TerraFirma
Earth Technologies, Ltd

Lake Conroe Dam Relief Well Rehabilitation Pilot Study Project Summary

Client: San Jacinto River Authority
SJRA Project No: LCPR0027.1001.2C006

June 11, 2018

Contents

Introduction

TerraFirma Earth Technologies, Ltd. (TF) was contracted by the San Jacinto River Authority (SJRA) to perform maintenance on three selected relief wells (RW-5, RW-10, and RW-18) along the toe of the Lake Conroe Dam in an effort to collect data to determine the best means and methods for developing a rehabilitation and maintenance program for the other seventeen relief wells.

Scope of Work

The work was broken down into several steps to both rehabilitate the selected relief wells, as well as to gather data on the efficacy of the methods employed in each step. The steps can generally be broken down as follows:

1. Premaintenance Inspection: This included sounding the well, performing a video inspection of the well, measuring the artesian flow, and performing a pump test to determine the specific capacity of the well.
2. Phase 1 – Maintenance
    a. Mechanical Cleaning: This process involved utilizing a double brush to mechanically scrub the interior faces of the casing and screened portions of the relief wells.
    b. Post-Mechanical Inspection: The same activities as the premaintenance inspection were repeated to determine changes in the performance of the well due to the mechanical cleaning process.

c. Chemical Treatment: Each well was treated with a chemical solution prepared utilizing Johnson Nuwell 120 liquid acid and Nuwell 310 acid dispersant. The acid solution was jetted into each well and then surged/agitated utilizing a surge block over a period of four days to allow the solution to remove deposits from the riser and screen as well as the surrounding formation.

3. Phase 2 – Disinfection: A solution of Sodium Hypochlorite (12.5%) and Johnson Nuwell 410 chlorine enhancer was introduced into each well to disinfect them. Upon completion, the wastewater was collected into a holding tank and neutralized with Johnson Nuwell 500 Chlorout prior to being discharged into a ditch as directed by SJRA.

4. Post-Maintenance Inspection: The same activities as the premaintenance inspection were repeated to determine changes in the performance of the well due to the combined mechanical\chemical cleaning process.

Field Operation Summary

TF began field operations on April 18, 2018. Work on the three selected wells was substantially completed by May 14, 2018.

Premaintenance Inspections

We began the process by first performing the video inspection; however, the resulting video showed that the well was filled with growth\deposits which made it difficult to determine the condition of the well riser and screen. It was then determined to perform the initial video inspection of the wells following the initial artesian flow tests and pump tests, to allow for the removal as much debris from the wells as possible, prior to the video inspection.

The initial artesian flow test involved placing a 6” x 5’, SCH 40 PVC riser extension, fitted with a flexible coupling over the relief well, then immediately recording the rate of rise of the groundwater level within the riser extension. Problems were encountered, however, when we were unable to get a proper seal between the riser extension coupling, and the relief well head. The following day we were able to achieve a proper seal by installing a rubber O-ring inside a riser with a rigid Schedule 40 PVC Coupling. The artesian flow test was successfully performed on the 3 wells.

Following the completion of the artesian flow test, the initial pump test was performed on each of the three wells. The specific capacity for each of the three wells was determined to be 0.32 gpm/ft, 0.72 gpm/ft, and 1.20 gpm/ft for wells RW-5, RW-10, and RW-18, respectively.

Following the initial pumping test, it was decided to let each well sit overnight to allow for any suspended particulates to settle prior to performing the video inspection of the well. The video inspection was then successfully performed for each well.

Mechanical Cleaning

Prior to mechanical cleaning, each well was sounded, and the well depth recorded. Mechanical cleaning consisted of brushing of the well casing and screen utilizing a double brush assembly manufactured by Cotey Chemical Corporation. Each well was brushed for 1 minute per foot of screen/riser in 5-foot segments. Brushing of the well was followed up by running a surge block up and down along the well screen surface. A Bobcat S300, fitted with a mast fitted with a variable speed hydraulic hoist, was utilized to run both the brush and the surge block up and down within the well assembly, at the desired speeds. Upon completion of the mechanical brushing/surging, each well was airlifted into a holding tank until reasonably free and clear of debris. The waste water was allowed to settle before the clear water was decanted and discharged into a ditch on-site, as directed by SJRA. Each well was then sounded and the well depth recorded.

Post-Mechanical Inspections

Following the mechanical cleaning of the relief wells, TF performed the post-mechanical inspection of each relief well. This included sounding each well to determine the amount of debris collected in the bottom of each well, artesian flow tests, pump testing for specific capacity, and a video inspection. It was noted for each well that the mechanical cleaning made a significant visual difference in each well during the video inspection.

The specific capacity for each of the three wells was determined to be 0.35 gpm/ft, 0.71 gpm/ft, and 1.34 gpm/ft for wells RW-5, RW-10, and RW-18, respectively.

