TECHNICAL MEMORANDUM

Title: Pumping Test of Test Wells East and West, Owens Lake, California – Results and Recommendations

Project: Task Order 003 – Owens Lake Groundwater Development Program Assistance

Prepared For: Los Angeles Department of Water and Power

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Technical Memorandum

Pumping Test of Test Wells East and West, Owens Lake, California – Results and Recommendations

Owens Lake Groundwater Development Program Support

Owens Lake, California

January 2020

Project No. 185865039

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Best	Best Drilling and Pump, Inc.
bgs	below ground surface
CEQA	California Environmental Quality Act
DTW	depth to water
ft msl	feet above mean sea level
ft	feet
gpm	gallons per minute
gpm/ft	gallons per minute per foot of drawdown
LADWP	The City of Los Angeles Department of Water and Power
RPPs	Resource Protection Protocols
SFIP	South Flood Irrigation Project
TM	Technical Memorandum
TW-E	Test Well East
TW-W	Test Well West
ΔH	change in head

EXECUTIVE SUMMARY

In order to resolve data gaps and improve the understanding of the effects of pumping from deeper aquifers and to inform measures to protect sensitive resources, the LADWP installed two testing wells at the northern portion of Owens Lake, designated Test Well East (TW-E), and Test Well West (TW-W), as shown on **Figure ES-1**. These wells were constructed and developed, then tested for a short duration (24 hours) in order to observe effects and evaluate the need and potential rates for longer term testing. During the testing, groundwater levels were observed in both the pumped well and numerous observation wells located around the wells. TW-E and TW-W were drilled and completed in October and December 2018, respectively. Both wells were completed using direct rotary drilling methods by Best Drilling and Pump, Inc. of Colton California. TW-E was drilled to a total depth of 1,500 feet (ft) and screened from 620 to 1,490 ft below ground surface (bgs). TW-W was drilled to a total depth of 1,520 ft and screened from a depth of 440 to 880 ft bgs.

Drawdown data from the testing wells was utilized to evaluate aquifer properties using the specialized software AQTESOLV. The AQTESOLV evaluation indicates an aquifer transmissivity of 515 ft^2/day at TW-E and 4,994 ft^2/day at TW-W. Calculated storage coefficients for TW-E and TW-W are 0.037 and 0.002, respectively.

The results of the pumping test at TW-E and TW-W have been utilized to improve the existing groundwater model of Owens Lake by adjusting aquifer parameters such that the model replicates the drawdown observed in the pumping and the few observation wells that showed influence of the testing. Unfortunately, a response to testing was not observed in the majority of observation wells because of the relatively low pumping rate and duration. Although the model replicates this behavior, opportunities to improve the model based on the testing observations are limited because drawdown was not observed at most monitoring locations.

Testing of TW-E and TW-W was also compared to previous pumping tests at the River Wells and the South Flood Irrigation Project (SFIP) Well. In both cases, drawdown was localized, and widespread effects could not be documented. These tests also suffered in that many of the current monitoring sites for resource protection were not in place yet. In addition, because the focus of the current investigation is the northern portion of the lake between the Owens Valley and River Fault Zones, the River site is located on the wrong side of the Owens River Fault Zone while the SFIP site is too far south to aid the current investigation.

It is therefore recommended that longer term pumping tests be performed. As a conservative measure, it is recommended that longer term pumping initially involve only one of the wells. Testing of TW-E is recommended in order to observe the effects of local fault zones, and because the relatively low production rate at this location is more conservative. A duration of 6 months during the dust season is recommended in order to mimic conditions under which the well might eventually be used.

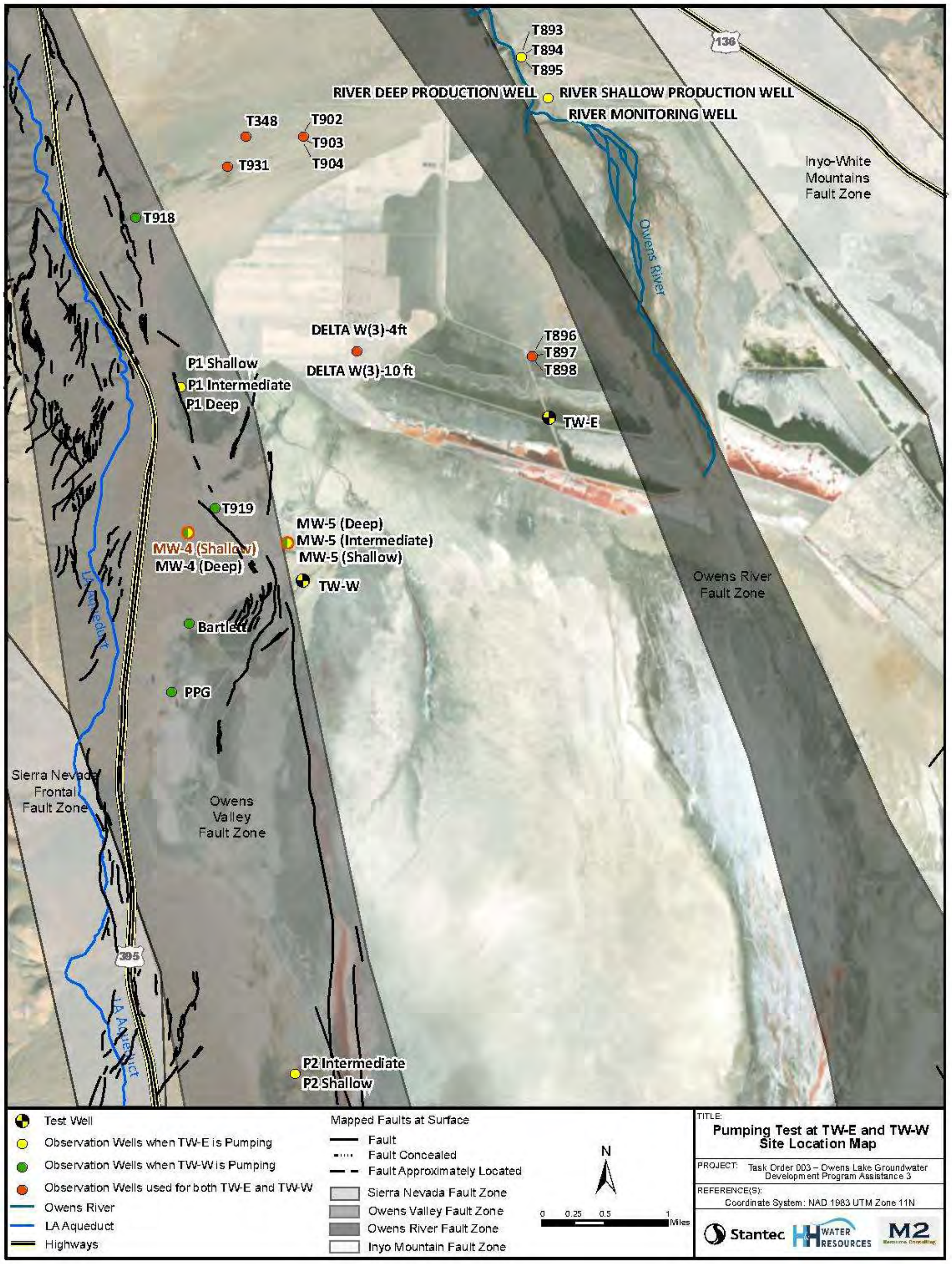


Figure ES-1: Pumping Test at TW-E and TW-W Site Location Map

This recommended pumping test was simulated at rates of 800, 1,200, 1,600, and 3,600 gallons per minute (gpm) utilizing the recently updated and improved groundwater model of Owens Lake. Even though pumping TW-E at a rate of 3,600 gpm for a period of 6 months is not projected to violate any of the resource protection protocols (RPPs) developed with the Groundwater Working Group, a lower rate is recommended as a conservative measure. Based on analysis of pumping test data and computer simulations, a pumping rate greater than 1,200 gpm is recommended in order to observe response in more geographic locations than occurred in the 24-hour testing, but not to exceed 2,000 gpm to be conservative in protecting sensitive resources.

An extensive groundwater monitoring plan has been developed for the proposed pumping test, including hydrologic RPPs. Although the groundwater modeling indicates that sensitive resources will not be significantly affected during the proposed pumping test, strict adherence to the triggers and management actions described in the RPPs that would initiate management actions such as reducing or stopping pumping is also deemed imperative. This pumping test is anticipated to significantly improve the understanding of the hydrogeology of the area and contribute to continuing sustainable groundwater management at Owens Lake.

1.0 INTRODUCTION

The City of Los Angeles Department of Water and Power (LADWP) has been investigating the potential use of groundwater to supplement water supply for dust mitigation at Owens Lake since 2009. This work has consisted of extensive data compilation, field work involving installation of deep monitoring wells on the lake, geochemical analysis of groundwater, installation of shallow monitoring wells around the lake margin, and development of conceptual hydrogeologic and numerical groundwater models. The LADWP has also worked with various stakeholders, landowners, and regulatory entities to establish guidelines for eventual groundwater pumping on and around the lake that will be utilized to develop a monitoring and pumping management framework under the California Environmental Quality Act (CEQA).

Based on drilling data from previous investigations, the subsurface geology of the lake consists of interbedded sequences of permeable sands and gravels (aquifers) separated by layers of clay and silt (aquitards). The shallowest aquifer in the vicinity of the lake is considered an "unconfined" or water table aquifer, whereas the deeper aquifers are "confined" aquifers. Confined aquifers underneath the lake have artesian pressures, which means that the groundwater levels in wells completed in some of the deeper aquifers rises above the ground surface. There are numerous existing production wells on or near the lake owned by others, which generally extract relatively small volumes of water from the shallowest (generally unconfined) aquifer. The conceptual plan for development of groundwater for dust mitigation by LADWP involves extraction of groundwater from relatively deep aquifers (generally located on the northern portion of the lake) as a means to reduce impacts on local non-LADWP wells and critical habitat that surrounds the lake.

There is relatively little information on the effects of pumping deep confined aquifers under the lake. Although extensive groundwater modeling has been conducted, actual field data on long-term pumping from deep aquifers is generally not available. A key data gap is the effect that numerous fault zones have on the flow of groundwater during deep groundwater pumping.

In order to resolve data gaps and improve the understanding of the effects of pumping from deeper aquifers and to inform measures to protect sensitive resources, the LADWP installed two testing wells at the northern portion of the lake, designated Test Well East (TW-E), and Test Well West (TW-W). These wells were constructed and developed, then conducted a pumping test for a short duration in order to observe effects and evaluate the need for longer term testing. During the testing, groundwater levels were observed in both the pumping well and numerous observation wells located around the lake.

The purpose of this Technical Memorandum (TM) is to:

- Document the construction characteristics of TW-E and TW-W,
- Describe the analysis methods and results of pumping tests of the two wells,
- Provide recommendations for longer-term pumping tests of the wells (primarily based on groundwater modeling), and
- Describe recommended monitoring during a longer-term pumping test of the wells.

The locations of the two test wells and observation wells monitored during the test are shown on **Figure 1**.

2.0 CONSTRUCTION OF TEST WELLS EAST AND WEST

TW-E and TW-W were drilled and completed in October and December 2018, respectively. Both wells were completed using the direct rotary drilling method by Best Drilling and Pump, Inc. of Colton California (Best).

TW-E was drilled to a total depth of 1,500 feet (ft) and screened from 620 to 1,490 ft below ground surface (bgs). TW-W was drilled to a total depth of 1,520 ft and screened from a depth of 440 to 880 ft bgs. Both wells were completed in areas with several hundred feet of sands and clays from ancestral Owens Lake sediments and on-lapping alluvial fans and braided stream deposits. Artesian conditions (groundwater level in the well above ground surface) were encountered at TW-W and a very shallow depth to groundwater of 2.2 ft bgs was encountered at TW-E on April 2, 2019.

Construction of each well commenced with the installation of a conductor casing at the surface to prevent caving and artesian flow during construction. After installation of the conductor casing, a pilot hole was competed for the purposes of lithologic and geophysical logging. Samples of subsurface materials were collected at 10-foot intervals during drilling of both wells. These subsurface materials were described (logged) under the direction of a California-certified hydrogeologist to produce a lithologic log of the well.

After reaching the total depth of the pilot hole, geophysical logs consisting of spontaneous potential, short and long normal resistivity, sonic, and gamma logs were completed at each location. When combined with lithologic logging, these geophysical logs provide an accurate depiction of changes in the physical nature of the sediments with depth. After completion of geophysical logging, one or more casings were installed in the wells for testing and future monitoring of groundwater quality and piezometric head. The lithologic and geophysical logs, along with the construction characteristics of both wells is summarized in **Figures 2 and 3.**

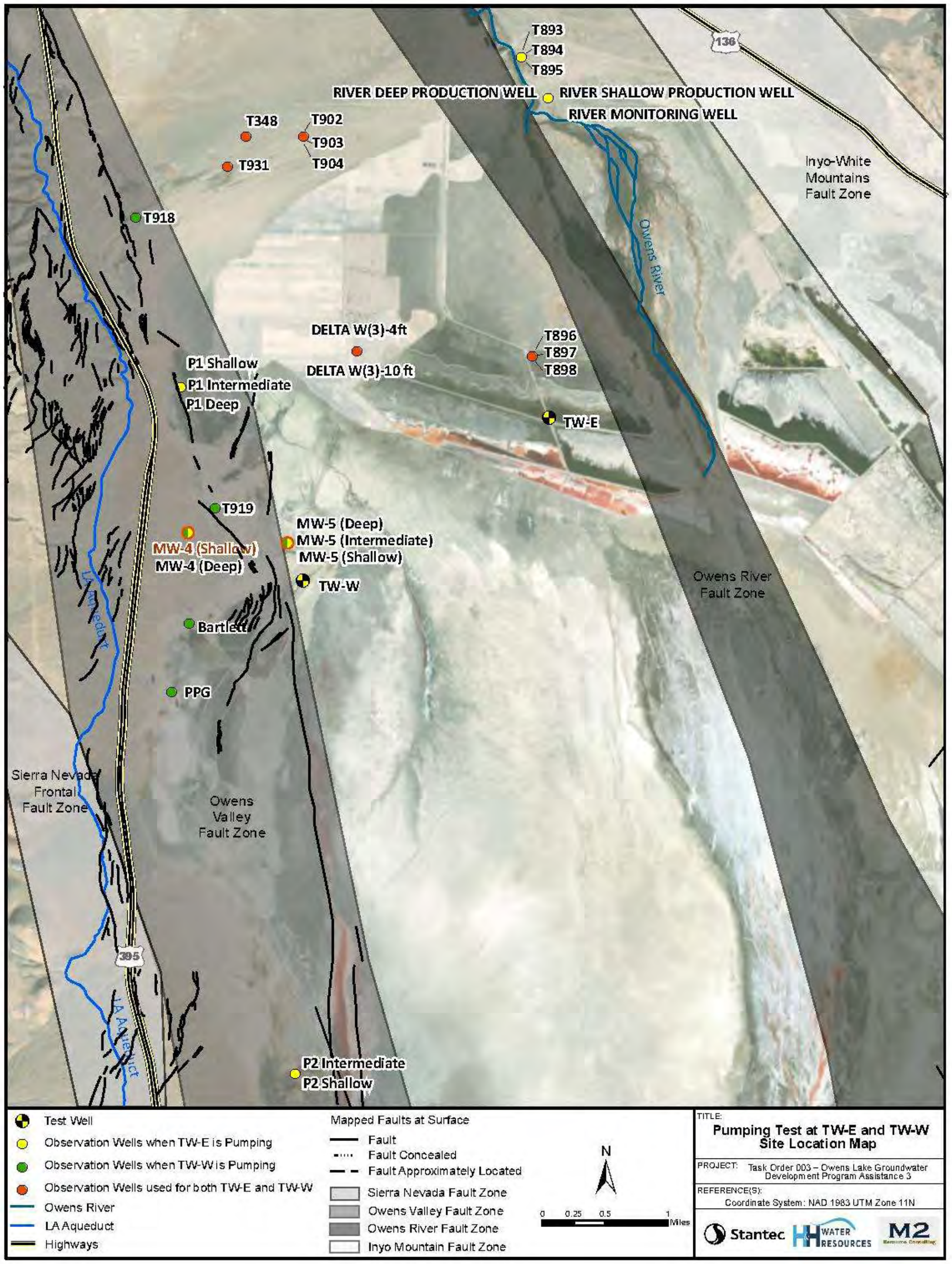
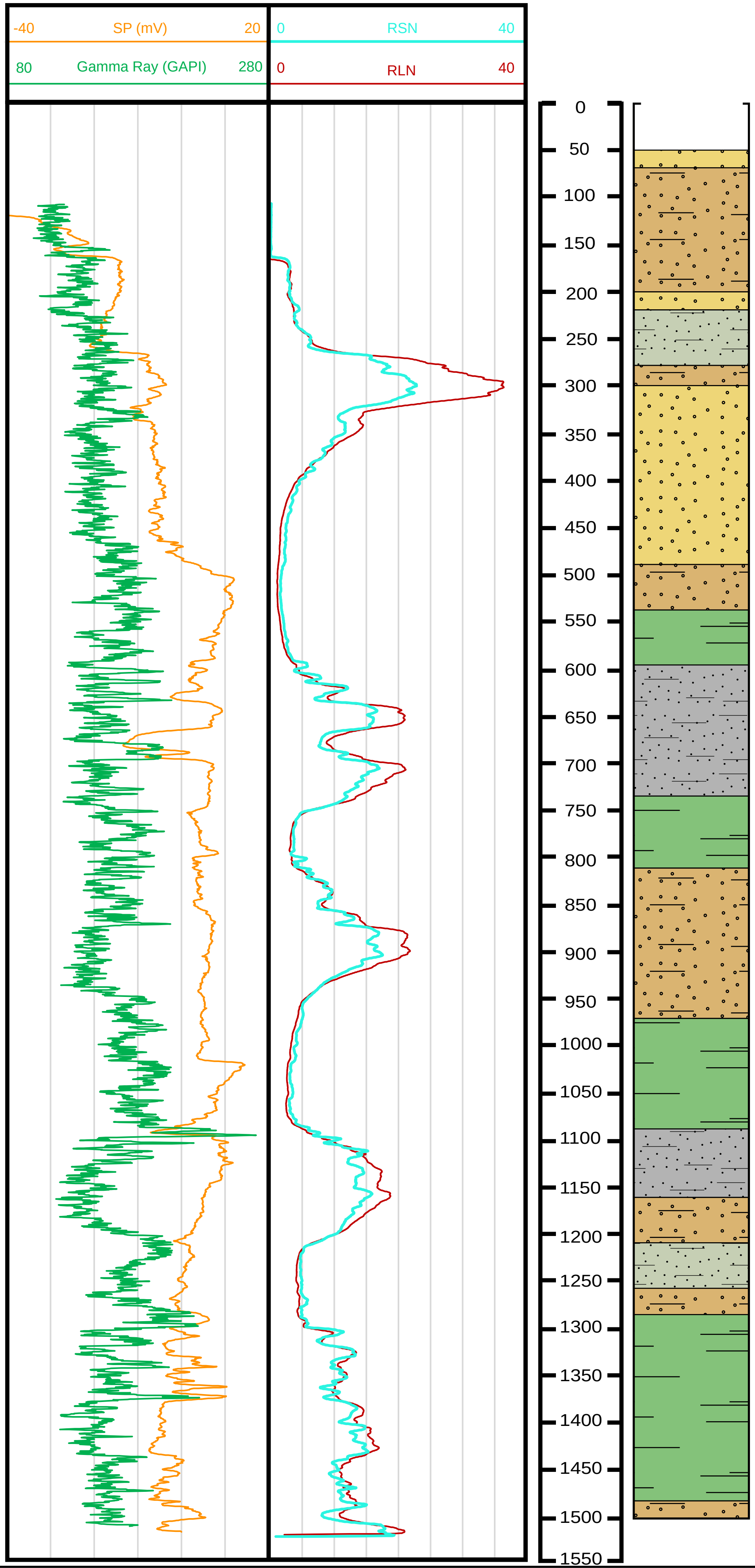


Figure 1: Pumping Test at TW-E and TW-W Site Location Map

TW-E

Geophysical Logs | Depth (feet bgs) | Lithologic Description* | Well Completion



SAND; Dark greyish brown (2.5Y, 4/2), mostly fine sand, subrounded to rounded, well sorted

SAND WITH SILT; Dark greyish brown (2.5Y, 4/2), fine sand and silt, well sorted

SAND; Light yellowish brown (2.5Y, 6/3), coarse sand, medium sand, subangular, quartz, well sorted, granitic source

CLAYEY SAND; Dark grey (2.5Y, 4/1) with black (2.5Y, 2.5/1), clay with fine sand, organic decay odor, effervescence with HCl, mica flakes

SILT WITH SAND; Light olive brown (2.5Y, 5/3) with lighter chroma (2.5Y, 5/4) spots, silt and fine sand, weak effervescence

SAND; Dark greyish brown (2.5Y, 4/2), mostly coarse sand with medium sand and trace silt, subangular to subrounded, well sorted

SILTY SAND; Greyish brown (2.5Y, 5/2), fine and medium sand, silt, and coarse sand, subangular to subrounded, poorly sorted, organic decay

CLAY; Dark grey (2.5Y, 4/1), clay, some black (2.5Y, 2.5/1) streaks, faint biodegradation odor

SANDY CLAY; Black (2.5Y, 2.5/1) clay and greyish brown (2.5Y, 5/2) sand, fine to coarse, subangular grains, poorly sorted, some organic

CLAY; Very dark grey (2.5Y, 3/1), clay, medium plasticity, trace sand

SANDY SILTY CLAY; Dark grey (2.5Y, 4/1), clay with silt and fine and medium sand, subangular to subrounded, organic decay odor

SILTY CLAY WITH SAND; Dark grey (2.5Y, 4/1), clay with silt and fine sand, subangular, organic decay odor

SANDY CLAY; Dark grey (2.5Y, 4/1), clay with silt and fine, medium, and coarse sand, subangular, organic decay odor

SANDY SILT; Dark grey (2.5Y, 4/1), silt with medium and fine sand, subangular to subrounded, organic decay odor

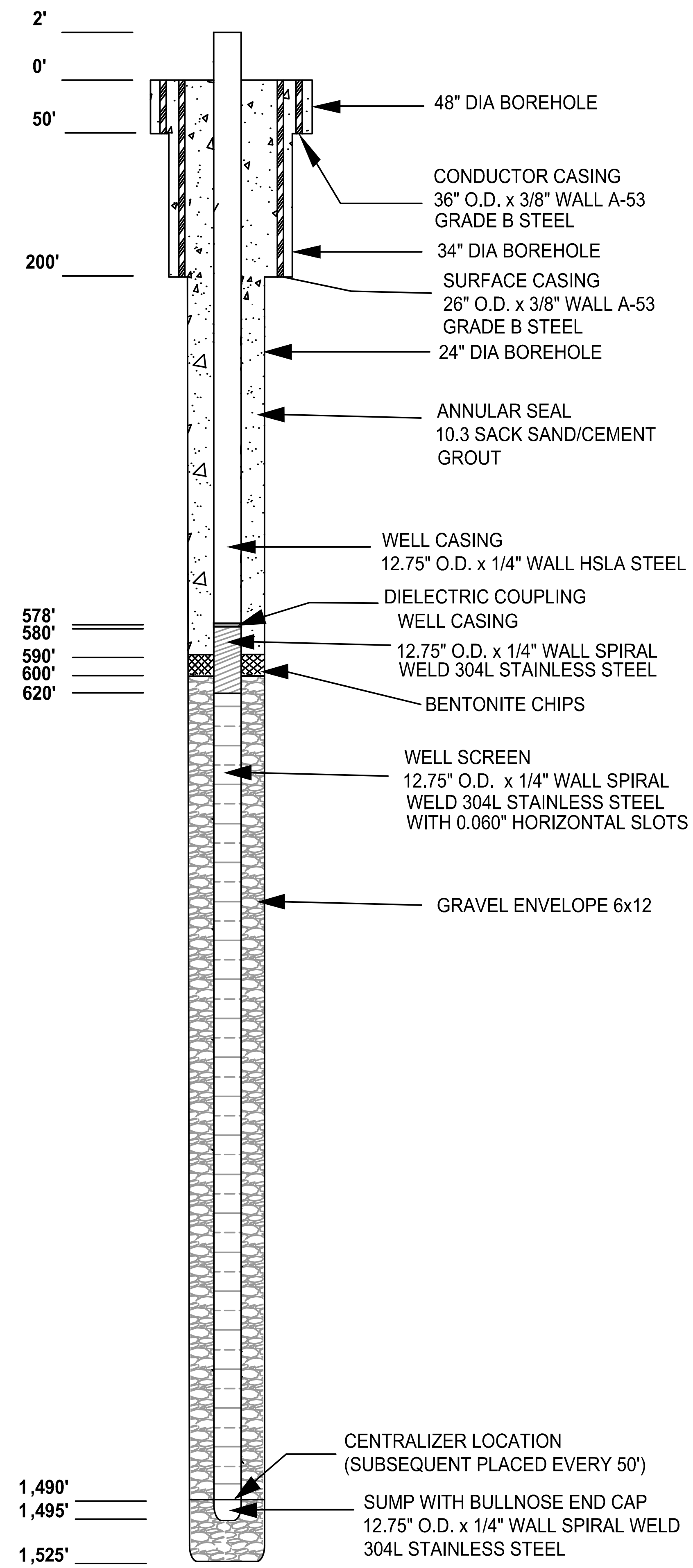
CLAY WITH SAND; Dark grey (2.5Y, 4/1), clay with trace fine sand, organic decay odor

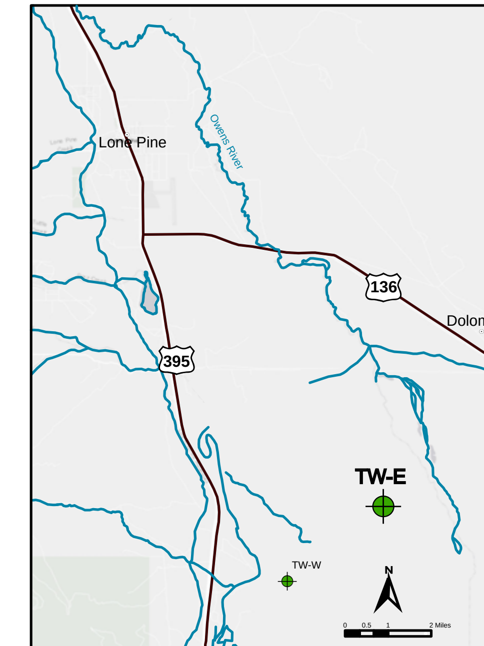
SANDY CLAY WITH SILT; Dark grey (2.5Y, 4/1), clay with silt and coarse, medium, and fine sand, subangular, organic decay odor

SANDY CLAY WITH SILT; Dark grey (2.5Y, 4/1), clay and silt with fine, medium, and coarse sand, organic decay odor

SILTY SAND; Dark grey (2.5, 4/1), silty sand, poorly sorted, subangular to subrounded, organic decay odor

*In some instances, the lithologic description and graphic log differ from the field based geophysical log due to the interpreted time delay in mud rotary circulation to the surface.





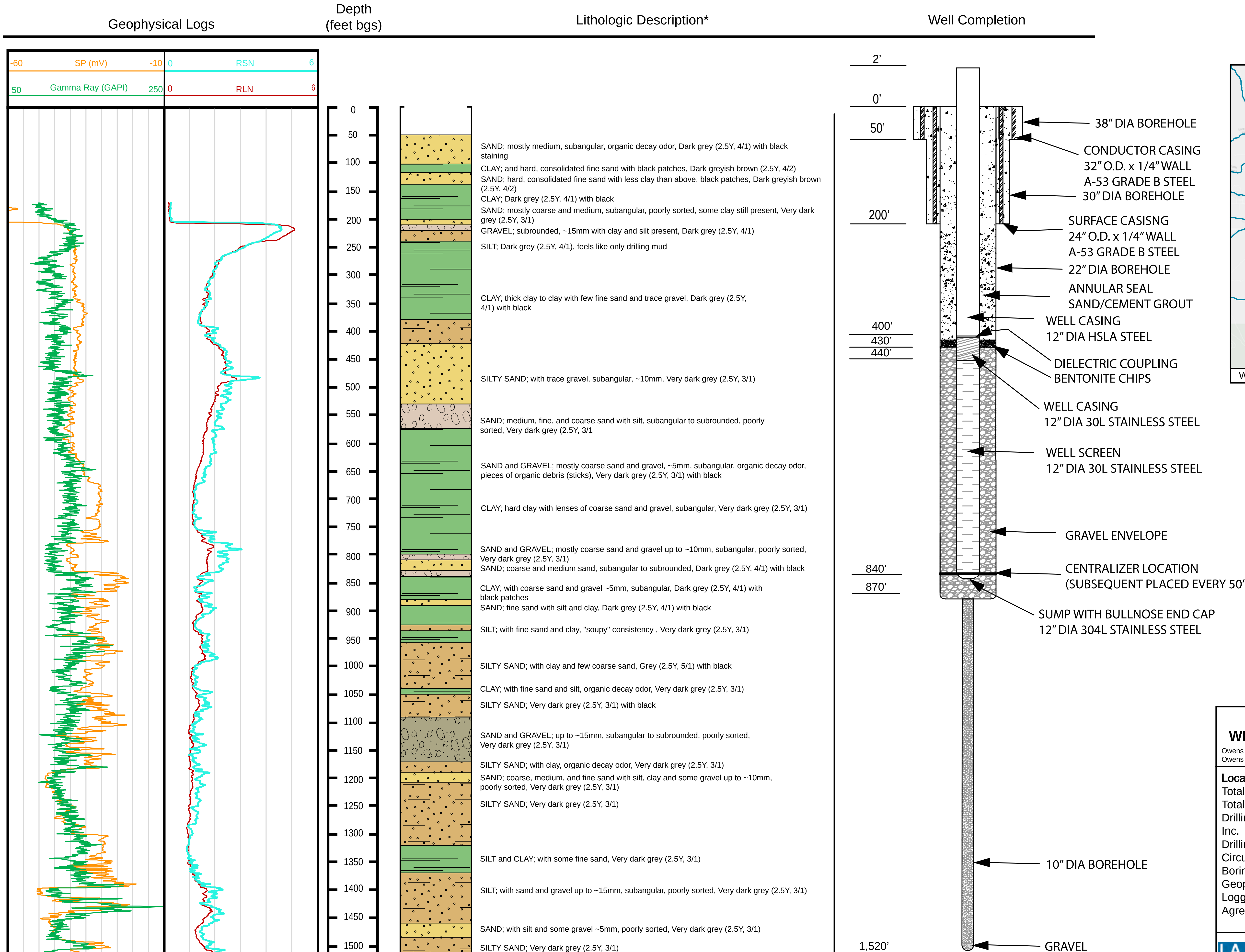
Well Location Map

FIGURE 2:
WELL COMPLETION-AS BUILT

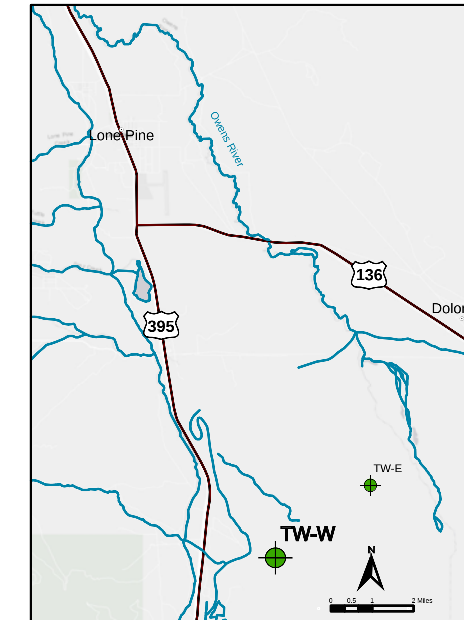
Owens Lake Groundwater Development Program Assistance
Owens Lake, CA

Location: TW-E
Total depth: 1525 feet
Total depth date: 10/23/18
Drilling contractor: Best Drilling and Pumping, Inc.
Drilling method: Mud Rotary – Direct circulation
Boring diameter: 24 inch
Geophysical survey by: Pacific Surveys, LLC
Logged by: V. Vathanasin/K. Shugart – Stantec
Agreement No: 47381-6

LA DWP Los Angeles Department of Water & Power | Stantec



*In some instances, the lithologic description and graphic log differ from the field based geophysical log due to the interpreted time delay in mud rotary circulation to the surface.



Well Location Map

FIGURE 3:
WELL COMPLETION-AS BUILT

Owens Lake Groundwater Development Program Assistance
Owens Lake, CA

Location: TW-W
Total Depth (ft): 1520
Total Depth Date: 12/4/2018
Drilling Contractor: Best Drilling & Pumping, Inc.
Drilling Method: Mud Rotary – Direct Circulation
Boring Diameter: 22 inch
Geophysical Survey: Pacific Surveys, LLC
Logged by: K. Shugart – Stantec
Agreement No: 47381-6

LA DWP Los Angeles Department of Water & Power
Stantec

3.0 TESTING METHODS

In order to determine the specific capacity of the wells and estimate the hydraulic conductivity and storage properties of the deep aquifer in vicinity of the wells, a step-drawdown and a 24-hour constant rate test were conducted at both wells. Prior to this testing, the wells were developed to remove drilling fluids and sediment from the wells.

A step-drawdown test is typically the first test of a newly completed well, whereby the well is pumped for short durations (typically 1-2 hours) at increasing rates (or "steps") for a total of eight (8) hours or less. The objective of a step test is to observe the amount of drawdown at various rates for the purposes of evaluating a potential longer-term test that can be sustained without causing the groundwater level to drop to the level, where the pump is installed. Extrapolations to different pumping rates can be evaluated by observing the specific capacity of the well, which is a measure of the amount of water level drop in the well (drawdown) relative to the pumping rate, typically expressed as gallons per minute (gpm) per foot of drawdown, or gpm/ft.

