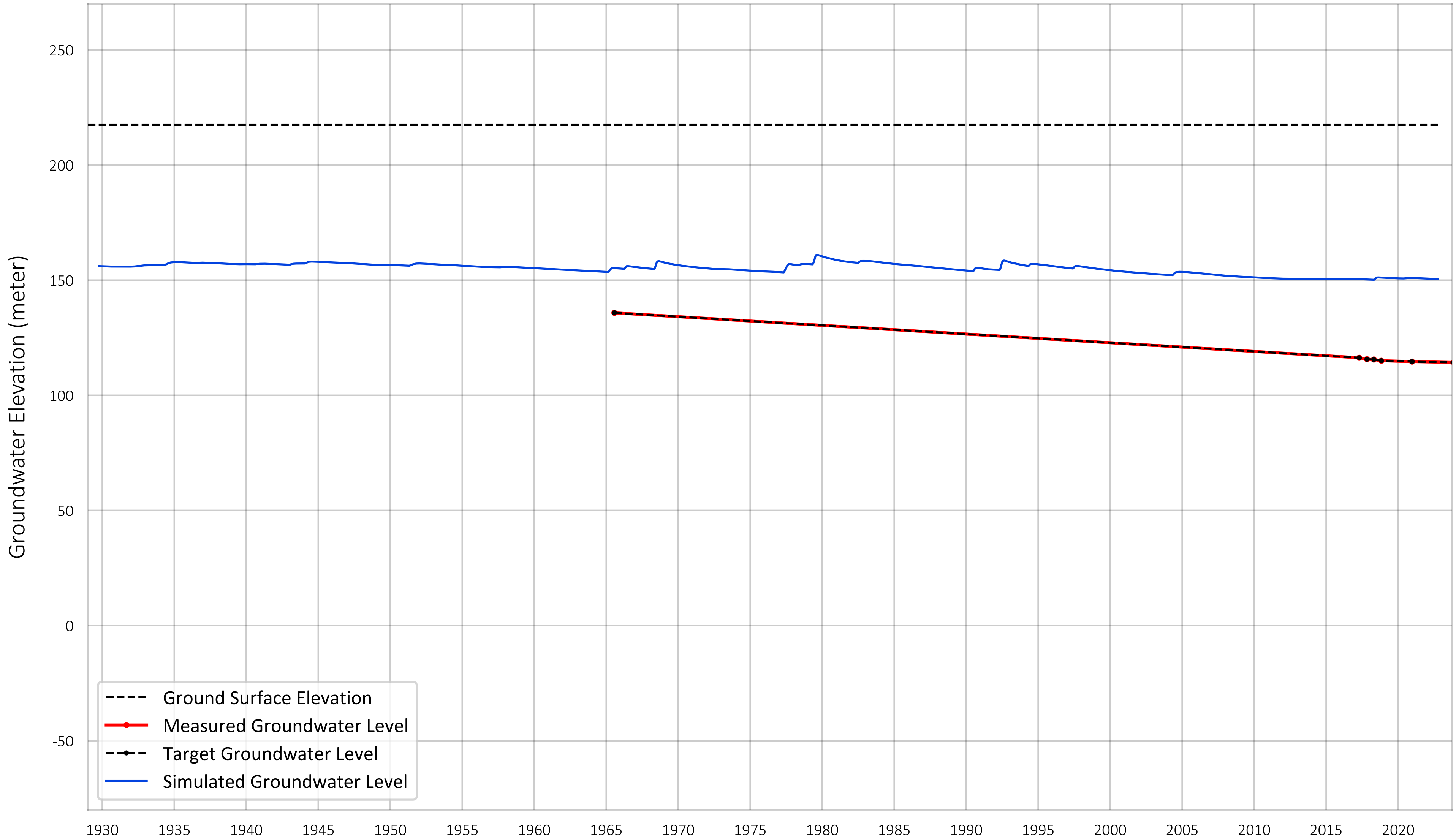
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Evans

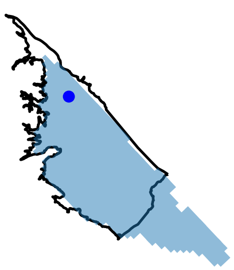
Figure A-34



Prepared by:

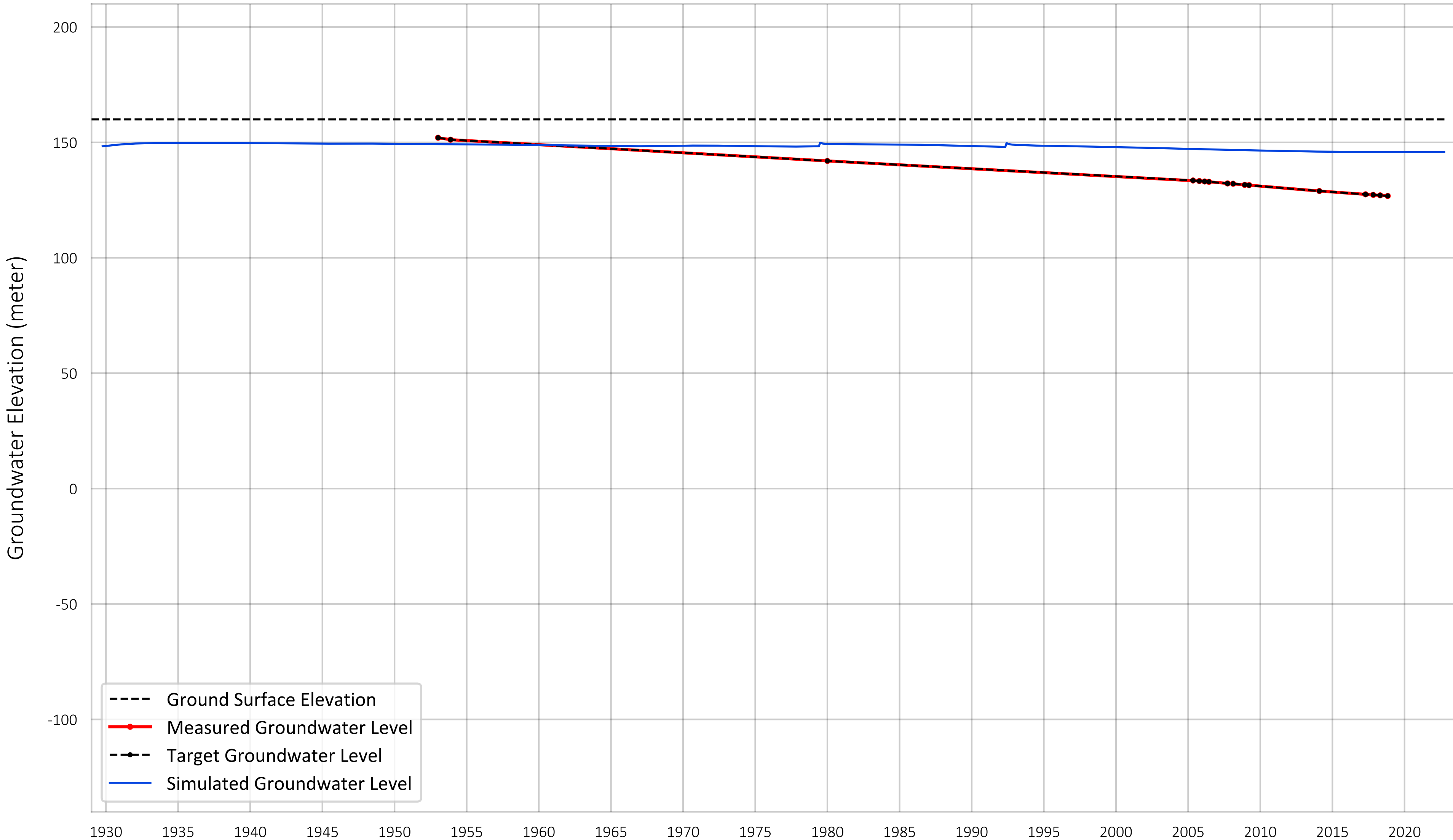
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Fortiner #1 (Allegre 1)

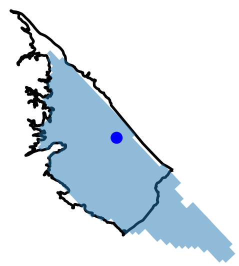
Figure A-35



Prepared by:

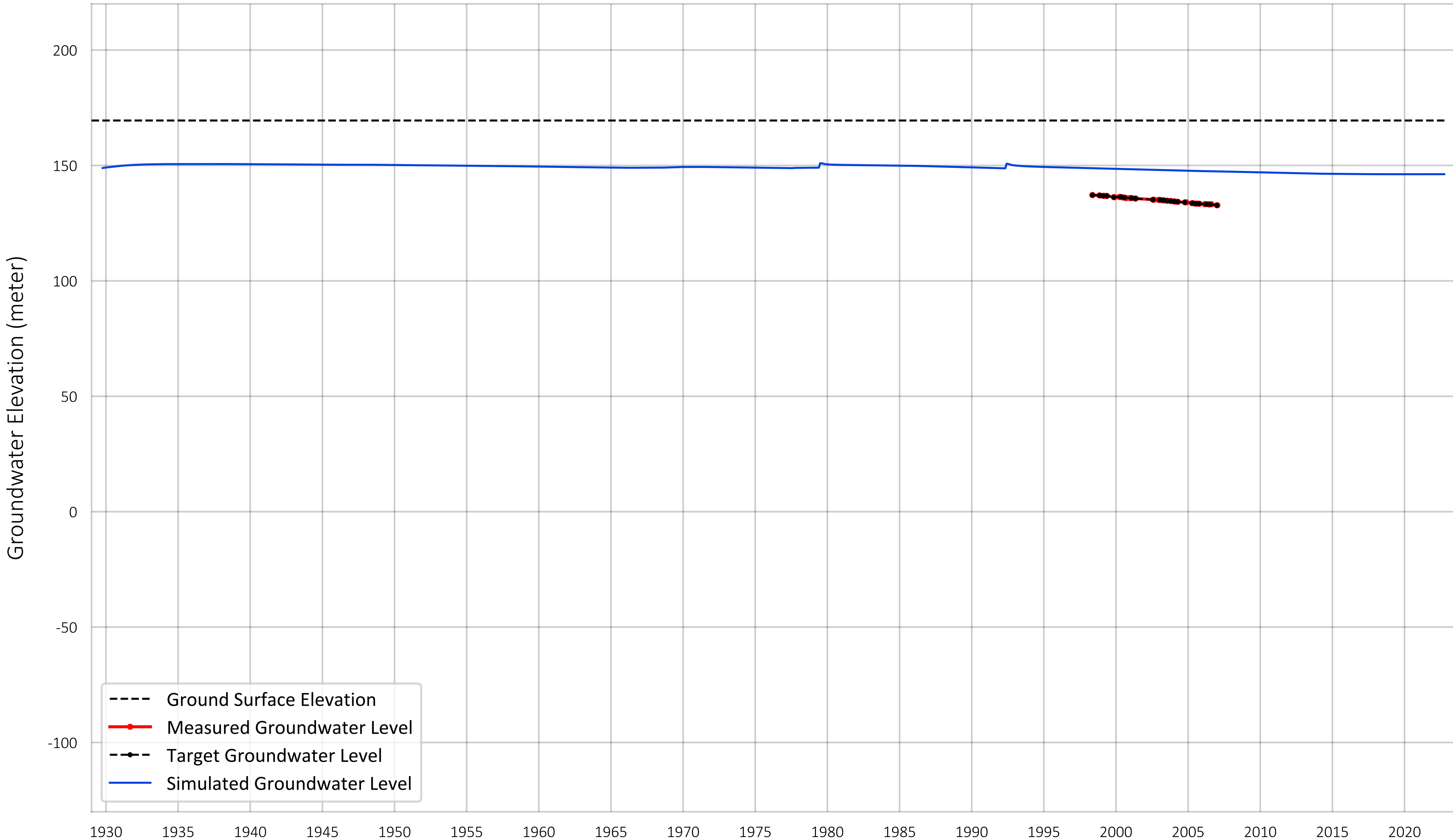
WEST YOST
Water. Engineered.

Well Location



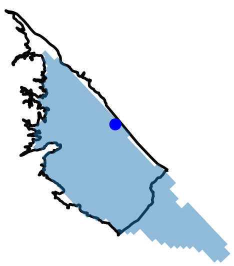
Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Gabrych #2

Figure A-36



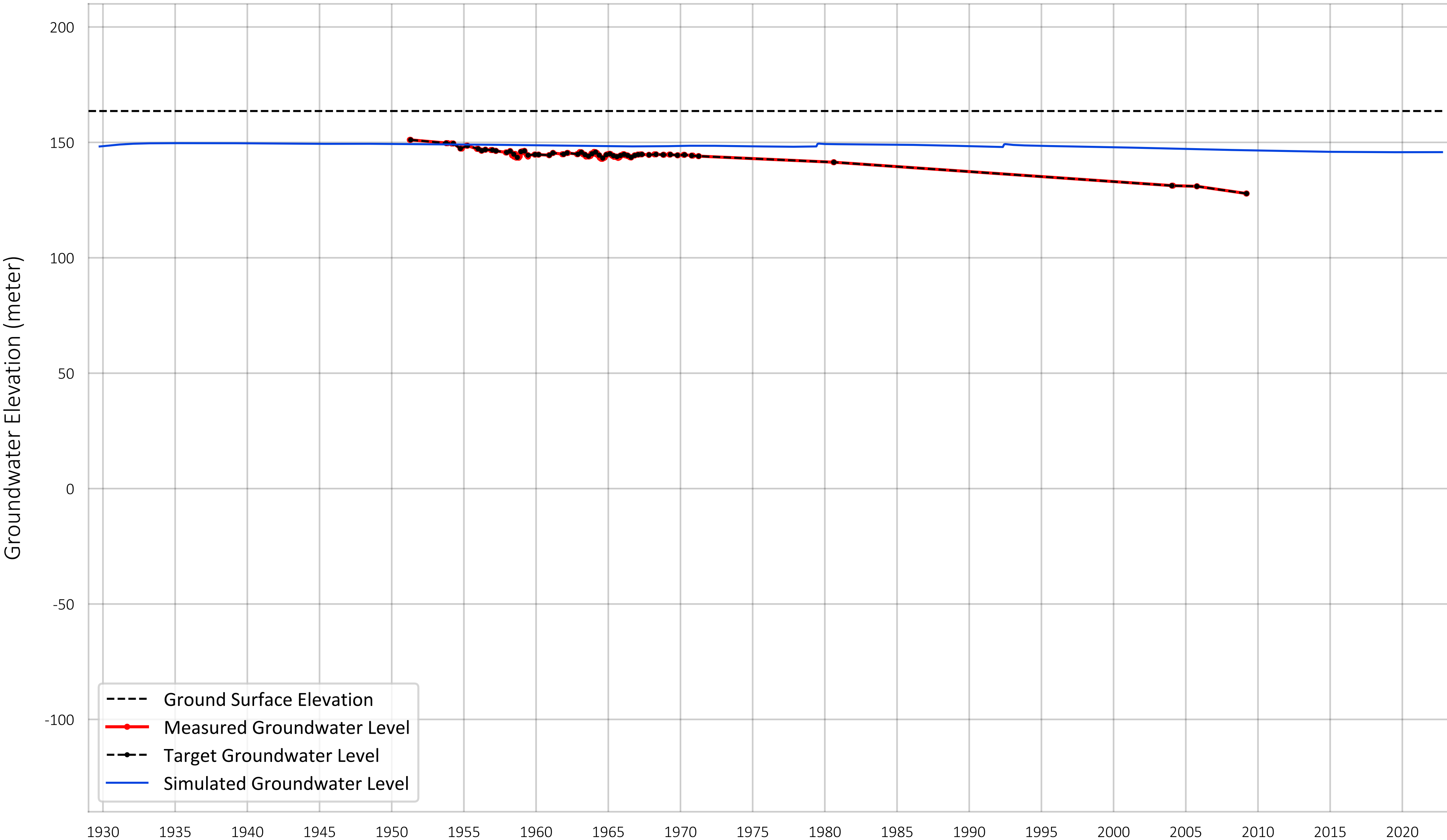
Prepared by:

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Gray Irrigation

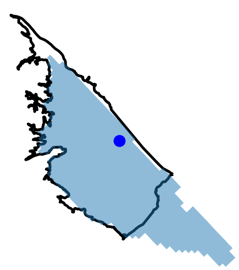
Figure A-37



Prepared by:

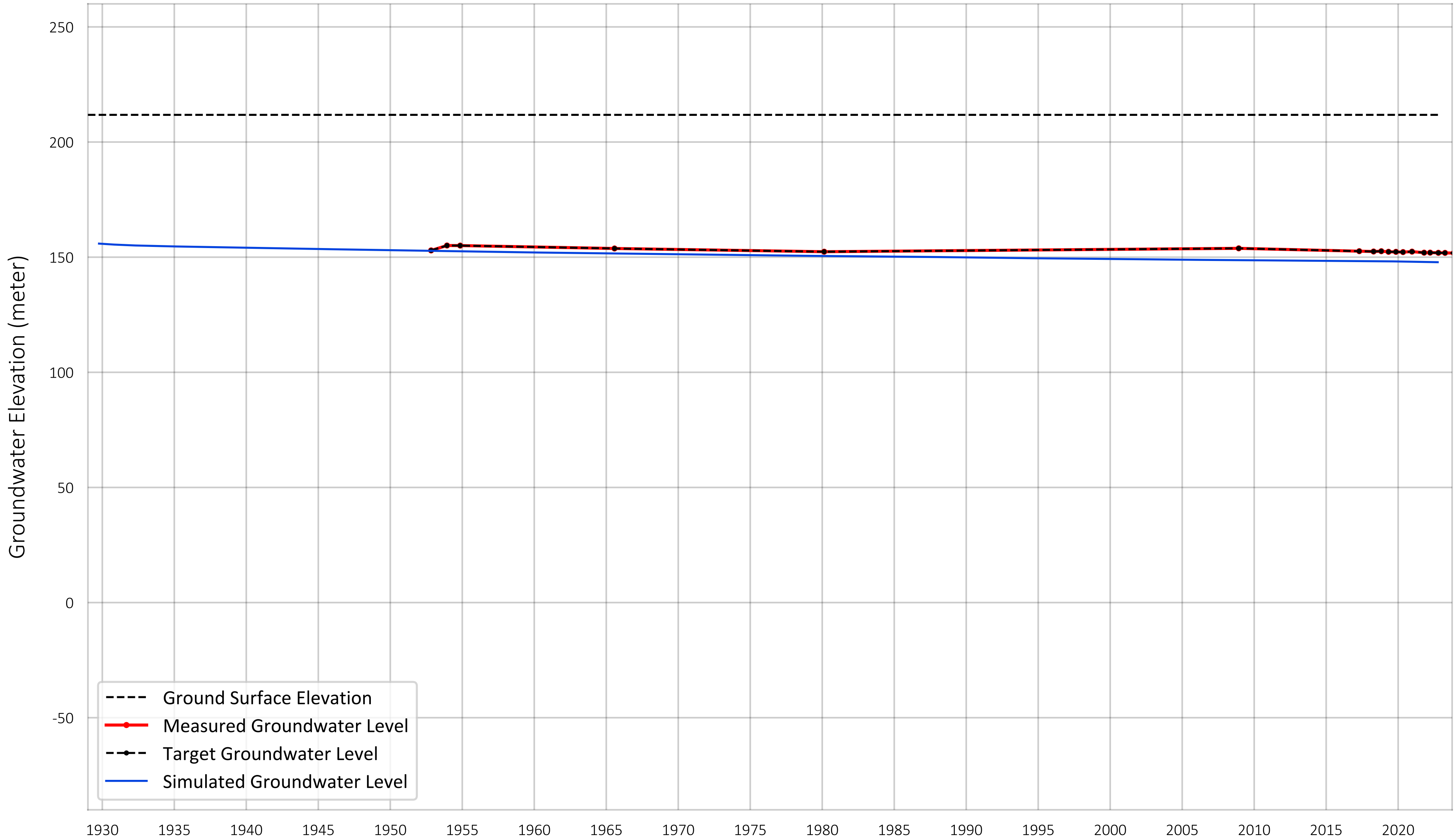
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Hawkins

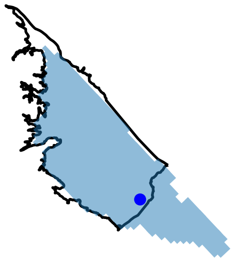
Figure A-38



Prepared by:

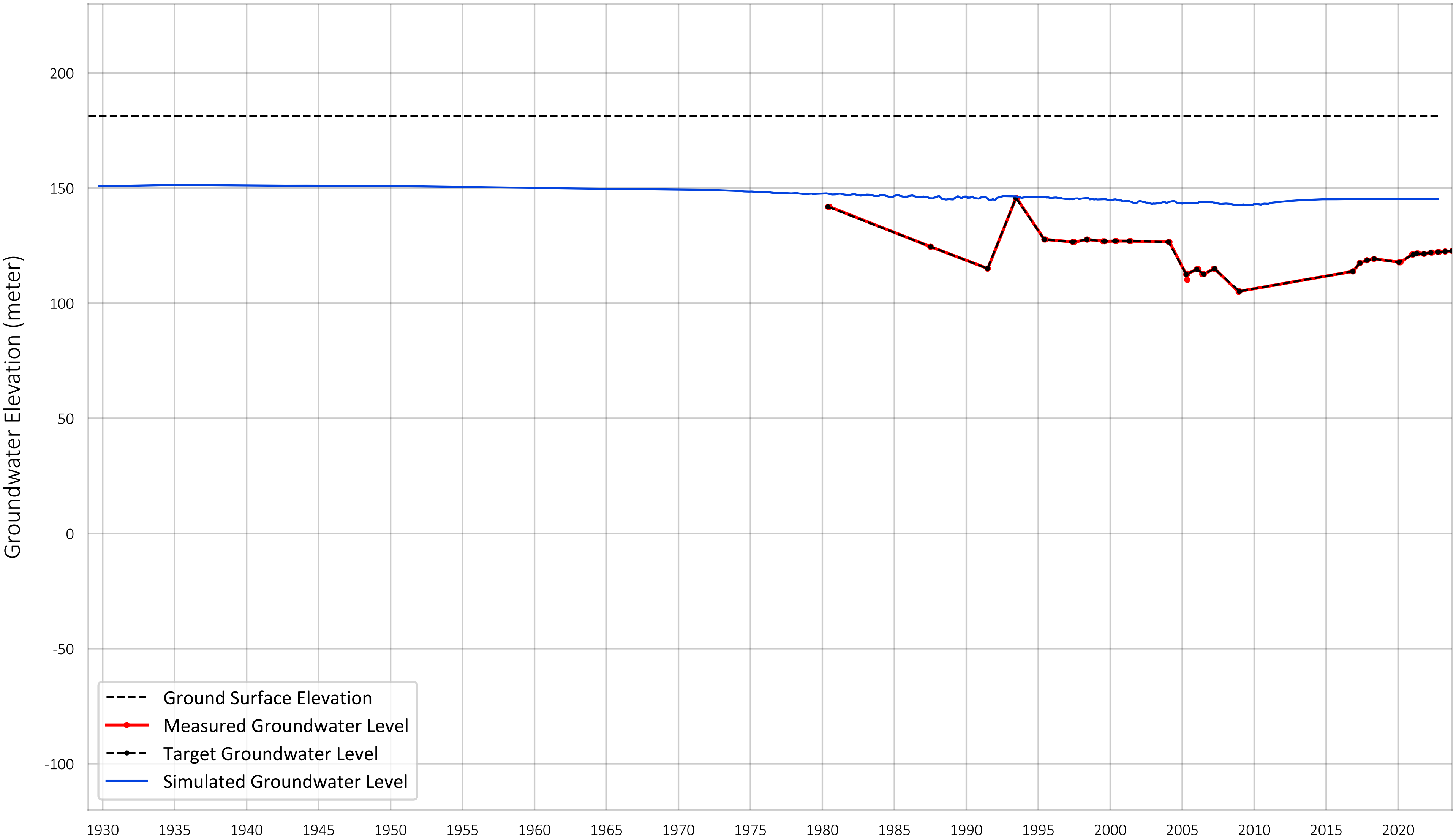
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Hayden (32Q1)

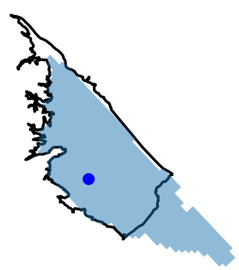
Figure A-39



Prepared by:

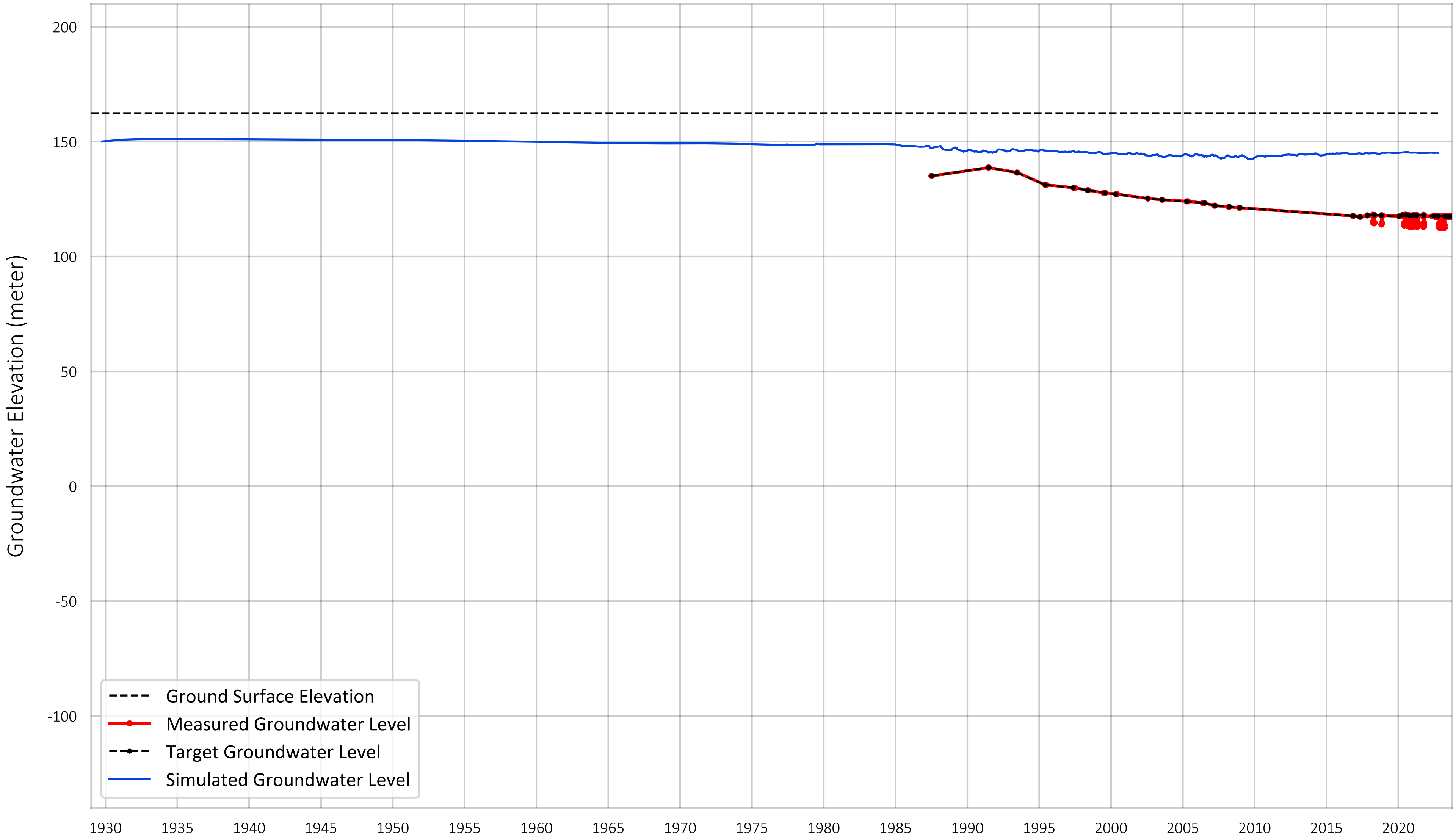
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID1-10

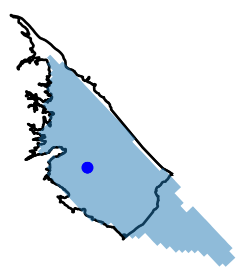
Figure A-40



Prepared by:

