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Date: APR 25 2017
Refer To: ADEM-17-0088
LAUR: 17-23263
Locates Action No.: U1600104_03

John Kieling, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Chromium Extraction Well Evaluation Report and Recommendations for CrEX-2

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Chromium Extraction Well Evaluation Report and Recommendations for CrEX-2. The document satisfies Appendix B, Milestones and Targets, Milestone 10, of the 2016 Compliance Order on Consent.

If you have any questions, please contact Stephani Swickley at (505) 606-1628 (sfuller@lanl.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
Los Alamos National Laboratory

Sincerely,

David S. Rhodes, Director
Office of Quality and Regulatory Compliance
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Field Office

BR/DR/SS:sm

Enclosures: Two hard copies with electronic files – Chromium Extraction Well Evaluation Report and Recommendations for CrEX-2 (EP2017-0065)

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LA-UR-17-23263
May 2017
EP2017-0065

Chromium Extraction Well Evaluation Report and Recommendations for CrEX-2

Los Alamos
NATIONAL LABORATORY
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Prepared by the Associate Directorate for Environmental Management

EP2017-0065

Chromium Extraction Well Evaluation Report and Recommendations for CrEX-2

May 2017

Responsible project manager:

for Stephani Swickley	[signature]	Project Manager	Environmental Remediation Program	4/20/2017
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CONTENTS

Figures

Tables

Appendixes

1.0 INTRODUCTION

This report presents an analysis of relevant data to support the evaluation of chromium extraction CrEX-2 for the "Interim Measure Work Plan for Chromium Plume Control" in accordance with a requirement of the New Mexico Environment Department's (NMED's) approval with modifications letter, dated October 15, 2015 (LANL 2015, 600458; NMED 2015, 600959). A drilling work plan for an additional extraction well, CrEX-2, was submitted by the U.S. Department of Energy and Los Alamos National Security (DOE/LANS) to the NMED on February 13, 2017, and was subsequently approved by NMED on February 20, 2017 (LANL 2017, 602160; NMED 2017, 602181). This report presents the evaluation of water-level responses at monitoring wells within the chromium plume primarily from pumping at CrEX-1 and CrEX-3. The evaluation specifically addresses how CrEX-2 will support the objective of the interim measure (IM).

The primary objective of the IM is to achieve hydraulic control of off-site plume migration via a combination of extraction and injection of treated groundwater. Extraction has been occurring for limited durations (up to approximately 2 continuous months) in 2016 at the IM extraction well, CrEX-1, and at plume-center characterization well, CrEX-3. The analysis conducted in this report incorporates pumping results from both of the existing extraction wells because both provide treated water to use in IM injection wells CrIN-1 through CrIN-5. A sixth injection well, CrIN-6, is scheduled to be installed by summer 2017 (Figure 1.0-1).

Modeling indicates that injection of treated water plays a major role in controlling the downgradient edge of the plume. The amount of water currently available from CrEX-1 and CrEX-3 for disposition into injection wells is approximately 140–150 gallons per minute (gpm), equating to a nominal 25 gpm into each of the six injection wells. Because of the importance of injection in meeting the IM objective, an additional volume provided by CrEX-2 will likely help achieve the primary objective of the IM, hydraulic control of plume migration. Another key purpose that drives the need and proposed location of CrEX-2 is to capture chromium flux in a portion of the plume as identified by samples collected from piezometer CrPZ-1. Nearby piezometer CrPZ-1 shows chromium concentrations consistently above 400 ppb.

The evaluation presented in this report includes a modeling analysis conducted using the Theis approach for evaluating water-level responses to extended pumping at extraction wells and limited pumping at newly installed injection wells and existing monitoring wells in 2016. The details of the Theis analyses are provided in Appendix A of this report.

2.0 EVALUATION OF PUMPING DATA

2.1 Drawdown Analysis of Pumping in the Plume Area

A drawdown analysis was conducted to assess the effects of extended-duration pumping in 2016 at extraction wells CrEX-1 and CrEX-3 and shorter-term pumping at CrIN-1, CrIN-2, CrIN-3, CrIN-4, CrIN-5, R-28, and R-42. The primary objective of this modeling analysis is to evaluate aquifer properties in the plume area and to conduct a preliminary evaluation of the effects of pumping at a new extraction well, CrEX-2, with respect to the IM objective. This evaluation used estimates for hydrogeological properties in the CrEX-2 area that are based on the model because CrEX-2 is still under construction and the specific hydraulic data surrounding the well are not yet available.

Table 2.0-1 summarizes the pumping activities conducted in 2016. Pumping at CrEX-1 was conducted in support of the IM for plume control, and pumping at CrEX-3 was conducted as part of the plume-center characterization activities. Pumping at CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 was conducted as a part of well development and pumping tests following installation of each of the wells. Wells R-28 and R-42 were pumped in relation to the field tracer-test activities. For some of the wells, the pumps were shut off intermittently for various reasons, including maintenance and completion of infrastructure elements at the wells. Approximate average pumping rates are also shown in Table 2.0-1 for periods when the wells were pumping. The evaluated pumping period occurred from May 31 to December 21, 2016. Figure 2.1-1 shows daily average pumping rates in 2016, and Figure 2.1-2 shows the pumping rates in 2016 along with pump activities from previous years. During the tests, the water levels were observed at the following locations: CrEX-1, CrEX-3, CrPZ-1, CrPZ-2, CrPZ-3, CrPZ-4, CrPZ-5, R-1, R-11, R-13, R-15, R-28, R-33, R-35a, R-35b, R-36, R-42, R-43, R-44, R-45, R-50, R-61, R-62, and SIMR-2.

A key observation that can be made from the analysis presented in Appendix A of this report is that water-level responses at the observation wells from pumping at the two extraction wells is moderate to very small. Maximum drawdowns observed during the 2016 CrEX-1 and CrEX-3 pumping are generally less than 20 cm and are not uniform in the plume area. These are maximum drawdowns observed from relatively limited pumping in 2016. Longer-term continuous pumping at CrEX-1and CrEX-3 is expected to produce larger drawdowns at the monitoring wells. An elongated area of preferential, but limited, drawdown is observed generally westward from the two extraction wells (Figure 2.1-3). These depicted drawdown areas are based on data from single-screen wells and the upper screens in two-screen wells, and therefore, the figure presents somewhat of a two-dimensional perspective. Some preferential drawdown was observed in deeper screens within the monitoring network (e.g., the drawdown in R-50 screen 2 caused by pumping at CrEX-1). Monitoring locations CrPZ-5 and R-15 are not shown inside the 0.1-m contour line in Figure 2.1-3 because of the low confidence in the estimated values for those locations. Longer-term pumping may also provide additional insights into the nature of drawdowns at those monitoring locations.

An area of elevated chromium concentrations in the regional aquifer in the location of proposed CrEX-2 has been determined based on samples collected from piezometer CrPZ-1. It is likely this represents an area of potentially significant chromium mass and/or ongoing arrival into the regional aquifer from the vadose zone at or upgradient of CrPZ-1. Pumping influences from CrEX-1 and CrEX-3 do not appear to reach into that area. Pumping at CrEX-2 is likely to provide important control for chromium mass flux in that area and therefore provides significant benefit to meeting the IM objective.

2.2 Modeling Analysis of Plume Performance.

Modeling was also conducted to evaluate the potential benefit to the IM objective because of the combination of pumping and injection of the additional water volume that will be available from CrEX-2. To conduct this evaluation, two scenarios are modeled and presented here. The first scenario assumes only existing extraction wells CrEX-1 and CrEX-3 are pumping at 80 and 70 gpm, respectively. Under this scenario, the available 150 gpm is distributed into six injection wells at 25 gpm per well. Figure 2.2-1 shows a modeled estimate of the plume edge after approximately 3 yr of extraction and injection under this scenario. Figure 2.2-2 shows the modeled estimation of the plume edge after approximately 3 yr of extraction and injection under a scenario that includes extraction at CrEX-1, CrEX-2, and CrEX-3 at 80, 60, and 70 gpm, respectively. Under this scenario, the available 210 gpm is distributed into the injection wells as follows: 35 gpm at CrIN-1, 35 gpm in CrIN-2, 25 gpm in CrIN-3, 40 gpm at CrIN-4, 40 gpm at CrIN-5, and 35 gpm at CrIN-6. These modelling results indicate the plume footprint is smaller in the area south of CrEX-2 with CrEX-2 pumping at 60 gpm. Plume control generally occurs from the combination of extraction and injection, although injection probably plays a lesser role than extraction in the area south of CrEX-2 because of limits on the upgradient reach of injected water in CrIN-5. If CrEX-2 can pump at rates greater than 60 gpm, the additional volume in this second scenario could be used to optimize injection strategies to favorably affect plume response. Operational scenarios for injection are expected to change over time based on observations at nearby performance monitoring wells (e.g., R-44, R-45, and R-50) and to accommodate periodic well rehabilitation.

3.0 PLUME RESPONSE TO PUMPING AT EXTRACTION WELLS

Monitoring has been consistently conducted at the extraction wellheads and at nearby monitoring wells. Figure 3.0-1 shows the time-series of chromium concentrations at CrEX-1 and CrEX-3 for continuous periods of pumping in 2015 and 2016, as applicable. For both of these wells, the chromium concentrations have stayed relatively steady throughout the pumping period. It is likely that pumping within the 50-ft screens in each of these wells at the relatively high pumping rates is effectively characterizing an integration of hydraulically variable strata within different chromium concentrations. In contrast, monitoring well R-28, located approximately 150 ft north of CrEX-3, shows an apparent response in contaminant trends related to an extended, but still relatively short, period of pumping at CrEX-3 or possibly CrEX-1 (Figure 3.0-2). The concentration of four representative plume constituents (chloride, nitrate, sulfate, and chromium) in R-28 initially dropped following injection of tracer and clean “chase” water on September 29, 2016 (Time=0). Concentrations of the same four constituents increased to levels above the T=0 concentrations as tracer and chase water drifted away from the well, and “ambient” plume conditions returned. Increases over the “time-zero” concentrations (Co) shown in Figure 3.0-2 as C/Co values greater than 1 may have been caused by pumping at nearby CrEX-3. It is possible that pumping at CrEX-3 and/or CrEX-1 has influenced the groundwater flow direction in the R-28 area and is pulling a zone with higher chromium concentrations into the flow path accessed in the R-28 well screen.

Monitoring is ongoing within wells in and downgradient of the chromium plume area. Several of the wells, including R-50 screens 1 and 2; R-45, screens 1 and 2; R-44, screens 1 and 2; and SIMR-2 are currently sampled monthly. Additional insights into plume response are expected when all three extractions wells are pumping and all six injection wells are operating.

Even though mass removal is not a direct measure of plume response or IM performance, it can be informative to estimate the mass of chromium removed during these pumping activities. For these estimates, the pumping periods presented in Table 2.0-1 are used. To simplify the calculations, it is also assumed pumping occurred for the entire day at the beginning and end of each discrete pumping period. For both wells, a concentration of 170 µg/L chromium is used for the mass removal estimates based on the time-series plots shown in Figure 3.0-1. For CrEX-1, a pumping rate of 75 gpm is used for the estimates, and for CrEX-3, a pumping rate of 40 gpm is used. The estimated chromium mass removed in 2016 from CrEX-1 was 4.9 kg (10.8 lb). The estimated mass removed from CrEX-3 was 3.8 kg (8.4 lb). The total estimated mass of chromium present in the regional aquifer is currently being reevaluated using the significant addition of information available from the corehole piezometers and injection wells. A previous estimate of 555 kg (1224 lb) was reported in the “Investigation Report for Sandia Canyon” (LANL 2009, 107453). More recent unpublished studies suggest potentially more than 555 kg of chromium is present in the regional aquifer. Future reports will document the updated estimates.

4.0 CONCLUSIONS

Based on the drawdown evaluation of pumping effects specifically related to pumping at CrEX-1 and CrEX-3 and the model analysis for plume performance with and without CrEX-2, it is anticipated that CrEX-2 will enhance attainment of the primary objective of the IM to control migration of the downgradient portion of plume. As of the date of this report, CrEX-2 is under construction and is expected to be available for continuous pumping, with associated treatment and injection, by September 2017.

5.0 REFERENCES AND MAP DATA SOURCES

5.1 References

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ERID or ESHID. This information is also included in text citations. ERIDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESHIDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the ESH Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), October 2009. "Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-09-6450, Los Alamos, New Mexico. (LANL 2009, 107453)

LANL (Los Alamos National Laboratory), May 2015. "Interim Measures Work Plan for Chromium Plume Control," Los Alamos National Laboratory document LA-UR-15-23126, Los Alamos, New Mexico. (LANL 2015, 600458)

LANL (Los Alamos National Laboratory), February 13, 2017. "Drilling Work Plan for Groundwater Extraction Well CrEX-2," Los Alamos National Laboratory letter ADEM-17-0027 to J. Kieling (NMED-HWB) from B. Robinson (LANL) and D. Rhodes (DOE-EM-LA), Los Alamos, New Mexico. (LANL 2017, 602160)

NMED (New Mexico Environment Department), October 15, 2015. "Approval with Modifications, Interim Measures Work Plan for Chromium Plume Control," New Mexico Environment Department letter to D. Hintze (DOE-NA-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2015, 600959)

NMED (New Mexico Environment Department), February 20, 2017. "Approval [for the] Drilling Work Plan for Groundwater Extraction Well CrEX-2," New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2017, 602181)

5.2 Map Data Sources

Point features; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder 15-0059;\\slip\gis\GIS\Projects\14-Projects\14-0062\project_data_NEPA_plate.gdb;merge_all_well_features; 2017

Drilling azimuth from well to well screen; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder; \\slip\gis\GIS\Projects\16-Projects\16-0027\project_data.gdb; azimuth_bearing; 2017

Drainage channel; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder; \\slip\gis\GIS\Projects\11-Projects\11-0108\gdb\gdb_11-0108_generic.mdb; drainage; 2017

Paved Road Arcs; Los Alamos National Laboratory, FWO Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010

Paved Parking; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 12 August 2002; as published 29 November 2010

Unpaved road; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder; \\slip\gis\GIS\Projects\14-Projects\14-0062\project_data.gdb; digitized_site_features; digitized_road; 2017

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010

LANL Areas Used and Occupied; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 13 August 2010

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 13 August 2010

Hillshade; Los Alamos National Laboratory, ER-ES, As published; \\slip\gis\Data\HYP\LiDAR\2014\Bare_Earth\BareEarth_DEM_Mosaic.gdb; 2014

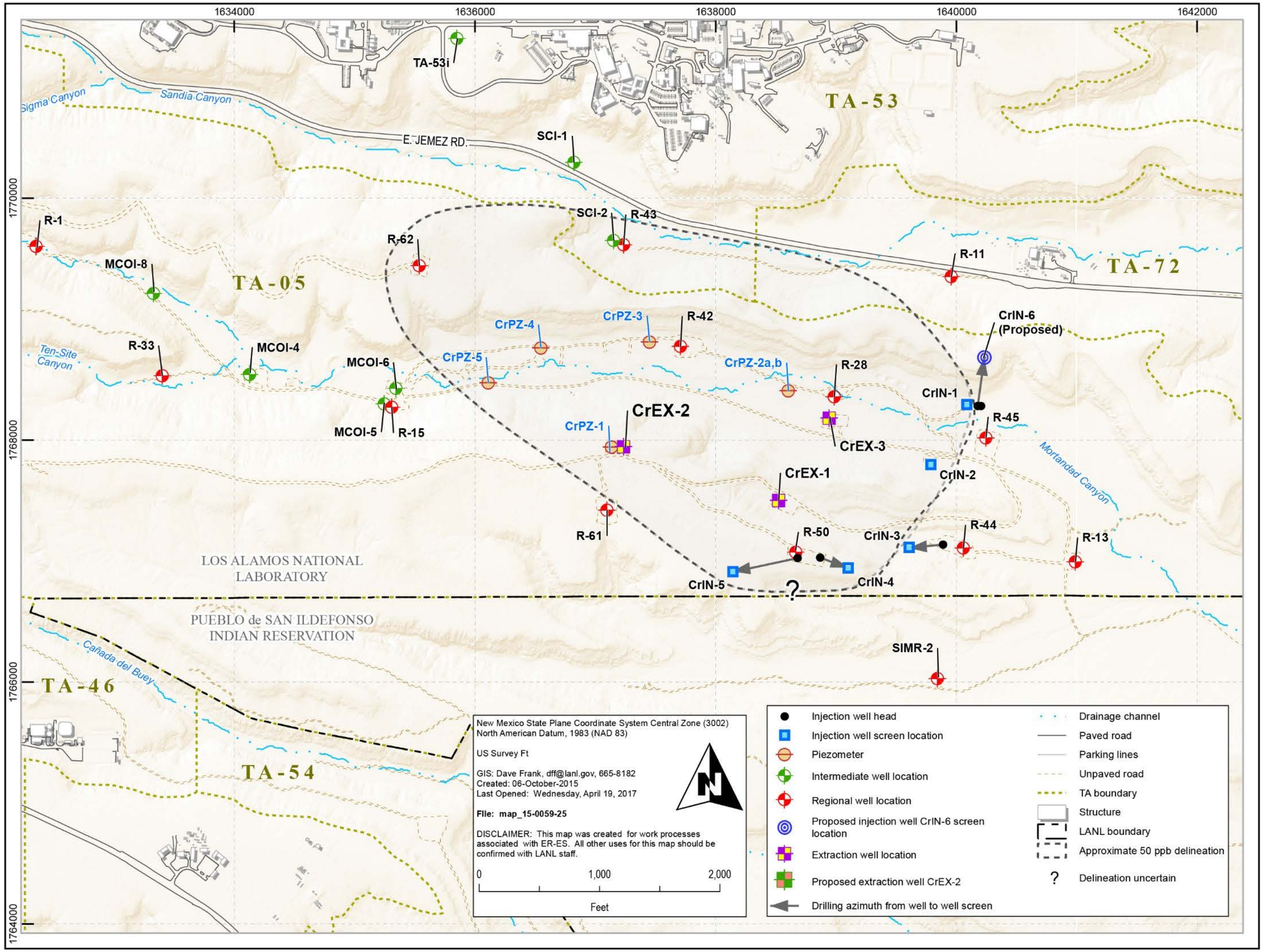


Figure 1.0-1 Injection, extraction, and monitoring wells in the area of the chromium plume

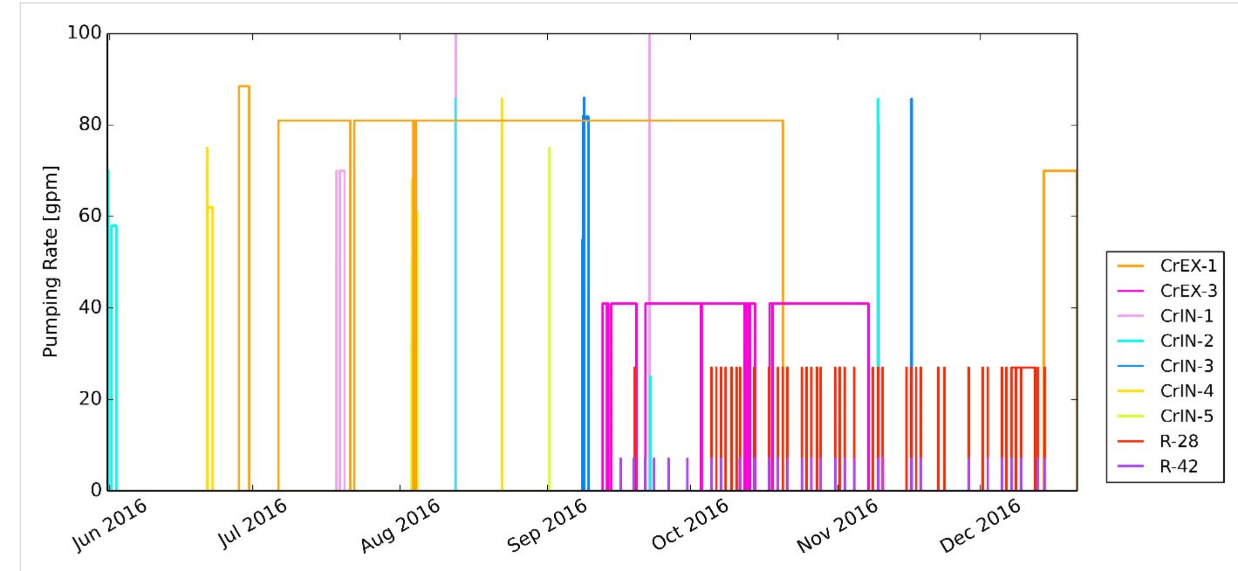


Figure 2.1-1 Record of daily average pumping rates (gpm) in 2016

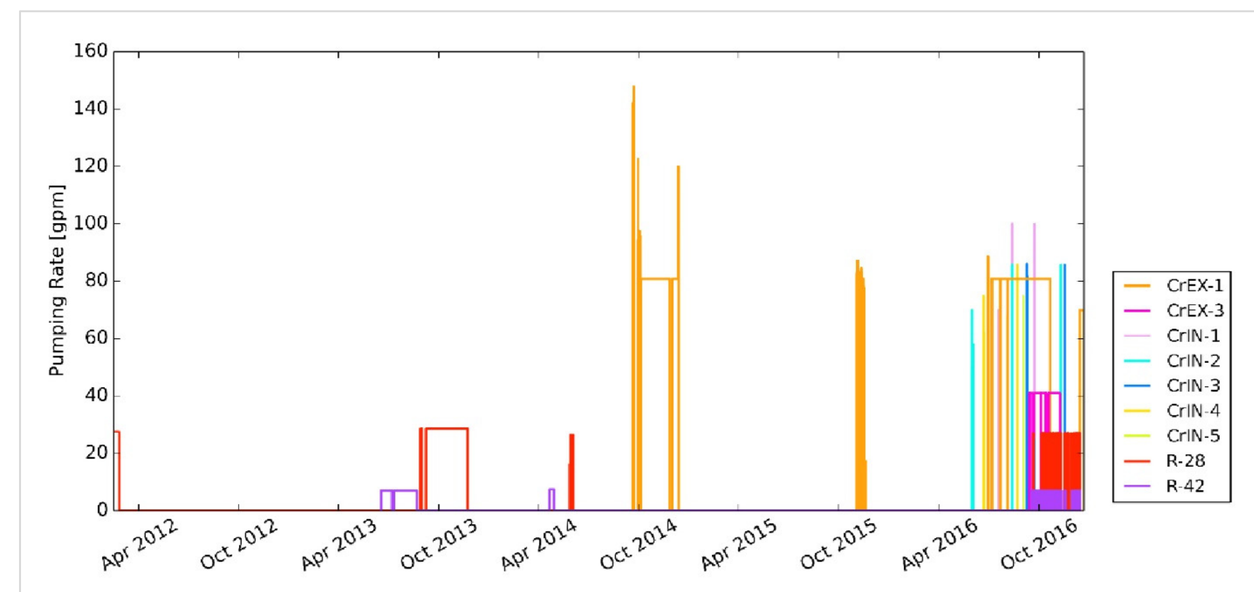


Figure 2.1-2 Full record of daily average pumping rates (gpm)