A longer-term 24-hour test at a constant flow rate was performed at both wells after the step test. The purpose of this test is to evaluate aquifer parameters such as hydraulic conductivity and storage coefficient, observe the effects at adjacent monitoring (or "observation") wells, and utilize this information to improve the groundwater model, and ultimately provide for protection of sensitive resources.

Both types of tests were performed on TW-E and TW-W, while observation of the effects on nearby observation wells was conducted. Groundwater level observations were recorded using pressure transducers and data loggers. The following paragraphs describe this testing in more detail.

3.1 Test Well East

A four and one half-hour (4.5) step-drawdown test was conducted at TW-E on April 2, 2019 with each step of 1.5 hours duration as indicated in **Table 1**. During the test, the pump operator (Best), measured discharge rates using a totalizing flow meter. Groundwater levels were recorded using a pressure transducer. TW-E was pumped at discharge rates of 402, 599, and 824 gpm. Upon conclusion of the step-drawdown tests, groundwater elevations at the test well were allowed to recover. Following a period of recovery, a 24-hour constant rate pumping test was conducted the following day at an average rate of 860 gpm.

Table 1: Flow Rates and Time Periods for Testing at TW-E

Test Well	Test Type	Start	End	Flow Rate (gpm)
TW-E	Step-Drawdown 1	4/2/19 17:00	4/2/19 18:30	402
	Step-Drawdown 2	4/2/19 18:30	4/2/19 20:00	599
	Step-Drawdown 3	4/2/19 20:00	4/2/19 21:30	824
	Constant Rate	4/3/19 7:12	4/4/19 7:12	860

During testing at TW-E, drawdown in numerous observations wells was monitored as summarized in **Table 2**. The groundwater levels in these wells were measured using a pressure transducer.

Table 2: Observation Wells and Frequency of Measurement During Pumping Test of TW-E

Well ID	Northing (ft)	Easting (ft)	Surface Elevation (ft msl)*	RP Elevation (ft msl)*	Head/ DTW** (ft)	Start	End	Measurement Frequency
TW-E	4,040,565.70	412,675.90	3,565.00		DTW	3/29/19 17:19	4/10/19 15:28	1 min
TW-W	4,038,469.60	409,511.20	3,559.30		Head	4/2/2019 8:18	4/4/2019 7:33	1 min
T896	4,041,347.60	412,453.50	3,572.10	3,572.10	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T897	4,041,340.10	412,453.60	3,572.39	3,572.39	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T898	4,041,332.40	412,453.30	3,572.22	3,572.22	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T893	4,045,191.30	412,319.00	3,599.49	3,599.49	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T894	4,045,196.00	412,325.00	3,599.72	3,599.72	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T895	4,045,200.90	412,330.60	3,600.07	3,600.07	Head	3/1/19 0:00	4/30/19 23:00	1 hr
T931	4,043,782.92	408,540.85	3,616.91	3,620.07	Head	3/1/19 0:00	5/1/2019 0:00	1 hr
DeltaW(3) 4ft	4,041,420.18	410,203.90	3,567.19	3,567.16	DTW	4/2/2019 7:00	4/8/2019 13:10	5 min
DeltaW(3) 10ft	4,041,418.48	410,203.90	3,567.26	3,567.22	DTW	4/2/2019 7:00	4/8/2019 13:10	5 min
T348	4,044,160.00	408,766.00	3,643.31	3,642	DTW	3/1/2019 0:00	5/1/2019 0:00	1 hr
River PW (Deep)	4,044,605.00	412,624.13	3,588	3,589.20	erroneous data			
River PW Shallow	4,044,605.00	412,624.13	3,588	3,589.33	Head	4/2/2019 9:40	4/9/2019 12:30	5 min
T902	4,044,157.40	409,502.00	3,631.19	3,631.19	DTW	4/2/2019 10:50	4/18/2019 9:00	5 min
T903	4,044,165.80	409,501.70	3,631.30	3,631.30	Head	4/2/2019 10:50	4/18/2019 9:00	5 min
T904	4,044,174.40	409,501.40	3,631.46	3,631.46	DTW	4/2/2019 10:50	4/18/2019 9:00	5 min
MW-4(Shallow)	4,039,084.10	408,038.80	3,643.50	-	DTW	4/2/2019 13:19	4/8/2019 10:19	5 min
MW-4(Deep)	4,039,084.10	408,038.80	3,643.50	-	DTW	4/2/2019 13:14	4/8/2019 10:24	5 min

Well ID	Northing (ft)	Easting (ft)	Surface Elevation (ft msl)*	RP Elevation (ft msl)*	Head/ DTW** (ft)	Start	End	Measurement Frequency
MW-5(Shallow)	4,038,944.20	409,308.80	3,558.90	-	Head	4/2/2019 16:03	4/18/2019 14:10	5 min
MW-5(Intermediate)	4,038,944.20	409,308.80	3,558.90	-	DTW	4/2/2019 16:11	4/8/2019 11:51	5 min
P1 Deep	407,934.42	4,040,957.32	3,571.80	3,573.94	DTW	4/2/2019 15:08	4/8/2019 9:33	5 min
P1 Intermediate	407,934.42	4,040,957.32	3,571.80	3,573.99	DTW	4/2/2019 15:16	4/8/2019 9:36	5 min
P1 Shallow	407,934.42	4,040,957.32	3,571.80	3,574.08	DTW	4/2/2019 15:55	4/8/2019 10:15	5 min
P2 Intermediate	409,408.08	4,032,138.39	3,566.01	3,568.08	DTW	4/2/2019 16:42	4/8/2019 8:27	5 min
P2 Shallow	409,408.08	4,032,138.39	3,566.01	3,568.35	DTW	4/2/2019 17:24	4/8/2019 9:09	5 min
* = feet above mean sea level; ** = Depth to Water								

3.2 Test Well West

Due to flowing artesian conditions and permit restrictions, flowing tests were conducted at TW-W for similar step drawdown and constant rate testing at TW-E. A "flowing" test on an artesian well is similar to a pumping test, except that a pump in not utilized. Instead, the well is sealed initially, then allowed to flow at increasing rates using a valve, causing a similar hydraulic effect as pumping the well. Like TW-E, upon conclusion of the step-drawdown tests, groundwater elevations at the testing well were allowed to recover. Following a period of recovery, a 24-hour constant rate flowing test was conducted the next day. The time periods and flow rates for testing of TW-W are summarized in **Table 3**.

Table 3: Flow Rates and Time Periods for Testing at TW-W

Well	Test	Time	Time	Flow (gpm)
TW-W	Step 1	4/16/19 11:01	4/16/19 12:30	391
	Step 2	4/16/19 12:55	4/16/19 14:25	596
	Step 3	4/16/19 14:30	4/16/19 15:45	798
	Constant Rate	4/17/19 8:00	4/18/19 7:30	720

The discharge rate and drawdown data collected during these tests provided estimates of the specific capacity of each well in units of gallons per minute per foot of drawdown (gpm/ft).

During flowing test at TW-W, drawdown in numerous observations wells were monitored as summarized in **Table 4**. The groundwater levels in these wells were measured using a pressure transducer. Upon conclusion of the step-drawdown tests, groundwater elevations at the testing wells were allowed to recover. Following a period of recovery, a 24-hour constant rate flow test was conducted the next day.

The following section describes the results of the testing of the two wells in terms of changes in groundwater elevations observed during testing.

Table 4: Observation Wells and Frequency of Measurement During Pumping Test of TW-W

Well ID	Northing (ft)	Easting (ft)	Surface Elevation (ft msl)	RP Elevation (ft msl)	Head/DTW (ft)	Start	End	Measurement Frequency
TW-W	4,038,469.60	409,511.20	3,559.30	-	Head	4/16/19 11:01	4/18/19 7:35	15 min
MW-5(Shallow)	4,038,944.20	409,308.80	3,558.90	-	Head	4/2/2019 16:03	4/18/2019 14:10	5 min
MW-5(Deep)	4,038,944.20	409,308.80	3,558.90	-	Head	4/15/2019 9:00	4/18/2019 14:00	5 min
MW-5(Intermediate)	4,038,944.20	409,308.80	3,558.90	-	DTW	4/15/2019 9:00	4/18/2019 14:10	5 min
PPG	4,037,042.26	407,820.93	3,577	-	DTW	4/15/2019 10:00	4/18/2019 13:30	5 min
Bartlett	4,037,918.27	408,049.05	3,578	-	DTW	4/15/2019 9:00	4/18/2019 14:10	5 min
TW-E	4,040,565.70	412,675.90	3,565.00	-	Head	4/15/2019 11:00	4/18/2019 8:35	5 min
T348	4,044,160.00	408,766.00	3,643.31	3,642	DTW	3/1/2019 0:00	4/18/2019 10:55	1 hr/5 min
T896	4,041,347.60	412,453.50	3,572.10	3,572.10	Head	3/1/2019 0:00	4/18/2019 9:10	1 hr/5 min
T897	4,041,340.10	412,453.60	3,572.39	3,572.39	Head	3/1/2019 0:00	4/18/2019 9:10	1 hr/5 min
T898	4,041,332.40	412,453.30	3,572.22	3,572.22	Head	3/1/2019 0:00	4/18/2019 9:10	1 hr/5 min
T902	4,044,157.40	409,502.00	3,631.19	3,631.19	DTW	4/2/2019 10:50	4/18/2019 9:00	5 min
T903	4,044,165.80	409,501.70	3,631.30	3,631.30	Head	4/2/2019 10:50	4/18/2019 9:00	5 min
T904	4,044,174.40	409,501.40	3,631.46	3,631.46	DTW	4/2/2019 10:50	4/18/2019 9:00	5 min
DeltaW(3) 4ft	4,041,420.18	410,203.90	3,567.19	-	DTW	4/15/19 12:00	4/18/19 14:15	5 min
DeltaW(3) 10ft	4,041,418.48	410,203.90	3,567.26	-	DTW	4/15/19 11:55	4/18/19 14:15	5 min
T918	4,042,483.24	406,949.66	3,604.90	3,606.20	DTW	4/16/2019 7:00	4/18/2019 12:00	5 min
T919	4,039,442.61	408,327.35	3,599.73	3,601.72	DTW	4/16/2019 7:35	4/18/2019 12:30	5 min
T931	4,043,782.92	408,540.85	3,616.91	3,620.07	DTW	3/1/2019 0:00	4/18/2019 11:25	1 hr/5 min

4.0 OBSERVATIONS DURING PUMPING TESTS

The following section describes groundwater elevation observations before, during, and after testing at both TW-E and TW-W.

4.1 Test Well East

Appendix A contains hydrographs of water levels observed in the pumping well and nearby observation wells during pumping of TW-E.

Figure 4 shows detail of the drawdown occurring in TW-E during the step-drawdown test. As shown, the drawdown after the third step was approximately 175 feet at a pumping rate of 824 gpm. After this step test, the groundwater level, or in this case drawdown from static (initial) condition, was allowed to return to pre-pumping conditions before the start of the next test.

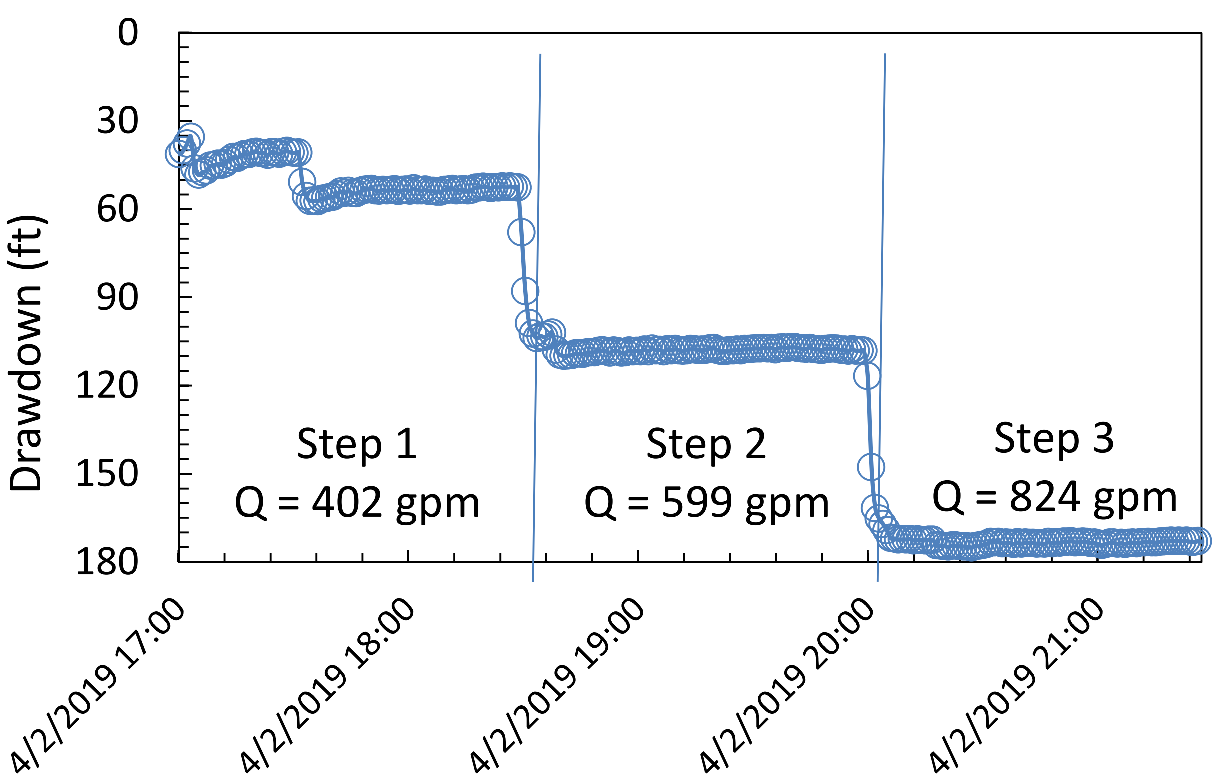


Figure 4: Step Testing Results at TW-E showing Pumping Rates and Associated Drawdown

After recovery of groundwater levels to pre-test conditions, the 24-hour test commenced at TW-E. **Figure 5** depicts both the step test and 24-hour test at TW-E.

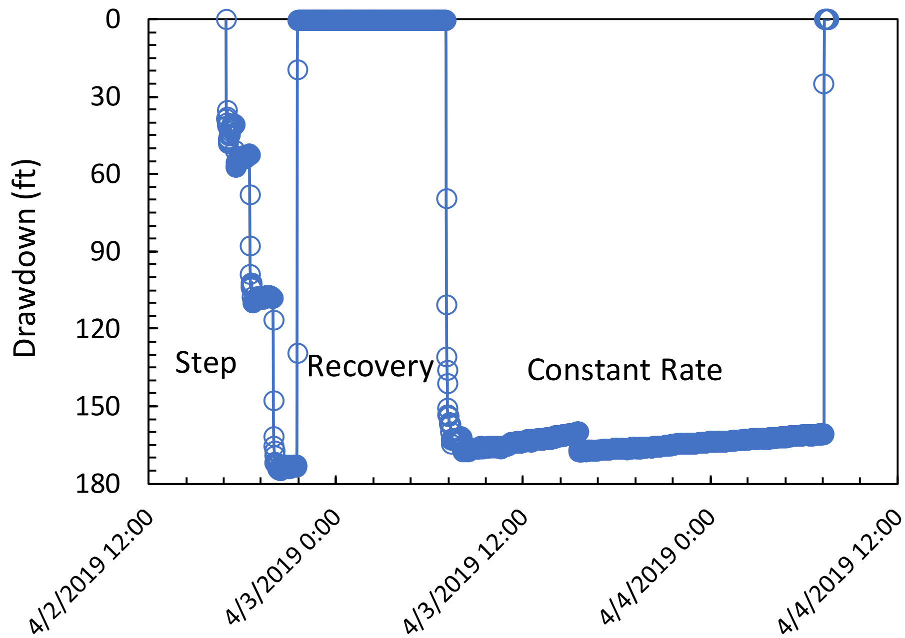


Figure 5: Drawdown at TW-E During Both Step and Constant Rate Tests

Figures 4 and 5 depict the drawdown that occurred in the pumping well TW-E. However, of significant interest is the groundwater elevation changes that occurred at nearby observation wells (listed in **Table 2**) during the pumping of TW-E.

Summary data for testing at TW-E was collected as shown in **Table 5.**

When the step-drawdown and constant rate pumping tests were conducted at TW-E (**Table 1**), drawdown was observed at a variety of wells as listed in **Table 2**. The results of these observations are summarized in **Table 5**, whereby a rise in groundwater levels before and after the testing is shown by a positive value, and a decline in groundwater elevation is shown with a negative value.

Table 5: Drawdown Summary for Testing at TW-E

Note: Groundwater level was recorded at the start and end of each respective test; the difference between them is shown as "(ΔH)". A rise in groundwater levels before and after the testing is shown by a positive value, and a decline in groundwater elevation is shown with a negative value.

ID	Step 1			Step 2			Step 3			Constant Rate		
	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)
	4/2/2019 4:59:08 PM	4/2/2019 6:29:08 PM		4/2/2019 6:29:08 PM	4/2/2019 7:59:08 PM		4/2/2019 7:59:08 PM	4/2/2019 9:30:08 PM		4/3/2019 7:04:08 AM	4/3/2019 7:16:08 AM	
TW-E	253.125	200.517	-52.608	200.517	144.984	-55.533	144.984	79.8312	-65.1528	252.832	92.3016	-160.53
TW-W	73.8587	73.8862	0.0275	73.8862	73.8581	-0.0281	73.8581	73.8597	0.0016	73.8696	73.8768	0.0072
T896	53.8	53.76	-0.04	53.76	53.74	-0.02	53.74	53.69	-0.05	53.7	53.48	-0.22
T897	56.41	56.42	0.01	56.42	56.44	0.02	56.44	56.55	0.11	56.35	56.1	-0.25
T898	46.9	46.9	0	46.9	46.9	0	46.9	46.9	0	46.92	46.95	0.03
T893	30.505	30.486	-0.019	30.486	30.477	-0.009	30.477	30.468	-0.009	30.494	30.508	0.014
T894	31.198	31.166	-0.032	31.166	31.134	-0.032	31.134	31.092	-0.042	31.133	31.07	-0.063
T895	32.02	32	-0.02	32	31.97	-0.03	31.97	31.96	-0.01	31.95	31.95	0
T931	15.25	15.24	-0.01	15.24	15.18	-0.06	15.18	15.17	-0.01	15.04	15.11	0.07
DeltaW(3)_4ft	2.943	2.958	0.015	2.958	2.989	0.031	2.989	2.989	0	3.035	3.036	0.001
DeltaW(3)_10ft	2.848	2.879	0.031	2.879	2.879	0	2.879	2.91	0.031	2.956	2.972	0.016
T348	7.55	7.56	0.01	7.56	7.61	0.05	7.61	7.61	0	7.63	7.61	-0.02
River_PW_Shallow	39.33	39.39	0.06	39.39	39.43	0.04	39.43	39.47	0.04	39.54	39.47	-0.07
T902	0.625	0.568	-0.057	0.568	0.549	-0.019	0.549	0.527	-0.022	0.263	0.337	0.074
T903	3.46	3.32	-0.14	3.32	3.32	0	3.32	3.22	-0.1	3.19	3.2	0.01
T904	1.846	1.836	-0.01	1.836	1.833	-0.003	1.833	1.827	-0.006	1.769	1.779	0.01
MW-4(Shallow)	58.79	58.8	0.01	58.8	58.83	0.03	58.83	58.86	0.03	58.93	58.89	-0.04
MW-4(Deep)	49	48.99	-0.01	48.99	49.02	0.03	49.02	49.04	0.02	49.06	49.08	0.02
MW-5 (Shallow)	Data unreliable due to gas pressure in the well, which has since been fitted with a gas release valve (based on field notes).											
MW-5 (Intermediate)	52.87	52.85	-0.02	52.85	52.87	0.02	52.87	52.82	-0.05	52.88	52.9	0.02
P1 (Deep)	2.15	2.16	0.01	2.16	2.17	0.01	2.17	2.16	-0.01	2.13	2.13	0
P1 (Intermediate)	2.69	2.7	0.01	2.7	2.69	-0.01	2.69	2.68	-0.01	2.63	2.62	-0.01

ID	Step 1			Step 2			Step 3			Constant Rate		
	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)
	4/2/2019 4:59:08 PM	4/2/2019 6:29:08 PM		4/2/2019 6:29:08 PM	4/2/2019 7:59:08 PM		4/2/2019 7:59:08 PM	4/2/2019 9:30:08 PM		4/3/2019 7:04:08 AM	4/3/2019 7:16:08 AM	
P1 (Shallow)	2.87	2.9	0.03	2.9	2.91	0.01	2.91	2.91	0	2.83	2.81	-0.02
P2 (Intermediate)	3.616	3.62	0.004	3.62	3.62	0	3.62	3.61	-0.01	3.549	3.549	0
P2 (Shallow)	3.86	3.86	0	3.86	3.86	0	3.86	3.86	0	3.79	3.79	0

Table 6 summarizes significant confirmed declines in groundwater elevations during the testing of TW-E. "Confirmed" declines in groundwater elevations are described below. Review of **Table 6** indicates that the majority of drawdown occurs in the pumping well TW-E, as expected, with approximately 160 feet of drawdown after the end of the 24-hour constant rate test. Changes in groundwater levels in observation wells are much more subtle, and in many cases, groundwater elevation rose by a minor amount during the step and constant rate tests. This is not entirely unexpected, as minor changes in groundwater level can be ascribed to diurnal changes in evapotranspiration, barometric pressure, or other boundary conditions, or to accuracy in the transducers being used. For this reason, very small negative changes (declining) groundwater elevations may not be considered a direct result of the testing itself because they cannot be separated from "noise" or inaccuracy of measurement.

In addition, detailed review of the hydrographs (Appendix A) reveals that even though the groundwater elevation may be lower at the end of the test compared to the start of the test, the pattern of groundwater level change suggests it is not related to pumping from testing well. For example, if the groundwater level drops, then rises during the test, then drops again below the starting point of the test, it suggests some other influence other than the pumping well. Examples of this are wells T897 and TW-E when TW-W was pumped (Appendix A). These wells do not have "confirmed" drawdown.

Table 6: Summary of Significant Drawdown During Testing at TW-E

Well Name	Observed Drawdown (feet)
TW-E (pumping well)	160.53
T896	0.22
T897	0.25

Groundwater elevations or piezometric head can be influenced by a variety of factors other than pumping, including earth tides, seismic activity, or barometric pressure (Fenelon, 2000). Barometric pressure can cause inaccuracies even in gauged (vented) pressure loggers (Mann, 2012). The influence of barometric pressure during the test is illustrated in **Figure 6**, whereby barometric pressure varied by approximately 0.34 to 0.68 feet of water during the tests at TW-E and TW-W, respectively. Groundwater levels measured in wells penetrating confined aquifers at depth can incorrectly record the real piezometric pressure in the aquifer adjacent to the well screen. This is due to the difference in pressure being transmitted directly to the free surface of a well and the pressure being transmitted to groundwater in the aquifer itself (Ferris and others, 1962). When barometric pressure increases over an aquifer penetrated by a tightly cased well, the water level in the well decreases. Conversely, when the barometric pressure decreases over the same aquifer, the water level increases (Landmeyer 1996). The water level response varies by well according to the barometric efficiency. Barometric efficiency is the ratio of well's water level change to barometric pressure change. Theoretically, a well with a full response to changes in barometric pressure would have a barometric efficiency of 100 percent, and a well unaffected by changes in barometric pressure would have a barometric efficiency of 0 percent. Typically, barometric efficiency values range from 20 to 70 percent (Todd, 1980).

This suggests that barometric pressure alone may account for variations of 0.07 feet of water (20% of 0.34 feet of water) to 0.48 feet of water (70% of 0.68 feet of water). Because the barometric efficiency of each well is unknown, and the impact of barometric pressure can be delayed, no attempt to correct for barometric pressure has been made. However, it does suggest that small variations in piezometric head variations (less than approximately 0.20 feet) that are not due to pumping are expected.

Earth tides are caused by the forces exerted on the Earth's surface by the Moon and the Sun. Changes in groundwater level resulting from Earth tides are actual diurnal fluctuations of the head in the aquifer. As a result of Earth tides, groundwater levels will peak near moonrise and moonset, and be lowest near the upper and lower culmination of the Moon (Ferris and others, 1962). For example, earth tides at the Nevada test site cause groundwater levels to fluctuate several hundredths of a foot, which is about an order of magnitude less than fluctuations caused by barometric pressure (Fenelon, 2000).

When changes of less than 0.20 foot are ignored (potentially due to barometric influences), and the hydrographs are reviewed in detail, measurable or "confirmed" drawdown at the end of the 24-hour test can be summarized as follows.

Drawdown observed at T896 and T897 is expected because not only are they the closest wells (**Figure 1**), but they are deeper wells. As explained in the following section, deeper wells located in the confined aquifer are expected to have greater drawdown than shallower wells.

It is particularly noteworthy is that there was no significant drawdown observed at all shallow well locations, such as the piezometers surrounding the lake and other adjacent monitoring wells. This is significant because the sensitive resources are generally associated with the shallow aquifer. The geographic distribution of confirmed drawdown in groundwater elevations is shown in **Figure 7**.

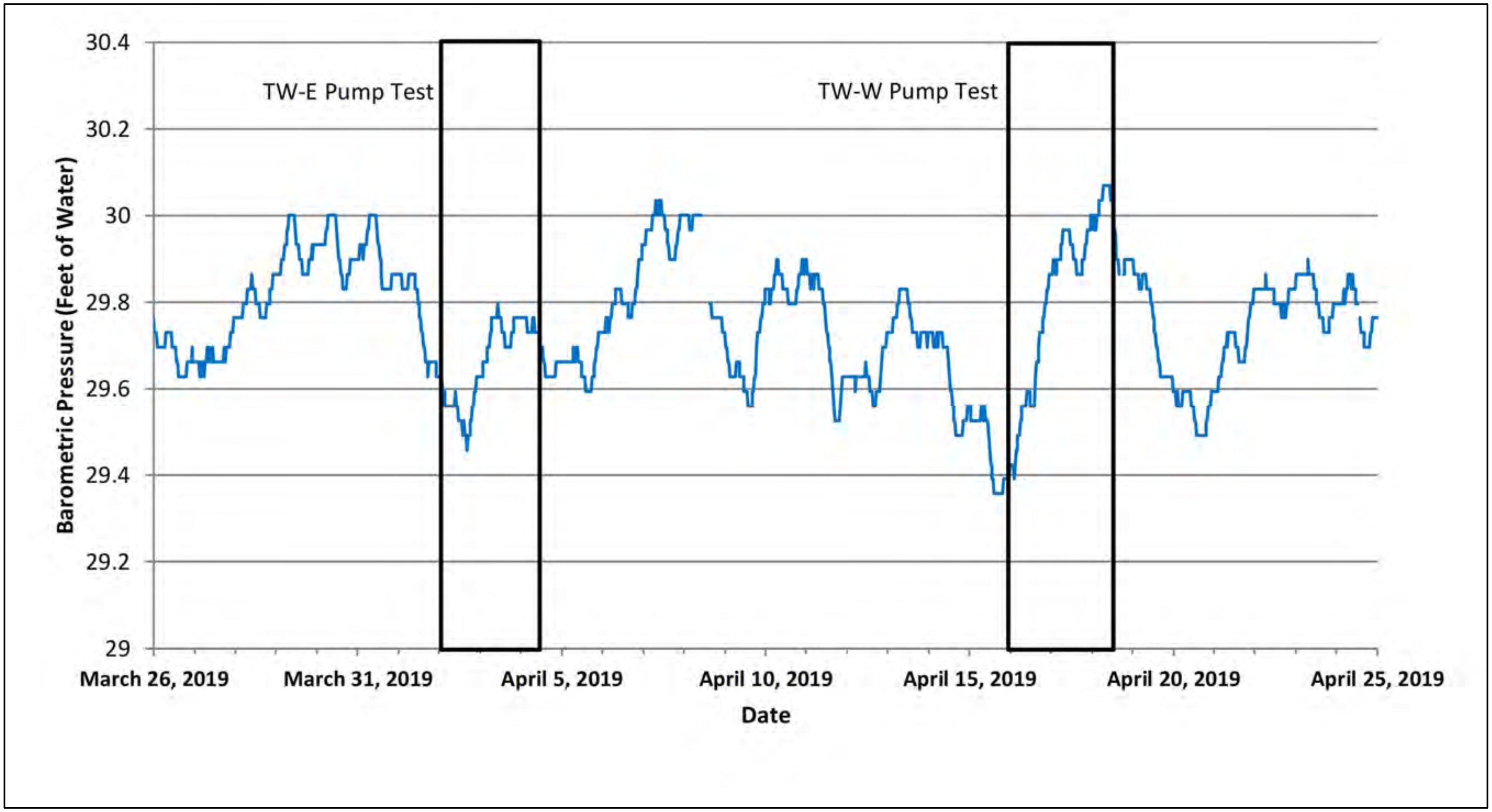


Figure 6: Barometric Pressure Fluctuations at Owens Lake

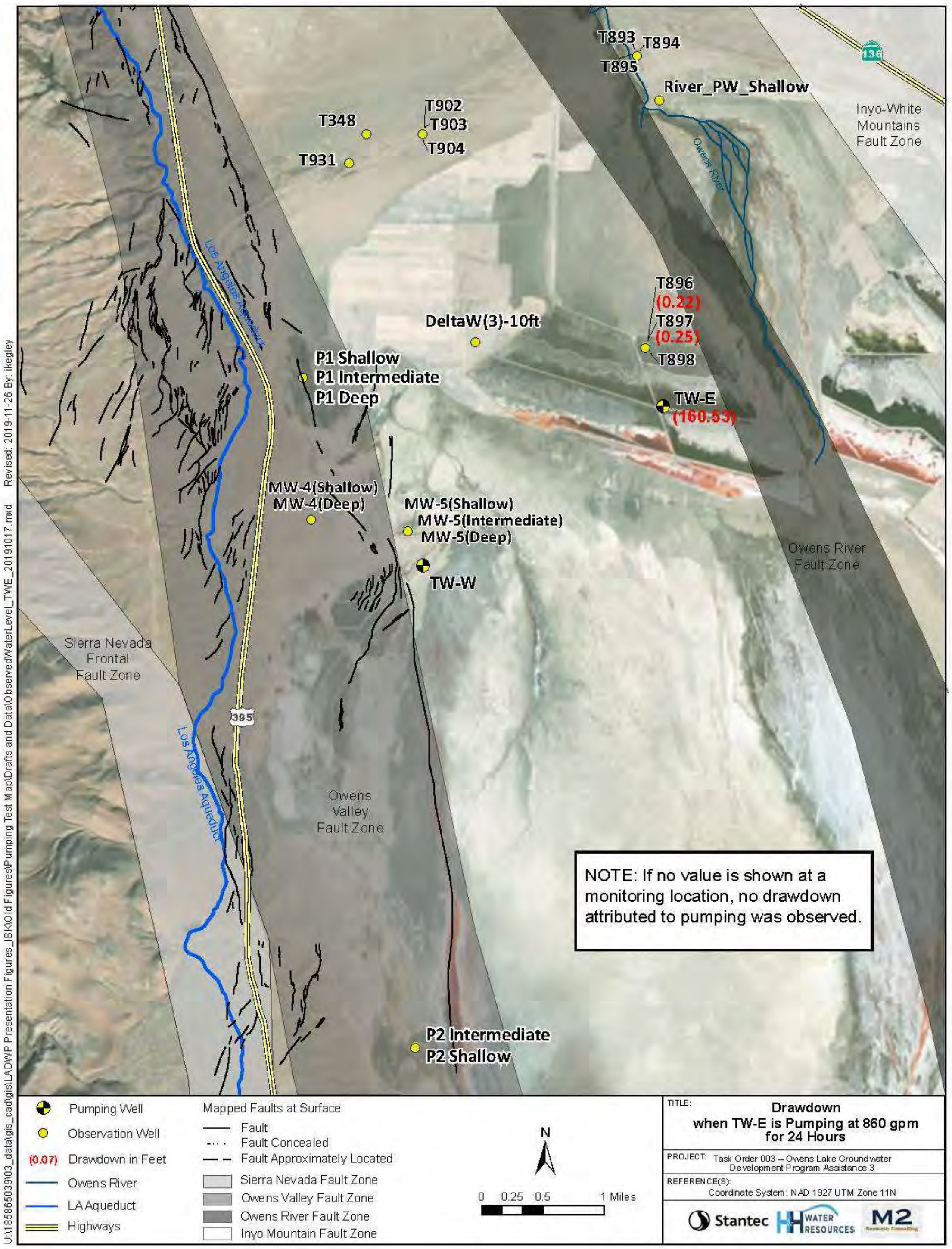


Figure 7: Drawdown when TW-E is Pumping at 860 gpm for 24 Hours

4.2 Test Well West

TW-W was tested in similar fashion as TW-E (except that it was allowed to flow instead of being pumped), whereby a step test was conducted followed by a resting period to allow the well to recover, after which a 24-hour test was conducted. Appendix A contains hydrographs of groundwater levels observed in the flowing well and nearby observation wells during flowing test of TW-W.

Figure 8 depicts the drawdown observed in the flowing well TW-W during three steps at rates outlined in **Table 3**.