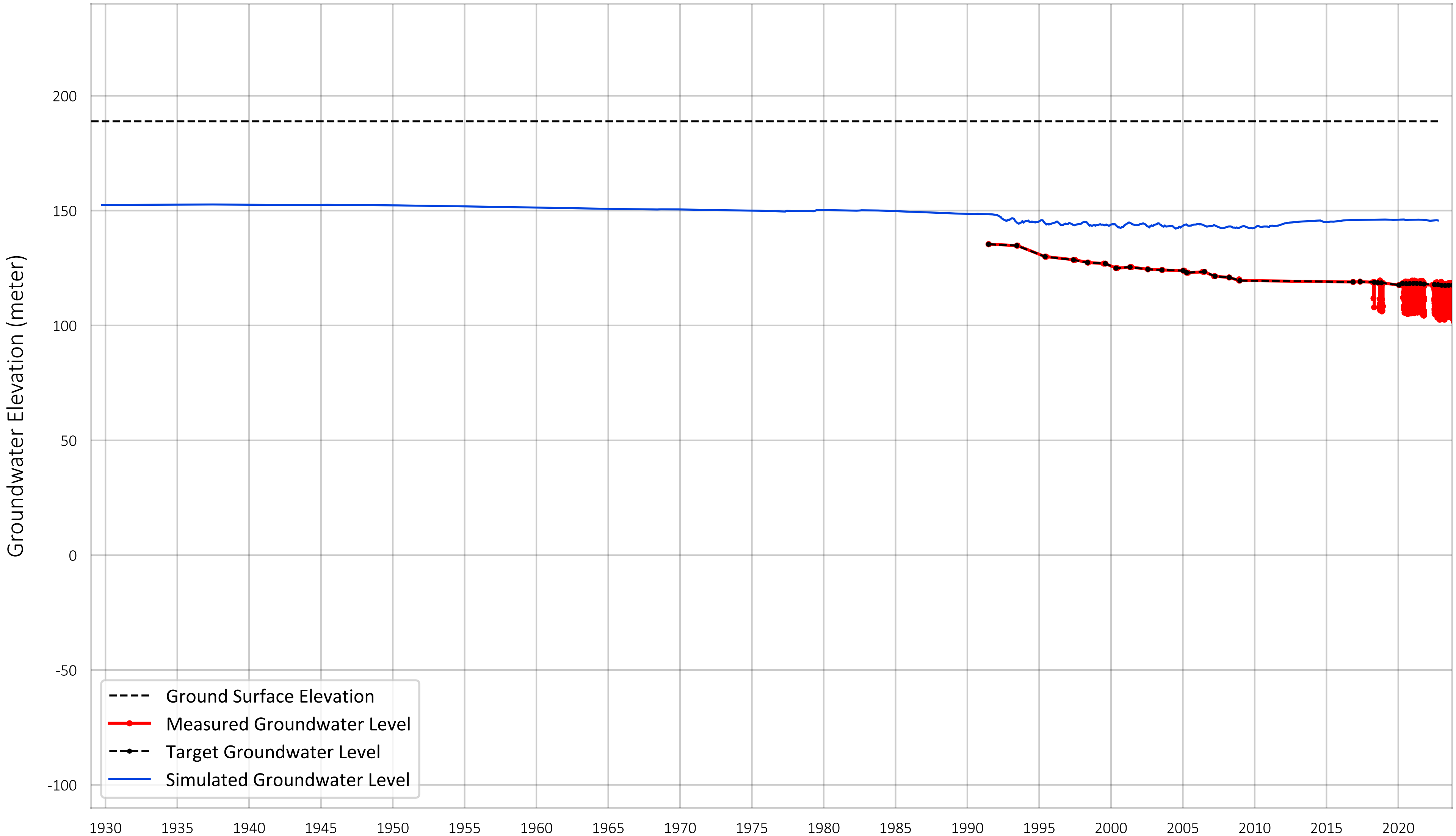
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID1-12

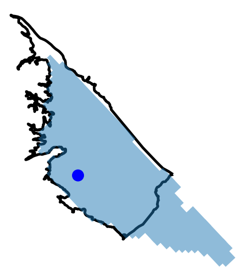
Figure A-41



Prepared by:

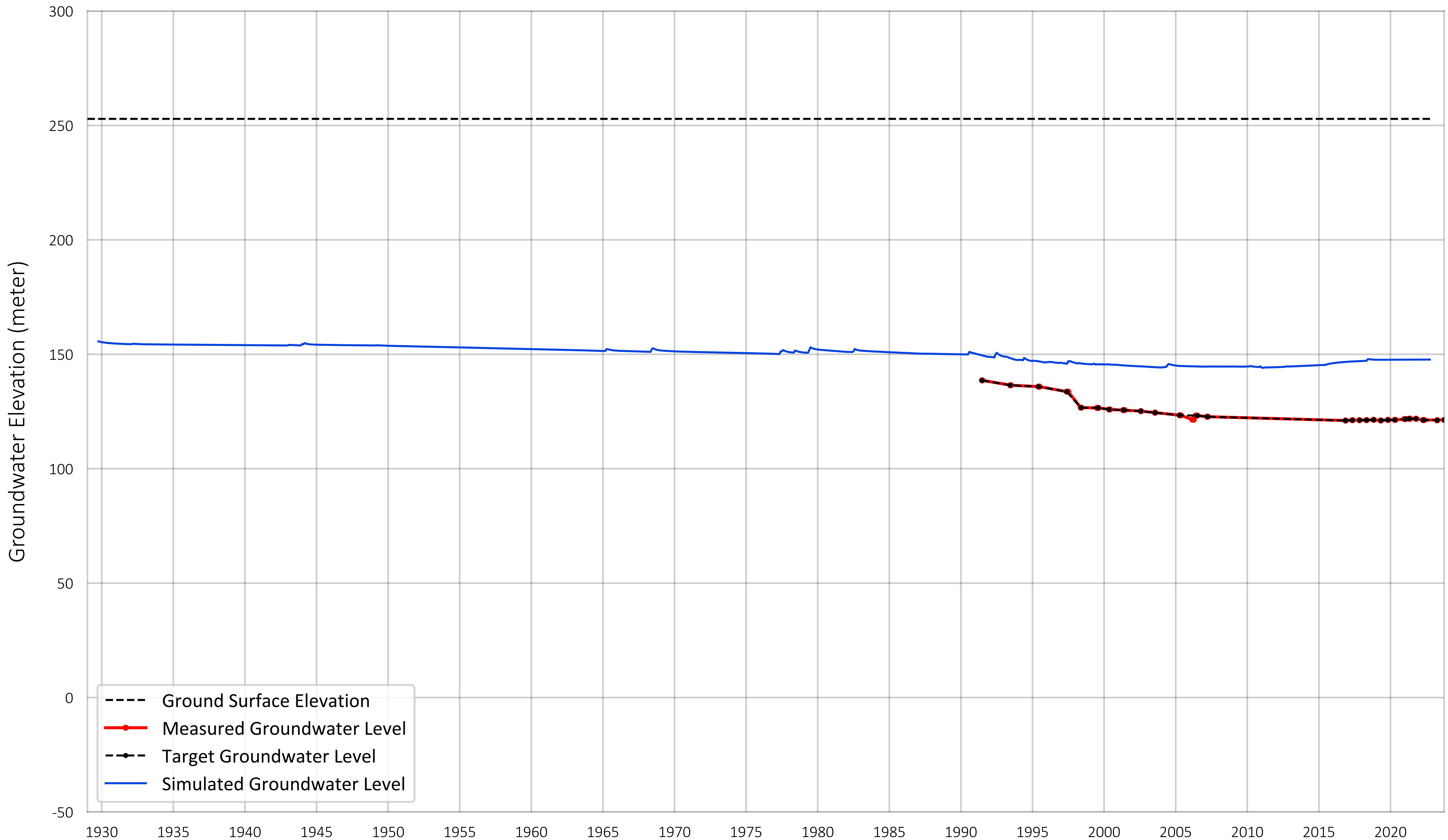
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID1-16

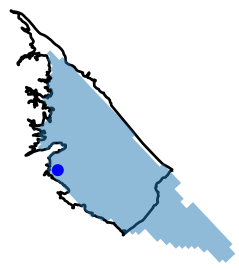
Figure A-42



Prepared by:

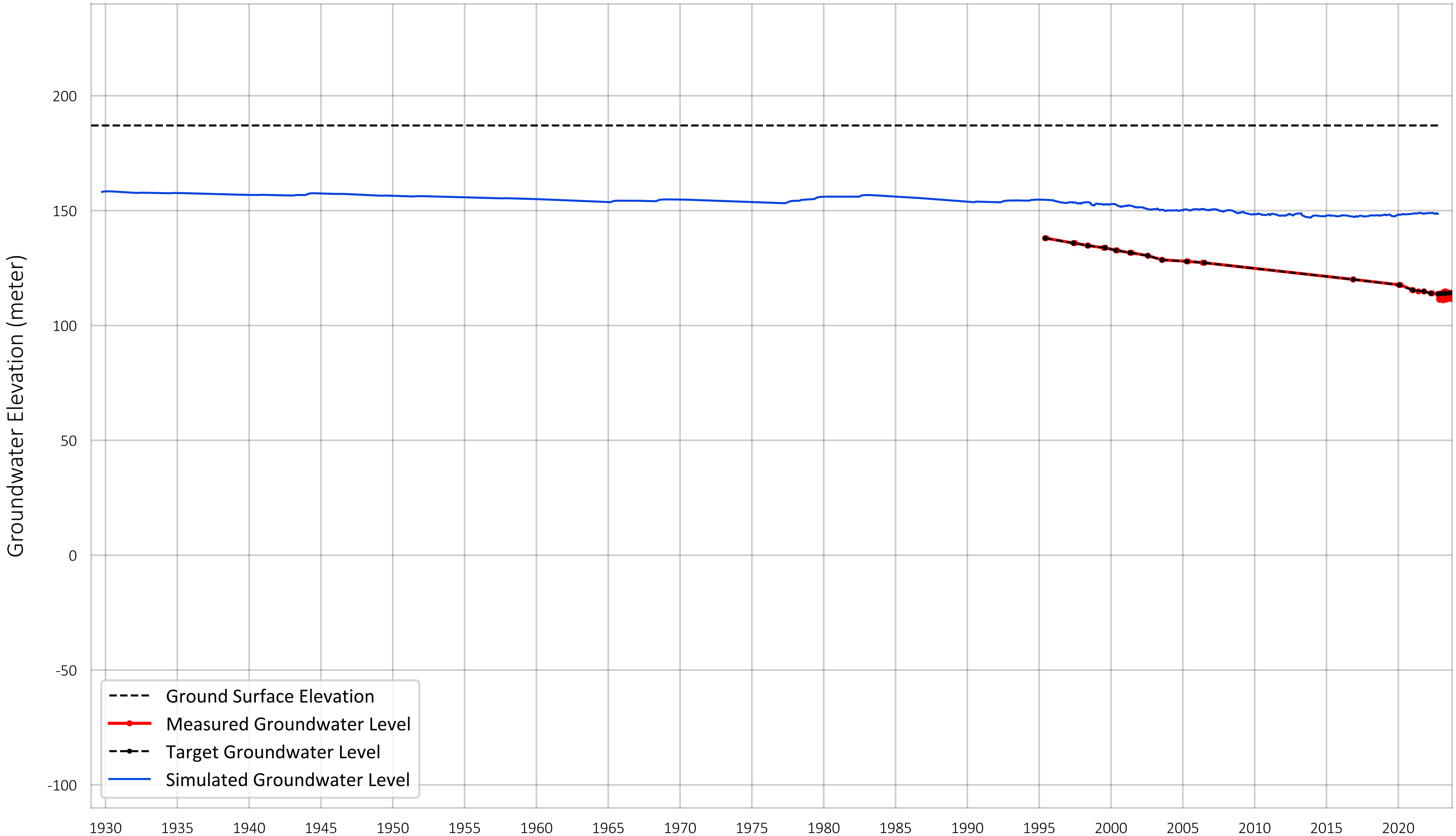
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-10

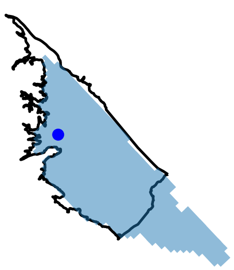
Figure A-43



Prepared by:

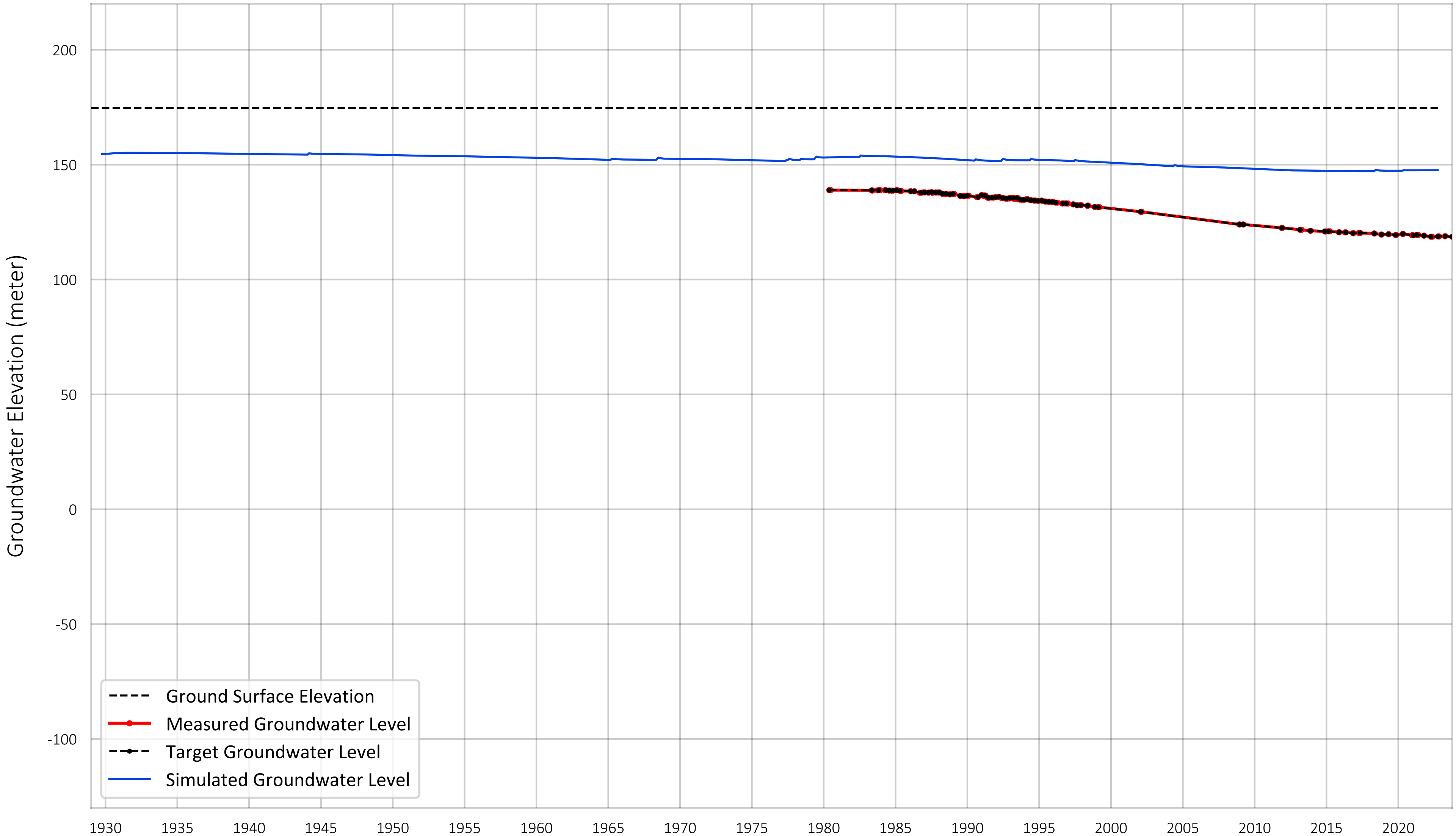
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-11

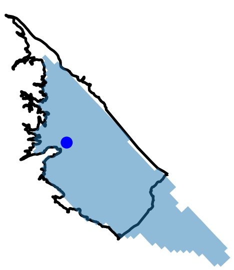
Figure A-44



Prepared by:

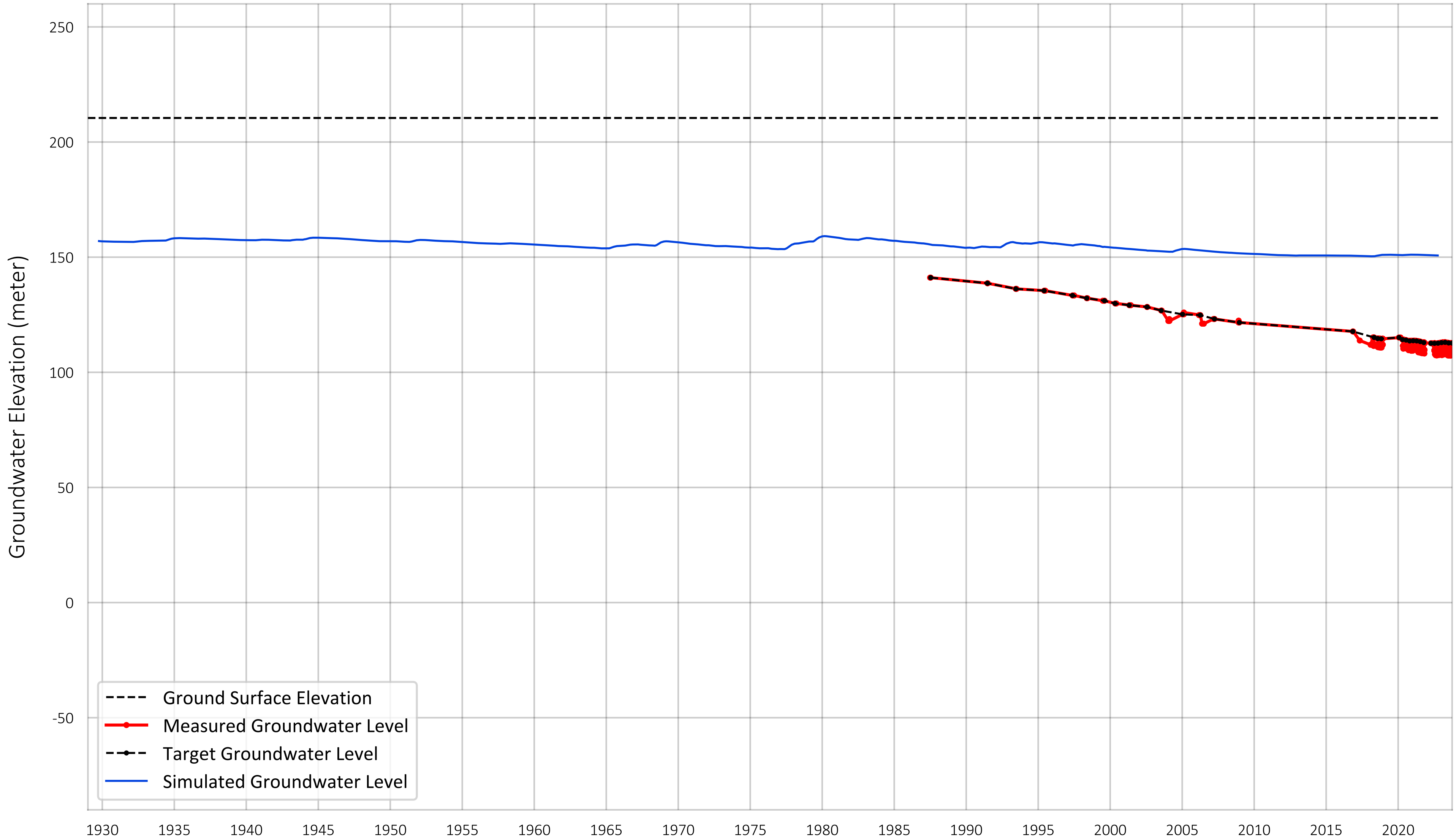
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-1

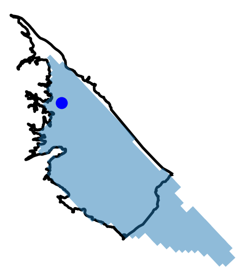
Figure A-45



Prepared by:

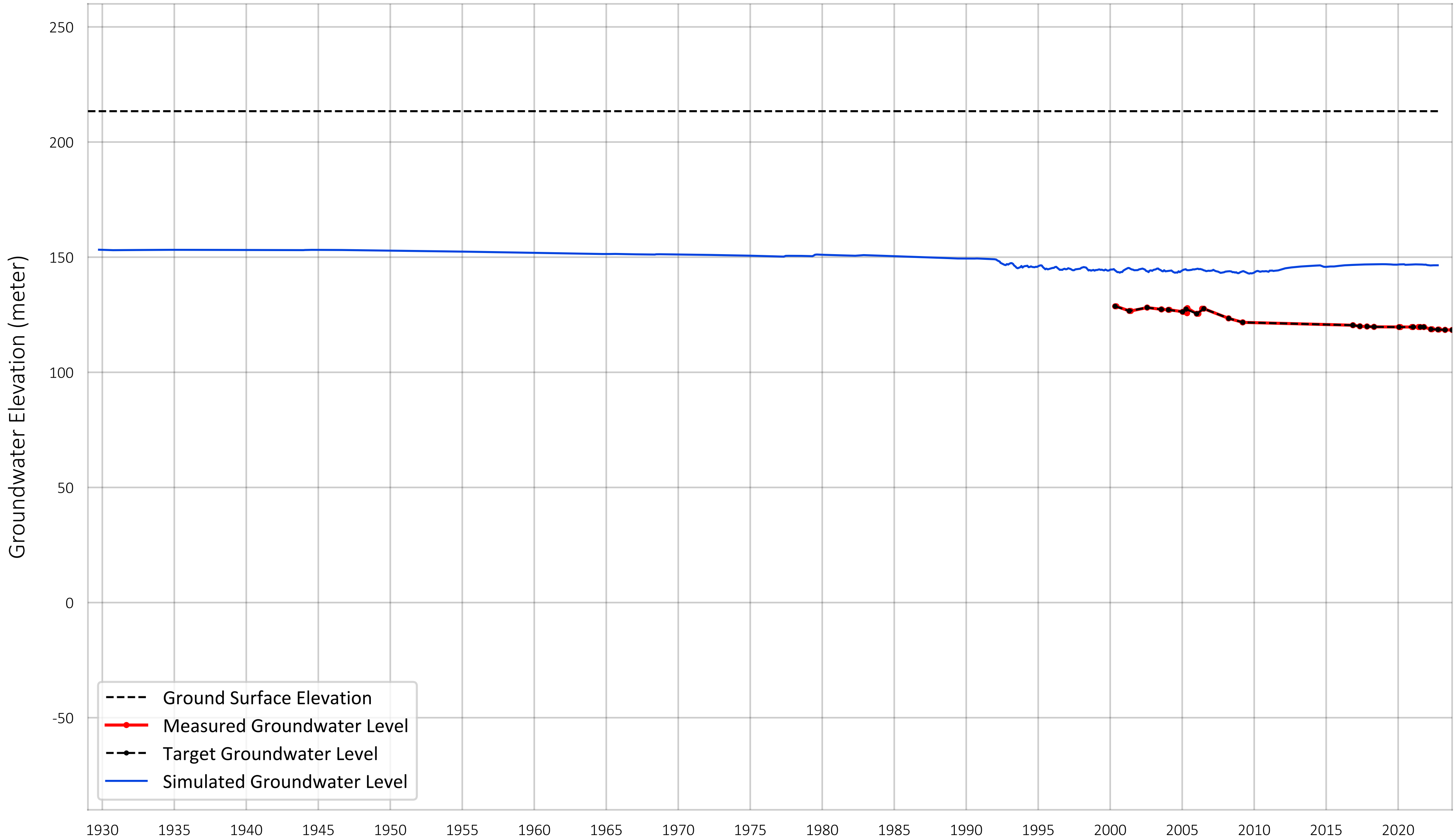
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-18

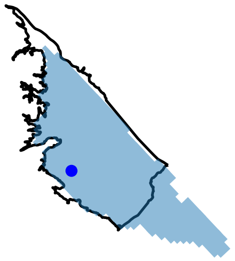
Figure A-46



Prepared by:

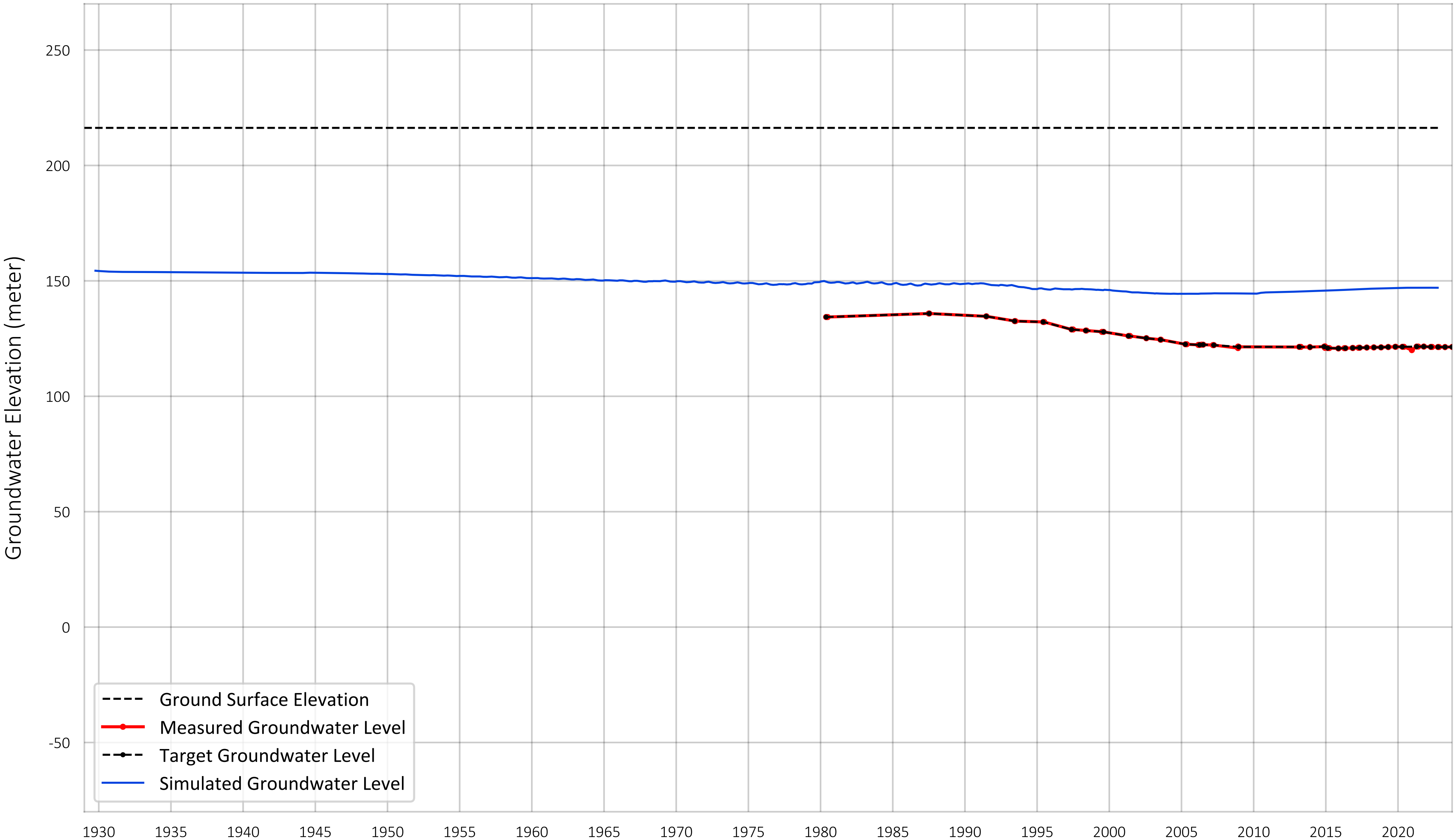
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-20 (Wilcox)

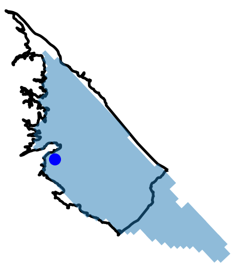
Figure A-47



Prepared by:

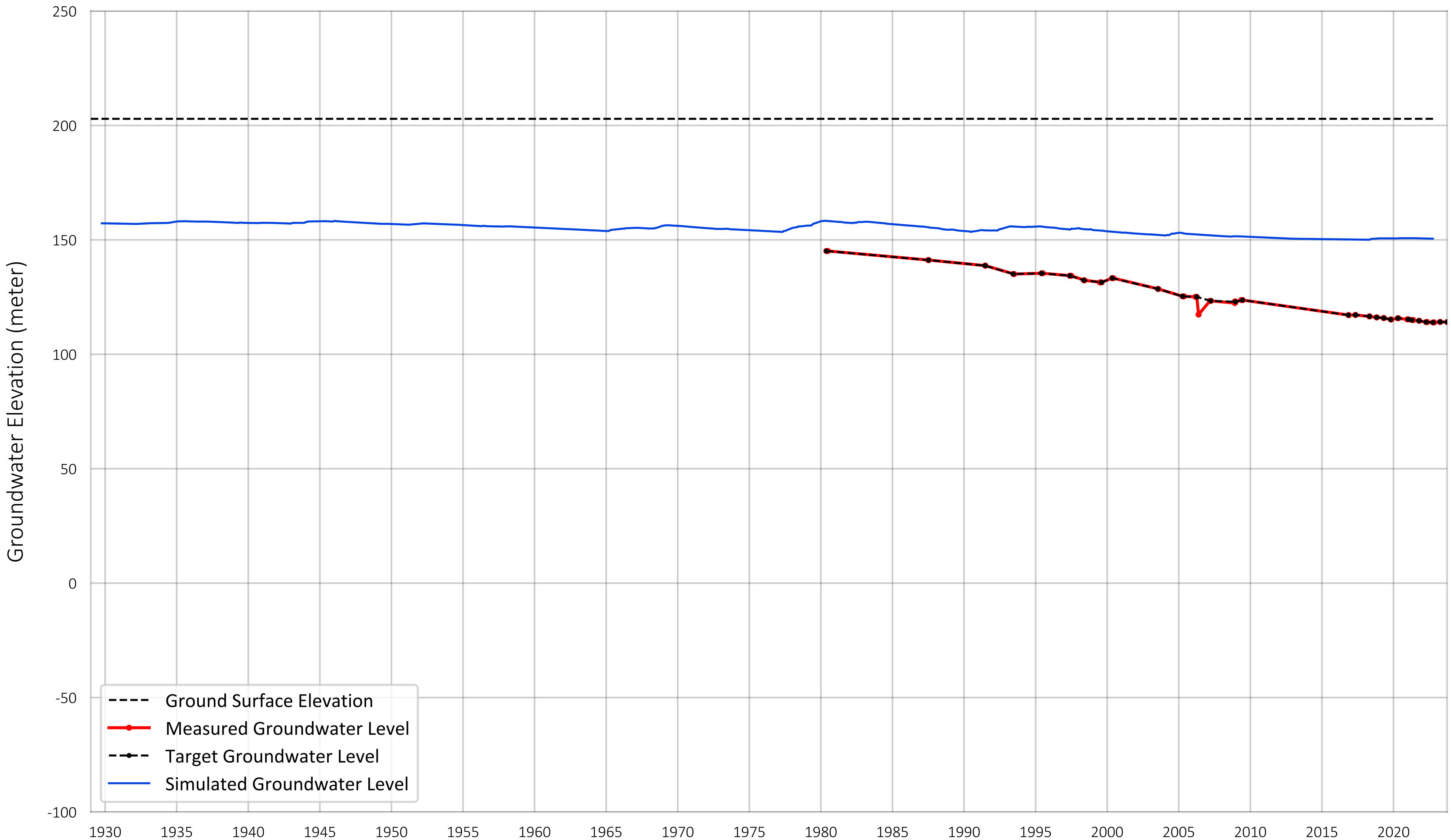
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-2