Chemical Treatment

A solution of Johnson Nuwell acid and acid dispersant was mixed in a 250 gallon tank. Per the spec, we first added 150 gallons of water to the tank, then added 12 gallons of Nuwell 120 liquid acid, followed by 4 gallons of Nuwell 310 acid dispersant. The solution was recirculated through the tank to ensure thorough mixing of the product.

The product was jetted into each relief well utilizing a high-pressure water pump, and high-pressure water supply hose fitted with a conical spray pattern tip. The injection was started at the base of each well. The hose was slowly raised, then lowered the entire length of the well, multiple times. During the injection, the water level in the wells remained below the top of the riser pipe extension. A digital pH meter was utilized to verify that at the end of the injection the pH of each was 3.0, or lower.

After the initial injection of the acid solution a double surge block was slowly raised and lowered in the well to blend the solution throughout the well column. After blending, the speed of the surging action was increased to approximately 3fps. Each well was surged for approximately 2 minutes per foot of screen and 1 minute per foot of casing. Upon completion of the surging action, the pH was again taken and product was re-introduced in the same manner as described above to ensure the well pH was maintained below 3.0.

Over the course of four days, the wells were intermittently agitated in manner described above, during normal working hours. In the original scope, it was planned to perform this work over three days, but also at night. In conjunction with SJRA and Freese and Nichols, it was determined to add a fourth day of agitation, and eliminate the nighttime agitation, due to safety concerns.

On the fourth day, each well was airlifted into a holding tank until reasonably free and clear of debris. Each well was then sounded and the well depth recorded. The holding tank was allowed to sit over the weekend to allow settlement before the wastewater was decanted from the sediment and discharged into the on-site ditch. Sediment was retained in the tank and was disposed of off-site after demobilization from the project.

Post-Maintenance Inspection

Following the chemical cleaning of the relief wells, TF performed the post-maintenance inspection of each relief well. This included sounding each well to determine the amount of debris collected in the bottom of each well, artesian flow tests, pump testing for specific capacity, and a video inspection. The only discrepancy we encountered is that the pump test for RW-10 had to be performed three times. During the first pump test, suction was lost at approximately 27'. The test was performed again using a flowrate of 10gpm. After speaking to SJRA, the test was performed a third time with the suction hose installed to 40' and the test was successfully performed at 20gpm.

The specific capacity for each of the three wells was determined to be 0.52 gpm/ft, 0.79 gpm/ft, and 1.41 gpm/ft for wells RW-5, RW-10, and RW-18, respectively.

Disinfection

A solution of sodium hypochlorite and Nuwell 410 Chlorine Enhancer was prepared to disinfect all each of the three wells to neutralize any remaining contaminates within the wells. The solution was prepared by first filling the holding tank with approximately 620 gallons of water. Next, 2.5 quarts of Nuwell 410 were added to the tank. Finally, one gallon of Sodium Hypochlorite 12.5% was added to the solution. A trash pump was utilized to recirculate the solution during the mixing process to ensure a homogenous blend throughout the solution. Prior to mixing the solution, it was noted that our quantities were generated using the documentation from the manufacturer and differed from those called for in the specifications. We were advised that our quantities were acceptable. Specifically, the amount of Sodium Hypochlorite was adjusted per the manufactures application guide to compensate for a12.5% solution, vs the 5% solution in the specifications, and it was calculated to use 2.5 quarts of Nuwell 410 per the application guide versus the 4 gallons called for in the specification.

Starting at RW-18, the solution was jetted into the well starting at the bottom. The jetting tool was slowly raised as the solution was added. The water level in the riser extension always remained below the top of the extension indicating that the solution was penetrating into the formation surrounding the relief wells. An attempt was made to measure the chlorine concentration at the top of the well using standard pool test strips, however, they did not react to the water. TF consulted Johnson Well Products, and they determined that it was likely that our concentration was too high outside of the range for these strips. As the solution had been mixed to the manufacturers specification, we continued with the disinfection process. Once the solution had been jetted in, a surge block was placed into the well and the solution was blended for 5 minutes to ensure equal distribution of the disinfectant throughout the well. Following this, this procedure was repeated for wells RW-10, and finally RW-5.

Once the solution had been jetted into each relief well, TF began surging the wells in a cyclic manner using our double surge block, surging each for approximately 30 minutes, then repeating this at the subsequent well. After each surge period, the well was topped off with disinfectant solution. This process continued for the remainder of the day.

The following day, each well was surged a final time, then airlifted into a holding tank. Once the discharge water from all wells had been collected, a trash pump was plumbed to allow the water to be recirculated through the tank. Once recirculation had been established, Nuwell 500 Chlorout was added to neutralize the wastewater. Another attempt was made to utilize the test strips to determine the chlorine concentration of the water, but again they did not work. After consulting with SJRA, they contacted one of their personnel who used a colorimeter to measure the chlorine concentration. When a sample was taken from the tank, the meter could not read the sample due to the turbidity of the water. It was decided to allow the tank to settle overnight and retest the next day. Samples from each relief well were taken and tested, each testing well below the 2.0ppm threshold. The next day, another tank sample was taken and tested below the threshold. TF was given clearance to discharge the wastewater into the on-site ditch.

