Third Updated
Groundwater Flow Model and
Predictive Simulation Results

Coso Operating Company
Hay Ranch Water Extraction and Delivery System
Conditional Use Permit (CUP) 2007-003

Prepared for **County of Inyo**
Independence, California

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Third Updated Groundwater Flow Model and Predictive Simulation Results

Coso Operating Company

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1. Introduction

This report documents the third updated groundwater flow model completed by Daniel B. Stephens & Associates, Inc. (DBS&A) and predictive simulation results conducted in July 2017 in accordance with the *Addendum to the Hydrologic Monitoring and Mitigation Plan for Conditional Use Permit #2007-003/Coso Operating Company, LLC* (County of Inyo Water Department, 2011). A base map of the Rose Valley area is provided in Figure 1. The groundwater model grid and monitoring and production well locations are provided in Figure 2.

The model update was completed to account for (1) Coso Operating Company (Coso) Hay Ranch pumping that occurred since the model was last updated in 2016, (2) estimated groundwater recharge based on climatic conditions for the period 2013 through June 2017, and (3) the release of 1,812 acre-feet from Haiwee Reservoir in March 2017 by the Los Angeles Department of Water and Power (LADWP). The released Haiwee Reservoir water flowed in the natural channel along the axis of Rose Valley until it infiltrated into the subsurface or evaporated, although evaporation rates would be small in March. In addition, Coso significantly reduced their pumping since April 2016 and had effectively ceased pumping in September 2016.

The County of Inyo (County) requested that DBS&A update the existing Rose Valley groundwater model, and if necessary adjust the model calibration to account for the observed conditions since the last model update. Model calibration is conducted to minimize the differences between observed values (i.e., measured groundwater levels and measured flow amounts) and simulated values to the extent possible. The County also requested that the updated model be used to assess the length of time (if any) for which Coso could pump at an average rate of 1,000 gallons per minute (gpm) from the Coso Hay Ranch production wells without exceeding the criterion of 10 percent reduction of groundwater flow into Little Lake in accordance with the conditions of CUP #2007-003.

2. Previous Rose Valley Groundwater Models

The first groundwater model developed by DBS&A is documented in DBS&A (2011). This model was a significant update and recalibration of prior models developed by MHA (2008a and 2008b) and Brown and Caldwell (2006). The model was developed in accordance with Mitigation Measure Hydrology-4 of the Mitigation Monitoring and Reporting Program of CUP #2007-03. This 2011 model has been updated several times, as summarized in Table 1. All model updates included extension of the historical simulation period to include metered pumping from the two Coso Hay Ranch production wells; some model updates included adjusted model input parameters to better simulate estimated groundwater inflow to Little Lake and long-term average groundwater recharge.

3. Current (2017) Model Update and Recalibration

For the current model, the most recent model (DBS&A, 2014) as updated in 2016 (Table 1) was updated as follows:

- The historical simulation period was extended to include the period through the end of May 2017. Metered pumping for the Coso Hay Ranch wells was included in the model for this period.

- Average long-term groundwater recharge was updated by calculating recharge for the period 2013 through June 2017 (June 2017 was the most recent month for which climate data was available); therefore, the full period of time used to estimate recharge is 2000 through June 2017. The method of recharge calculation is the same as that documented in prior DBS&A reports. Average groundwater recharge in the current groundwater flow model is 3,623 acre-feet per year (ac-ft/yr), which is reduced from the prior value of 4,001 ac-ft/yr (DBS&A, 2013).

- Recharge of 906 acre-feet (50 percent of LADWP released water) was assumed along the axis of Rose Valley south of Haiwee Reservoir (Figure 3). The recharge from the LADWP release was assigned from the base of the Haiwee Reservoir dam to a point south of Coso Junction but north of Red Hill (Figure 3). The assumed recharge volume was assigned in the model over the 3-month period March through May 2017 to approximately account for travel time through the unsaturated zone between the land surface and the water table. An unknown amount of water was subsequently released from Haiwee Reservoir for a period of several weeks; however, the amount of water is currently unknown, and was therefore not included in this model update.

Steady-state, historical, and predictive simulations were all rerun using the newly calculated average recharge. To maintain the calibration of the model, the hydraulic conductivity values for two zones in model layer 1 were reduced (Figure 4) to reasonably match the observed data (Appendix A). Hydraulic conductivity and recharge are strongly correlated, and a change in one parameter will often require a similar percentage change to the other parameter to maintain model calibration. Simulated and observed water levels for the current model and previous models are provided in Appendix A.

In addition to hydraulic conductivity, the general head boundary (GHB) conductance at the southern end of the model was decreased from 4,125 square feet per day (ft^2/d) to 2,625 ft^2/d. The current model simulates groundwater inflow of 1,247 ac-ft/yr to Little Lake at the end of 2009, and an average simulated groundwater inflow for the 7-year period 2010 through 2016 of 1,251 ac-ft/yr. These values are similar to estimates of groundwater inflow to Little Lake derived from monitoring data (Table 2). For 2009, the estimated groundwater inflow to Little Lake based on monitoring data is 1,252 ac-ft/yr, and the average estimated inflow for the period 2010 through 2016 is 1,245 ac ft/yr.

Table 3 provides a comparison of one of the key calibration statistics for all of the DBS&A model versions, the root mean squared error (RMSE). The values provided in Table 3 and the plots provided in Appendix A indicate that the current model is reasonably calibrated to observed historical conditions.

4. Predictive Simulations Using the 2017 Updated Model

Predictive simulations were run for the period June 2017 through the end of 2047 using the updated model. Three predictive simulations were conducted, as follows:

- *Scenario A:* The model was run without any additional pumping from the two Coso Hay Ranch wells and with no assumed recharge from the release of Haiwee water by LADWP in March 2017.

- *Scenario B:* The model was run without any additional pumping from the two Coso Hay Ranch wells, and recharge of 906 ac-ft of Haiwee water released by LADWP was assumed to occur over the 3-month period of March through May 2017.

- *Scenario C:* The model was run with additional pumping from the southern Hay Ranch well at a rate of 1,000 gpm starting in June 2017. Recharge from the Haiwee Reservoir water release was assumed to be 906 ac-ft, assumed to occur over the 3-month period from March through May 2017. The period of time for which the southern Hay Ranch well can pump at the rate of 1,000 gpm was determined through a trial and error process until the maximum duration of pumping was identified at which simulated groundwater flow to Little Lake would approximately reach the 10 percent allowable reduction threshold.

The simulated groundwater flow to Little Lake for each scenario is plotted in Figure 5. As indicated in the figure, Scenario A resulted in a maximum reduction in groundwater inflow to Little Lake (relative to 2009 values) of about 8.3 percent in December 2025. Because the hydraulic conductivity in model layer 1 was reduced compared to prior versions of the model, the simulated drawdown from Coso pumping does not propagate as far as simulated in previous versions of the model. The reduction in hydraulic conductivity results in a better match between the observed and predicted hydrographs in Appendix A. This is the reason for the smaller simulated reduction in Little Lake flows compared to prior versions of the model and the greater delay in time to reach the maximum reduction in simulated groundwater inflows.

Scenario B, where assumed recharge from the release of Haiwee water is considered, resulted in a maximum reduction in groundwater flows to Little Lake of about 7.7 percent, with the maximum reduction still predicted to occur in December 2025. The difference in the simulated percent reduction of about 0.6 percent is attributable solely to the assumed recharge of the released Haiwee water.

The final simulation results for Scenario C indicate that Coso can pump an additional amount at 1,000 gpm starting June 2017 for a period of 24 months. Under this scenario, a maximum reduction in Little Lake flows of 9.9 percent is predicted to occur in February 2028. The 24-month period is longer than would be predicted by the previous version of the groundwater model, and is attributable to the groundwater recharge from the release of Haiwee water by LADWP and the recalibration of the model.

In addition to the simulation of groundwater flow to Little Lake, Rose Valley monitor well trigger levels were also recalculated based on the updated groundwater flow model. The updated drawdown levels are provided in Table 4. Trigger levels (drawdown at cessation of pumping) increased from the DBS&A (2014) model by 0.3 to 0.6 foot for the monitor wells south of Hay Ranch.

5. Summary and Conclusions

The groundwater flow model for Rose Valley was extended to include metered Coso pumping through May 2017, recharge estimates through June 2017, and the LADWP release of 1,812 acre-feet along the axis of the valley from Haiwee Reservoir in March 2017. Consideration of the updated average recharge of 3,623 ac-ft/yr (formerly 4,001 ac-ft/yr) required changes to the some model hydraulic properties and GHB cell conductance to maintain a reasonable model calibration to observed water levels and estimated groundwater inflow to Little Lake. In the current model, the assumption was made that 50 percent of the water released from Haiwee Reservoir infiltrated to the water table over a 3-month period.

Predictive scenarios were conducted to illustrate the effects of the model changes and to assess the length of time for which Coso can pump 1,000 gpm, starting in June 2017. The updated model predictive simulation results indicate that Coso can pump 1,000 gpm for

24 months without violating the 10 percent reduction of groundwater inflow criteria relative to Little Lake. Updated trigger levels for the Hay Ranch project monitor wells were also computed using the updated model.

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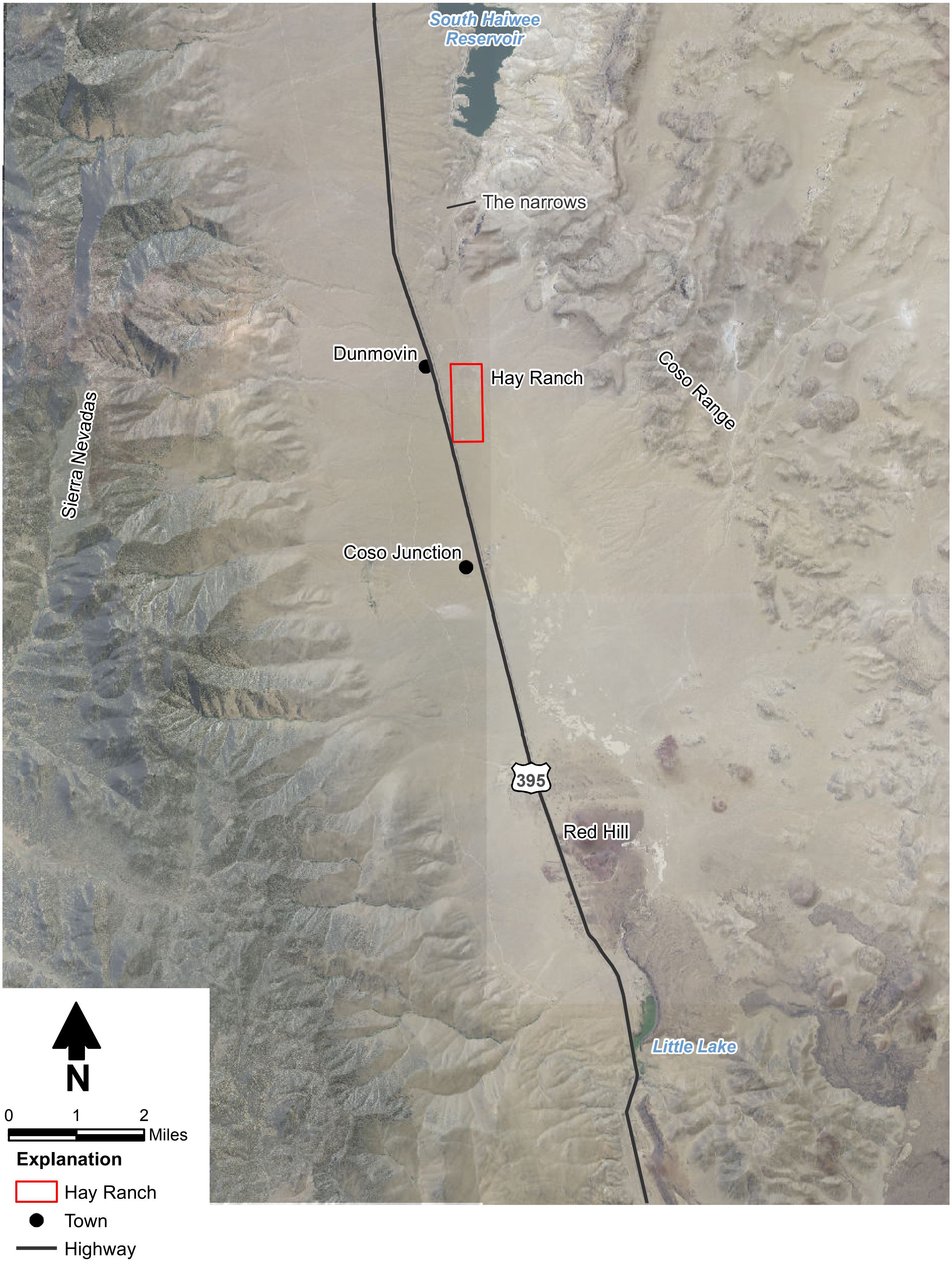
Figures