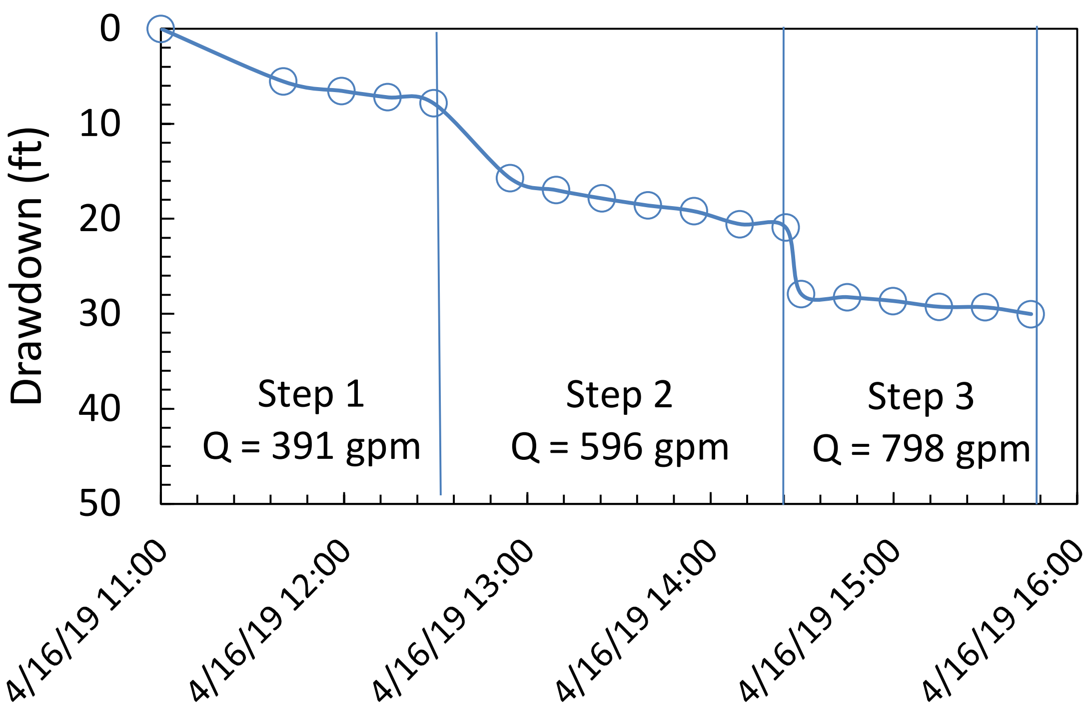


Figure 8: Drawdown in Flowing Well TW-W During Step Testing

TW-W was tested for a 24-hour period after the step testing was completed. Drawdown for both the step tests and the longer-term test at TW-W is shown in **Figure 9**.

Summary data for testing at TW-W was collected as shown in **Table 7.**

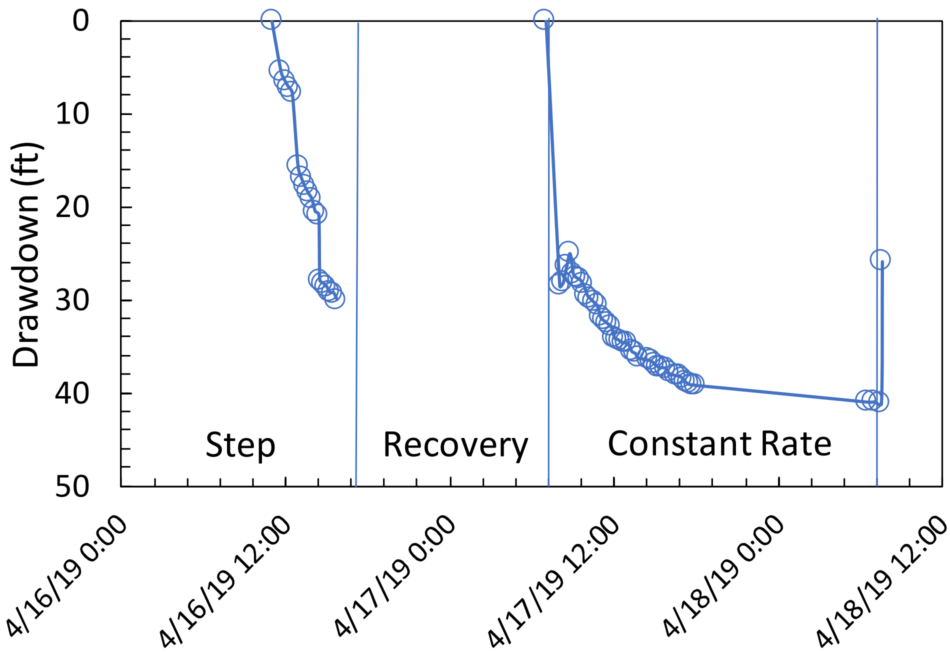


Figure 9: Drawdown Observed at TW-W During Flowing Test at TW-W

Table 7: TW-W Flowing Test Summary

***Note:** Groundwater level was recorded at the start and end of each respective test and the difference between them is shown as "(ΔH)". A rise in groundwater levels before and after the testing is shown by a positive value, and a decline in groundwater elevation is shown with a negative value.

ID	Step 1			Step 2			Step 3			Constant Rate		
	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)	Start	End	ΔH (ft)
	4/16/2019 11:01:00 AM	4/16/2019 12:30:00 PM		4/16/2019 12:55:00 PM	4/16/2019 2:25:00 PM		4/16/2019 2:30:00 PM	4/16/2019 3:45:00 PM		4/17/2019 8:00:00 AM	4/18/2019 7:30:00 AM	
TW-W	46	38.16	-7.84	30.28	25.09	-5.19	18.09	15.97	-2.12	43.22	4.89	-38.33
MW-5(Shallow)	6.57	6.34	-0.23	6.83	6.73	-0.1	6.46	6.48	0.02	5.84	6	0.16
MW-5(Deep)	53.15	53.17	0.02	53.16	53.13	-0.03	53.12	53.06	-0.06	52.41	47.97	-4.44
PPG	0.2	0.2	0	0.2	0.2	0	0.2	0.2	0	0.19	0.19	0
Bartlett	0.33	0.33	0	0.32	0.33	0.01	0.33	0.34	0.01	0.33	0.32	-0.01
TW-E	52.74	53.32	0.58	53.3	53.66	0.36	53.67	54.32	0.65	54.65	53.74	-0.91
T348	7.72	7.7	-0.02	7.71	7.71	0	7.74	7.74	0	7.8	7.82	0.02
T896	53.85	53.85	0	53.85	53.83	-0.02	53.83	53.8	-0.03	53.8	53.79	-0.01
T897	56.48	56.42	-0.06	56.47	56.56	0.09	56.56	56.83	0.27	56.67	56.52	-0.15
T898	46.93	46.92	-0.01	46.91	46.92	0.01	46.92	46.93	0.01	46.96	46.94	-0.02
T902	0.61	0.62	0.01	0.62	0.56	-0.06	0.56	0.56	0	0.42	0.71	0.29
T903	3.35	3.36	0.01	3.36	3.35	-0.01	3.35	3.29	-0.06	3.18	3.2	0.02
T904	1.88	1.89	0.01	1.9	1.85	-0.05	1.84	1.84	0	1.87	1.95	0.08
DeltaW(3)_4ft	3.171	3.14	-0.031	3.14	3.171	0.031	3.171	3.14	-0.031	3.186	3.233	0.047
DeltaW(3)_10ft	3.157	3.157	0	3.157	3.173	0.016	3.173	3.142	-0.031	3.188	3.188	0
T918	21.58	21.59	0.01	21.591	21.593	0.002	21.593	21.56	-0.033	21.43	21.53	0.1
T919	18.9	18.9	0	18.9	18.89	-0.01	18.89	18.93	0.04	18.93	18.93	0
T931	15.278	15.294	0.016	15.315	15.281	-0.034	15.282	15.236	-0.046	15.1	15.2	0.1

Similar to the testing at TW-E, groundwater elevations rose in some locations during the testing of TW-W, while others had changes in groundwater levels that were ascribed to diurnal changes in barometric pressure, earth tides, evapotranspiration, and/or measurement error, based on detailed review of the hydrographs (Appendix A). **Table 8** summarizes significant confirmed declines in groundwater elevations during the testing of TW-W. Well T902 contains a question mark because of the relatively low potential drawdown observed and the ambiguous pattern of drawdown.

Table 8: Summary of Significant or Drawdown During Testing at TW-W

Well Name	Observed Drawdown (feet)
TW-W (pumping well)	38.33
MW-5 (Deep)	4.44
T902	0.29 (?)

Again, as with testing at TW-E, it is particularly noteworthy that there was no significant drawdown observed at all shallow well locations, such as the piezometers surrounding the lake and other adjacent monitoring wells. The geographic distribution of changes in groundwater elevations is shown in **Figure 10**.

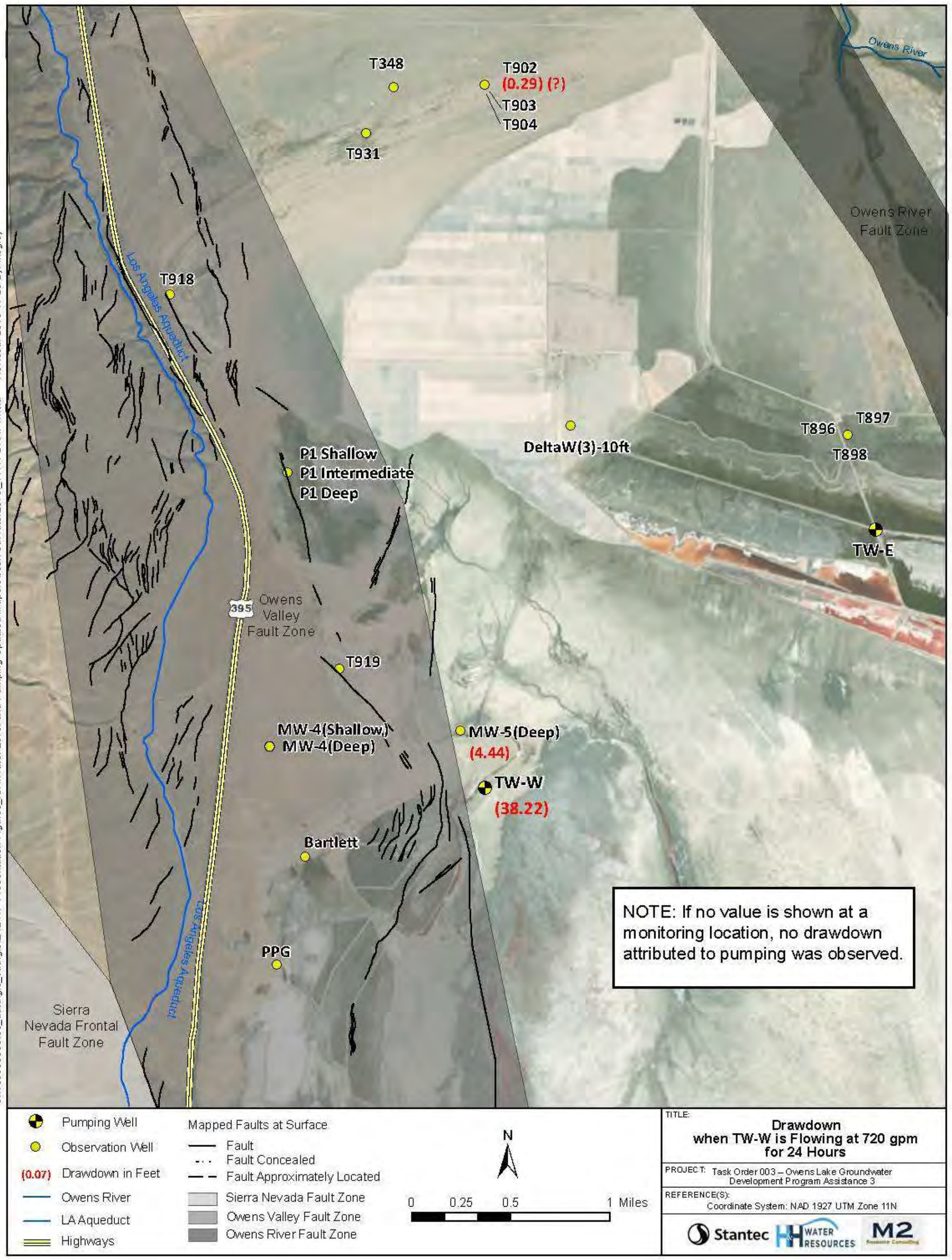


Figure 10: Drawdown when TW-W is Flowing at 720 gpm for 24 Hours

5.0 ANALYSIS OF TESTING

The primary reason for aquifer testing is to improve the understanding of the aquifer properties and to gain the ability to predict the response of the aquifer when pumped at different rates or durations. Of particular importance is the observation of drawdown at a variety of locations (observation wells) near the pumping well. Generally speaking, groundwater drawdown near a pumping well in a confined aquifer is greatest near the well, decreasing rapidly with distance from the well. However, the situation at Owens Lake is complicated by the fact that the testing wells produce water from confined aquifers which are separated from shallow wells by thick sequences of clays and silt. This means that although drawdown in a confined aquifer may be observable at depth, shallow monitoring wells may have little or no drawdown. This concept is shown schematically in **Figure 11**.

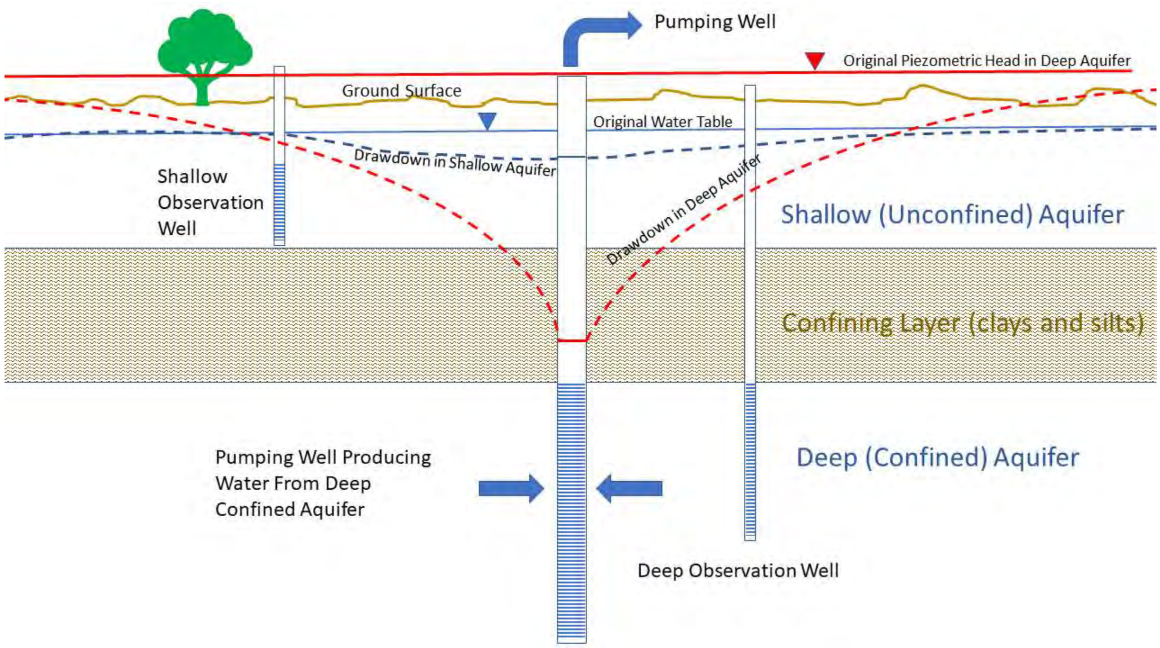


Figure 11: Schematic Depiction of Drawdown in a Shallow Unconfined Aquifer during Pumping of a Deep Confined Aquifer

Whereas drawdown in a confined aquifer may be significant as measured by observation wells in the confined aquifer itself, drawdown in the shallow aquifer due to pumping in the deep aquifer is muted or absent during short term testing. This is apparently the case with testing of TW-E and TW-W in that significant drawdown was observed typically only in deeper wells, such as wells MW-5 (deep), T897, and T896, all of which are deep wells completed in the deeper aquifer. Observations of data at MW-5 during testing of TW-W, where monitoring wells are competed in both deep and shallow zones at the same location illustrate this point. Whereas a clear drawdown effect is noted in the deep aquifer, there is no significant effect in the shallow aquifer (Appendix A).

Table 9 provides a summary of the step drawdown and constant rate pumping test results at Well TW-E and the step-drawdown and constant rate flowing tests at TW-W. Average drawdowns are used to accommodate minor variations in groundwater levels due to variable pumping rates reported during testing.

Table 9: Summary of Pumping/Flowing Tests at TW-E and TW-W

Test Well	Test Type	Discharge Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
TW-E	Step-Drawdown 1	402	53.60	7.50
	Step-Drawdown 2	599	107.42	5.58
	Step-Drawdown 3	824	172.68	4.77
	Constant Pumping Rate	860	164.12	5.24
TW-W	Step-Drawdown 1	391	7.84	49.87
	Step-Drawdown 2	596	20.91	28.50
	Step-Drawdown 3	798	30.03	26.57
	Constant Flow Rate	720	38.33	18.78

Preliminary results of the step-drawdown test data indicate well specific capacity ranged between 4.77 and 7.50 gpm/ft at TW-E and between 49.87 and 26.57 gpm/ft at TW-W. Likewise, preliminary results of the constant rate pumping test at TW-E and constant rate flowing test at TW-W indicated well specific capacity was 5.24 gpm/ft and 18.78 gpm/ft, respectively.

Drawdown data from the testing wells was utilized to evaluate aquifer properties using the specialized software AQTESOLV authored by HydroSOLVE, Inc. of Reston, Virginia. Results of these analysis are given in Appendix B. The AQTESOLV evaluation indicates an aquifer transmissivity of 515 ft^2/day at TW-E and 4,994 ft^2/day at TW-W. Calculated storage coefficients for TW-E and TW-W are 0.037 and 0.002, respectively.

6.0 COMPARISON TO PREVIOUS TESTING

Pumping tests of wells at or near the lake have been performed by LADWP on the "River" site (both shallow and deep wells) as well as the South Flood Irrigation Project (SFIP) Well in 2011 and 2012. These tests are described below. Graphics of this test are included in Appendix C.

The River (deep) well was pumped at an average rate of 1,335 gpm for a period of approximately 1 month in December of 2011 through January of 2012. During this test, wells that existed at that time were monitored for drawdown. Declines in groundwater levels during this test were only observed (other than the pumping well) in wells T348, T903, Down Valley (deep and intermediate), and the River monitoring well adjacent to the test well. While the adjacent River monitoring well showed a drawdown of approximately 38 feet, the only other monitoring wells that showed observable drawdown were wells T348 and T903 (both having approximately 1.25 feet of drawdown) and the Down Valley deep and intermediate wells (both approximately 2.5 feet of drawdown). No other wells showed drawdown due to the testing.

The River (shallow) well was also pumped for a period of approximately 1 month in February and March of 2012 at an average rate of 2,156 gpm. During this test, declines in groundwater levels were documented in wells T898 (approximately 6.5 feet), T892 (approximately 3.1 feet), Down Valley South and North (both approximately 1.5 feet), T904 (7.5 feet), and the shallow River Monitoring Well (approximately 38 feet). No other wells showed drawdown due to testing.

The SFIP Well was pumped for a period of approximately two weeks in June and July of 2012 at an average pumping rate of 1,000 gpm. During this test, drawdown was observed in the adjacent SFIP monitoring well (approximately 42.5 feet), T915 (approximately 21 feet), and a barely observable 0.25 feet in Well OL-92. No other wells showed drawdown due to testing.

Both of these tests, while valuable for localized model calibration of both deep and shallow aquifers, did not show widespread drawdown desired for understanding of long-term pumping. Drawdown in these cases was localized in the vicinity of the pumping wells.

The current focus of investigation is the norther area of Owens Lake between Owens River and Owens Valley Fault Zones. Future wells are anticipated to be located between these two fault zones in order to minimize potential impacts on sensitive resources, which are located across these faults. Well TW-E is a prime candidate for long-term testing because it is located between the Owens River and Owens Valley Fault Zones. The SFIP well is too far south to be utilized for testing this area.

7.0 CONCLUSIONS AND RECOMMENDATIONS

One of the primary reasons for constructing the testing wells is to observe the effects of pumping and to further develop resource protection protocols (RPPs) for pumping and improve the groundwater model of the lake. The groundwater model of Owens Lake is an essential tool for groundwater management and development of pumping scenarios. The original groundwater model developed during the 2009 to 2012 time period has been recently updated and improved to incorporate new hydrologic data and to improve the accuracy of the model.

The results of the testing at TW-E and TW-W have also been utilized to improve the model by adjusting aquifer parameters such that the model replicates the drawdown observed in the pumping well and the few observation wells that showed influence of the testing. Unfortunately, a response to testing was not observed in the majority of observation wells because of the relatively low pumping rate and duration. Although the model replicates this behavior, opportunities to improve the model based on the testing observations at a variety of locations are limited because drawdown was not observed at most monitoring locations.

Similarly, the testing of the River and SFIP wells in the 2011-12 time frame do not provide the needed hydrogeologic information because observed drawdown was limited to the areas adjacent to the wells, and the shallow monitoring facilities associated with RPPs were not in place at that time. TW-E represents an ideal well for long-term testing because it is located in between the Owens Valley and Owens River Fault Zone where future groundwater pumping is anticipated.

Another key goal of testing of TW-E and TW-W is to observe drawdown in either side of the major fault zones (Owens Valley and Owens River Fault Zones). Again, testing was not conducted at a high enough rate or for a long enough duration to observe differential drawdown across fault zones. The degree to which these fault zones act as groundwater barriers is a significant data gap that is most accurately resolved by long-term aquifer testing.

It is therefore recommended that longer term testing be performed on one or both wells. As a conservative measure, it is recommended that longer term pumping initially involve only one of the wells. Testing of TW-E is recommended in order to observe the effects of local fault zones, and because the relatively low production at this location is more conservative. A duration of 6 months during or slightly before the dust season is recommended in order to mimic conditions under which the well might eventually be used.

During this testing, it is essential to carefully observe drawdown effects in monitoring locations similar to the shorter-term test. Appendix D describes the recommended monitoring (locations and frequency) during the 6-month test. Utilization of the hydrologic RPPs as developed with the Groundwater Working Group will also be essential to ensure that resources are protected during the longer-term test. These locations are included in the monitoring plan.

In order to predict the impacts of testing, the improved groundwater model was utilized to simulate four (4) long-term (6-month) pumping test alternatives at TW-E at continuous rates of 899, 1,200, 1,600, and 3,600 gallons per minute.

The hydrologic RPPs involve evaluation of the groundwater gradient toward springs and seeps that provide sensitive habitat. These RPPs involve observation of a set of two wells to document the gradient between them. For example, the difference between shallow piezometer P2 Lower (30 foot depth) and P2 Upper (4 foot depth) located next to each other indicates an upward vertical gradient. The horizontal gradient toward the springs and seeps is observed by noting the groundwater elevation on wells located on the alluvial fans, and shallow piezometers located near springs and seeps (for example, the gradient between monitoring well T922 and P2 Upper). In general, the initial "early warning" management tier is a 50% reduction in gradient either vertically or horizontally to the springs and seeps.

The potential effect on the gradient toward the springs and seeps was evaluated using the groundwater model of Owens Lake. **Table 10** summarizes the simulated gradient change when TW-E is pumped at various rates for a period of 6 months. Note that not all RPP gradient monitoring wells are listed in **Table 10**. The simulated gradient change among the remaining pairs of RPP gradient monitoring wells is zero for all four simulated pumping rates.

For example**, Table 10** indicates that when TW-E is pumped at a flow rate of 1,200 gpm for 6 months, the simulated gradient change between T920 and T919 is a reduction of 0.23 percent. Even when TW-E is pumped at 3,600 gpm for 6 months, the maximum gradient change is less than 1percent (0.86%) between T920 and T919. These results suggest that the first RPP tier of a 50% reduction in gradient toward the springs and seeps will not be approached during 6-month testing of TW-E, even if it is pumped at a rate of 3,600 gpm. In practice however, the diameter of the well and the design of a pump may limit the production rate to less than this amount.

Table 10: Simulated Gradient Change at RPP Gradient Monitoring Wells at Various Pumping Rates When TW-E is Pumped for A Period of 6 Months

RPP Gradient Monitoring Wells		Simulated Gradient Change (-)			
Up Gradient	**Down Gradient**	**800 gpm**	**1,200 gpm**	**1,600 gpm**	**3,600 gpm**
P2 Lower	P2 Upper	0.00%	-0.03%	-0.04%	-0.07%
P6 Lower	P6 Upper	-0.06%	-0.14%	-0.22%	-0.66%
P7 Lower	P7 Upper	0.00%	0.00%	0.00%	0.00%
T920	T919	-0.10%	-0.23%	-0.32%	-0.86%
T922	P2 Upper	-0.01%	-0.03%	-0.03%	-0.06%
T923	P3 Upper	-0.02%	-0.04%	-0.04%	-0.05%
T928	P6U	-0.04%	-0.11%	-0.16%	-0.55%

Simulated groundwater level drawdown at non-LADWP wells is summarized in **Table 11**. The simulation results show that the maximum drawdown at Boulder Creek RV Park well is less than 1 (0.799) foot, when TW-E is pumped at a flow rate of 3,600 gpm for 6 months.

Even though pumping TW-E at a rate of 3,600 gallons per minute for a period of 6 months is not projected to violate any of the RPPs, a lower rate is recommended as a conservative measure, and because of practical limitation of the size of pump that can be installed. Based on analysis of pumping test data and computer simulations, a pumping rate greater than 1,200 gpm is recommended in order to observe response in more geographic locations than occurred in the 24-hour testing, but not to exceed 2,000 gpm to be conservative in protecting sensitive resources.

Although the groundwater modeling indicates that critical resources will not be significantly affected during the testing, strict adherence to the triggers and management actions described in the RPPs that would initiate management actions such as stopping or reducing pumping is also imperative. Of key importance is the observation of drawdown and/or significant decline in gradient toward the spring and seeps surrounding the lake and observation of drawdown across major fault zones. This is expected to greatly improve the conceptual model of the hydrogeology of the lake, which in turn will result in more accurate modeling and better tools to protect sensitive resources.

Table 11: Simulated Groundwater Level Drawdown at Non-LADWP RPP Groundwater Monitoring Wells When TW-E is Pumped at Various Rates for a Period of 6 Months

RPP Groundwater Level Monitoring Well	Simulated Groundwater Level Drawdown (ft)			
	800 gpm	1,200 gpm	1,600 gpm	3,600 gpm
Mt. View Trailer Park	0.035	0.093	0.142	0.307
T858	0.001	0.001	0.001	0.003
Boulder Creek RV Park	0.168	0.328	0.466	0.799
FW Aggregates Well 2	0.003	0.009	0.014	0.043
FTS_Production_Deep_T5	0.034	0.056	0.074	0.124
FTS_Production_Shallow_T6	0.023	0.040	0.053	0.095
Keeler CSD	0.010	0.023	0.034	0.104
Cartago Mutual	0.054	0.080	0.080	0.083
Rio Tinto	0.021	0.036	0.035	0.032
Mortensen	0.095	0.188	0.262	0.737

As an example, **Figure 12** shows model-simulated drawdown and/or gradient change at selected locations after pumping TW-E at a rate of 1,200 gpm for 6 months.

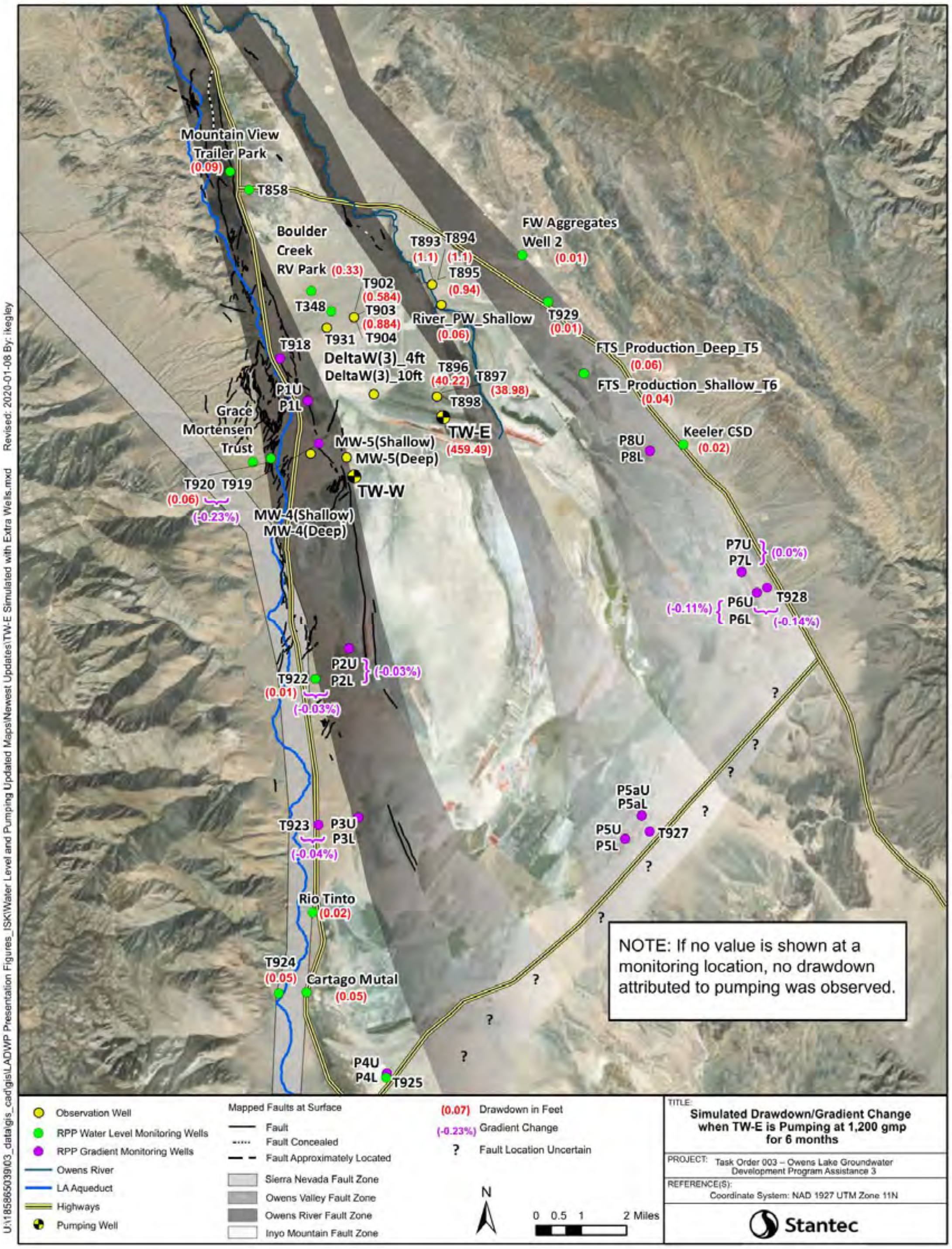


Figure 12: Simulated Drawdown when TW-E is Pumping at 1,200 gpm for 6 Months

8.0 REFERENCES

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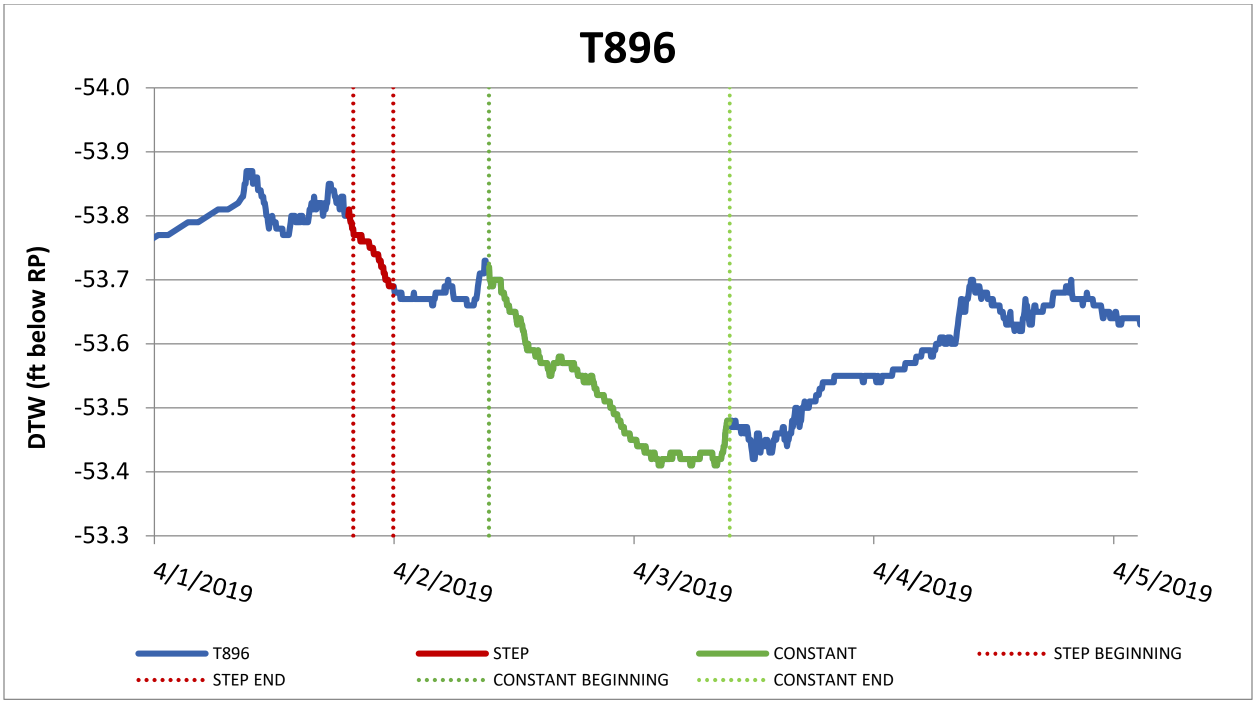
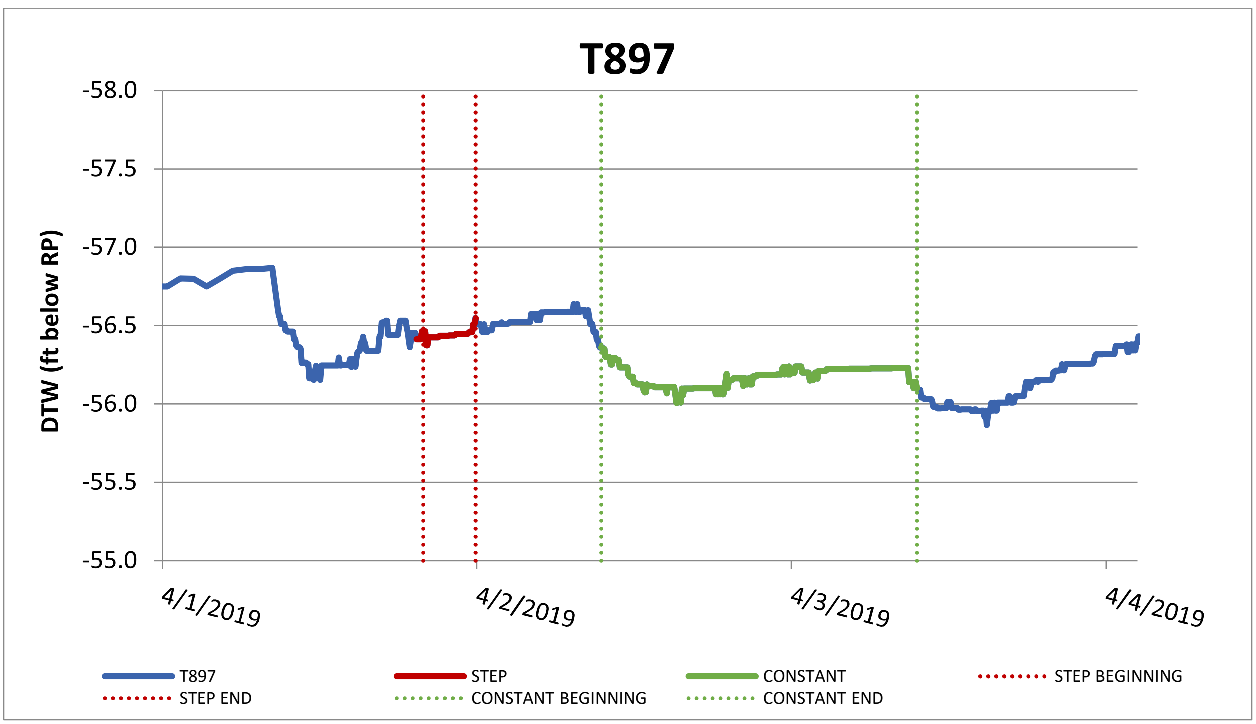
Appendix A – Pumping Test Hydrographs