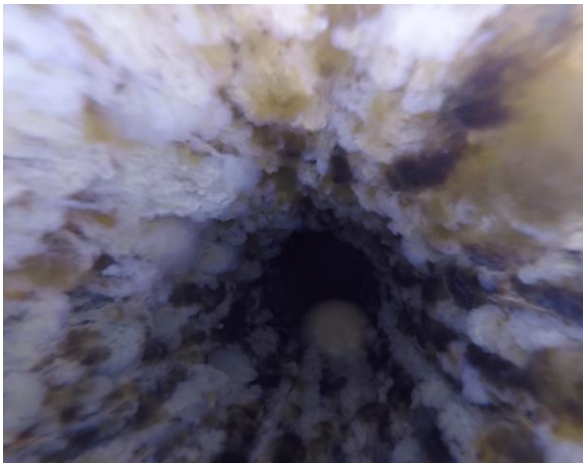
Demobilization

After the completion of the disinfection, TF reinstalled the check valves and covers at each relief well. A survey was made of the work areas to ensure that no trash or tooling was left. All of our equipment and materials were demobilized from the project site over the next two days. The only exceptions were the portable toilet and storage connex. These were picked up by the respective rental companies based on the first availability of their dispatch departments.

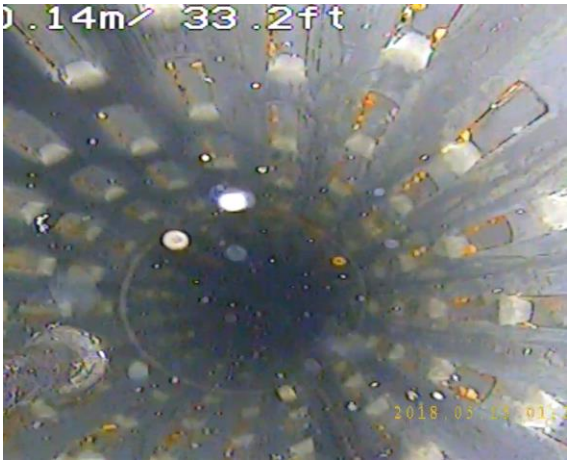
Recommendations

The following are some recommendations based on our experience during this project, and from our experience on other past well rehabilitation and maintenance projects:

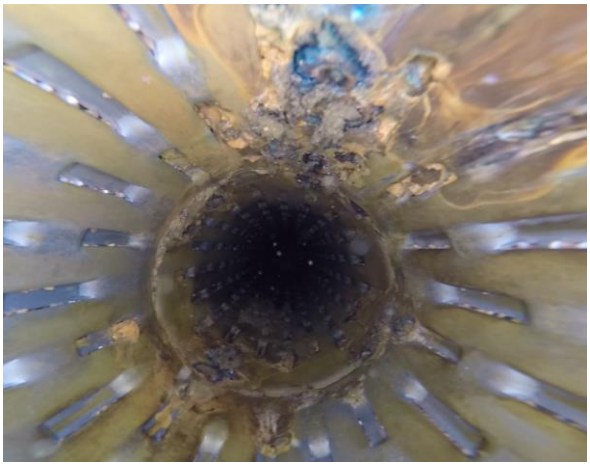
- Mechanical cleaning: We believe the method utilized on this project is an efficient means of dislodging loose deposits and scouring hardened deposits to allow for a more effective chemical treatment. If an annual maintenance program is adopted, this step may not be necessary after the initial treatment, as the deposits will not be as developed.
- Chemical treatment: We believe that this process could be modified to allow for a more cost-effective treatment of the well.
    - We have had effective results utilizing Cotey Chemical Corp's Liquid Acid Descaler product. This produce is easier to use (it is one-part) and more cost efficient.
    - The contact time/surging operations can be shortened to 24-48 hours and remain effective.
- Disinfection: The disinfection of the wells is valuable in that it can help to increase the longevity of the benefits of the treatment.