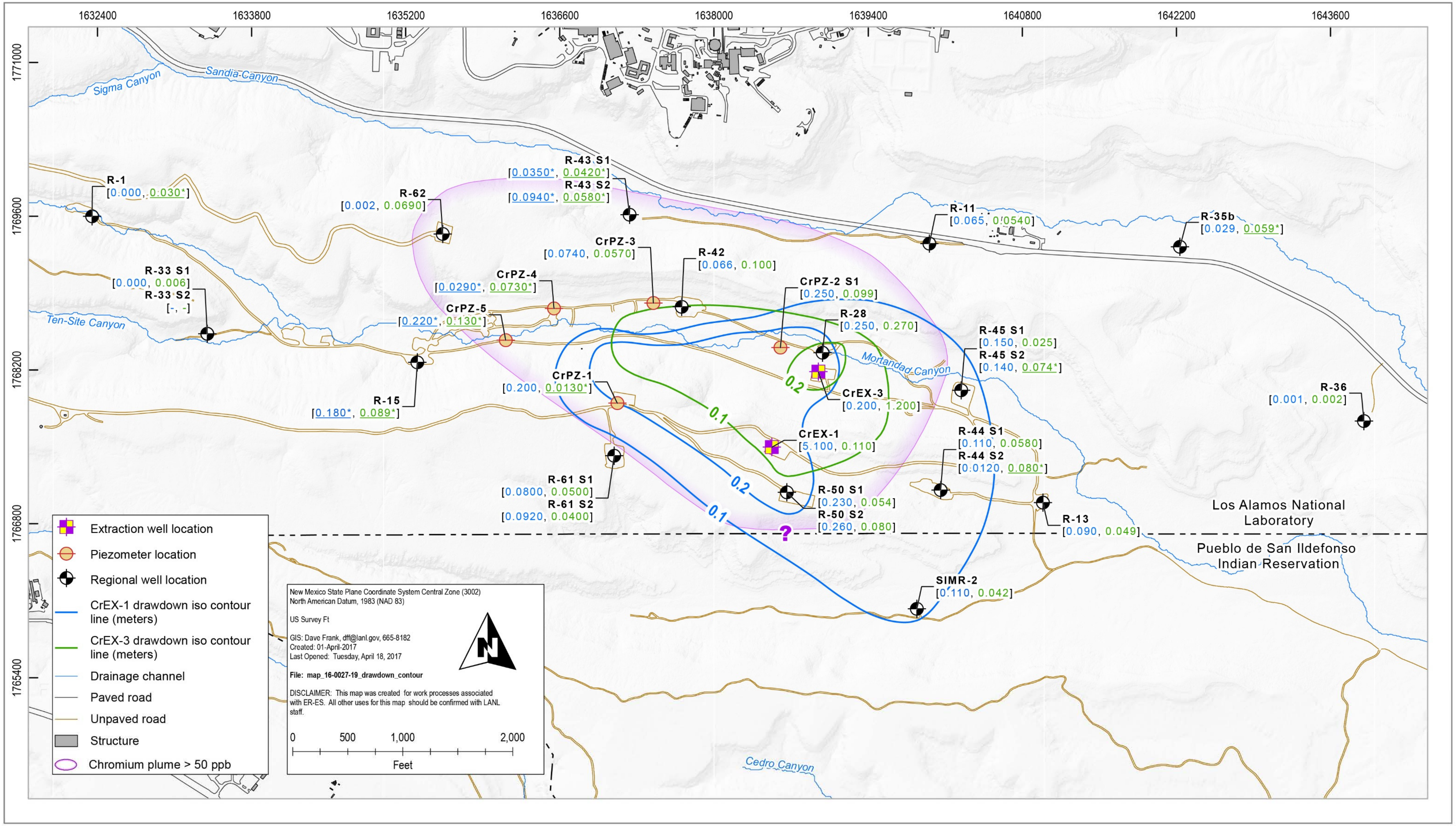


Figure 2.1-3 **Area of preferential drawdown observed from extraction wells CrEX-1 and CrEX-3. The numbers in brackets represent maximum drawdown caused by pumping wells, CrEX-1 (blue) and CrEX-3 (green). Values that are underlined and have an asterisk (*) are uncertain. Dashed (-) values are shown at locations where drawdown could not be determined. CrPZ-5 and R-15 are not shown inside of the 0.1-m contour line because of the low confidence in the estimated values for those locations.**

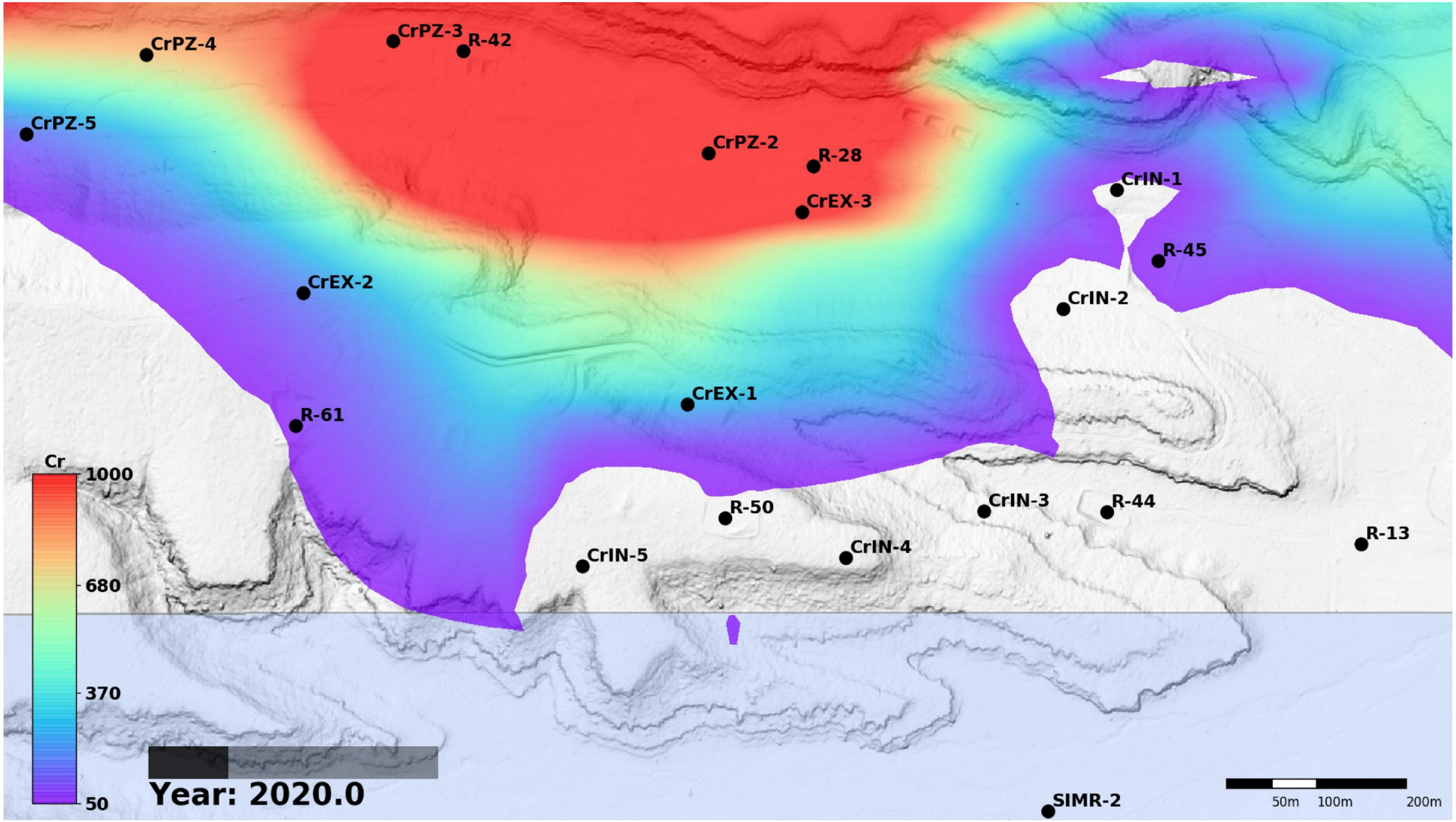


Figure 2.2-1 Model predicted chromium concentrations (in ppb) along the top of the regional aquifer in 2020 after 3 yr of pumping/injection. CrEX-2 is not being pumped in this model.

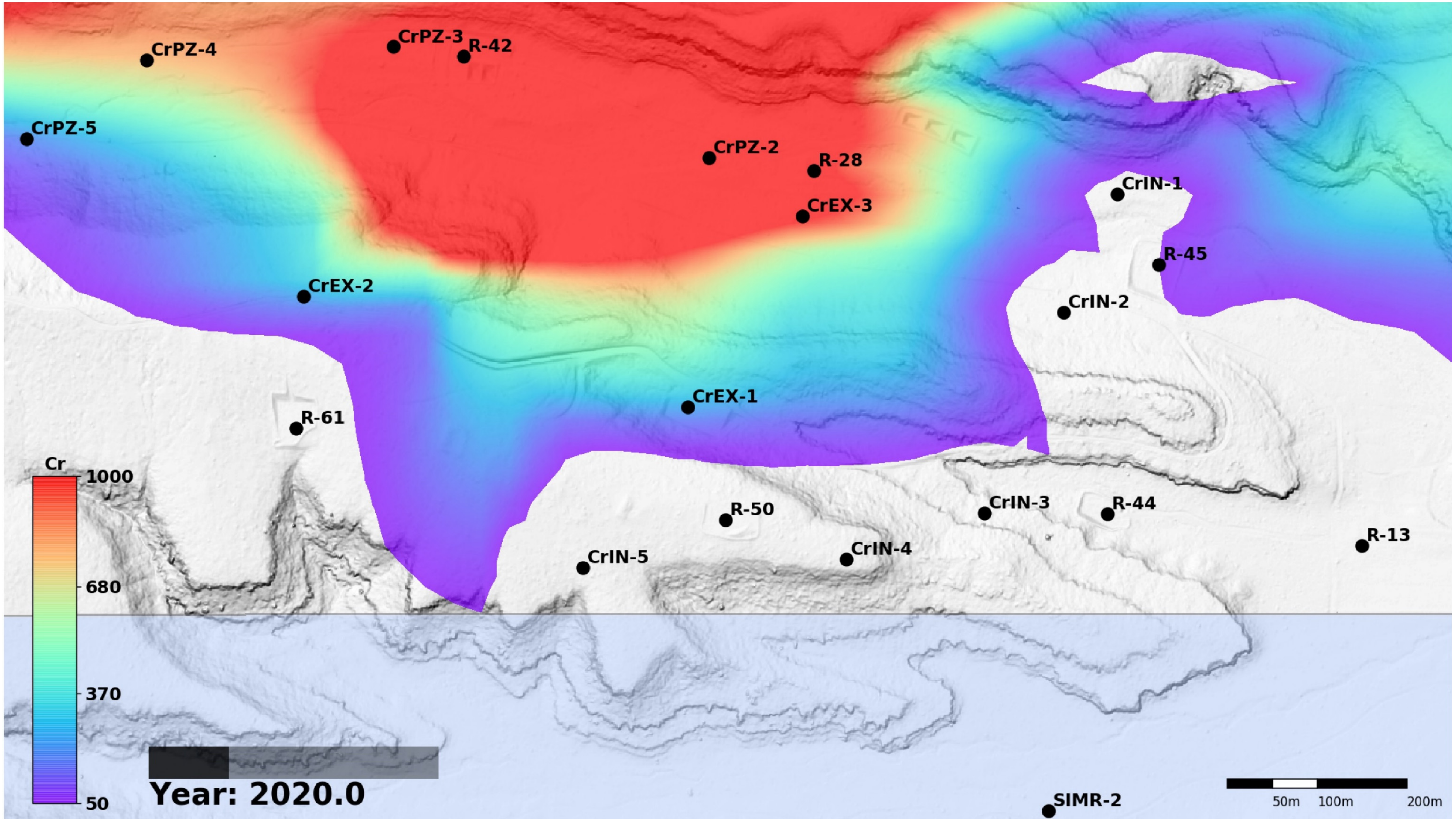
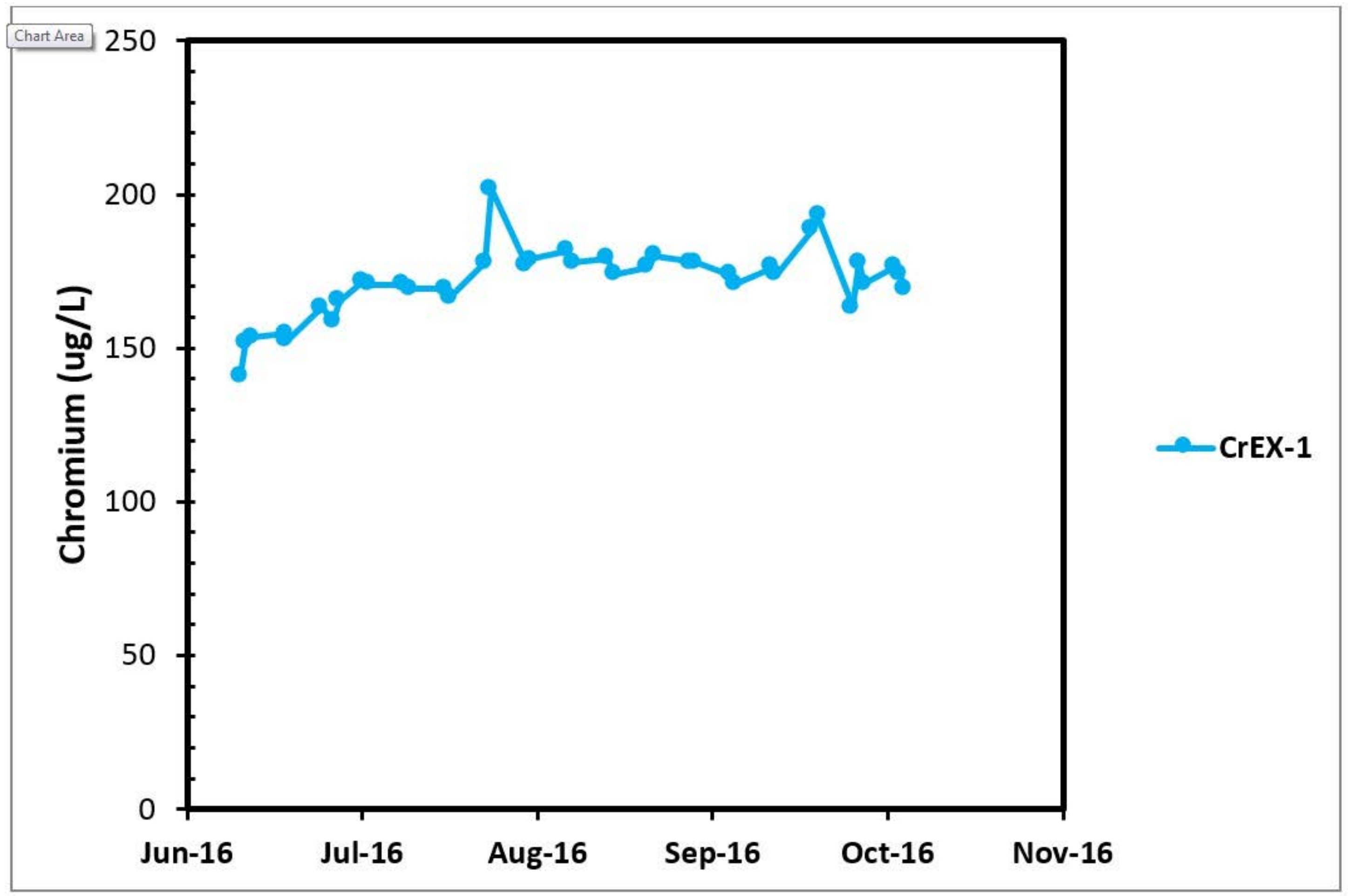


Figure 2.2-2 Model predicted chromium concentrations (in ppb) along the top of the regional aquifer in 2020 after 3 yr of pumping/injection. CrEX-2 is being pumped in this model.



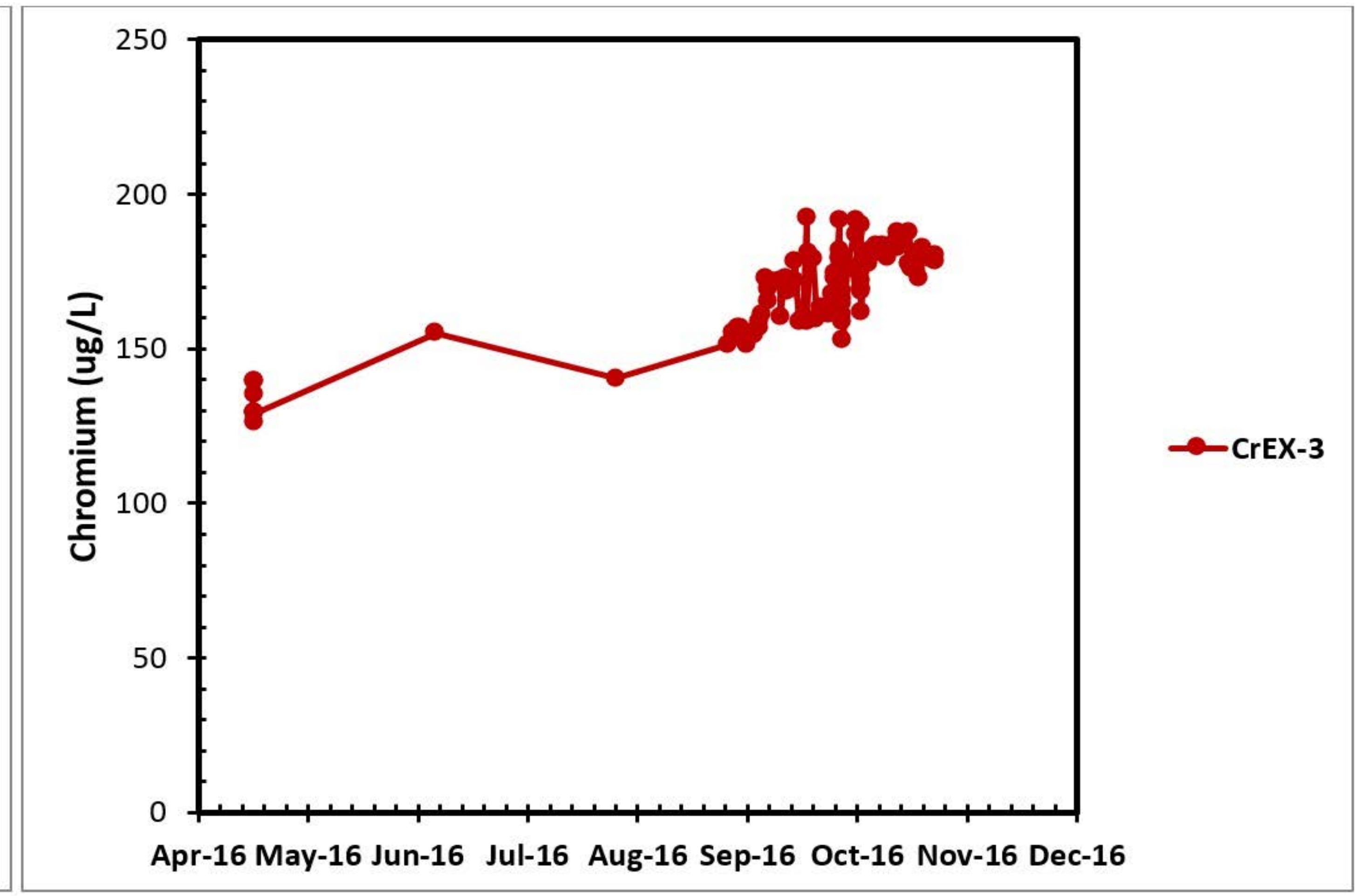


Figure 3.0-1 Time-series of chromium concentrations at CrEX-1 and CrEX-3 for continuous periods of pumping in 2015 and 2016

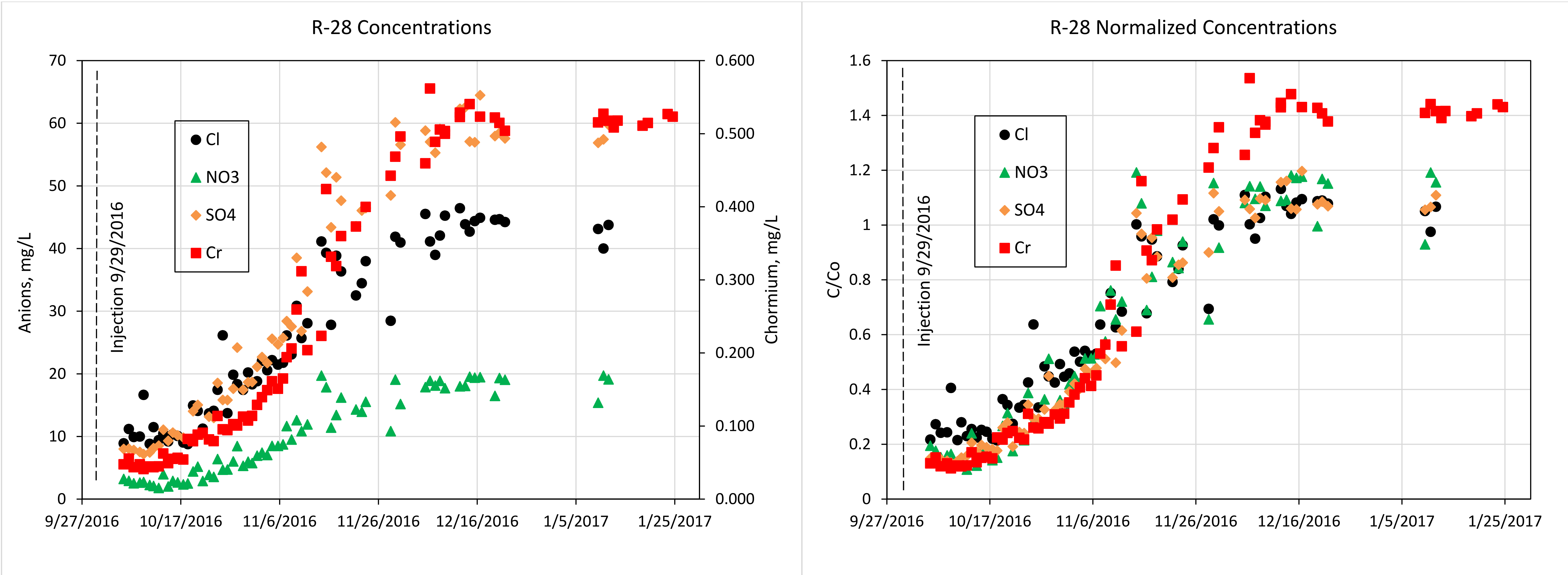


Figure 3.0-2 **Trends for four constituents at monitoring well R-28 following injection of tracer and clean "chase" water on September 29, 2016 (T=0). Left panel shows the trends in concentrations; right panel shows the trends normalized to the concentration that was present in the well before injection of tracers (i.e., water that is free of site contaminants). Concentrations of Cl, NO_3, SO_4, and Cr increased to levels above the T=0 concentrations as tracer and chase water drifted away from the well. Increases over the T=0 concentrations shown as C/Co values greater than 1 may be from pumping at nearby CrEX-3.**

Table 2.0-1
Summary of 2016 Pumping Activities

Well	Approximate Pumping Rate (gpm)	Major Pumping Periods
CrEX-1	80	6/28/16–6/30/16; 7/6/16–8/3/16; 10/20/16–11/20/16; 12/14/16–12/21/16
CrEX-3	41	9/12/16–9/19/16; 9/21/16–10/14/16; 10/17/16–11/7/16
CrIN-1	65	7/18/16–/20/16; 8/12/16, 9/22/16, 11/9/16
CrIN-2	56	5/31/16–6/3/16; 8/12, 9/22/16; 11/9/16
CrIN-3	75	9/8/16–9/10/16; 11/16/16
CrIN-4	62	6/21/16–6/23/16; 8/22/16
CrIN-5	55	8/3/16–8/5/16; 9/1/16
R-28	27	9/19/16–12/14/16
R-42	7.1	9/16/16–12/14/16

Notes: Pumping rates listed are the averages in 2016. When calculated average pumping rate, only data points where the pump was on are included.

Appendix A

Drawdown Analysis of Pumping in the Plume Area

ANALYSIS OF WATER-LEVEL DATA

Figures A-1 to A-31 show the water-level record after removal of barometric pressure effects for wells monitored in the chromium plume area with an emphasis on the 2016 period of record. The observation well screens are CrEX-1, CrEX-3, CrPZ-1, CrPZ-2, CrPZ-3, CrPZ-4, CrPZ-5, R-1, R-11, R-13, R-15, R-28, R-33 screen 1, R-33 screen 2, R-35a, R-35b, R-36, R-42, R-43 screen 1, R-43 screen 2, R-44 screen 1, R-44 screen 2, R-45 screen 1, R-45 screen 2, R-50 screen 1, R-50 screen 2, R-61 screen 1, R-61 screen 2, R-62, and SIMR-2 (a total of 30 observation locations). The barometric pressure and tidal effects in the observed water levels were removed using a Laboratory-developed code called CHIPBETA that utilizes the methodology developed by Toll and Rasmussen (2007, 104799). The code allows for automated removal of the barometric and tidal effects in the water-level data. After the barometric pressure and tidal effects are removed, the pumping effects in the water-level data were analyzed using the method described in Harp and Vesselinov (2011, 227709). The analyses utilize two open-source codes also developed at the Laboratory: WELLS (http://wells.lanl.gov) and MADS (http://mads.lanl.gov; http://madsjulia.github.io/Mads.jl). WELLS is applied to simulate the drawdowns caused by the pumping. MADS is applied to (1) deconstruct pumping impacts caused by different pumping wells and (2) estimate hydrogeologic properties of the tested saturation zone by matching the simulated and observed hydraulic heads at the observation wells. The performed analyses are highly computationally intensive. In a serial mode (without parallelization), a single model analysis for a single observation point takes about 1 h. Some of the analyses had to be repeated several times to address different computational issues.

Figures A-1 to A-31 also present the results of this analysis. Each figure shows the model-based deconstruction of the water-level transients observed in each monitoring well. The upper panel in each figure depicts the observed and simulated water levels at the monitoring well and compares it with the pumping rates at each test well. The lower panel depicts the individual contributions of each pump test to drawdown at the observation well. Dashed lines, labeled “trend,” in the bottom panel represent a general linear trend of water decline caused by physical processes that are not explicitly represented in the model but that may influence water-levels (these values are included while calculating simulated “total” hydraulic head). For all observation wells, the model was calibrated using water-level data and pumping-rate data during the 2016 pumping activities (Table 2.0-1 and Figure 2.1-1 of the report). For observation wells with longer, more reliable water-level records, pumping test data from previous years were also included (Figure 2.1-2 of the report).