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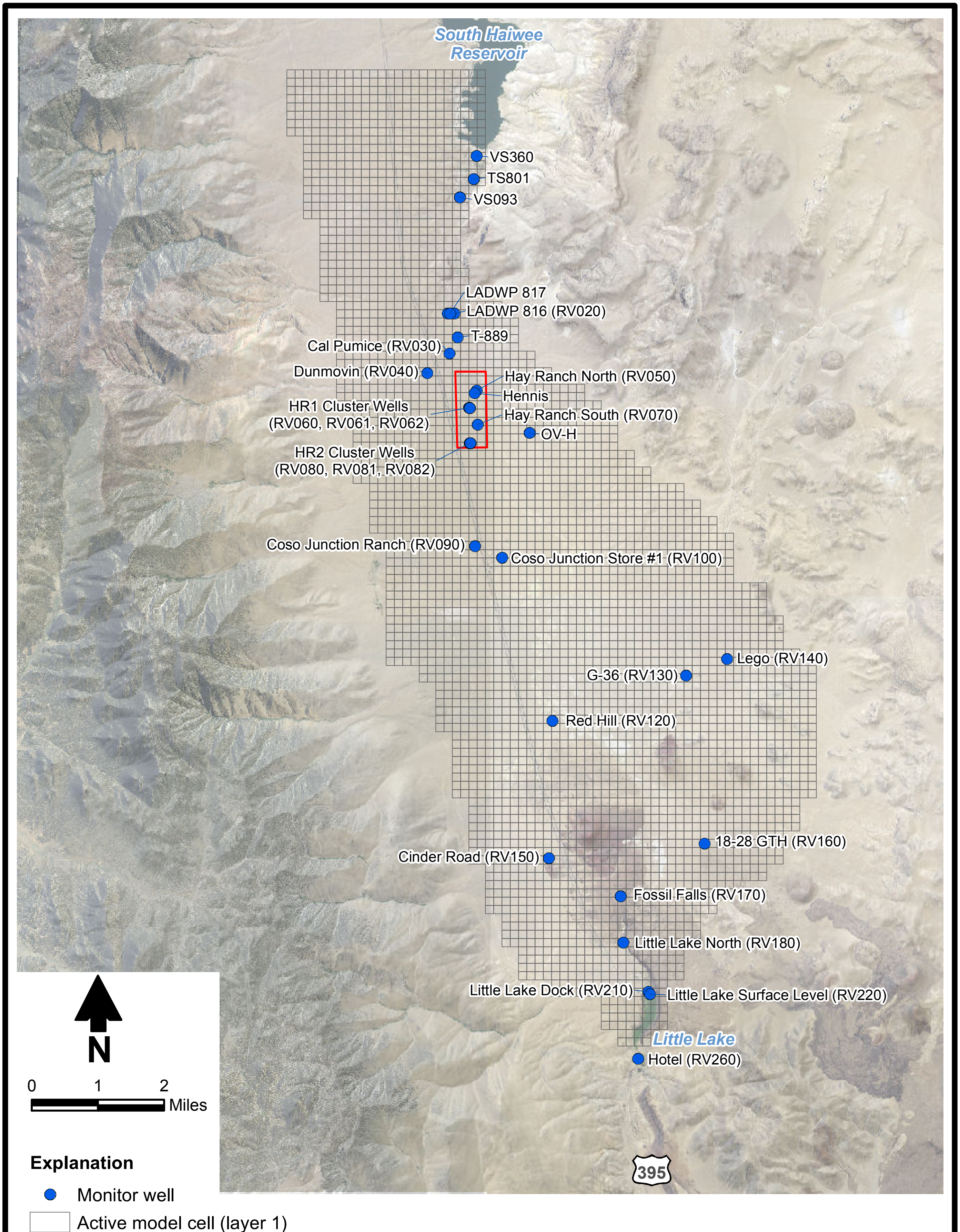
ROSE VALLEY MODEL
Base Map

Daniel B. Stephens & Associates, Inc.
8/23/2017
JN LT09.0311

Figure 1



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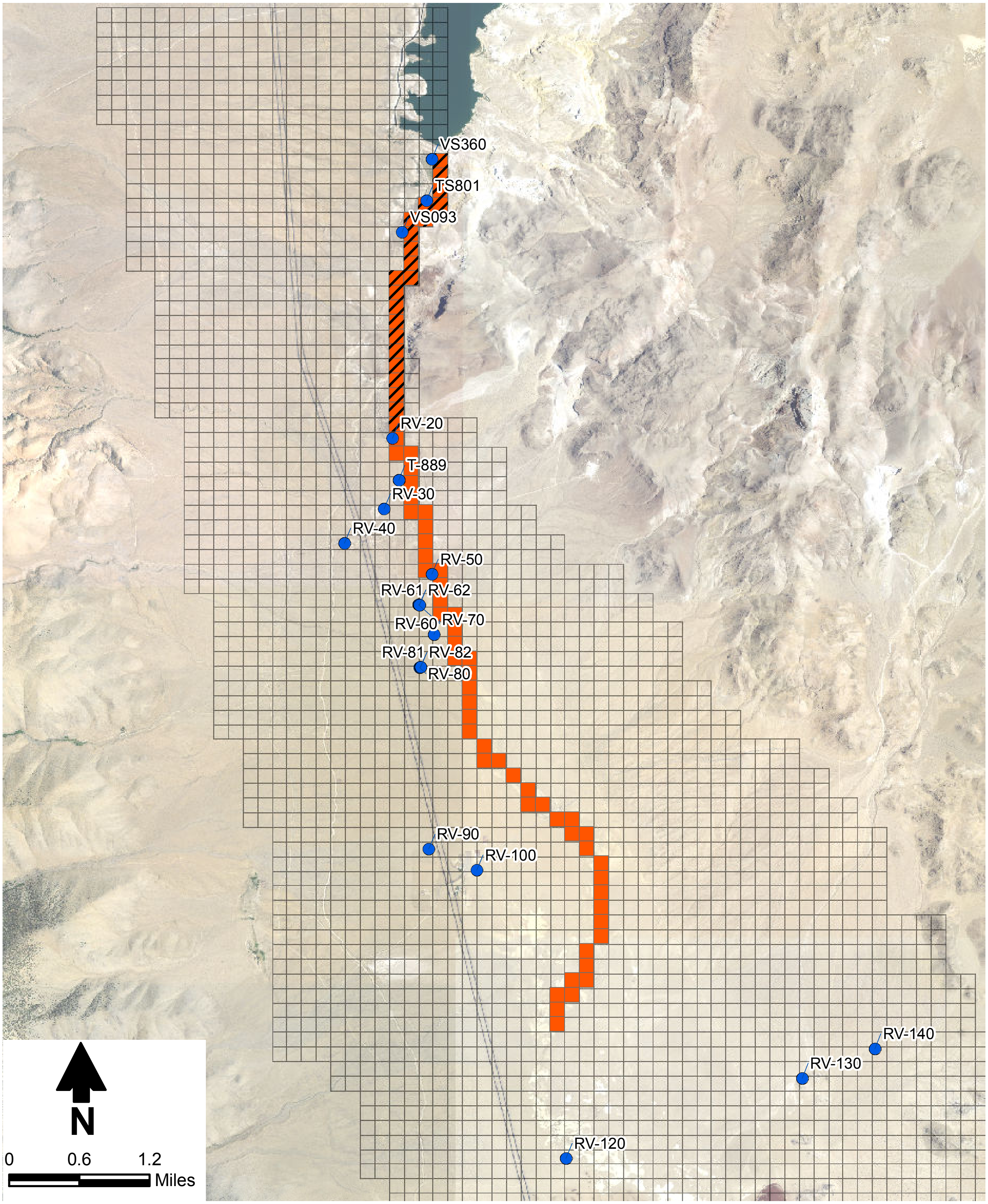
ROSE VALLEY MODEL
Well Locations

Daniel B. Stephens & Associates, Inc.
8/23/2017
JN LT09.0311

Figure 2



Explanation

- Monitor well
- Active model grid
- Recharge from toe drain flows
- Recharge from LADWP release

ROSE VALLEY MODEL

Simulated Recharge from LADWP Release of Water from Haiwee Reservoir

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8/24/2017

JN LT09.0311

Figure 3

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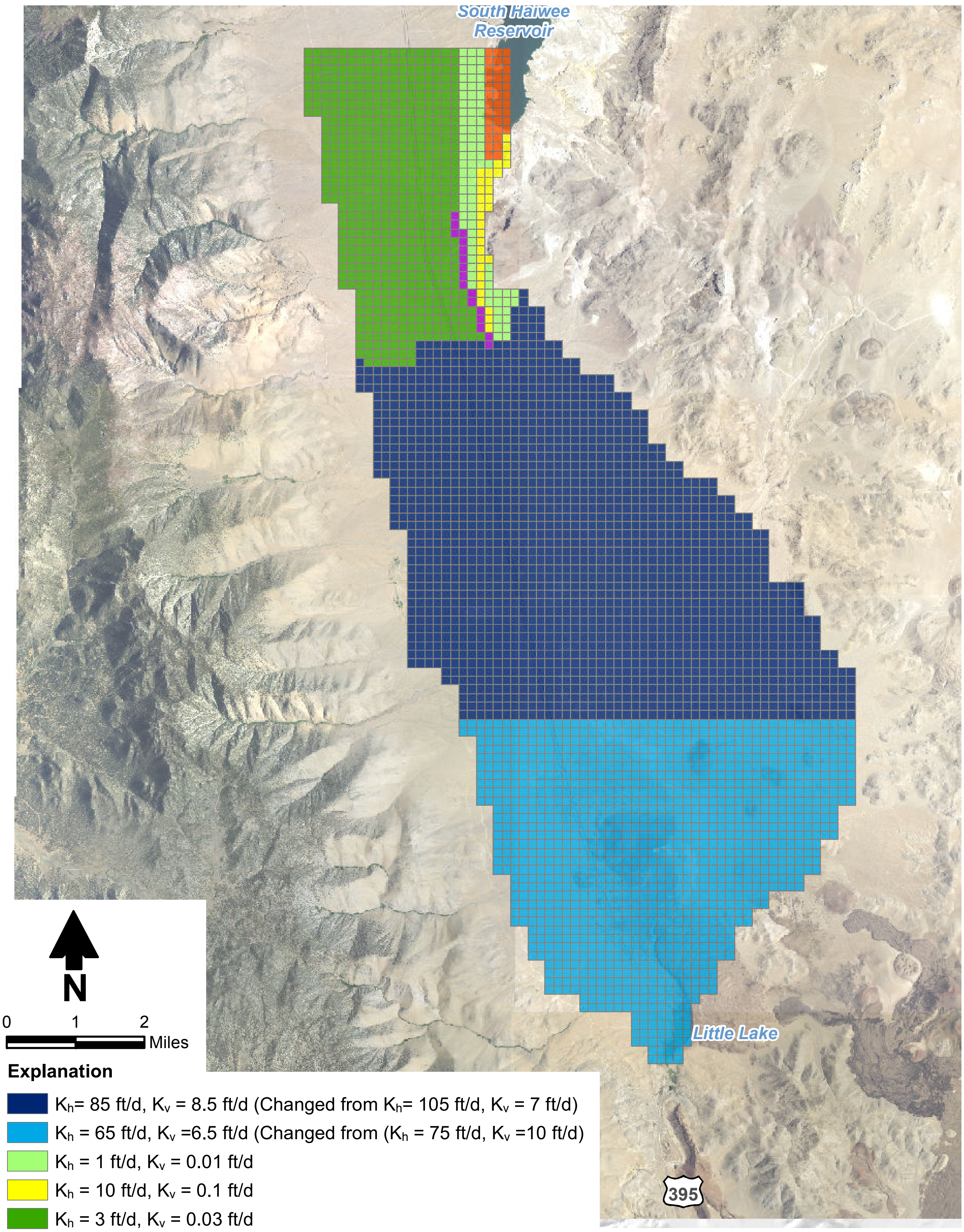

ROSE VALLEY MODEL

Original and Updated Hydraulic Conductivity of Model Layer 1

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JN LT09.0311

Figure 4

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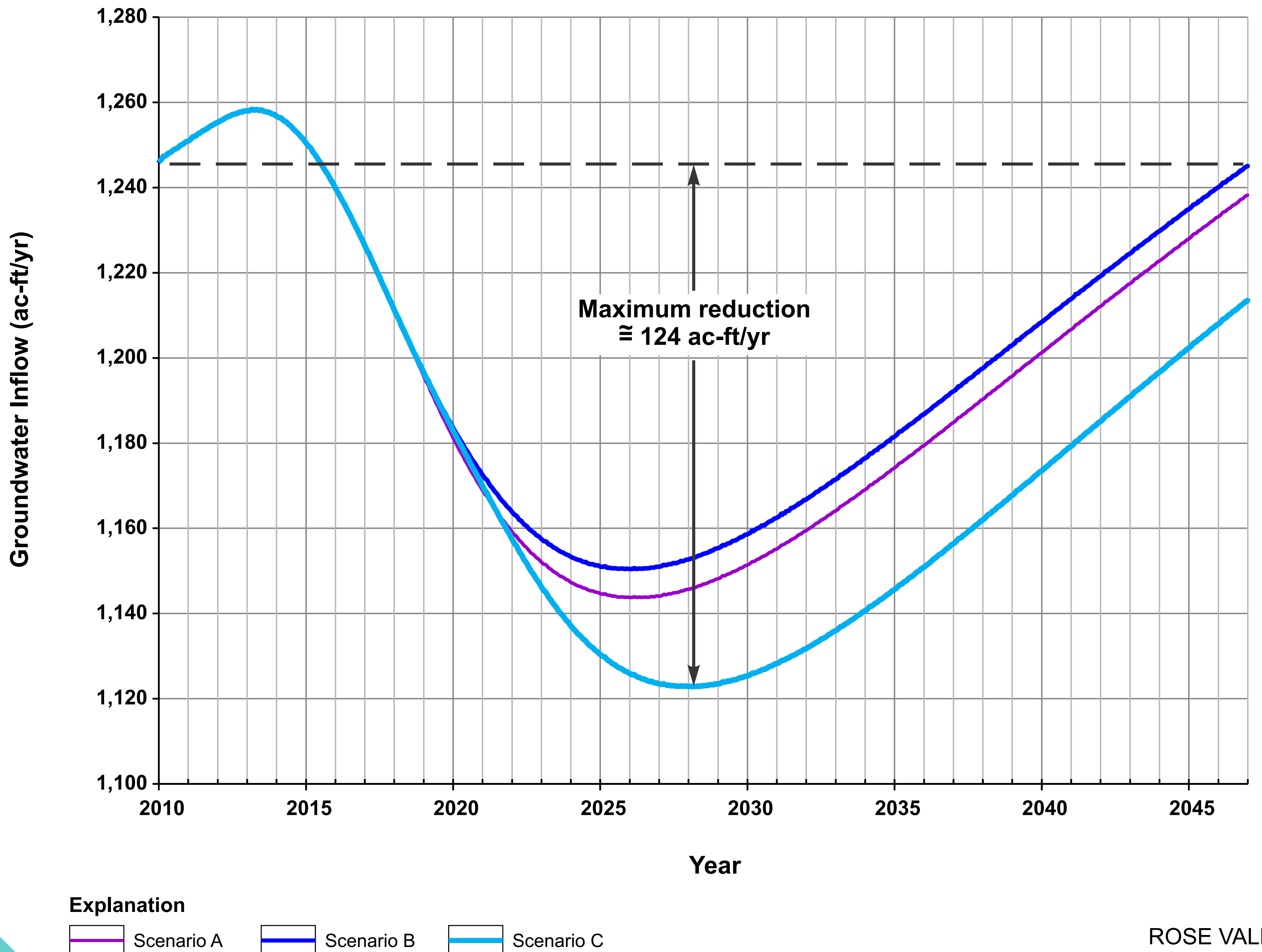