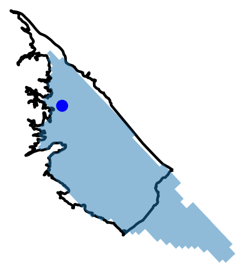
Figure A-48



Prepared by:

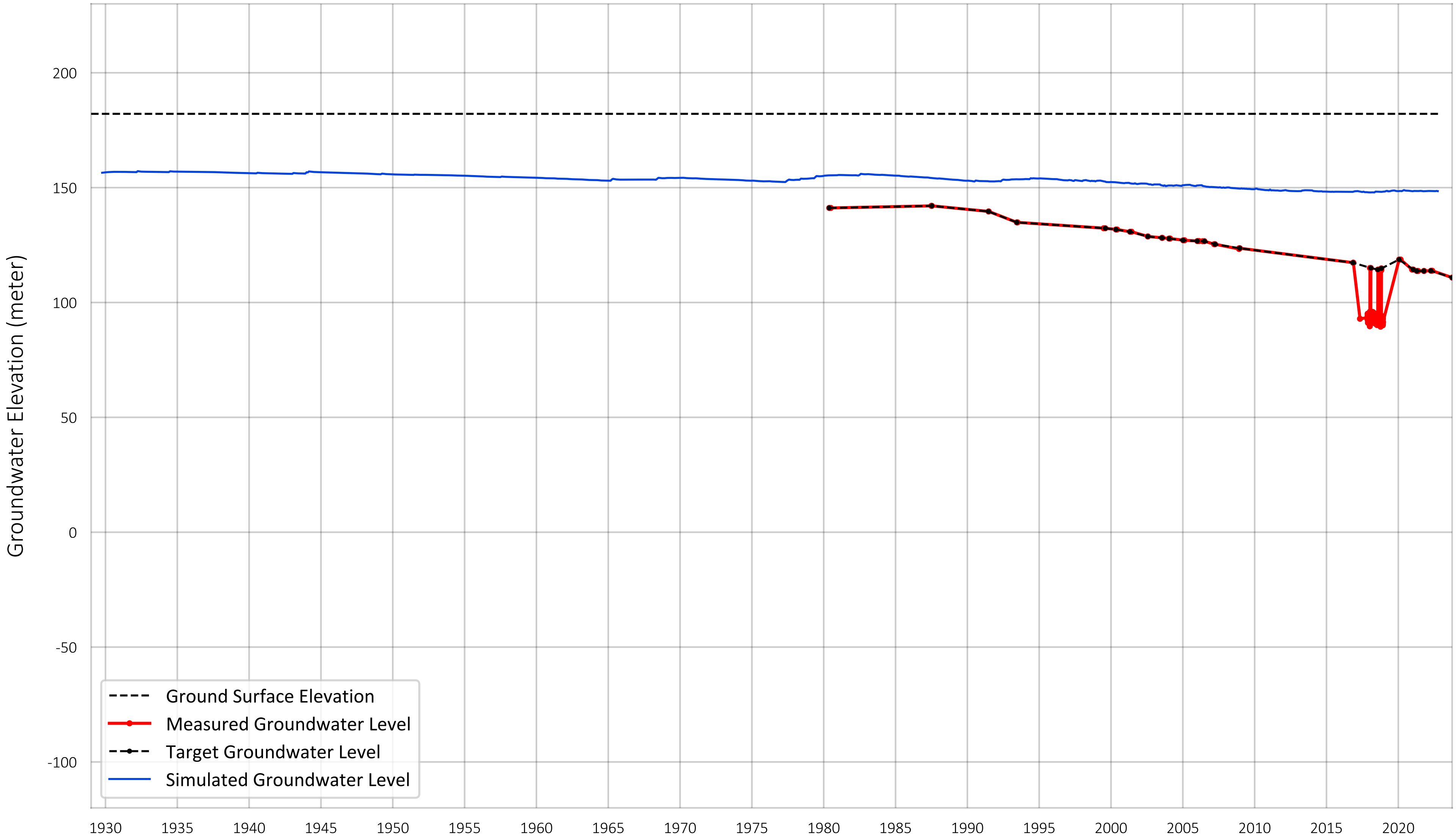
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-3

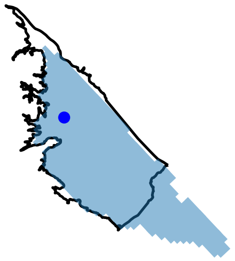
Figure A-49



Prepared by:

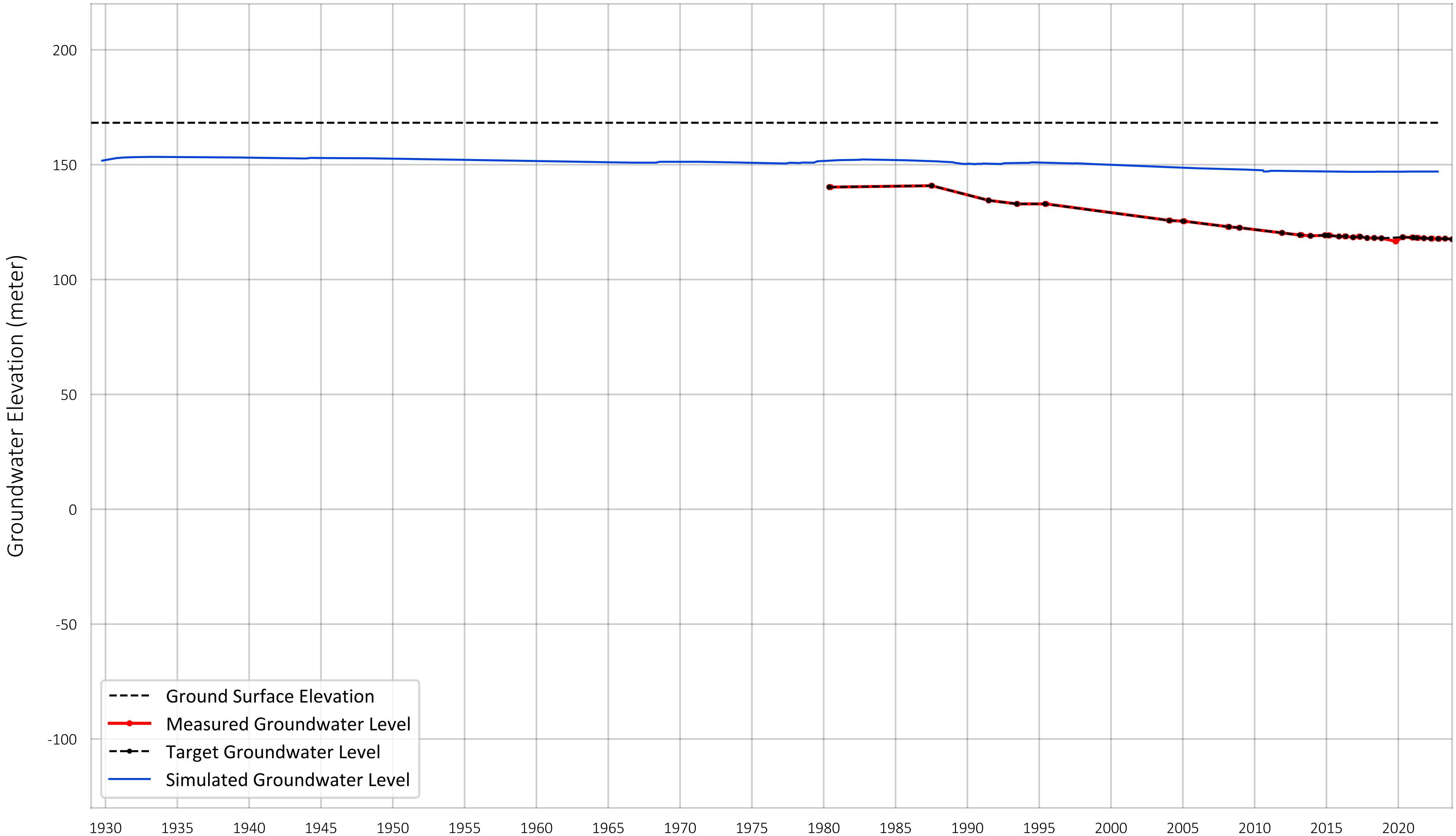
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-4

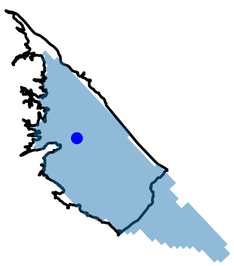
Figure A-50



Prepared by:

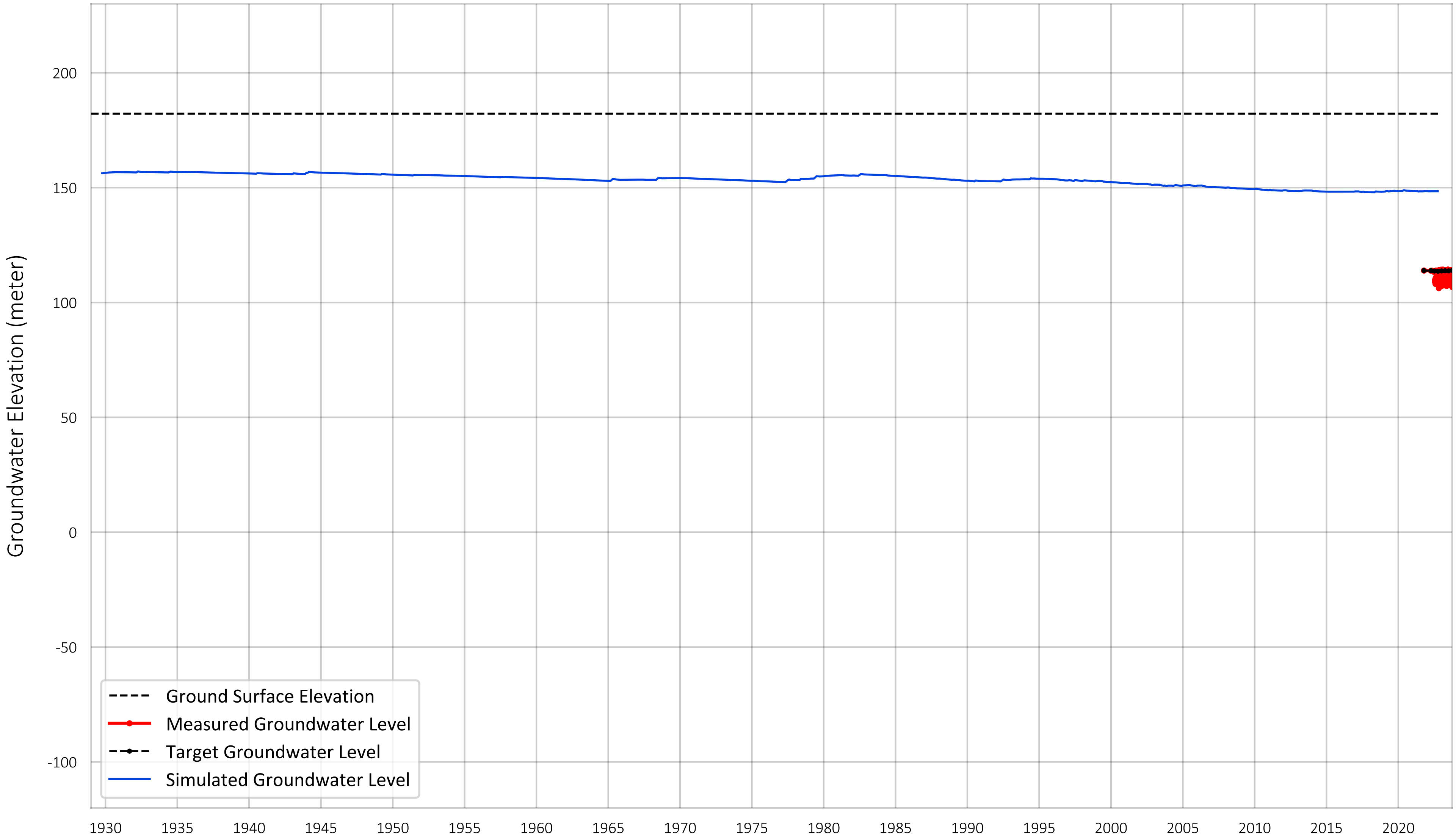
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-5

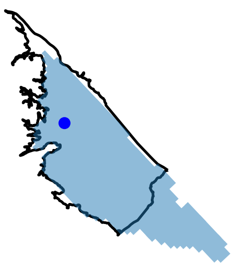
Figure A-51



Prepared by:

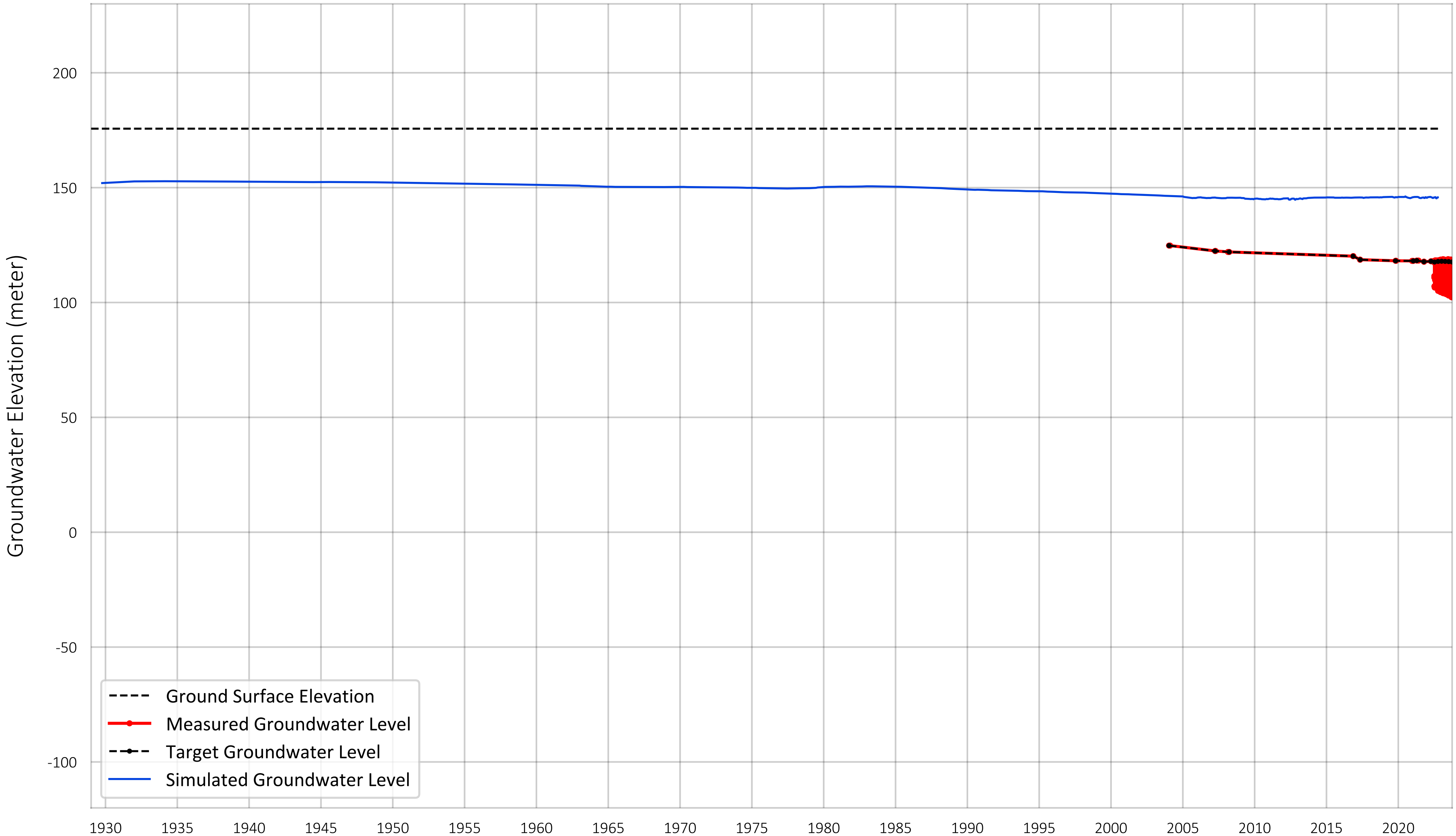
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID4-9

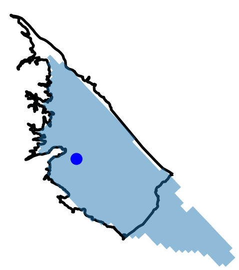
Figure A-52



Prepared by:

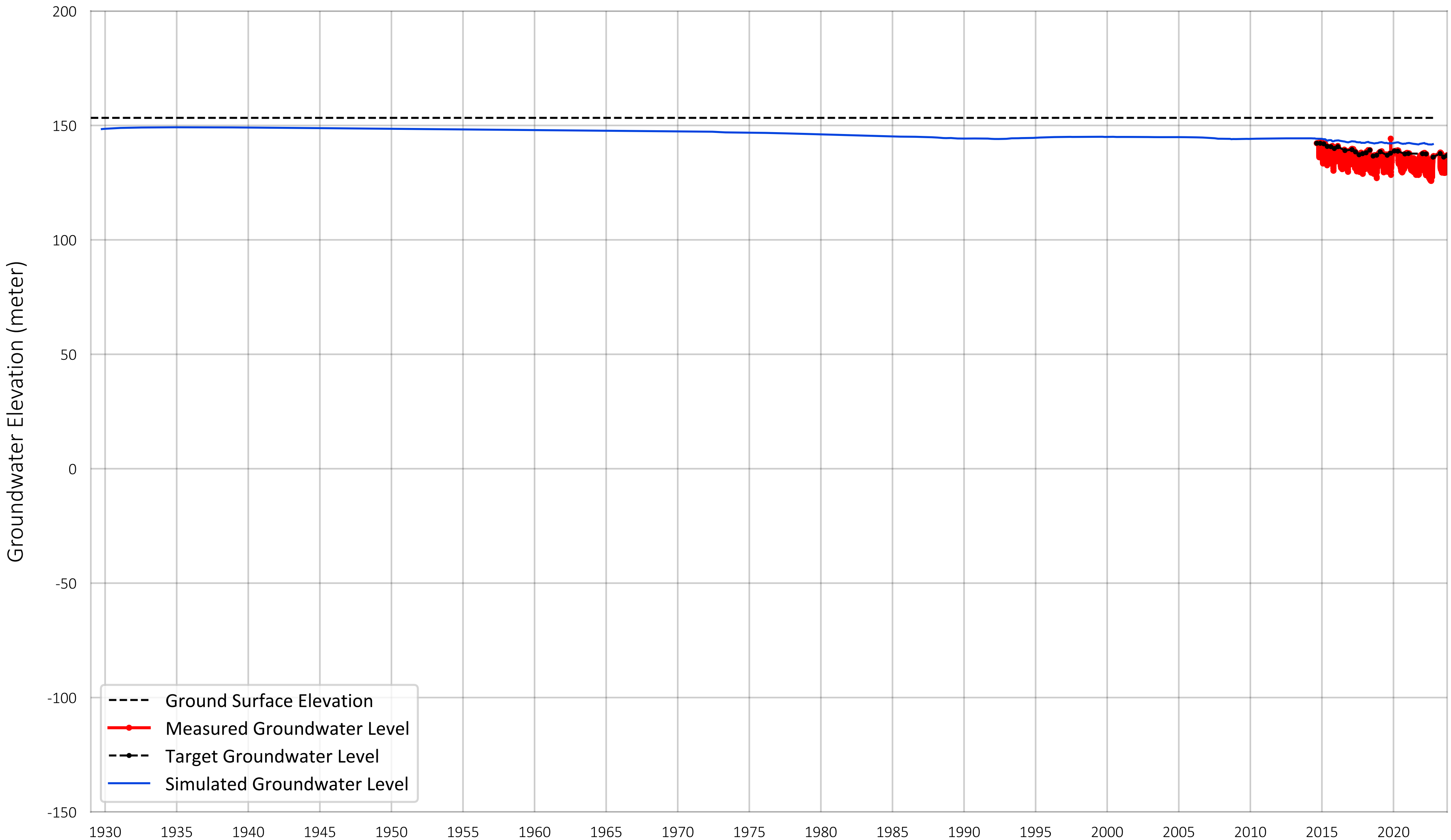
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: ID5-5

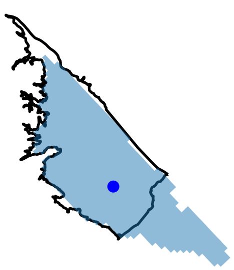
Figure A-53



Prepared by:

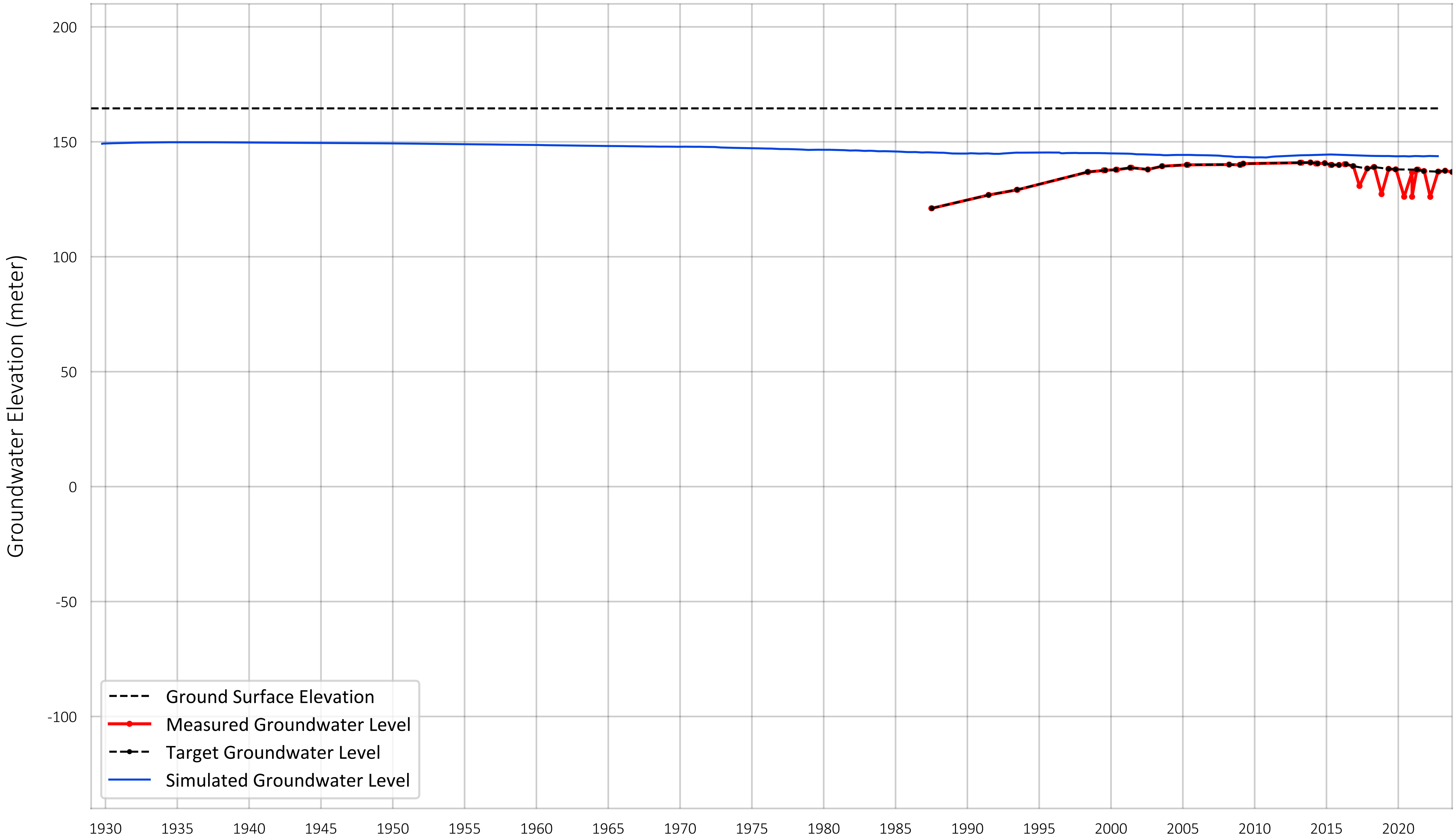
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: JC Well

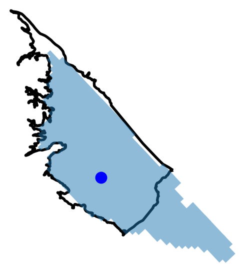
Figure A-54



Prepared by:

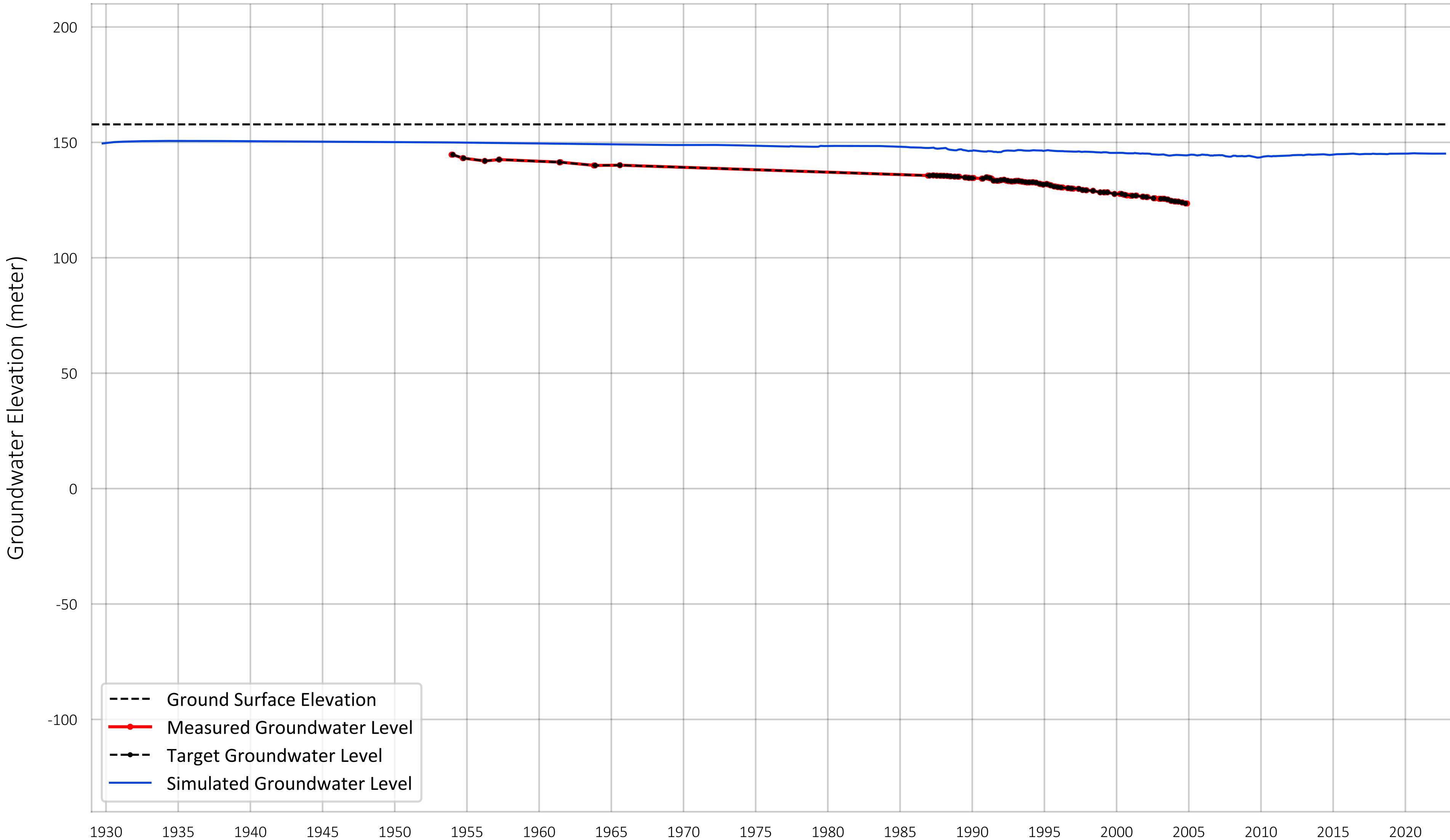
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: La Casa