Hydrographs for TW-E

TW-E Pumping Test

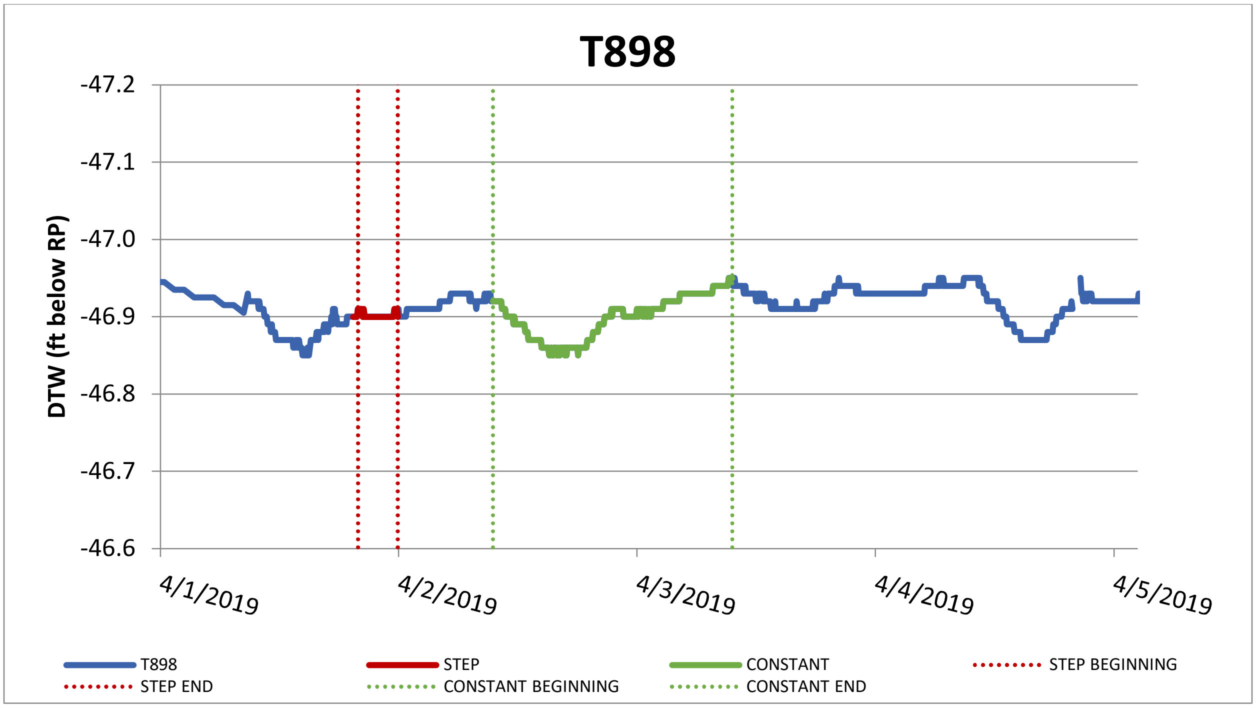


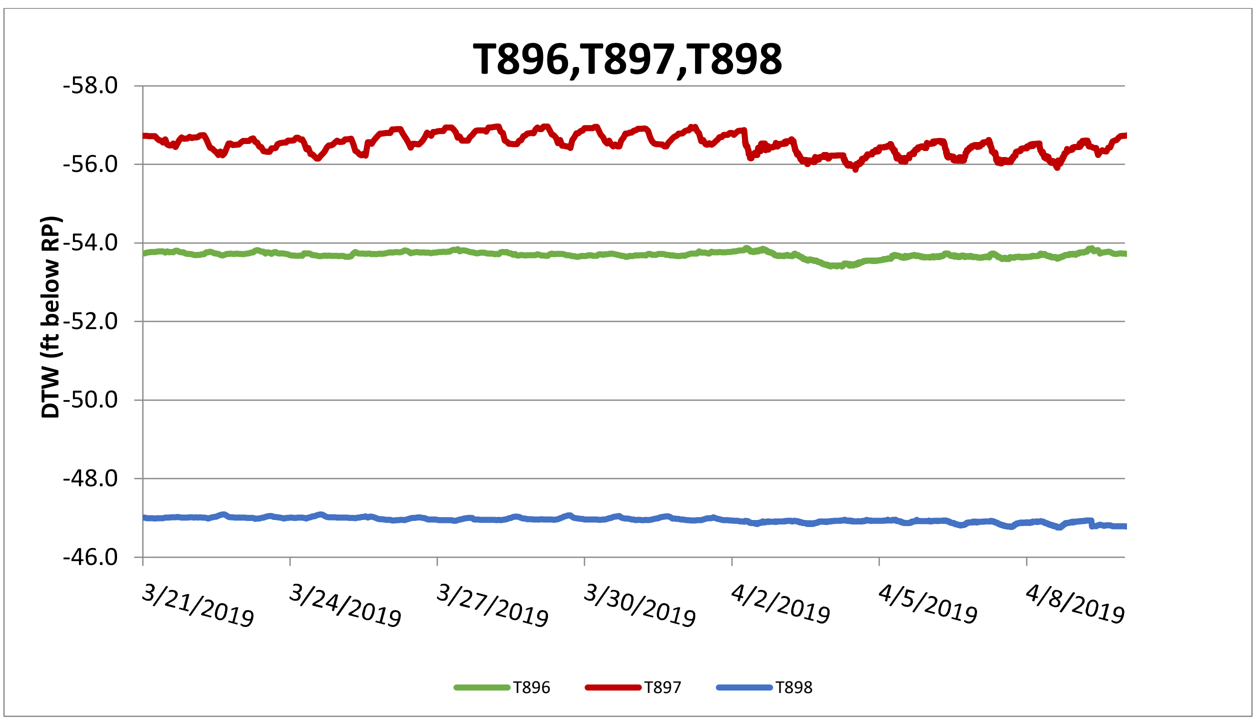


Depth-to-Water (DTW) is defined as groundwater level measurements below Reference Point (RP).

A negative DTW indicates groundwater level measurement above RP.

TW-E Pumping Test





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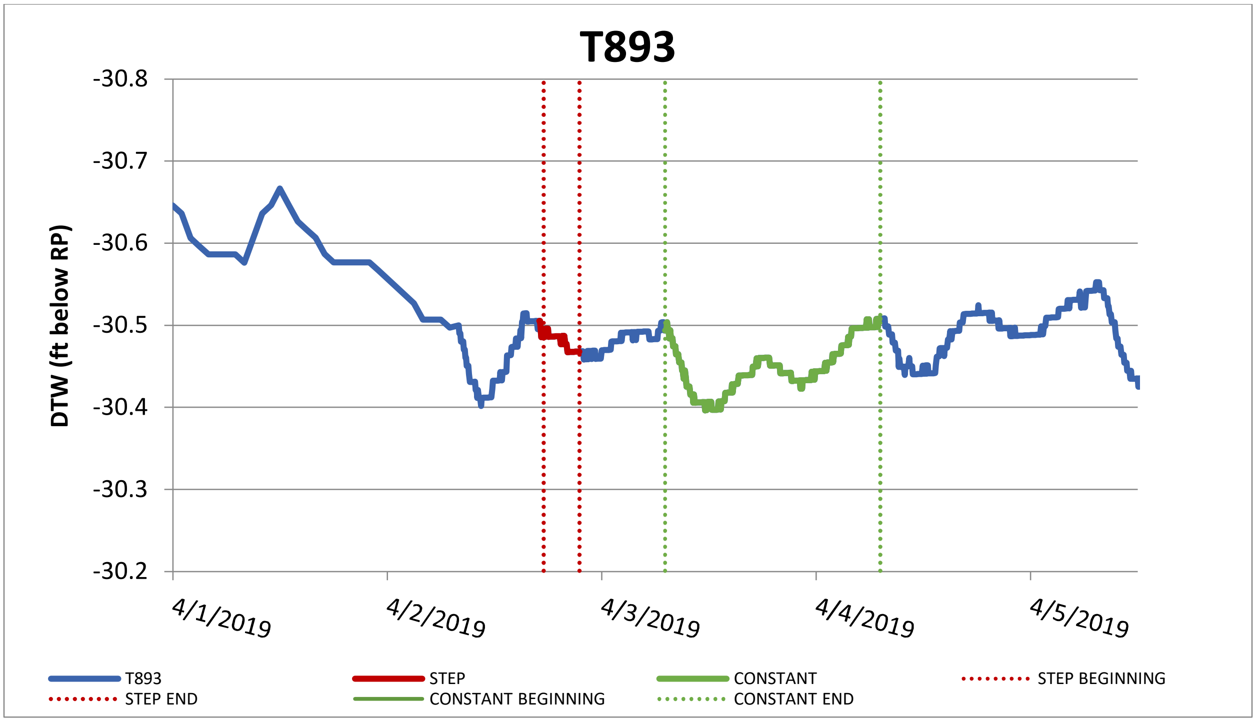
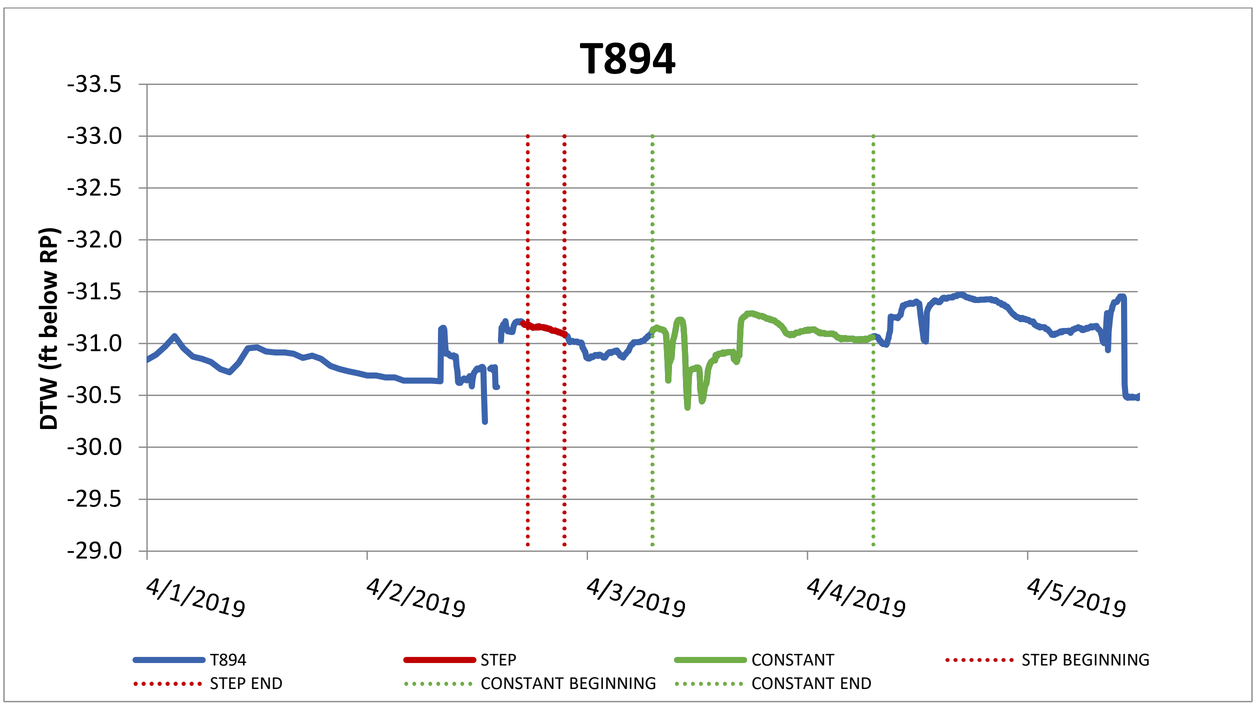
TW-E Pumping Test





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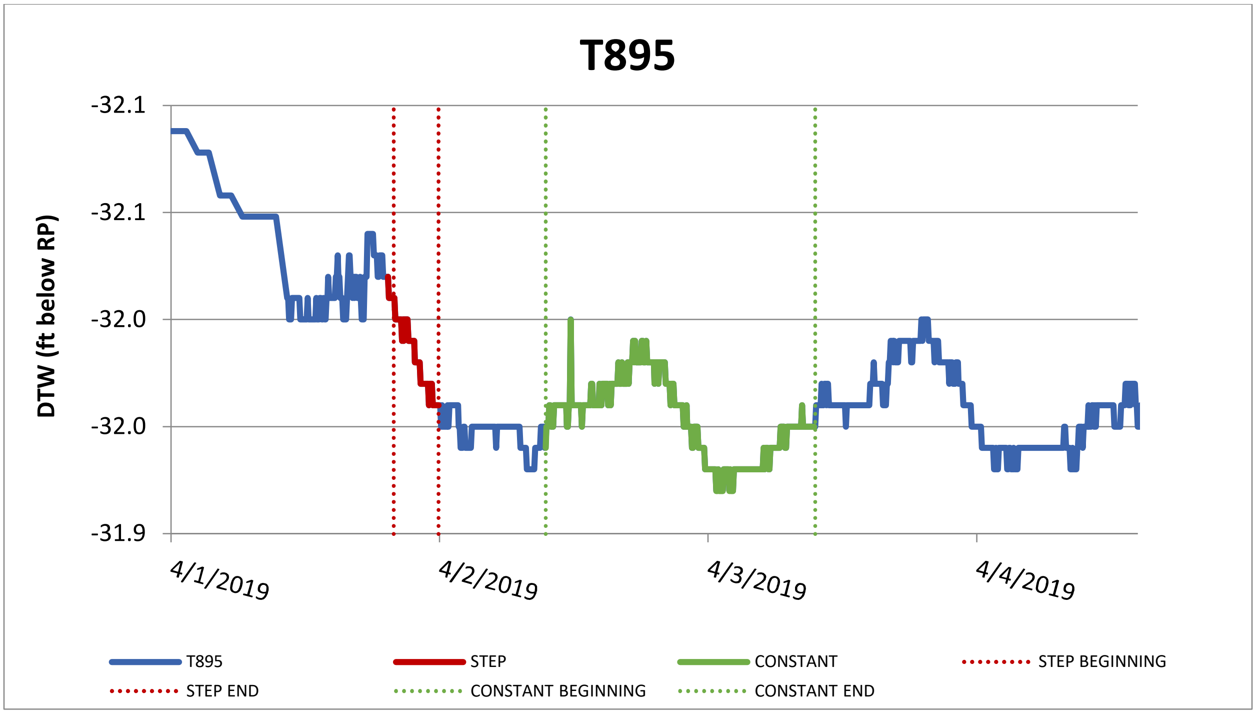

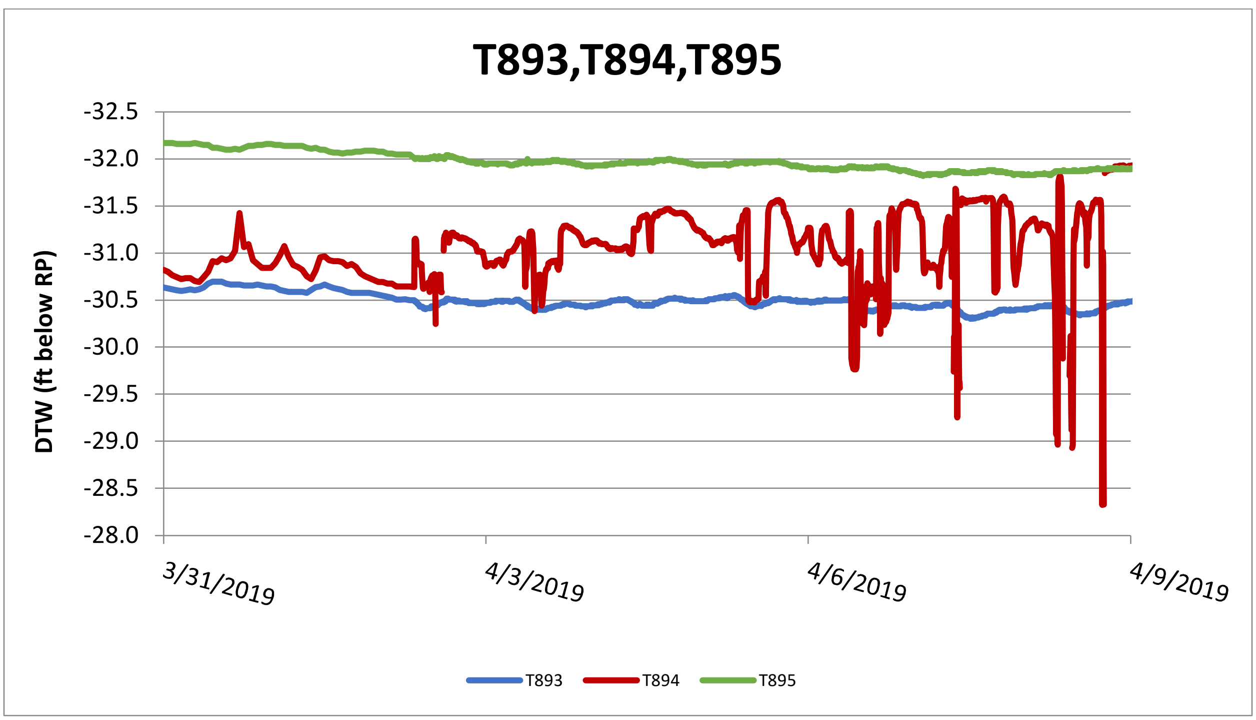

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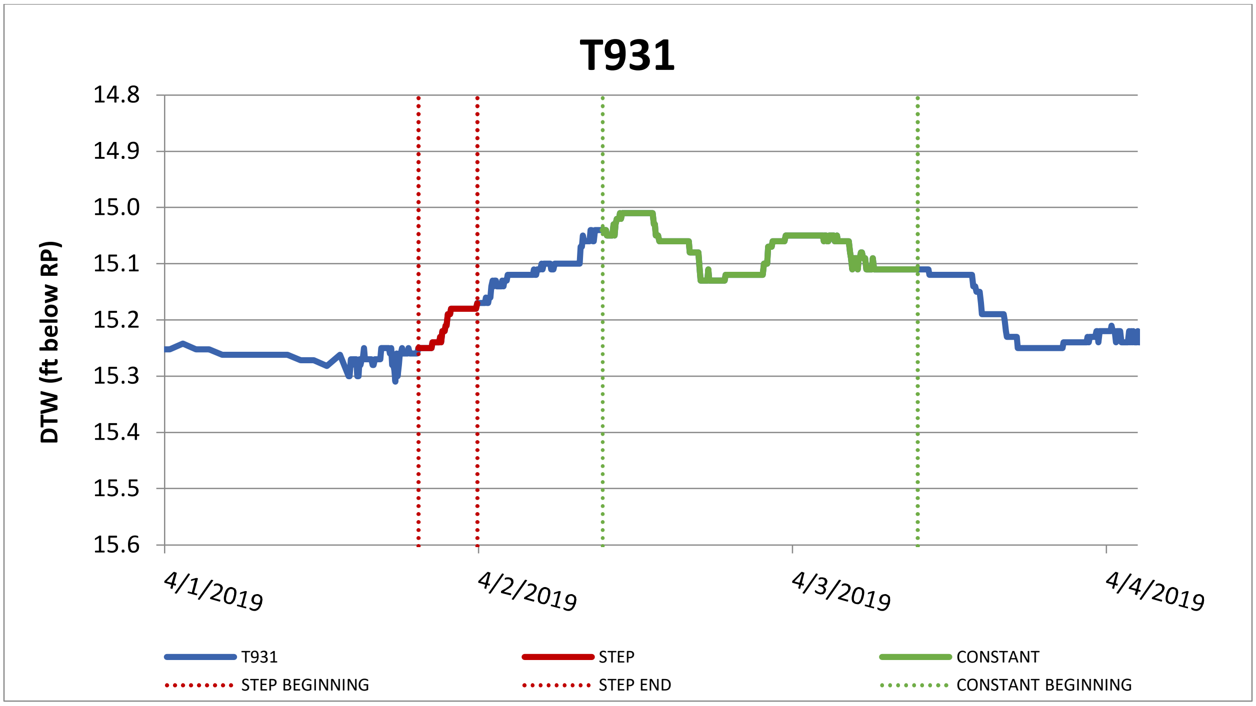

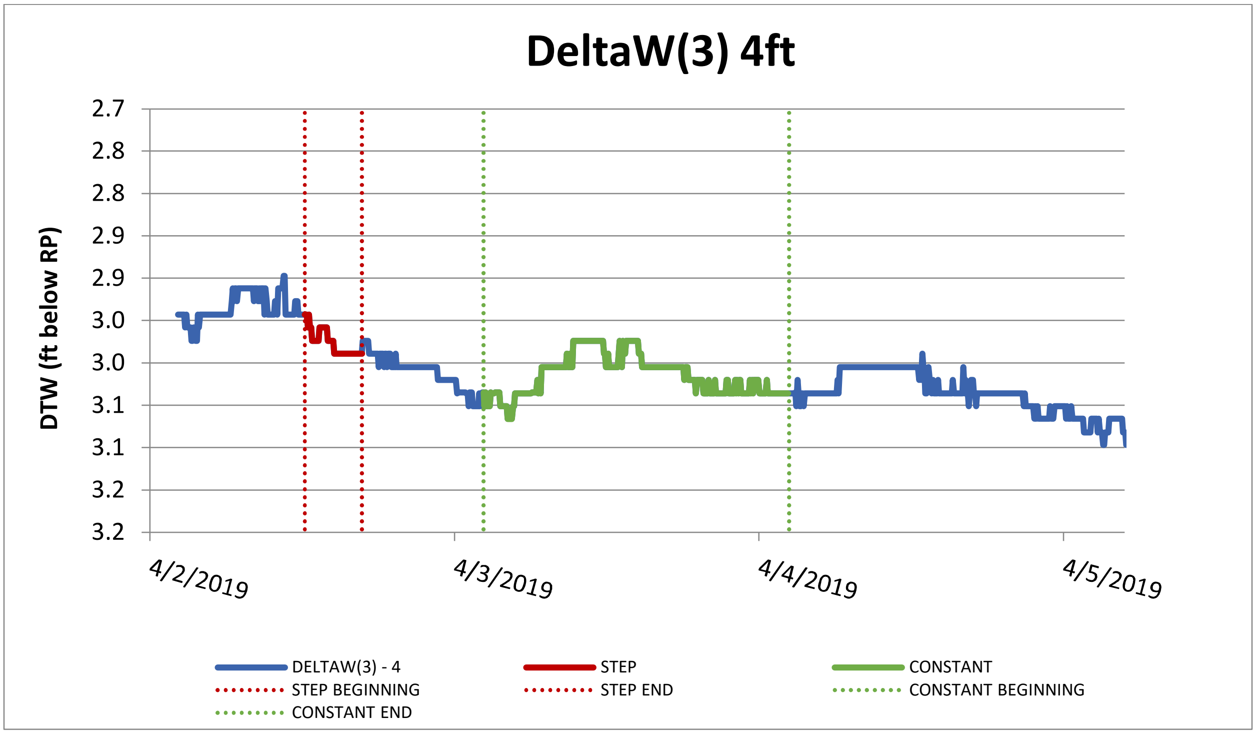

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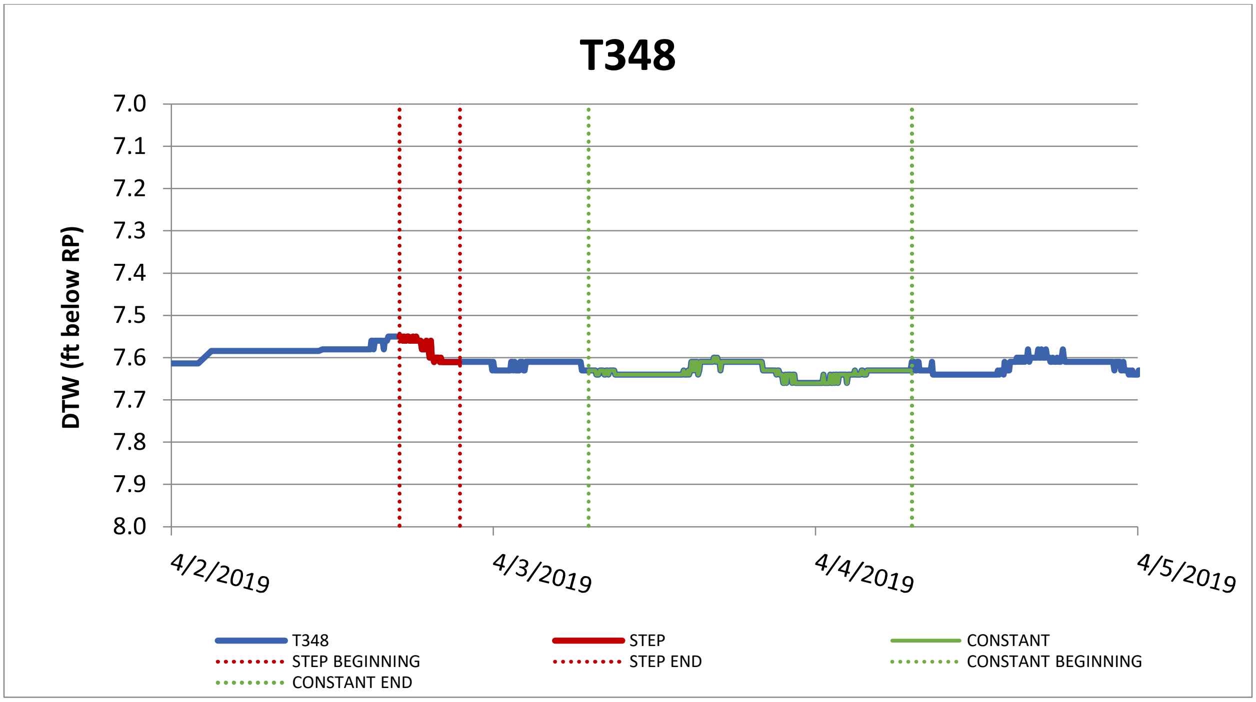
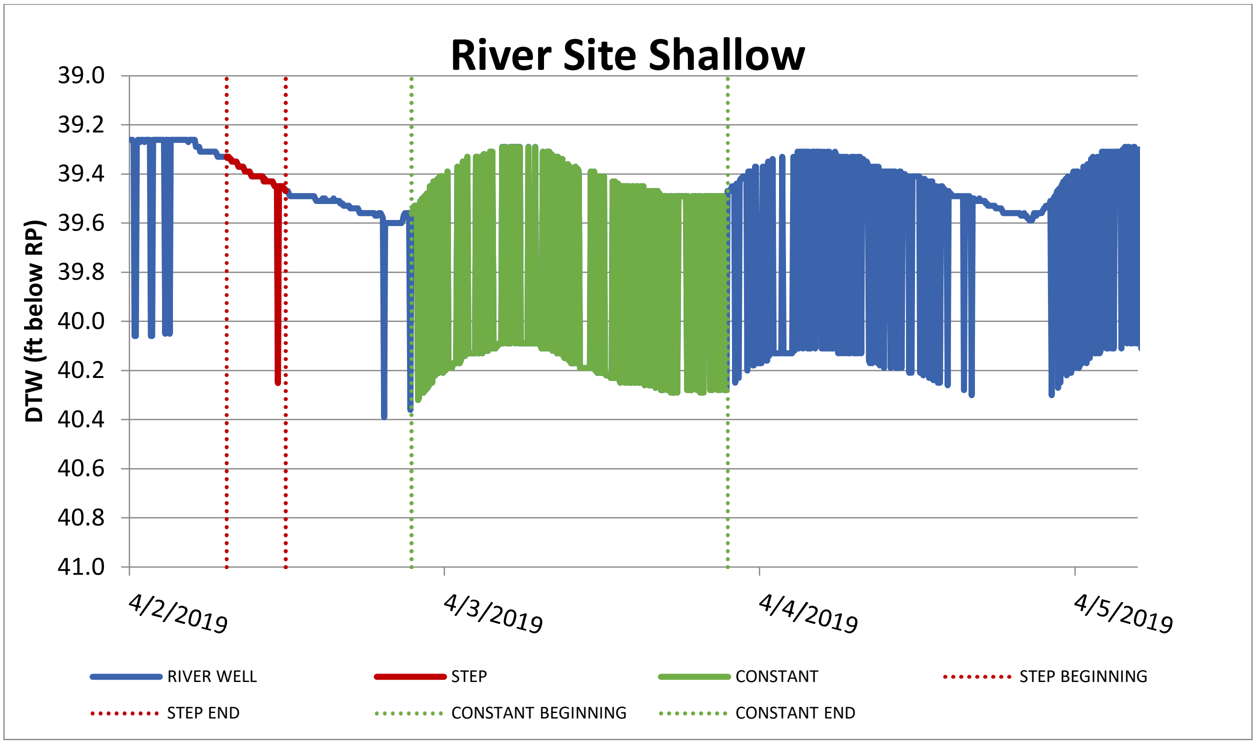
TW-E Pumping Test





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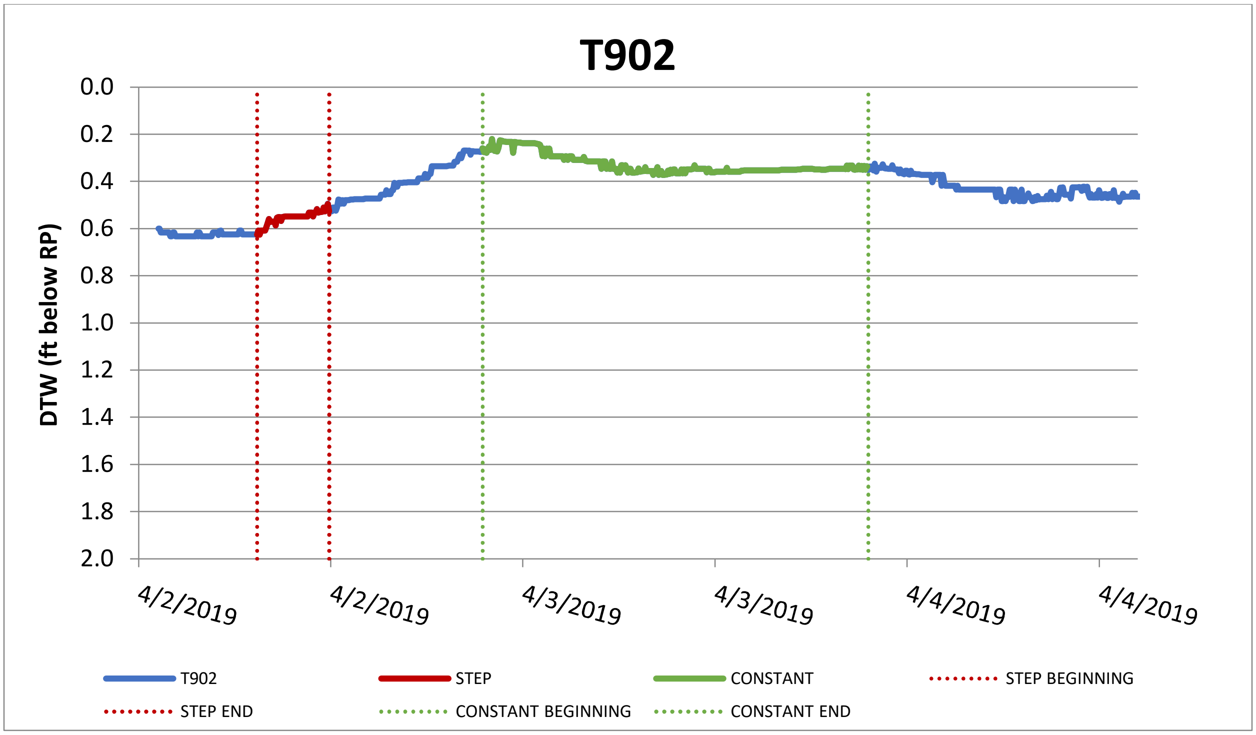