ROSE VALLEY MODEL

Simulated Groundwater Inflow to Little Lake

Figure 5

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8-22-17 JN DB17.1161

Tables

Table 1. DBS&A Rose Valley Groundwater Models

Model	Major Features and Updates	Model Calibration
DBS&A (2011)	Original model. Long-term average groundwater recharge was estimated using climatic data for the period 2000 through 2009.	Original model calibration
DBS&A (2013)	Estimated groundwater recharge was updated using climatic data for the period 2000 through 2012. Conductance of the GHB model cells at the southern end of the model was decreased from 26,400 ft^2/d to 15,000 ft^2/d.	Similar but deteriorated model calibration statistics compared to DBS&A (2011)
DBS&A (2014)	The estimated average groundwater inflow to Little Lake for the period 2010 through 2013 was updated based on monitoring data. The updated estimate was 1,256 ac-ft/yr; the original estimate in DBS&A (2011) was 918 ac-ft/yr. Conductance of GHB model cells at the southern end of the model was decreased from 15,000 ft^2/d to 4,125 ft^2/d to better match estimated groundwater inflow to Little Lake.	Slightly improved model calibration relative to DBS&A (2013); but slightly deteriorated calibration relative to DBS&A (2011)
DBS&A (2016)	The DBS&A (2014) model was extended to June 2016 by adding metered pumping from the two Hay Ranch production wells. This model update was not documented in a formal report. Estimated groundwater recharge was not updated.	Same as DBS&A (2014)

GHB = General head boundary
ft^2/d = Square feet per day
ac-ft/yr = Acre-feet per year

Table 2. Estimated Groundwater Inflow to Little Lake

Date Range	Little Lake Stage (feet msl)		Change in Stage (feet)	Change in Little Lake Storage [a] (acre-feet)	Flow at North Culvert [b] (acre-feet)	Precipitation at Haiwee [c], 10/01–9/30 (feet)	Evaporation, 10/01–9/30 (feet)	Groundwater Inflow to Little Lake [d] (ac-ft/yr)
	Start of Period	End of Period						
10/16/2009–10/15/2010	3,147.18	3,147.00	–0.18	–16.20	754	0.68	6.09	1,252
10/16/2010–10/15/2011	3,147.01	3,147.03	0.02	1.95	791	0.70	6.09	1,305
10/16/2011–10/15/2012	3,147.04	3,146.85	–0.19	–16.99	743	0.25	6.09	1,280
10/16/2012–10/15/2013	3,146.86	3,146.92	0.06	5.40	610	0.07	6.09	1,187
10/16/2013–10/15/2014	3,146.94	3,146.69	–0.25	–22.50	754	0.23	6.09	1,288
10/16/2014–10/15/2015	3,146.69	3,147.23	0.46	48.60	590	0.33	6.09	1,186
10/16/2015–10/15/2016	3,147.23	3,146.42	–0.81	–72.90	738	0.29	6.09	1,216

[a] Little Lake acreage assumed to be 90 acres, two ponds assumed to be 5 acres. Storage is change in lake stage multiplied by 90 acres; negative storage corresponds to drop in lake stage.
[b] North Culvert outflow from daily average values at flume.
[c] Precipitation from the LADWP station at Haiwee.
[d] Groundwater inflow to LLR area = Change in Storage + North Culvert Flow +(Evaporation – Precipitation) * 95

msl = Above mean sea level
ac-ft/yr = Acre-feet per year

Table 3. Root Mean Square Error for DBS&A Rose Valley Groundwater Models

Calculation Date	Root Mean Square Error				
	DBS&A (2011)	DBS&A (2013)	DBS&A (2014)	DBS&A (2016)	DBS&A (2017)
December 2009	8.23	9.66	9.45	9.45	9.23
September 2010	11.06	10.74	10.68	10.68	10.99
May 2013	12.97	13.17	13.07	13.07	13.10
May 2014	—	11.56	11.43	11.43	11.42
February 2016	—	—	—	12.40	12.36

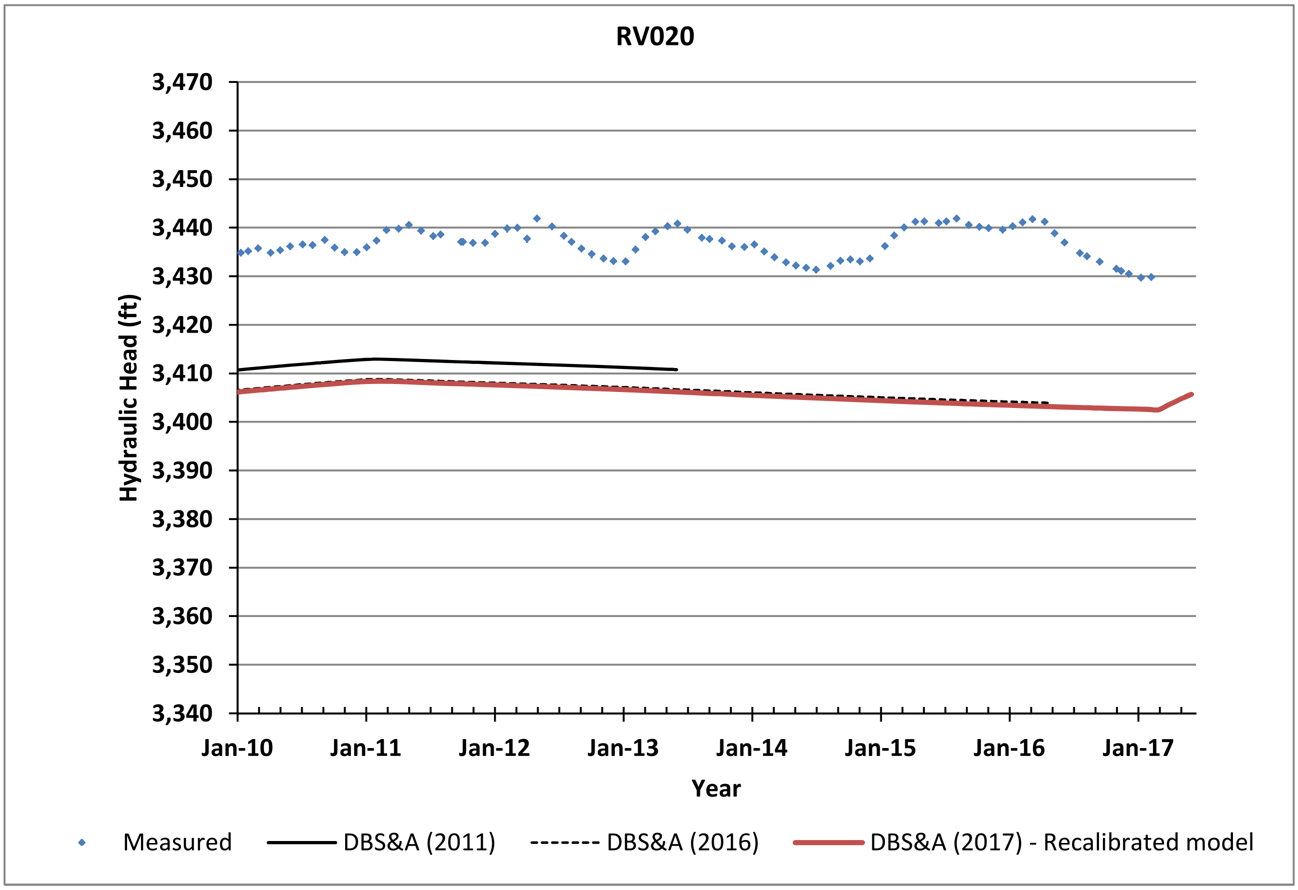
Table 4. Predictive Simulation Results

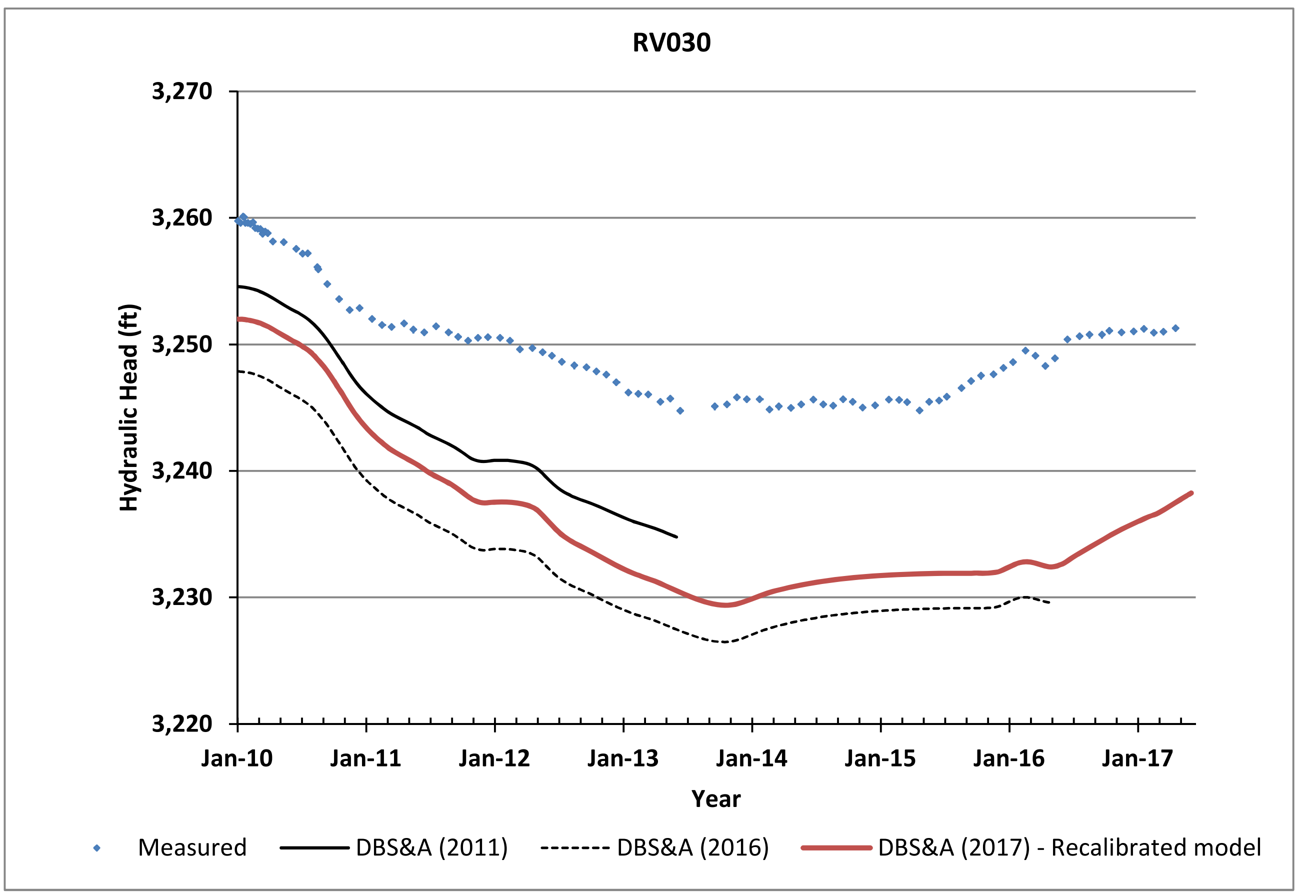
Monitor Well	Maximum Acceptable Drawdown (feet)	Date of Maximum Acceptable Drawdown (years since pumping began)	Drawdown at Cessation of Pumping (feet)
Dunmovin Well (RV040)	21.3	*Oct-2013 (3.9)*	15.6
Cal Pumice Well (RV030)	22.5	*Oct-2013 (3.9)*	15.6
HR1 Shallow Cluster Well (RV060)	24.2	*Aug-2013 (3.7)*	18.4
HR2 Shallow Cluster Well (RV080)	17.6	*Mar-2012 (2.3)*	16.9
Coso Junction Ranch Well (RV090)	9.7	Aug-2019 (9.7)	9.6
Coso Junction Store #1 Well (RV100)	8.7	Sep-2019 (9.8)	8.6
Red Hill Well (RV120)	4.0	Sep-2022 (12.8)	3.4
Well G36 (RV130)	3.6	Feb-2024 (14.2)	2.7
Lego Well (RV140)	2.7	Nov-2028 (18.9)	1.3
Cinder Road Well (RV150)	2.4	Mar-2026 (16.3)	1.5
Well 18-28 GTH (RV160)	2.3	Jun-2027 (17.5)	1.2
Little Lake North Well (RV180)	1.4	Jun-2027 (17.5)	0.7