Because all the well screens are located within the regional aquifer, much of the observed drawdowns are a result of pumping at water-supply wells (PM-2, PM-4, PM-5, and O-04). However, the modeling approach used here allows for drawdown at observation wells caused by pumping at the pump wells to be quantified. The following is a summary of the interpretation of modeling results for the observation wells analyzed. In addition to Figures A-1 to A-31, the maximum simulated drawdown contribution (dd_{max}) of each pumping well that occurred at each observation well in 2016 is presented in Table A-1. The validity or confidence of model predictions of water-level responses was also assessed and is reported in Table A-1 using color coding that reflects the quality of model fit. In the table, predicted water-level responses are designated as certain (red), potential (blue), and uncertain (grey). Drawdown contributions less than 1 cm are considered to be negligible with certainty (red). Table A-2 shows the dates at which the maximum simulated drawdown from Table A-1 occurred. Table A-3 shows the calibrated model parameter values for transmissivity (T) and storativity (S) between the observation and pumping wells. Large storativity is caused by low sensitivity of the observed water-level transients at the observation well to the pumping transients. Large transmissivity suggests negligible influence of pumping on observed drawdown.

In the following summary, deconstructed water-level responses that occurred as a result of pumping are categorized as substantial ($dd_{max} \geq 0.05$ m), minor ($0.01 < dd_{max} < 0.05$ m), or negligible ($dd_{max} \leq 0.01$ m). Additionally, water-level responses are designated as questionable if model predictions do not closely match the observed water-level transients. Questionable model predictions correspond with the grey color code in Table A-1. In general, water-level responses from pumping of wells within the chromium contamination site in 2016 are difficult to analyze because most of the wells were pumped for very short durations. This is especially true for the case of CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5. The majority of water-level responses from pumping in these wells are evaluated as negligible with high certainty in Table A-1, but more data are needed to confirm this. Despite this limitation, the modeling approach is still an effective tool for interpreting water-level transients in 2016. In particular, water-level transients resulting from pumping at CrEX-1 and CrEX-3 are accurately predicted in many of the observation wells and indicate likely hydraulic connectivity. Furthermore, observation wells with longer water-level records provide additional information by allowing the pumping activities that occurred in R-28, R-42, and CrEX-1 before 2016 to be included in the analysis.

Analysis of CrEX-1 (Figure A-1) is dominated by drawdown from pumping at this well (dd_{max} = 5.1 m). The relatively large pumping drawdown at CrEX-1, compared with surrounding monitoring locations, makes it difficult to analyze the validity of the other predicted water-level responses because they are of a much smaller magnitude. As a result, some of the pumping responses are designated as potential (blue) in Table A-1. The model predicts substantial drawdown at this well in response to pumping at CrEX-3 (dd_{max} = 0.11 m). The model predicts a minor water-level response from pumping at R-28, CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5, although impacts from CrIN-1 and CrIN-3 pumping are questionable. The water-level response from pumping at R-42 is negligible.

Analysis of CrEX-3 (Figure A-2) is dominated by drawdown from pumping at this well (dd_{max} = 1.2 m). The relatively large pumping drawdown at CrEX-3, compared with surrounding monitoring locations, makes it difficult to analyze the validity of the other predicted water-level responses because they are of a much smaller magnitude. As a result, some of the pumping impacts are designated as potential (blue) in Table A-1. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.20 m) and CrIN-3 (dd_{max} = 0.16 m), although impacts from CrIN-3 pumping are questionable. The model predicts a minor water-level response from pumping at R-28, CrIN-1, CrIN-4, and CrIN-5, although impacts from CrIN-5 pumping are questionable. The water-level response from pumping at R-42 and CrIN-2 is negligible.

Analysis of CrPZ-1 is shown in Figures A-3 and A-4. Figure A-3 shows results of model calibration using water-level data that are not corrected for an inconsistent water-level jump that occurred between December 15 and 17, 2016. Figure A-4 shows results of model calibration using water-level data after correcting for this jump. Model results where the water-level jump is corrected are more plausible (Figure A-4). Based on this calibration analysis, the model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.11 m). The model predicts a minor water-level response from pumping at CrEX-3, R-28, CrIN-3, and CrIN-4, although the impact of R-28 pumping is questionable (because of the jump correction). The impact of CrIN-4 pumping is also questionable. The water-level response from pumping at R-42, CrIN-1, CrIN-2, and CrIN-5 is negligible.

Analysis of CrPZ-2 screen 1 is shown in Figure A-5. Modeled water-level response for this well is difficult to interpret given the poor quality of the observation data. In general, the water-level data contain many gaps and jumps. However, the model does capture the major water-level transients. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.25 m), CrEX-3 (dd_{max} = 0.099 m), and CrIN-3 (dd_{max} = 0.11 m). The model predicts a minor water-level response from pumping at CrIN-1, CrIN-2, and CrIN-4, although these pumping impacts are questionable. The water-level response from pumping at R-28, R-42, and CrIN-5 is negligible.

Analysis of CrPZ-3 is shown in Figure A-6. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.074 m) and CrEX-3 (dd_{max} = 0.057 m). The model predicts a minor water-level response from pumping at R-28. The water-level response from pumping at R-42, CrIN-1, CrIN-2, CrIN-3, and CrIN-5 is negligible.

Analysis of CrPZ-4 is shown in Figure A-7. In general, the model does a poor job of capturing the water-level transients at this well. The model predicts substantial drawdown at this well from pumping at CrEX-3 (dd_{max} = 0.073 m) and predicts a minor water-level response from pumping at CrEX-1 and R-28. However, impacts of pumping at CrEX-1, CrEX-3, and R-28 are designated only as potential (blue) in Table A-1 because of the poor model fit. The water-level response from pumping at R-42, CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of CrPZ-5 is shown in Figure A-8. Large jumps in the water-level data are most likely from piezometer error (e.g., drift) and make analysis difficult. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.22 m), CrEX-3 (dd_{max} = 0.13 m), CrIN-2 (dd_{max} = 0.081 m), and CrIN-4 (dd_{max} = 0.059 m). However, impacts of pumping at these wells are designated only as potential (blue) in Table A-1 because of the relatively poor model fit. The model predicts a minor water-level response from pumping at R-28, but the impact of R-28 pumping is questionable. The water-level response from pumping at R-42, CrIN-1, CrIN-3, and CrIN-5 is negligible.

Analysis of R-1 is shown in Figure A-9. The model does not predict substantial drawdown at this well from pumping at any well. The model predicts a minor water-level response from pumping at CrEX-3, although the modeled impact is designated as potential in Table A-1. The water-level response from pumping at all of the other wells is negligible.

Analysis of R-11 is shown in Figure A-10. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.065 m) and CrEX-3 (0.054 m). The model predicts a minor water-level response from pumping at CrIN-2 and CrIN-3. Modeled water-level response from pumping at R-28 is negligible in 2016 but was appreciable during previous pumping tests; as such, this result is designated as questionable (grey) in Table A-1. The water-level response from pumping at R-42, CrIN-1, CrIN-4, and CrIN-5 is negligible with certainty.

Analysis of R-13 is shown in Figure A-11. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.090 m) and CrEX-3 (dd_{max} = 0.049 m). The model predicts a minor water-level response from pumping at CrIN-2 and CrIN-3. Modeled water-level response from pumping at R-28 is negligible in 2016 but was appreciable during previous pumping tests; as such, this result is designated as questionable (grey) in Table A-1. The water-level response from pumping at R-42, CrIN-1, CrIN-4, and CrIN-5 is negligible.

Analysis of R-15 is shown in Figure A-12. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.18 m) and CrEX-3 (dd_{max} = 0.089 m). However, it is difficult to assess the validity of these predicted drawdown contributions because the water levels in this well are predominantly influenced by water-supply pumping (PM-4) and because large gaps exist in the data set. The water-level response from pumping at all of the other wells is negligible.

Analysis of R-28 (Figure A-13) is dominated by drawdown from pumping at this well (dd_{max} = 0.56 m), making it difficult to analyze the validity of the other predicted water-level responses because they are of a much smaller magnitude. The model predicts substantial drawdown at this well from pumping at CrEX-1

(dd_{max} = 0.25 m) and CrEX-3 (dd_{max} = 0.27 m). The model predicts minor water-level responses from pumping at CrIN-3 and CrIN-4. However, impacts of pumping at these wells are designated as potential (blue) in Table A-1. Water-level response from pumping at R-42, CrIN-1, CrIN-2, and CrIN-5 is negligible.

Analysis of R-33 screen 1 is shown in Figure A-14. The model predicts minor changes to water levels as a result of pumping at CrIN-3, but this prediction is questionable. Water-levels at the well appear to be dominated by the linear trend with some perturbations resulting from water-supply pumping.

Analysis of R-33 screen 2 (Figure A-15) was unsuccessful. R-33 screen 2 transients were associated with PM-5 pumping transients in previous analyses; however, here the model failed to establish this connection. The model is not capable of producing drawdowns that reflect pumping transients at any of the pumping wells, and the signal is dominated by linear drawdown trends. Thus, all predicted water-level responses reported in Table A-1 are designated as questionable (grey).

Analysis of R-35a is shown in Figure A-16. It is apparent from the analysis that water-level fluctuations at this well are dominated by pumping at water-supply well PM-3. R-35a is essentially adjacent to PM-3, and the screen for R-35a is within the upper portion of the louvers at PM-3, which begin relatively deep below the water table.

Analysis of R-35b is shown in Figure A-17. Unlike R-35a, water levels at this well are not dominated by pumping at PM-3, despite their close proximity. R-35b is screened near the aquifer water table, well above the louvered section of PM-3. The differing responses in R-35a and R-35b to pumping at PM-3 suggest pronounced vertical aquifer anisotropy. The model predicts substantial drawdown at this well from pumping at CrEX-3 (dd_{max} = 0.059 m). The model predicts a minor water-level response from pumping at CrEX-1 and R-28. The water-level response from pumping at R-42, CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of R-36 is shown in Figure A-18. Model predictions during the 2016 pumping activities poorly fit the observed water-level data, and the model predicted water-level response from pumping transients at all of the pumping wells is negligible. This may indicate problems with the water-level data. Thus, all values in Table A-1 for this well are designated as questionable (grey).

Analysis of R-42 is shown in Figure A-19. The response is dominated by drawdown from pumping at this well (dd_{max} = 1.4 m), making it difficult to analyze the validity of the other predicted water-level responses because they are of a much smaller magnitude. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.066 m) and CrEX-3 (dd_{max} = 0.1 m). The model predicts a minor water-level response from pumping at R-28. The water-level response from pumping at CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of R-43 screen 1 is shown in Figure A-20. Water levels at the well appear to be dominated by water-supply pumping, making it difficult to analyze the validity of the other predicted water-level responses because they are of a much smaller magnitude. The model predicts substantial drawdown at this well from pumping at CrIN-2 (dd_{max} = 0.075 m), which is most probably coincidental and should be considered unreliable. The model predicts a minor water-level response from pumping at CrEX-1 and CrEX-3. Impacts of pumping at CrIN-2, CrEX-1, and CrEX-3 are designated as potential (blue) in Table A-1. Water-level response from pumping at R-28, R-42, CrIN-1, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of R-43 screen 2 is shown in Figure A-21. Water levels at the well appear to be dominated by water-supply pumping, similar to R-43 screen 1, but the model predicted water-level responses are more apparent. However, the large gap in the water-level data set during the summer of 2014 further complicates model interpretation. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.094 m) and CrEX-3 (dd_{max} = 0.058 m). Modeled water-level responses from pumping at R-28 and R-42 were negligible in 2016 but were appreciable during previous pumping tests; as such, these results are designated as questionable (grey) in Table A-1. The model predicts a minor water-level response from pumping at CrIN-2. The water-level response from pumping at CrIN-1, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of R-44 screen 1 is shown in Figure A-22. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.11 m), CrEX-3 (dd_{max} = 0.058 m), and CrIN-3 (dd_{max} = 0.069 m). A distinct drop in water level occurred during the pumping of CrIN-3 and strongly indicates hydraulic connectivity. Modeled water-level response from pumping at R-28 was negligible in 2016 but was appreciable during previous pumping tests; as such, this result is designated as questionable (grey) in Table A-1. The model predicts a minor water-level response from pumping at CrIN-2. Water-level response from pumping at, R-42, CrIN-1, CrIN-4, and CrIN-5 is negligible.

Analysis of R-44 screen 2 is shown in Figure A-23. The lack of water-level data during 2016 pumping activities makes it difficult to interpret the validity of the modeled drawdown responses from pumping. The model does predict substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.12 m), CrEX-3 (dd_{max} = 0.08 m), and CrIN-2 (dd_{max} = 0.11 m). A distinct drop in water level during the pumping of CrIN-2 indicates strong hydraulic connectivity. A drop in water level that occurred during the pumping of CrIN-3 (dd_{max} = 0.041 m) is similar to the decrease in R-44 screen 1, but no water-level data are available to assess its validity. The model predicts a minor water-level response from pumping at R-28 and CrIN-3, although these predictions are questionable given the large gap in the data. The minor water-level response that occurred during R-28 pumping in 2016 is difficult to confirm because of the gap in the data set, but model predictions during pumping tests before 2016 indicate a hydraulic connection exists between R-44 screen 2 and R-28. Water-level response from pumping at R-42, CrIN-1, and CrIN-4 is negligible. The model predicts negligible water-level response because of pumping at CrIN-5, but this effect is difficult to confirm because the data are not available.

Analysis of R-45 screen 1 is shown in Figure A-24. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.15 m), CrIN-1 (dd_{max} = 0.056 m), and CrIN-4 (dd_{max} = 0.059 m). A distinct drop in water level that occurred during the pumping of CrIN-1 indicates strong hydraulic connectivity. The model predicts a minor water-level response from pumping at CrEX-3 and CrIN-3. The modeled impacts of CrIN-2, CrIN-3, and CrIN-4 are difficult to verify and are designated as potential (blue) in Table A-1. The modeled water-level response from pumping at R-28 was negligible in 2016 but was appreciable during previous pumping tests; as such, this result is designated as questionable (grey) in Table A-1. The water-level response from pumping at R-42 and CrIN-5 is negligible.

Analysis of R-45 screen 2 is shown in Figure A-25. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.14 m), CrEX-3 (dd_{max} = 0.074 m), CrIN-2 (dd_{max} = 0.053 m), and CrIN-5 (dd_{max} = 0.051 m). However, the modeled impacts of CrEX-3, CrIN-2 and CrIN-5 are difficult to verify and are designated as potential (blue) in Table A-1. Modeled water-level response from pumping at R-28 was minor in 2016 but was much more substantial during previous pumping tests. The model predicts a minor water-level response from pumping at CrIN-1 and CrIN-3, but these impacts are questionable. The water-level response from pumping at R-42 and CrIN-4 is negligible.

Analysis of R-50 screen 1 is shown in Figure A-26. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.23 m), CrEX-3 (dd_{max} = 0.054 m), and CrIN-1 (dd_{max} = 0.068 m). The model predicts a minor water-level response from pumping at CrIN-2, CrIN-3, CrIN-4, and CrIN-5. However, the modeled impacts of CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 are difficult to verify and are designated as potential (blue) in Table A-1. Modeled water-level response from pumping at R-28 was negligible in 2016 but was appreciable during previous pumping tests; as such, this result is designated as questionable (grey) in Table A-1. Water-level response from pumping at R-42 is negligible.

Analysis of R-50 screen 2 is shown in Figure A-27. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.26 m), CrEX-3 (dd_{max} = 0.08 m), and CrIN-1 (dd_{max} = 0.26 m). The model predicts a minor water-level response from pumping at R-28, CrIN-2, CrIN-3, CrIN-4, and CrIN-5. The modeled impacts of CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 are difficult to interpret, and are designated as potential (blue) in Table A-1. The water-level response from pumping at R-42 is negligible.

Analysis of R-61 screen 1 is shown in Figure A-28. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.08 m) and CrEX-3 (dd_{max} = 0.05 m). The model predicts a minor water-level response from pumping at CrIN-2 and CrIN-3, but these impacts are questionable. The water-level response from pumping at R-28, R-42, CrIN-1, CrIN-4, and CrIN-5 is negligible.

Analysis of R-61 screen 2 is shown in Figure A-29. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.092 m) and minor drawdown from pumping at CrEX-3. The model appears to underpredict the impact of pumping at R-28. The modeled water-level response from pumping at R-28 was negligible in 2016, but the figure shows drops in the water level occurred shortly after pumping at R-28 during pumping tests in 2013 and 2014; as such, this result is designated as questionable (grey) in Table A-1. The model predicts a minor water-level response from pumping at CrIN-5, but this may also be underpredicted because a drop in the water-level of R-61 screen 2 does appear during the first CrIN-5 pumping test (August 3 to 5, 2016). The water-level response from pumping at R-42, CrIN-1, CrIN-2, CrIN-3, and CrIN-4 is negligible.

Analysis of R-62 is shown in Figure A-30. The model predicts substantial drawdown at this well from pumping at CrEX-3 (dd_{max} = 0.069 m). However, this impact is questionable because the model predictions of drawdown does not clearly match the changes in water level. A large gap in the water-level data set occurred in 2014, making it difficult to evaluate the impact of pumping at R-28. The water-level response from pumping at CrEX-1, R-42, CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 is negligible.

Analysis of SIMR-2 is shown in Figure A-31. Although the model does not capture all the water-level transients at this well, the results of the analysis are informative. A longer water-level record and observations from pending injection and nearby injection wells will allow for a better understanding of hydraulic conductivity of this well. The model predicts substantial drawdown at this well from pumping at CrEX-1 (dd_{max} = 0.11 m). The model predicts a minor water-level response from pumping at CrEX-3, R-28, CrIN-3, and CrIN-4. The impact of pumping at R-28 and CrIN-4 is questionable. However, the impact of pumping at CrIN-3 is fairly certain and may be underpredicted by the model. Water-level response that pumping at R-42, CrIN-1, CrIN-2, and CrIN-5 is negligible. However, the impact of CrIN-1 and CrIN-2 may be underpredicted by the model because drops in the water level of SIMR-2 seem to occur during pumping at these wells.

In summary, the largest drawdowns caused by water-supply pumping at PM-2 are observed in CrEX-1, CrPZ-1, and R-15. Water-supply pumping at PM-4 is primarily observed at CrEX-1, R-15, and CrPZ-4. Pumping at PM-5 is primarily observed at CrEX-1, R-42, and CrPZ-4. Pumping at water-supply well O-4 is primarily observed at CrEX-1, CrPZ-3, and R-62. It is important to note that CrEX-1 is quite responsive to the water-supply pumping, which may suggest that the pumping of CrEX-1 might be more hydraulically connected with deeper portions of the aquifer than at CrEX-3 and the injection wells. The cone of depression caused by pumping at CrEX-1 and CrEX-3 appears to be predominantly extended upgradient (to the west), which potentially indicates higher aquifer permeability to the west of CrEX-1 and CrEX-3.

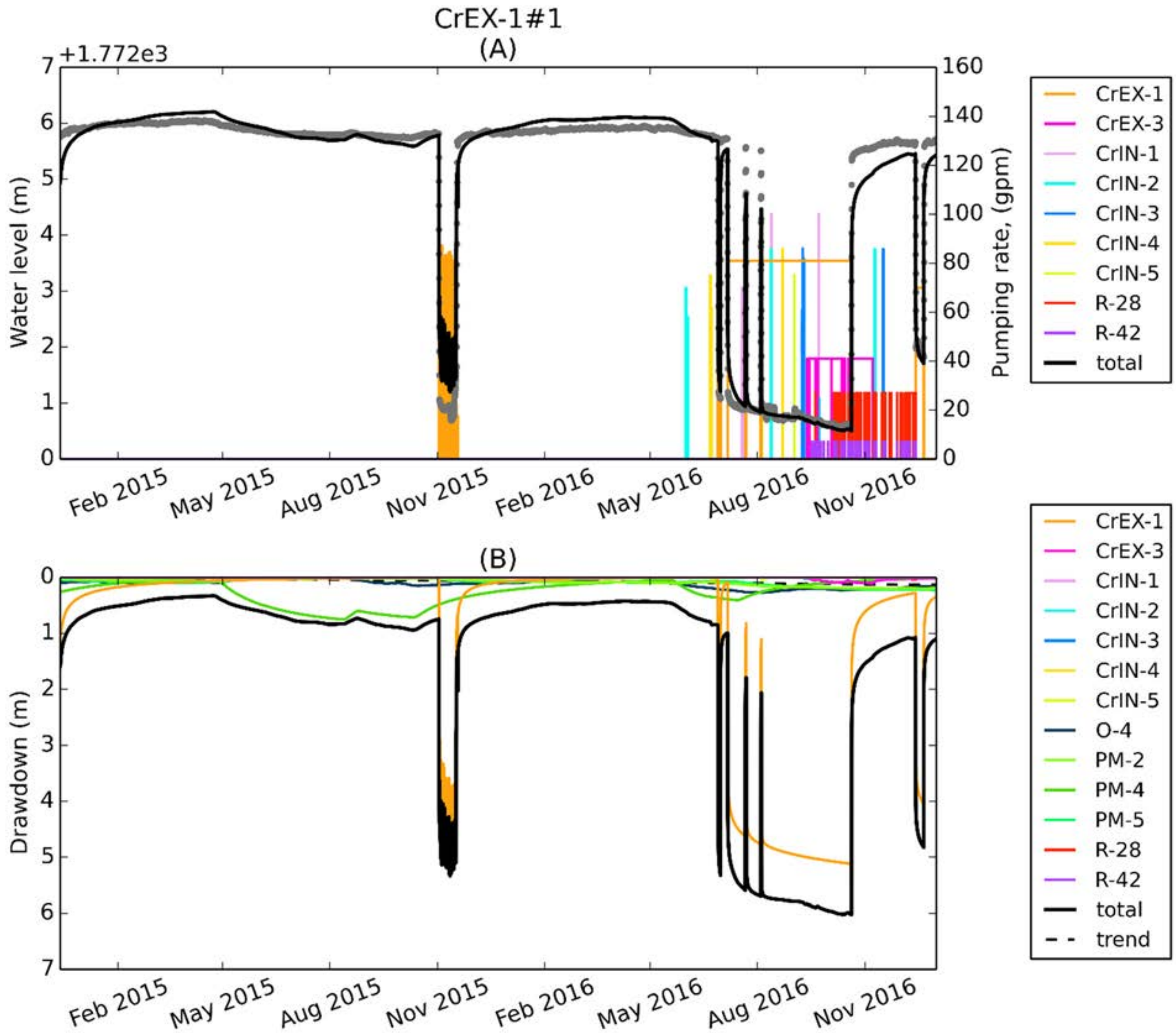


Figure A-1 **Calibrated model results for CrEX-1. Panel A shows observed (grey dots) and simulated (black line) water levels (m), along with pumping rates (gallons per minute [gpm], colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

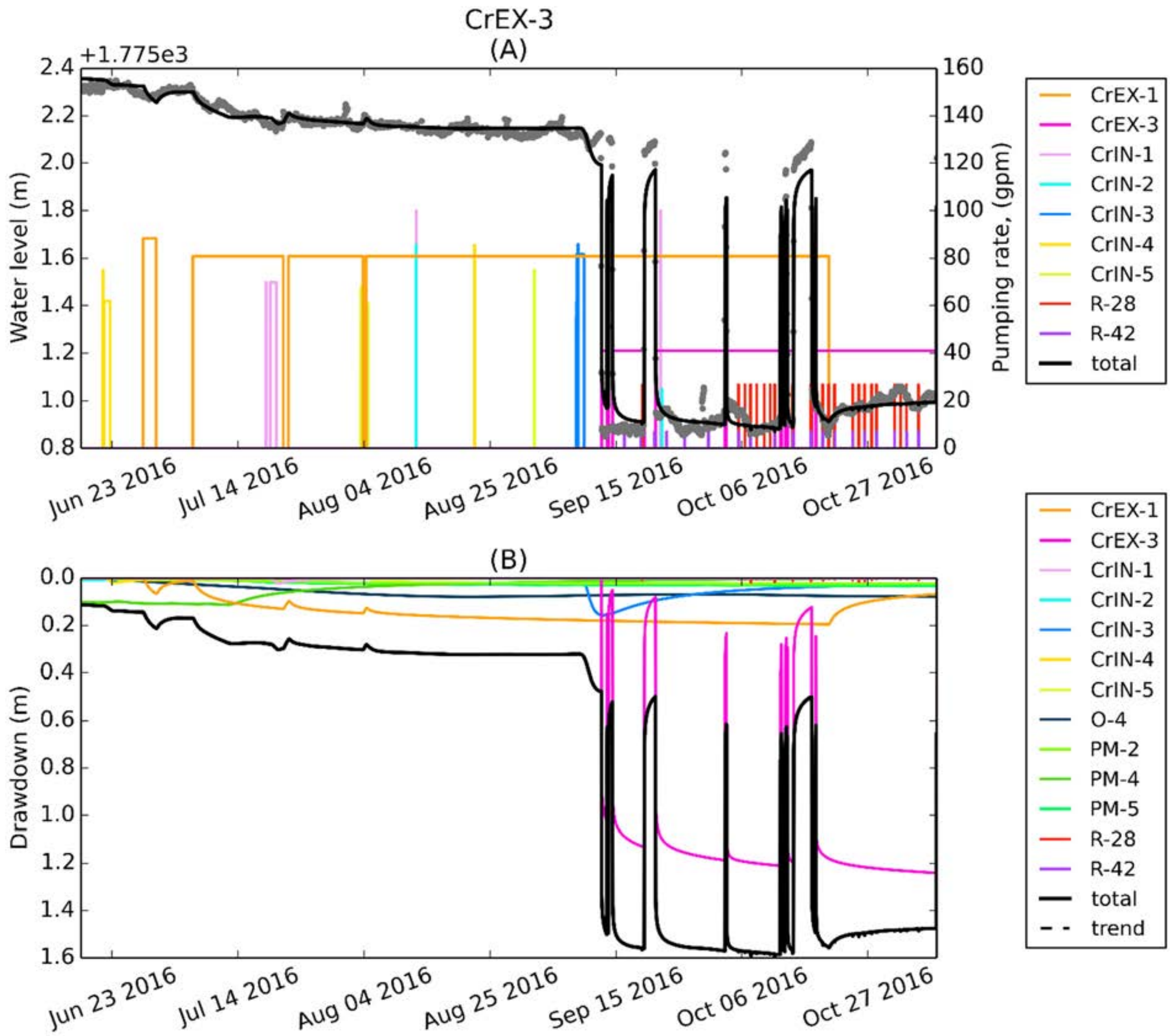


Figure A-2 **Calibrated model results for CrEX-3. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