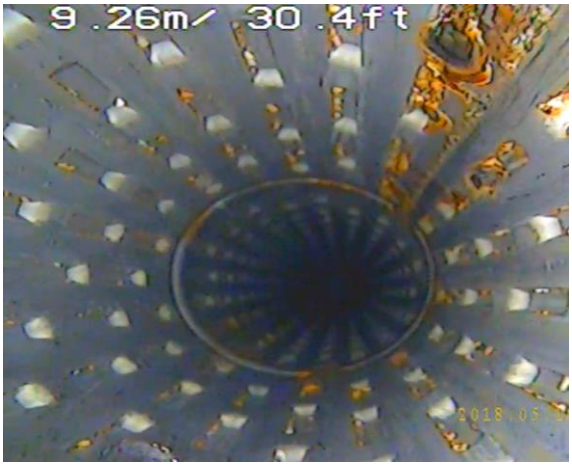
Relief Well 5: Pre-Maintenance



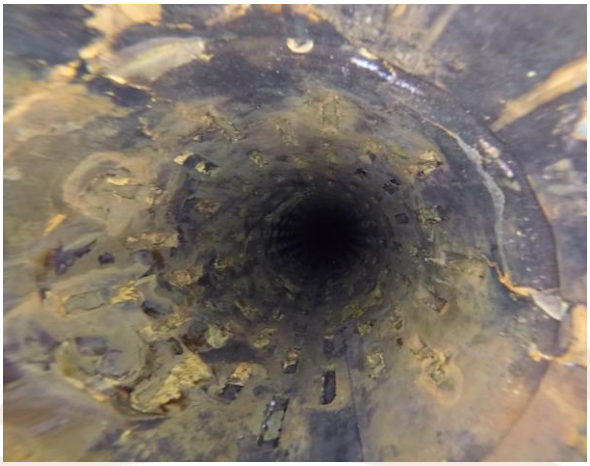
Relief Well 5: Post-Maintenance



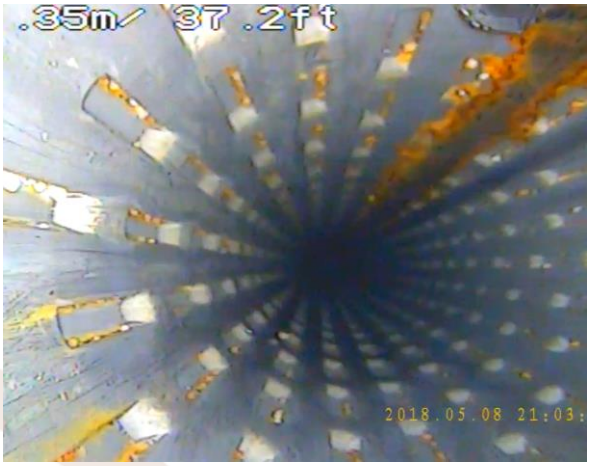
Relief Well 10: Pre-Maintenance (After Pump Test)



Relief Well 10: Post-Maintenance



Relief Well 18: Pre-Maintenance (After Pump Test)



Relief Well 18: Post-Maintenance

Appendix 1: Premaintenance Inspection Reports

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 5
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Pre-Maintenance

General Information

Date:	4/18/2018
Top of Manhole El:	178.5
Top of Casing El:	172.32
Top of Screen El:	152.06
Bottom of Screen El:	132.13
Total Depth:	40.19
Sounded Depth:	40.68
Sounded El:	131.68

Artesian Flow Measurements

Start Time:	11:12AM	Water Outside Casing:	172.6
Inside Casing Readings (EL)			
0:15	169.22	3:00	171.61
0:30	169.48	4:00	172.23
0:45	169.71	5:00	172.74
1:00	169.96	6:00	172.95
1:15	170.21	7:00	173.03
1:30	170.42	8:00	173.1
1:45	170.63	9:00	173.16
2:00	170.84	10:00	173.2

Pump Test

Target GPM:			5	**Start Time:**	8:18AM		**Static:**	174.3	**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	169.42	4.72	**11:00**	160.68	4.82	**21:00**	158.92	5.12	**1:00**	161.51
2:00	167.62	4.48	**12:00**	160.45	4.82	**22:00**	158.79	5.12	**2:00**	164
3:00	165.93	5.72	**13:00**	160.26	4.8	**23:00**	158.7	5.12	**3:00**	166.2
4:00	164.39	4.92	**14:00**	160.11	4.82	**24:00**	158.59	5.12	**4:00**	167.9
5:00	163.54	4.88	**15:00**	159.86	4.8	**25:00**	158.52	5.1	**5:00**	169.32
6:00	162.79	4.88	**16:00**	159.85	4.8	**26:00**	158.46	5.12	**6:00**	170.39
7:00	162.15	4.86	**17:00**	159.78	5.1	**27:00**	158.41	5.12	**7:00**	171.36
8:00	161.66	4.84	**18:00**	159.47	5.14	**28:00**	158.36	5.12	**8:00**	172.09
9:00	161.28	4.84	**19:00**	159.28	5.14	**29:00**	158.33	5.1	**9:00**	172.71
10:00	160.95	4.84	**20:00**	159.09	5.14	**30:00**	158.29	5.1	**10:00**	173.15

Drawdown: 16.01 GPM: 5.10 Specific Capacity: 0.318551 gpm/ft

Notes:

Bailed 3 bailers of water prior to start of artesian flow measurements. Performed initial pump test at 10gpm, but well ran dry. Reduced to 5gpm test.