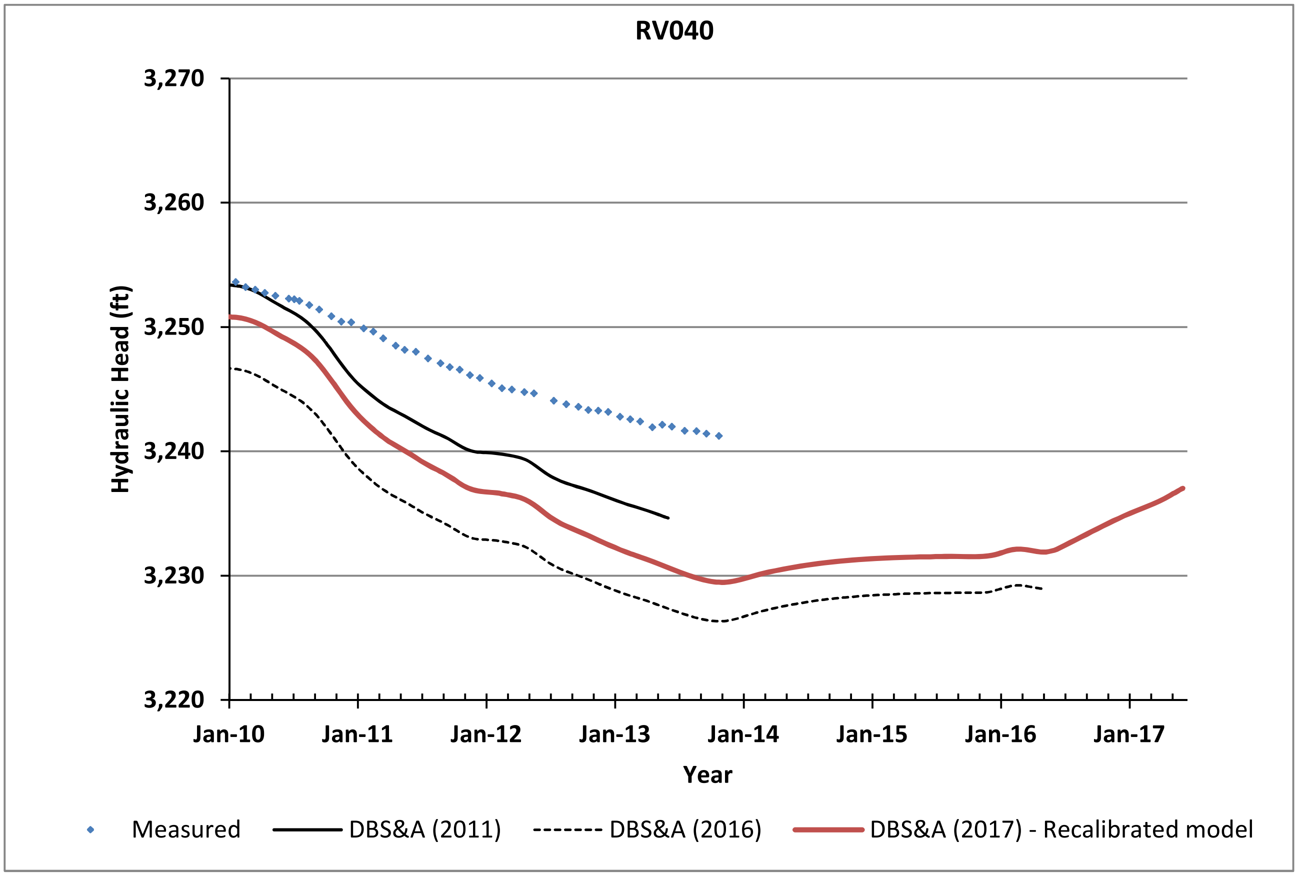
Italics indicate that maximum drawdown has already occurred.

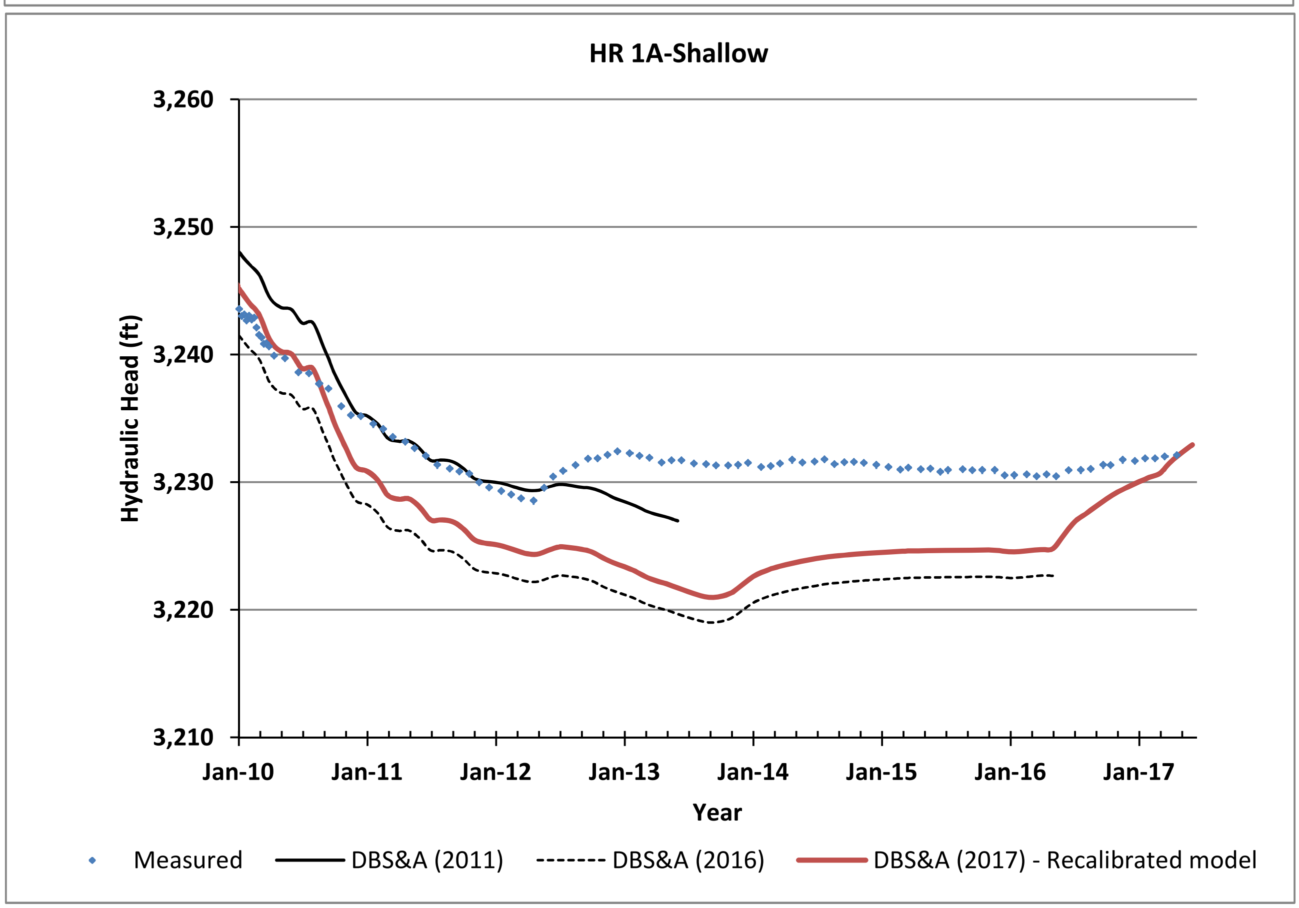
Appendix A

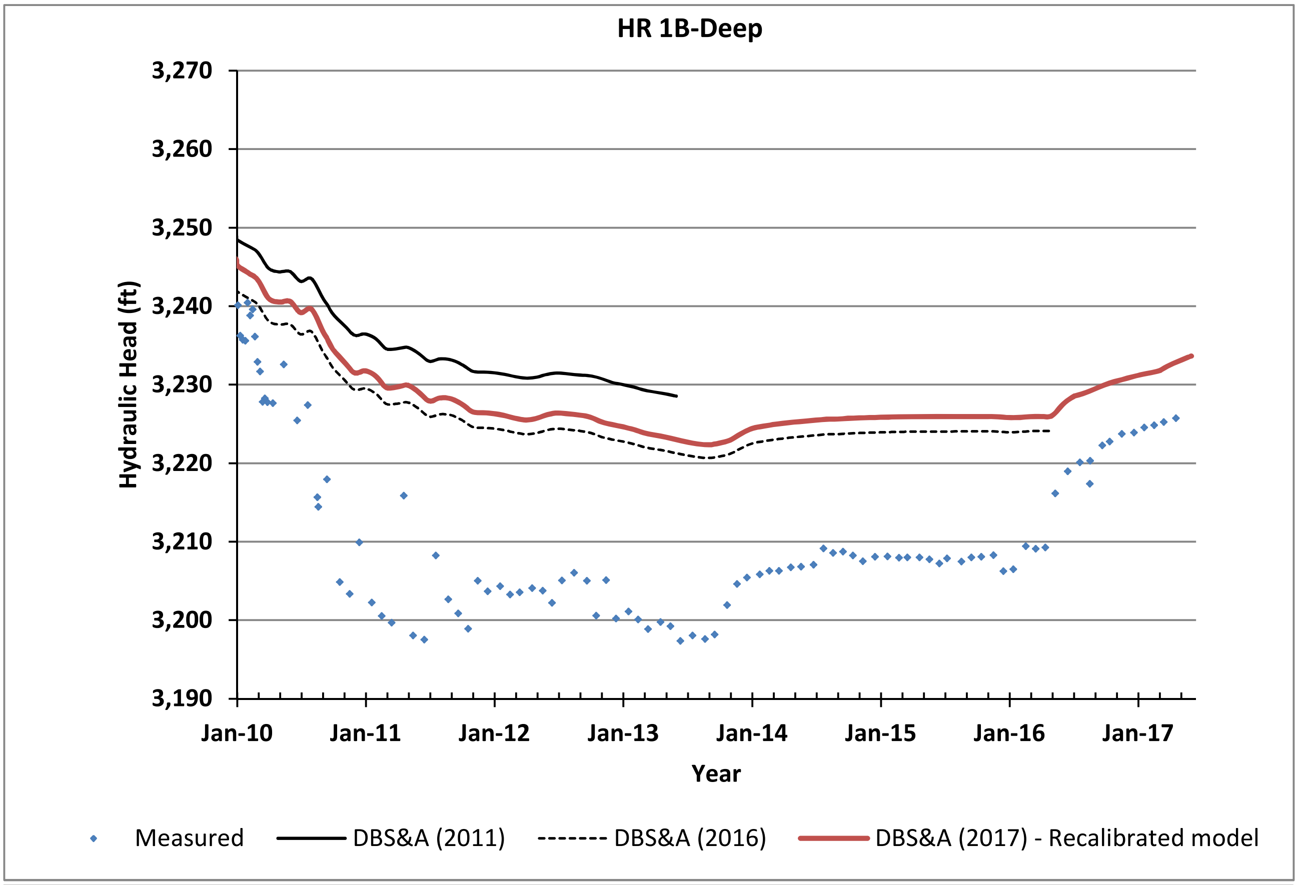
Simulated and Observed Water Levels

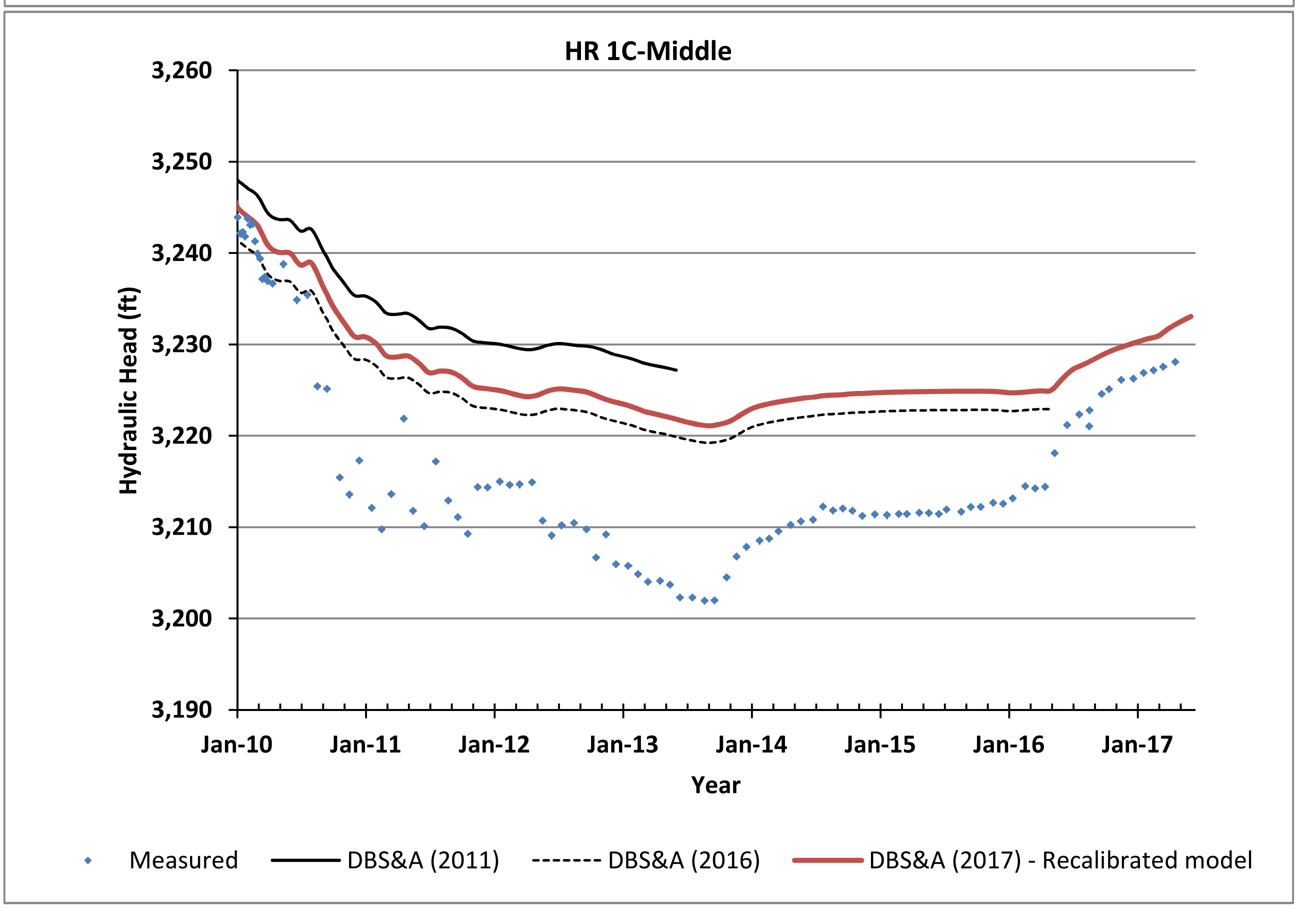

RV020
3,470
3,460
3,450
3,440
3,430
3,420
3,410
3,400
3,390
3,380
3,370
3,360
3,350
3,340
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