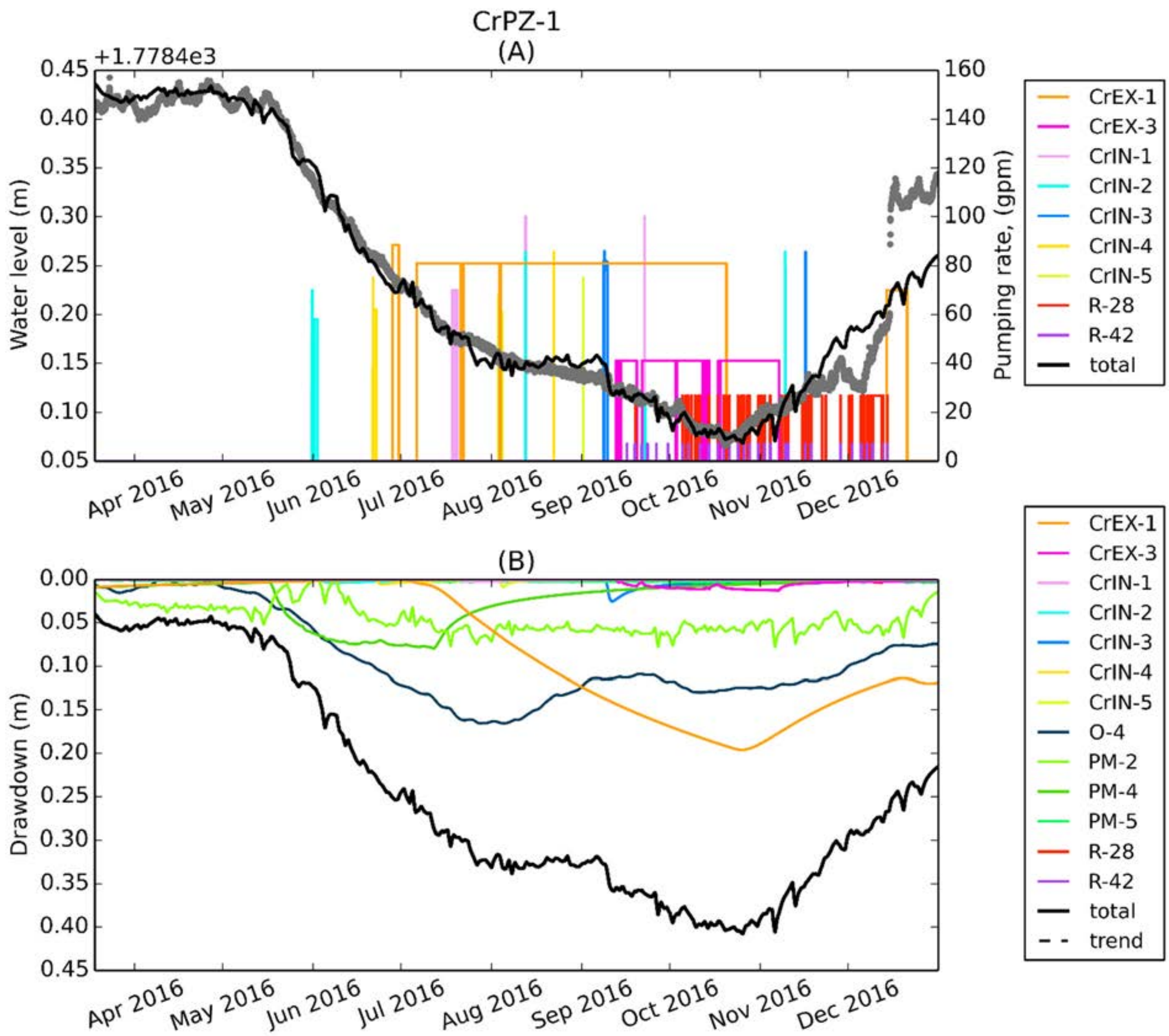


Figure A-3 **Calibrated model results for CrPZ-1. Panel A shows observed (grey dots) and simulated (black line) water levels (m), along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

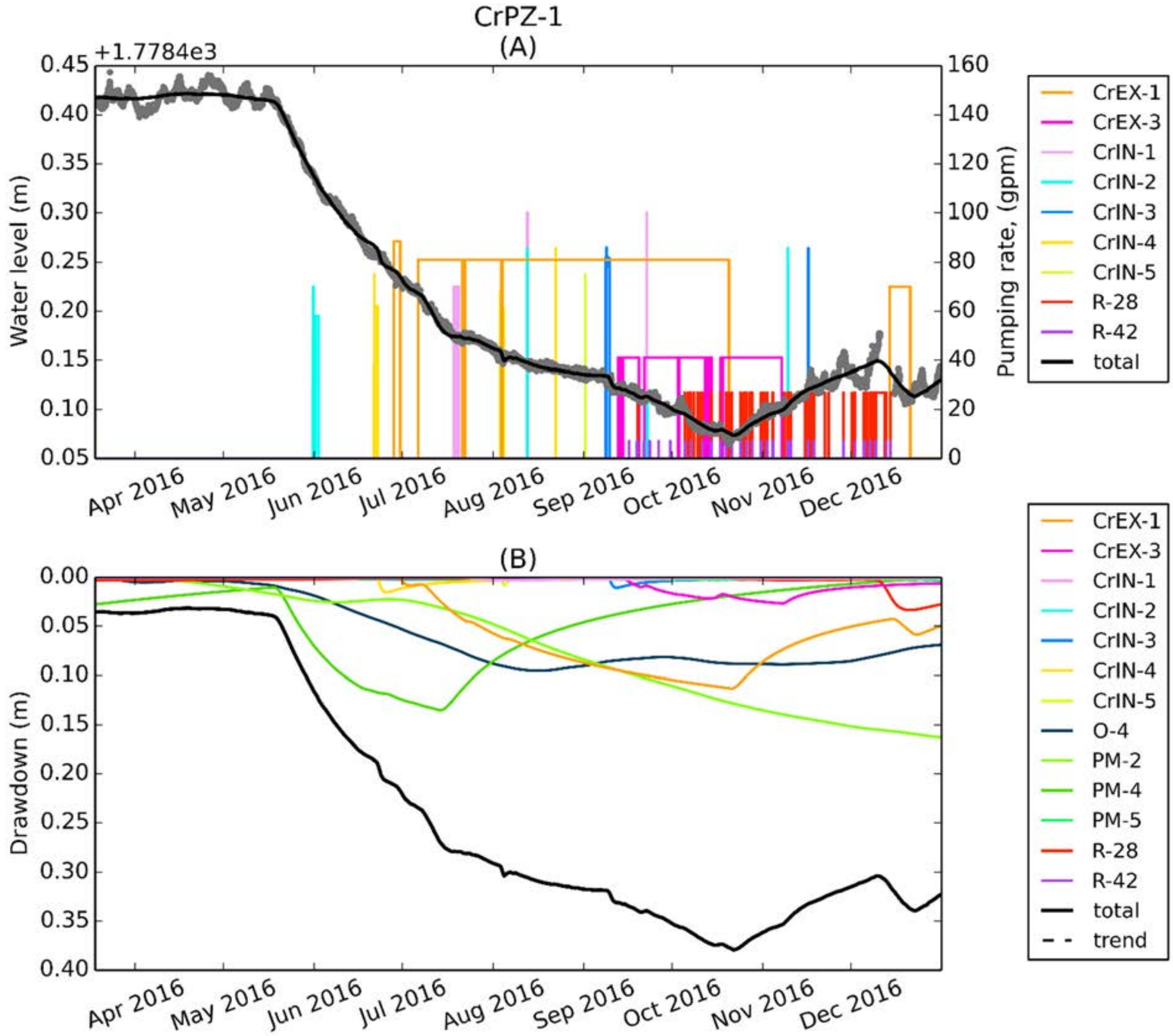


Figure A-4 **Calibrated model results for CrPZ-1 with corrected water levels. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

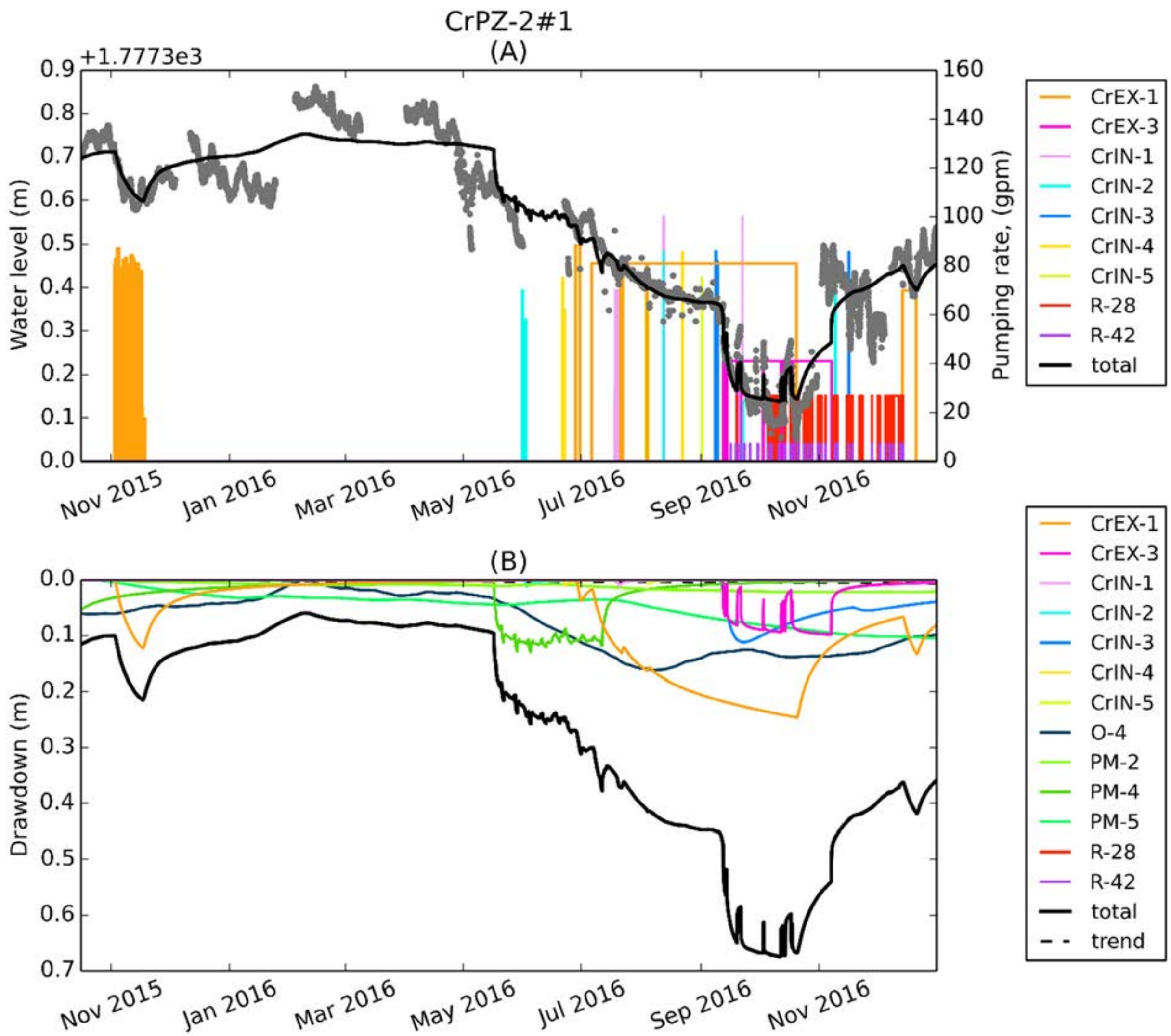


Figure A-5 **Calibrated model results for CrPZ-2 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

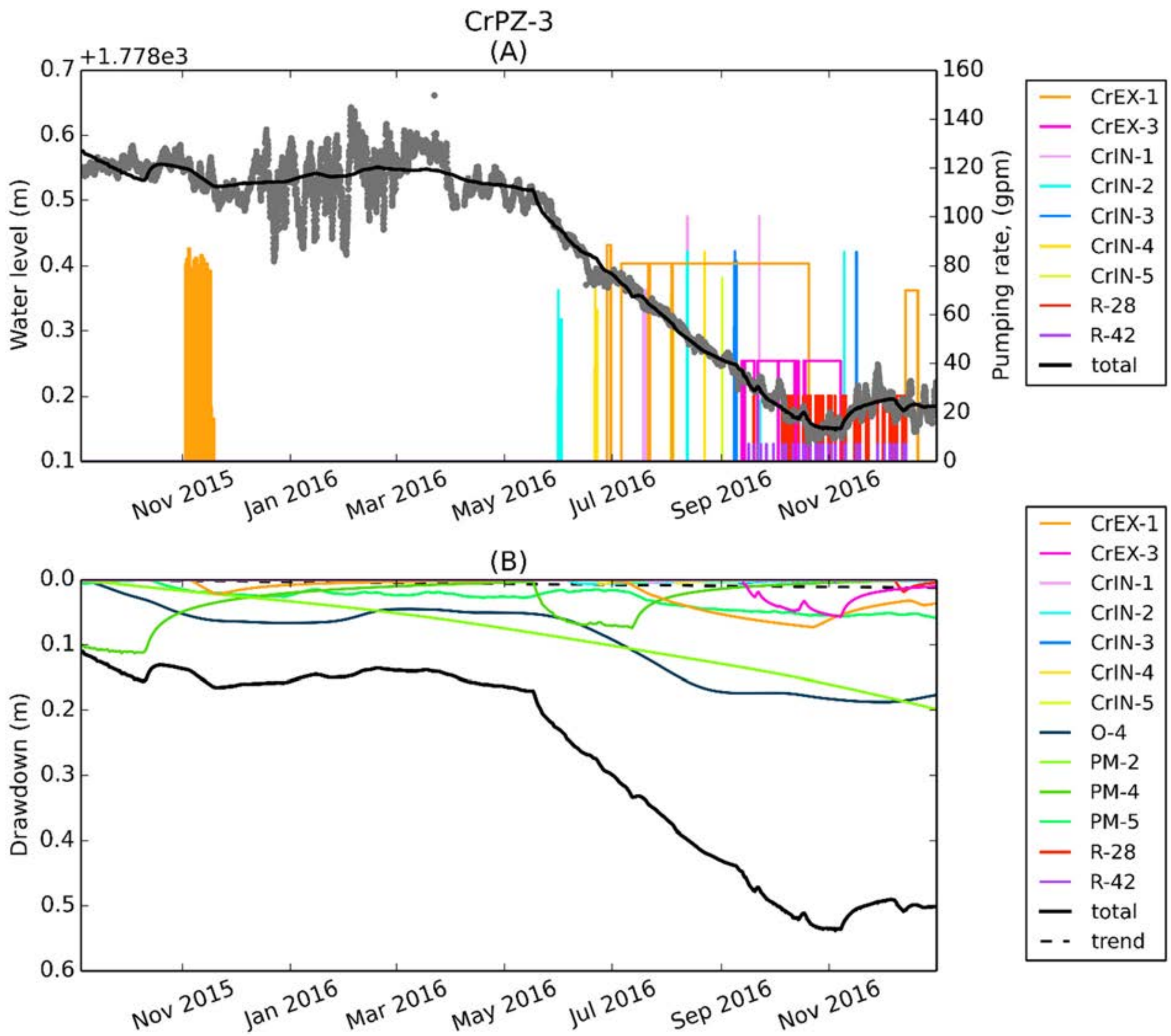


Figure A-6 **Calibrated model results for CrPZ-3. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

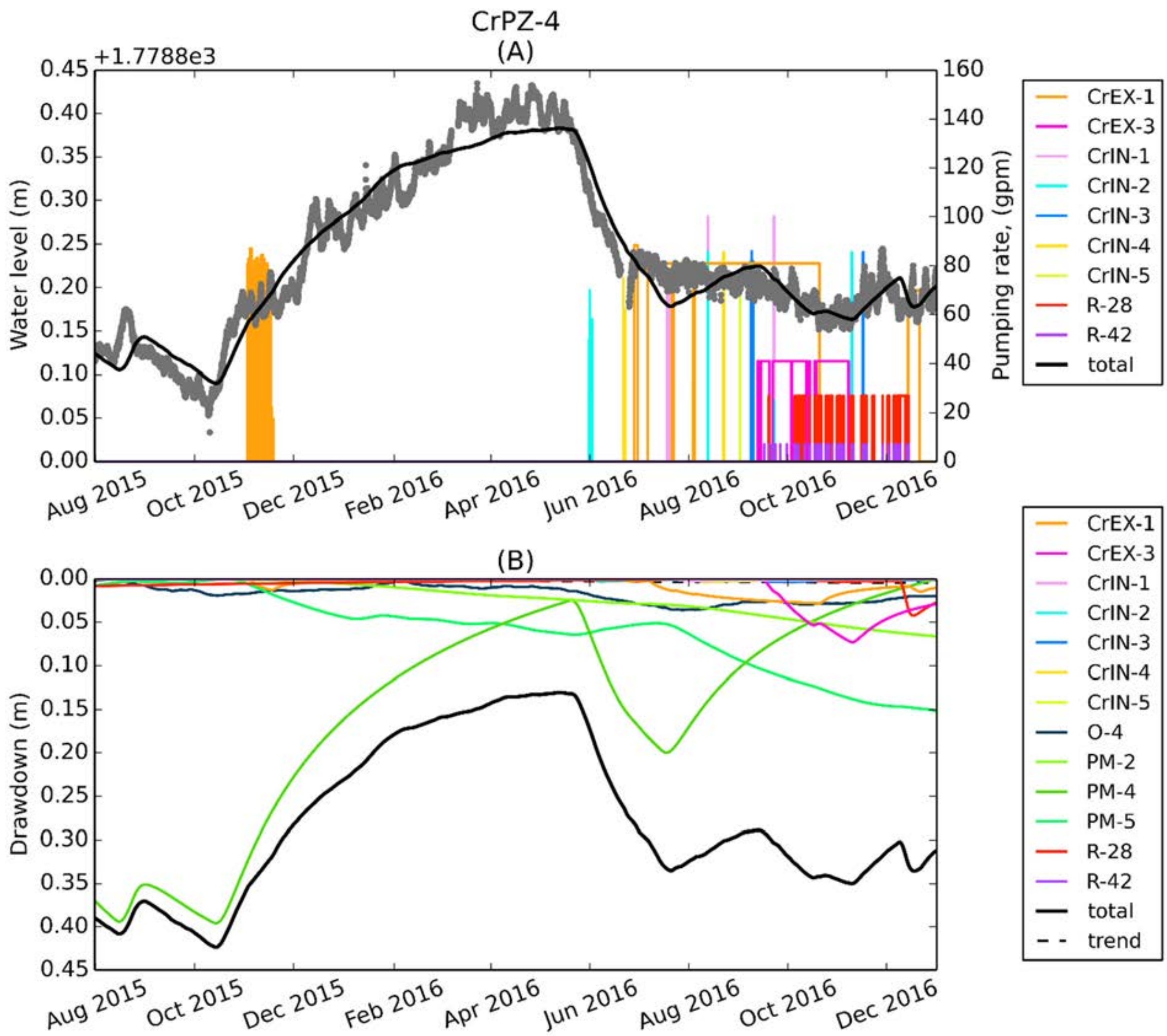


Figure A-7 Calibrated model results for CrPZ-4. Panel A shows observed (grey dots) and simulated (black line) water levels (m), along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

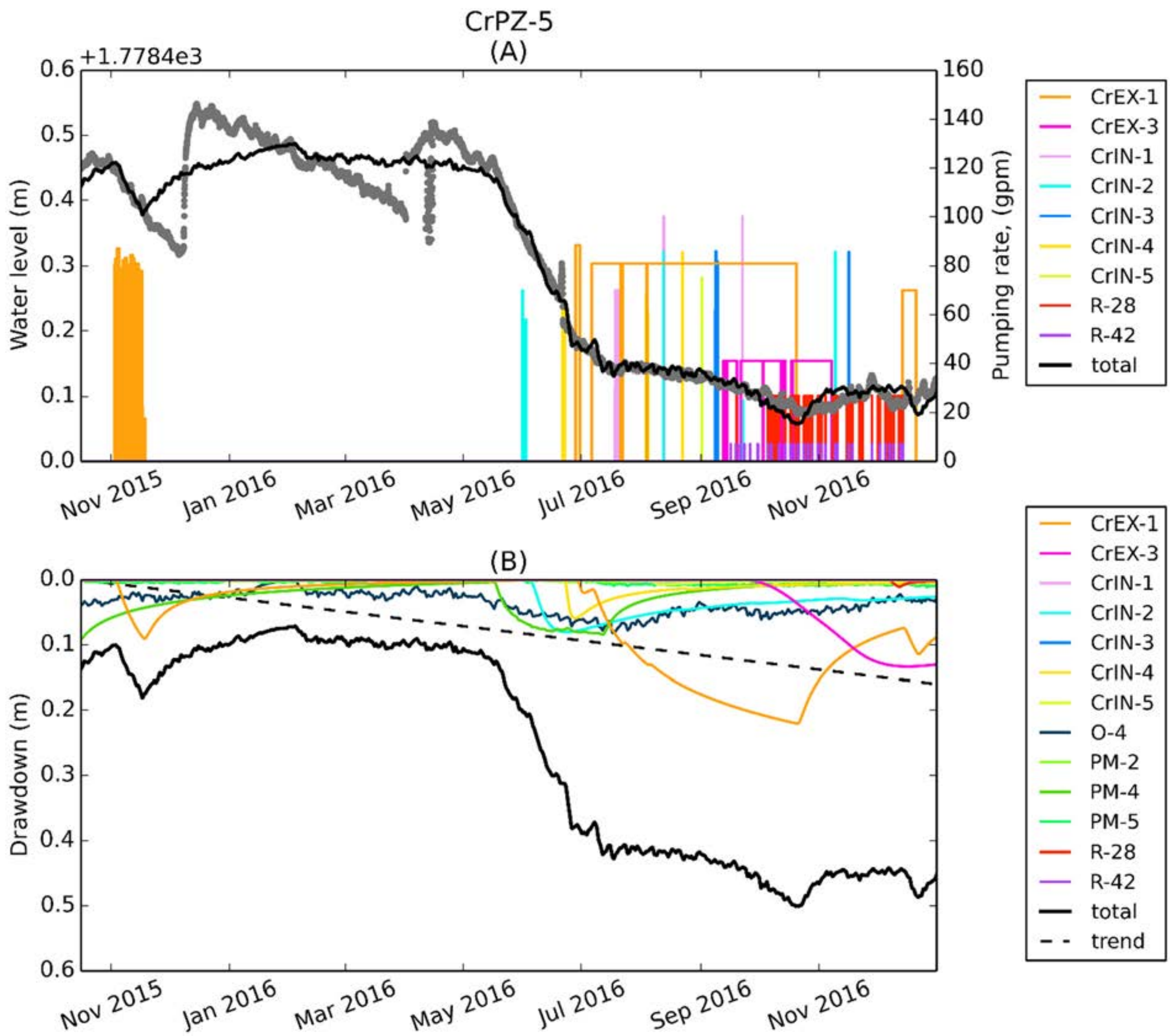


Figure A-8 **Calibrated model results for CrPZ-5. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