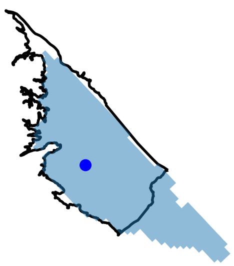
Figure A-55



Prepared by:

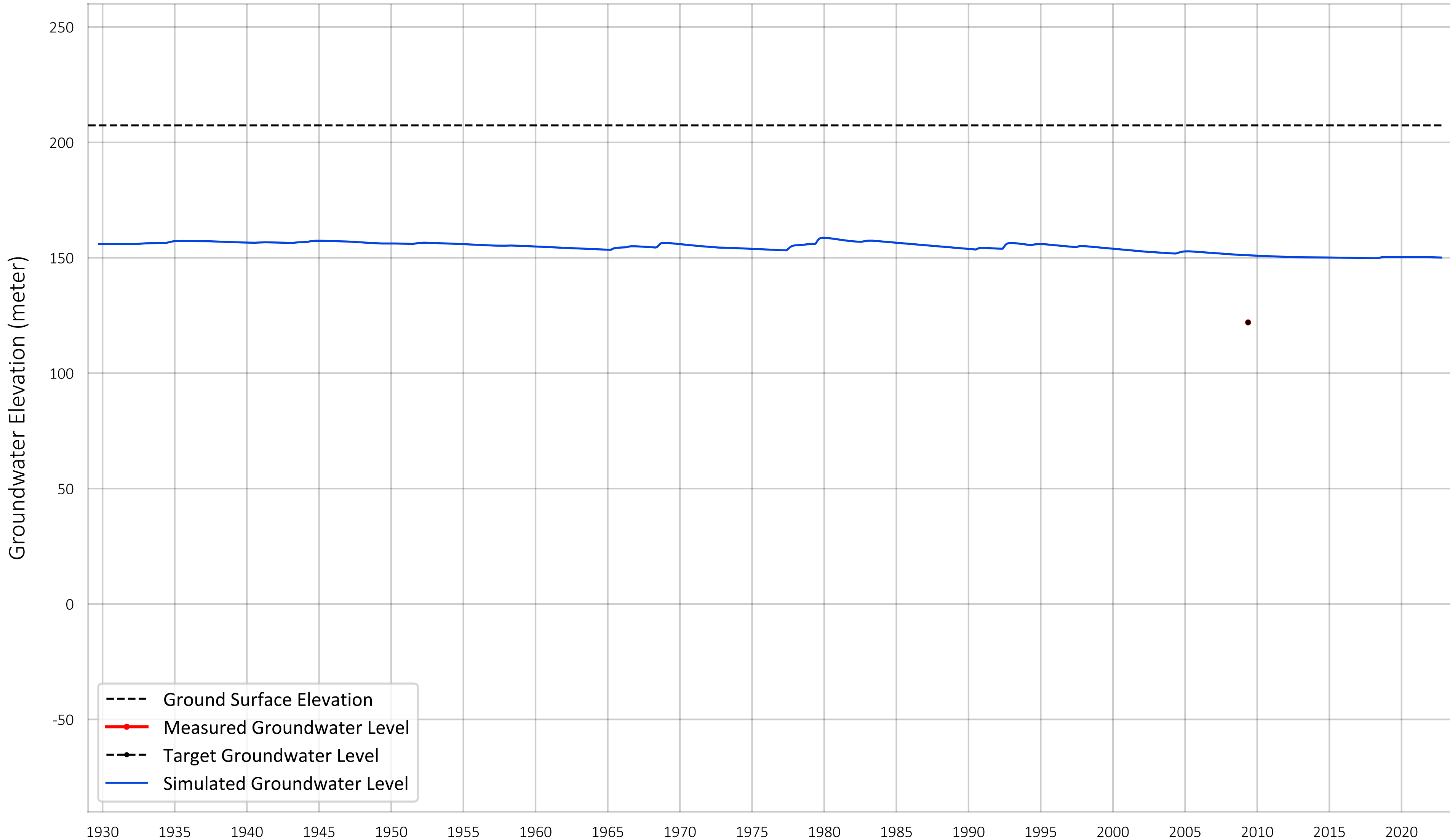
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Levie Well

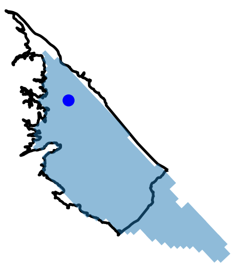
Figure A-56



Prepared by:

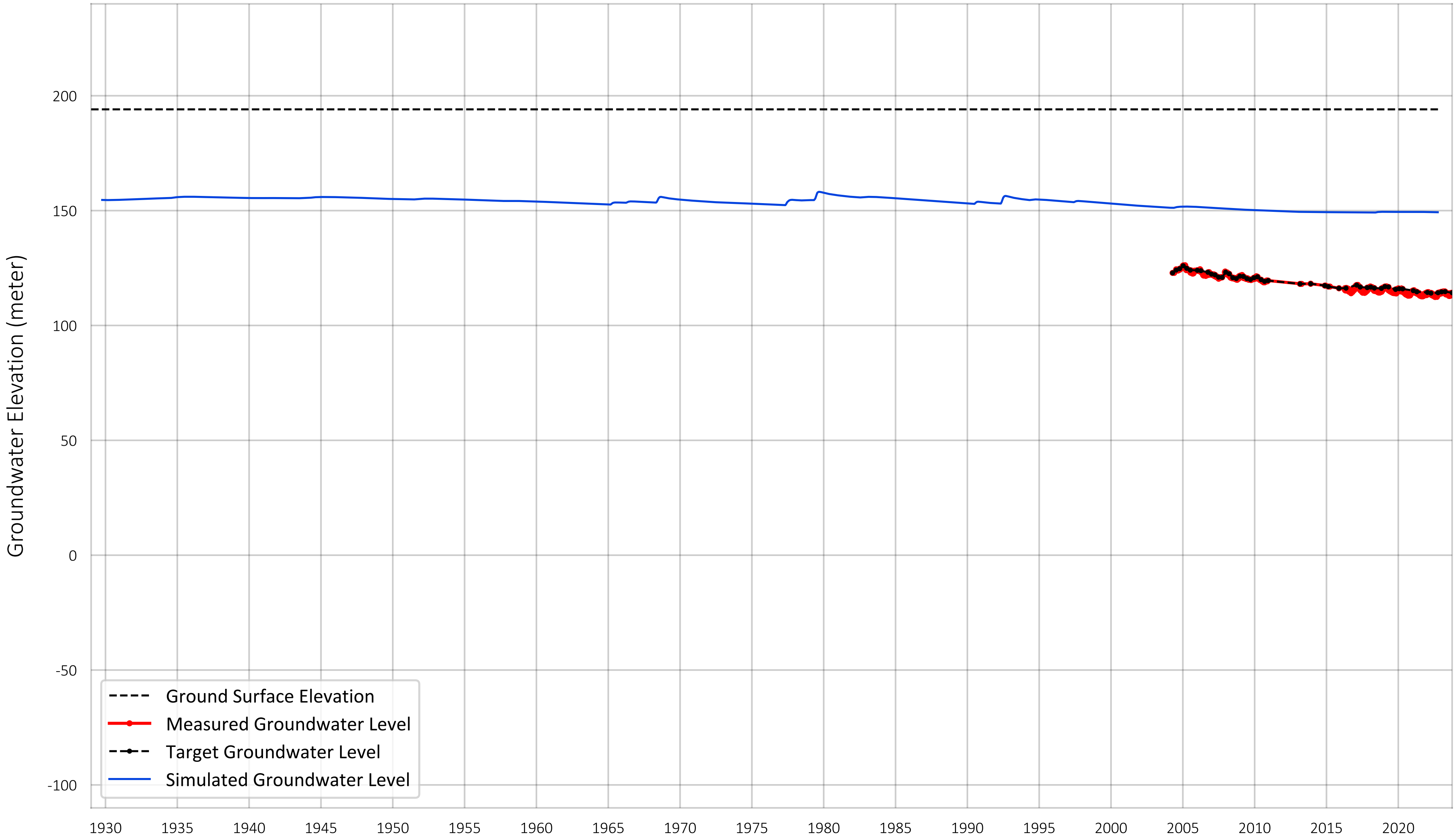
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MSO Well 1

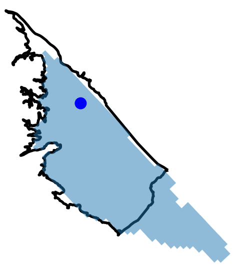
Figure A-57



Prepared by:

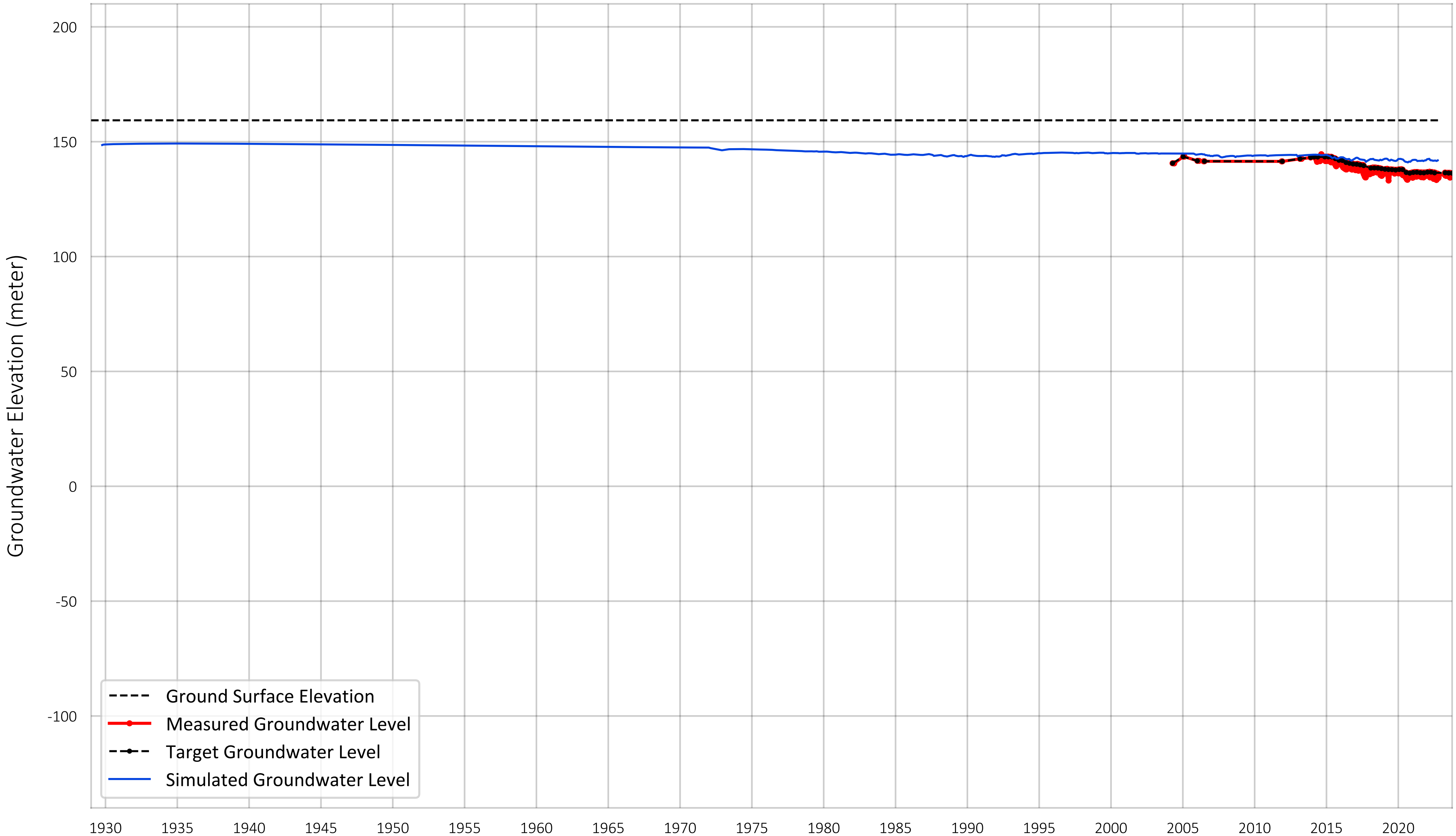
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MW-1

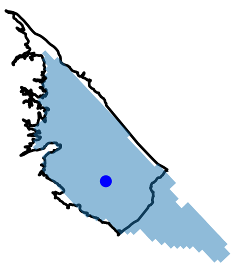
Figure A-58



Prepared by:

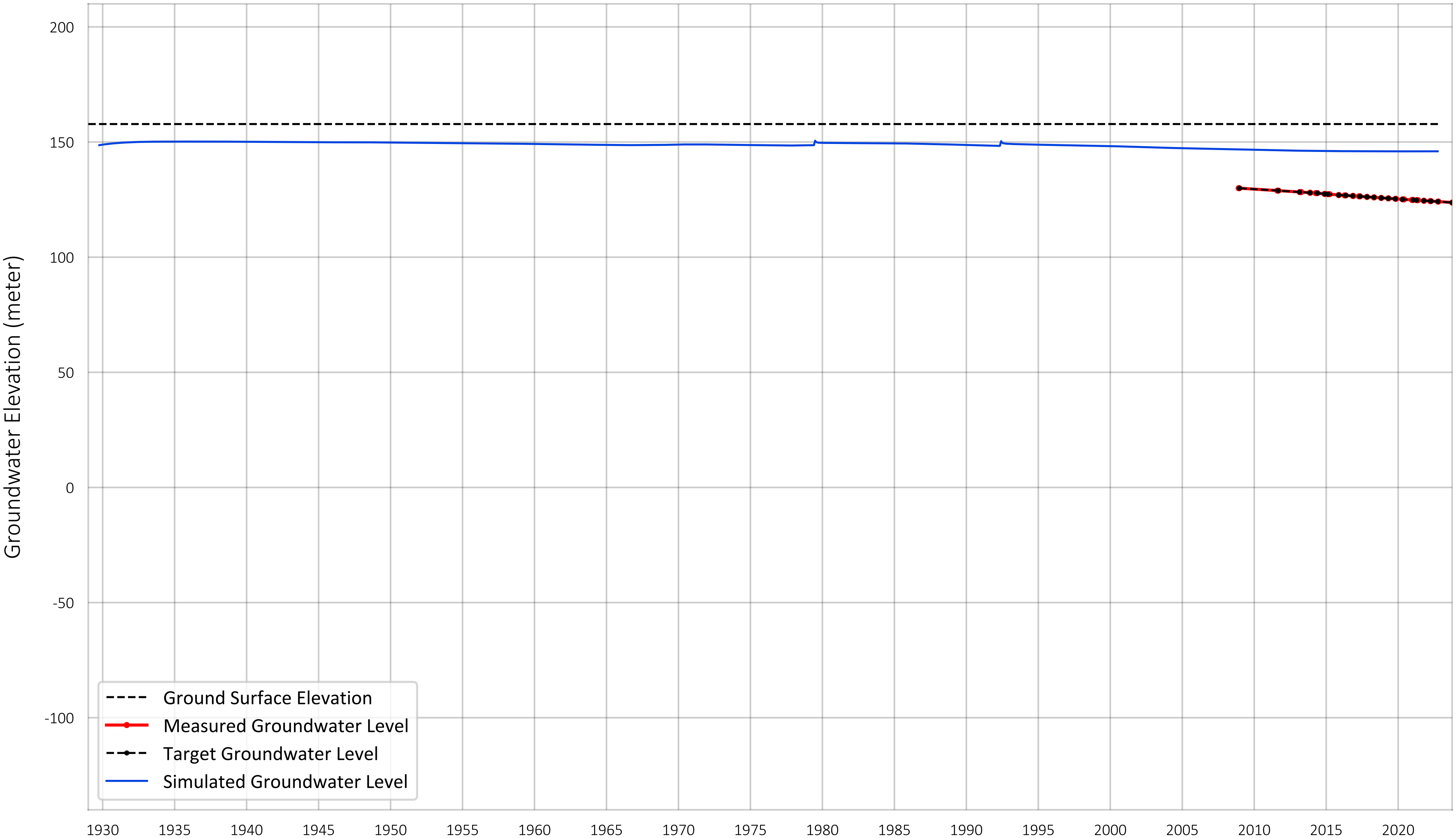
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MW-3

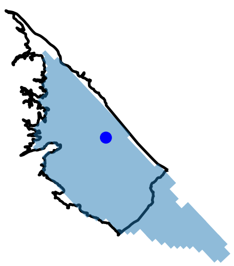
Figure A-59



Prepared by:

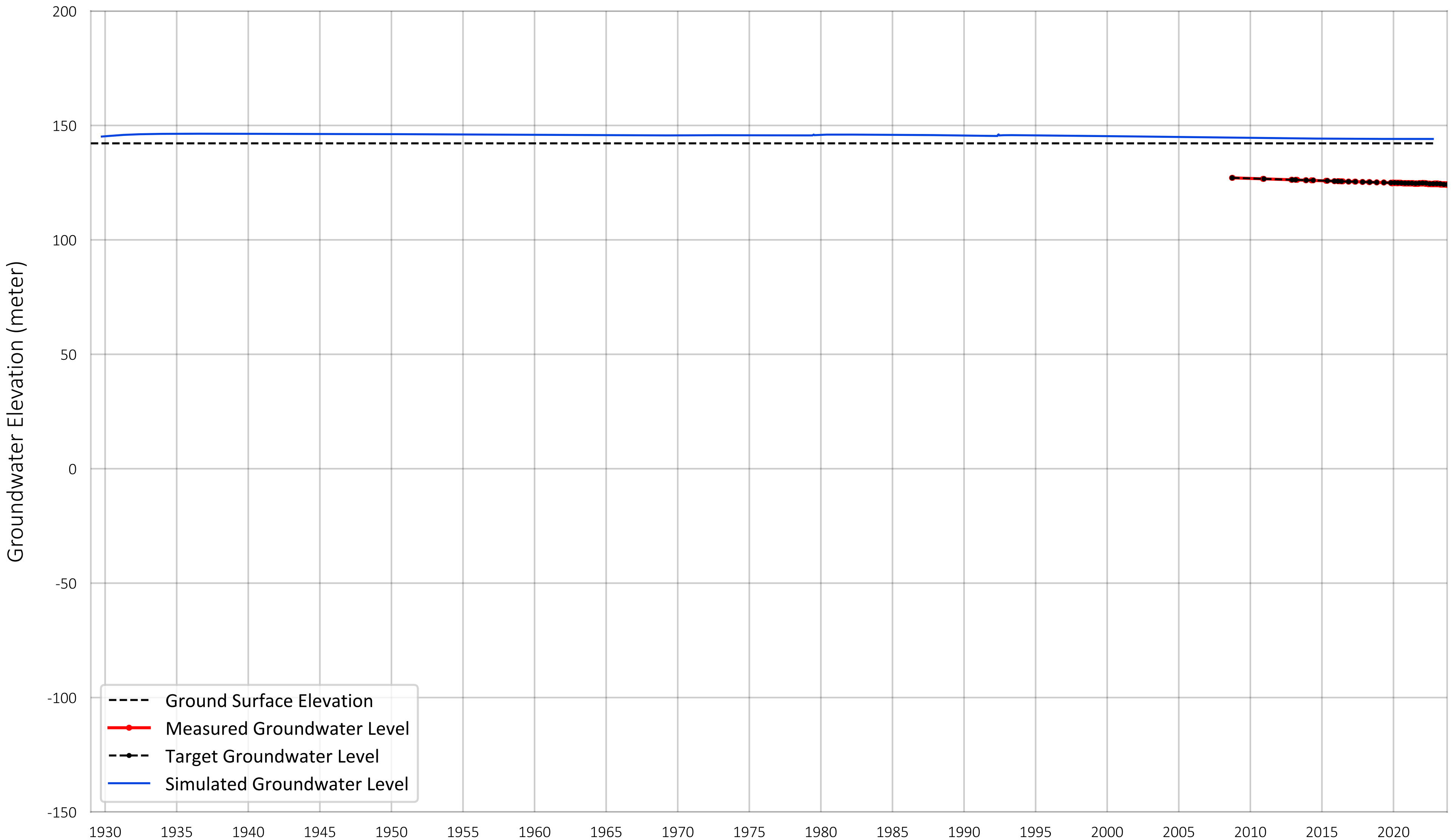
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MW-4

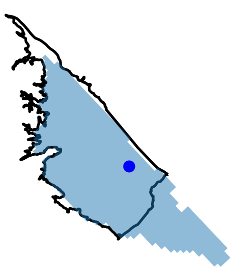
Figure A-60



Prepared by:

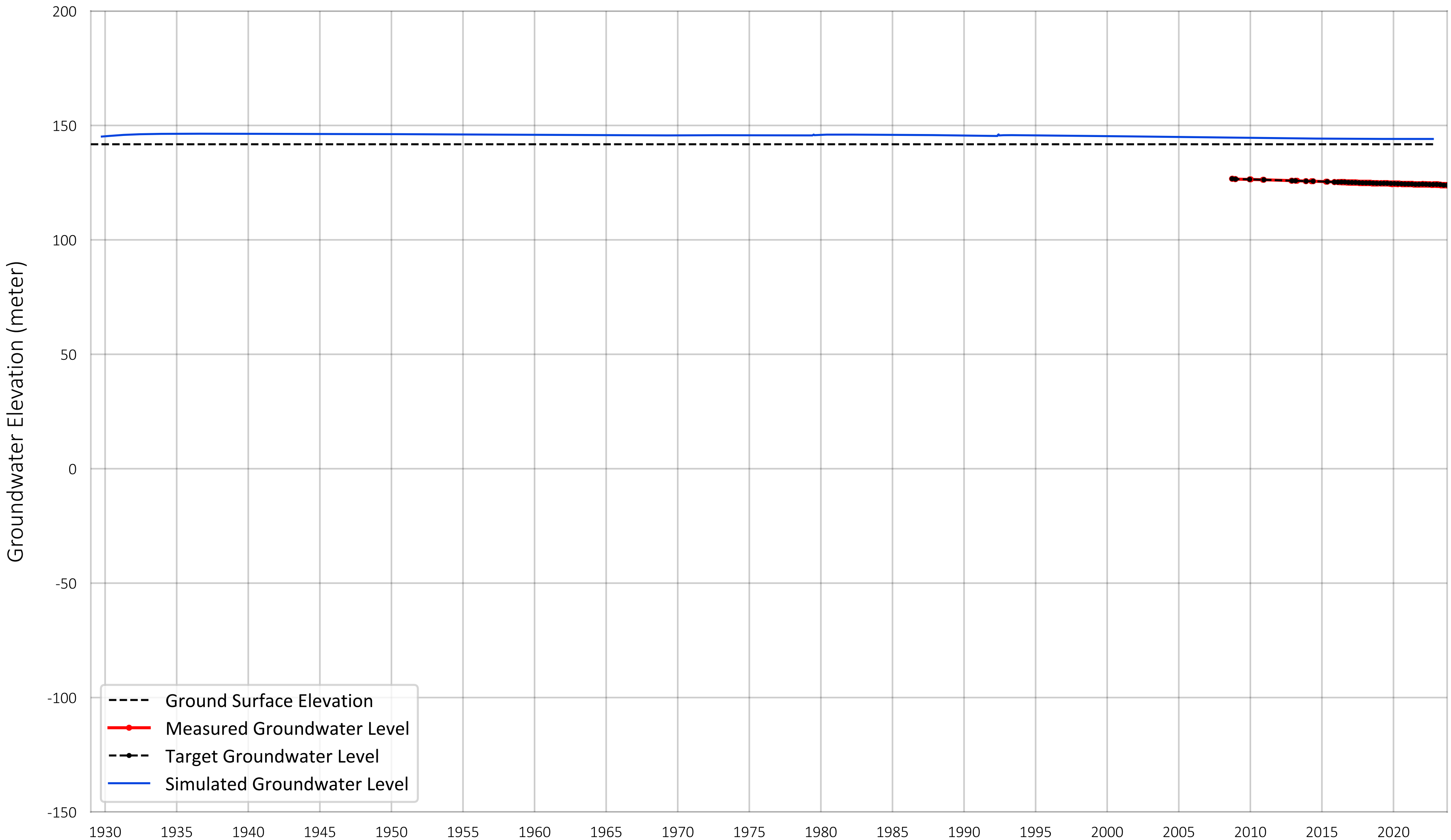
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MW-5A (East-Lower)

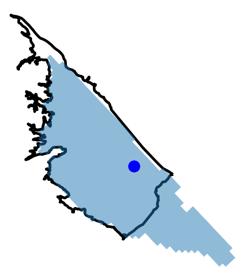
Figure A-61



Prepared by:

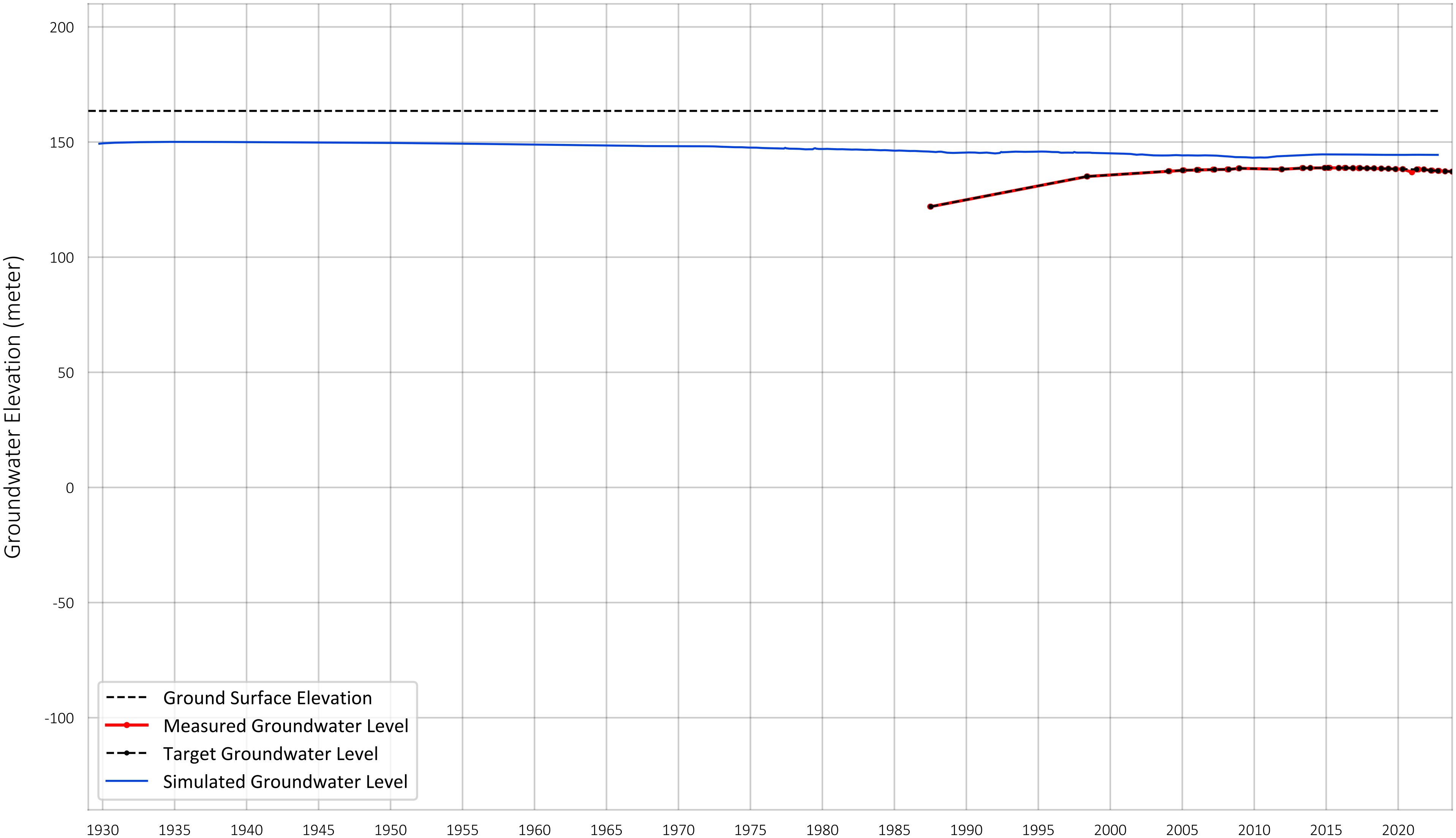
WEST YOST
Water. Engineered.