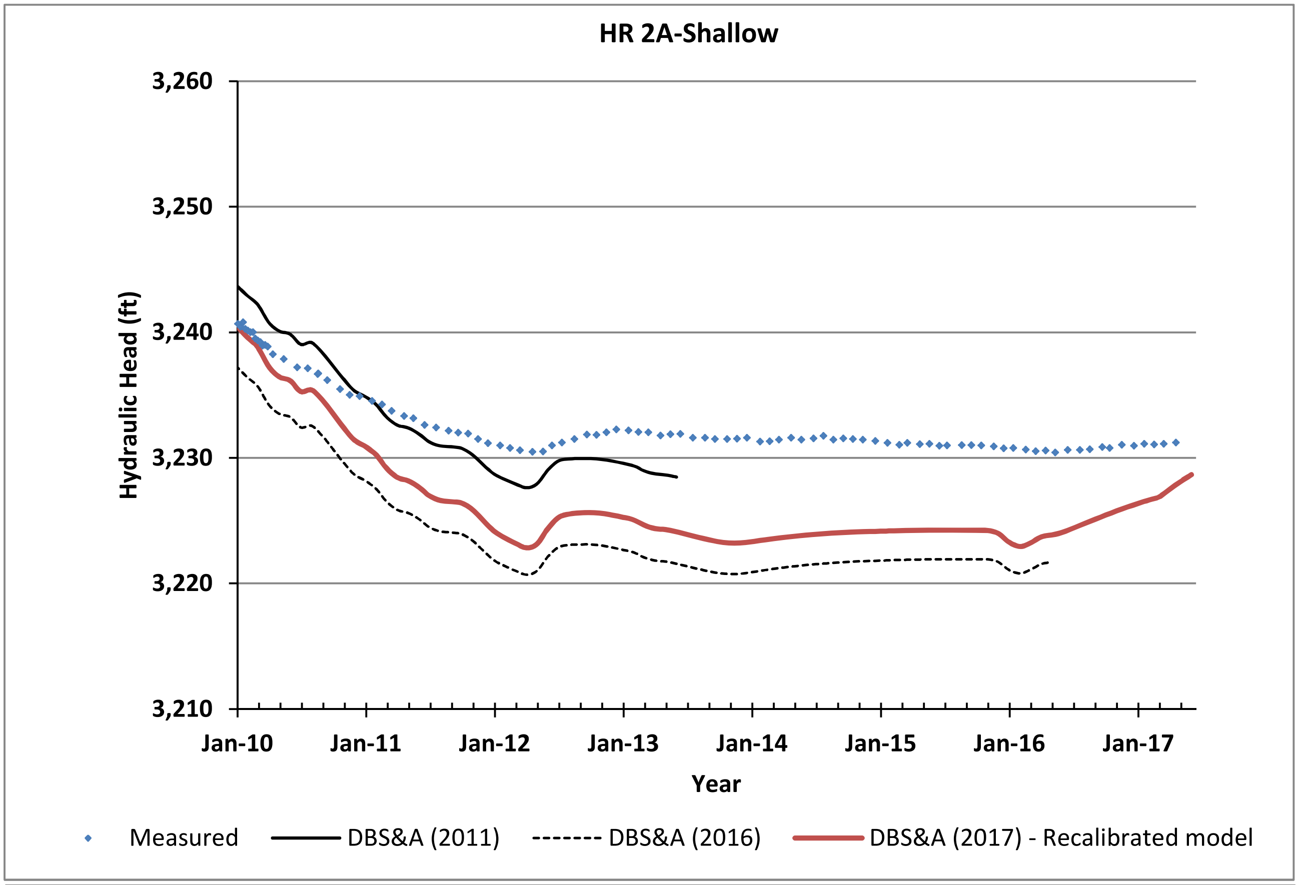

RV030
3,270
3,260
3,250
3,240
3,230
3,220
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

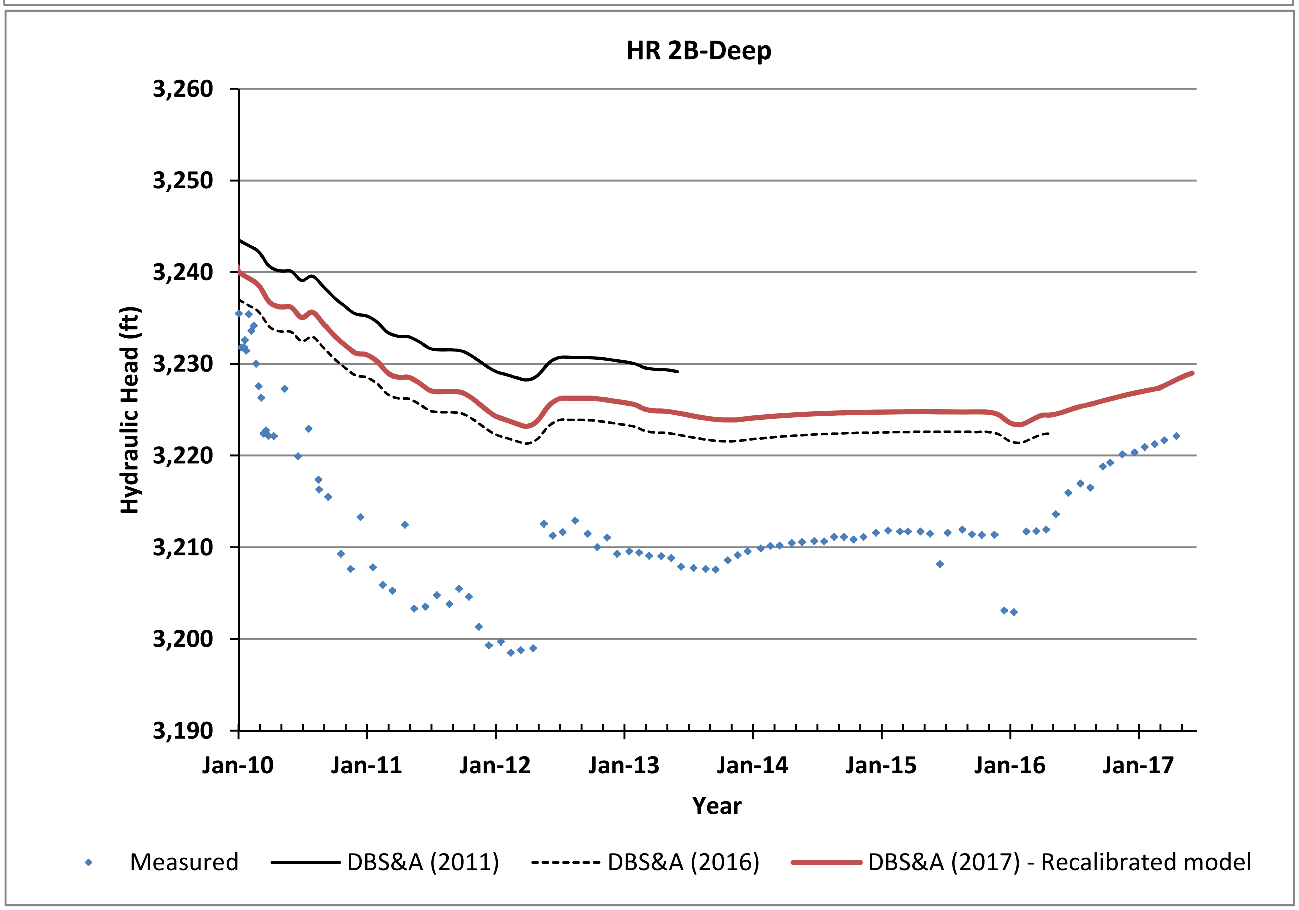

RV040
3,270
3,260
3,250
3,240
3,230
3,220
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

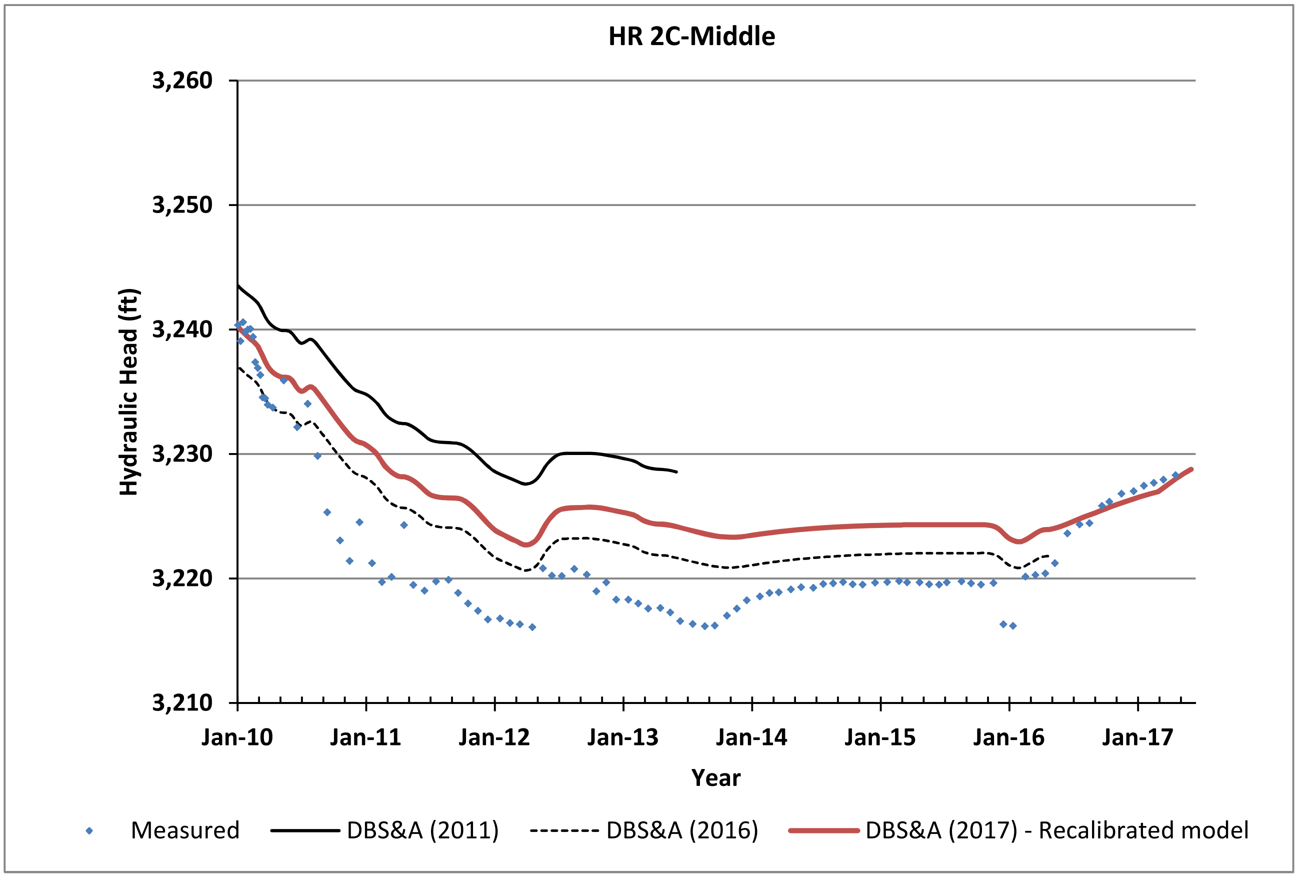

HR 1A-Shallow
3,260
3,250
3,240
3,230
3,220
3,210
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