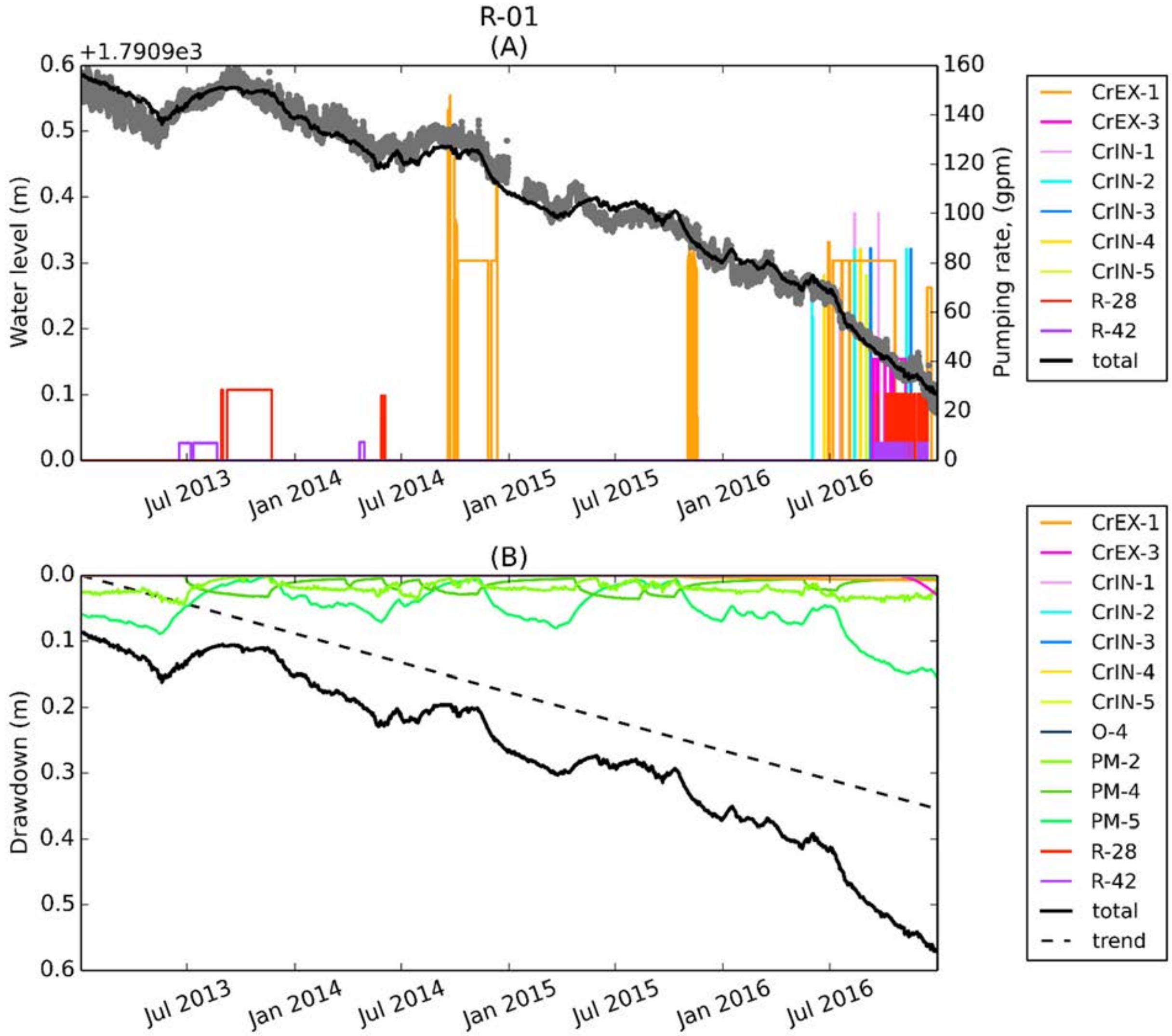


Figure A-9 **Calibrated model results for R-1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

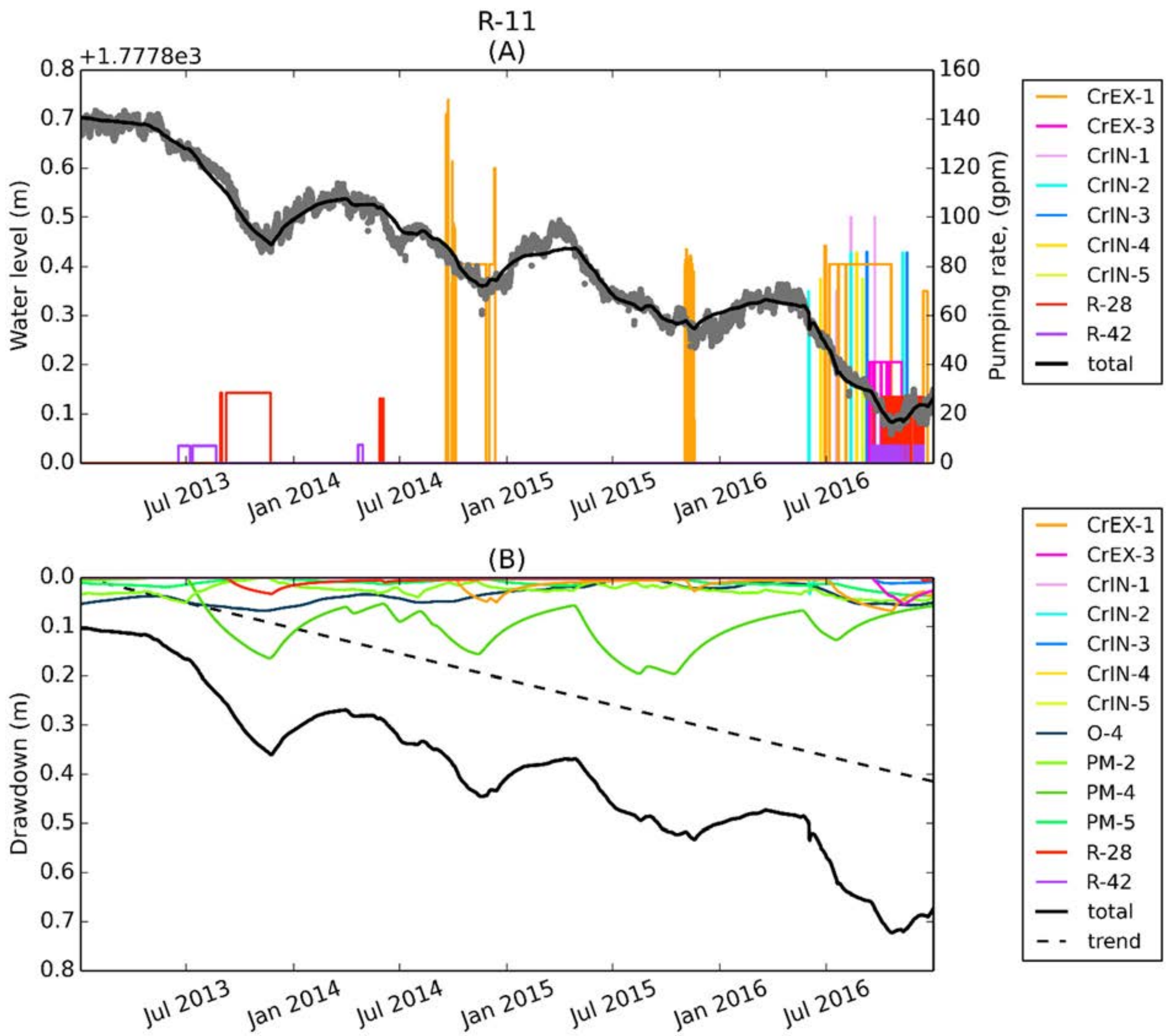


Figure A-10 **Calibrated model results for R-11. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

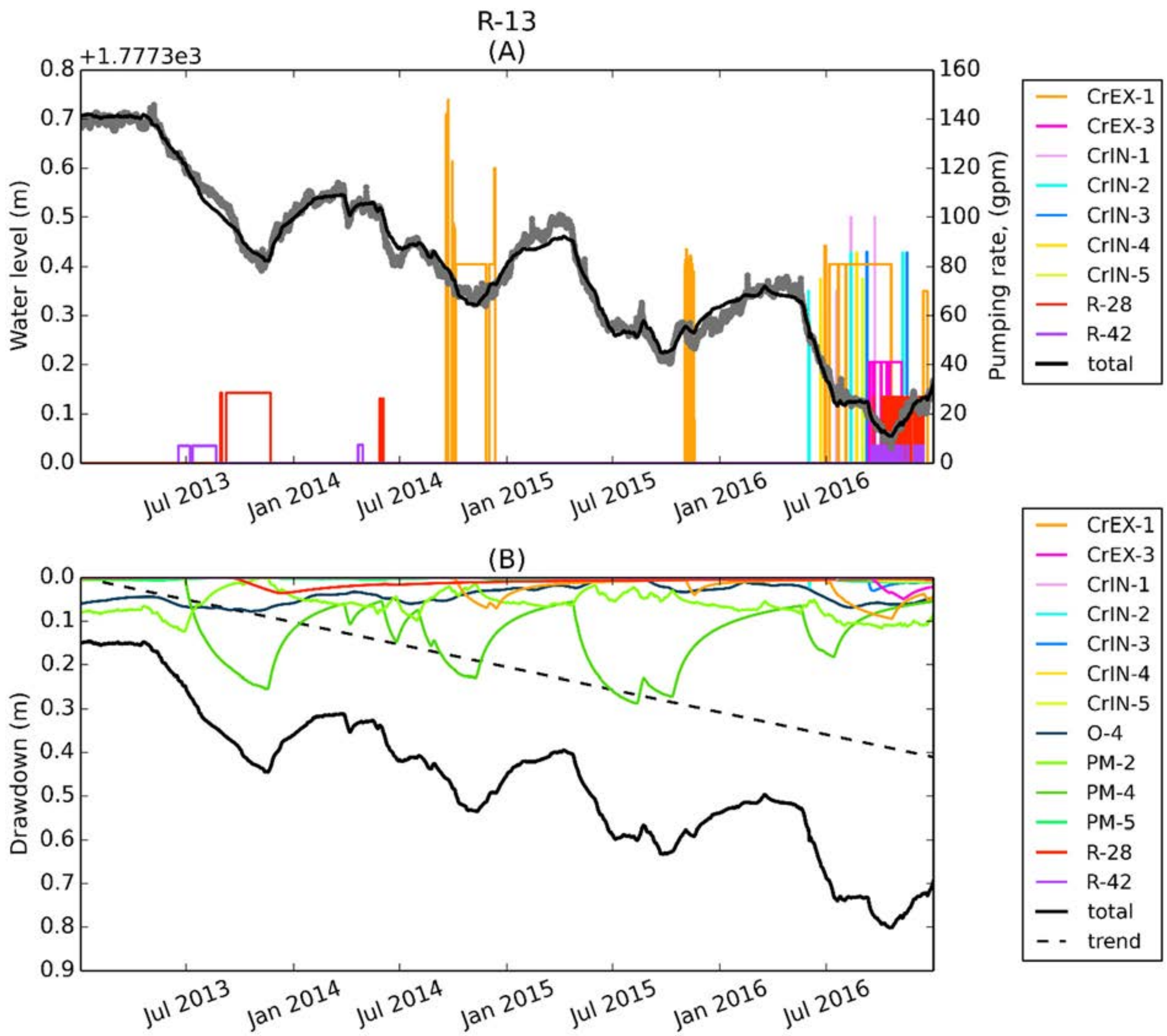


Figure A-11 **Calibrated model results for R-13. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

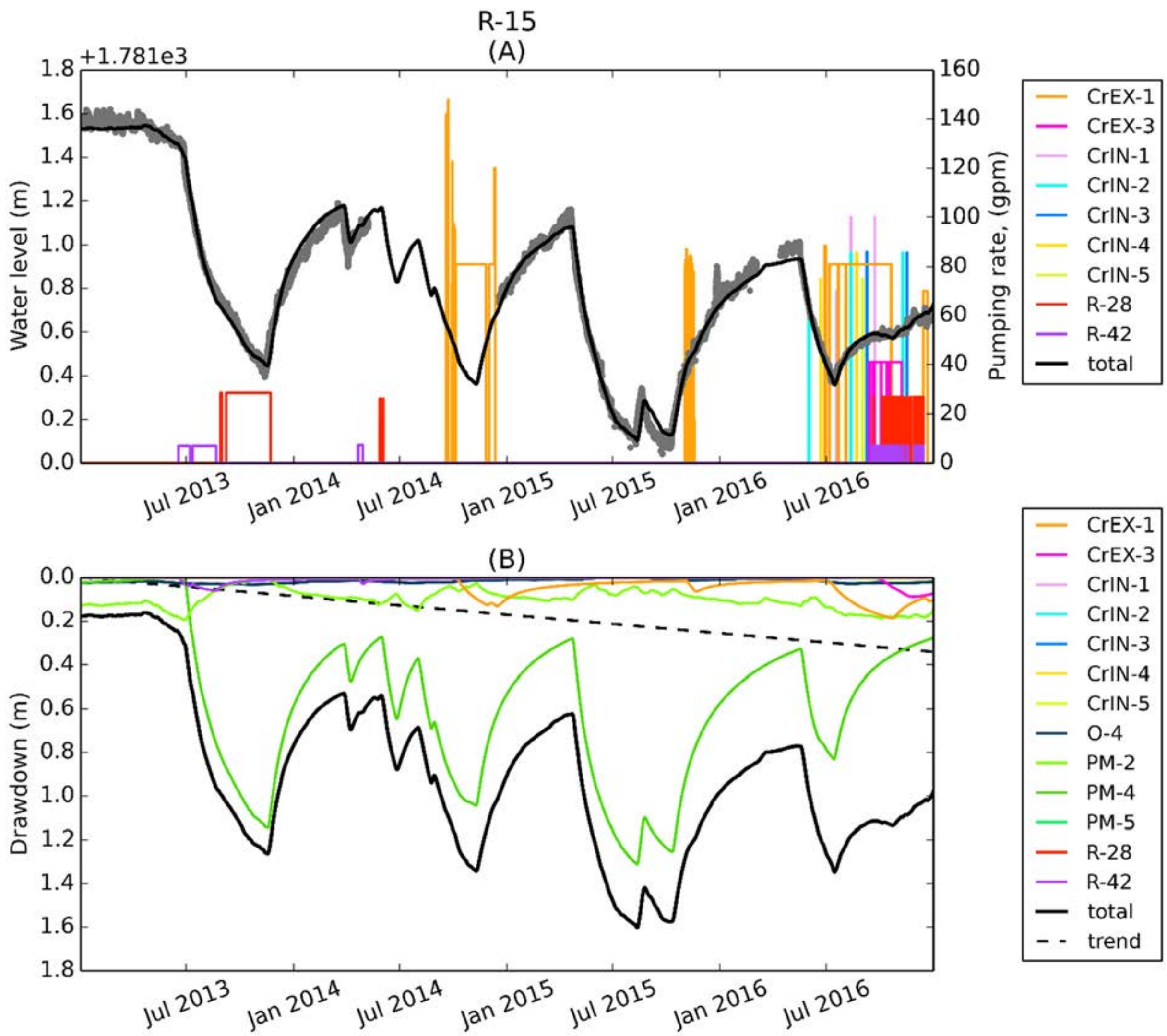


Figure A-12 Calibrated model results for R-15. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

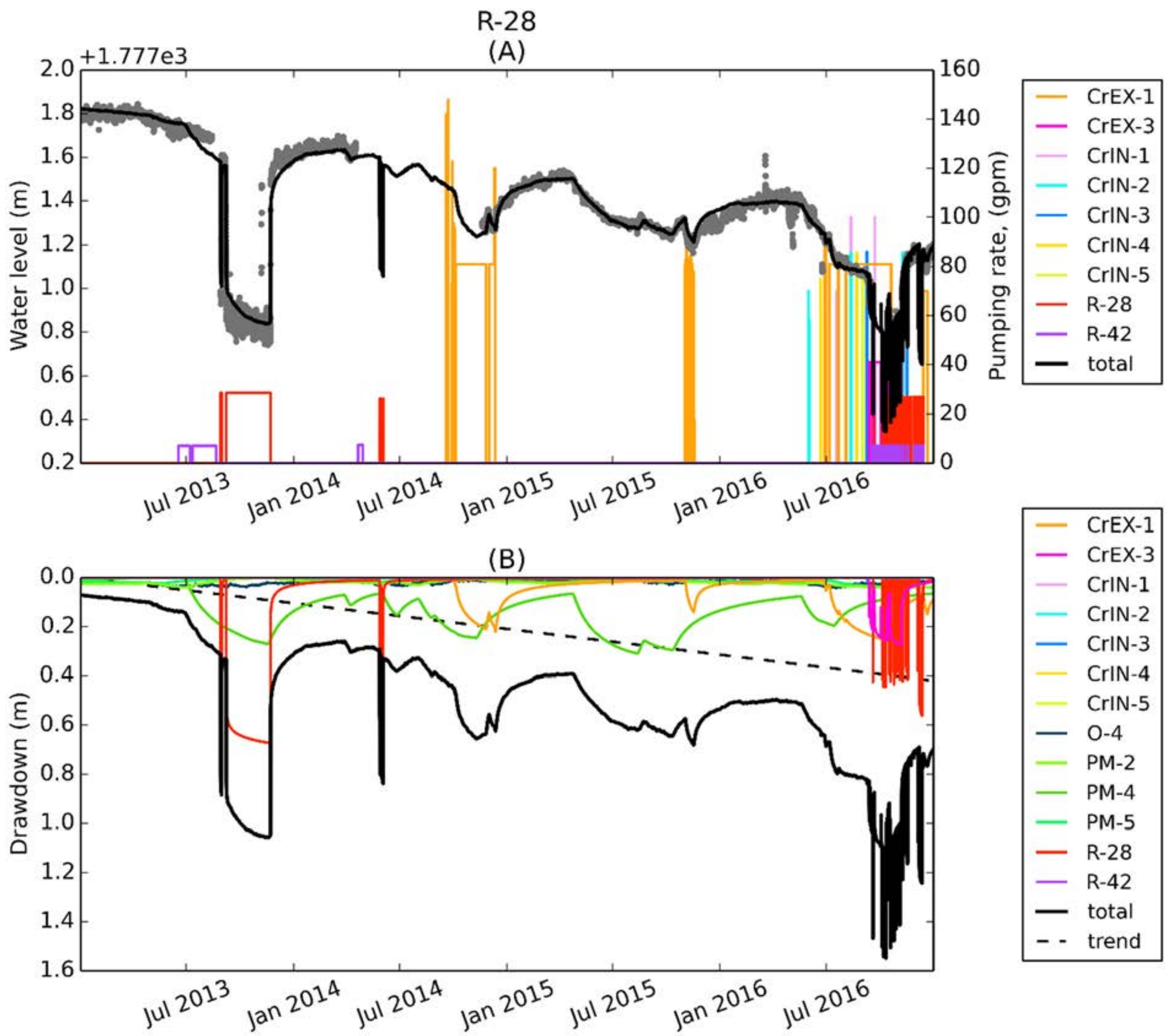


Figure A-13 Calibrated model results for R-28. Panel A shows observed (grey dots) and simulated (black line) water-levels (m), along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

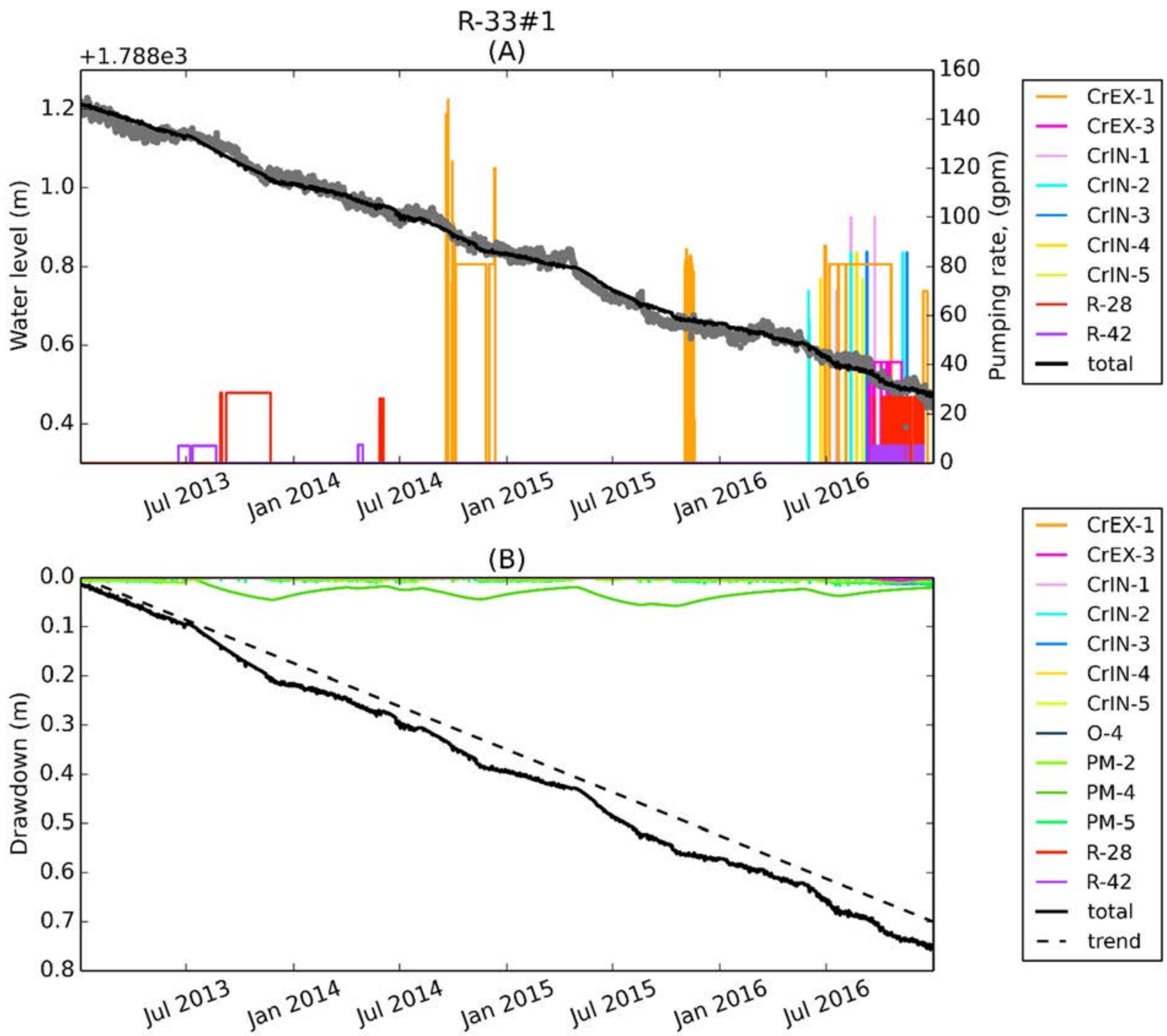


Figure A-14 Calibrated model results for R-33 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

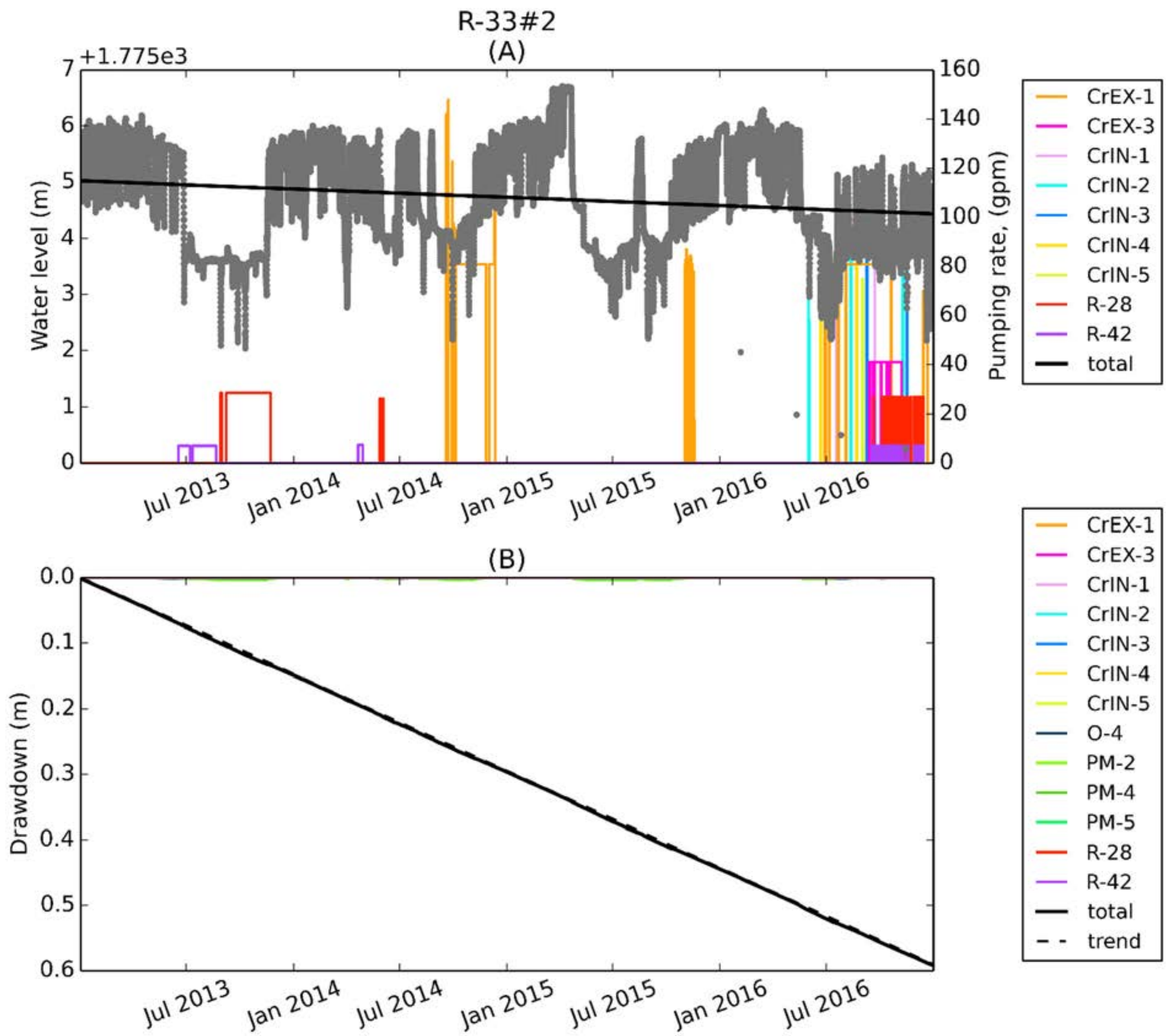


Figure A-15 **Calibrated model results for R-33 screen 2. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