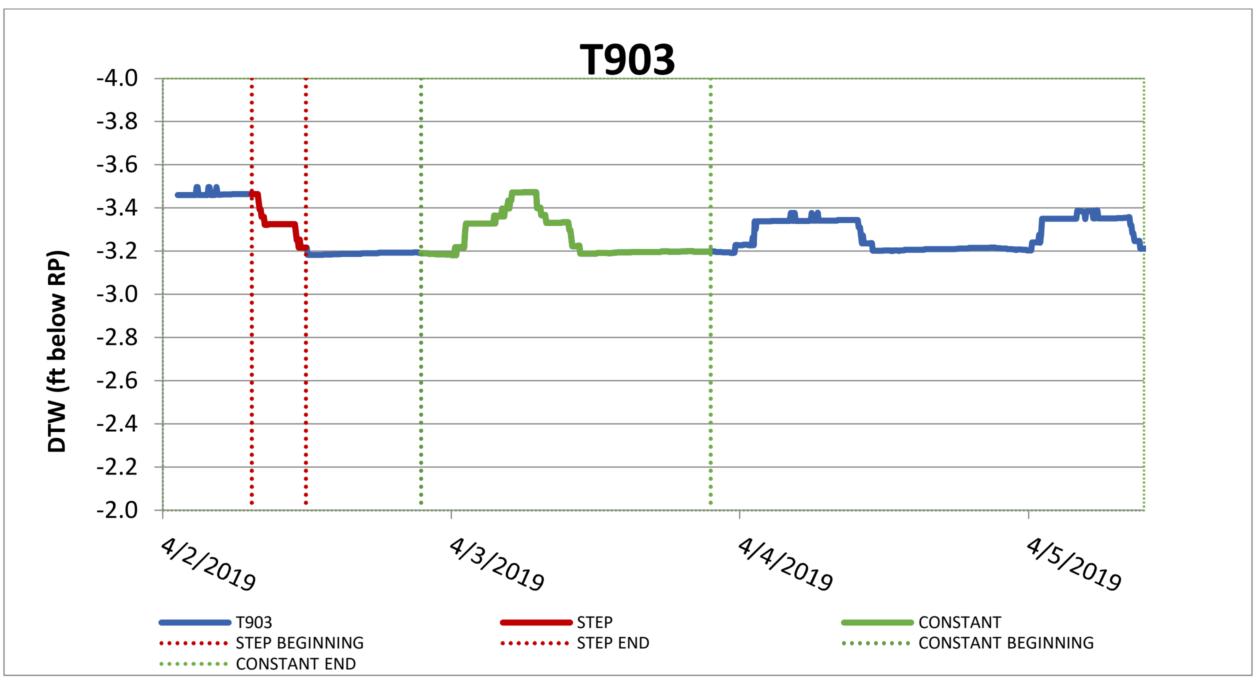

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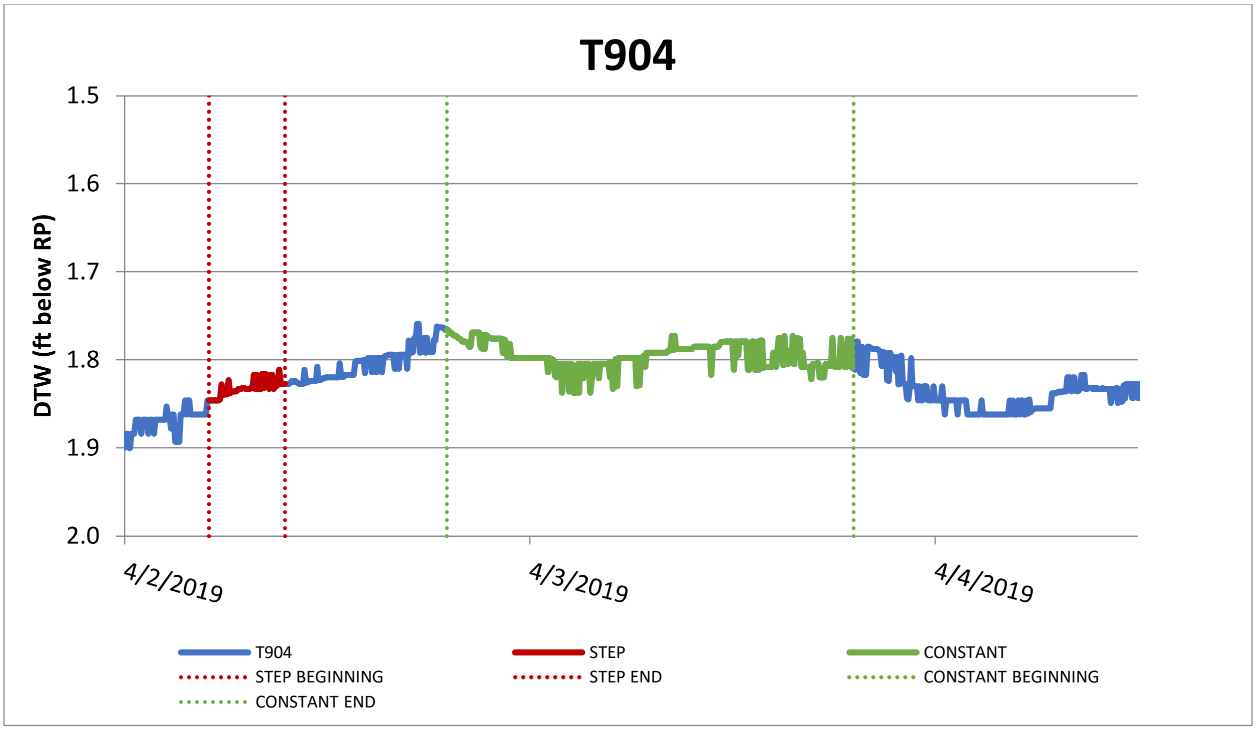

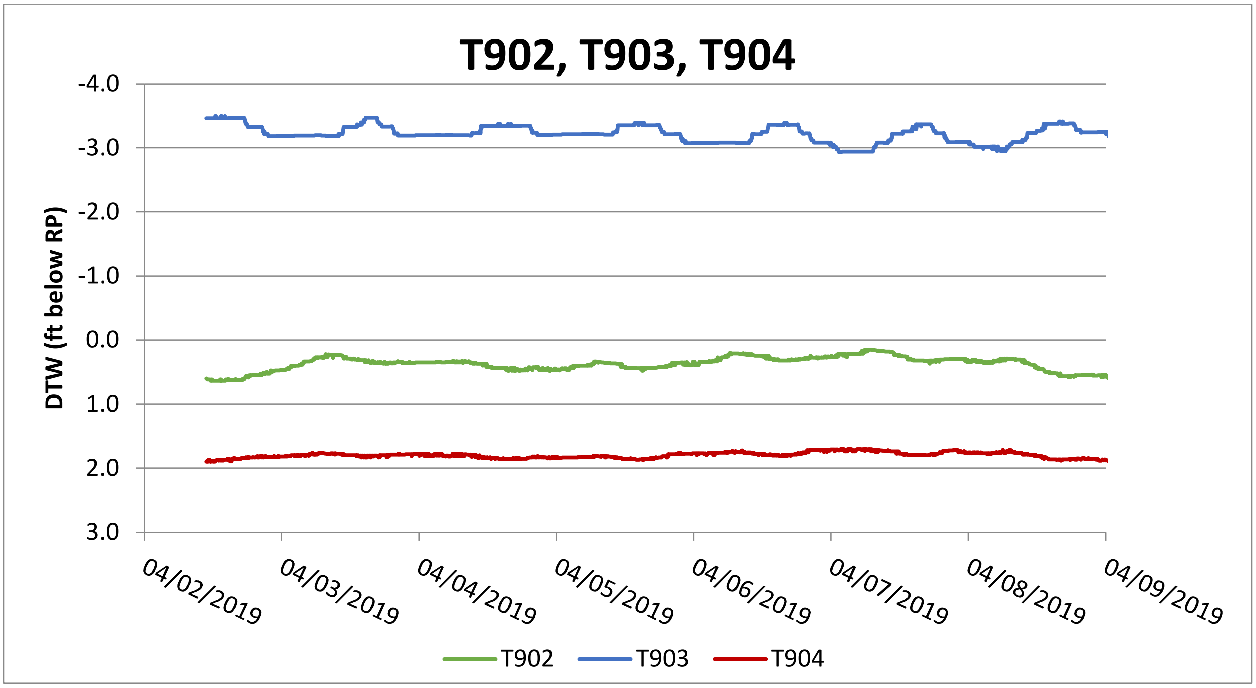

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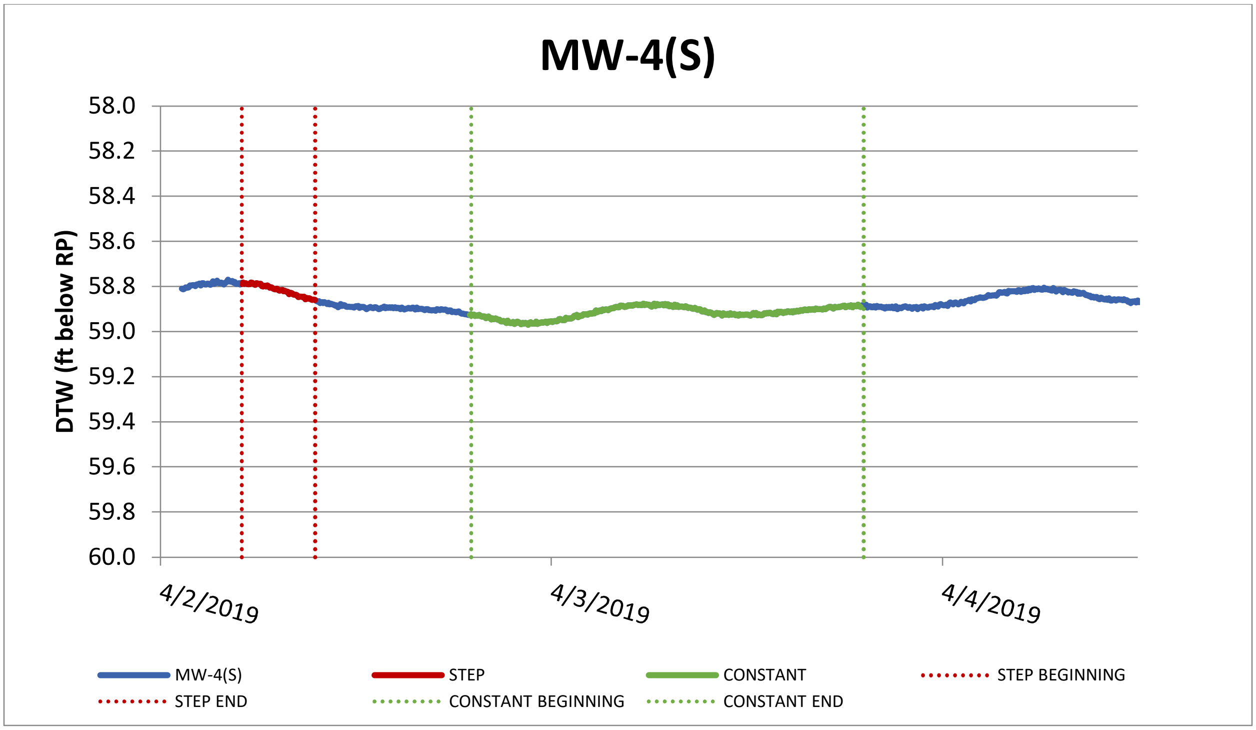

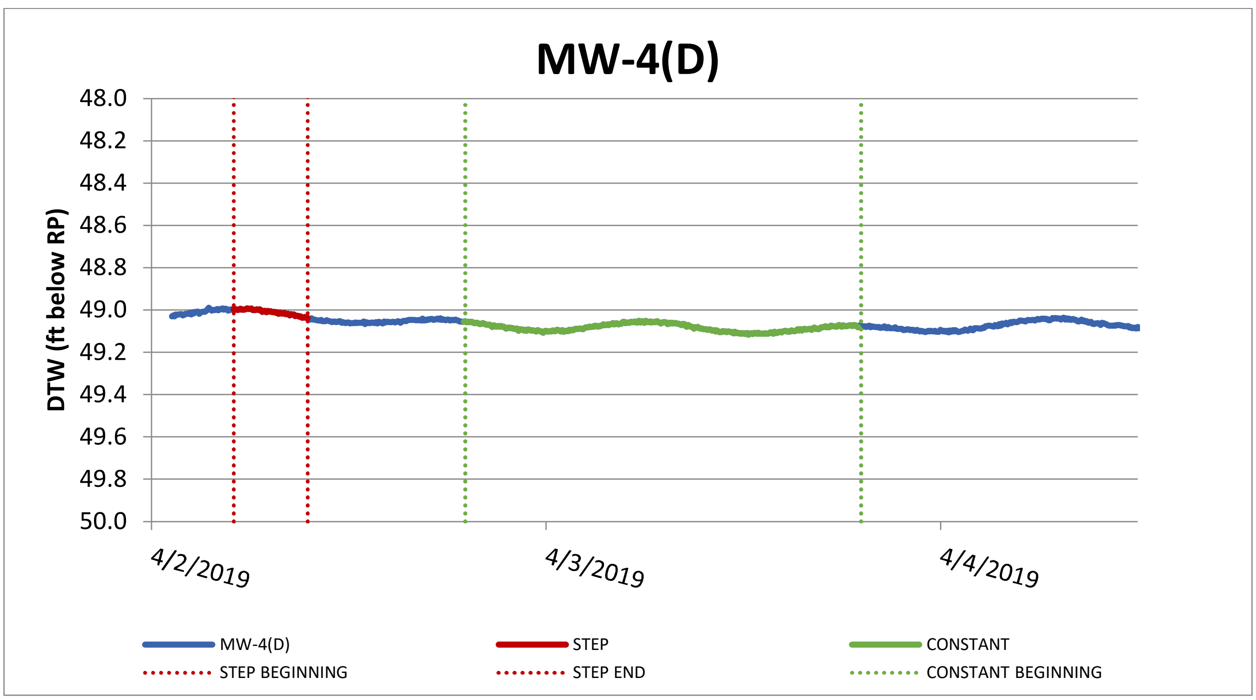

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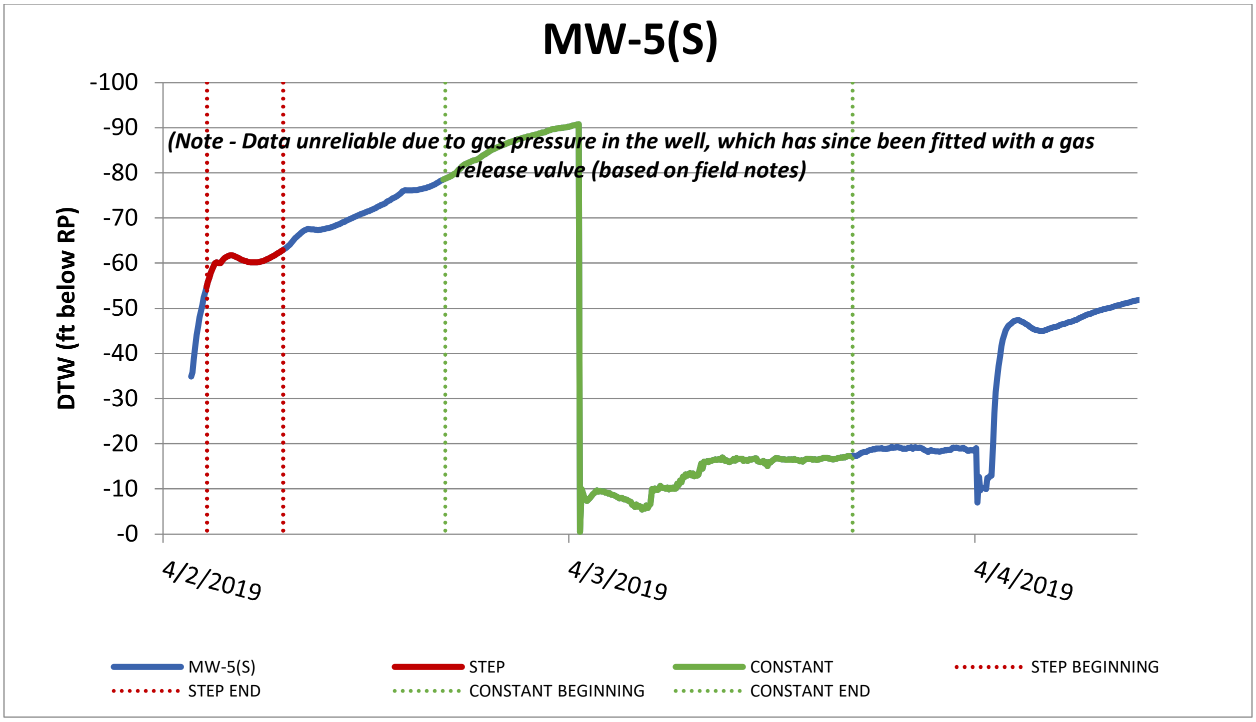

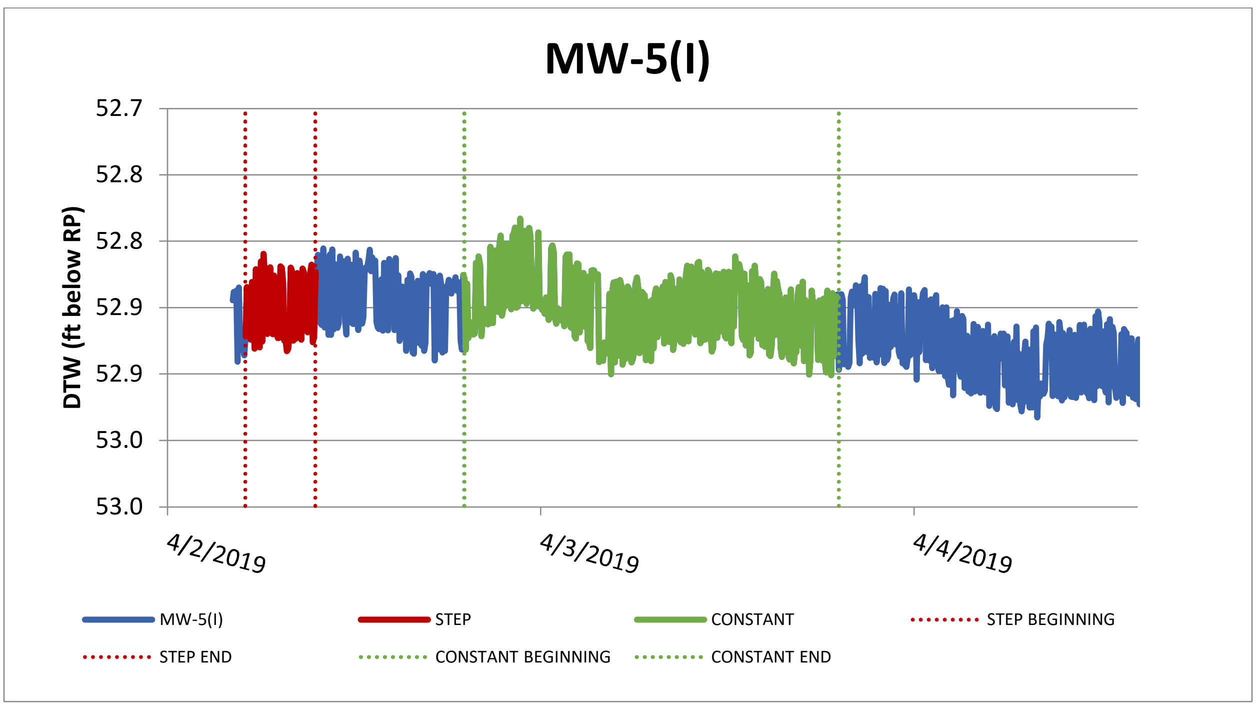

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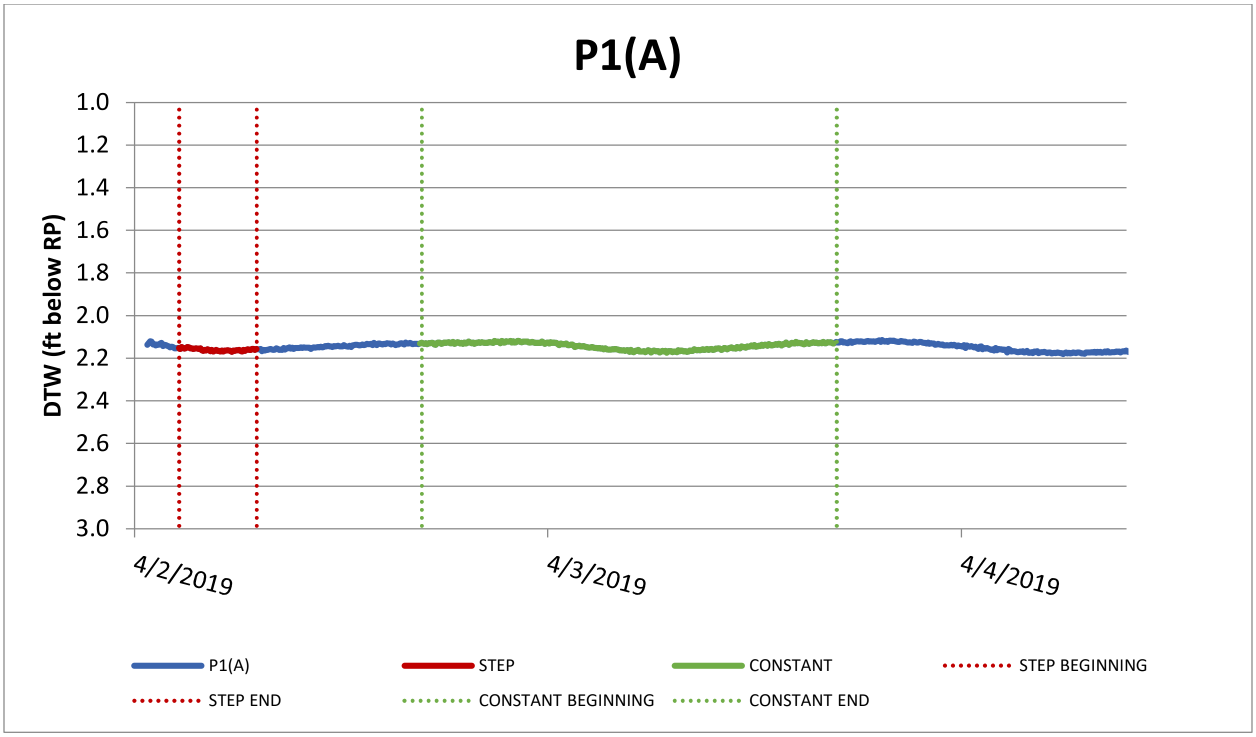

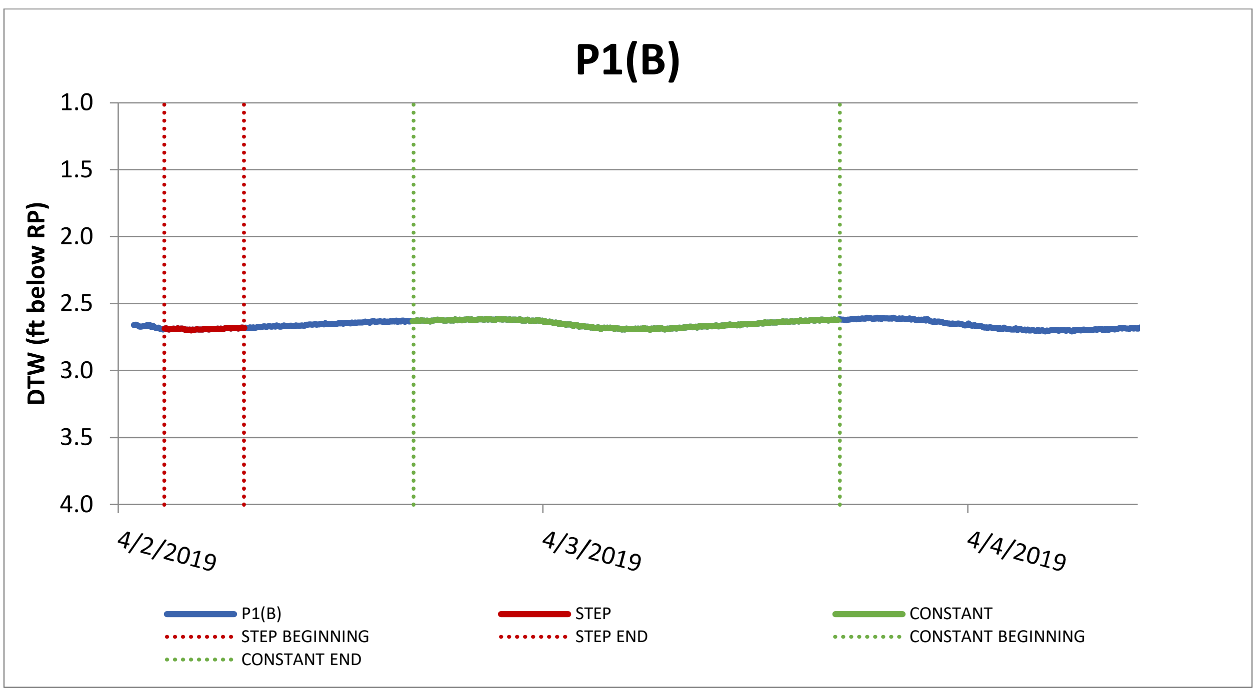

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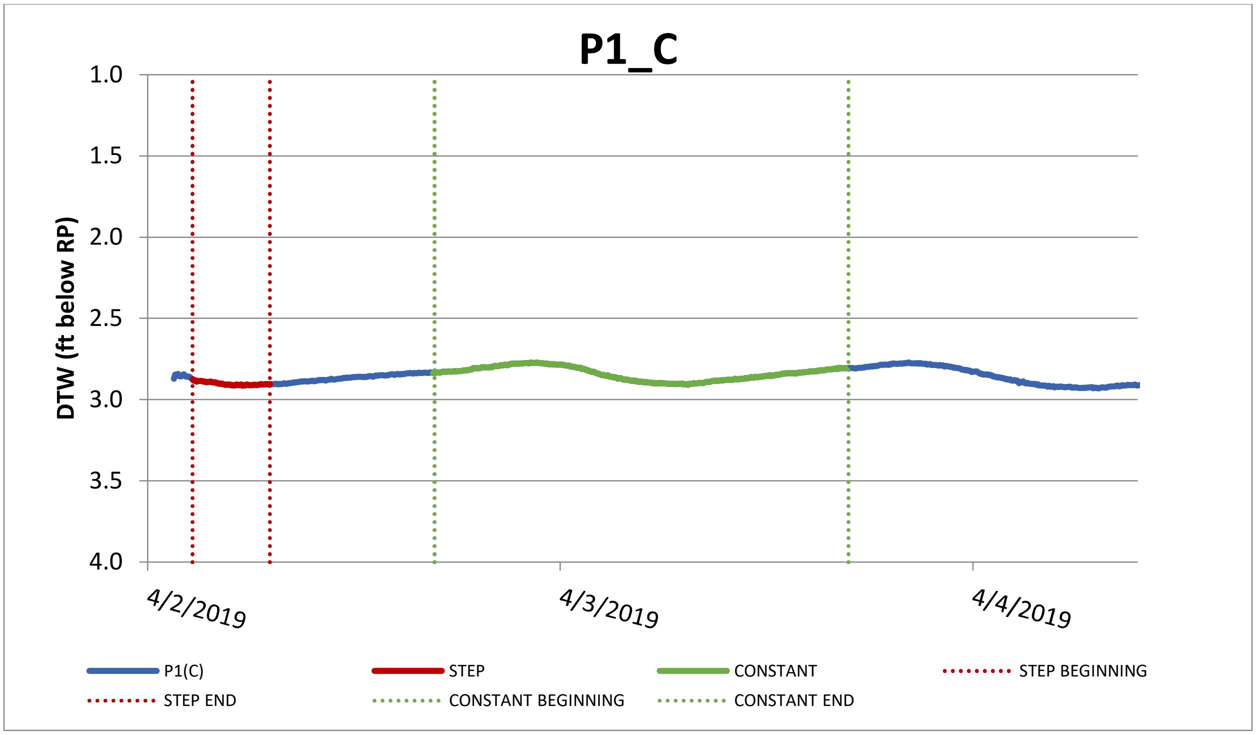

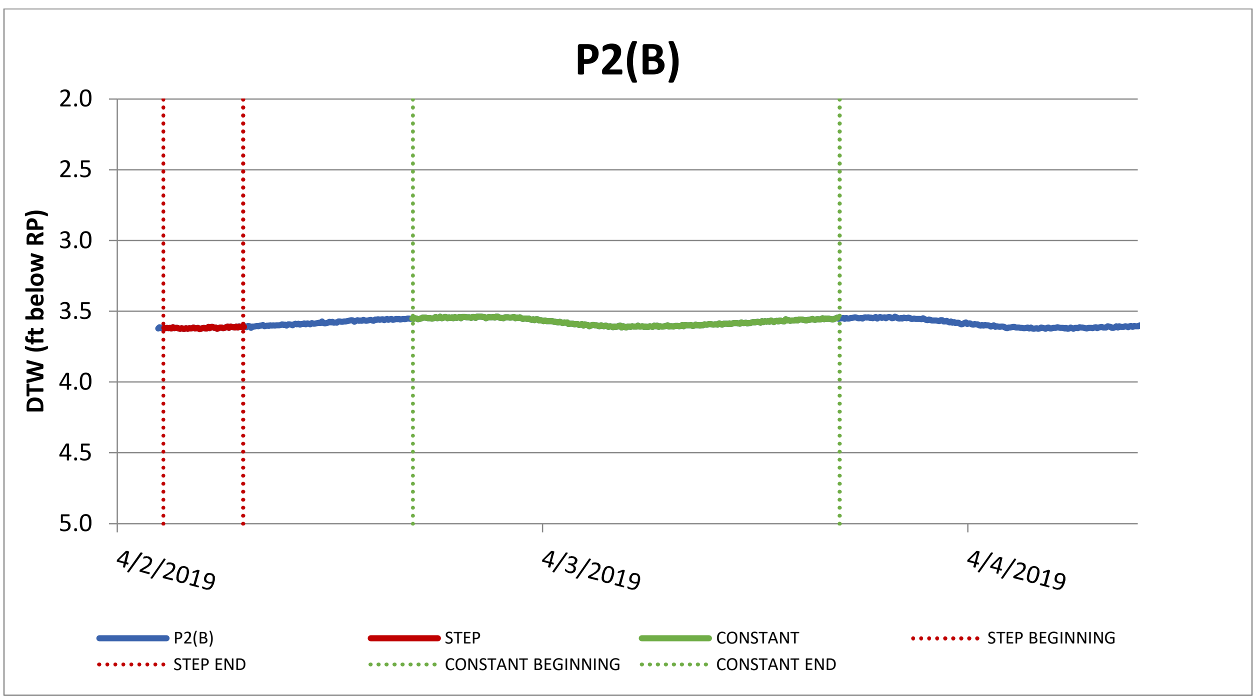

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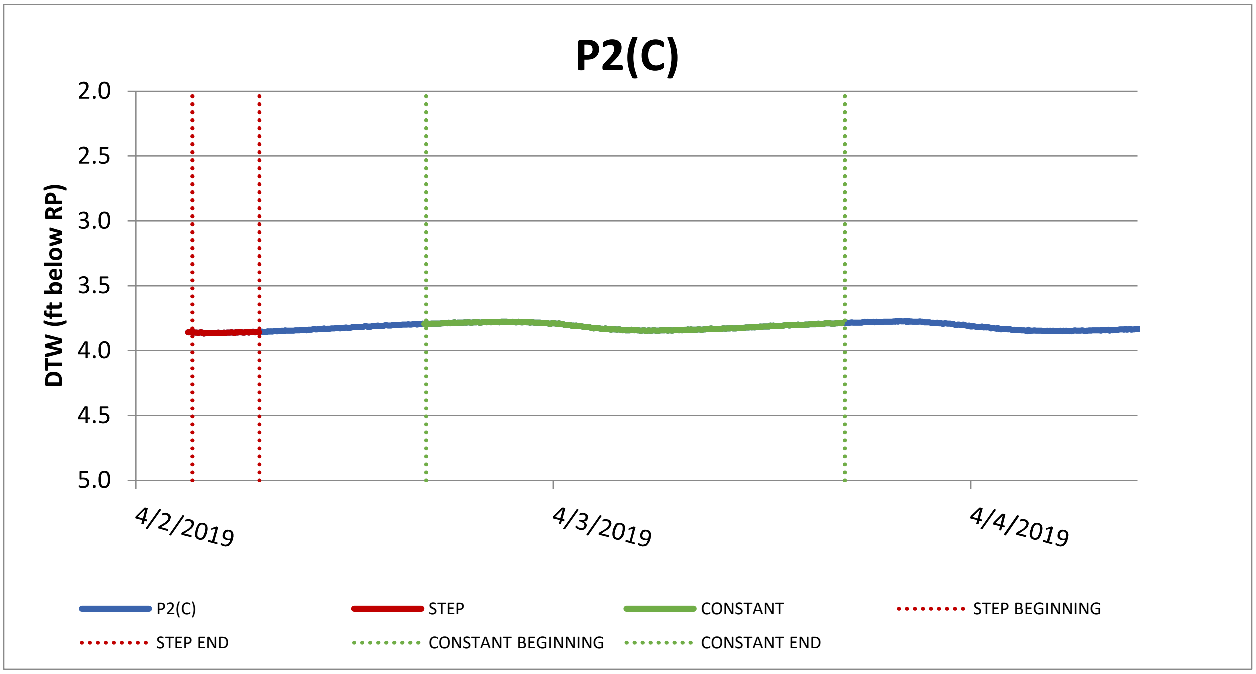
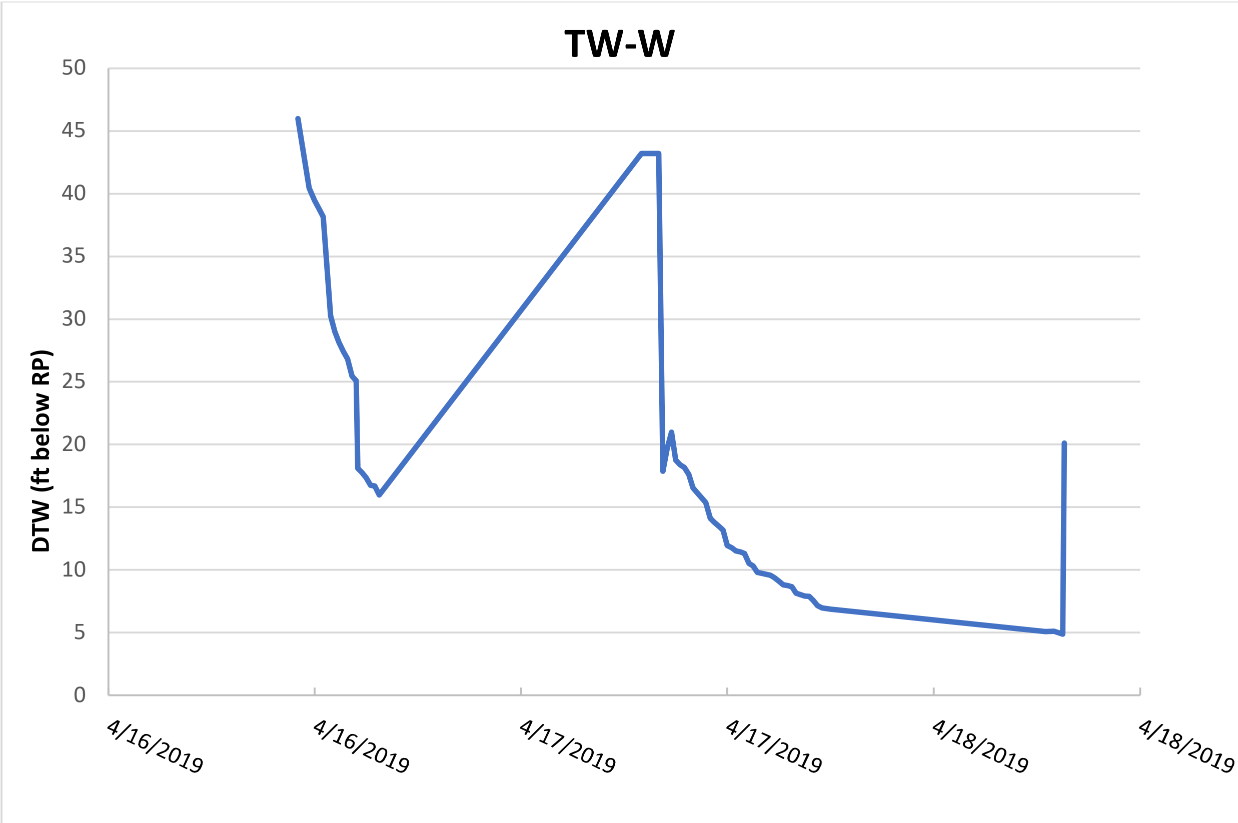