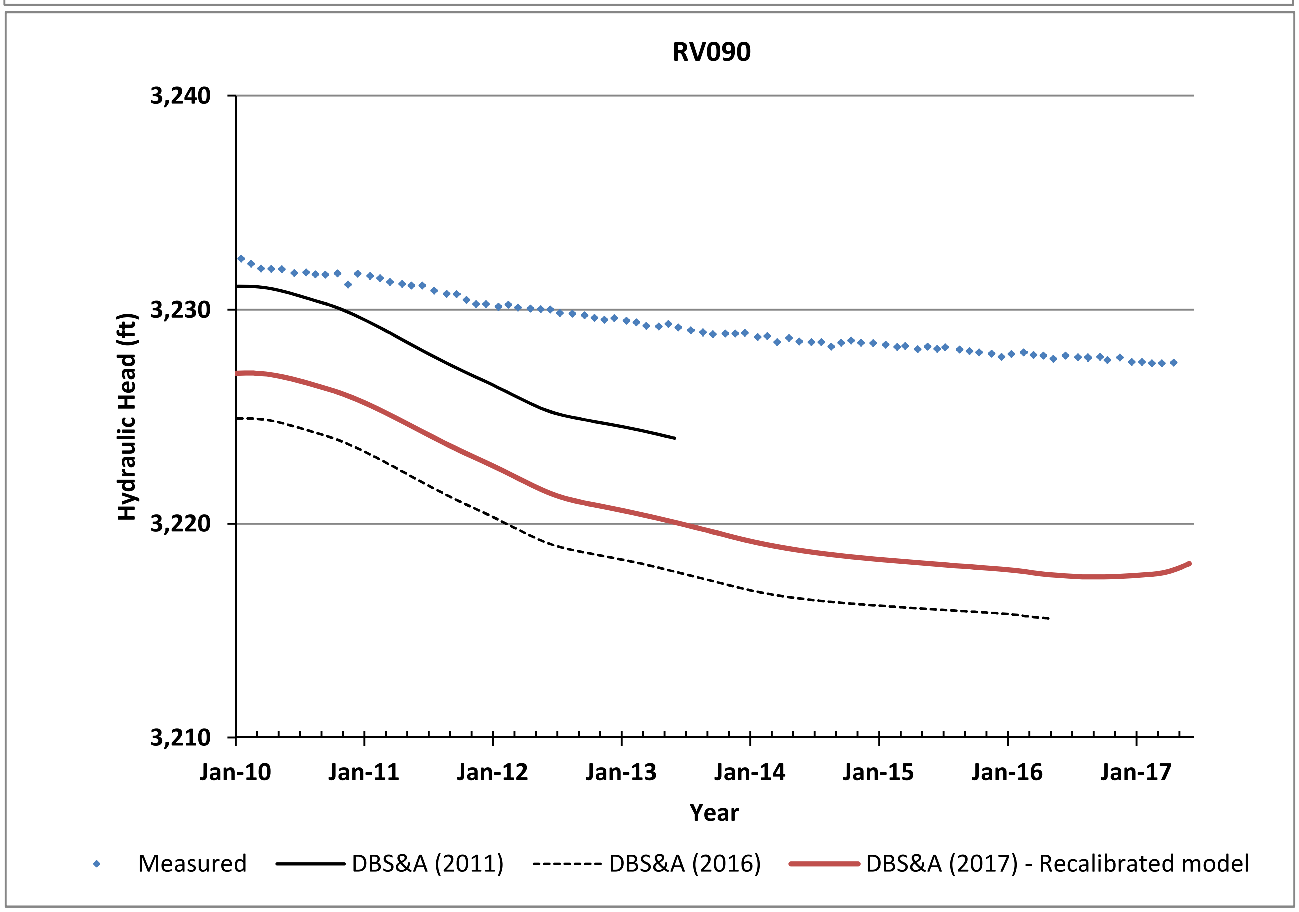

HR 1B-Deep
3,270
3,260
3,250
3,240
3,230
3,220
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

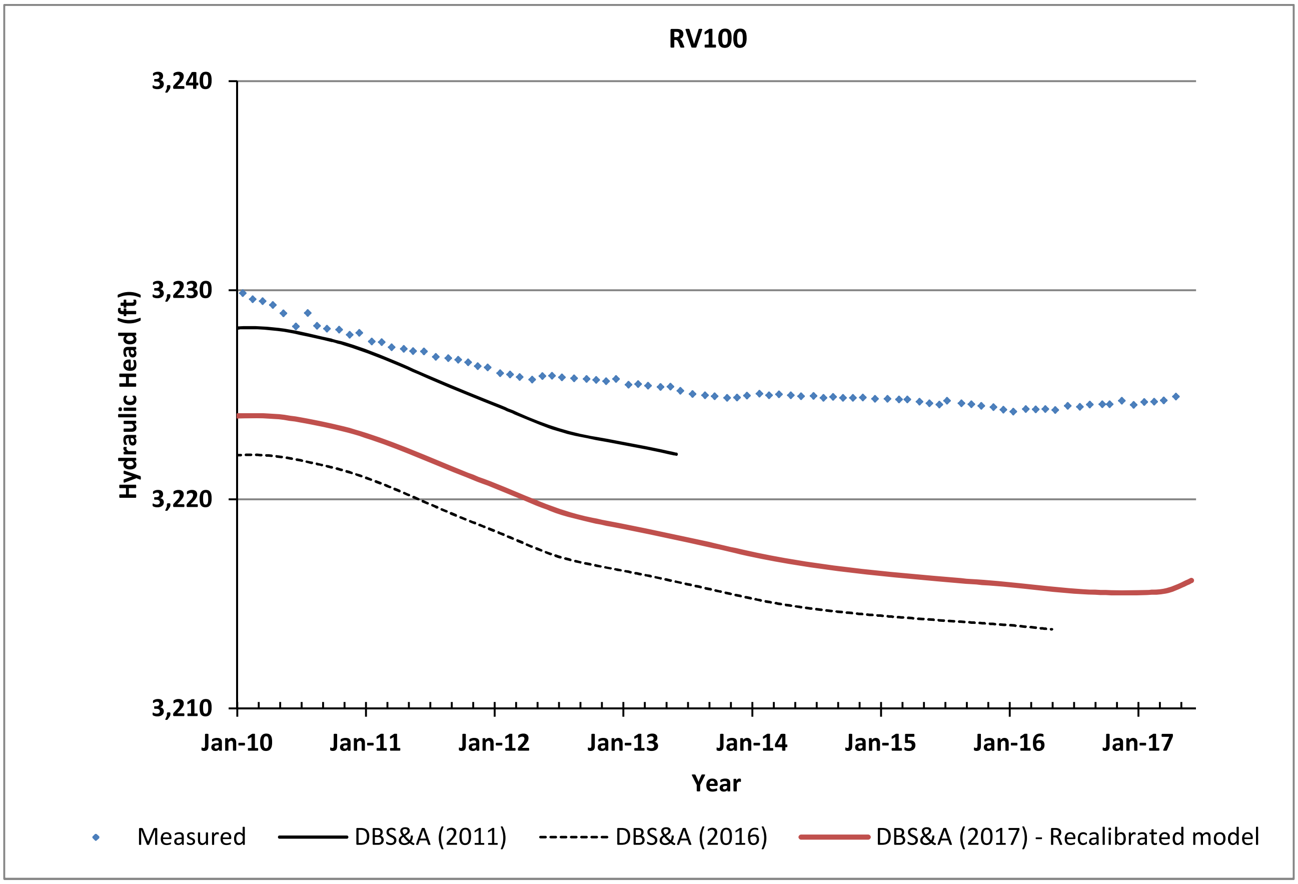

HR 1C-Middle
3,260
3,250
3,240
3,230
3,220
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


HR 2A-Shallow
3,260
3,250
3,240
3,230
3,220
3,210
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


HR 2B-Deep
3,260
3,250
3,240
3,230
3,220
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