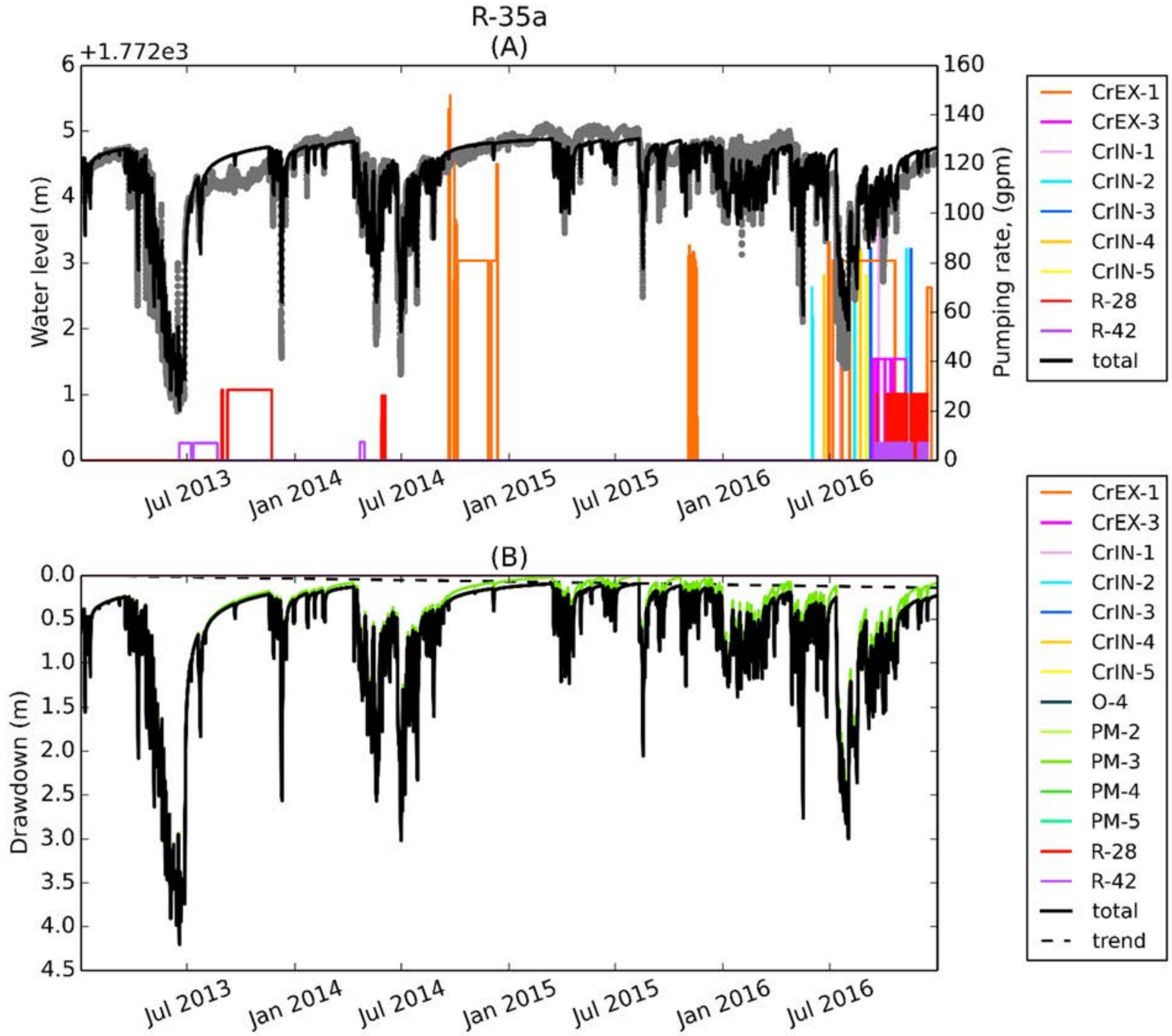


Figure A-16 Calibrated model results for R-35a. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

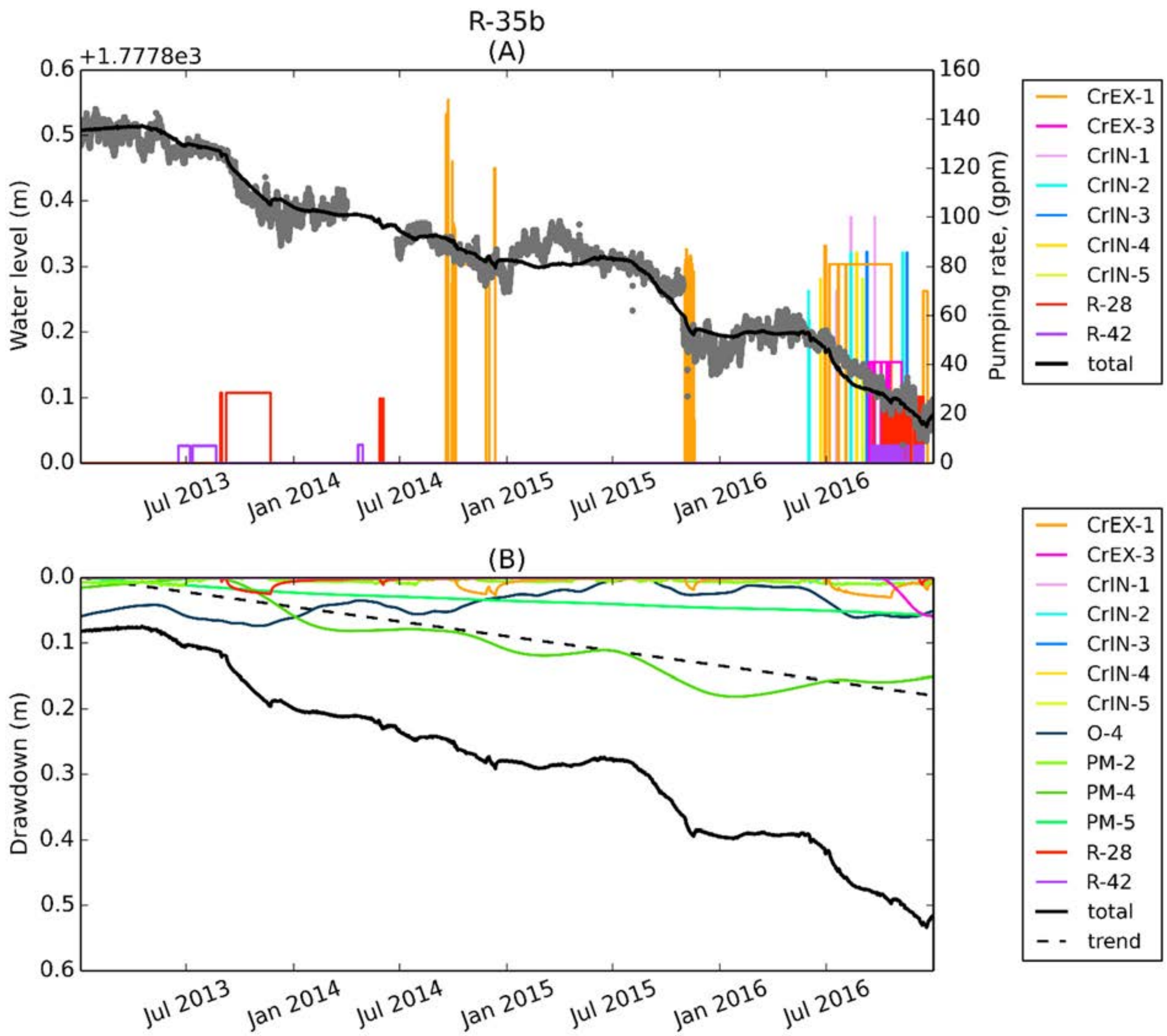


Figure A-17 Calibrated model results for R-35b. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

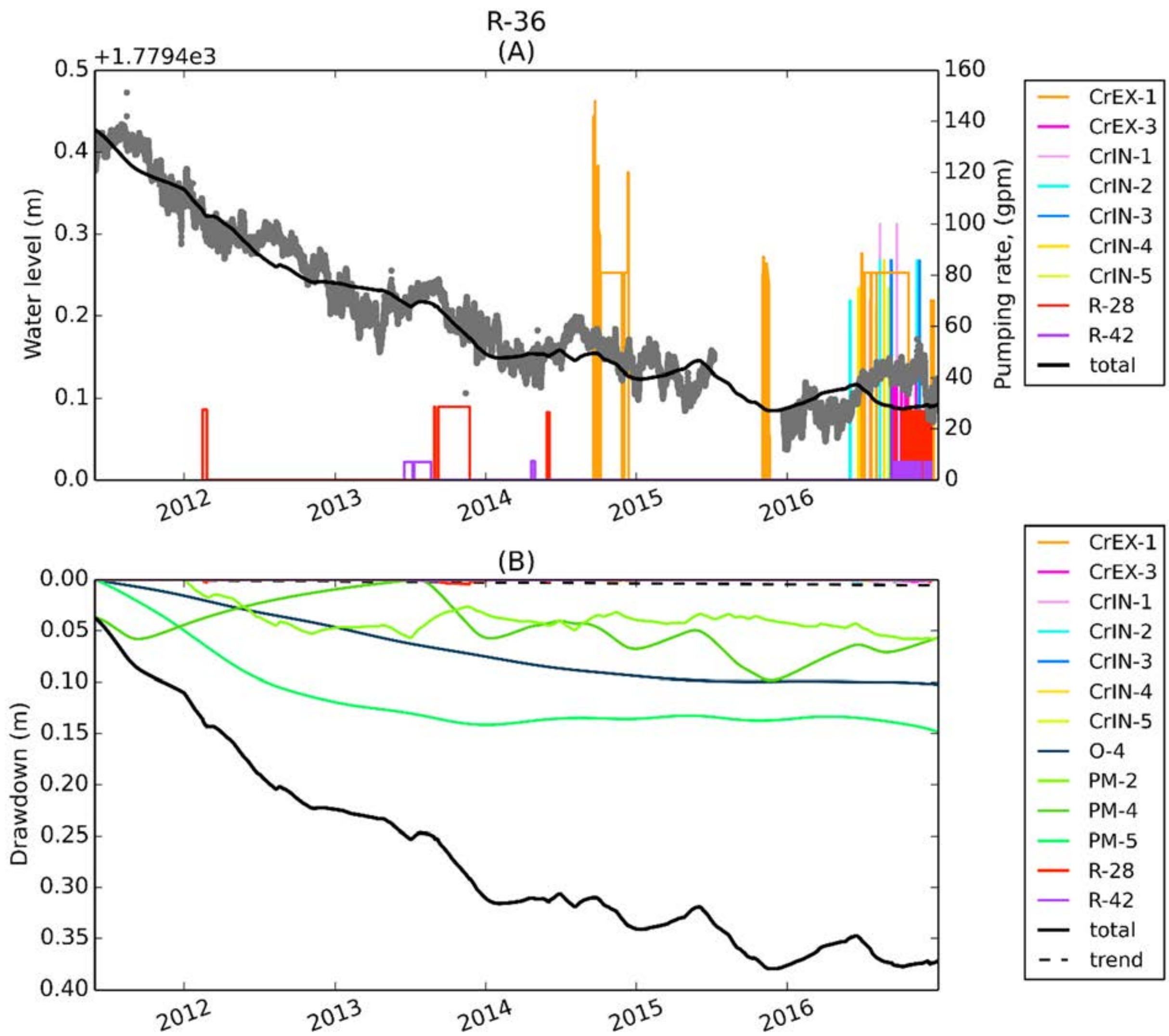


Figure A-18 **Calibrated model results for R-36. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

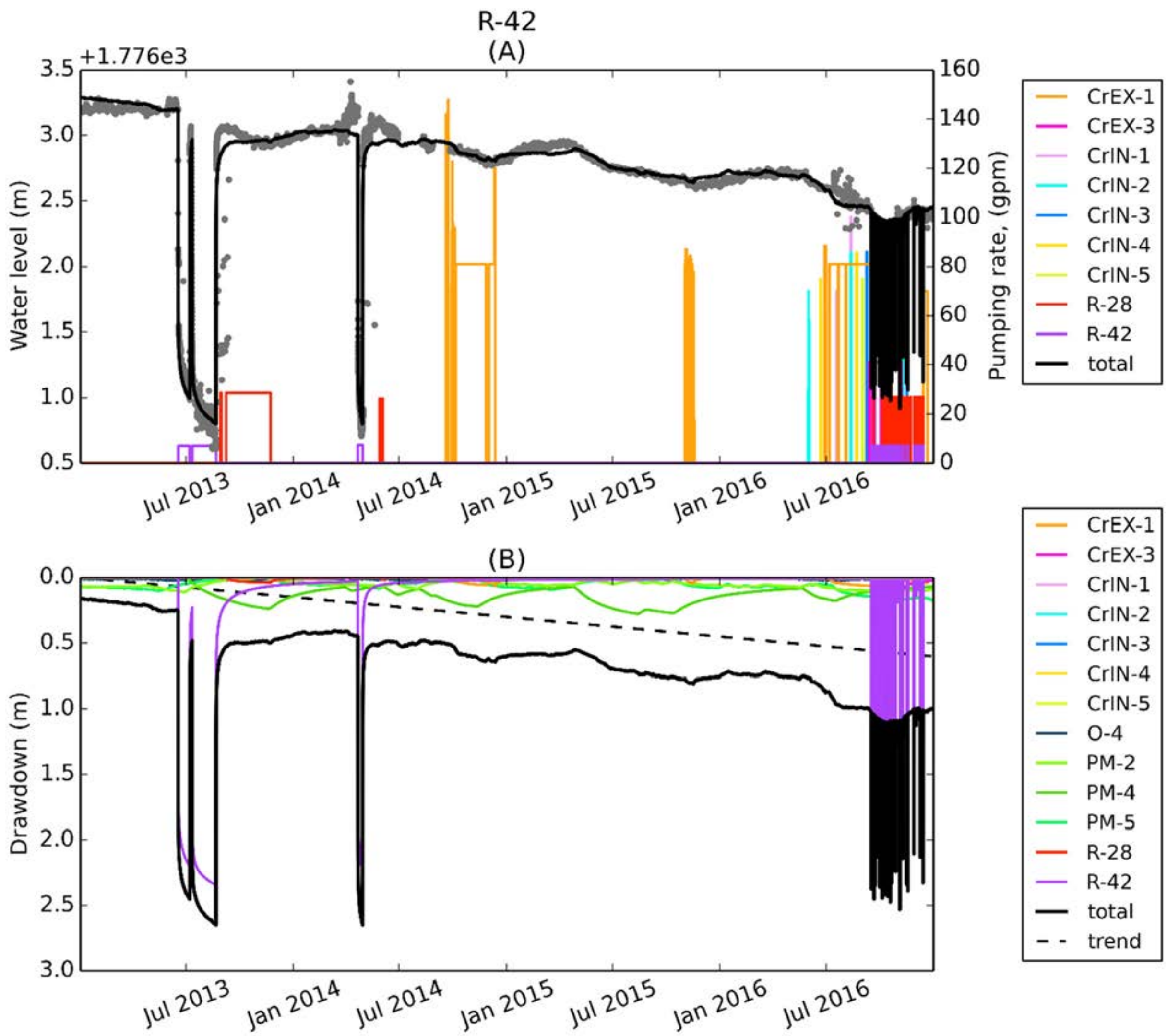


Figure A-19 Calibrated model results for R-42. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

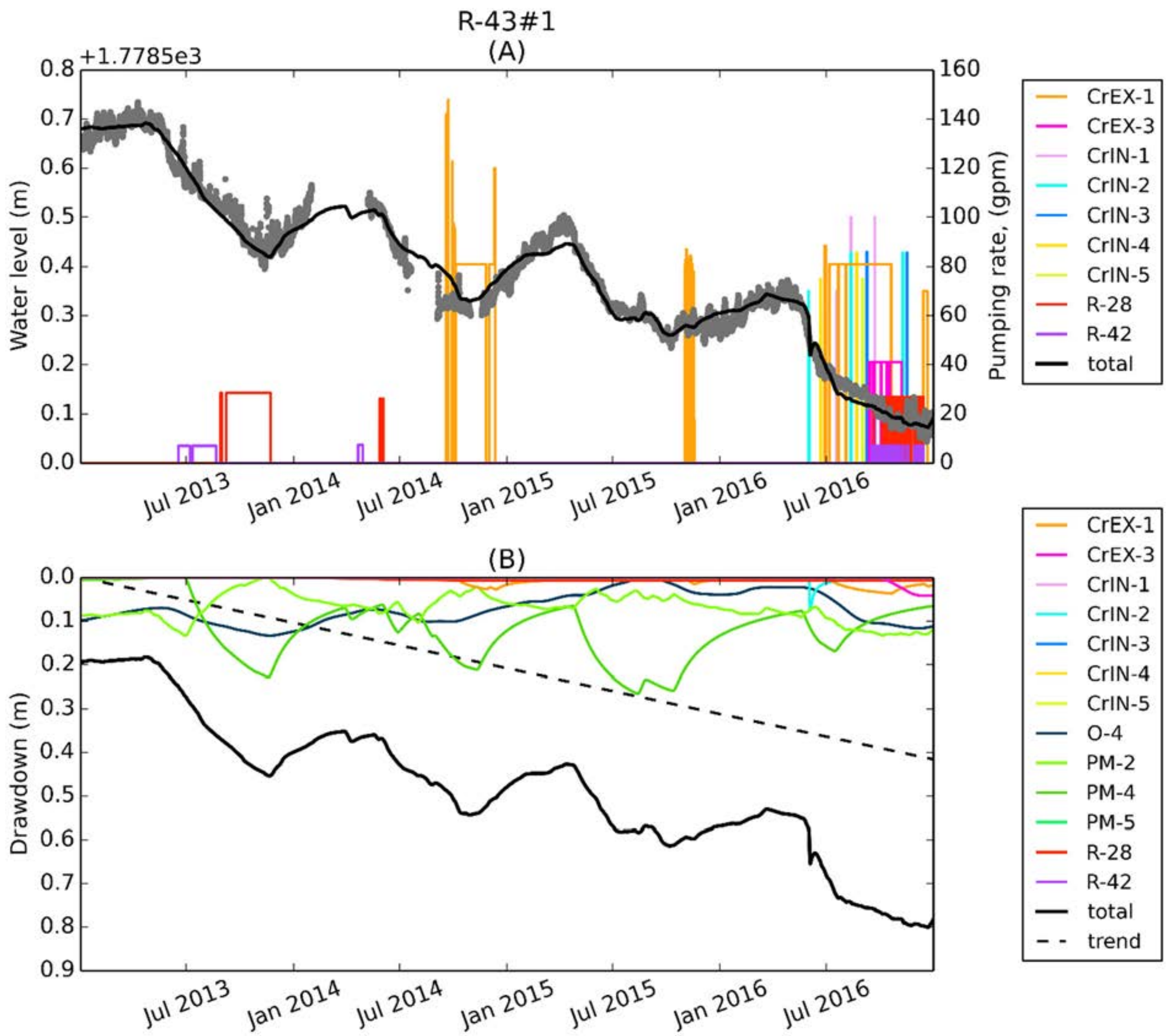


Figure A-20 Calibrated model results for R-43 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

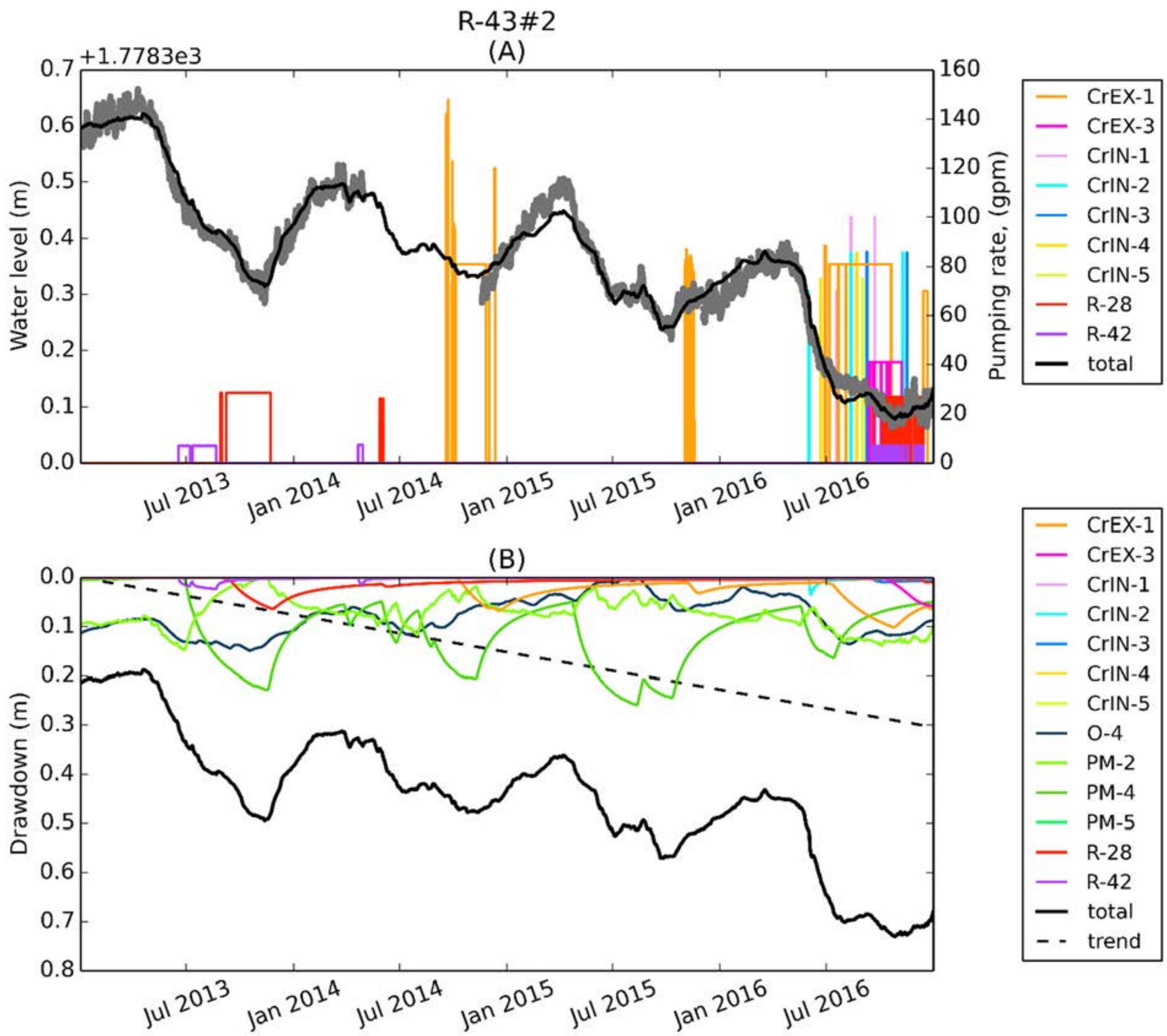


Figure A-21 Calibrated model results for R-43 screen 2. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