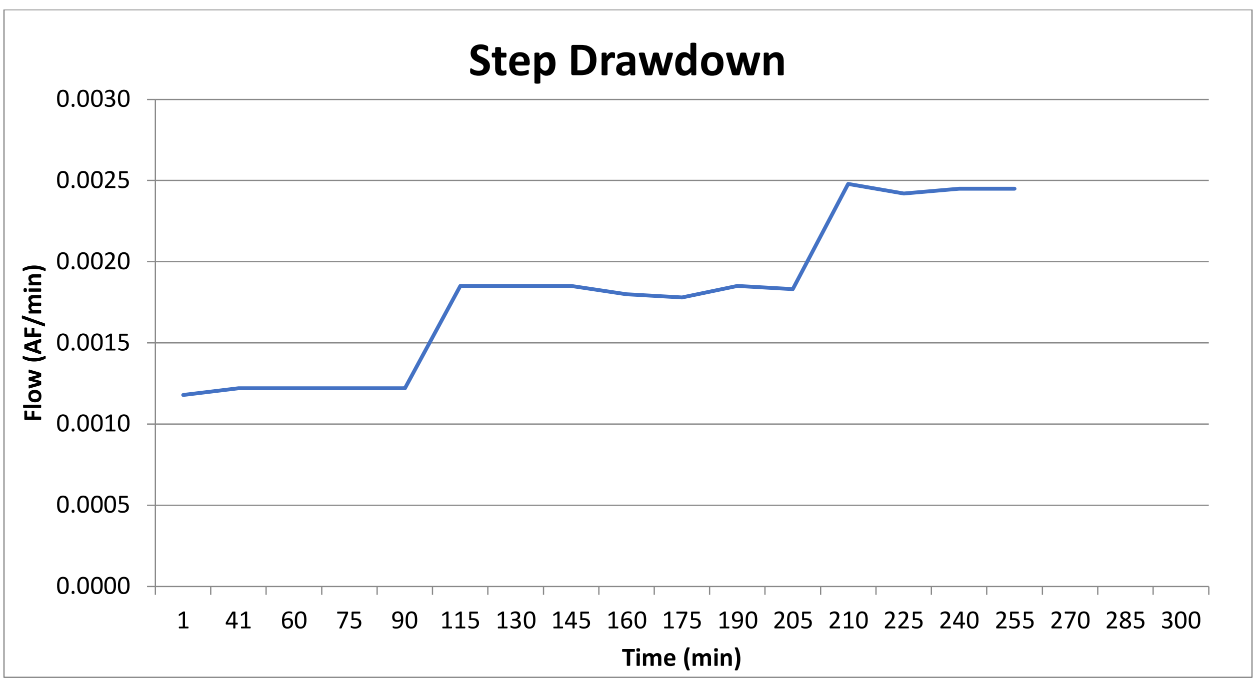
Depth-to-Water (DTW) is defined as groundwater level measurements below Reference Point (RP).

A negative DTW indicates groundwater level measurement above RP.

Hydrographs for TW-W

TW-W Pumping Test





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TW-W Pumping Test

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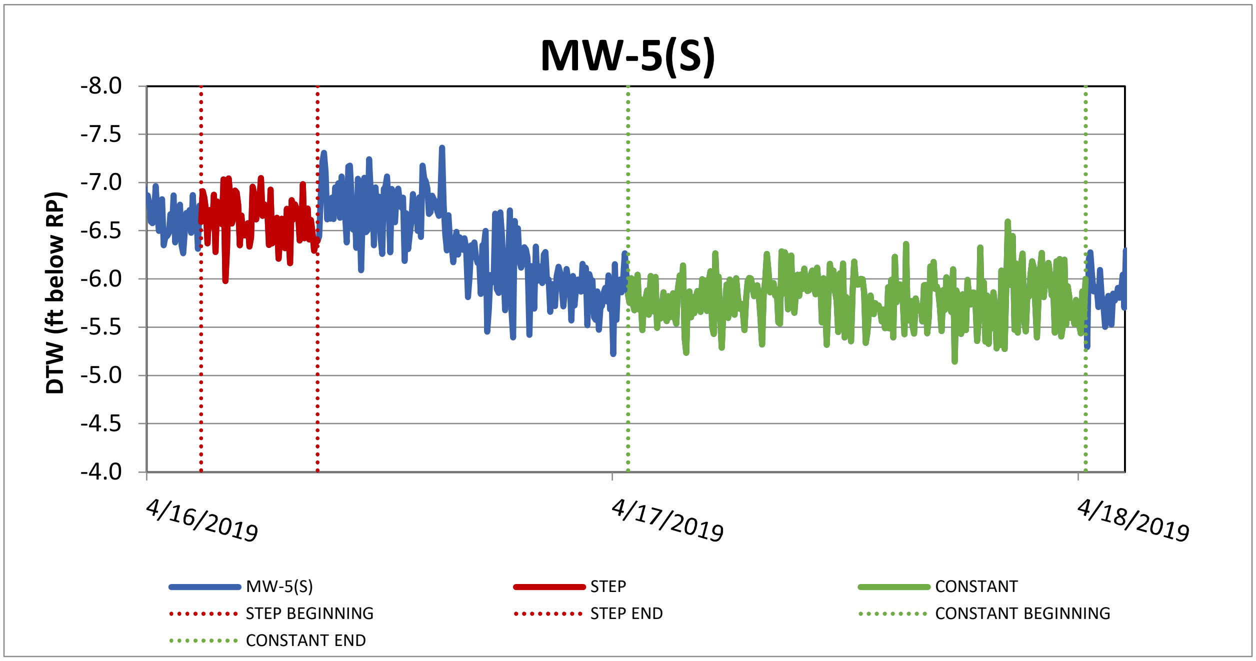

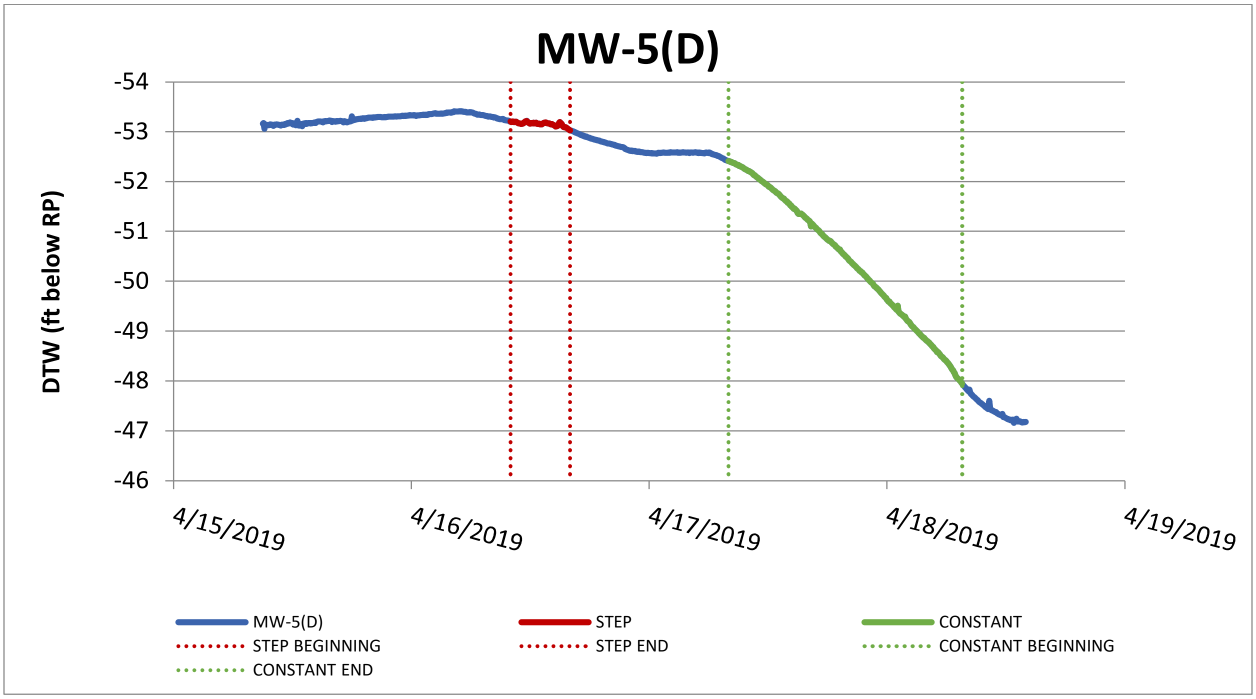

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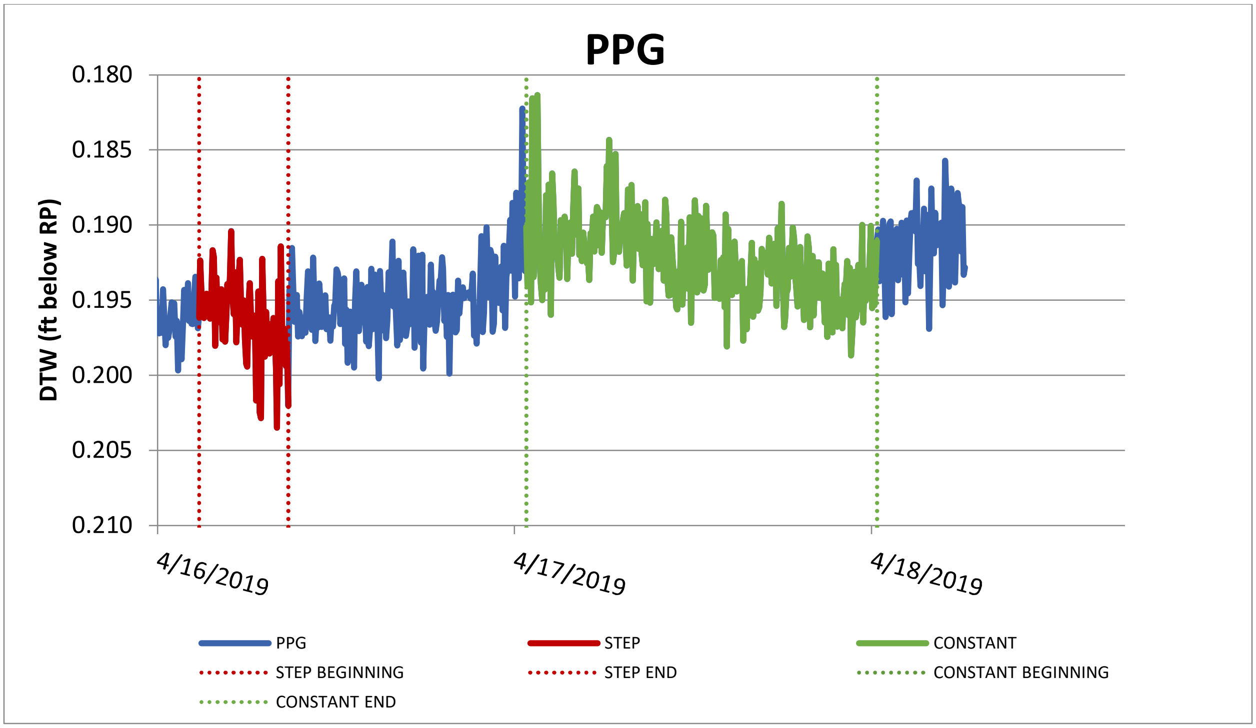

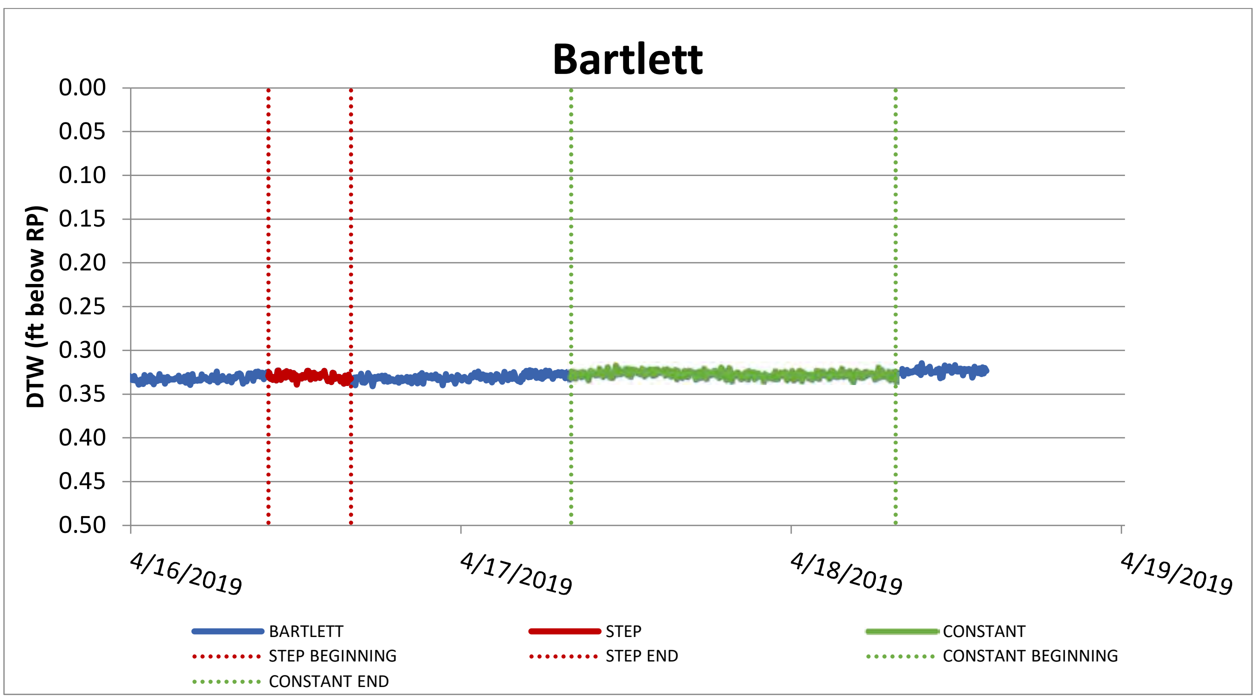

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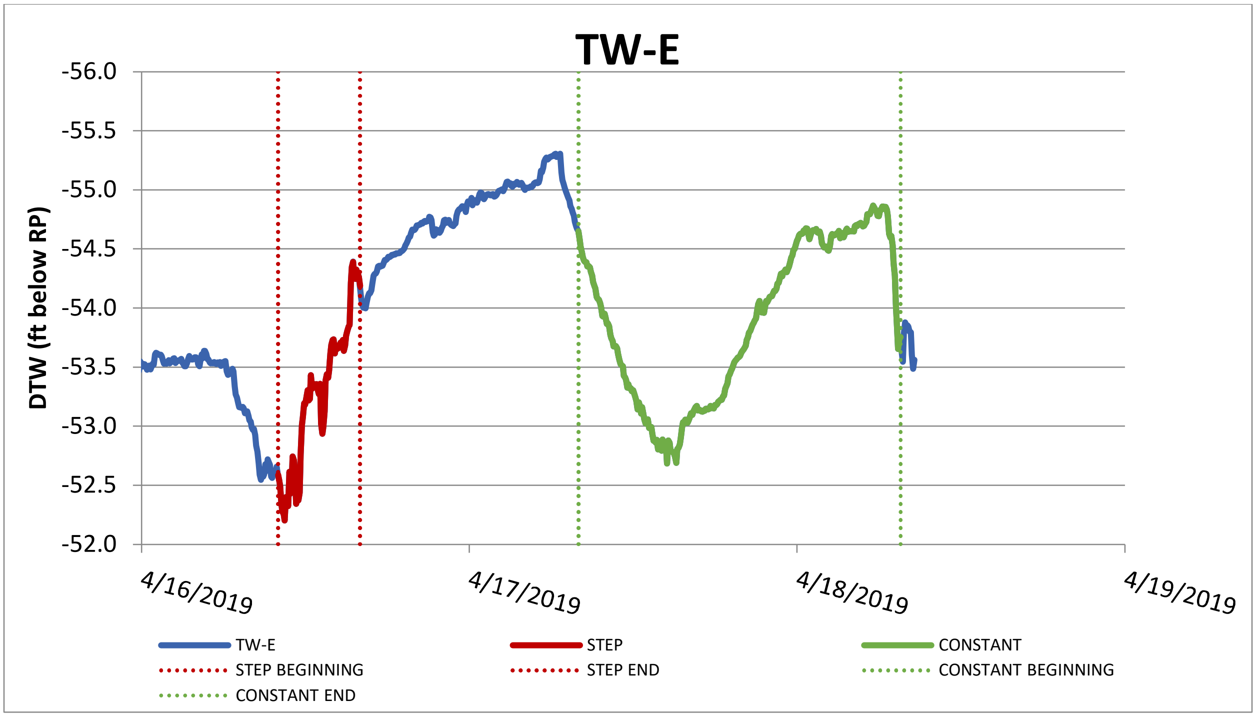

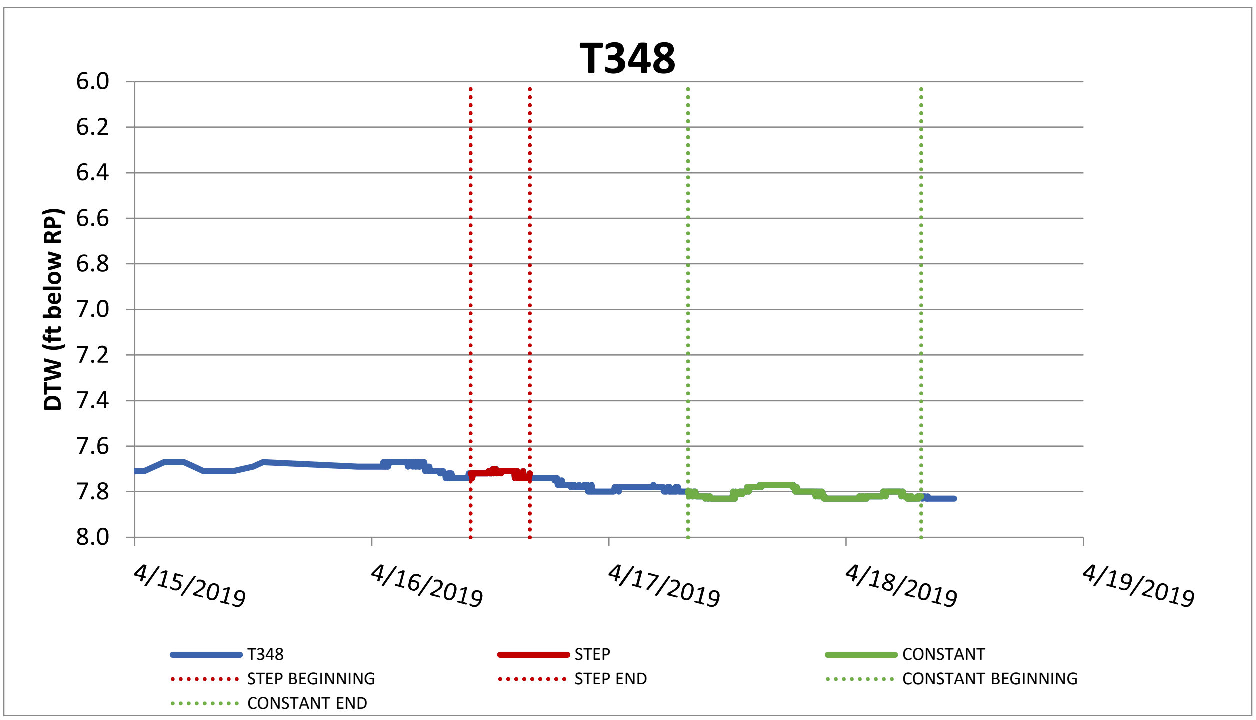

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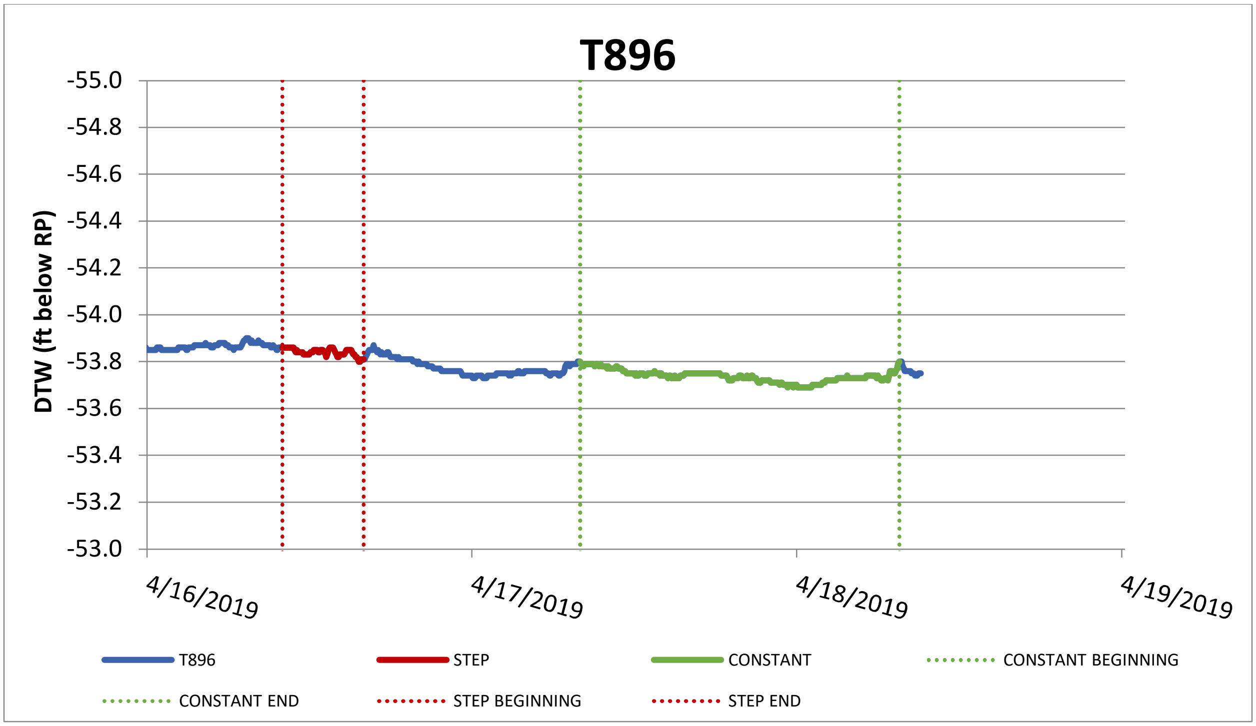

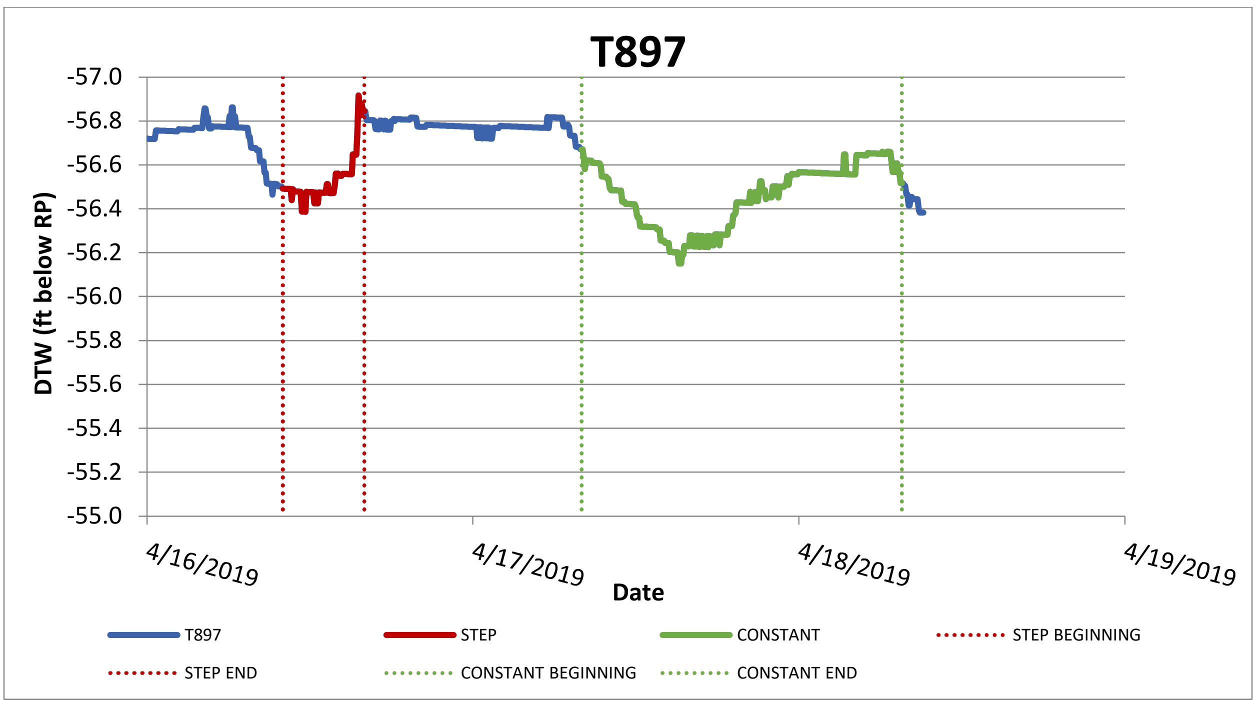

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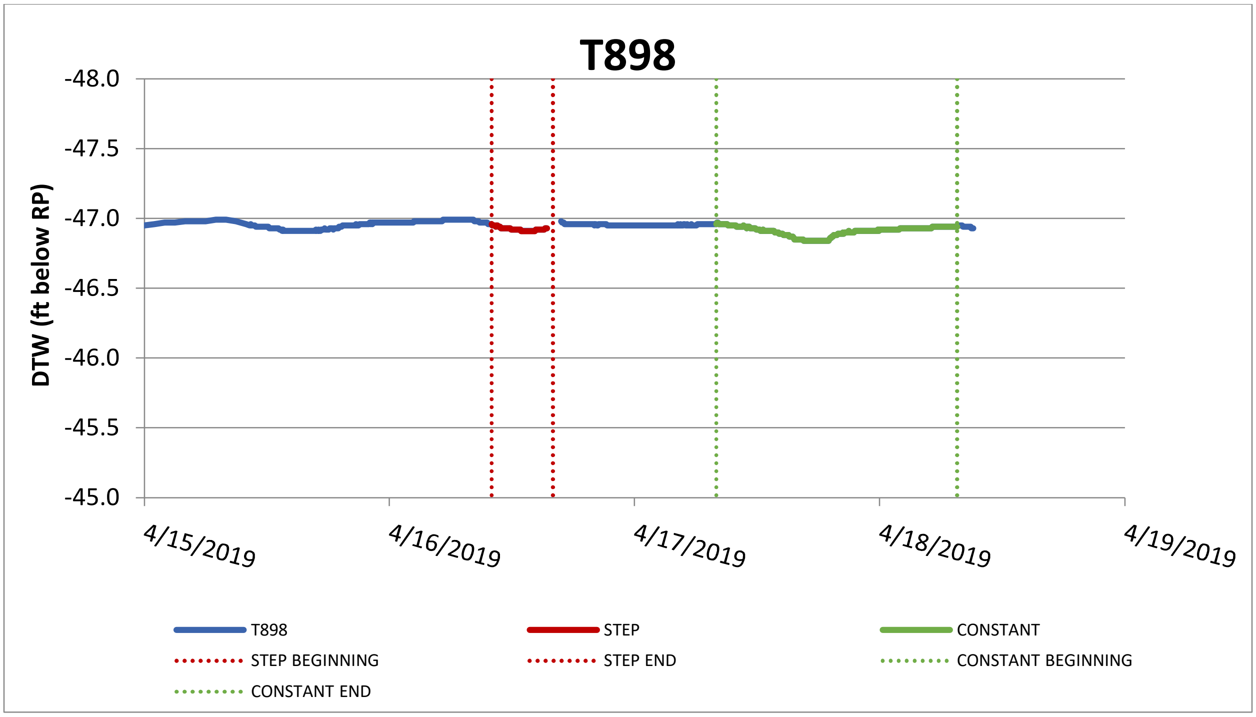