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 10
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Pre-Maintenance

General Information

Date:	4/18/2018
Top of Manhole El:	178.35
Top of Casing El:	172.27
Top of Screen El:	150.12
Bottom of Screen El:	130.12
Total Depth:	42.15
Sounded Depth(TOM):	42.82
Sounded El:	130.23

Artesian Flow Measurements

Start Time:	1:23PM	Water Outside Casing:	172.9
Inside Casing Readings (EL)			
0:15	172.93	3:00	
0:30	173.21	4:00	
0:45	173.46	5:00	
1:00	173.67	6:00	
1:15	173.82	7:00	
1:30	173.99	8:00	
1:45	174.15	9:00	
2:00	174.25	10:00	

Pump Test

Target GPM:	20		**Start Time:**	1:58PM		**Static:**	174.84		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	163.65	19.75	**11:00**	152.33	15.76	**21:00**	151.9	16.57	**1:00**	158.75
2:00	158.86	19.75	**12:00**	152.35	16.84	**22:00**	151.84	16.63	**2:00**	163.83
3:00	155.78	18.78	**13:00**	152.3	17	**23:00**	151.83	16.59	**3:00**	167.25
4:00	154.43	16.92	**14:00**	152.49	16.98	**24:00**	151.83	16.72	**4:00**	168.95
5:00	153.24	19.23	**15:00**	152.2	17	**25:00**	151.82	16.82	**5:00**	170.25
6:00	152.28	18.34	**16:00**	152.15	18.18	**26:00**	151.85	17.07	**6:00**	171.38
7:00	152.25	17.82	**17:00**	151.91	16.9	**27:00**	151.78	16.92	**7:00**	171.92
8:00	152.27	15.98	**18:00**	151.88	16.72	**28:00**	151.82	16.59	**8:00**	172.44
9:00	152.52	18.11	**19:00**	151.9	16.7	**29:00**	151.77	17	**9:00**	172.77
10:00	152.23	17.65	**20:00**	151.95	16.88	**30:00**	151.75	16.55	**10:00**	173.05

Drawdown: 23.09 GPM 16.55 Specific Capacity: 0.716761 gpm/ft

Notes:

Bailed 3 bailers of water for artesian flow test.

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 18
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Pre-Maintenance

General Information

Date:	4/18/2018
Top of Manhole El:	178.55
Top of Casing El:	172.44
Top of Screen El:	154.08
Bottom of Screen El:	122.13
Total Depth:	50.31
Sounded Depth(TOM):	50.34
Sounded El:	122.1

Artesian Flow Measurements

Start Time:	3:17PM	Water Outside Casing:	172.57
Inside Casing Readings (EL)			
0:15	173.51	3:00	175.42
0:30	173.98	4:00	175.53
0:45	174.29	5:00	175.62
1:00	174.67	6:00	
1:15	174.85	7:00	
1:30	174.94	8:00	
1:45	175.06	9:00	
2:00	175.16	10:00	

Pump Test

Target GPM:	20		**Start Time:**	3:35PM		**Static:**	175.93		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	172.89	3.54	**11:00**	160.01	20.76	**21:00**	159.22	20.62	**1:00**	167.8
2:00	167.19	21.43	**12:00**	159.86	20.72	**22:00**	159.11	20.58	**2:00**	170.96
3:00	164.1	20.12	**13:00**	159.76	20.66	**23:00**	159.1	20.58	**3:00**	172.37
4:00	162.82	19.98	**14:00**	159.7	20.66	**24:00**	159.09	20.56	**4:00**	173.21
5:00	162.17	19.94	**15:00**	159.61	20.62	**25:00**	159.04	20.56	**5:00**	173.63
6:00	161.74	19.88	**16:00**	159.56	20.68	**26:00**	159	20.54	**6:00**	173.93
7:00	160.92	20.79	**17:00**	159.43	20.66	**27:00**	158.93	20.54	**7:00**	174.17
8:00	160.51	20.79	**18:00**	159.36	20.72	**28:00**	158.92	20.54	**8:00**	174.41
9:00	160.36	20.66	**19:00**	159.32	20.64	**29:00**	158.89	20.54	**9:00**	174.48
10:00	160.16	20.72	**20:00**	158.38	20.64	**30:00**	158.84	20.52	**10:00**	174.63

Drawdown: 17.09 GPM: 20.52 Specific Capacity: 1.200702 gpm/ft

Notes:

Appendix 2: Post-Mechanical Inspection Reports

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 5
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Mechanical

General Information

Date:	4/23/2018
Top of Manhole El:	178.5
Top of Casing El:	172.32
Top of Screen El:	152.06
Bottom of Screen El:	132.13
Total Depth:	40.19
Sounded Depth(TOM):	40.69
Sounded El:	131.67