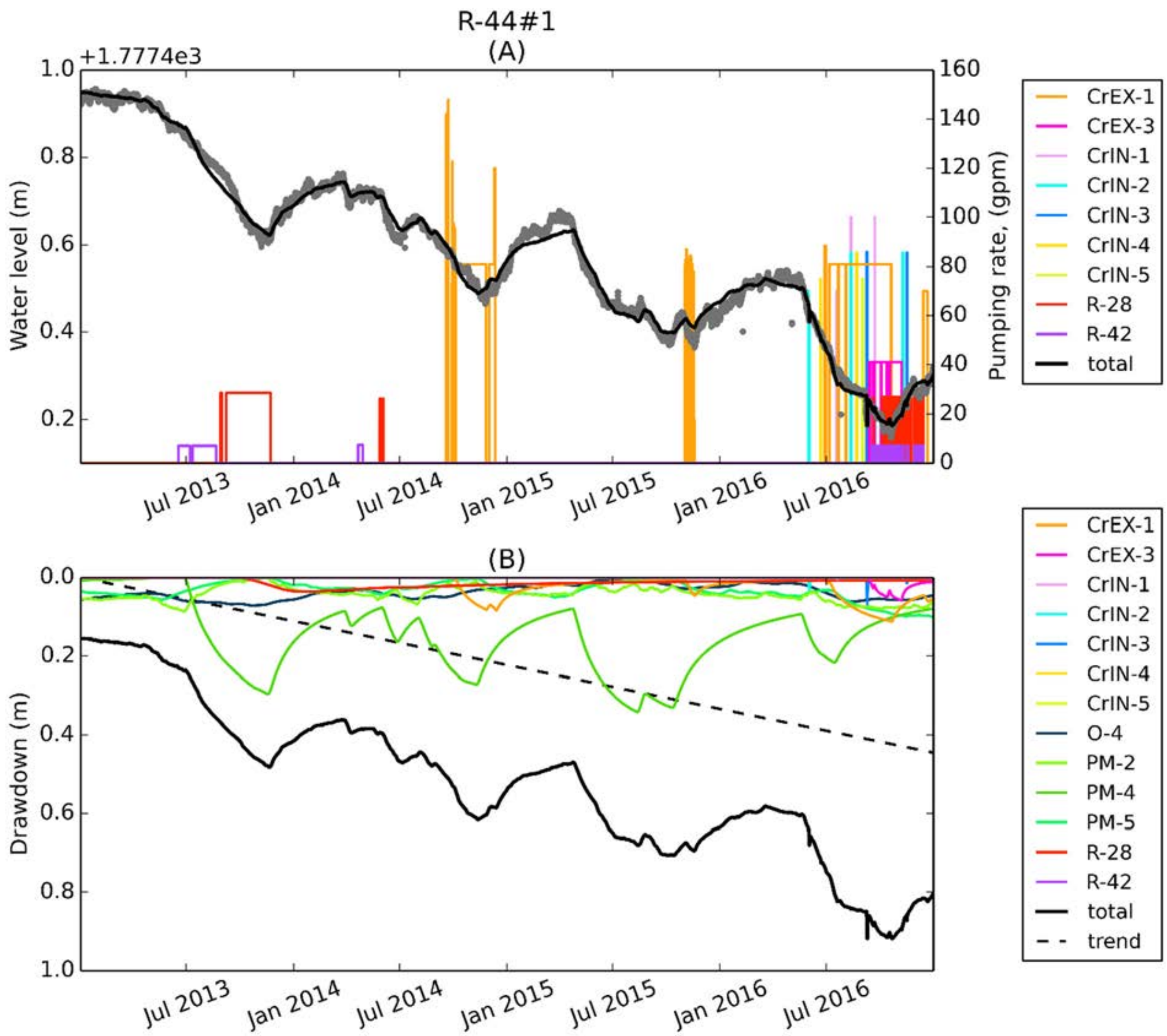


Figure A-22 Calibrated model results for R-44 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

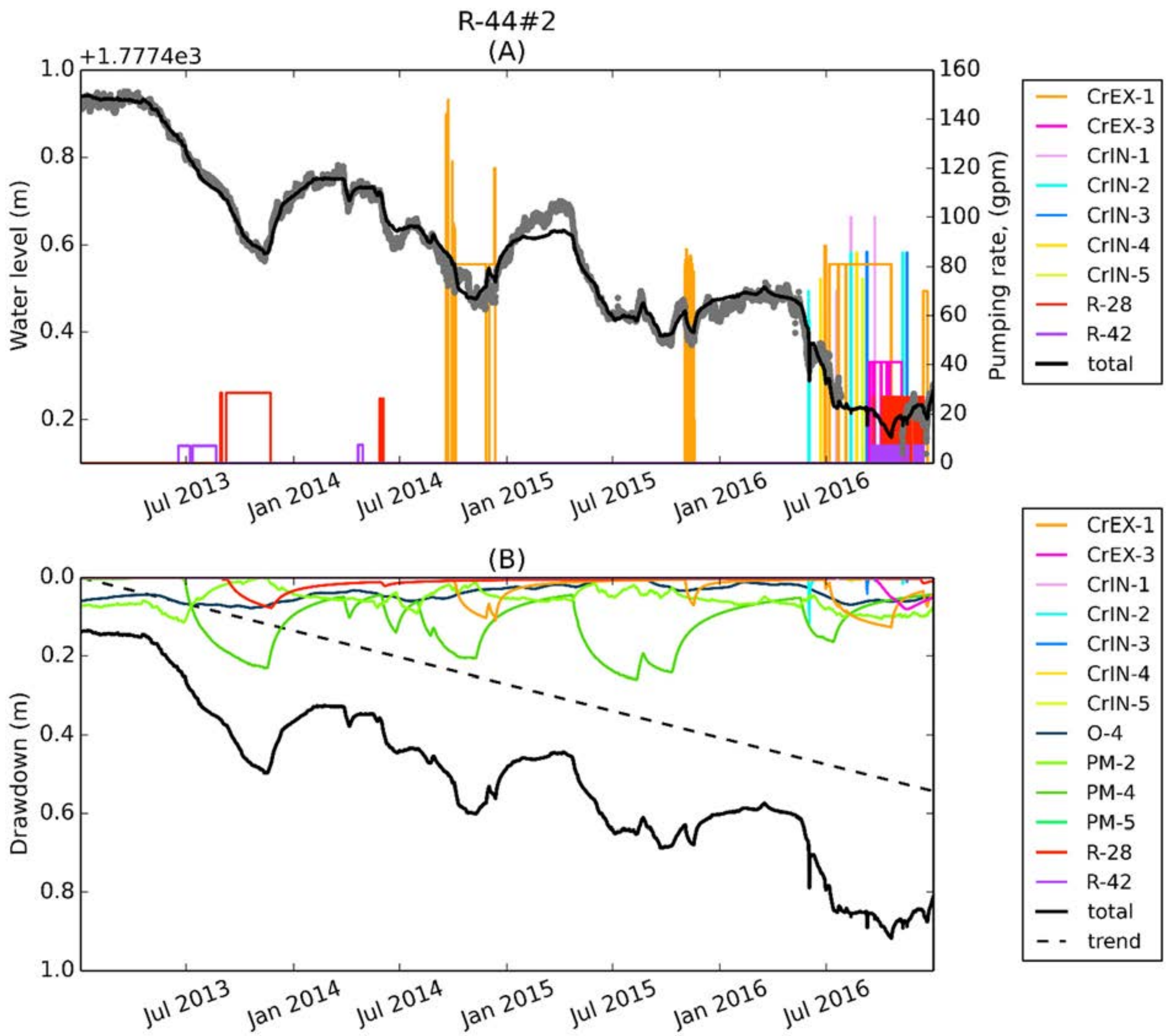


Figure A-23 Calibrated model results for R-44 screen 2. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

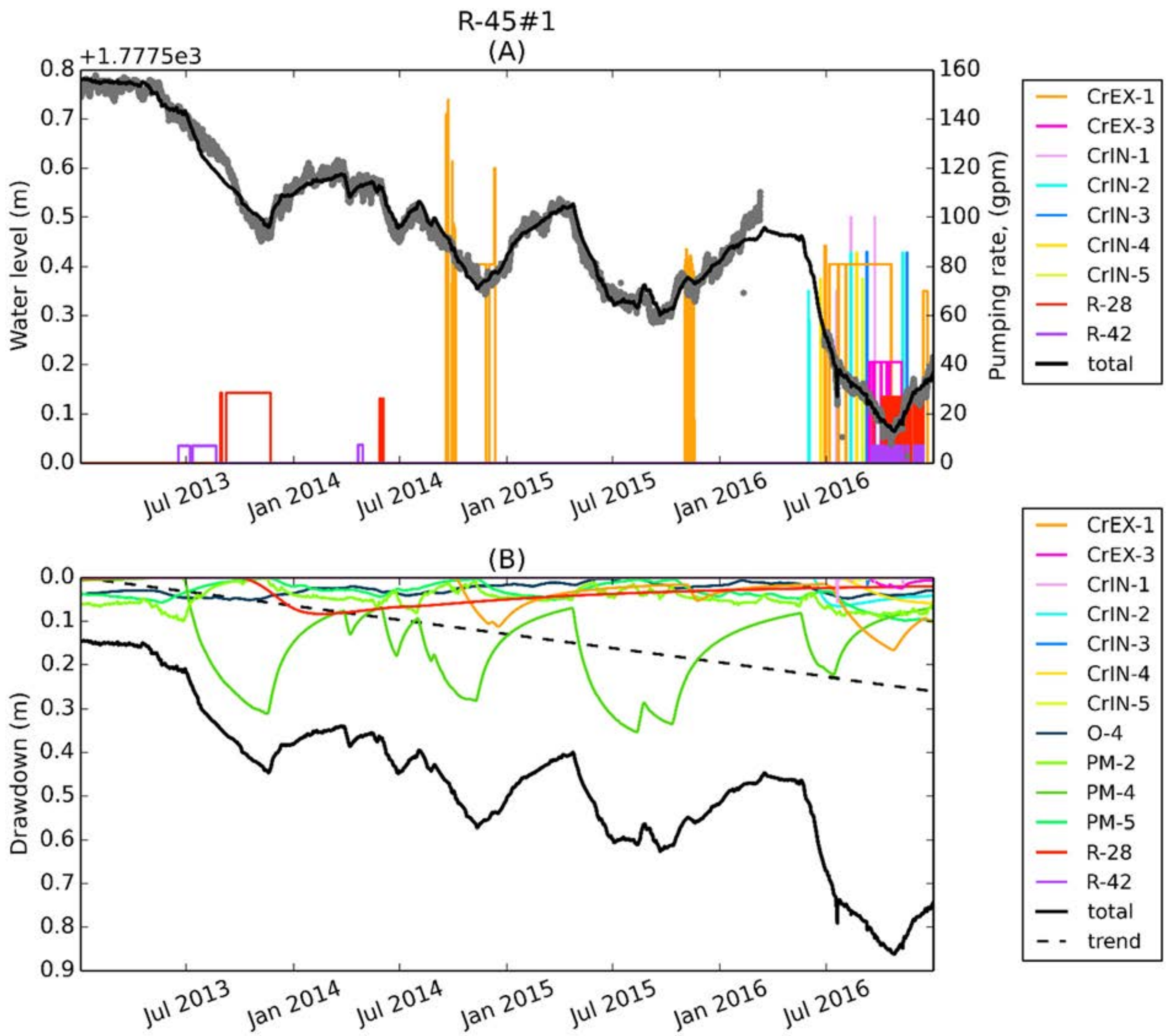


Figure A-24 Calibrated model results for R-45 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

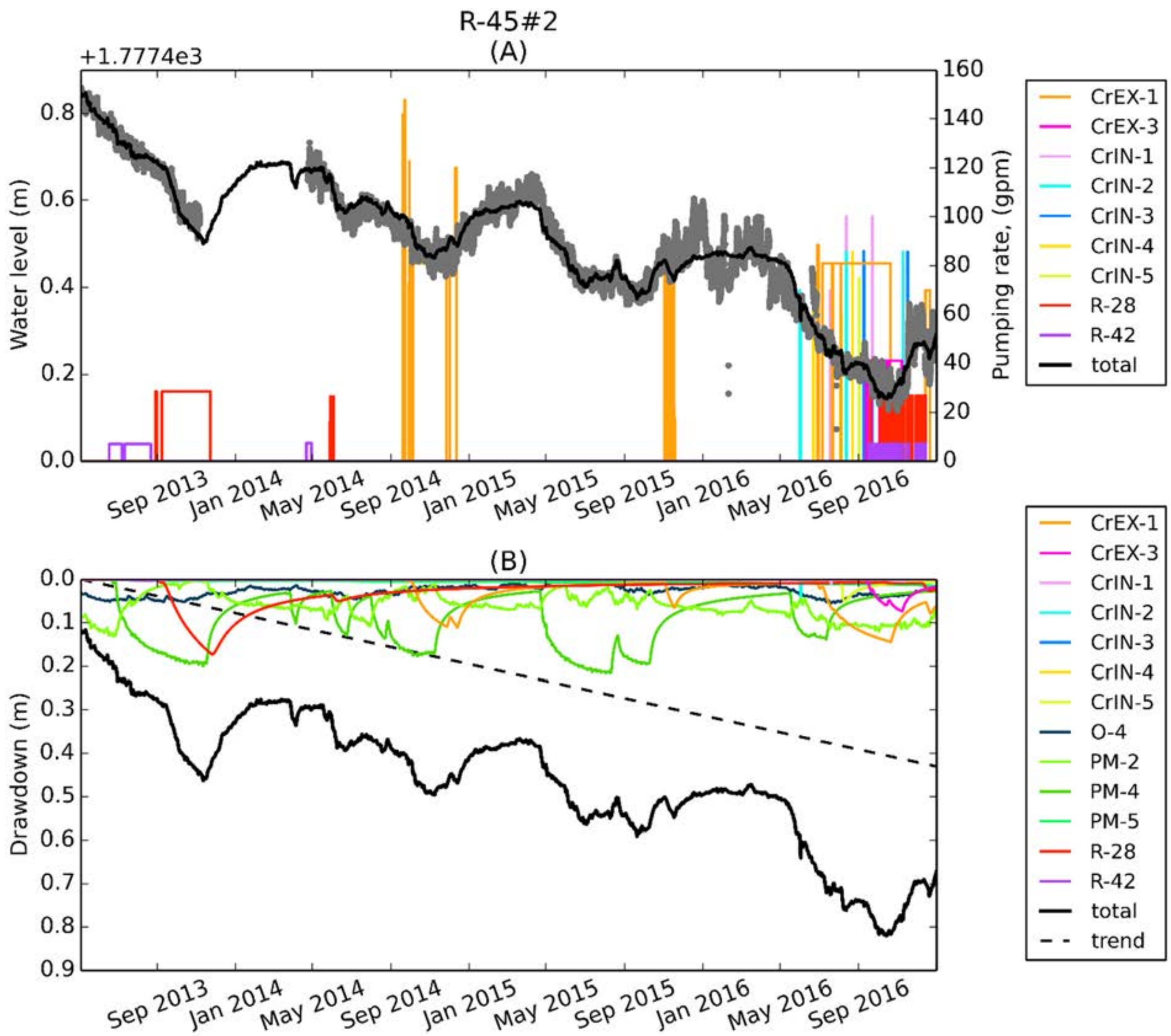


Figure A-25 Calibrated model results for R-45 screen 2. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

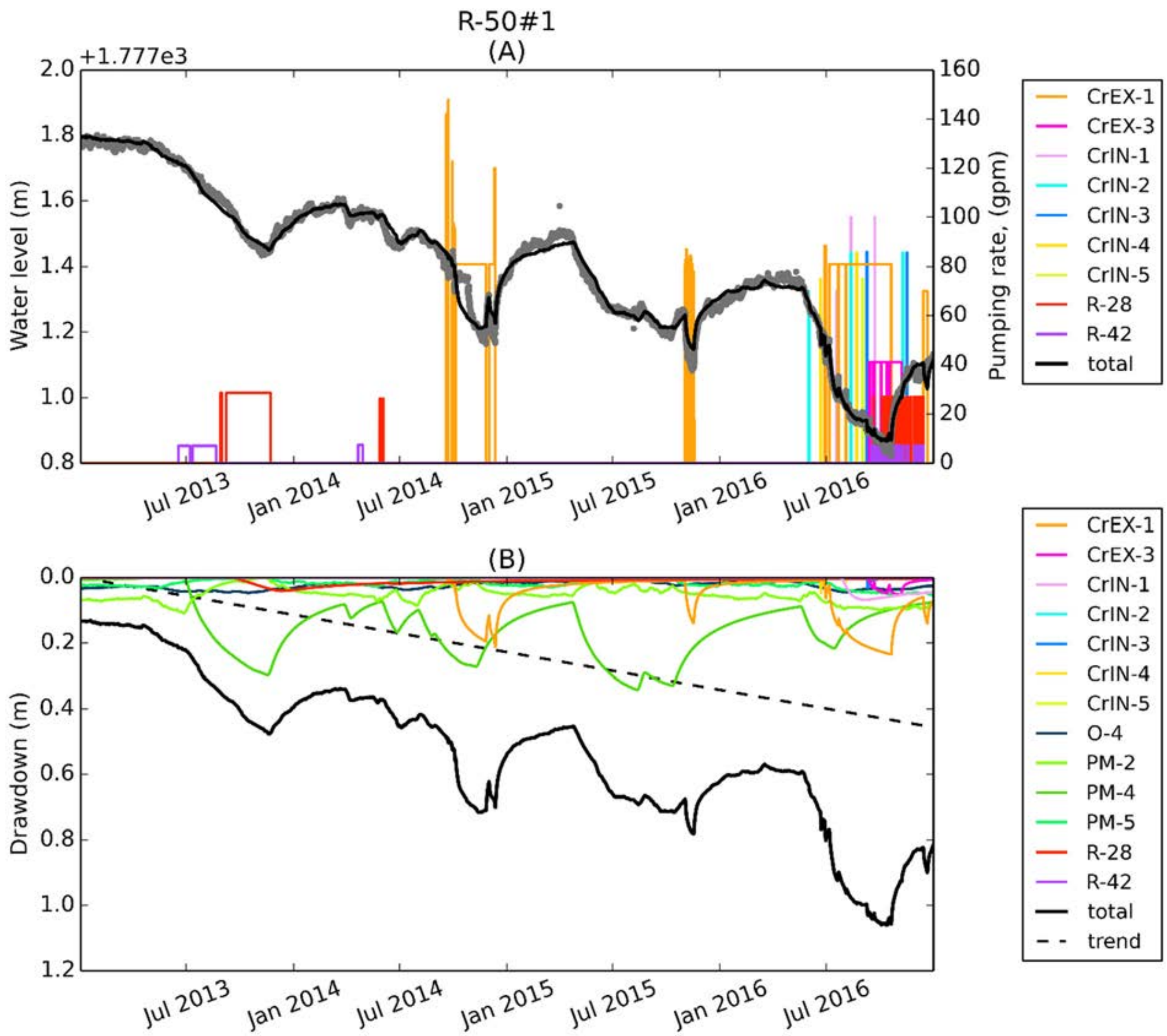


Figure A-26 Calibrated model results for R-50 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

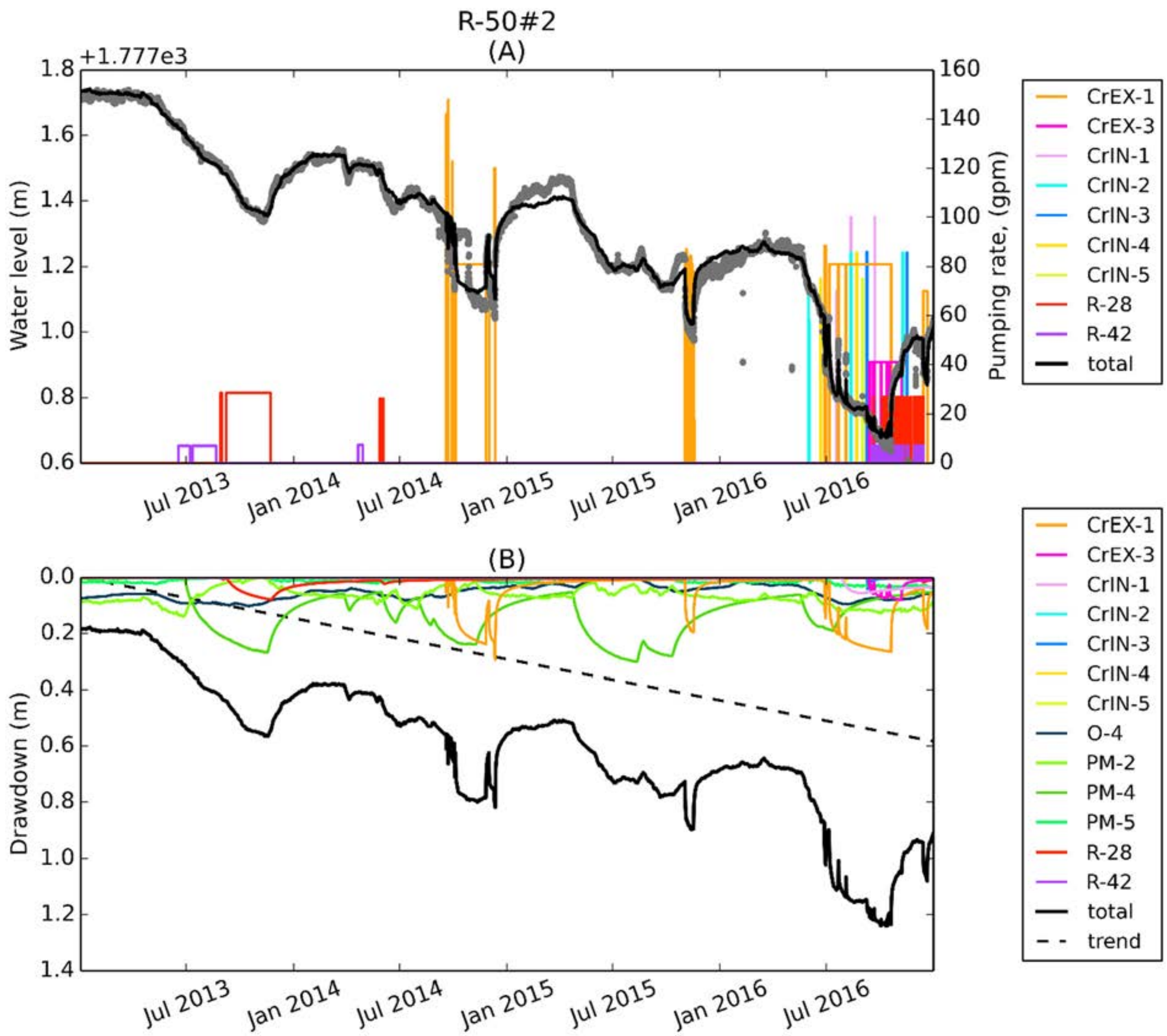


Figure A-27 Calibrated model results for R-50 Screen 2. Panel A shows observed (grey dots) and simulated (black line) water-levels (m), along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

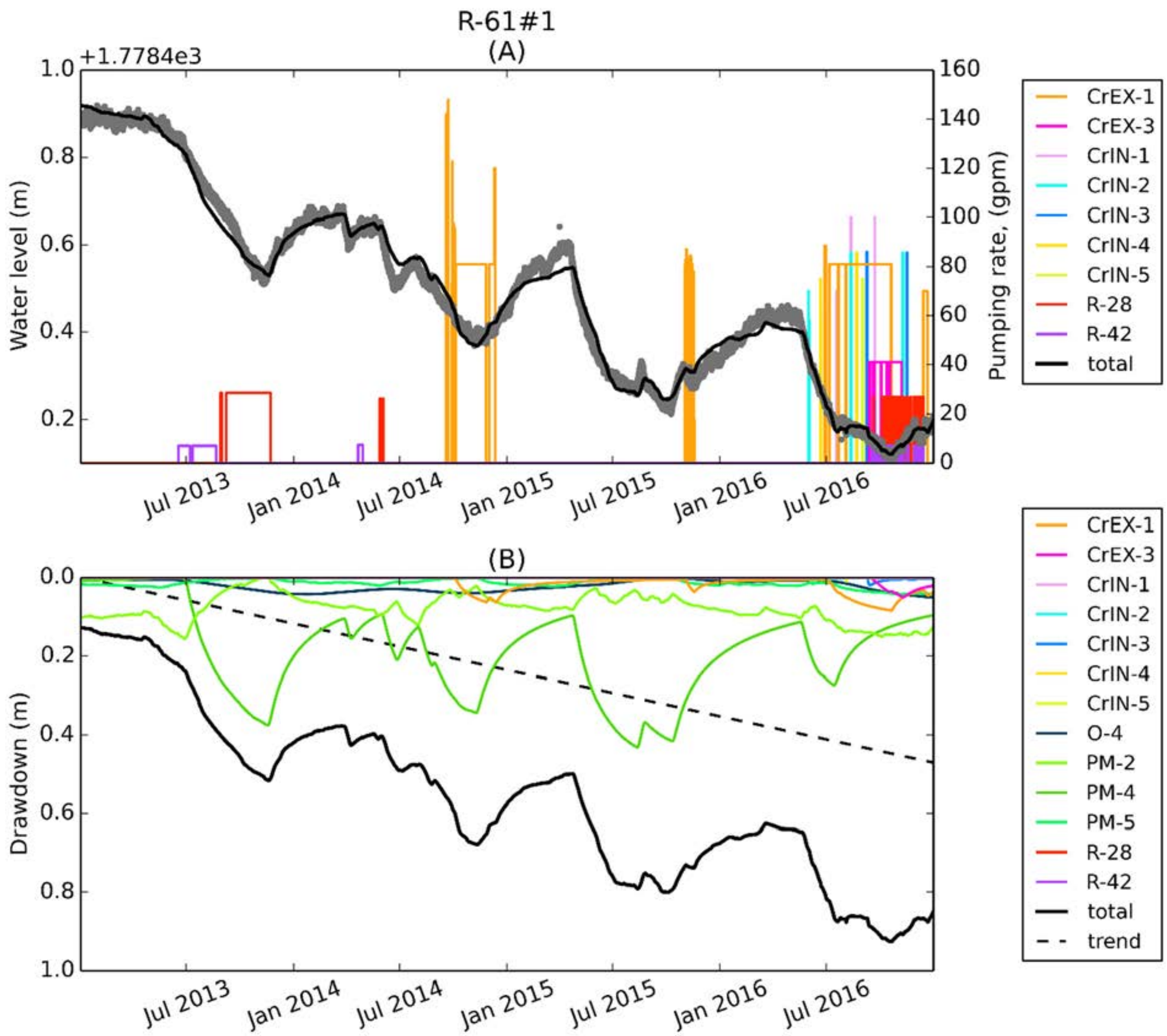


Figure A-28 Calibrated model results for R-61 screen 1. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