Well Location



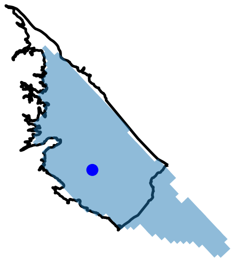
Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: MW-5B (West-Upper)

Figure A-62



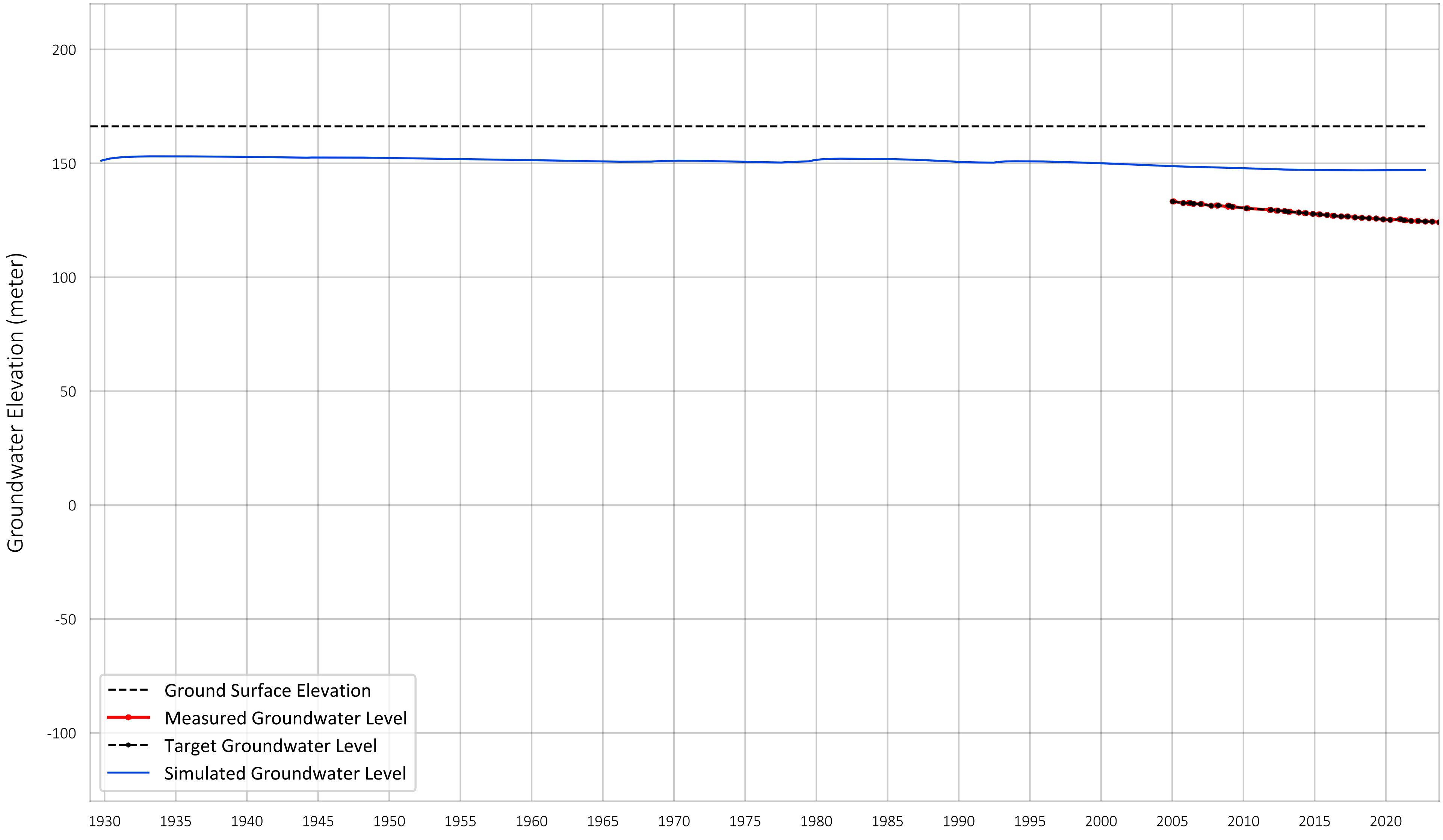
Prepared by:

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Paddock

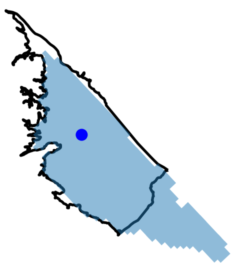
Figure A-63



Prepared by:

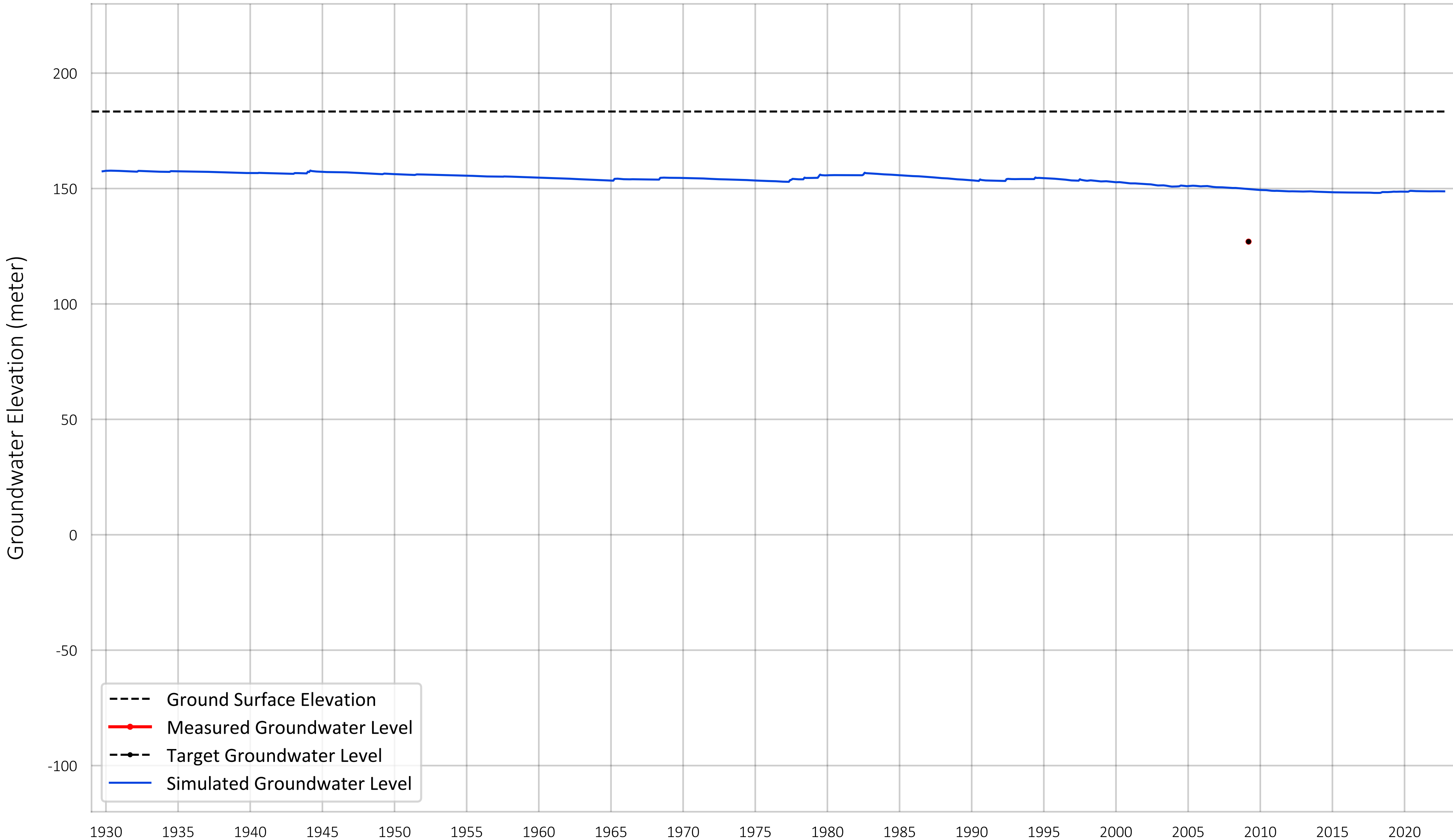
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Palleson

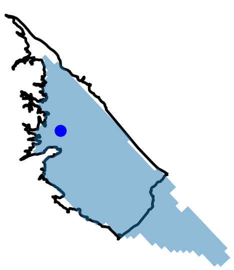
Figure A-64



Prepared by:

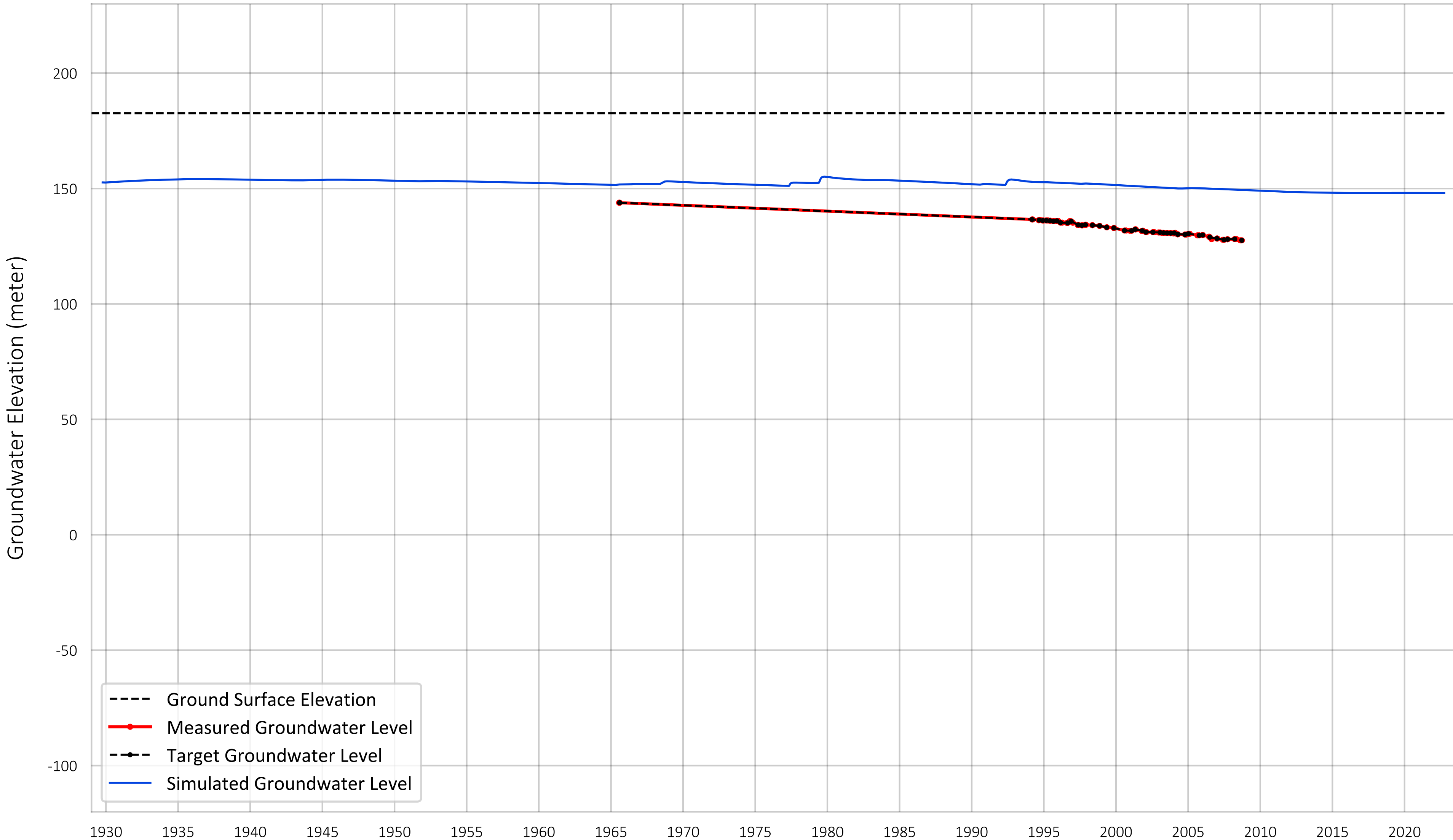
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Pecoff 2

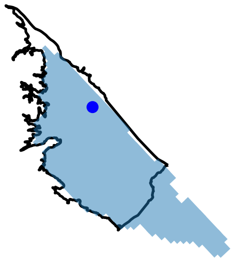
Figure A-65



Prepared by:

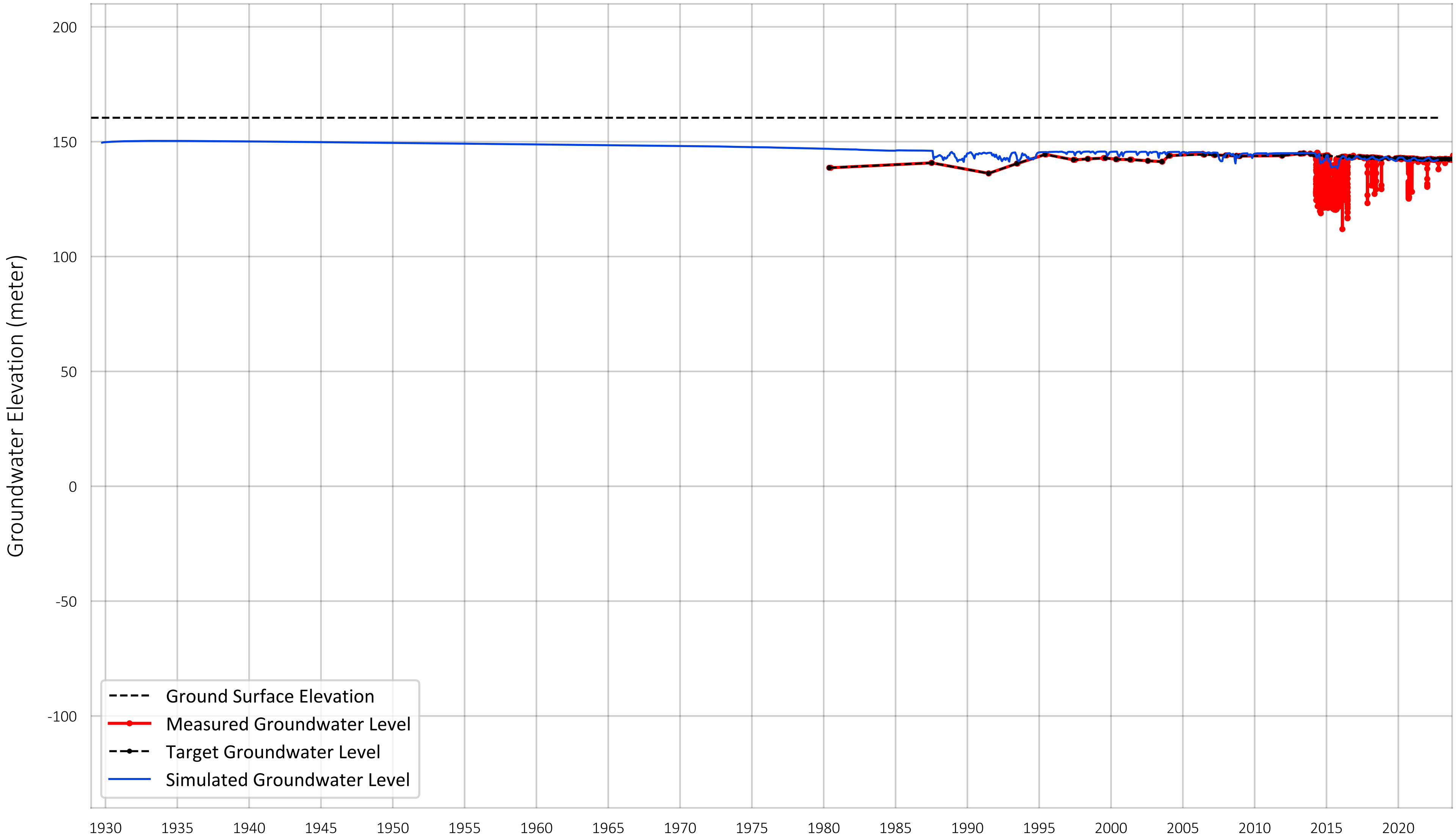
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Potato Field

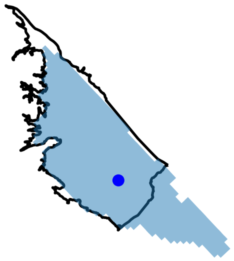
Figure A-66



Prepared by:

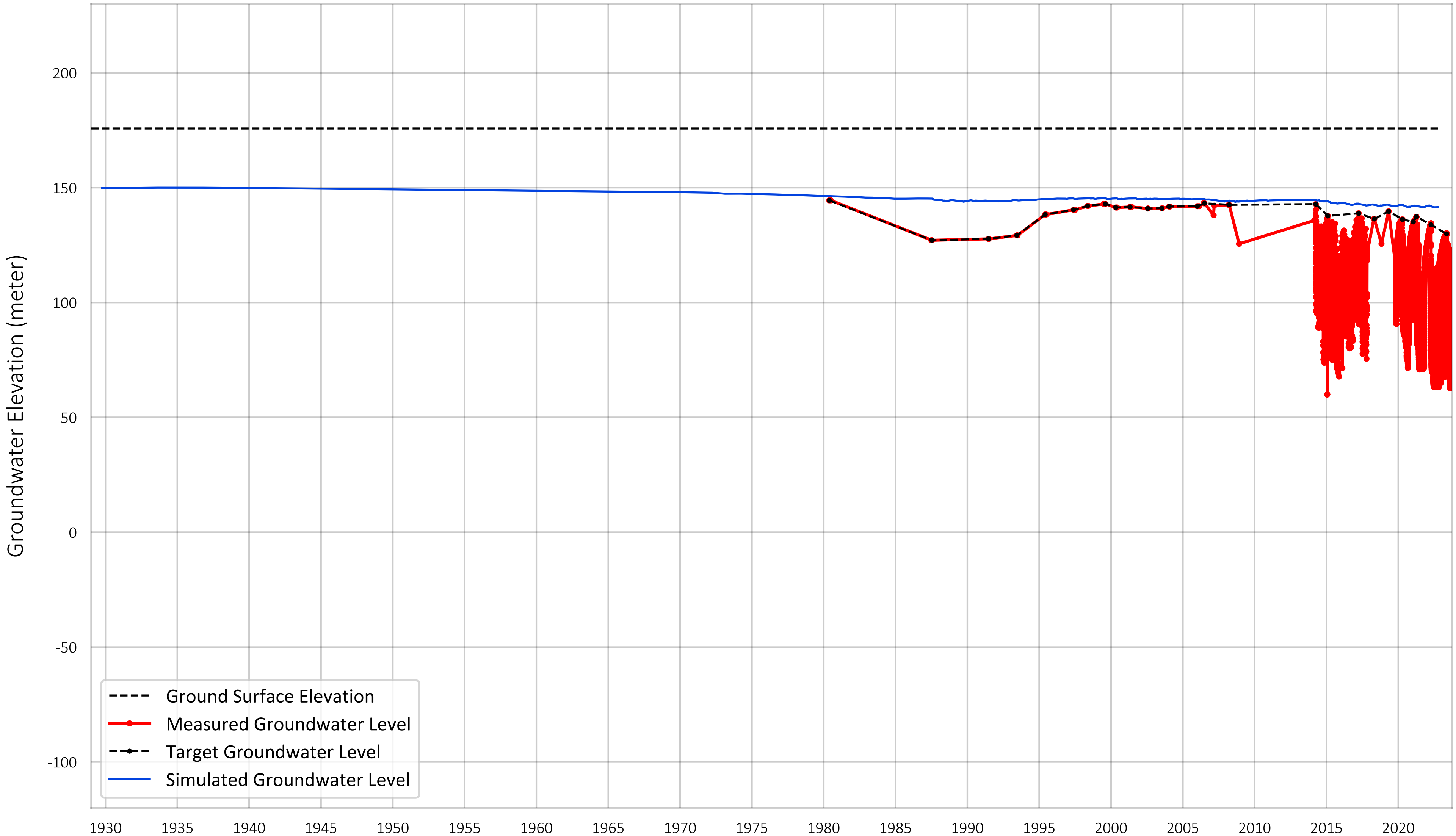
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-1 (ID1-1)

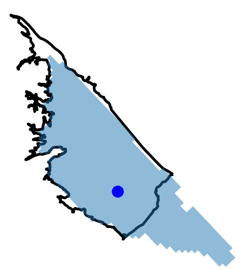
Figure A-67



Prepared by:

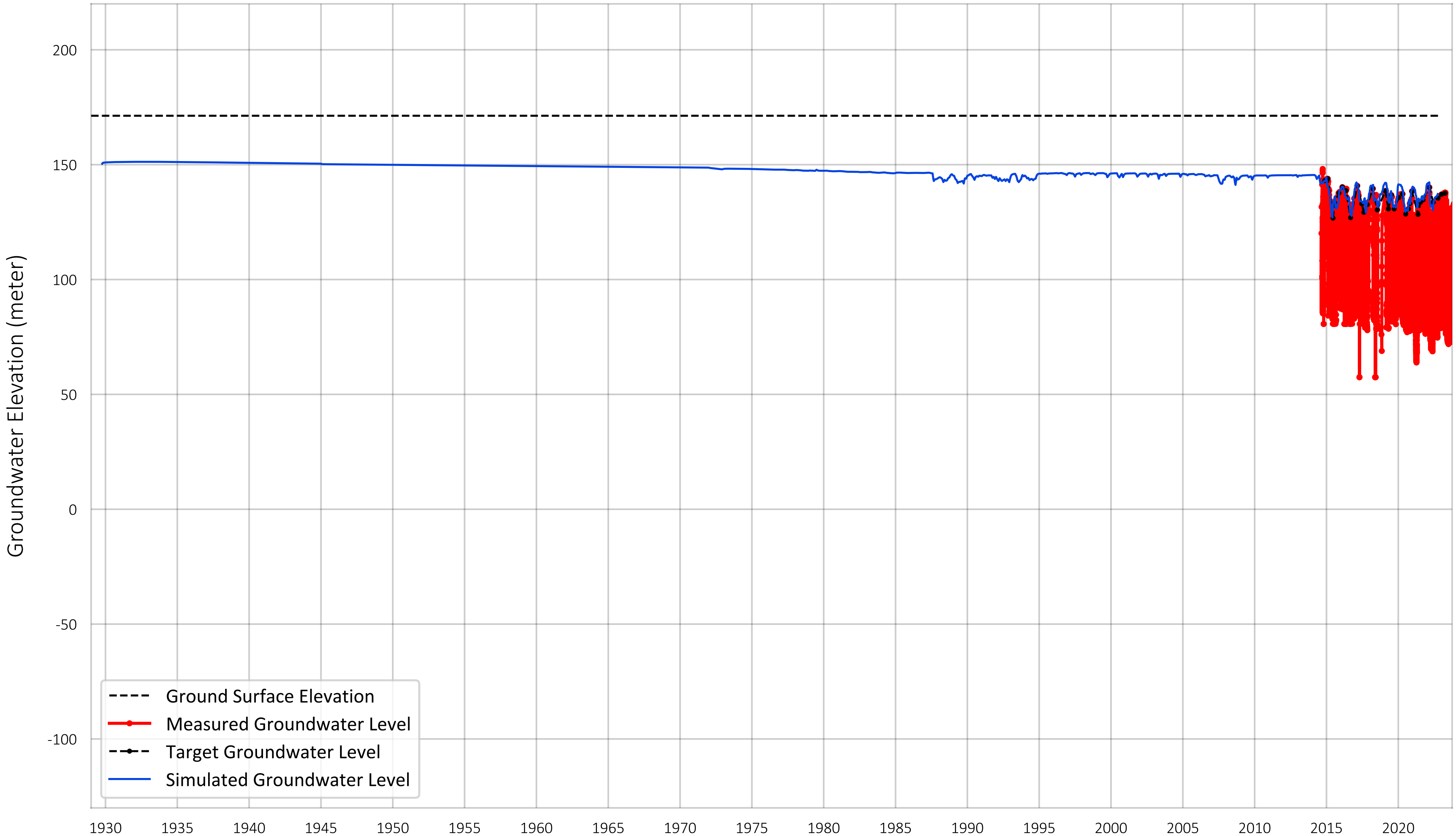
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-2 (ID1-2)

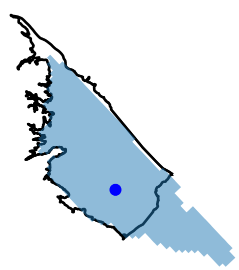
Figure A-68



Prepared by:

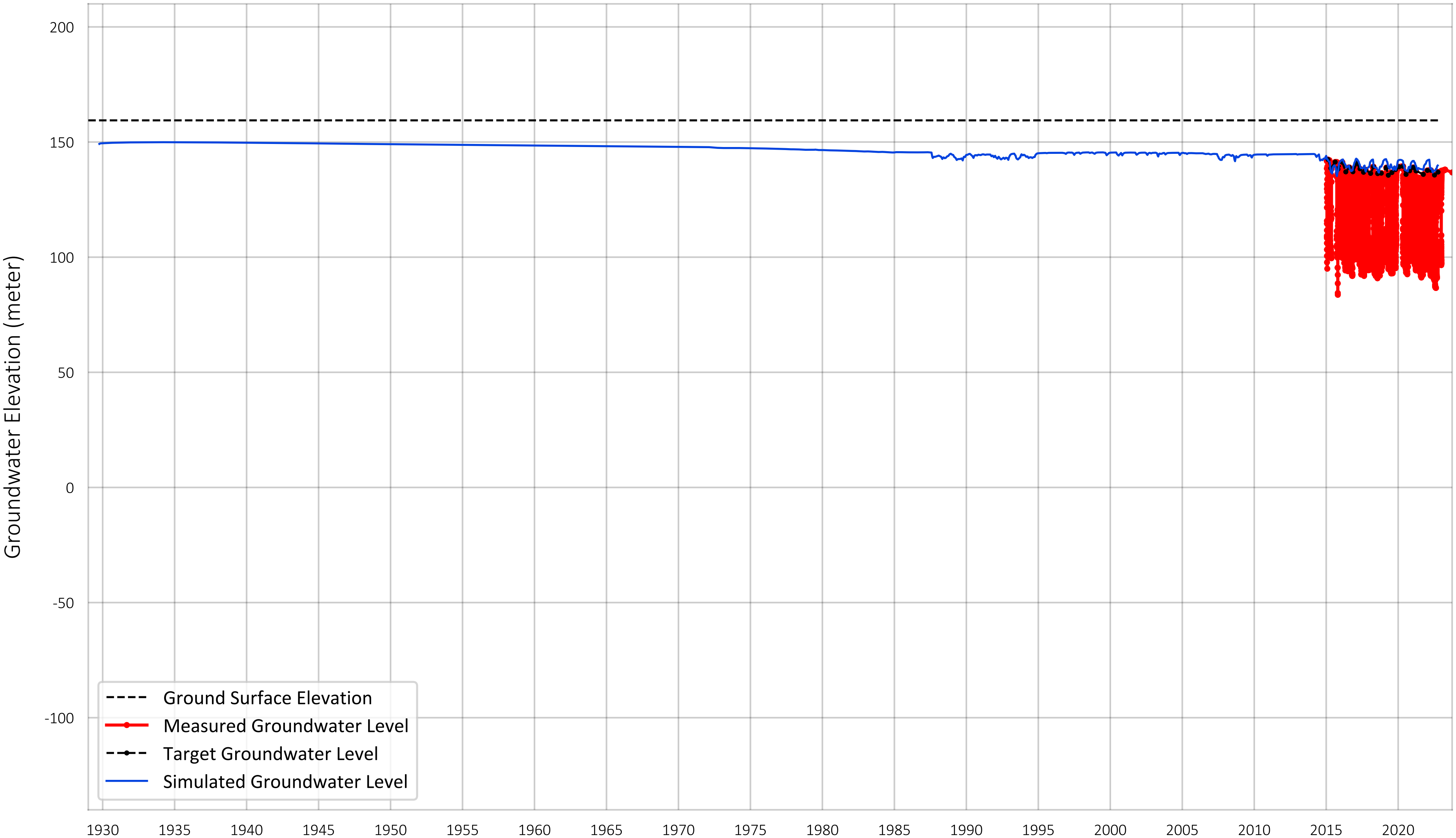
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-3

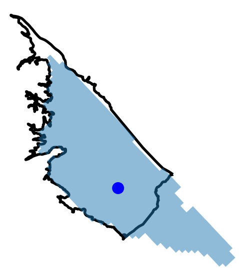
Figure A-69



Prepared by:

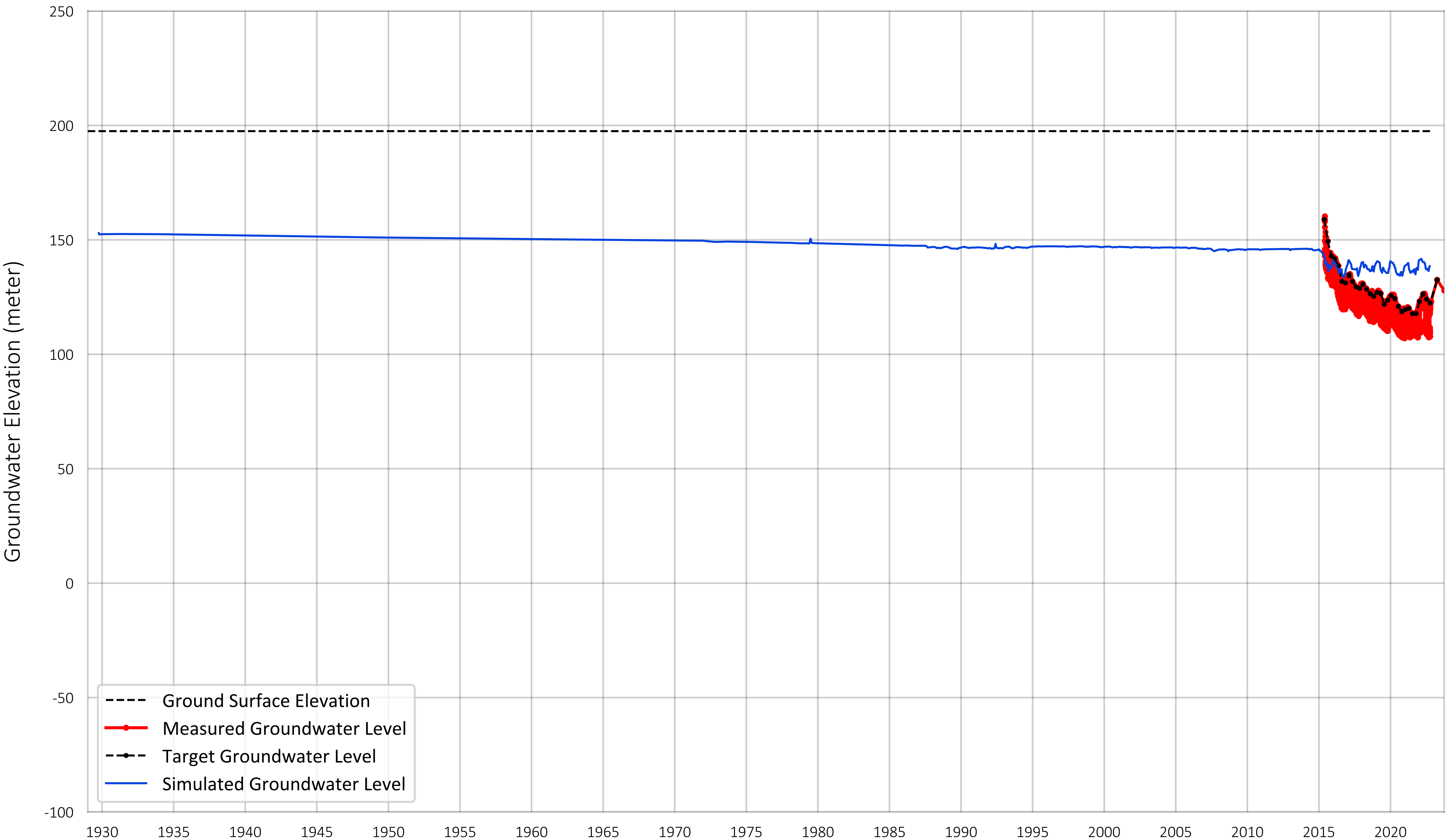
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-4

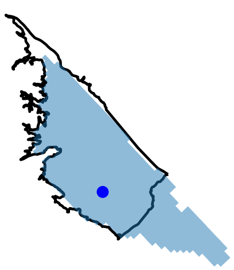
Figure A-70



Prepared by:

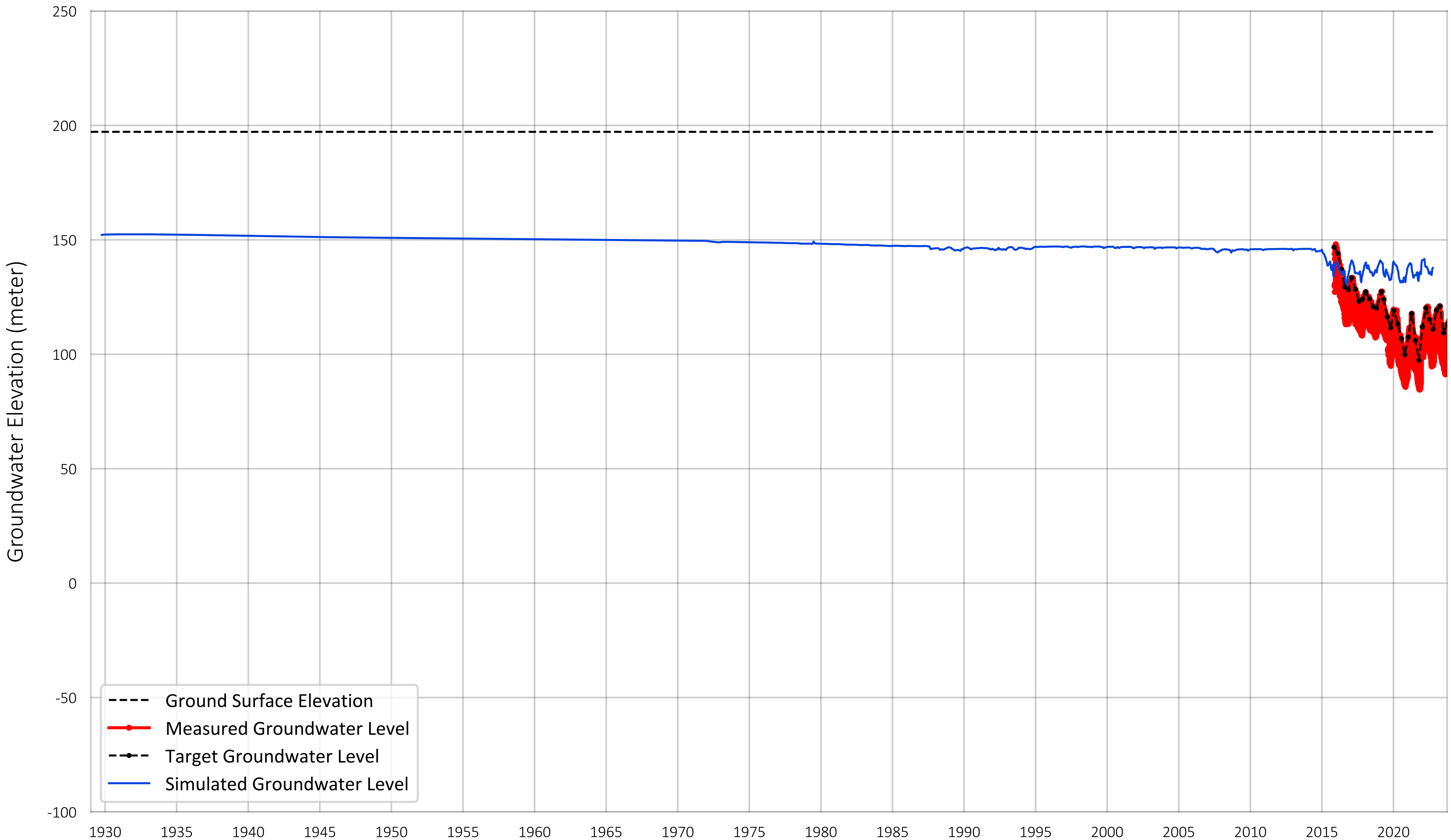
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-5

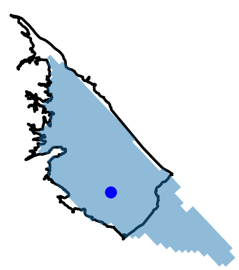
Figure A-71



Prepared by:

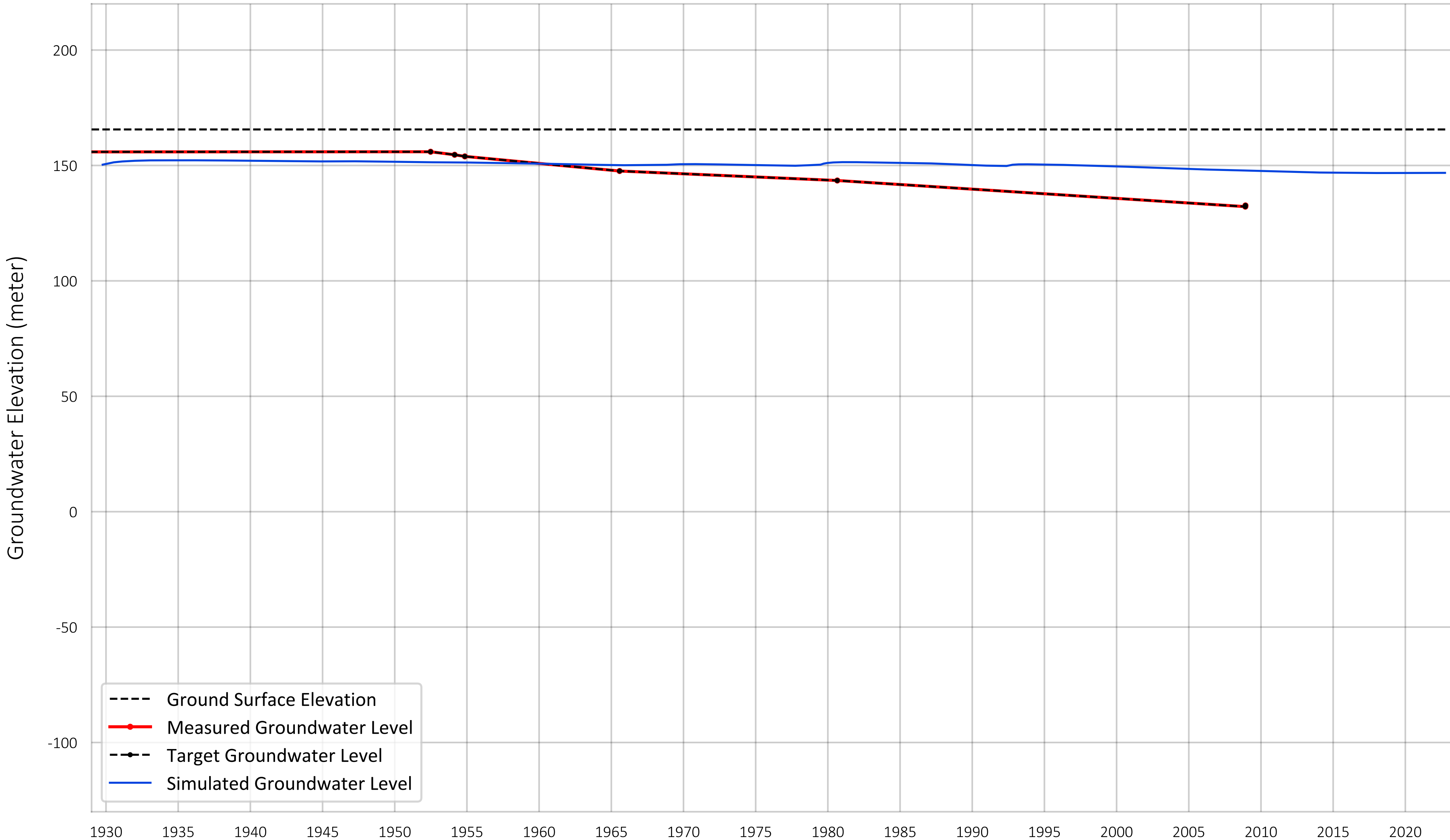
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: RH-6

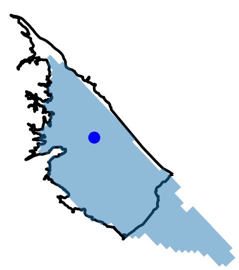
Figure A-72



Prepared by:

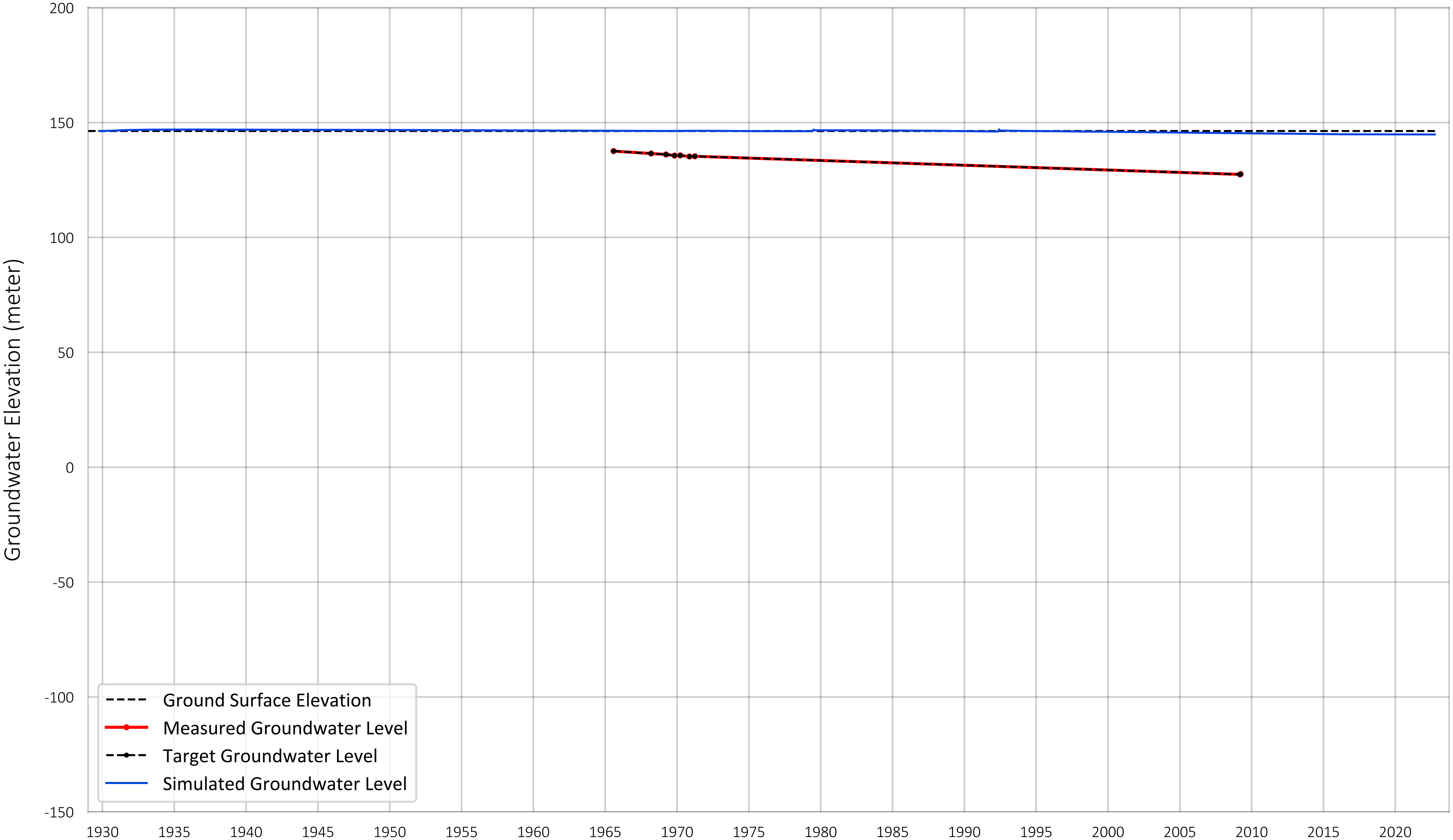
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Redimix Plant

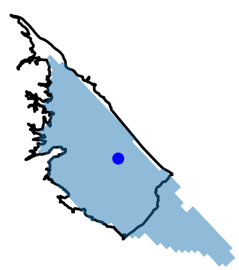
Figure A-73



Prepared by:

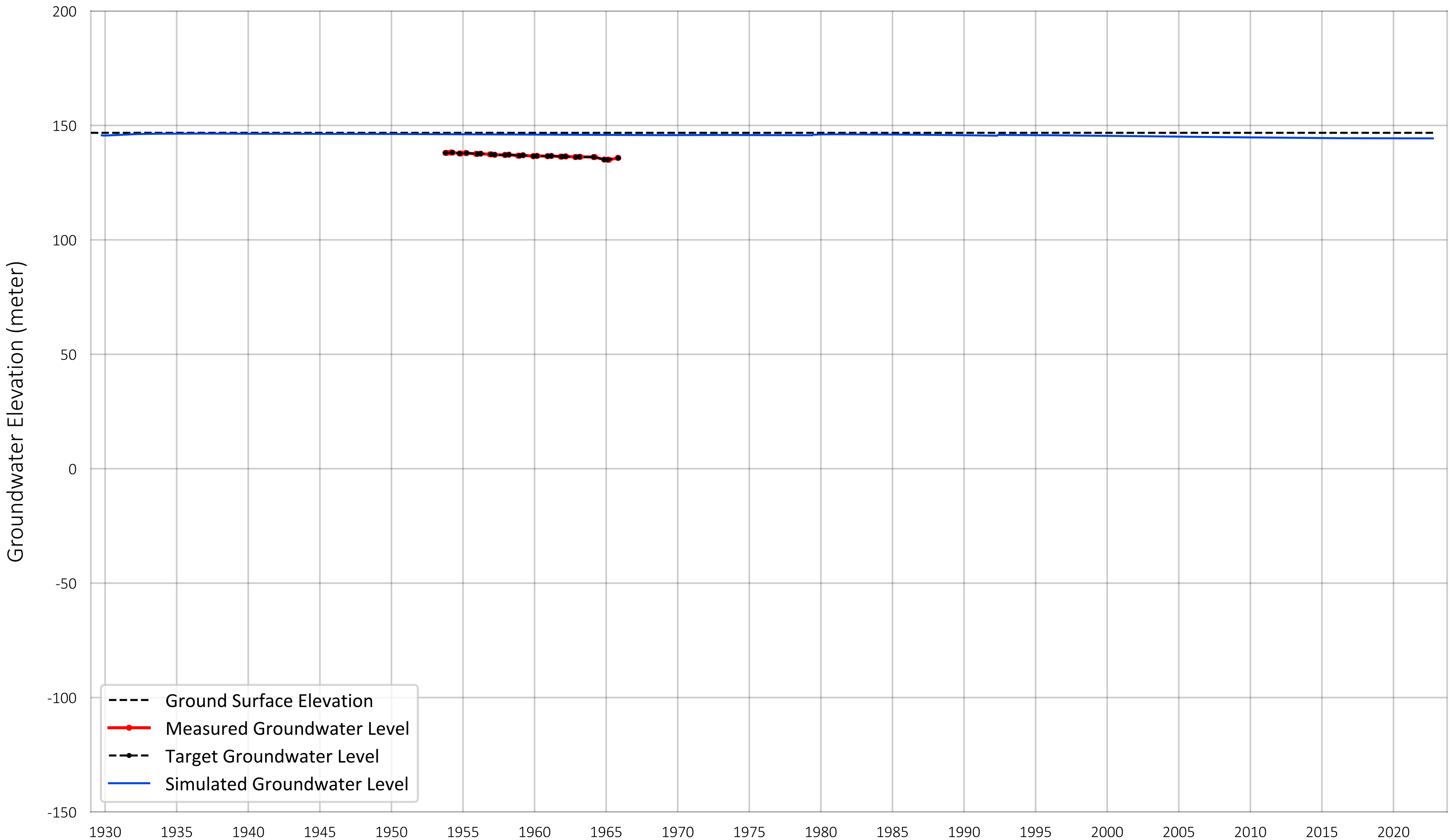
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Sink - 12G1

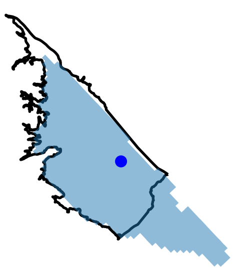
Figure A-74



Prepared by:

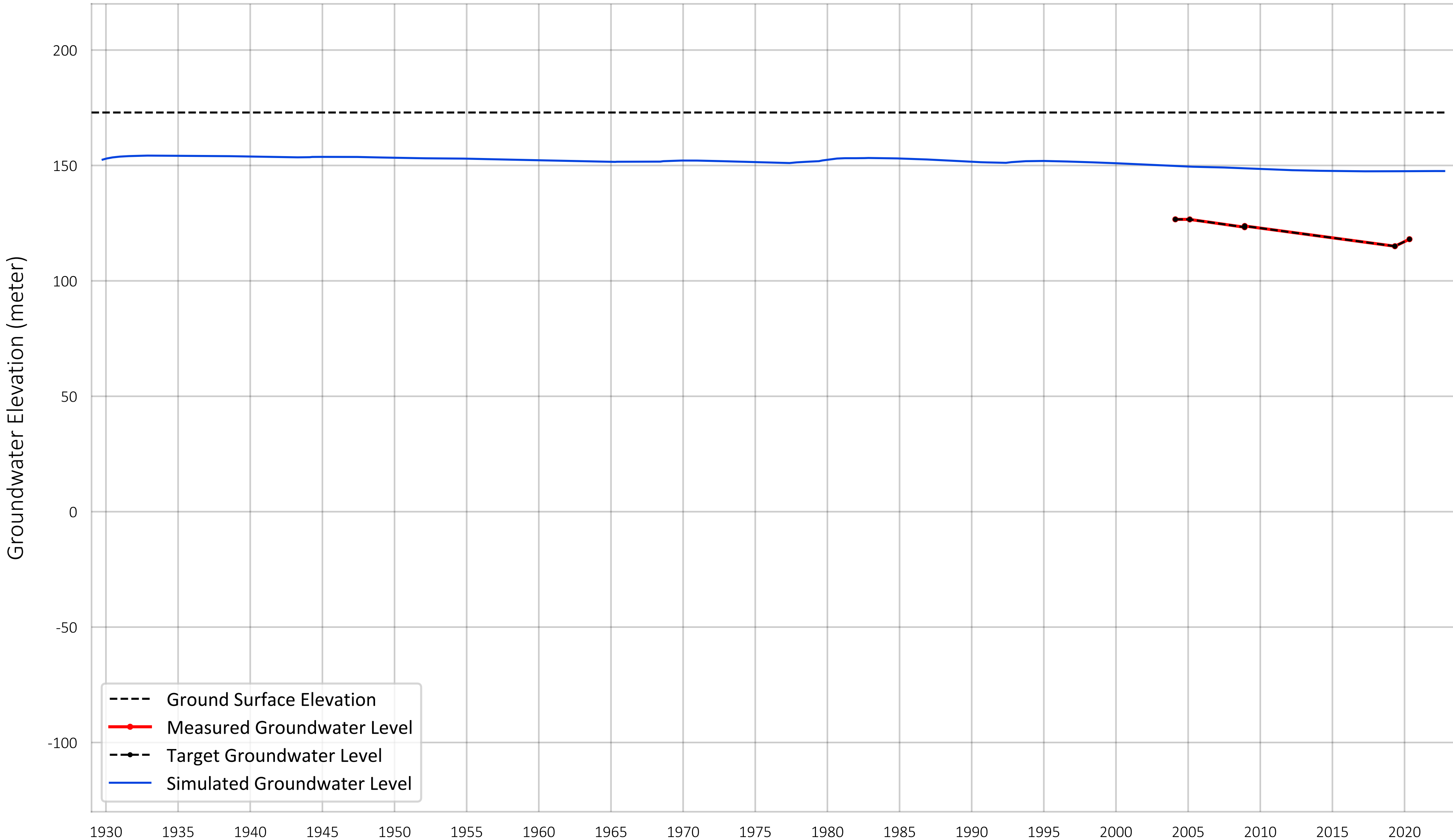
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Sink - 7N1

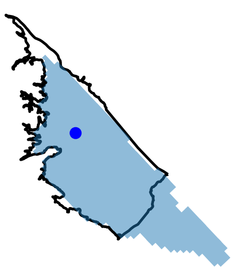
Figure A-75



Prepared by:

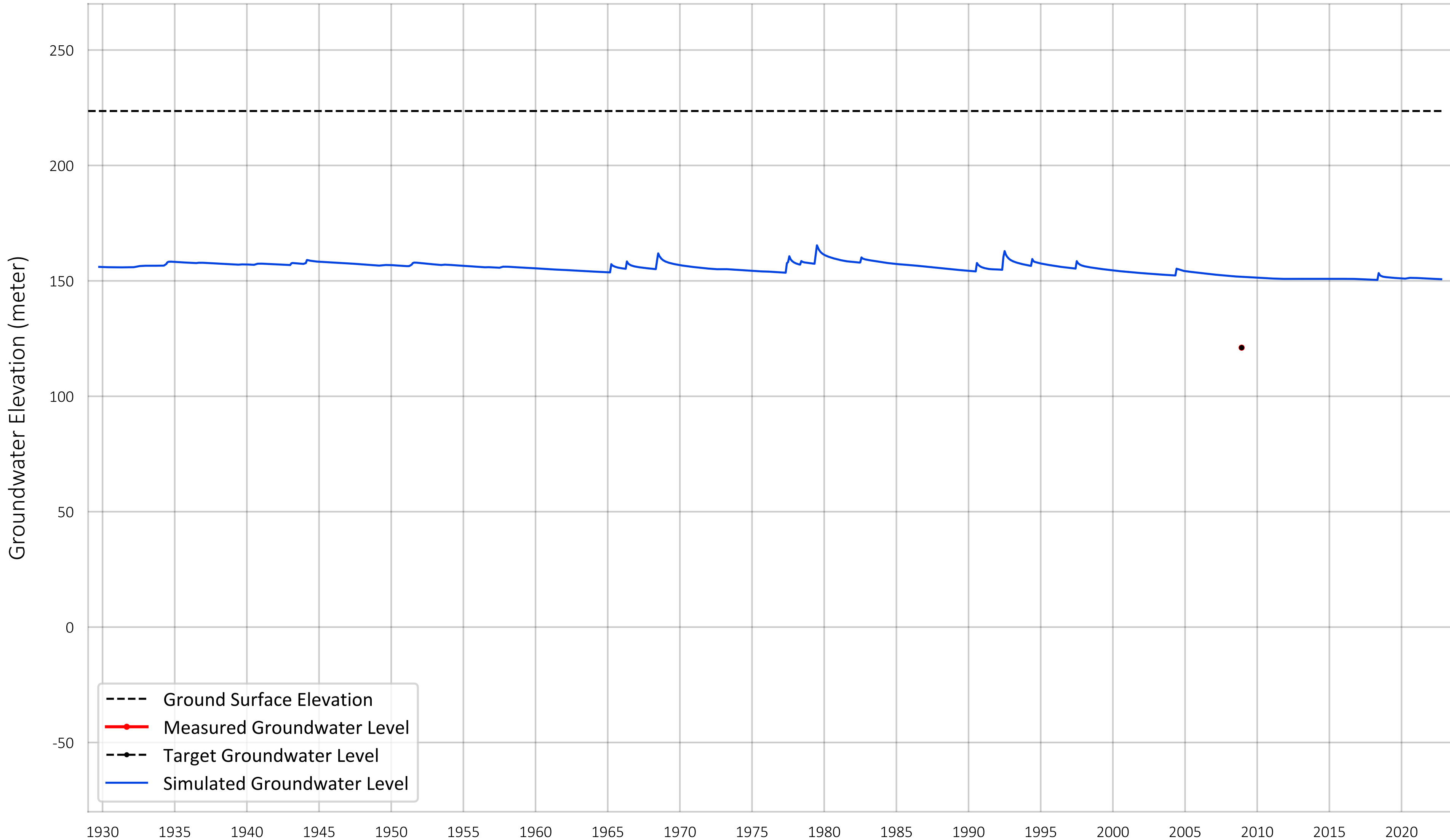
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Springs 2

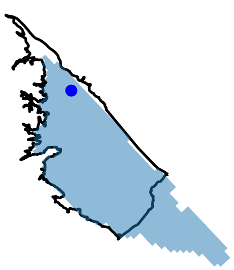
Figure A-76



Prepared by:

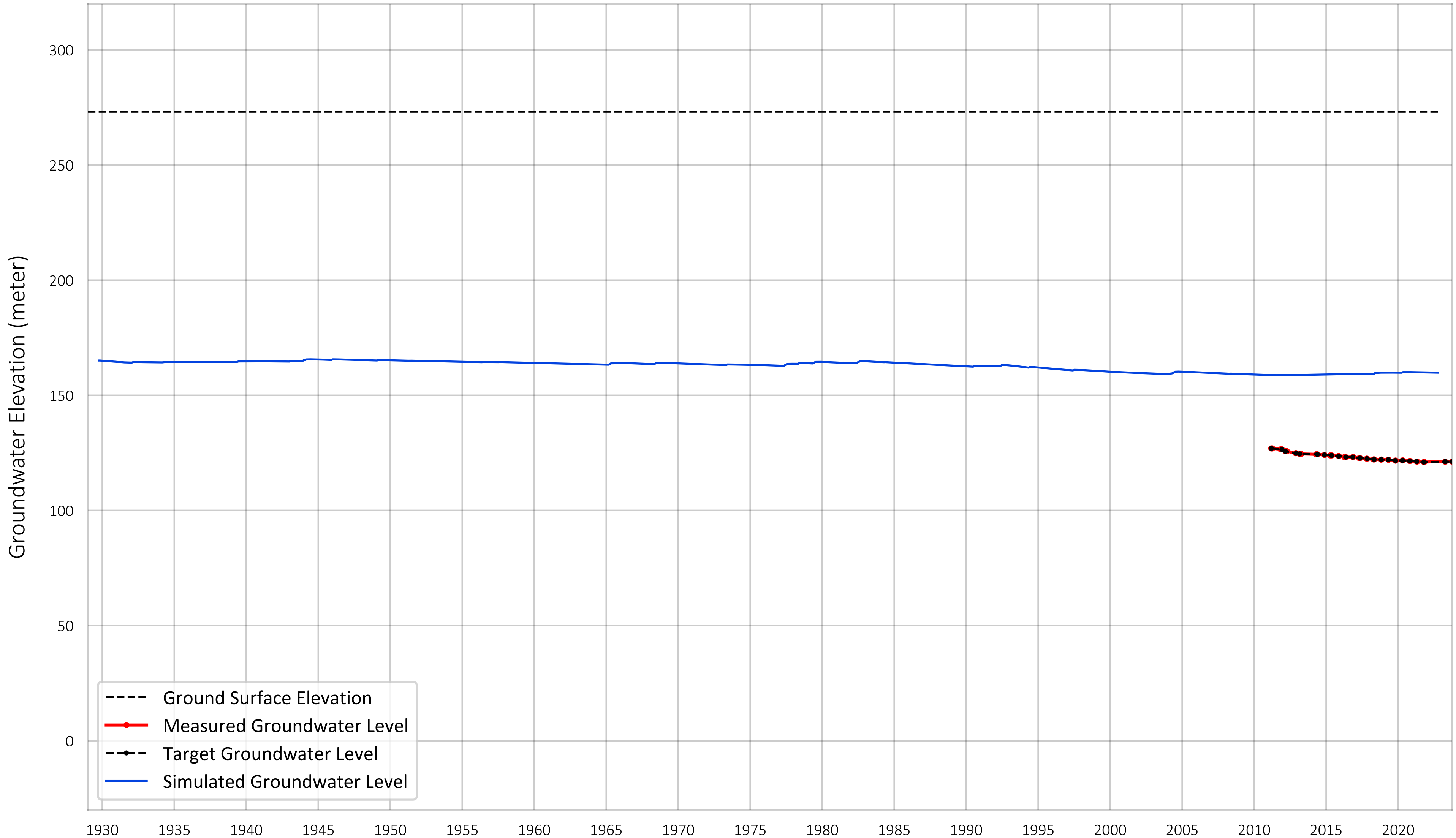
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: T2 Farms