Artesian Flow Measurements

Start Time:	8:54AM	Water Outside Casing:	172.6
Inside Casing Readings (EL)			
0:15	173.1	5:00	173.59
0:30	173.22	6:00	173.6
0:45	173.24	7:00	173.61
1:00	173.31	8:00	173.61
2:00	173.42	9:00	173.62
3:00	173.49	10:00	173.63
4:00	173.54		
5:00	173.57		

Pump Test

Target GPM:	5		**Start Time:**	9:48AM		**Static:**	174.2		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	169.74	4.88	**11:00**	161.05	5.1	**21:00**	159.78	5.04	**1:00**	
2:00	168	4.967	**12:00**	160.7	5.08	**22:00**	159.67	5.06	**2:00**	
3:00	166.57	4.92	**13:00**	160.58	5.06	**23:00**	159.63	5.04	**3:00**	
4:00	165.32	4.88	**14:00**	160.37	5.08	**24:00**	159.69	5.04	**4:00**	
5:00	164.37	4.88	**15:00**	160.17	5.14	**25:00**	159.67	5.1	**5:00**	
6:00	163.48	4.23	**16:00**	160.07	5.16	**26:00**	159.62	5.14	**6:00**	
7:00	162.8	5.1	**17:00**	159.92	5.16	**27:00**	159.54	5.14	**7:00**	
8:00	162.26	5.1	**18:00**	159.88	5.06	**28:00**	159.52	5.16	**8:00**	
9:00	161.83	5.1	**19:00**	159.8	4.92	**29:00**	159.6	5.14	**9:00**	
10:00	161.37	5.1	**20:00**	159.91	5.04	**30:00**	159.56	5.14	**10:00**	

Drawdown: 14.64 GPM: 5.14 Specific Capacity: 0.351093 gpm/ft

Notes:

pH: 7.83

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 10
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Mechanical

General Information

Date:	4/23/2018
Top of Manhole El:	178.35
Top of Casing El:	172.27
Top of Screen El:	150.12
Bottom of Screen El:	130.12
Total Depth:	42.15
Sounded Depth(TOM):	42.14
Sounded El:	130.13

Artesian Flow Measurements

Start Time:	11:15am	Water Outside Casing:	173.49
Inside Casing Readings (EL)			
0:15	173.63	6:00	175.19
0:30	173.89	7:00	175.25
0:45	174.13	8:00	175.27
1:00	174.55	9:00	175.28
2:00	174.76	10:00	175.32
3:00	174.93	11:00	175.34
4:00	174.94	12:00	175.34
5:00	175.13	13:00	175.34

Pump Test

Target GPM:	20		**Start Time:**	11:40AM		**Static:**	175.06		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	170.42	20	**11:00**	150.29	19.26	**21:00**	148.94	18.38	**1:00**	158.22
2:00	167.03	20	**12:00**	150	18.54	**22:00**	148.99	18.56	**2:00**	163.38
3:00	164.54	18.5	**13:00**	149.77	18.78	**23:00**	149	18.5	**3:00**	166.39
4:00	158.96	19.88	**14:00**	149.51	19.02	**24:00**	149.01	19	**4:00**	168.6
5:00	157.06	19.85	**15:00**	149.26	19.21	**25:00**	149.02	18.58	**5:00**	170.02
6:00	158.58	19.85	**16:00**	149.16	18.69	**26:00**	149.06	18.36	**6:00**	170.9
7:00	157.63	20.1	**17:00**	149.09	18.69	**27:00**	149.06	18.82	**7:00**	171.58
8:00	153.99	20.16	**18:00**	149.06	19.02	**28:00**	149	18.58	**8:00**	172.14
9:00	151.97	19.62	**19:00**	148.95	18.67	**29:00**	149.02	18.54	**9:00**	172.59
10:00	150.91	19.42	**20:00**	148.9	18.69	**30:00**	148.95	18.67	**10:00**	172.9

Drawdown: 26.11 GPM: 18.67 Specific Capacity: 0.715052 gpm/ft

Notes:

pH 8.3

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 18
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Mechanical

General Information

Date:	4/23/2018
Top of Manhole El:	178.55
Top of Casing El:	172.44
Top of Screen El:	154.08
Bottom of Screen El:	122.13
Total Depth:	50.31
Sounded Depth(TOM):	50.34
Sounded El:	122.1

Artesian Flow Measurements

Start Time:	1:52PM	Water Outside Casing:	173.2
Inside Casing Readings (EL)			
0:15	173.74	6:00	175.25
0:30	173.84	7:00	175.28
0:45	174.2	8:00	175.31
1:00	174.36	9:00	175.32
2:00	174.85	10:00	175.35
3:00	175.04	11:00	175.35
4:00	175.17	12:00	175.39
5:00	175.23	13:00	175.39