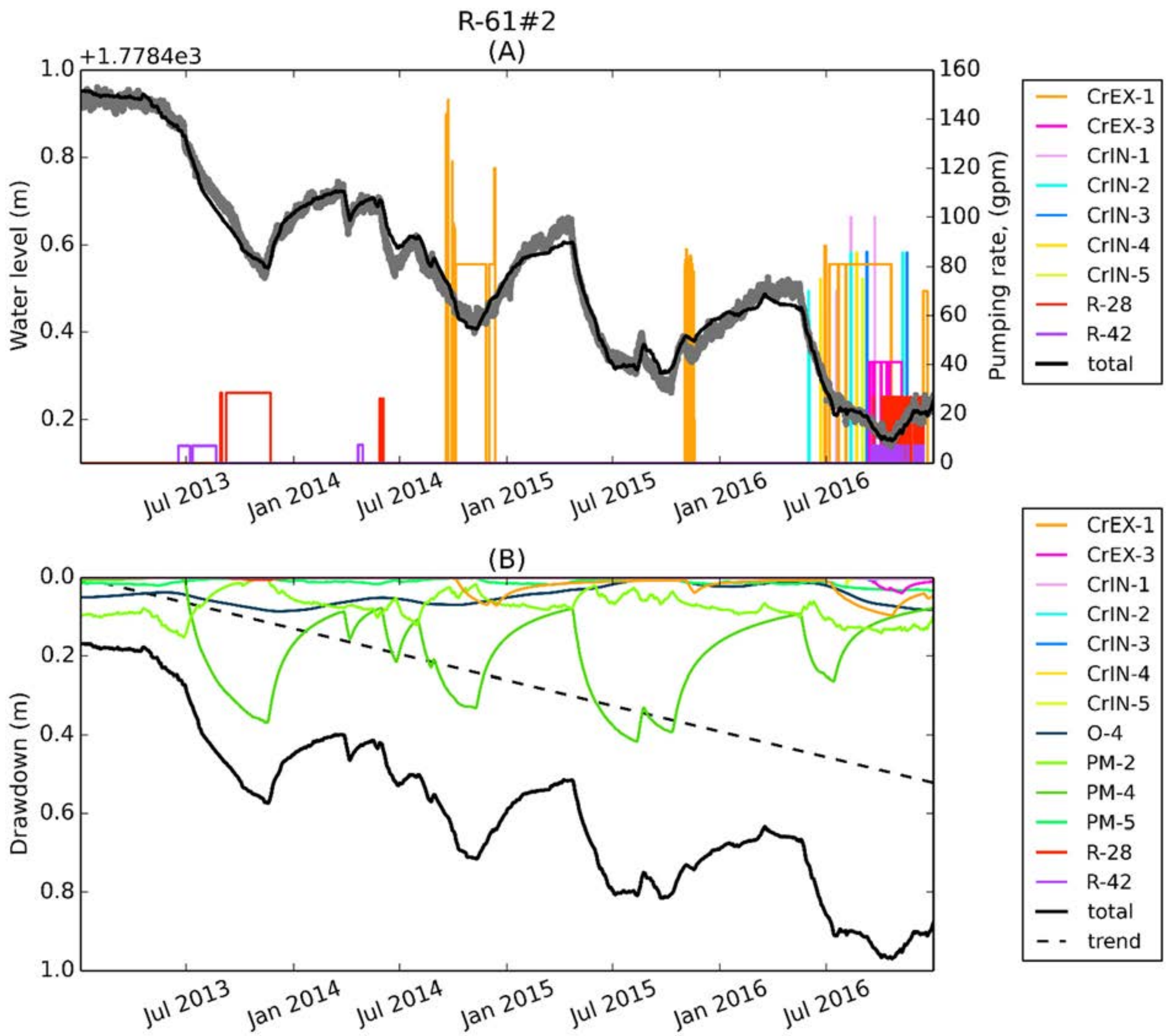


Figure A-29 **Calibrated model results for R-61 screen 2. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.**

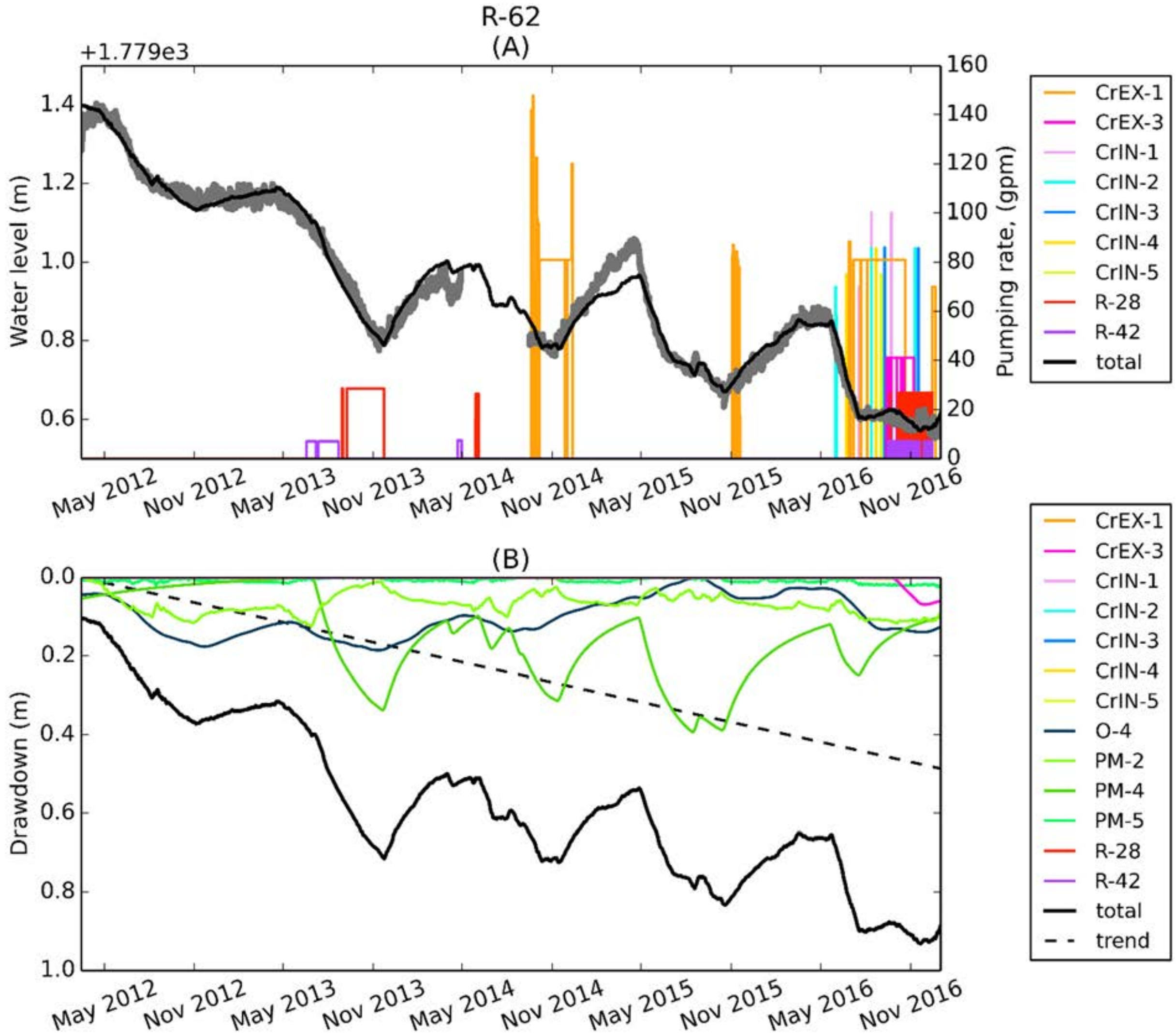


Figure A-30 Calibrated model results for R-62. Panel A shows observed (grey dots) and simulated (black line) water levels (m) along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

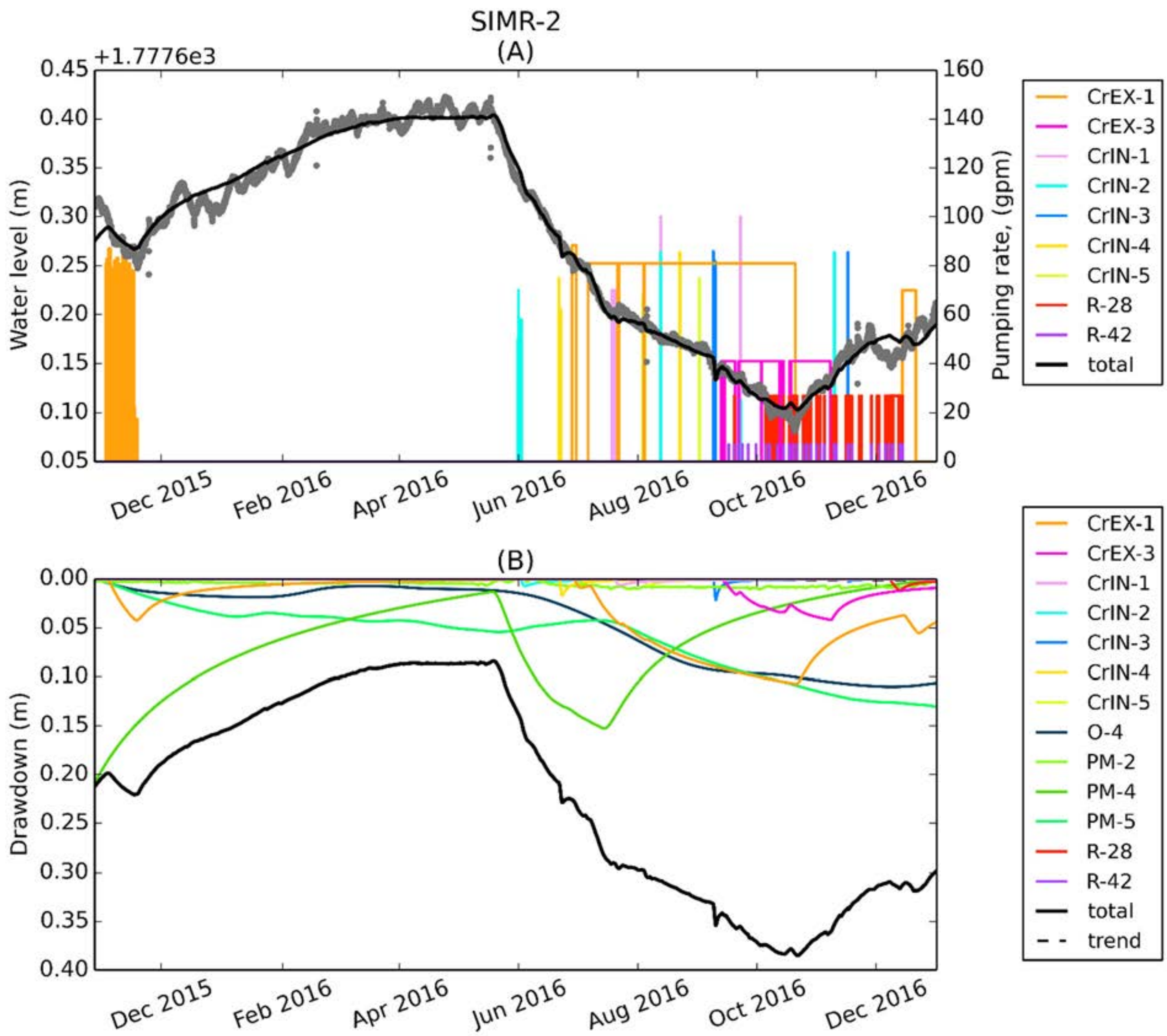


Figure A-31 Calibrated model results for SIMR-2. Panel A shows observed (grey dots) and simulated (black line) water-levels (m), along with pumping rates (gpm, colored lines). Panel B shows the simulated drawdowns (m) associated with each pumping well.

Table A-1
Estimated Potential Maximum Drawdown in 2016 at Each Screen as a Result of Pumping

	PM-2	PM-4	PM-5	O-4	CrEX-1	CrEX-3	R-28	R-42	CrIN-1	CrIN-2	CrIN-3	CrIN-4	CrIN-5
CrEX-1 screen 1	0.360	0.400	0.280	0.360	5.100	0.110	0.044	0.000	0.011	0.014	0.029	0.043	0.054
CrEX-3	0.031	0.110	0.038	0.120	0.200	1.200	0.018	0.000	0.024	0.009	0.160	0.020	0.01
CrPZ-1	0.083	0.080	0.004	0.210	0.200	0.013	0.004	0.000	0.003	0.004	0.025	0.006	0.009
CrPZ-1*	0.320	0.140	0.004	0.150	0.110	0.027	0.035	0.001	0.003	0.003	0.011	0.015	0.008
CrPZ-2 screen 1	0.040	0.130	0.130	0.260	0.250	0.099	0.005	0.001	0.012	0.012	0.110	0.011	0.008
CrPZ-3	0.150	0.074	0.069	0.300	0.074	0.057	0.019	0.003	0.004	0.007	0.006	0.007	0.005
CrPZ-4	0.110	0.200	0.190	0.048	0.029	0.073	0.043	0.000	0.002	0.003	0.004	0.003	0.004
CrPZ-5	0.006	0.085	0.014	0.097	0.220	0.130	0.011	0.000	0.002	0.081	0.002	0.059	0.007
R-1	0.045	0.018	0.180	0.001	0.000	0.030	0.000	0.000	0.000	0.000	0.001	0.000	0.000
R-11	0.060	0.070	0.048	0.110	0.065	0.054	0.005	0.000	0.005	0.034	0.012	0.003	0.002
R-13	0.140	0.130	0.013	0.110	0.090	0.049	0.002	0.000	0.003	0.022	0.030	0.004	0.009
R-15	0.230	0.550	0.005	0.044	0.180	0.089	0.000	0.001	0.002	0.001	0.002	0.001	0.006
R-28	0.052	0.130	0.051	0.050	0.250	0.270	0.560	0.000	0.006	0.006	0.017	0.017	0.007
R-33 screen 1	0.011	0.018	0.019	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.014	0.000	0.000
R-33 screen 2	0.001	0.002	3.7E-05	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-35b	0.013	0.028	0.006	0.110	0.029	0.059	0.010	0.000	0.003	0.008	0.002	0.002	0.001
R-36	0.043	0.020	0.030	0.007	0.001	0.002	0.002	0.000	0.002	0.002	0.002	0.001	0.001
R-42	0.130	0.110	0.200	0.031	0.066	0.100	0.014	1.400	0.005	0.005	0.006	0.006	0.008
R-43 screen 1	0.170	0.100	0.001	0.240	0.035	0.042	0.000	0.000	0.002	0.075	0.005	0.004	0.002
R-43 screen 2	0.160	0.110	0.001	0.200	0.094	0.058	0.007	0.001	0.002	0.034	0.009	0.003	0.002
R-44 screen 1	0.096	0.140	0.120	0.100	0.110	0.058	0.001	0.000	0.004	0.039	0.069	0.007	0.003
R-44 screen 2	0.120	0.120	0.001	0.100	0.120	0.080	0.013	0.000	0.003	0.110	0.041	0.002	0.008
R-45 screen 1	0.100	0.150	0.120	0.069	0.150	0.025	0.001	0.000	0.056	0.066	0.016	0.059	0.008
R-45 screen 2	0.140	0.110	0.001	0.067	0.140	0.074	0.020	0.000	0.010	0.053	0.011	0.003	0.051
R-50 screen 1	0.120	0.140	0.062	0.061	0.230	0.054	0.003	0.000	0.068	0.017	0.033	0.047	0.013
R-50 screen 2	0.150	0.140	0.041	0.130	0.260	0.080	0.015	0.000	0.055	0.018	0.042	0.015	0.014
R-61 screen 1	0.190	0.180	0.052	0.110	0.080	0.050	0.000	0.000	0.002	0.011	0.019	0.005	0.010
R-61 screen 2	0.170	0.190	0.040	0.180	0.092	0.040	0.002	0.000	0.004	0.004	0.007	0.005	0.015
R-62	0.130	0.150	0.026	0.280	0.002	0.069	0.000	0.000	0.002	0.001	0.002	0.002	0.003
SIMR-2	0.017	0.150	0.170	0.220	0.110	0.042	0.012	0.000	0.006	0.007	0.022	0.017	0.007

Notes: Drawdowns are in meters. The detections of pumping impacts at each observation well are labeled as certain (red), potential (blue), and unlikely or highly uncertain (grey). Values that are red and < 0.01 are likely to be negligible (i.e. ~0 m).

Table A-2
Aquifer Parameters Estimated Using the Theis Model between Pumping and Observation Wells

		Observation Wells														
		CrEX-1 screen 1	CrEX-3	CrPZ-1	CrPZ-1*	CrPZ-2#1	CrPZ-3	CrPZ-4	CrPZ-5	R-1	R-11	R-13	R-15	R-28	R-33#1	R-33#2
Pumping wells	^{T}PM-2	1300	8700	13000	630	86	170	1400	-*	29000	12000	5800	3000	12000	-	-
	^{S}PM-2	0.018	0.047	0.0029	0.028	0.046	0.045	0.1	-	0.0061	0.028	0.013	0.011	0.06	-	-
	^{T}PM-4	1500	10000	15000	4800	45000	17000	1800	14000	69000	5300	5700	1100	4800	-	-
	^{S}PM-4	0.03	0.023	0.061	0.1	0.026	0.038	0.076	-	0.089	0.095	0.036	0.026	0.057	-	-
	^{T}PM-5	1300	12000	-	-	25000	7800	1300	-	2500	5800	39000	-	8200	-	-
	^{S}PM-5	0.02	0.03	-	-	0.048	0.061	0.093	-	0.27	0.11	0.13	-	0.08	-	-
	^{T}O-4	2100	1600	2600	2500	7700	990	17000	19000	-	2900	4700	11000	33000	-	-
	^{S}O-4	0.02	0.078	0.028	0.088	0.068	0.12	0.22	0.017	-	0.29	0.072	0.34	0.04	-	-
	^{T}CrEX-1	130	970	250	800	3700	1000	4100	470	-	1400	1100	400	550	-	-
	^{S}CrEX-1	0.014	0.016	0.086	0.075	0.0049	0.12	0.068	0.0094	-	0.051	0.03	0.014	0.029	-	-
	^{T}CrEX-3	710	320	7100	1800	3400	1100	350	40	21	360	480	93	620	-	-
	^{S}CrEX-3	0.017	0.00052	0.014	0.04	0.0015	0.014	0.018	0.012	0.0046	0.076	0.032	0.011	0.0017	-	-
	^{T}R-28	330	910	-	63	-	570	76	1400	-	-	-	-	430	-	-
	^{S}R-28	0.016	0.018	-	0.008	-	0.017	0.0038	0.0067	-	-	-	-	0.0015	-	-
	^{T}R-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	^{S}R-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	^{T}CrIN-1	310	720	-	-	140	-	-	-	-	-	-	-	-	-	-
	^{S}CrIN-1	0.016	0.015	-	-	0.0059	-	-	-	-	-	-	-	-	-	-
	^{T}CrIN-2	320	-	-	-	480	-	-	5.9	-	340	1100	-	-	-	-
	^{S}CrIN-2	0.016	-	-	-	0.016	-	-	0.00037	-	0.0053	0.0082	-	-	-	-
	^{T}CrIN-3	320	24	250	450	7.5	-	-	-	-	28	44	-	2400	-	-
	^{S}CrIN-3	0.016	0.0024	0.0035	0.0085	0.0045	-	-	-	-	0.01	0.011	-	0.014	-	-
	^{T}CrIN-4	310	470	-	200	740	-	-	32	-	-	-	-	1100	-	-
	^{S}CrIN-4	0.016	0.015	-	0.0065	0.015	-	-	0.00071	-	-	-	-	0.012	-	-
	^{T}CrIN-5	310	430	-	-	-	520	-	-	-	-	-	-	-	-	-
	^{S}CrIN-5	0.016	0.019	-	-	-	0.021	-	-	-	-	-	-	-	-	-

Table A-2 (continued)

		Observation Wells														
		R-35b	R-36	R-42	R-43 screen 1	R-43 screen 2	R-44 screen 1	R-44 screen 2	R-45 screen 1	R-45 screen 2	R-50 screen 1	R-50 screen 2	R-61 screen 1	R-61 screen 2	R-62	SIMR-2
Pumping wells	^{T}PM-2	-	12000	5600	3600	4800	8100	6900	9500	7900	6800	6200	3600	5000	6300	-
	^{S}PM-2	-	0.062	0.015	0.014	0.0079	0.021	0.013	0.0084	0.0052	0.018	0.011	0.018	0.012	0.011	-
	^{T}PM-4	1300	3800	4400	4800	6300	3900	7200	4500	12000	4100	6100	3200	4000	2900	3700
	^{S}PM-4	0.19	0.22	0.1	0.082	0.051	0.06	0.039	0.033	0.014	0.093	0.061	0.12	0.086	0.075	0.066
	^{T}PM-5	-	160	2600	-	-	3000	-	3200	-	11000	25000	8900	15000	41000	1500
	^{S}PM-5	-	0.034	0.019	-	-	0.029	-	0.026	-	0.03	0.013	0.12	0.11	0.056	0.034
	^{T}O-4	3400	-	-	1100	2800	4400	4800	9000	19000	11000	4800	1100	1100	1100	1200
	^{S}O-4	0.13	-	-	0.27	0.14	0.1	0.083	0.13	0.038	0.11	0.056	0.24	0.15	0.15	0.061
	^{T}CrEX-1	5900	-	2600	2700	600	880	1200	390	780	710	1000	1300	980	-	920
	^{S}CrEX-1	0.0066	-	0.022	0.082	0.059	0.065	0.02	0.063	0.03	0.098	0.0067	0.092	0.099	-	0.036
	^{T}CrEX-3	69	-	490	130	64	1100	170	1900	630	1700	1600	490	1100	120	1200
	^{S}CrEX-3	0.019	-	0.017	0.065	0.048	0.015	0.059	0.084	0.031	0.0088	0.0011	0.042	0.029	0.014	0.015
	^{T}R-28	2300	-	1400	-	-	-	370	-	110	-	400	-	-	-	1000
	^{S}R-28	0.0038	-	0.021	-	-	-	0.028	-	0.031	-	0.037	-	-	-	0.0098
	^{T}R-42	-	-	23	-	-	-	-	-	-	-	-	-	-	-	-
	^{S}R-42	-	-	0.015	-	-	-	-	-	-	-	-	-	-	-	-
	^{T}CrIN-1	-	-	-	-	-	-	-	1800	14000	4	5.7	-	-	-	-
	^{S}CrIN-1	-	-	-	-	-	-	-	0.019	0.032	0.0023	0.0028	-	-	-	-
	^{T}CrIN-2	-	-	-	70	110	880	410	3.1	930	520	610	220	-	-	-
	^{S}CrIN-2	-	-	-	0.00057	0.0013	0.013	0.0032	0.045	0.024	0.012	0.011	0.005	-	-	-
	^{T}CrIN-3	-	-	-	-	-	1100	2300	1500	6600	390	330	140	-	-	1200
	^{S}CrIN-3	-	-	-	-	-	0.019	0.022	0.026	0.021	0.02	0.016	0.0049	-	-	0.02
	^{T}CrIN-4	-	-	-	-	-	-	-	0.88	-	1300	5900	-	-	-	640
	^{S}CrIN-4	-	-	-	-	-	-	-	0.0034	-	0.018	0.031	-	-	-	0.019
	^{T}CrIN-5	-	-	-	-	-	-	-	-	35	4100	4100	-	570	-	-
	^{S}CrIN-5	-	-	-	-	-	-	-	-	0.0016	0.057	0.046	-	0.021	-	-

Notes: T = Transmissivity; S = storativity.
*– = Parameters were not estimated.