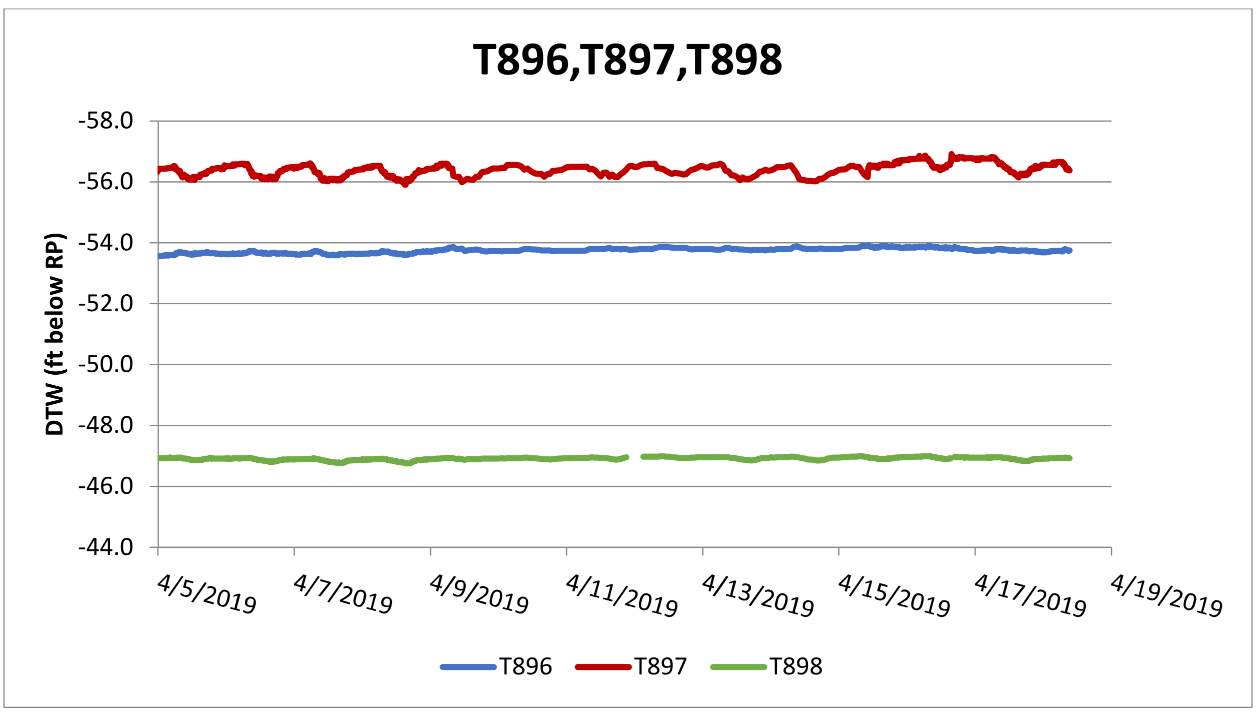

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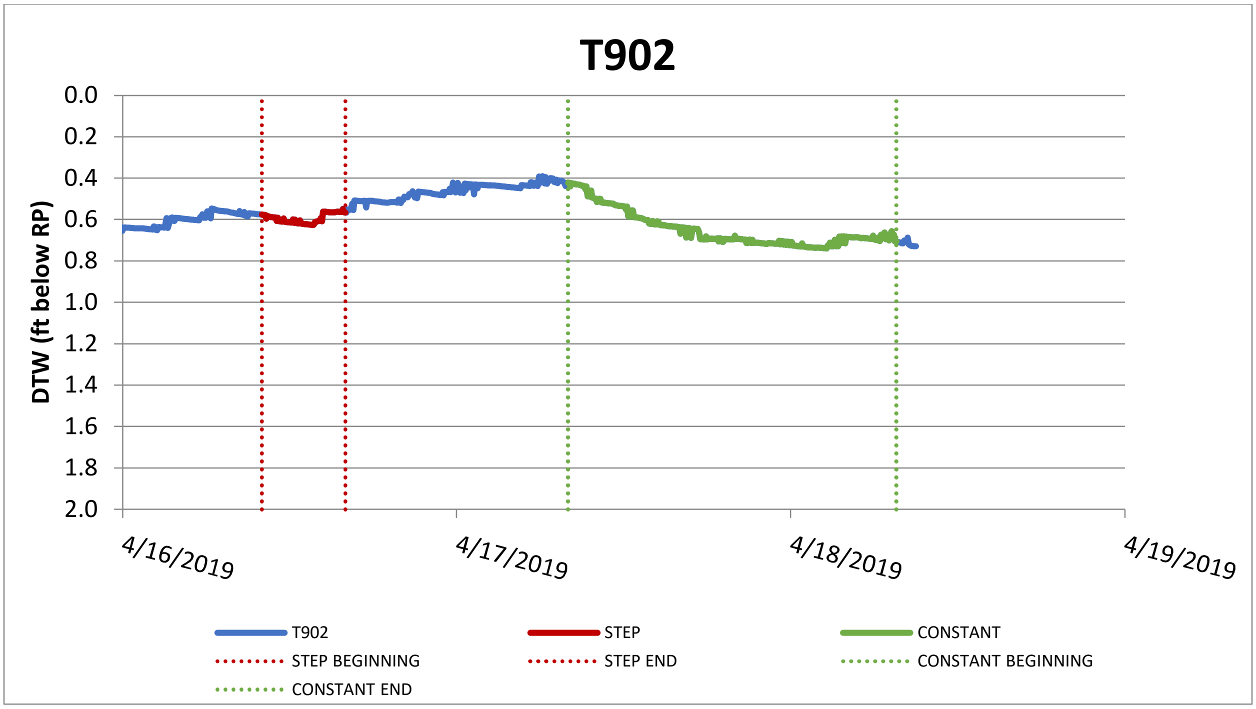

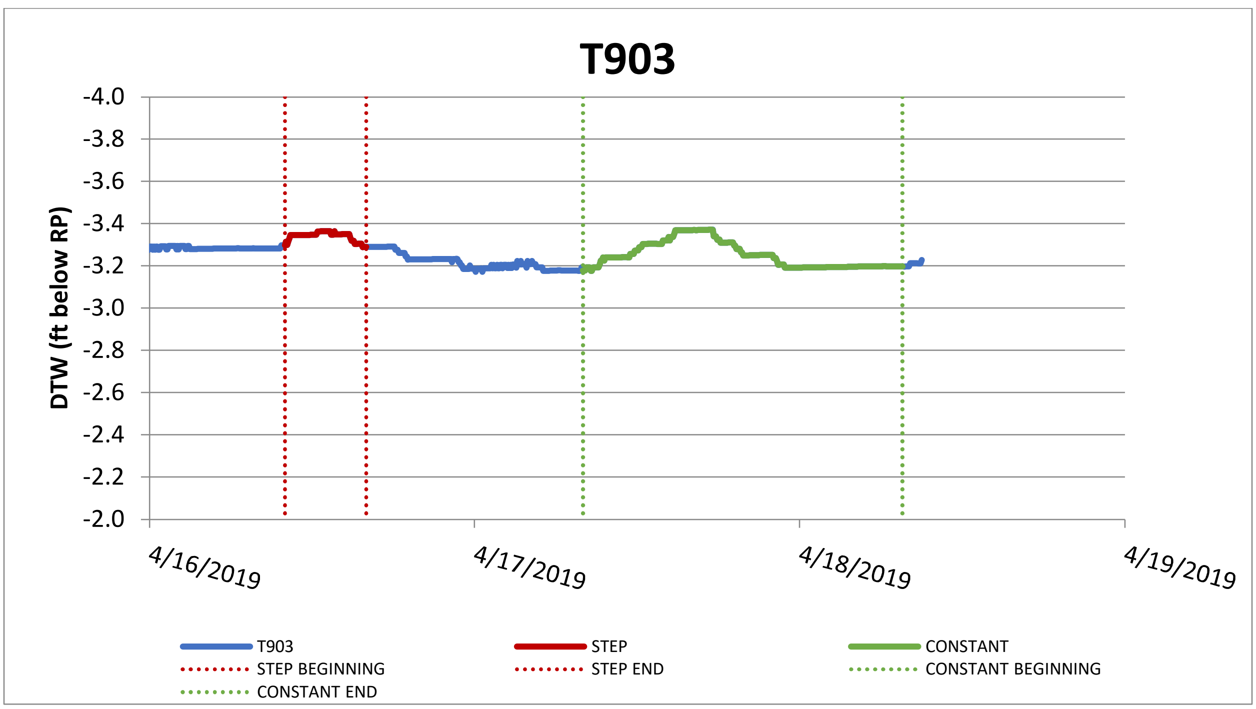

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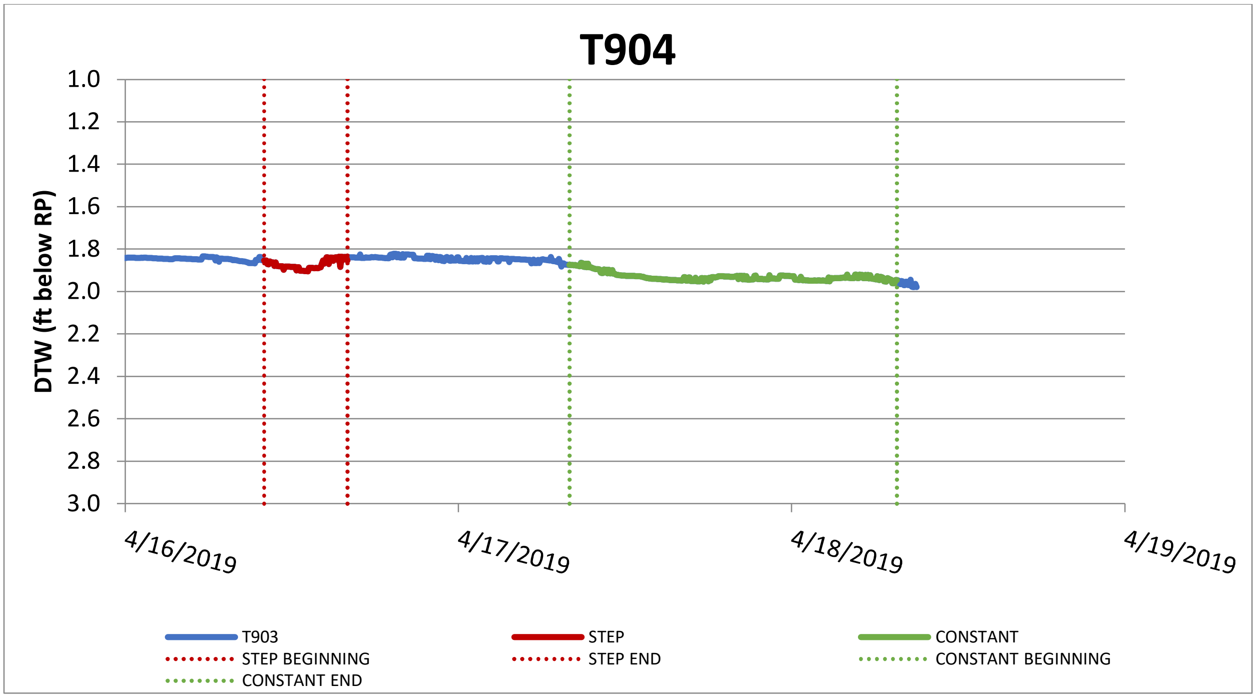

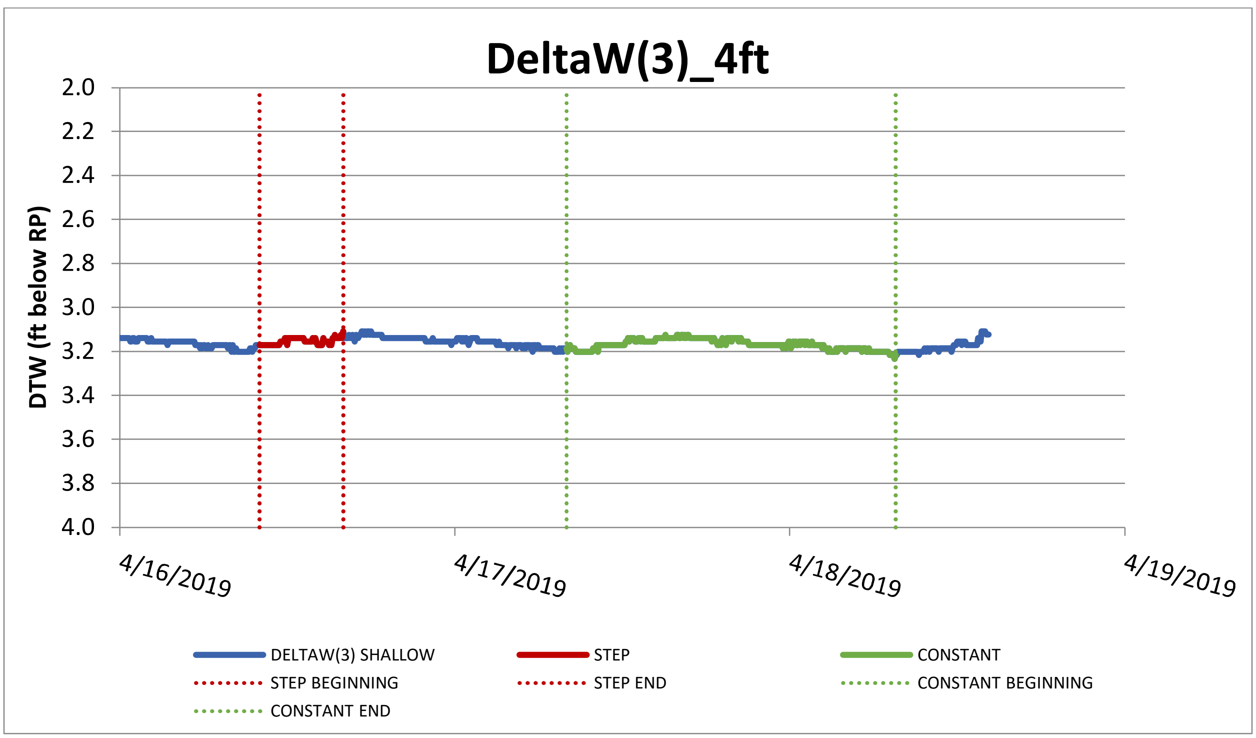

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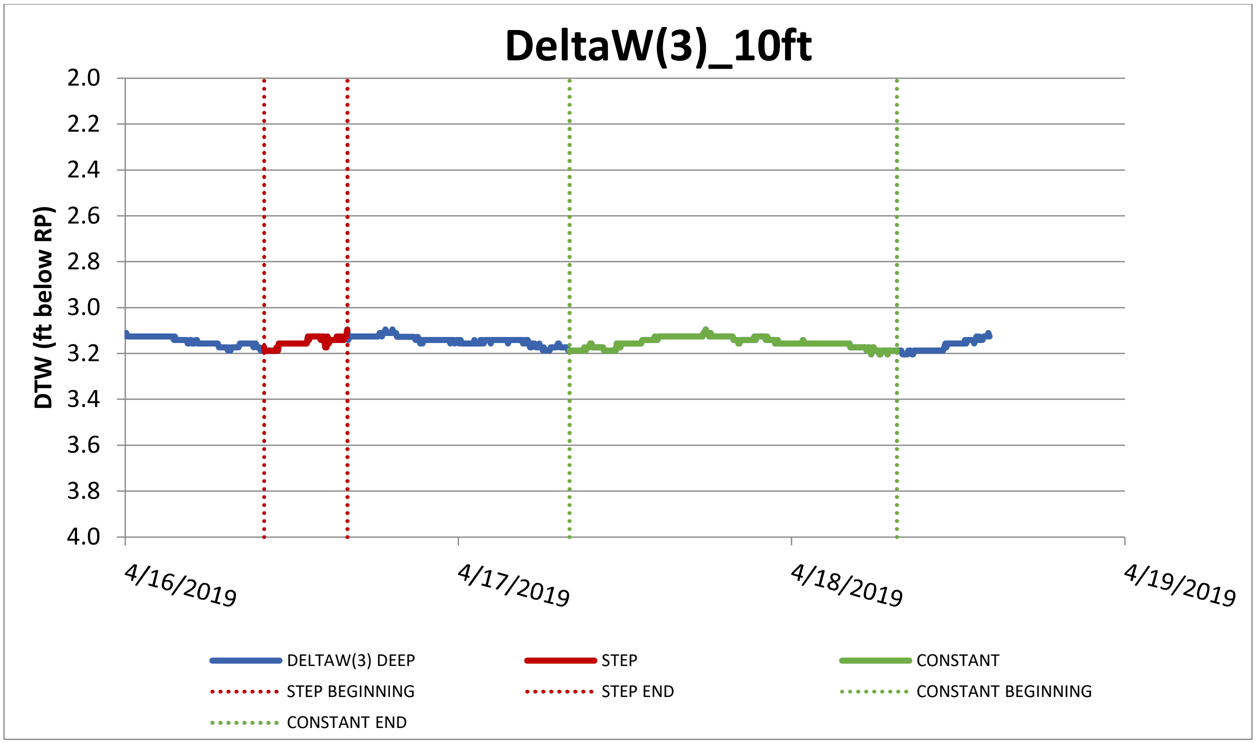

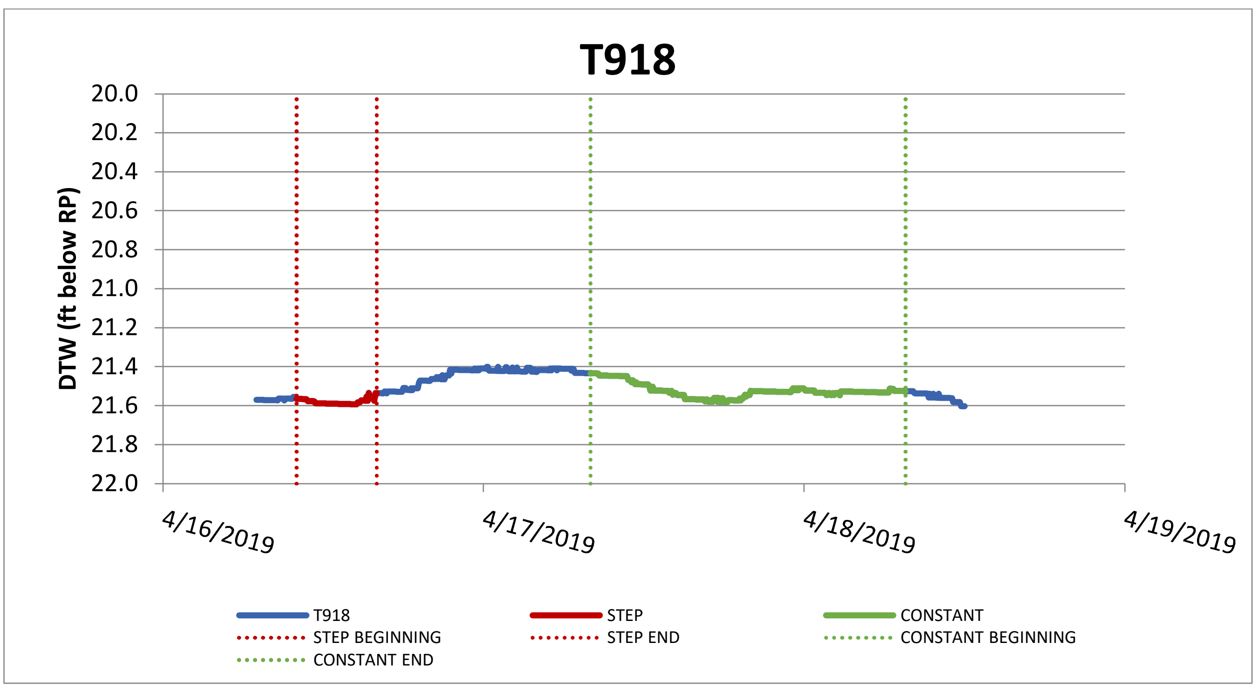

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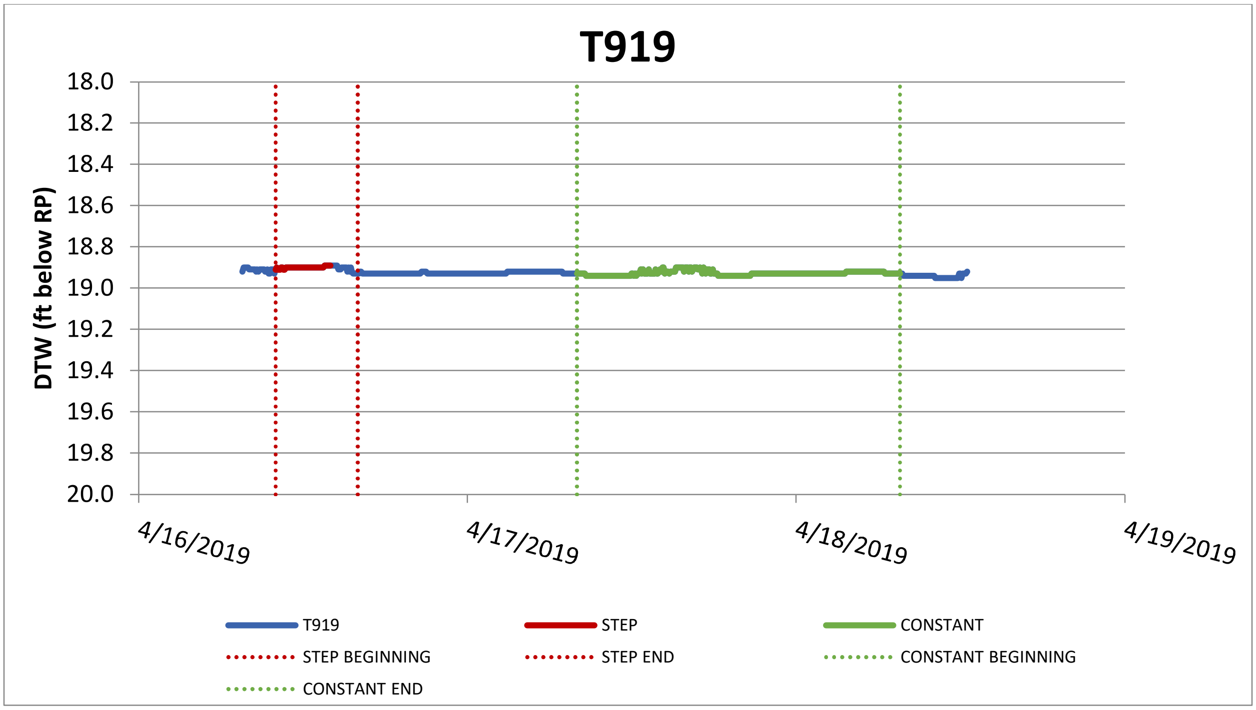

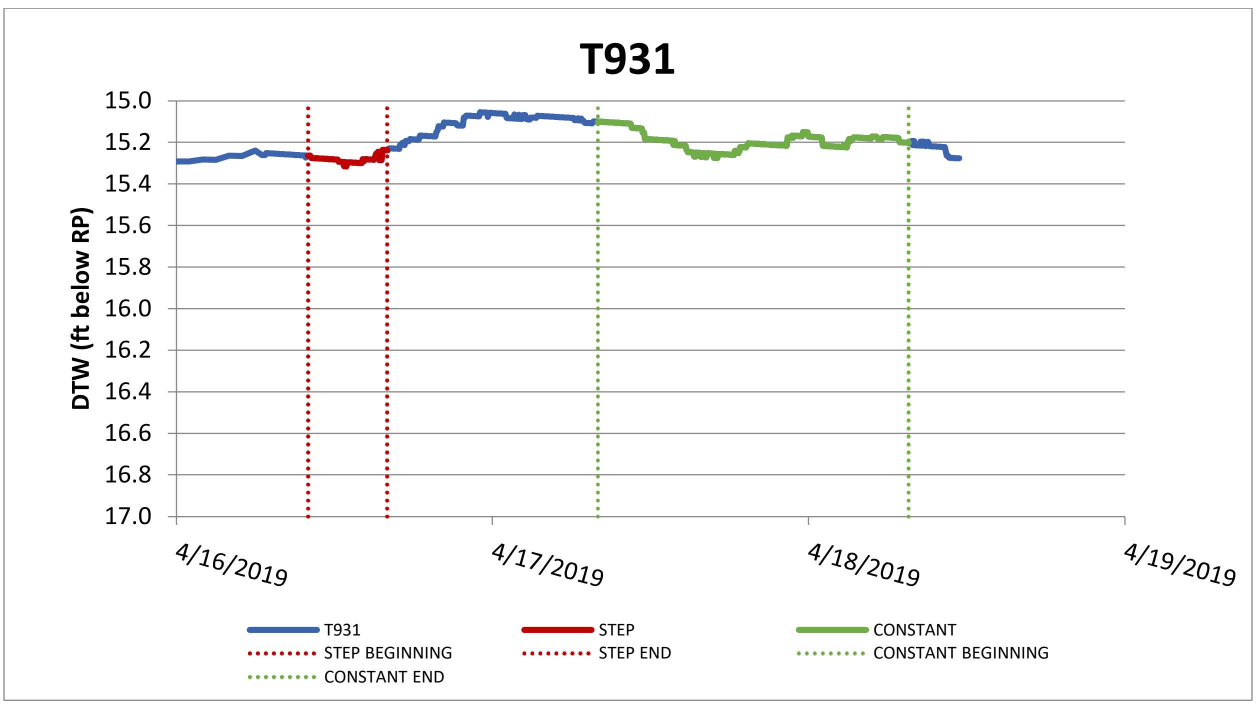

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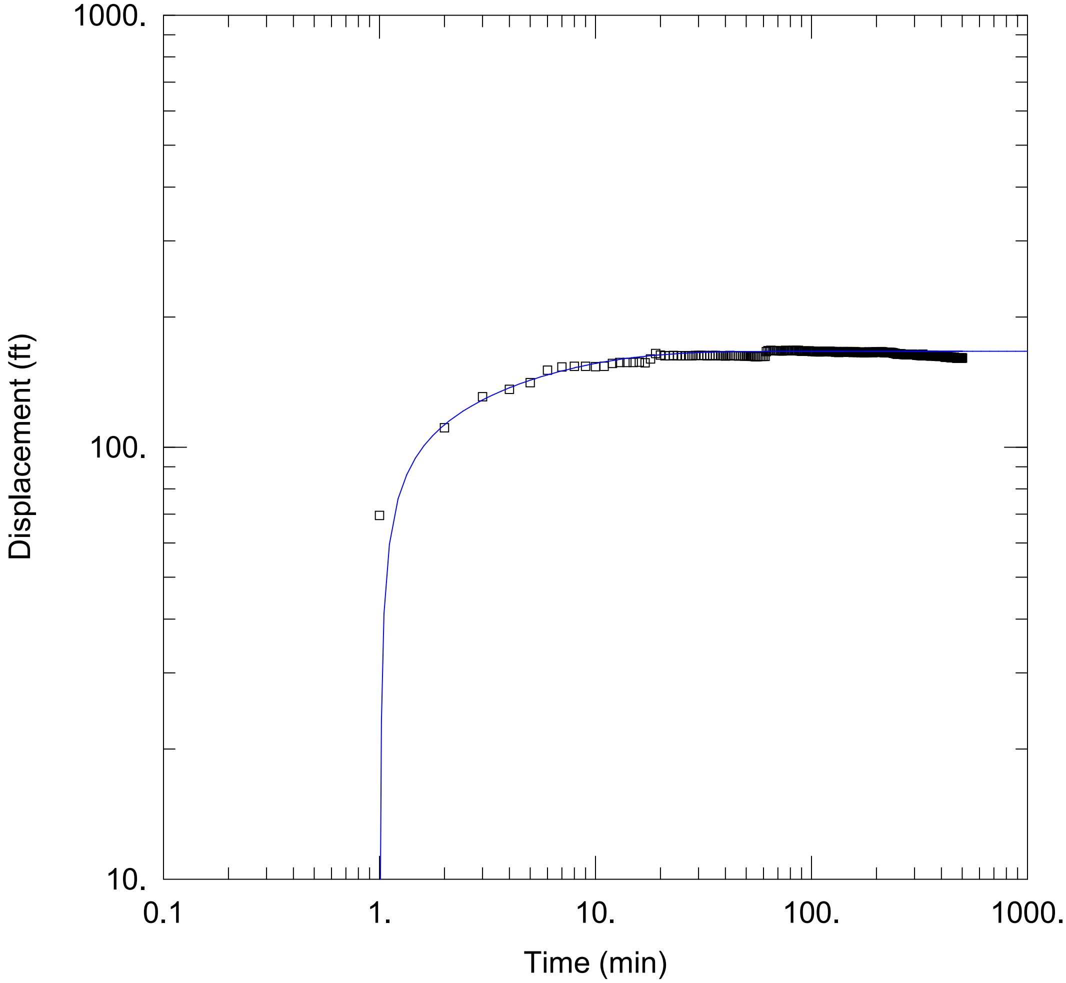
Appendix B- AQTESOLV Results



WELL TEST ANALYSIS

Data Set: Z:\Owens_Lake\Pumping_Tests\TWE\TWE_Constant_Rate_All.aqt
Date: 12/16/19 Time: 16:33:12

PROJECT INFORMATION

Company: Stantec
Client: LADWP
Location: Owens Lake
Test Well: TW-E

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TWE	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ TWE	0	0

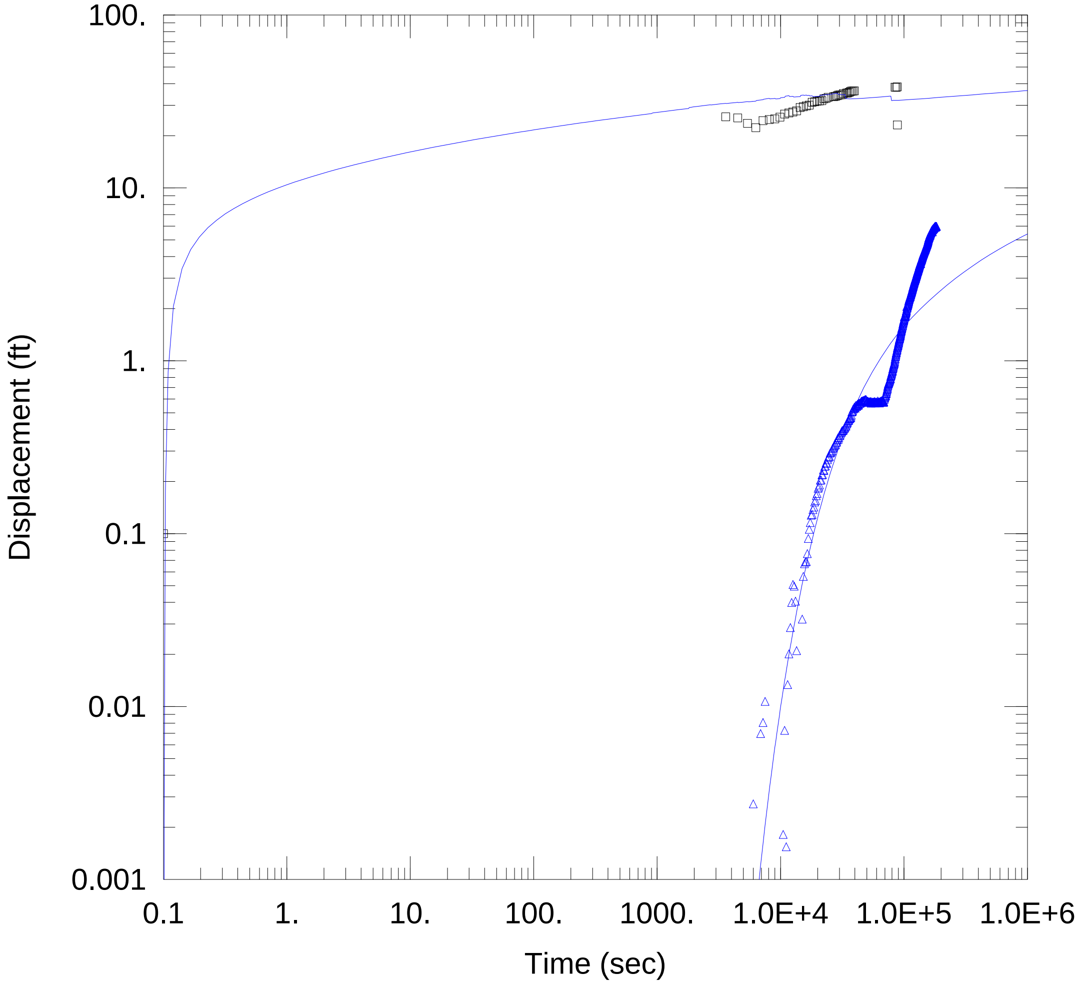
SOLUTION

Aquifer Model: Leaky

Solution Method: Hantush-Jacob

T = 515.1 ft^2/day
r/B = 0.04332
b = 870. ft

S = 0.03693
Kz/Kr = 1.