Pump Test

Target GPM:	10		**Start Time:**	2:26PM		**Static:**	175.66		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	169.76	7.18	**11:00**	168.64	10.77	**21:00**	164.91	14.5	**1:00**	170.58
2:00	170.59	8.06	**12:00**	168.46	10.95	**22:00**	-1275.59	14.55	**2:00**	173.04
3:00	171.89	4.28	**13:00**	167.61	12.88	**23:00**	164.83	14.58	**3:00**	173.77
4:00	172.52	4.8	**14:00**	166.53	13.48	**24:00**	164.79	14.62	**4:00**	174.13
5:00	172.77	4.8	**15:00**	165.93	13.85	**25:00**	164.7	14.71	**5:00**	174.47
6:00	172.86	4.85	**16:00**	165.56	14.12	**26:00**	164.69	14.72	**6:00**	174.69
7:00	172.85	10.83	**17:00**	165.29	14.23	**27:00**	164.61	14.8	**7:00**	174.81
8:00	170.54	11.1	**18:00**	165.18	14.31	**28:00**	164.59	14.82	**8:00**	174.88
9:00	169.38	11.02	**19:00**	165.1	14.48	**29:00**	164.5	14.91	**9:00**	174.96
10:00	168.91	11.02	**20:00**	164.93	14.48	**30:00**	164.51	14.9	**10:00**	175.06

Drawdown: 11.15 GPM: 14.90 Specific Capacity: 1.336323 gpm/ft

Notes:

Appendix 3: Post-Maintenance Inspection Reports

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 5
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Maintenance

General Information

Date:	5/7/2018
Top of Manhole El:	178.5
Top of Casing El:	172.32
Top of Screen El:	152.06
Bottom of Screen El:	132.13
Total Depth:	40.19
Sounded Depth(TOM):	40.71
Sounded El:	131.64

Artesian Flow Measurements

Start Time:	5/9/18 1:03pm	Water Outside Casing:	172.63
Inside Casing Readings (EL)			
0:15	172.82	3:00	173.61
0:30	172.91	4:00	173.73
0:45	173	5:00	173.79
1:00	173.05	6:00	173.8
1:15	173.08	7:00	173.8
1:30	173.15	8:00	
1:45	173.19	9:00	
2:00	173.34	10:00	

Pump Test

Target GPM:	5		**Start Time:**	5:36PM		**Static:**	174.37		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	170	5.2	**11:00**	164.07	5.33	**21:00**	163.77	5.29	**1:00**	
2:00	168.65	5.16	**12:00**	164.05	5.33	**22:00**	163.71	5.29	**2:00**	
3:00	167.79	5.12	**13:00**	163.97	5.33	**23:00**	163.66	5.29	**3:00**	
4:00	166.97	5.06	**14:00**	163.92	5.39	**24:00**	163.61	5.33	**4:00**	
5:00	166.32	5.1	**15:00**	163.88	5.31	**25:00**	163.57	5.4	**5:00**	
6:00	165.09	5.36	**16:00**	163.86	5.39	**26:00**	163.41	5.52	**6:00**	
7:00	164.77	5.38	**17:00**	163.81	5.31	**27:00**	163.31	5.78	**7:00**	
8:00	164.49	5.36	**18:00**	163.78	5.29	**28:00**	163.17	5.97	**8:00**	
9:00	164.31	5.33	**19:00**	163.77	5.31	**29:00**	163	5.93	**9:00**	
10:00	164.12	5.36	**20:00**	163.77	5.29	**30:00**	163	5.93	**10:00**	

Drawdown: 11.37 GPM 5.93 Specific Capacity: 0.521548 gpm/ft

Notes:

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 10
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Maintenance

General Information

Date:	5/7/2018
Top of Manhole El:	178.35
Top of Casing El:	172.27
Top of Screen El:	150.12
Bottom of Screen El:	130.12
Total Depth:	42.15
Sounded Depth:	42.51
Sounded El:	128.94

Artesian Flow Measurements

Start Time:	1:20pm	Water Outside Casing:	173.6
Inside Casing Readings (EL)			
0:15	179.17	3:00	174.47
0:30	173.34	4:00	174.58
0:45	173.72	5:00	174.67
1:00	173.89	6:00	174.72
1:15	173.96	7:00	174.72
1:30	174.05	8:00	
1:45	174.21	9:00	
2:00	174.29	10:00	