HR 2C-Middle
3,260
3,250
3,240
3,230
3,220
3,210
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV090
3,240
3,230
3,220
3,210
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV100
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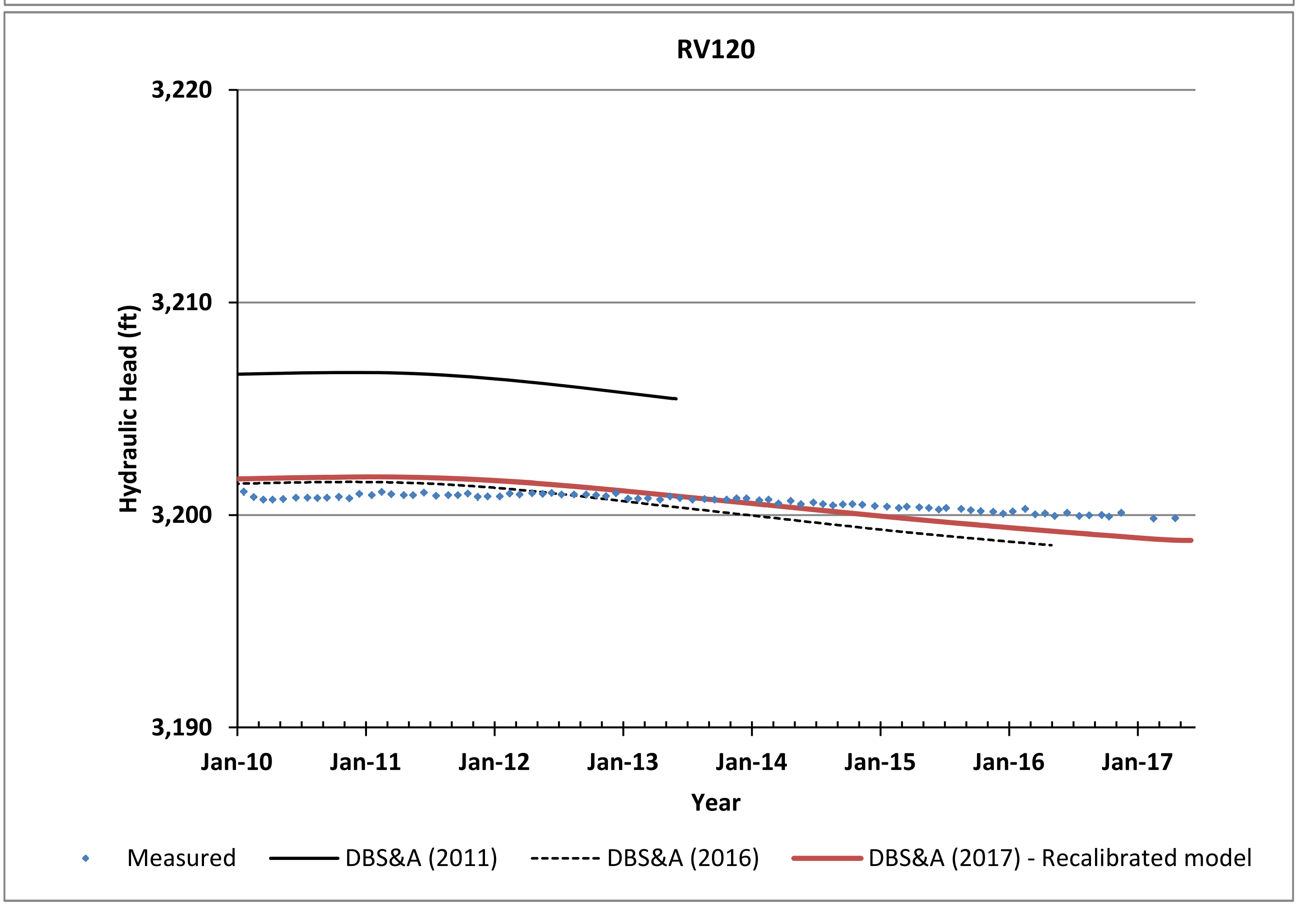
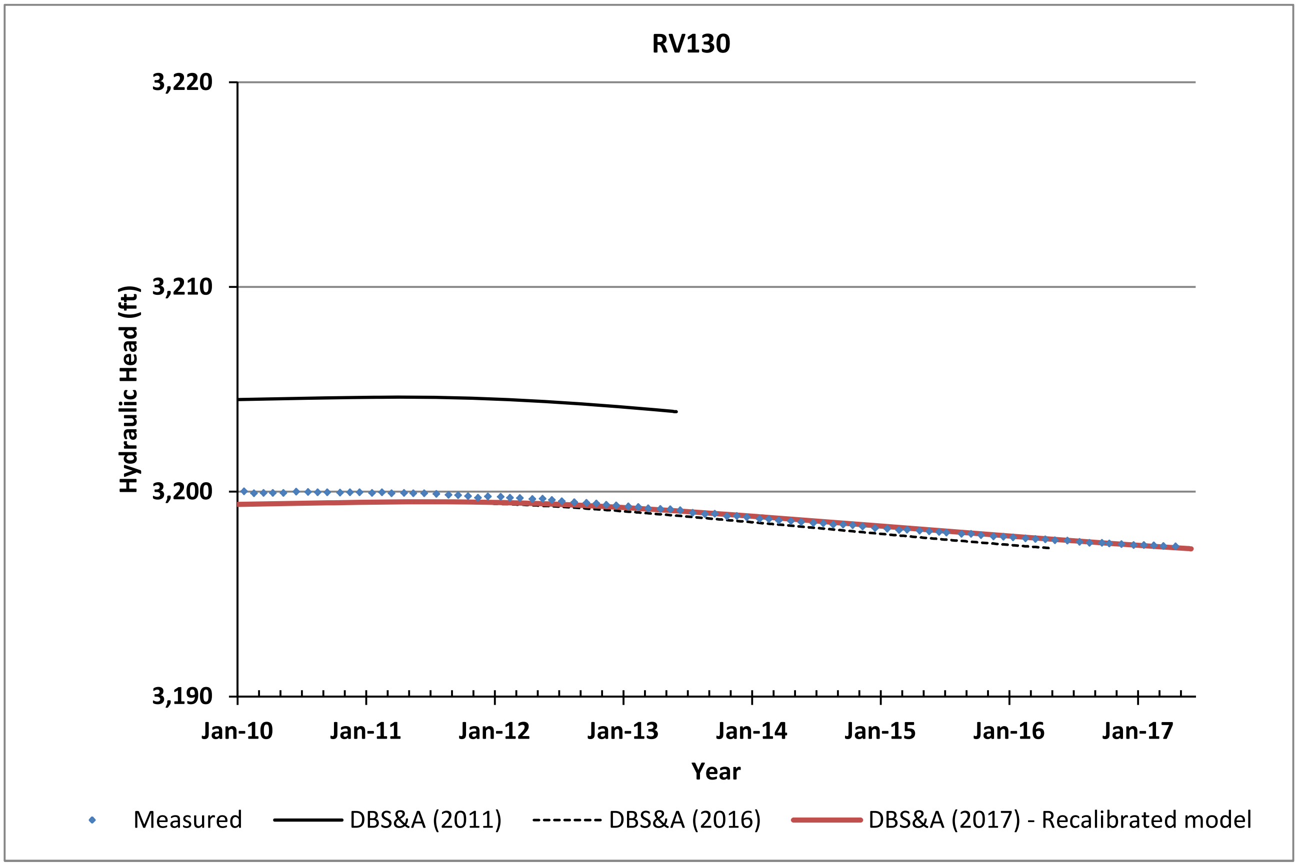
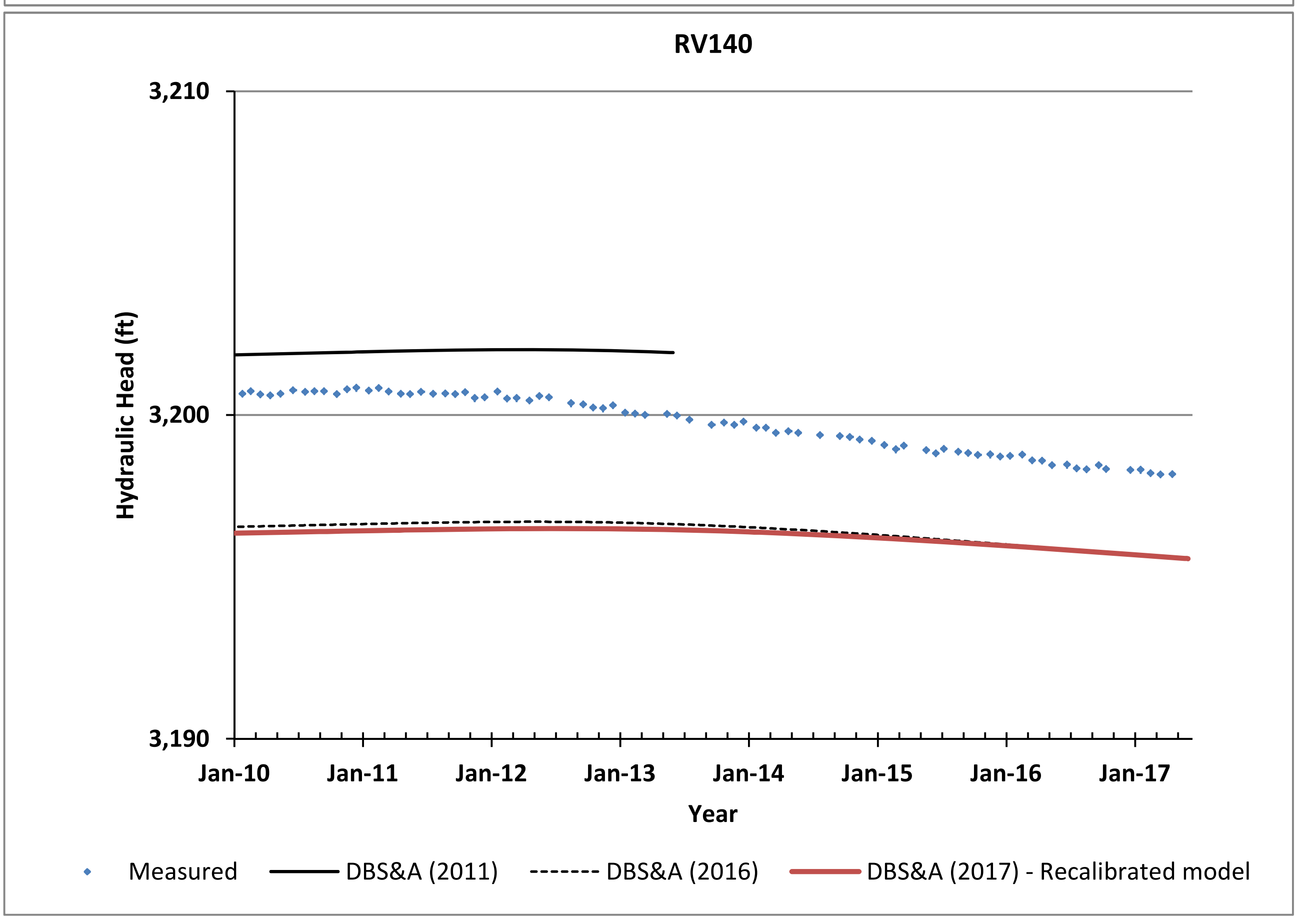
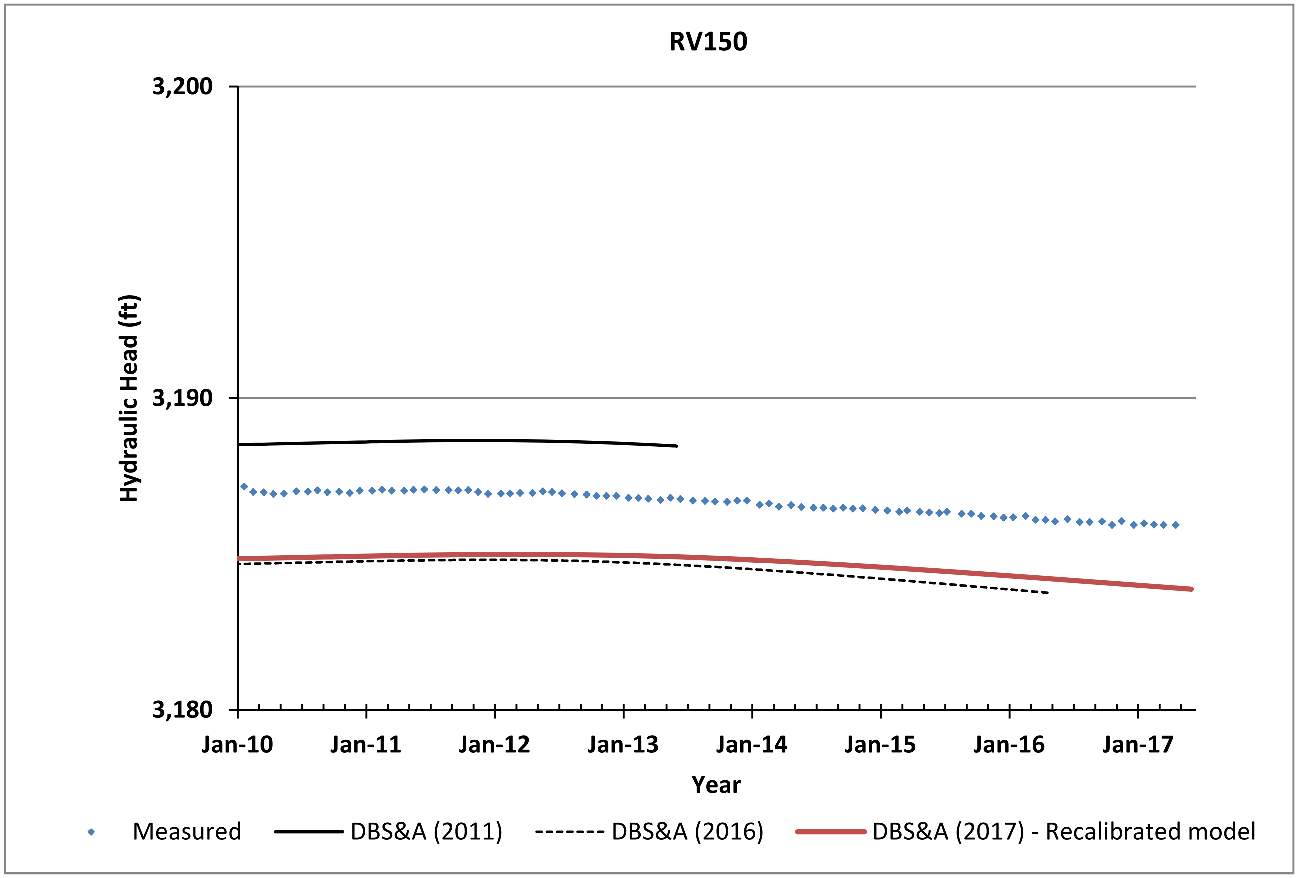
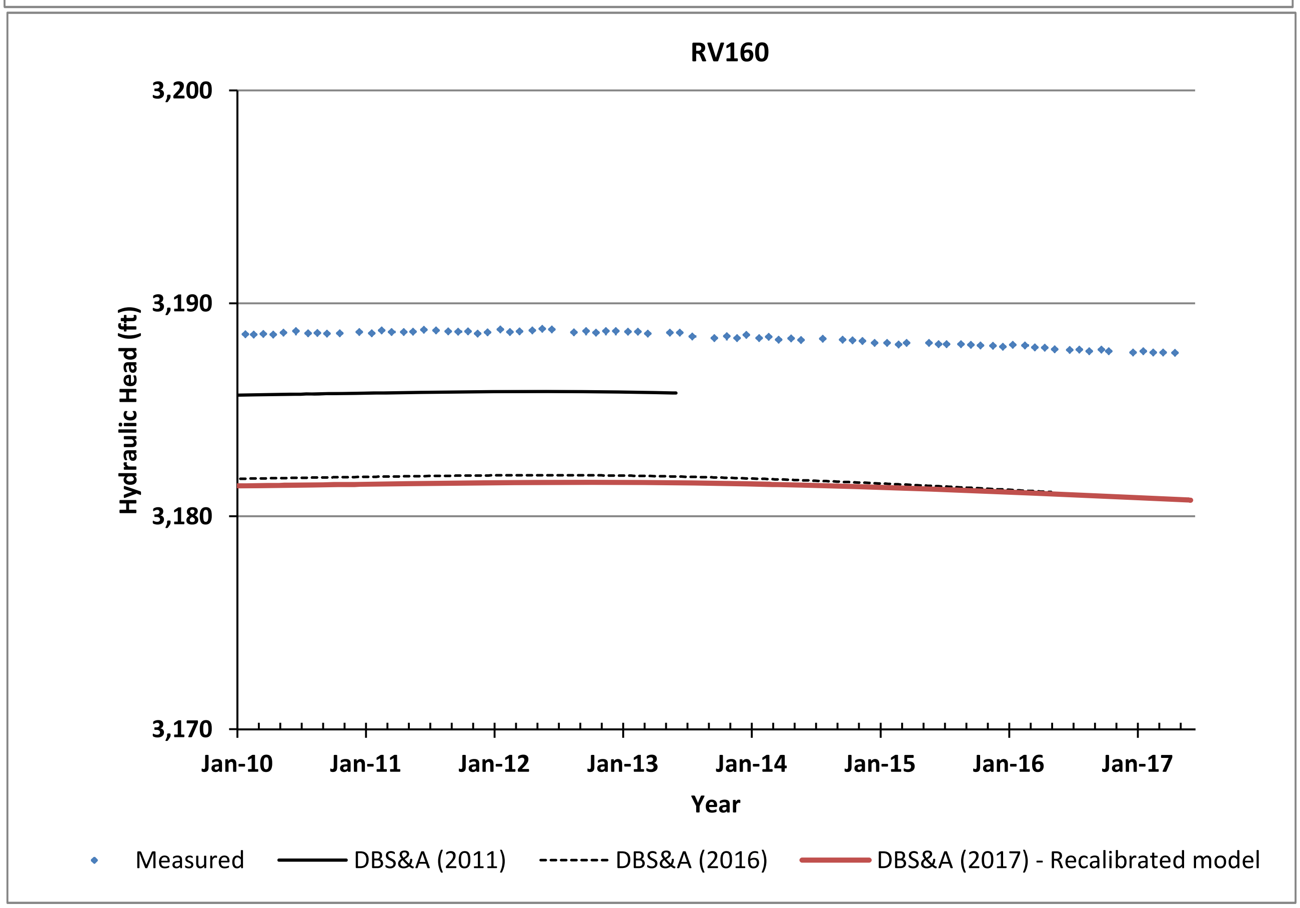
3,230
3,220
3,210
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