WELL TEST ANALYSIS

Data Set: Z:\Owens_Lake\Pumping_Tests\TWW\TWW_Constant_Rate_Test_01282020.aqt
Date: 01/28/20 Time: 13:06:24

PROJECT INFORMATION

Company: Stantec
Client: LADWP
Location: Owens Lake
Test Well: TW-W

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TWW	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
△ MW5	1740	1740
□ TWW	0	0

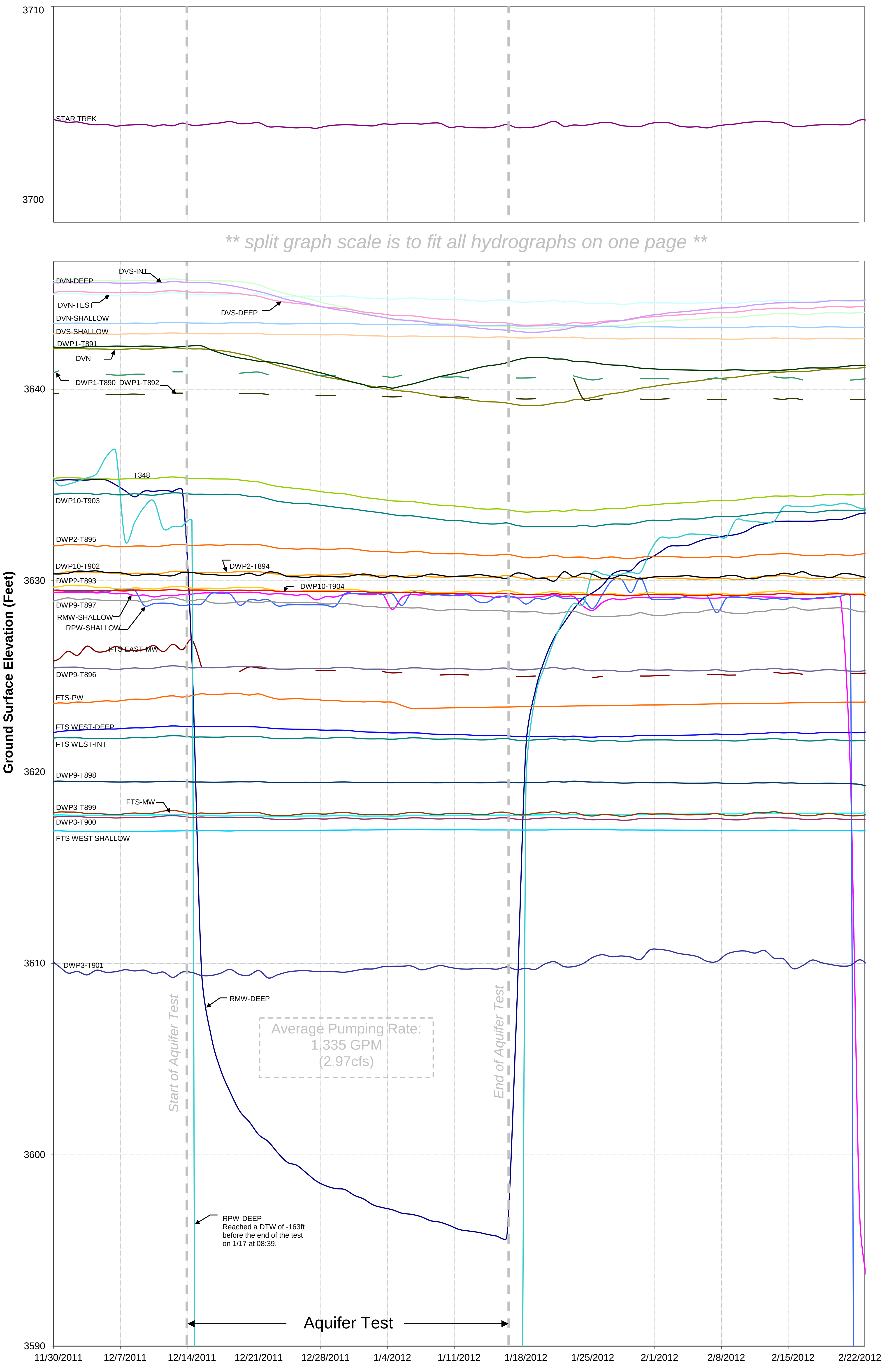
SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

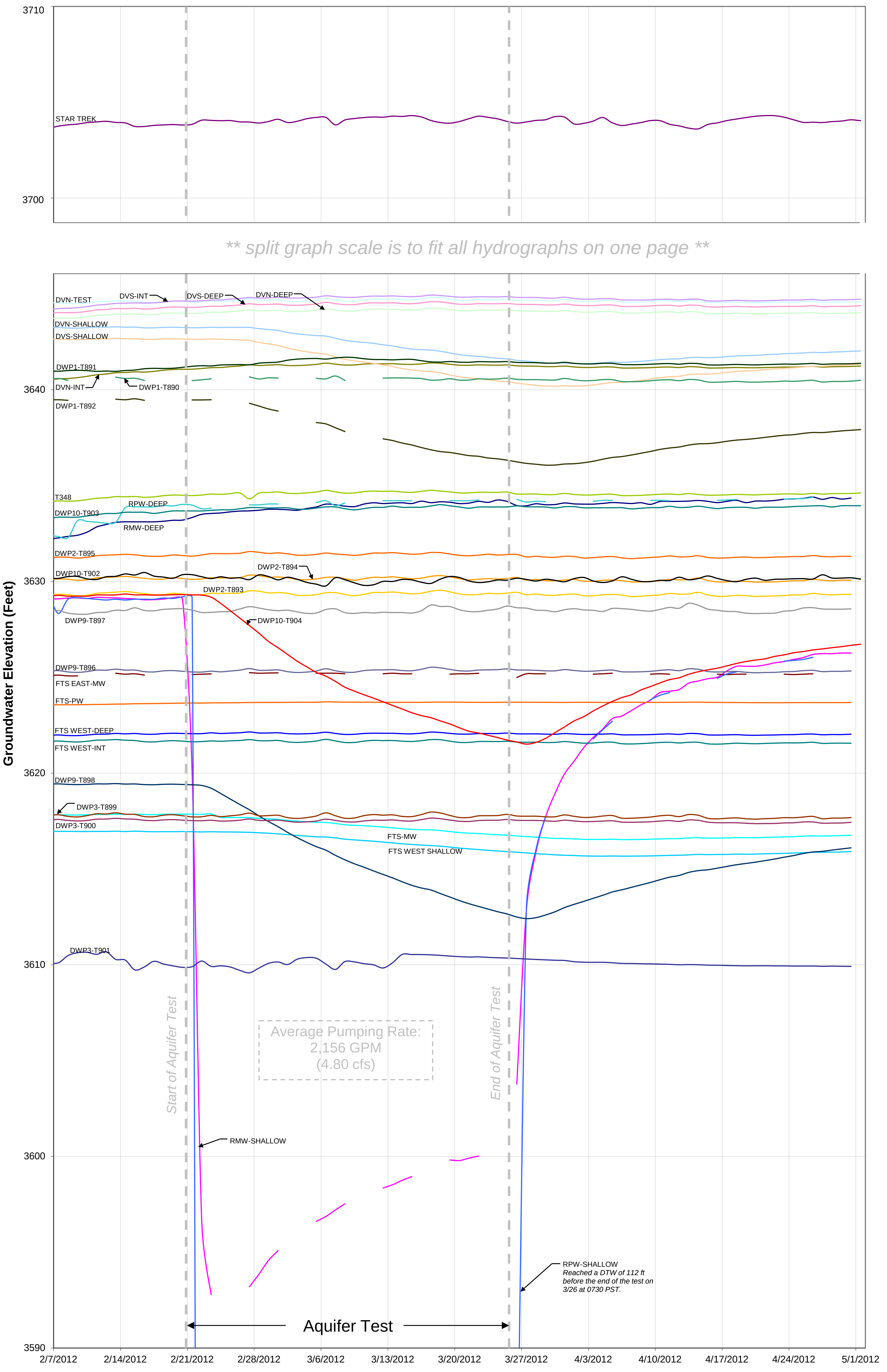
T = 4994. ft^2/day
1/B = 4.064E-9 ft^{-1}
b = 440. ft
S = 0.001502
Kz/Kr = 1.

Appendix C- Graphics of the River Site and SFIP Pumping Tests

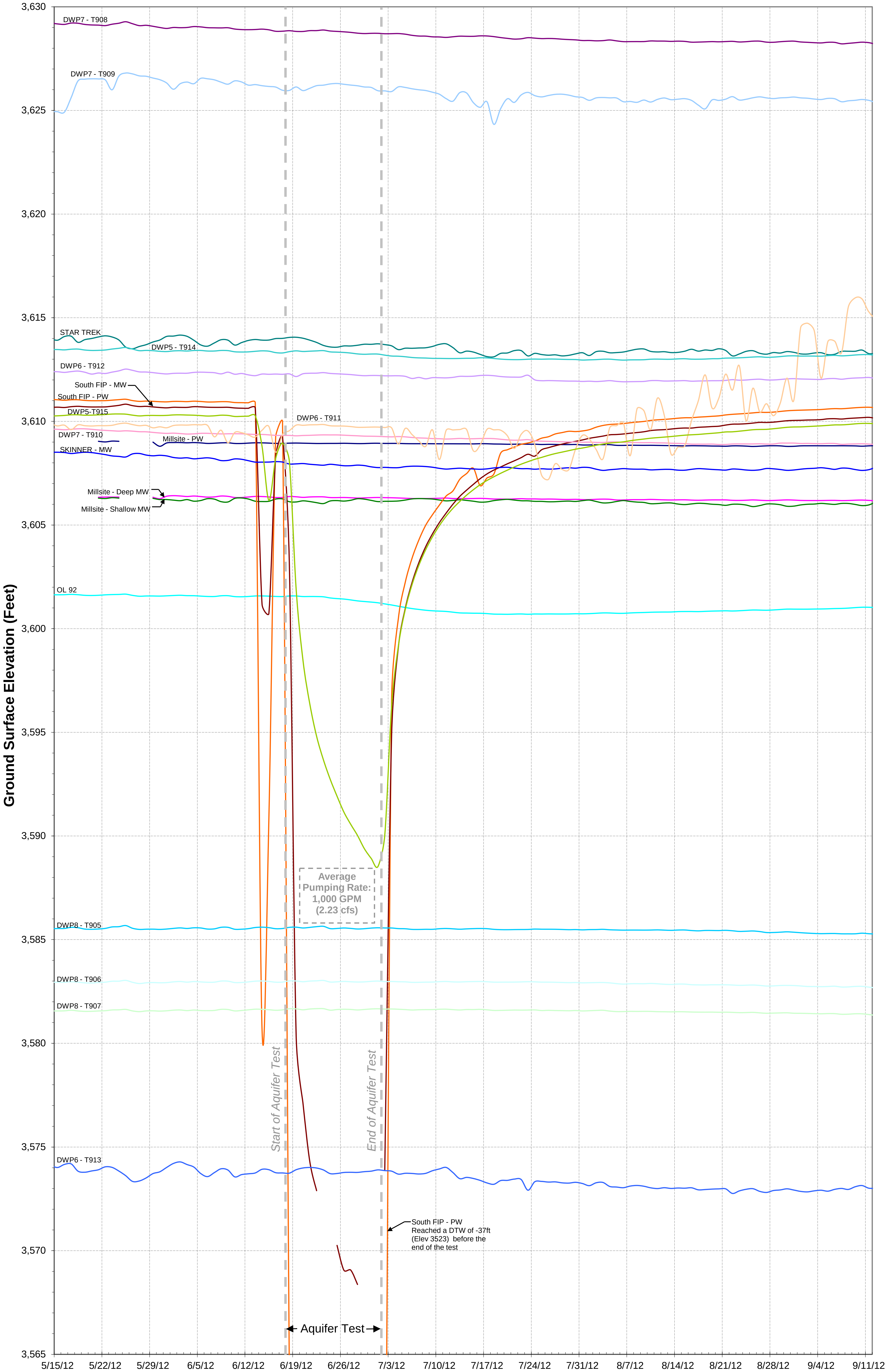
River Site Deep Well - Aquifer Test (Water Level)



River Site Shallow Well - Aquifer Test (Water Level)



South FIP Well - Aquifer Test (Water Level)



River Site Wells: Shallow & Deep

South Flood Irrigation Project Well

Appendix D- Monitoring Plan for TW-E Pumping Test

MONITORING PLAN

Title: Monitoring Plan for TW-E Pumping Test

Project: Task Order 003 – Owens Valley Groundwater Development Program Assistance

Prepared For: Los Angeles Department of Water and Power

Date: January 2020

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LIST OF ACRONYMS AND ABBEVIATIONS

bgs	below ground surface
ft	feet
ft msl	feet above mean sea level
gpm	gallons per minute
OVFZ	Owens Valley Fault Zone
RPPs	Resource Protection Protocols
TM	Technical Memorandum
TW-E	Test Well East

1.0 OBJECTIVE

In order to evaluate the degree to which fault zones influence the effects of groundwater pumping on springs and the overall aquifer response to pumping from deeper aquifers underlying Owens Lake, a long-term pumping test at Test Well East (TW-E) is planned with an anticipated duration of six (6) months. A site location map is provided as **Figure 1**, showing the testing well and monitoring locations described in this plan.

This monitoring plan addresses:

- Well to be pumped
- Pumping duration
- Hydrologic monitoring, methods, and frequency
- Anticipated post-testing analytical method

The monitoring recommended in this plan represents ideal conditions. It is recognized that access limitations and/or available resources may limit monitoring some of the locations or the frequency of data collection. It is recommended that monitoring be focused on Resource Protection Protocol (RPP) monitoring wells (included in this monitoring plan) as a first priority, while wells monitored routinely by LADWP will also be incorporated during review of test results.

2.0 PUMPING WELL

Well construction data for TW-E is summarized in **Table 1**. A 3-step step-drawdown and a 24-hour constant rate pumping test were conducted at TW-E from April 2 to April 3, 2019. Analysis of the test results provided the basis for the design of the long-term monitoring plan.

Table 1: Well Construction Data for TW-E

Well Name	Easting (ft)	Northing (ft)	Approximate Elevation (ft msl)	Depth (ft bgs)	Diameter (inch)	Top of Perforation (ft bgs)	Bottom of Perforation (ft bgs)
TW-E	412,675.90	4,040,565.70	3,565.00	1,500	12	620	1,490

ft = feet; ft msl = feet above mean sea level; bgs = below ground surface)

Figure 1: Long-Term Pumping Test Monitoring Location Map

3.0 PUMPING TEST DESIGN

It is recommended that the pump intake and pressure transducer be installed in Well TW-E at depths of 580 and 560 ft bgs, respectively, to accommodate drawdown in the pumping well during the long-term pumping test at an example discharge rate of 1,200 gpm, having been simulated to produce approximately 400 ft of drawdown in the pumping well. Specific capacities determined from the step drawdown and constant rate pumping tests were the lowest for the last step at 4.77 gpm/ft at a discharge rate of 824 gpm, and 5.24 gpm/ft at a discharge rate of 860 gpm in the constant rate test. These data should be used as guidelines in determining relative pump intake and pressure transducer depths for a range of discharge rates to allow for sufficient hydraulic head above each. Based on analysis of pumping test data and computer simulations, a pumping rate greater than 1,200 gpm is recommended in order to observe a geographically broader and vertically greater hydraulic response than was observed in the 24-hour pumping test, but not to exceed 2,000 gpm to be conservative in protecting sensitive resources.

Approximately 30 days prior to commencement of the long-term pumping test in TW-E, groundwater level data should be collected hourly with a pressure transducer to document background variations in groundwater levels, if practical. When the pressure transducer is installed in the well, manual depth to water measurements should be made and recorded to correlate transducer data. This process should be repeated when the pressure transducer is removed from the well, before pump installation and reinstalled after. During the first twelve hours of the pumping test, pressure transducer data should be collected every minute followed by 12 hours of 10-minute intervals. Hourly data will be collected during the second day of the pumping test followed by regular 4-hour interval data collection through the end of the test.

Pumping rate monitoring should be conducted at Well TW-E during the long-term pumping test using a totalizing flow meter. Instantaneous flow measurements and the total amount of groundwater pumped will be recorded manually every 30 minutes for the first 4 hours of testing to stabilize discharge and maintain consistent discharge. Manual readings of totalizer data and groundwater elevation will also be recorded daily for the first week of the pumping test followed by weekly measurements until the end of the test. Ideally, these data could be supplemented with data logged values if possible.

During the recovery portion of the pumping test, groundwater levels should be recorded via the pressure transducer at one-minute intervals for the first 12 hours, followed by 10-minute intervals for 12 hours, then hourly for 24 hours, and finally every four hours up to ten (10) days after conclusion of the pumping test. At the conclusion of the recovery portion of the pumping test, one manual groundwater level measurement will be performed prior to the removal of the pressure transducer. Data from the pressure transducer can then be downloaded and safeguarded in a secure location.

4.0 MONITORING PROGRAM

The monitoring program consists of groundwater flow and groundwater level monitoring, barometric pressure monitoring and ground elevation monitoring. Each of these monitoring components is discussed in terms of location, monitoring method, and frequency. Resource Protection Protocols (RPPs) for each resource were specified, where groundwater levels were determined to be management triggers/indicators. These RPP wells include key groundwater level monitoring wells (**Table 2**) and gradient monitoring wells (**Table 3**). LADWP key wells, identified in **Table 2** are nearest to associated Non-LADWP wells of concern. The Non-LADWP wells shown in **Table 2** are not considered for monitoring due to access limitations.

Table 2: Key Groundwater Level Monitoring Wells

Cluster Number	Cluster Name	Key Wells to Monitor	
		Non-LADWP Wells of Concern (not monitored)	LADWP Surrogate Wells to be Monitored
1	Lone Pine	Mt. View Trailer Park	T858
2	Dolomite	FW Aggregates Well 2	T929
3	Swansea	Fault Test Well	---
4	Keeler	Keeler CSD	---
5	Olancha	---	T925
6	Cartago	Cartago Mutual	T924
7	Rio Tinto	Rio Tinto	---
8	OLSAC	---	T922
9	Mortensen	Mortensen	T920
10	Lubken Creek	Boulder Creek RV Park	T348

Table 3: Gradient Monitoring Wells

Gradient Type	Upgradient Location	Downgradient Location	General Location on the Margins of Owens Lake
Vertical	P1L	P1U	Northwest (Northwest Spring)
	P2L	P2U	West-Central (Cottonwood)
	P3L	P3U	Southwest/Central (Ash Creek)
	P4L	P4U	South (Olancha)
	P5L	P5U	Southeast/Central (Tubman)
	P5aL	P5aU	East (Trucksticker)
	P6L	P6U	East (Swedes Pasture)
	P7L	P7U	East (Mill Site)
	P8L	P8U	Northeast (Horse Pasture)
Horizontal	MW-3	T918	Northwest
	MW-2	P1U	Northwest
	T920	T919	Northwest
	T922	P2U	West-Central
	T923	P3U	Southwest/Central
	T927	P5aL	Southeast/Central
	T928	P6U	East

Testing and monitoring well locations are shown on **Figure 1**. Monitoring methods and frequency of monitoring are summarized in **Tables 4** through **8**.

For the non-LADWP wells listed in **Table 4** that do not have a LADWP surrogate monitoring well (e.g., Fault Test Well, Keeler CSD, Rio Tinto), groundwater levels may be monitored manually, if practical and permission is granted by the well owner, on a monthly basis (if practical) during the pumping portion of the long-term pumping test. Manual groundwater level measurements at these wells, to the extent possible, should also be performed one time before the start of the long-term pumping test and one time at the end of the recovery portion of the pumping test. Pressure transducers will be utilized to monitor groundwater levels in the remaining RPP wells including those LADWP surrogate wells that will be monitored in lieu of certain non-LADWP wells of concern (e.g., T858 for Mt. View Trailer Park Well). Manual groundwater level measurements should be obtained at each of these wells before the long-term pumping test begins and at the end the recovery period for calibration purposes for the pressure transducers. Monitoring should commence one day before the long-term pumping test begins. When each pressure transducer is installed, the depth to water and submergence depth of the pressure transducer should be correlated with a manual depth to water measurement using an electric water level sounder and recorded. The groundwater level measurement frequency for the transducers should be set at 4 to 6 hour measurement intervals to capture the potential drawdown details while limiting the total amount of data to be stored in the transducer. At the end of the recovery portion of the test, a manual groundwater level measurement should be obtained and recorded before downloading the groundwater level data from the pressure transducer.

Groundwater levels in the wells listed in **Table 5** will be monitored utilizing pressure transducers, if practical. Manual groundwater level measurements will be obtained at each of these wells if possible before the long-term pumping test begins and at the end the recovery period for calibration purposes. Monitoring should commence one day before the long-term pumping test begins if possible. When the pressure transducer is installed, the transducer depth to water and submergence depth should be correlated with a manual static depth to water measurement using an electric water level sounder and recorded. The groundwater level measurement frequency for the pressure transducers should be set at five-minute measurement intervals in TW-E to capture the potential drawdown details while limiting the total amount of data to be stored in the pressure transducers. At the end of the recovery portion of the test, a manual groundwater level measurement should be obtained and recorded before downloading the groundwater level data from the pressure transducer.

Wells listed in **Table 6** will be monitored manually, if possible. Manual groundwater level measurements include one measurement before the long-term pumping test begins, biweekly during the long-term pumping test, and one time at the end of the subsequent recovery period. It should be noted that during the long-term pumping test, groundwater level measurements at any of these wells may be terminated if the preceding three consecutive measurements indicate no change in groundwater level.

Table 7 lists existing flow measurement sites, Cottonwood Flume (W3), PPG Flume (W4) and Bartlett (W5), and the recommended flow measurement methodology and frequency prior to, during and up to ten (10) days following completion of the pumping portion of the long-term pumping test.

Barometric pressure will be monitored at existing LADWP weather stations Owens Lake North and Owens Lake South sites which are shown on **Figure1**. Both stations record barometric pressure hourly.

Table 8 lists existing LADWP ground surface monitoring locations on Owens Lake. As shown in **Table 8**, five sites have been selected to be the primary ground elevation monitoring locations owing to their close proximity to TW-E (i.e., 7012) and to assess potential subsidence impacts on the east side of the Owens River Fault (i.e., 6527 and 6532) and the west side of the Owens Valley Fault Zone (OVFZ - i.e., 6371 and 6372).

Three back-up monitoring locations were also selected in the event the primary locations cannot be used. These sites include 6523, 6535 and 7016 as described in **Table 8** and shown on **Figure 2**. Recommended ground elevation monitoring frequency of the primary monitoring locations is one time within one month prior to commencement of the long-term pumping test, three months after commencement of the pumping test and at the end of the pumping test (6 months). To the extent any subsidence is observed at any of the primary ground elevation monitoring locations at the end of the pumping test, up to two more additional monitoring events should be performed if subsidence is observed. To the extent subsidence is observed at any of the primary or back-up subsidence monitoring locations, the latter if performed, at the end of the pumping test, up to two more additional monitoring events should be performed three months and six months after the long-term pumping test is completed.

Table 4: Wells to be Monitored Manually and Utilizing Transducers

Well ID	Well Depth (ft)	Groundwater Level Measurement Method	Frequency (during long-term pumping test)
MW-2	TBD	Transducer	4-6 hour intervals
MW-3	TBD	Transducer	4-6 hour intervals
P1L	33	Transducer	4-6 hour intervals
P1U	9	Transducer	4-6 hour intervals
P2L	33	Transducer	4-6 hour intervals
P2U	8	Transducer	4-6 hour intervals
P3L	34	Transducer	4-6 hour intervals
P3U	8	Transducer	4-6 hour intervals
P4L	34	Transducer	4-6 hour intervals
P4U	8	Transducer	4-6 hour intervals
P5aL	36	Transducer	4-6 hour intervals
P5aU	8	Transducer	4-6 hour intervals
P5L	36	Transducer	4-6 hour intervals
P5U	4	Transducer	4-6 hour intervals
P6L	34	Transducer	4-6 hour intervals
P6U	5	Transducer	4-6 hour intervals
P7L	34	Transducer	4-6 hour intervals
P7U	4	Transducer	4-6 hour intervals
P8L	32	Transducer	4-6 hour intervals
P8U	7	Transducer	4-6 hour intervals
T918	68	Transducer	4-6 hour intervals
T919	73	Transducer	4-6 hour intervals
T922	133	Transducer	4-6 hour intervals
T923	113	Transducer	4-6 hour intervals
T925	78	Transducer	4-6 hour intervals
T927	68	Transducer	4-6 hour intervals
T928	93	Transducer	4-6 hour intervals

Table 5: Existing LADWP Wells to be Monitored Utilizing Transducers

Well ID	Well Depth (ft)	Groundwater Level Measurement Method	Frequency (during long-term pumping test)
TW-E (Pumping Well)	1,500	Transducer	Variable-described in text
TW-W	890	Transducer	4-6 hours
MW-4S	950	Transducer	4-6 hours
MW-4D	950	Transducer	4-6 hours
MW-5S	900	Transducer	4-6 hours
MW-5D	900	Transducer	4-6 hours
MW-6S	50	Transducer(?)	4-6 hours
MW-6D	450	Transducer(?)	4-6 hours
T347	22	Transducer	4-6 hours
T349S	50	Transducer	4-6 hours
T349D	450	Transducer	4-6 hours
T725	20	Transducer	4-6 hours
T726	50	Transducer	4-6 hours
T727	450	Transducer	4-6 hours
T890	1,500	Transducer	4-6 hours
T891	540	Transducer	4-6 hours
T892	390	Transducer	4-6 hours
T893	1,530	Transducer	4-6 hours
T894	1,270	Transducer	4-6 hours
T895	960	Transducer	4-6 hours
T896	1,601	Transducer	4-6 hours
T897	880	Transducer	4-6 hours
T898	340	Transducer	4-6 hours
T899	1,003	Transducer	4-6 hours
T900	720	Transducer	4-6 hours
T901	190	Transducer	4-6 hours

Well ID	Well Depth (ft)	Groundwater Level Measurement Method	Frequency (during long-term pumping test)
T905	1,500	Transducer	4-6 hours
T906	530	Transducer	4-6 hours
T907	330	Transducer	4-6 hours
T914	1,500	Transducer	4-6 hours
T915	1,088	Transducer	4-6 hours
T902	1,500	Transducer	4-6 hours
T903	800	Transducer	4-6 hours
T904	380	Transducer	4-6 hours
T921	263	Transducer	4-6 hours
T931	62	Transducer	4-6 hours
DELTA W(3)-4 FT	4	Transducer	4-6 hours
DELTA W(3)-10 FT	10	Transducer	4-6 hours
DELTA E(1)-4 FT	4	Transducer	4-6 hours
DELTA E(1)-10 FT	10	Transducer	4-6 hours
DELTA W(1)-4 FT	4	Transducer	4-6 hours
DELTA W(1)-10 FT	10	Transducer	4-6 hours
River Site Lower	515	Transducer	4-6 hours
River Site Upper	230	Transducer	4-6 hours
River Deep Production Well	555	Transducer	4-6 hours
River Shallow Production Well	225	Transducer	4-6 hours
FTS-T1	726	Transducer	4-6 hours
FTS-T2U	154	Transducer	4-6 hours
FTS-T2L	435	Transducer	4-6 hours
FTS-T3	430	Transducer	4-6 hours
FTS-T4	168	Transducer	4-6 hours
FTS-T5	425	Transducer	4-6 hours
FTS-T6	173	Transducer	4-6 hours

Well ID	Well Depth (ft)	Groundwater Level Measurement Method	Frequency (during long-term pumping test)
Keeler-Swansea Lower	390	Transducer	4-6 hours
Keeler-Swansea Middle	190	Transducer	4-6 hours
Keeler-Swansea Upper	135	Transducer	4-6 hours
Star Trek	784	Transducer	4-6 hours
SFIP MW	902	Transducer	4-6 hours
OL-92-2	1,059	Transducer	4-6 hours

Table 6: Vegetated Dune Area and Salt Crust Area Wells to be Monitored if Possible

Well ID	Baseline (1 day before the long-term pumping test)	Method	Frequency (during the long-term pumping test)
C5(2)_4ft	1 manual	Transducer if Practical	4-6 hours
C5(1)_10ft	1 manual	Transducer if Practical	4-6 hours
6(1)_4ft	1 manual	Transducer if Practical	4-6 hours
D.5(1)_10ft	1 manual	Transducer if Practical	4-6 hours
Keeler(1)_10ft	1 manual	Transducer if Practical	4-6 hours
G9(1)_10ft	1 manual	Transducer if Practical	4-6 hours
I10(5)_4ft	1 manual	Transducer if Practical	4-6 hours
J10(1)_10ft	1 manual	Transducer if Practical	4-6 hours
K10(2)_4ft	1 manual	Transducer if Practical	4-6 hours
L9(1)_10ft	1 manual	Transducer if Practical	4-6 hours
M8(1)_10ft	1 manual	Transducer if Practical	4-6 hours
N7(3)_10ft	1 manual	Transducer if Practical	4-6 hours
P5(1)_4ft	1 manual	Transducer if Practical	4-6 hours
S3(3)_10ft	1 manual	Transducer if Practical	4-6 hours
VDA1-1	1 manual	Transducer if Practical	4-6 hours
VDA1-2	1 manual	Transducer if Practical	4-6 hours
VDA2-1	1 manual	Transducer if Practical	4-6 hours

Well ID	Baseline (1 day before the long-term pumping test)	Method	Frequency (during the long-term pumping test)
VDA2-2	1 manual	Transducer if Practical	4-6 hours
VDA3-1	1 manual	Transducer if Practical	4-6 hours
VDA3-2	1 manual	Transducer if Practical	4-6 hours
VDA8-1	1 manual	Transducer if Practical	4-6 hours
VDA8-2	1 manual	Transducer if Practical	4-6 hours

Table 7: Existing Flow Measurement Sites to be Monitored

ID	Flow Monitoring Method	Baseline (1 day before long-term pumping test)	Frequency (during long-term pumping test)	Recovery (10 days after long-term pumping test)	Notes
Cottonwood Flume (W3)	Pressure Transducer	1 manual	Hourly	1 manual	Site # 22
PPG Flume (W4)	Pressure Transducer	1 manual	Hourly	1 manual	Site # 23
Bartlett (W5)	Pressure Transducer	1 manual	Hourly	1 manual	Site # 24

Table 8: Existing LADWP Ground Elevation Monitoring Locations, Monitoring Method and Frequency

Subsidence Monitoring Location ID	General Location	Measurement Method	Frequency (prior to, during and after long-term pumping test)
Primary			
6371	West of OVFZ	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
6372	West of OVFZ	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
6527	East of Owens River Fault	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
6532	East of Owens River Fault	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
7012	Southwest of TW-E	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
Back-Up (if warranted)			
6523	West of Owens River Fault and southeast of TW-E	Survey	Within 1 month prior, at 6 months during, and at 3 and 6 months after, if warranted
6535	East of OVFZ and northwest of TW-E	Survey	Within 1 month prior, at 6 months during, and at 3 and 6 months after, the latter, if warranted
7016	West of Owens River Fault and east-southeast of TW-E	Survey	Within 1 month prior, at 6 months during, and at 3 and 6 months after, the latter, if warranted

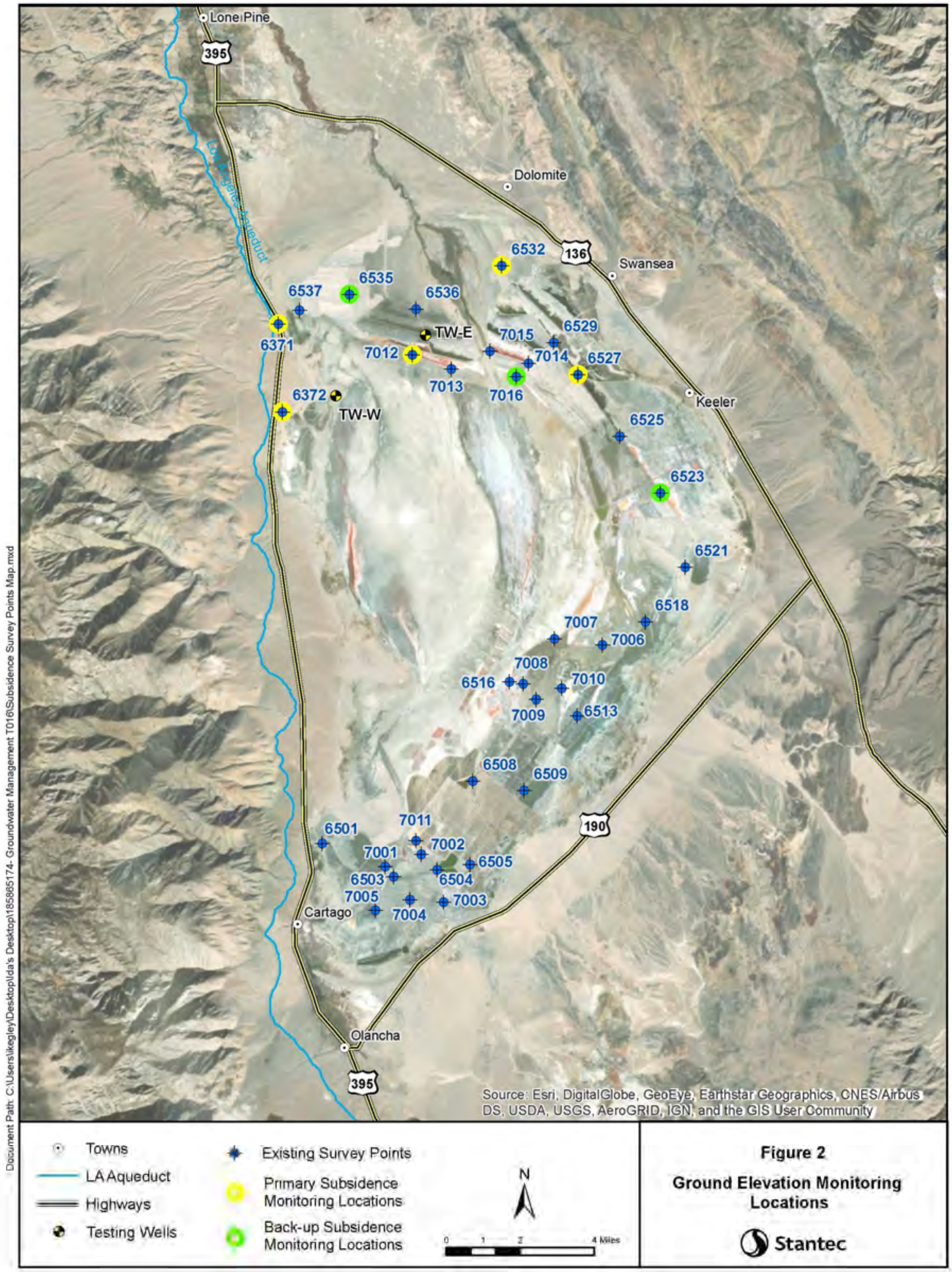

Figure 2: Ground Elevation Monitoring Locations

5.0 DATA ANALYSIS METHODS

Groundwater level and discharge rate data collected at Well TW-E, groundwater level data collected at the above-cited monitoring wells will be analyzed using AQTESOLV, a specialized software authored by HydroSOLVE, Inc. of Reston, Virginia, to calculate specific aquifer hydraulic parameters such as transmissivity, storativity, and hydraulic conductivity at Well TW-E and the wells monitored during the long-term pumping test to the extent possible. Hydrographs of groundwater levels in all wells monitored during this pumping test will be generated. The groundwater model of Owens Lake will also be re-calibrated to simulate the results of the test and improve the accuracy of the model.

6.0 DELIVERABLE

Upon completion of the long-term pumping test analysis a technical memorandum (TM) will be prepared that summarizes the testing performed, the wells monitored, the data collected, and analysis of the data collected including the hydraulic effects of pumping of local fault zones, if observed. The TM will also contain appendices of the data collected as well as the AQTESOLV analyses.

7.0 REFERENCES

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