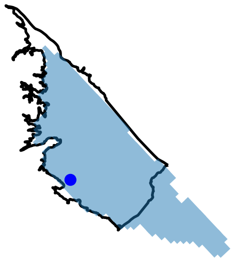
Figure A-77



Prepared by:

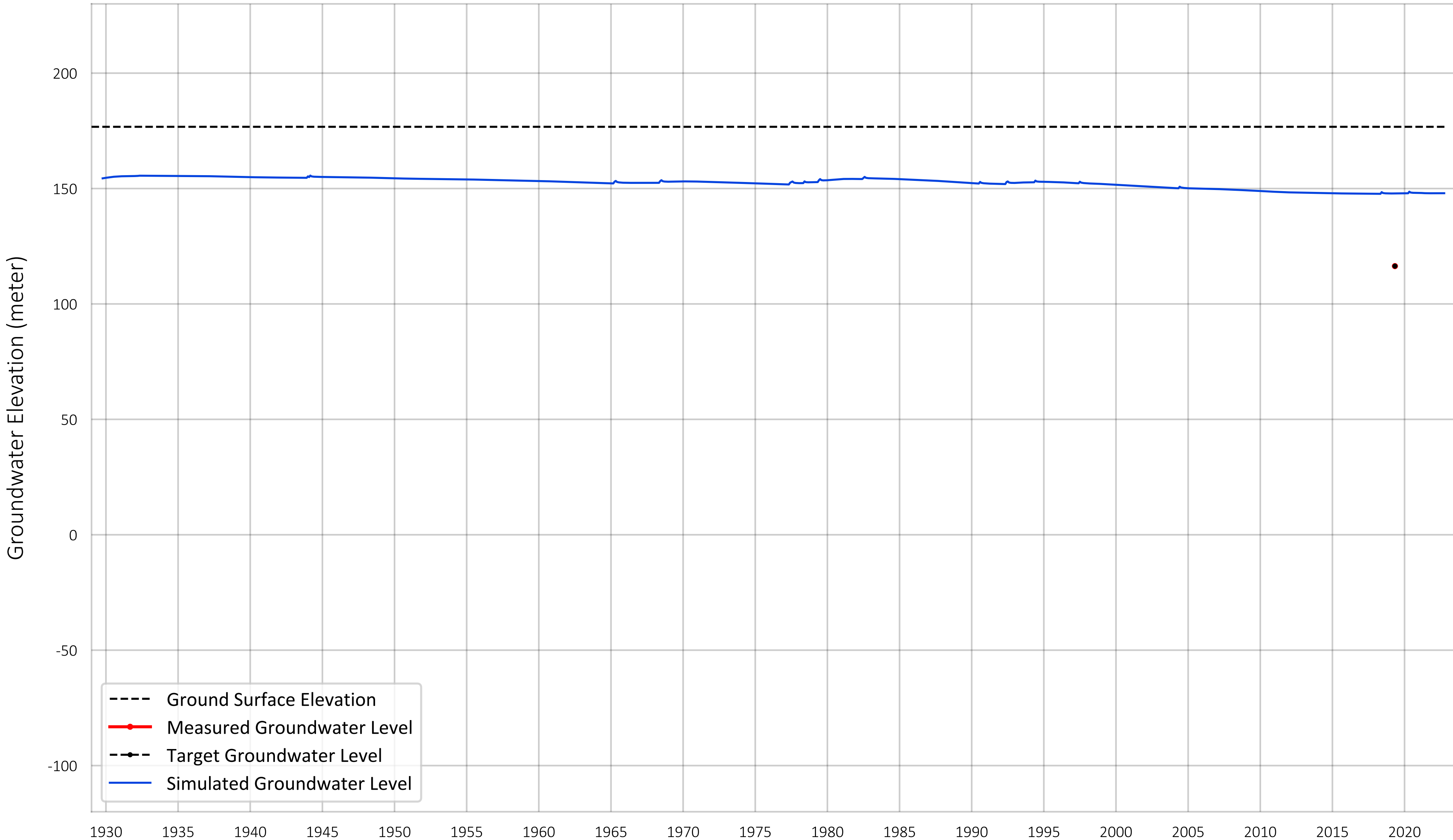
WEST YOST Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Terry Well

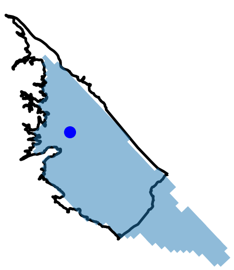
Figure A-78



Prepared by:

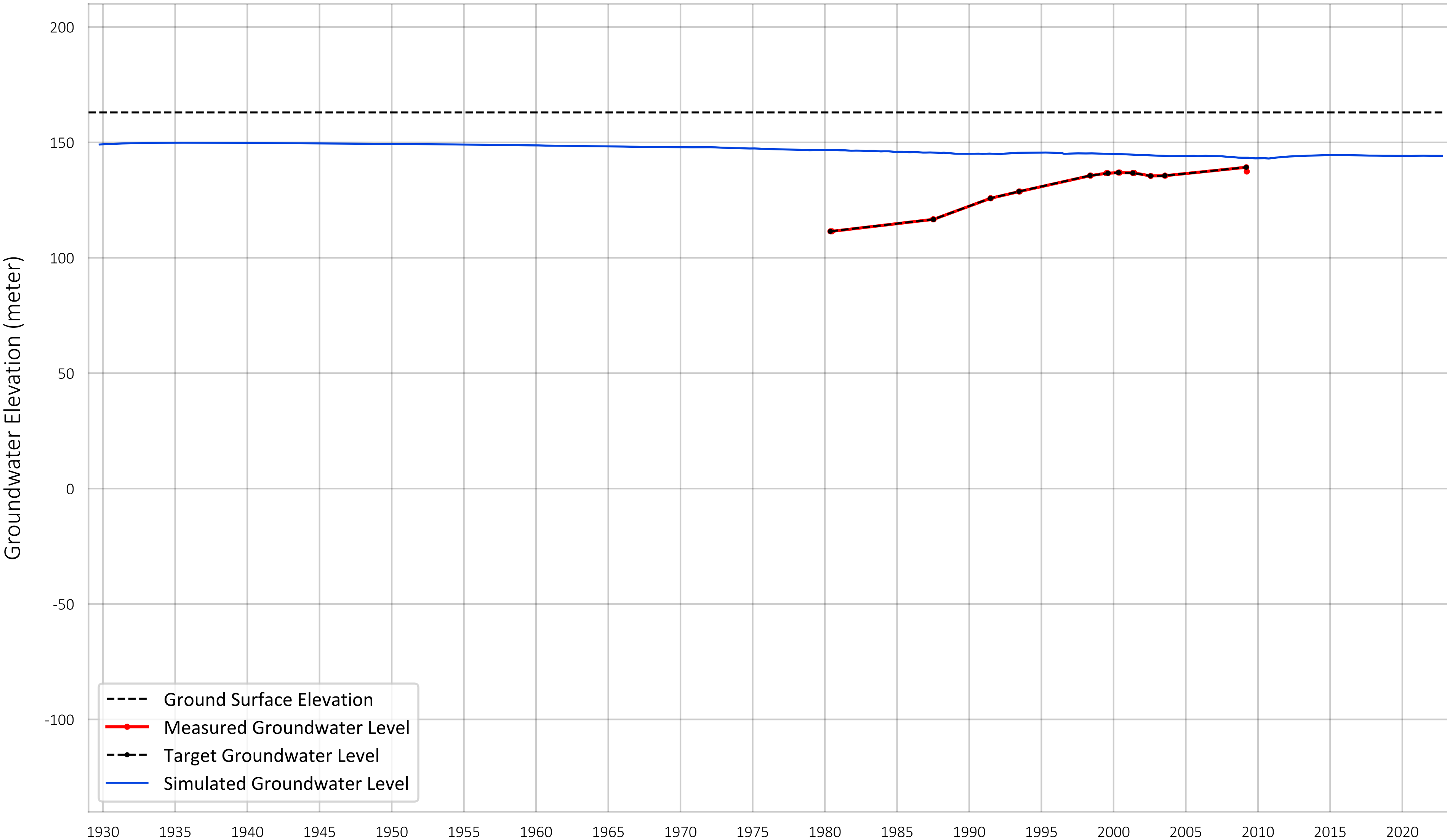
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: The Springs

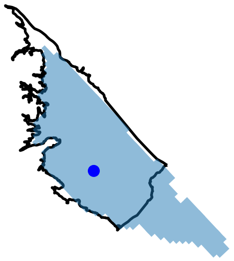
Figure A-79



Prepared by:

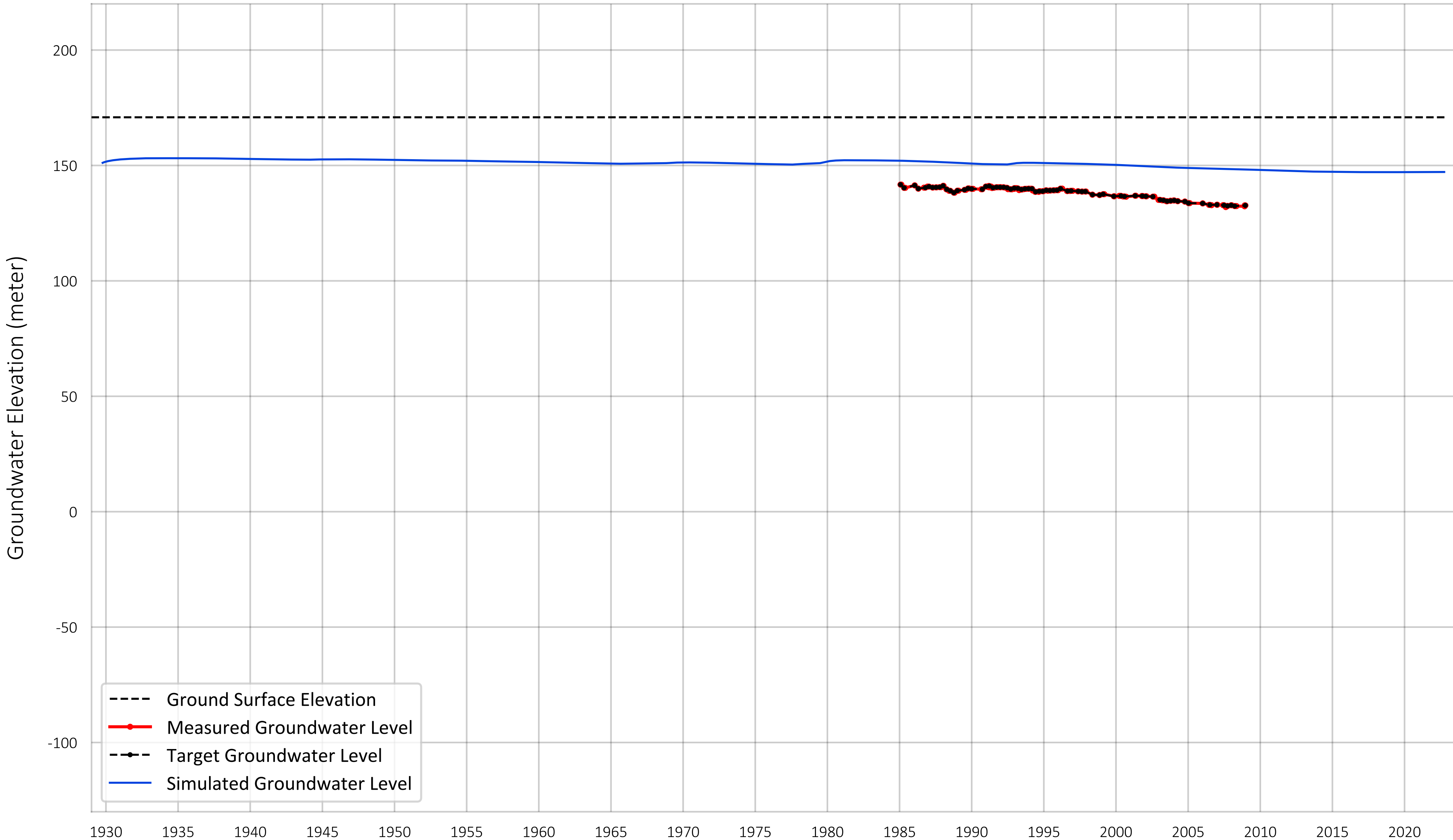
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Triangle

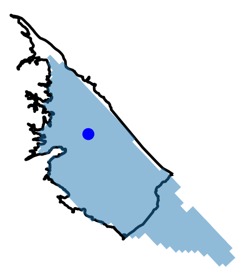
Figure A-80



Prepared by:

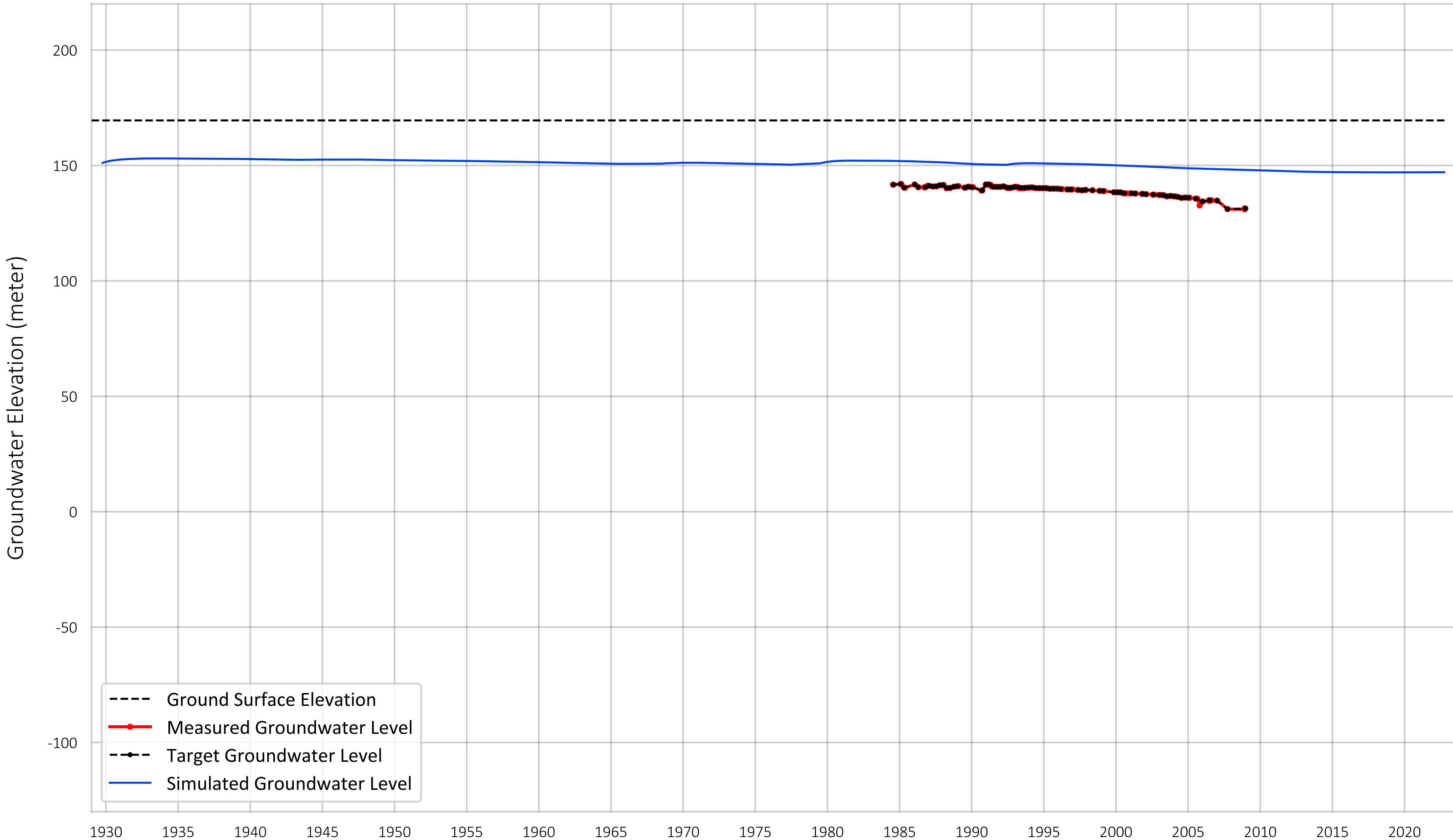
WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: UEC North

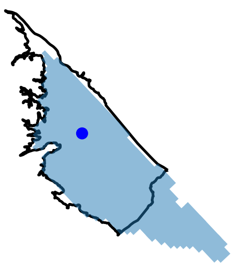
Figure A-81



Prepared by:

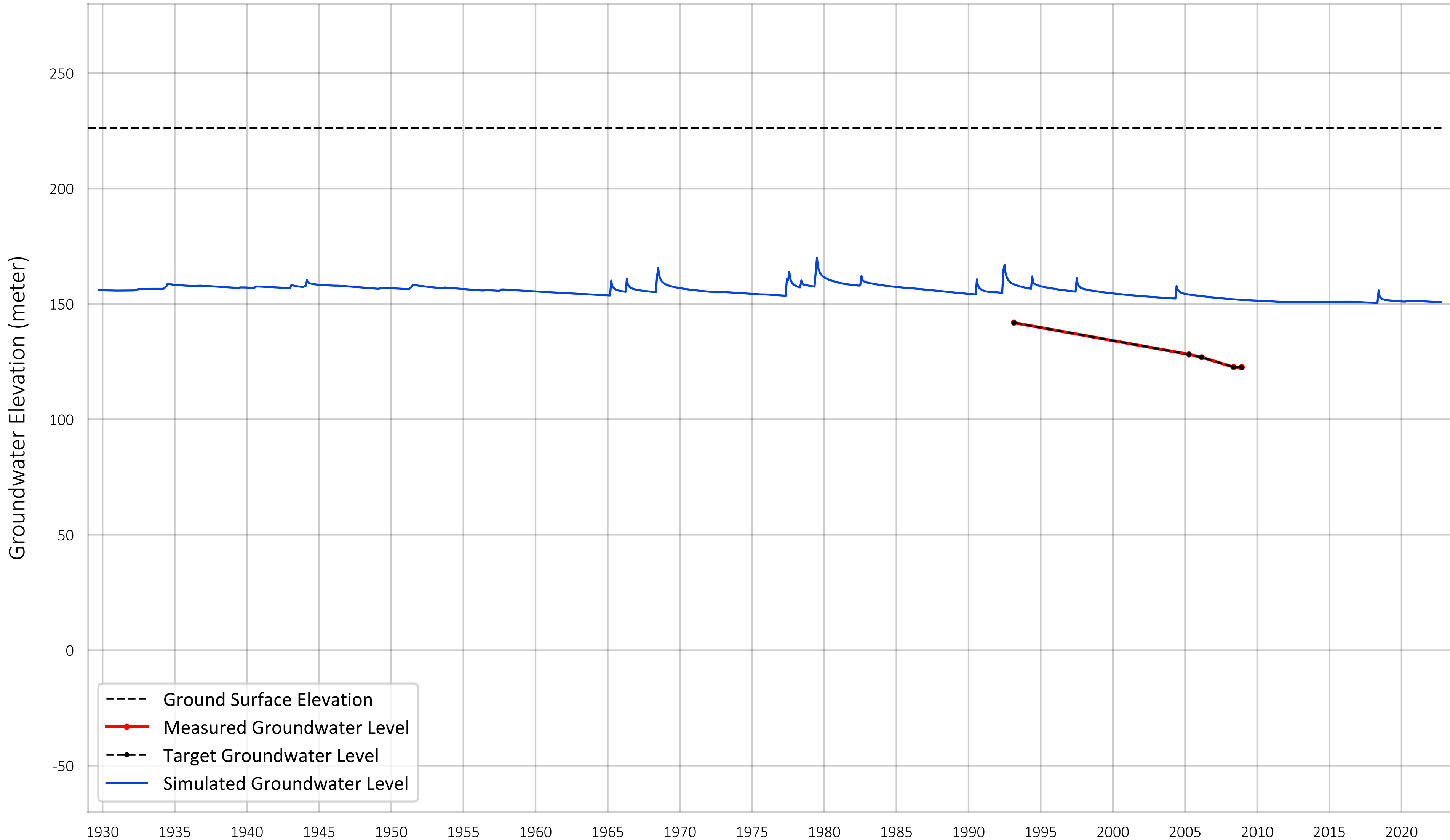
WEST YOST
Water. Engineered.

Well Location



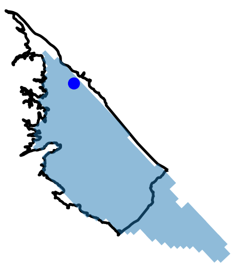
Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: UEC South

Figure A-82



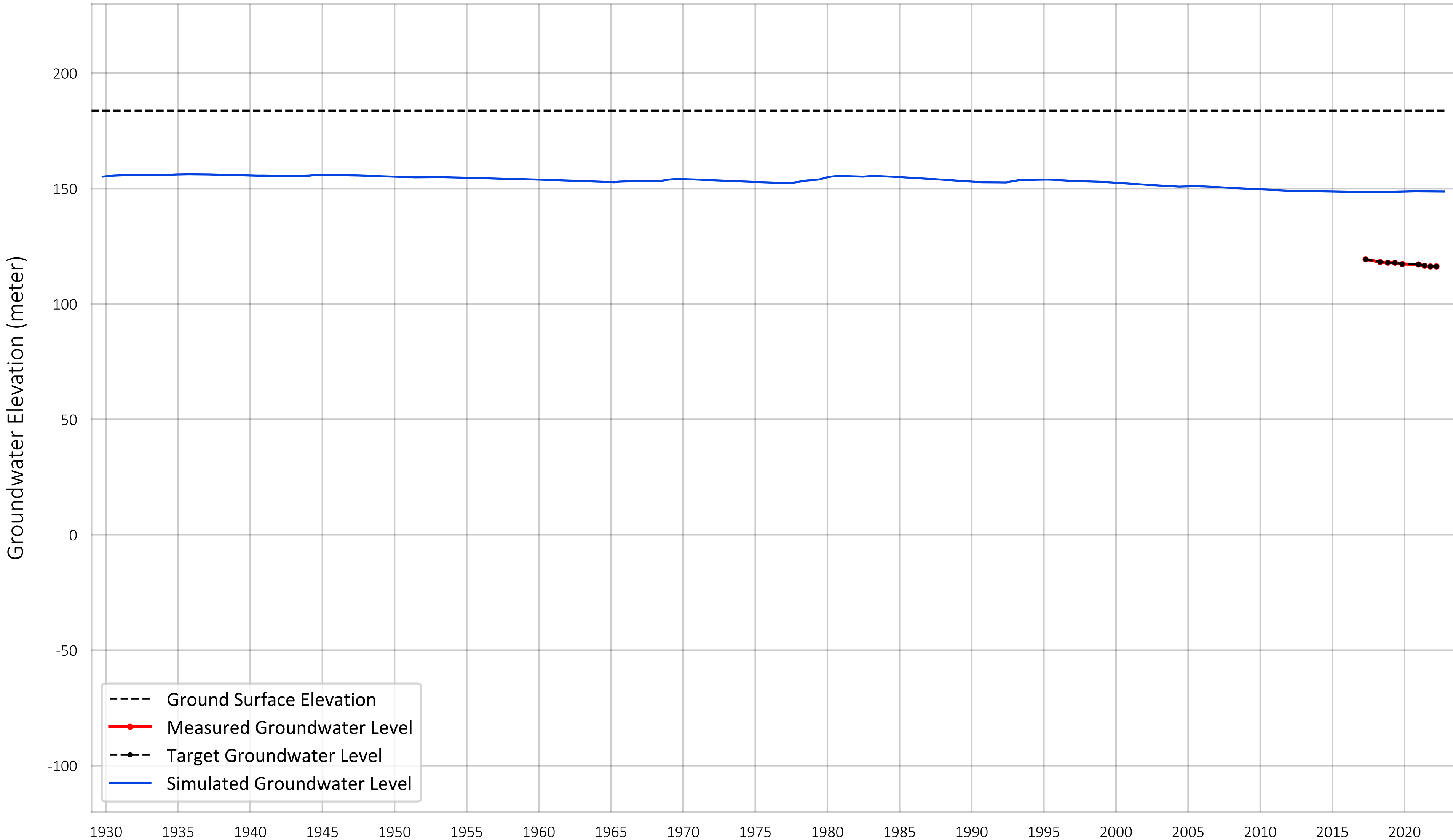
Prepared by:

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: Viking

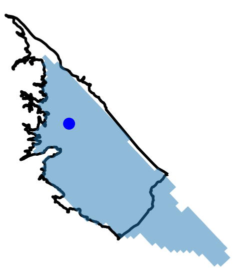
Figure A-83



Prepared by:

WEST YOST
Water. Engineered.

Well Location



Task 4 Pre-Calibrated BVHM
Groundwater Level
Well Name: White Well

Figure A-84

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.

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[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.