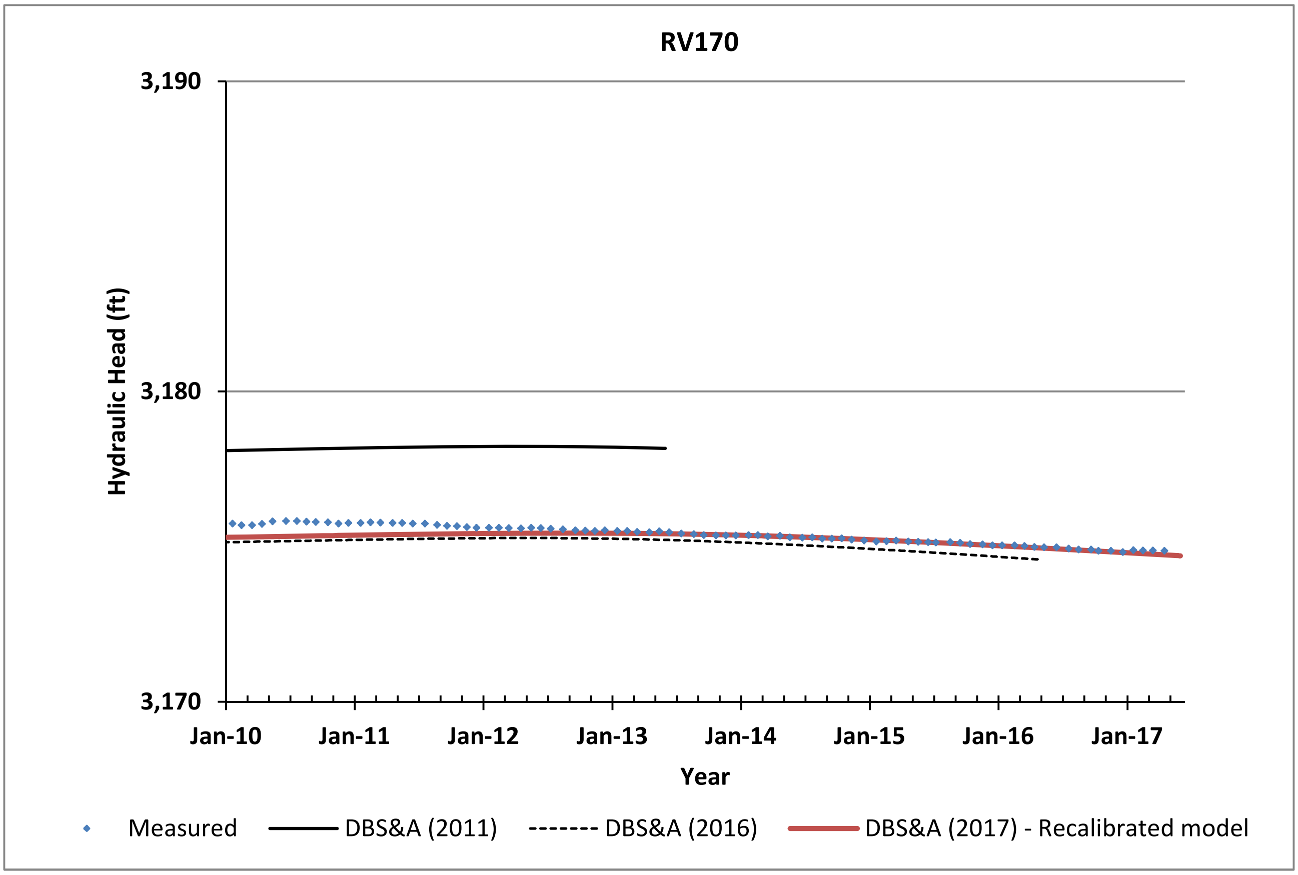

RV120
3,220
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

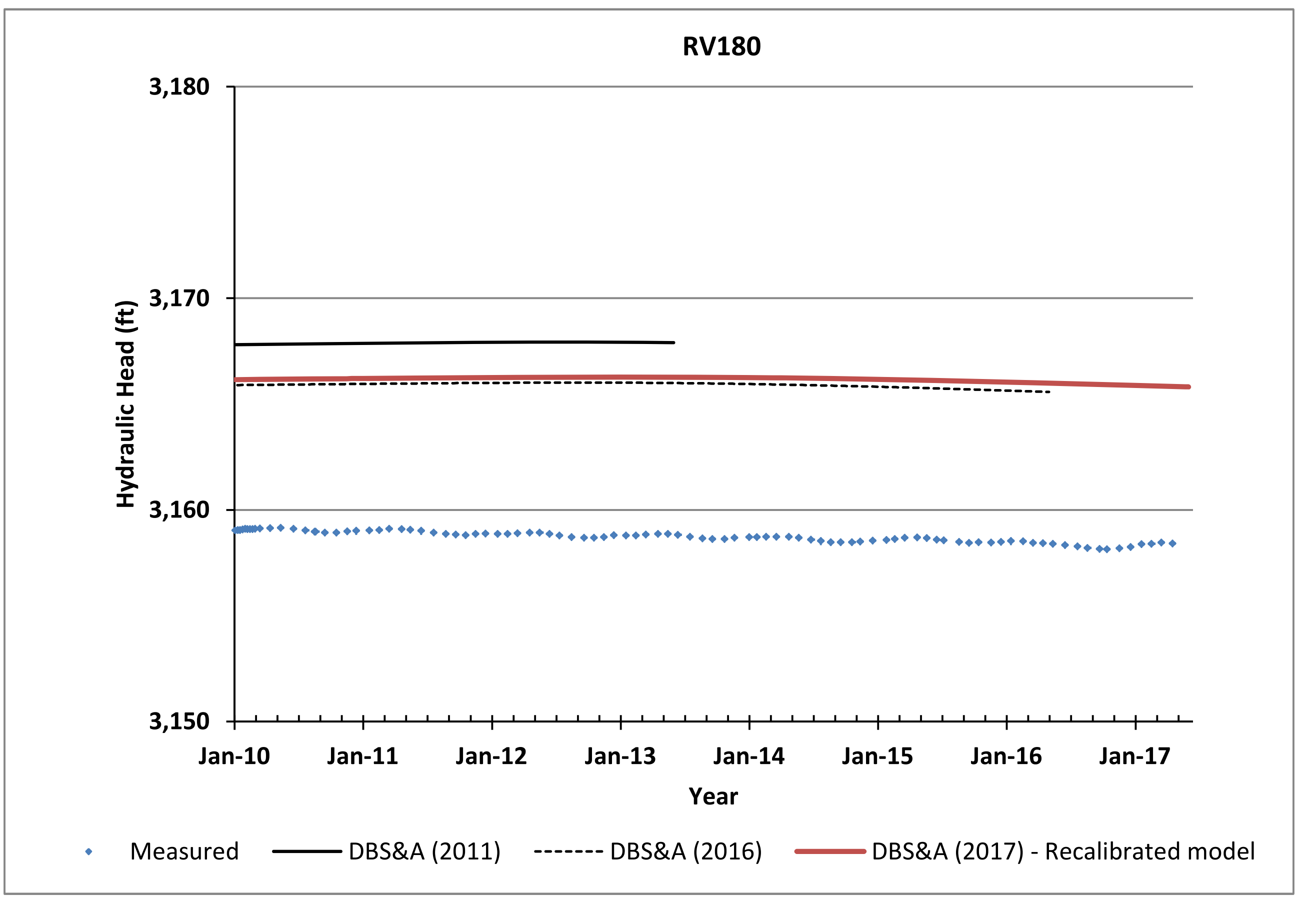

RV130
3,220
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

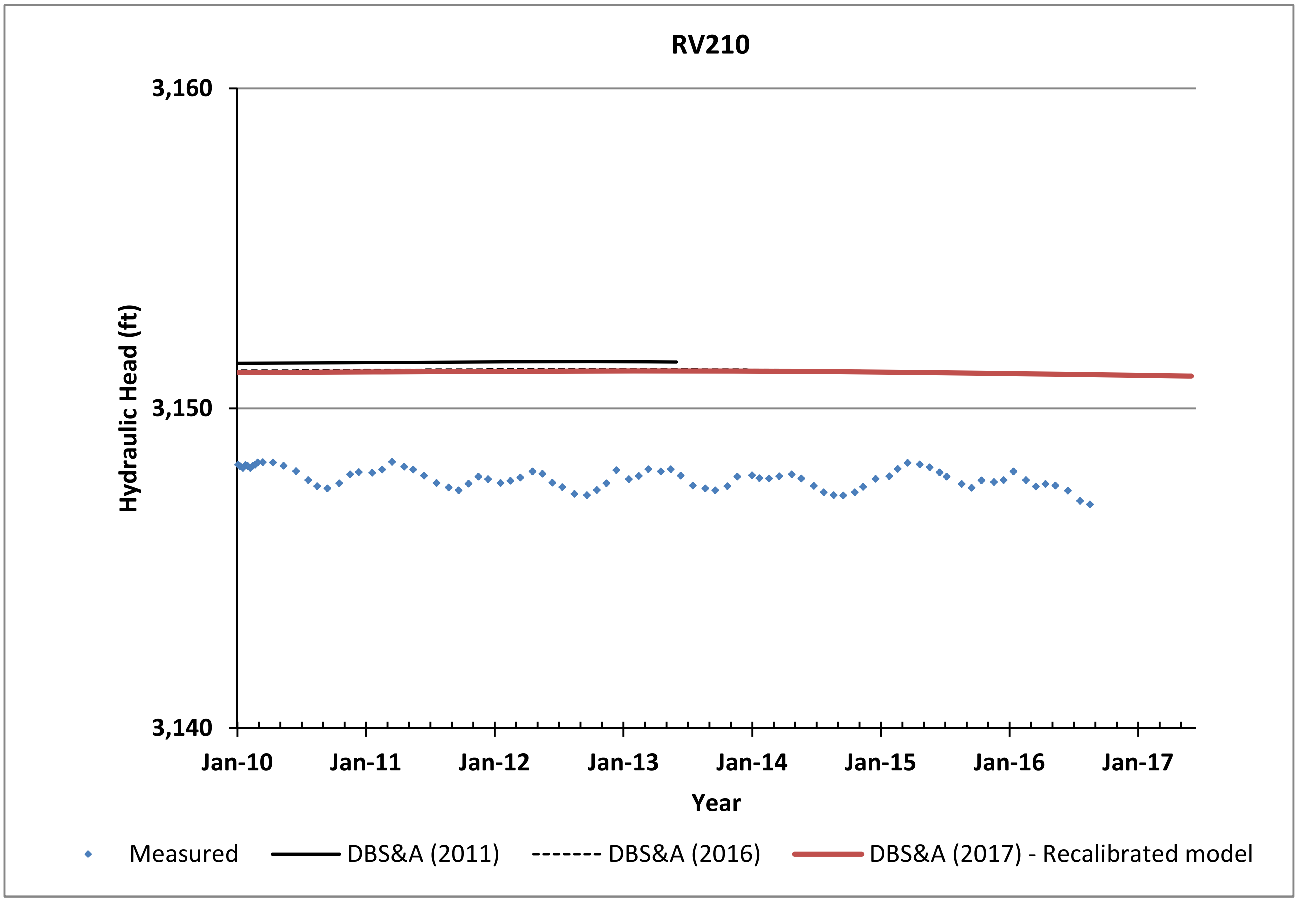

RV140
3,210
3,200
3,190
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model

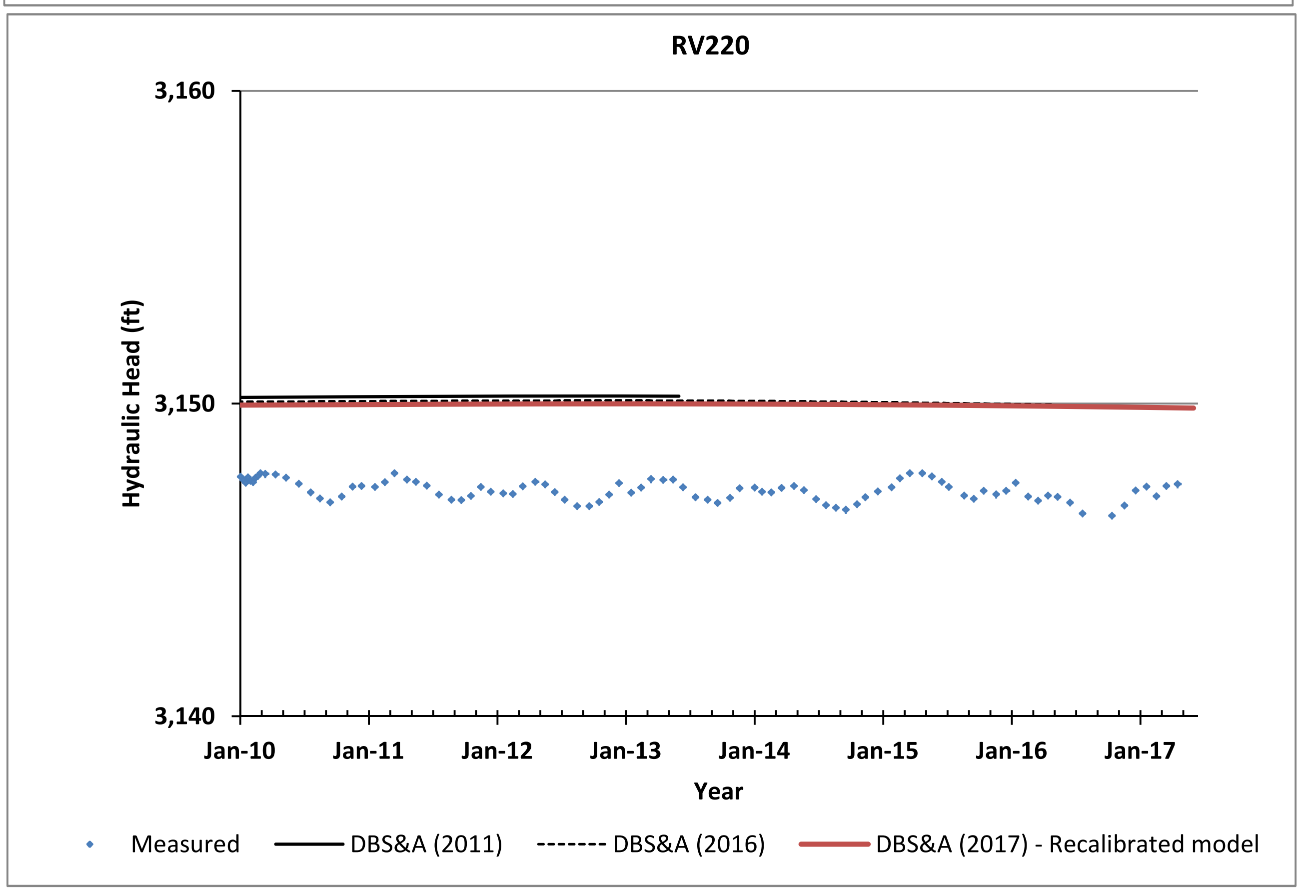

RV150
3,200
3,190
3,180
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV160
3,200
3,190
3,180
3,170
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV170
3,190
3,180
3,170
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV180
3,180
3,170
3,160
3,150
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV210
3,160
3,150
3,140
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model


RV220
3,160
3,150
3,140
Hydraulic Head (ft)
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Year
Measured
DBS&A (2011)
DBS&A (2016)
DBS&A (2017) - Recalibrated model