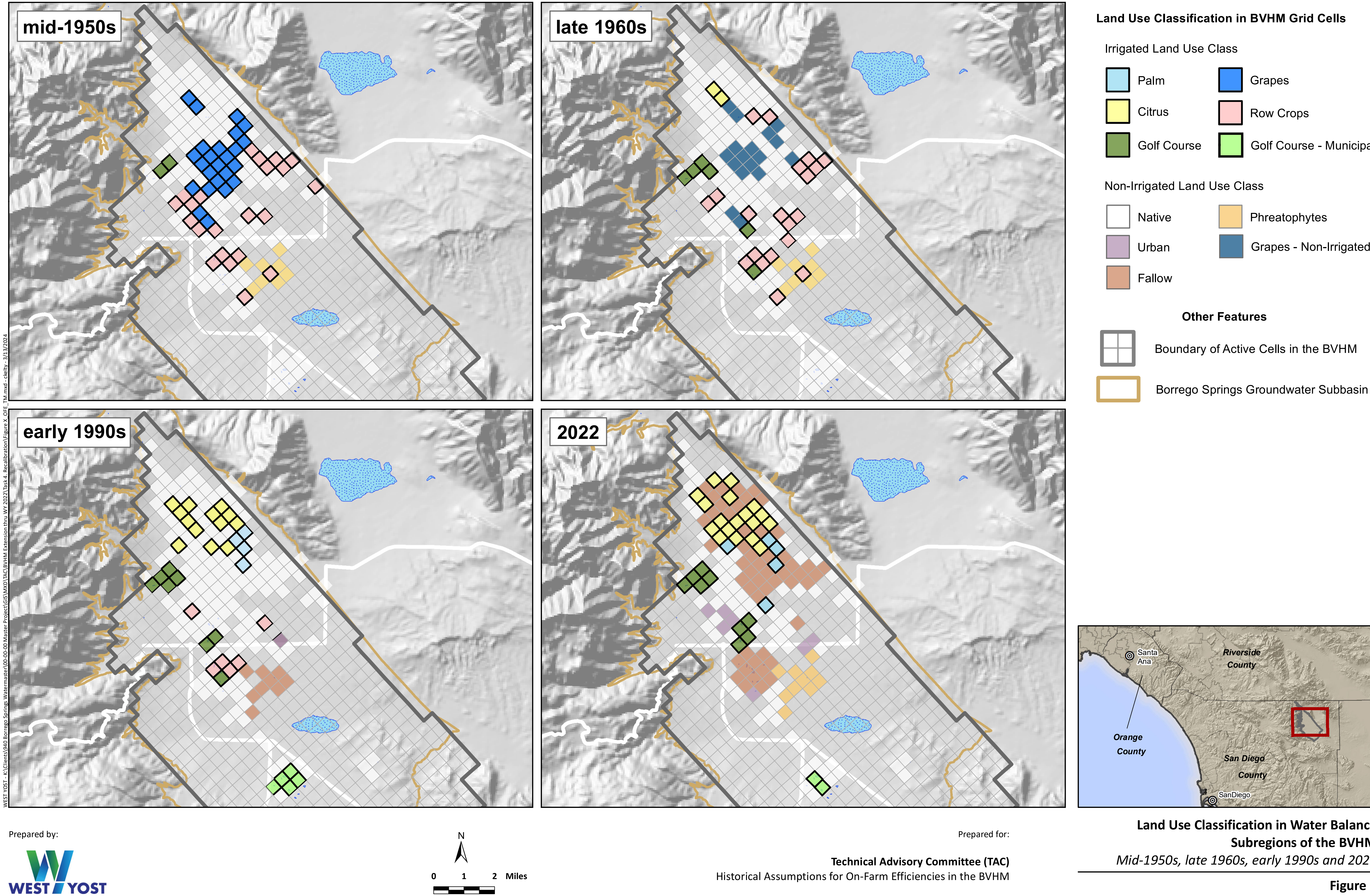
Table 3. Proposed Historical OFEs for Irrigated BVHM Grid Cells in Task 4

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

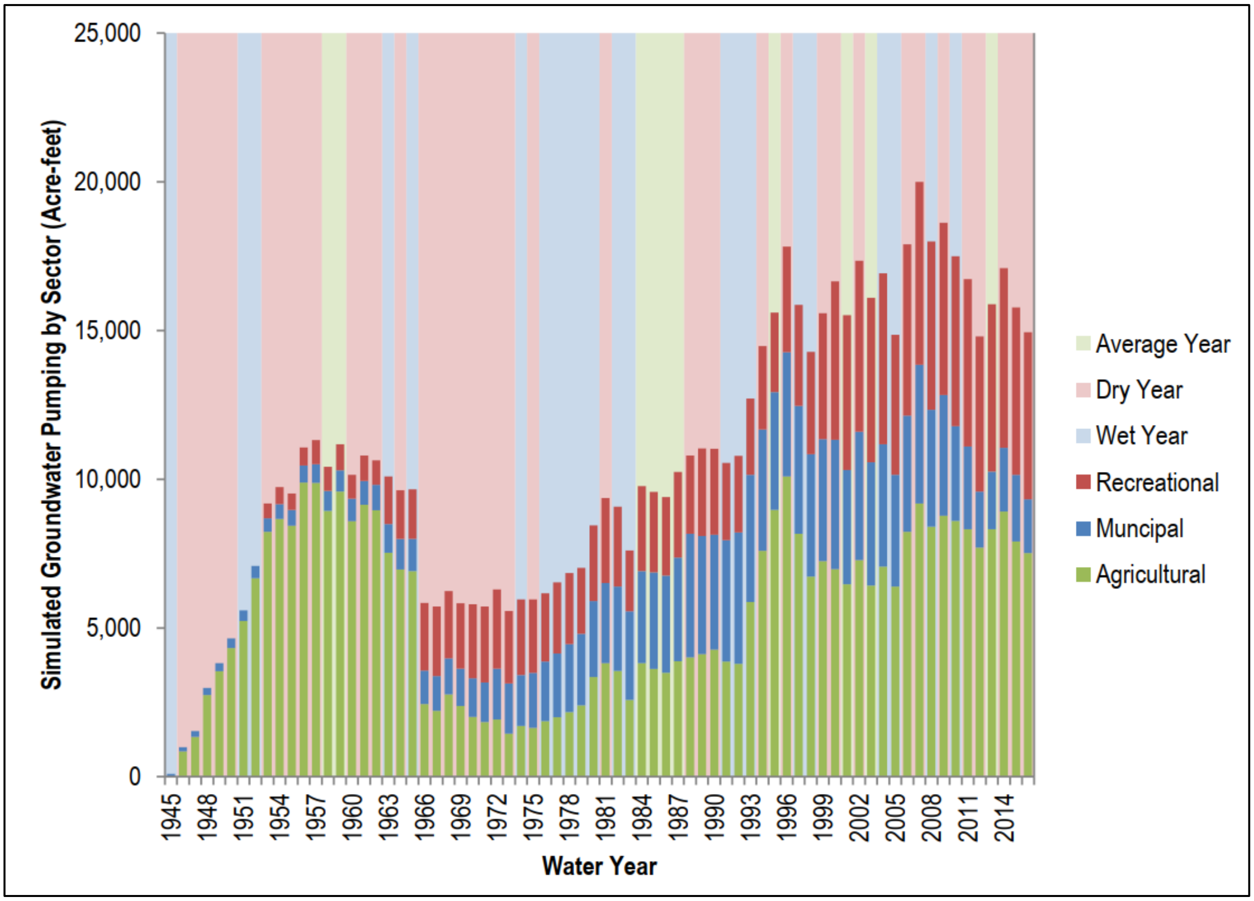
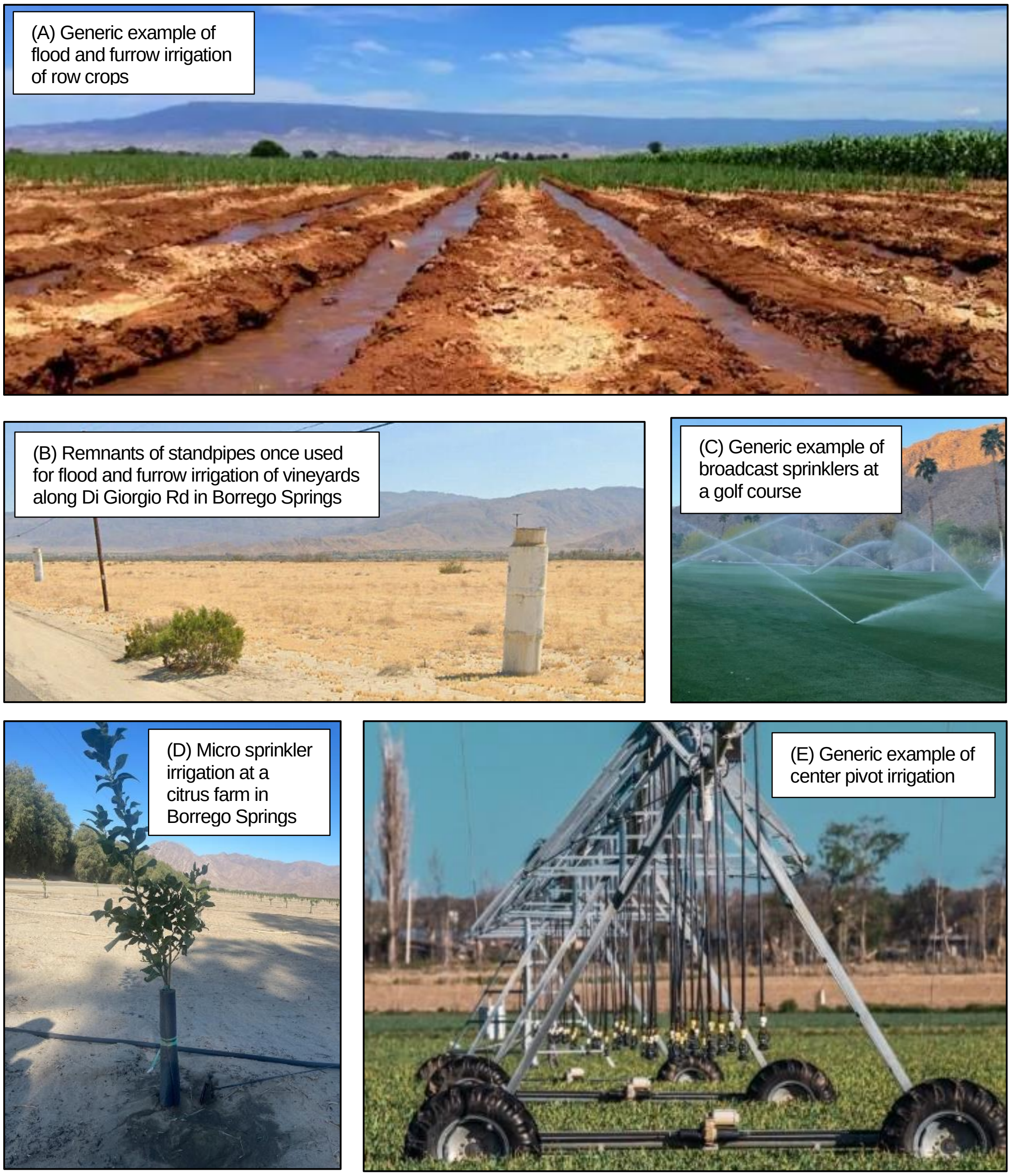


Figure 3. Irrigation Methods Employed in Borrego Springs



(A) Generic example of flood and furrow irrigation of row crops

(B) Remnants of standpipes once used for flood and furrow irrigation of vineyards along Di Giorgio Rd in Borrego Springs

(C) Generic example of broadcast sprinklers at a golf course

(D) Micro sprinkler irrigation at a citrus farm in Borrego Springs

(E) Generic example of center pivot irrigation

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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From: John Peterson <petersonenv@hotmail.com>
Sent: Saturday, March 16, 2024 12:16 PM
To: Andy Malone; Lauren Salberg; Samantha Adams; Jim Bennett
Cc: Jim Dax
Subject: Re: Preparatory Work for Task 4 - Model Recalibration

Thanks for that Andy. Just FYI: I will continue to monitor the progress as well as attend the meetings. However I really am a "old school" hydrogeologist and do not have a technical background in computer modeling. When I was first starting to take my technical courses we were just out of using slide rulers!

As such I will be taken a backseat on this process. I need to defer to those professionals who have experience in computer modeling.

Just FYI.

Also in regard to the groundwater monitoring network I am finding myself consumed by the time required being the new chair of the Sponsor Group. As a result I will be "slowing" my volunteer efforts in this area. Only so much volunteer time available and right now it is getting eaten up by being the chair of the group. Still trying to leave time to play some golf once in awhile.

JP

John Peterson
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From: Andy Malone <amalone@westyost.com>
Sent: Friday, March 15, 2024 6:10 PM
To: Lauren Salberg <lsalberg@westyost.com>; Samantha Adams <sadams@westyost.com>; Jim Bennett <PDS.LUEGGroundWater@sdcounty.ca.gov>; John Peterson <petersonenv@hotmail.com>; Robert Wagner <rcwagner@wbecorp.com>; Tom Watson <tom.watson@aquilogic.com>; Trey Driscoll <tdriscoll@intera.com>; Russ Detwiler <detwiler@uci.edu>
Subject: Preparatory Work for Task 4 - Model Recalibration

Lauren Salberg

From:	LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>
Sent:	Friday, March 22, 2024 1:02 PM
To:	Andy Malone; Lauren Salberg; Samantha Adams; LUEG, GroundWater, PDS; John Peterson; Robert Wagner; Tom Watson; Trey Driscoll; Russ Detwiler
Subject:	RE: Preparatory Work for Task 4 - Model Recalibration

Hi Andy, Lauren, and Samantha,

The County has no comments regarding the memo "Preparatory work for Task 4 – Model Recalibration." We appreciate the continued efforts West Yost is making.

Have a great weekend everyone!

Jim Bennett, P.G., C.HG.
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From: Andy Malone <amalone@westyost.com>
Sent: Friday, March 15, 2024 6:10 PM
To: Lauren Salberg <lsalberg@westyost.com>; Samantha Adams <sadams@westyost.com>; LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>; John Peterson <petersonenv@hotmail.com>; Robert Wagner <rcwagner@wbecorp.com>; Tom Watson <tom.watson@aquilogic.com>; Trey Driscoll <tdriscoll@intera.com>; Russ Detwiler <detwiler@uci.edu>
Subject: [External] Preparatory Work for Task 4 - Model Recalibration

TAC Members,

Please find attached a memorandum titled: ***Preparatory Work for Task 4 – Model Recalibration***.

This memo describes the preparatory work that has been performed by West Yost for BVHM recalibration to support the *2025 Redetermination of the Sustainable Yield*. The memo includes sections on:

- **Version of the BVHM to Recalibrate**
- **Model Calibration Targets and Data**
- **Pilot Points and Adjustable Model Parameters**
- **Historical On-Farm Efficiencies**

The memo is bookmarked and linked for easy navigation. We are soliciting your input and suggestions before we proceed with the model recalibration.

Lauren Salberg

From: Trey Driscoll <tdriscoll@intera.com>
Sent: Friday, March 22, 2024 2:51 PM
To: LUEG, GroundWater, PDS; Andy Malone; Lauren Salberg; Samantha Adams; John Peterson; Robert Wagner; Tom Watson; Russ Detwiler
Subject: RE: Preparatory Work for Task 4 - Model Recalibration

Hi Lauren,

Appreciate the update on the model recalibration efforts. INTERA offers the following high-level comments:

1. Open ET is about to release data back to about 1985 that may inform historical water use. Our current understanding is that the data is planned to be released around May 1, 2024. We think this may be important data to evaluate historical water consumption for ag, recreation, and native plants.
2. The updated water budget for 1945 to 2022 is for the entire model domain including areas outside of the Subbasin boundary as defined by Bulletin 118. Have you considered how to address the discrepancy in the boundaries as briefly discussed at previous TAC meetings (e.g., Zone Budget)?

Considering our comments are high-level and that the updated OpenET data is currently not available, we think that May 1st works as a good date to check in on model recalibration progress. It will also be more informative to review some recalibration results in May to provide additional input at that time.

Let me know if you have any questions or require further discussion.

Thank you and have a fantastic weekend y'all!

Cheers,
Trey
760.415.1425

From: LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>
Sent: Friday, March 22, 2024 1:02 PM
To: Andy Malone <amalone@westyost.com>; Lauren Salberg <lsalberg@westyost.com>; Samantha Adams <sadams@westyost.com>; LUEG, GroundWater, PDS <PDS.LUEGGroundWater@sdcounty.ca.gov>; John Peterson <petersonenv@hotmail.com>; Robert Wagner <rcwagner@wbecorp.com>; Tom Watson <tom.watson@aquilogic.com>; Trey Driscoll <tdriscoll@intera.com>; Russ Detwiler <detwiler@uci.edu>
Subject: RE: Preparatory Work for Task 4 - Model Recalibration

Hi Andy, Lauren, and Samantha,

The County has no comments regarding the memo "Preparatory work for Task 4 – Model Recalibration."
We appreciate the continued efforts West Yost is making.

Have a great weekend everyone!

Lauren Salberg

From: Tom Watson <tom.watson@aquilogic.com>
Sent: Saturday, March 23, 2024 9:29 AM
To: Robert Wagner; Andy Malone; Lauren Salberg; Samantha Adams; Jim Bennett; John Peterson; Trey Driscoll; Russ Detwiler
Cc: Dave Peterson; Leonardo Urrego-Vallowe; Bob Abrams
Subject: RE: Preparatory Work for Task 4 - Model Recalibration

Andy,
Bob Abrams and I also look forward to the discussion on 3/29.
Best,
Tom

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Keep it green, read from the screen
Privileged & Confidential, Attorney Work Product

From: Robert Wagner <rcwagner@wbecorp.com>
Sent: Friday, March 22, 2024 3:58 PM
To: Andy Malone <amalone@westyost.com>; Lauren Salberg <lsalberg@westyost.com>; Samantha Adams <sadams@westyost.com>; Jim Bennett <PDS.LUEGGroundWater@sdcounty.ca.gov>; John Peterson <petersonenv@hotmail.com>; Tom Watson <tom.watson@aquilogic.com>; Trey Driscoll <tdriscoll@intera.com>; Russ Detwiler <detwiler@uci.edu>
Cc: Dave Peterson <dpeterson@wbecorp.com>; Leonardo Urrego-Vallowe <lurrego@wbecorp.com>
Subject: Re: Preparatory Work for Task 4 - Model Recalibration

Andy and Lauren; Thank you for the opportunity to comment on the Preparatory Work for Task 4 – Model Recalibration Technical Memorandum. We look forward to discussing this next Friday, March 29th. Also, please copy Leonardo Urrego-Vallowe on all future correspondence related to the TAC.

Thank you,

Bob

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David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

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

From: Robert Wagner, P.E and A. Leonardo Urrego-Vallowe, EIT

Date: March 22, 2024

Re: **Comments on Technical Memorandum "Preparatory Work for Task 4 – Model Recalibration"**

This memo provides response to the comments requested by Watermaster Technical Consultant on March 15, 2023 with regard to the technical memorandum titled ***Preparatory Work for Task 4 – Model Recalibration*** (West Yost TM).

In **Task 2 BVHM –** ***Updated Water-Use Factors***, water-use factors (crop coefficients and irrigation efficiencies) used in the FMP were updated by removing scaling factors developed by the United States Geological Survey (USGS) during the initial development of the BVHM. The reason for this reevaluation is because the FMP significantly underestimated groundwater pumping.

As explained in the West Yost TM, Watermaster Consultant performed ***Task 4 Pre-Calibrated BVHM*** from Water Year (WY) 1945 to 2022. In this model run, Watermaster Consultant:

- Used the initial (unscaled) water-use factors in the FMP to provide more realistic values of groundwater pumping in WY 2021 and 2022.
- Corrected all the errors and discrepancies in the input files that were found in the previous version of the model.

The West Yost TM prepared a water budget from the output of the ***Task 4 Pre-Calibrated BVHM*** from WY 1945 to 2022. West Yost then compared the FMP-estimated pumping (modeled pumping) with the actual pumping for WY 2021 and 2022. The West Yost TM concluded that the difference between actual (metered) pumping and modeled pumping was less significant than the output from the previous model run (referred to as **Task 1 2022 BVHM** in the West Yost TM). We prepared a table based on West Yost TM that evaluates the ability of the model to predict total metered pumping for FMP-wells and for non-FMP wells (see **Table 1**).

Table 1. Comparison of updated FMP-estimated pumping to the Actual Pumping for WYs 2021 and 2022.

	Total Metered Pumping			Task 4 *Pre-Calibrated BVHM* Modeled Pumping		Difference between Actual Pumping and Modeled Pumping			
Water Year	Total BPA Parties	FMP Wells	Non-FMP Wells	FMP Wells	Non-FMP Wells	FMP Wells		Non-FMP Wells	
2021	15,221	12,857	2,364	11,625	1,720	1,232	9.6%	644	72.7%
2022	13,038	10,863	2,175	10,551	1,518	312	2.9%	657	69.8%

Notes:
[a] All values are provided in acre-feet.
[b] Total Metered Pumping from Non-FMP Wells = Total Pumping BPA Parties – Total Metered Pumping from FMP Wells.

According to **Table 1**, the model continues to underestimate groundwater pumping despite the use of the initial KC values (derived from literature) and the proposed OFE values derived from the ranges recommended by Howell (2003), interviews with farmers in the Basin, and the remains of historical irrigation infrastructure.

The water budget prepared by West Yost for the ***Task 4 Pre-Calibrated BVHM*** suggests that the update on the water-use factors continues to be inaccurate given that the model does not predict groundwater pumping for either FMP wells or non-FMP wells.

Based on the model outputs from ***Task 4 Pre-Calibrated BVHM***, the FMP underestimates the actual pumping in FMP wells by 10% in WY 2021 and by 3% in WY 2022 (see **Table 1**). Despite that the percentage of differences are smaller than in the previous model run (**Task 1 2022 BVHM**), the combination of KC and OFE values selected for this model run seem to match the actual pumping for WY 2022 but fails to replicate the realistic conditions for WY 2021. This suggests that the problem is not the KC and OFE values but rather the use of the traditional crop coefficient methodology itself.

We believe that the use of water-use factors in the FMP yield unrealistic results. Using the KC values is a theoretical methodology for planning purposes when developing a crop. Therefore, KC values and OFE values are not representative of the actual conditions of the Valley in the present time (and historical conditions are also still unknown).

Inaccuracy in the irrigation demand calculated via the water-use factors

As explained in West Yost TM, the FMP estimates the volume of groundwater pumping using the following equation:

$$GW = \frac{ET_0 * KC * Area}{OFE} - P - RU$$ (Equation 1 from WestYost TM)

The FMP relies on the product of crop coefficient (KC), reference evapotranspiration (ETo), and the area of the crop, divided by the irrigation efficiency (OFE). In Equation 1, crop demand is defined as

$$crop\ demand = \frac{ET_0 * KC * Area}{OFE}$$

As shown on Equation 1, groundwater pumping is calculated as the crop demand minus the precipitation (P) and the root uptake of shallow groundwater (RU) available to meet the crop demand. We expect both terms P and RU to be significantly low given the desert conditions of the Valley. Therefore, crop demand is the driven factor in the calculation of groundwater pumping.

Application of water-use factors (aka traditional crop coefficient method) depends on two variables with high level of uncertainty: KC and OFE. The West Yost TM proposes the use of historical OFEs for the irrigated BVHM cells. Despite the range of values derived from the literature review and the evaluation of historical infrastructure of irrigation systems used in the past, these two factors remain unknown for the Borrego Valley.

The traditional crop coefficient method employed by the FMP assumes that KC is the same for each specific crop and, in the case of orchards, it fails to account for variation in the amount of vegetation and crop height that can vary from year to year, and other factors such as the stomatal leaf resistance, vegetation density, tree training and management practices that vary from grower to grower (Hendrickx & Wagner, 2022).

We understand the time constraints for the current recalibration, however we suggest the use of satellite-based image processing models that are publicly available on the OpenET platform for future analyses. These processing tools calculate actual crop demand by applying an energy balance at the earth's surface. Advantages of the energy-based models over the traditional crop coefficient method is that they are completely independent of the crop type, the crop stages, irrigation practices, and irrigation efficiencies (OFE). Therefore, the water demand from the satellite-based algorithms removes the uncertainty encountered by the traditional crop coefficient method.

Comparative example for an irrigated field

This section presents an example of the application of the crop coefficient method vs. the results from OpenET to compute crop water demand. An evaluation of a 109-acre citrus field located at latitude 33.306326, longitude -116.374417 (see **Figure 1**) reveals actual water use in the field during recent years 2021, 2022 and 2023.

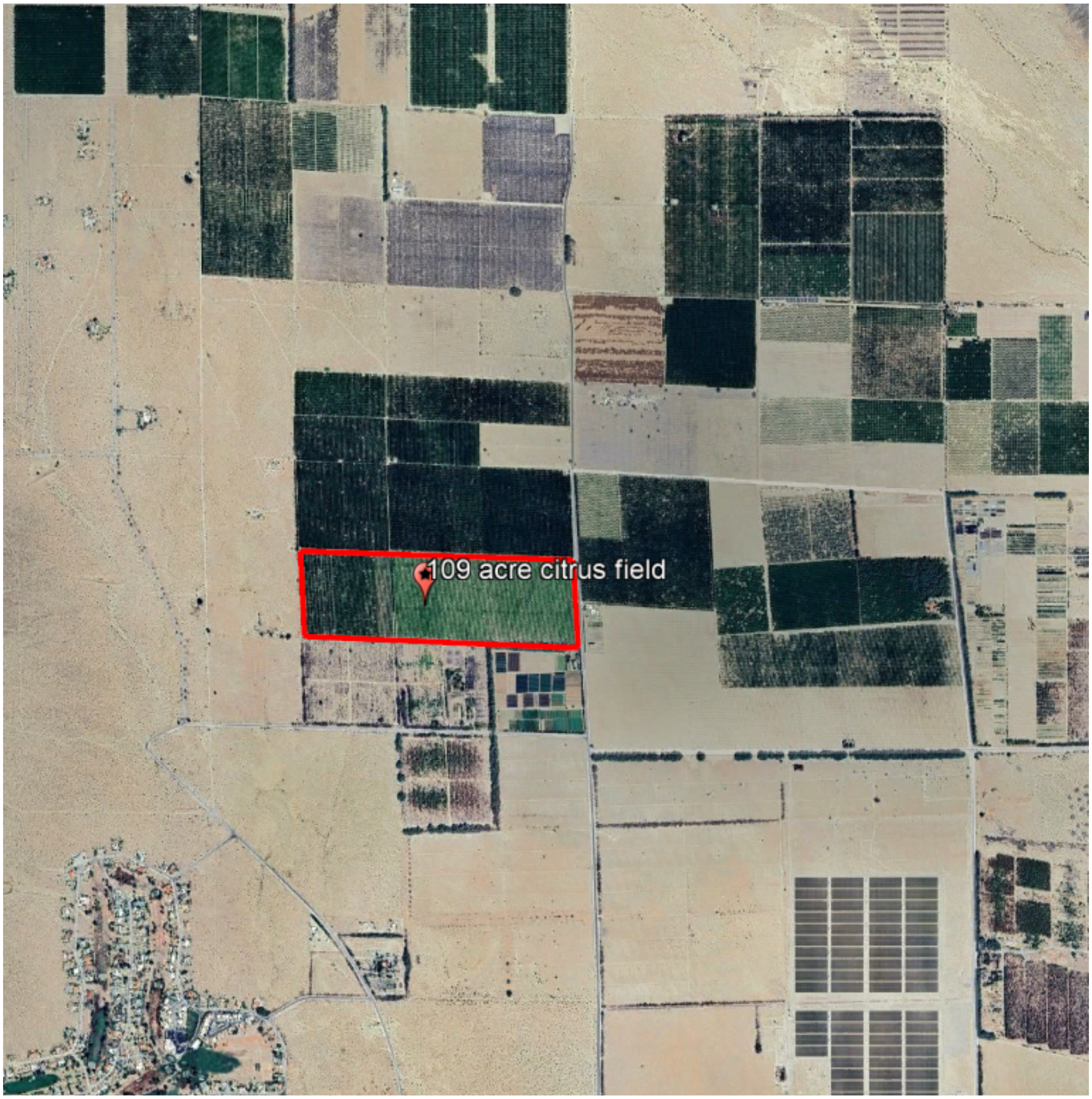

Figure 1. Location of 109-acre citrus field in Borrego Springs.

Table 2 is a comparison of the water crop demand using OpenET (actual water demand) vs. theoretical demand using the traditional crop coefficient for the most recent years. According to the results, the crop coefficient method yields water use values higher than the actual water use. The large errors shown on **Table 2** demonstrate that the crop coefficient yields a theoretical optimal crop water use that is not realistic because it does not capture the reduction of water use by the farmers.

Table 2. Comparison of crop water demand estimates between OpenET and the traditional crop coefficient methodology.

Year	OpenET [a]	Crop coefficient [b]	% Difference
2021	251	482	91.8%
2022	265	401	51.4%
2023	216	451	109.0%

Notes:
[a] Open ET data are generated using the METRIC methodology.
[b] Initial KC value of 0.65 for citrus (Table 1 of Task 2 technical memorandum) and OFE of 0.78 for micro-irrigation (Table 3 from West Yost TM).

The use of the KC factors is for well-watered agricultural crops and does not include any reductions due to water stress or other factors such as reduced density (Jensen & Allen, 2016).

By adjusting the KC and OFE values, the Watermaster Consultant proposes to find the KC and OFE combination that would closely match with the metered pumping, however the actual crop demand remains unknown and therefore, the historical pumping prior to the meters will also be unknown. Given that those KC values are from literature, they do not represent the real conditions in the Borrego Springs Valley. As shown in the example above, the initial KC value assigned to citrus crops is 0.65 (uniformly applied value for every month of the year and for all citrus crops in the Valley), which yielded the unrealistic results provided in **Table 2**.

The crop coefficient method worked quite well to design large irrigation projects in the 1900s but is not a proper method to manage water resources in a period of drought. We recommend the use of the recently developed technology (OpenET) to estimate the crop demand in lieu of the traditional crop coefficient method. OpenET captures the variability in the crop water demand in different years as demonstrated on **Table 2**. This will eliminate the uncertainty that the model has been carrying over, in particular the uncertainty of the water-use factors. The FMP-methodology needs to be redefined to incorporate OpenET data into the calculation (Equation 1).

Comments on Wells used to Recalibrate the BVHM by Aquifer Layer

Figure 1 of the West Yost TM provides the location of the 85 wells with groundwater elevation data that will be used for recalibration of the BVHM. This figure also identifies the aquifer layer where each well screen is located. Out of 85 wells, 21 are shown as “unknown” aquifer layer. It is recommended to investigate how these 21 wells will be modeled in the recalibration of the BVHM without information about their aquifer layer.

Comments on Calibration Data Hydrographs

Appendix A of West Yost TM provides time-series charts of groundwater-elevation data for 85 wells that will serve as calibration targets. West Yost proposes to use the calibration targets selected from groundwater elevation historical measurements.

- From the figures presented in the West Yost TM, some wells have historical groundwater levels for long periods of time whereas some wells have measurements for only one or two measurements (several years ago). We recommend that West Yost uses wells with relatively long periods of time in the recalibration effort because these will be more representative of historical conditions.
- We noticed that for most of the wells, measured groundwater elevations are generally lower than simulated groundwater levels. To calibrate the model, Watermaster Consultant may require adjusting recharge or aquifer properties (specific yield or hydraulic conductivity) to have the simulated water levels match the observed historical groundwater levels. However, none of these factors are supported by the data. Watermaster Consultant needs to document what changes will be made to the model during the calibration given that long term average natural inflows and outflows are constant, and metered pumping and measured groundwater elevations are the best available data.
- In addition, please include the simulated groundwater levels in Figure A-18 for well named "Army Well".
- Groundwater levels for some wells show a high variability in their elevation measurements (see figures A-68, A-69, and A-70 in West Yost TM). For instance, Figure A-69 well named "RH-3" shows measured groundwater levels ranging from 75 to 140 feet. Groundwater levels seem to be measured with high frequency each year. In general, target groundwater levels for these wells appear to be selected arbitrarily (usually elevated points). However, this needs to be investigated in more detail and West Yost should document the strategy or criteria being used to define target groundwater levels (e.g., annual average of the measurements, only measurements taken in the Spring, highest annual elevations, etc.) and maintain this methodology for consistency.

Closing

We think it would useful to have the Ad-Hoc TAC meeting scheduled for March 29, 2024 at 10:00 am in order to discuss the recalibration methods and available data for analysis. We look forward to that discussion.

Works Cited

Hendrickx, J., & Wagner, R. (2022). *Water Requirements of Jujube Trees in the Mojave Basin* (unpublished consultant's report).

Jensen, M. E., & Allen, R. G. (2016). *Evaporation, evapotranspiration, and irrigation water requirements: Task Committee on Revision of Manual 70.* American Society of Civil Engineers (ASCE).