Pump Test

Target GPM:	20		**Start Time:**	10:30AM		**Static:**	174.28		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	163.7	18.71	**11:00**	152.41	18.22	**21:00**	151.89	17.8	**1:00**	160.18
2:00	158.86	20.22	**12:00**	152.27	18.28	**22:00**	151.81	17.94	**2:00**	164.92
3:00	156.05	19.94	**13:00**	152.25	18.11	**23:00**	151.79	17.88	**3:00**	168.4
4:00	154.72	19.52	**14:00**	152.2	18	**24:00**	151.78	17.8	**4:00**	169.4
5:00	153.97	19.06	**15:00**	152.18	18.07	**25:00**	151.8	17.78	**5:00**	170.51
6:00	153.55	18.9	**16:00**	152.12	18.02	**26:00**	151.77	17.78	**6:00**	171.28
7:00	153	18.79	**17:00**	152.06	17.78	**27:00**	151.77	17.8	**7:00**	171.92
8:00	152.76	18.54	**18:00**	152.08	18	**28:00**	151.69	17.8	**8:00**	172.43
9:00	152.67	18.6	**19:00**	151.99	18.06	**29:00**	151.71	17.8	**9:00**	172.92
10:00	152.48	18.38	**20:00**	151.91	17.96	**30:00**	151.68	17.86	**10:00**	173.15

Drawdown: 22.6 GPM: 17.86 Specific Capacity: 0.790265 gpm/ft

Notes:

First two pump tests ran dry (max drawdown to 27.68'). Reran test at 10 gpm. Reran again at 20gpm with suction hose down to 40' and were able to complete. We believe the suction hose broke suction at 27' on first two tests.

TerraFirma
Earth Technologies, Ltd

Job No: 480680
Well No: 18
Project: Lake Conroe Dam Relief Well Rehab Pilot
Client: San Jacinto River Authority

Relief Well Inspection Report

Post-Maintenance

General Information

Date:	5/7/2018
Top of Manhole El:	178.55
Top of Casing El:	172.44
Top of Screen El:	154.08
Bottom of Screen El:	122.13
Total Depth:	50.31
Sounded Depth(TOM):	50.22
Sounded El:	122.22

Artesian Flow Measurements

Start Time:	10:15AM	Water Outside Casing:	173.28
Inside Casing Readings (EL)			
0:15	174.27	3:00	175.06
0:30	174.49	4:00	175.07
0:45	174.67	5:00	
1:00	174.78	6:00	
1:15	174.87	7:00	
1:30	174.94	8:00	
1:45	174.97	9:00	
2:00	175.02	10:00	

Pump Test

Target GPM:	20		**Start Time:**	10:55AM		**Static:**	175.31		**Recovery Data**	
Time	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**	**GPM**	**Time**	**Waterlevel**
1:00	166.86	20.04	**11:00**	161.89	20.6	**21:00**	161.31	20.42	**1:00**	
2:00	164.89	22.4	**12:00**	161.61	20.56	**22:00**	161.25	20.35	**2:00**	
3:00	163.89	20.68	**13:00**	161.775	20.385	**23:00**	161.13	20.25	**3:00**	
4:00	163.37	20.64	**14:00**	161.68	20.5	**24:00**	161.11	20.46	**4:00**	
5:00	163.21	20.62	**15:00**	161.61	20.44	**25:00**	161.1	20.33	**5:00**	
6:00	162.71	20.58	**16:00**	161.59	20.5	**26:00**	161.06	20.24	**6:00**	
7:00	163.32	20.56	**17:00**	161.52	20.4	**27:00**	161.11	20.18	**7:00**	
8:00	162.3	20.54	**18:00**	161.46	20.4	**28:00**	161.11	20.1	**8:00**	
9:00	162.18	20.52	**19:00**	161.39	20.44	**29:00**	161.09	20.16	**9:00**	
10:00	161.98	20.52	**20:00**	161.18	20.44	**30:00**	161.1	20.1	**10:00**	

Drawdown: 14.21 GPM 20.10 Specific Capacity: 1.414497 gpm/ft

Notes:

Appendix 4: Relief Well Maintenance Logs

TerraFirma
Earth Technologies, Ltd

Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-5

Date	Time	Activity
4/18/2018	10:30am	started video inspection
4/18/2018	10:38am	sound well from top of manhole 46.82'
4/18/2018	11:10am	started flow test
4/18/2018	11:32am	restarted flow test
4/18/2018	11:45am	video inspection
4/19/2018	10:38am	try to seal extentsion
4/19/2018	11:12am	started flow test
4/19/2018	11:23am	end of flow test
4/19/2018	12:15pm	pump test set-up
4/19/2018	12:26pm	Stop pump test, ran dry
4/20/2018	8:18am	start pump test 2 at 5gpm
4/20/2018	8:48am	end pump test
4/20/2018	11:52am	set-up decon equipment
4/20/2018	11:55am	started brushing well
4/20/2018	12:57pm	end brushing of well
4/20/2018	2:50pm	began air lift
4/20/2018	3:10pm	stop air lift
4/23/2018	8:54am	started artisian flow test
4/23/2018	9:15am	end of artisian flow test
4/23/2018	9:48am	pump test
4/23/2018	10:30am	ph= 7.83
4/30/2018	5:00pm	induced product to well
5/1/2018	7:30am	jetted well with product
5/1/2018	9:30am	re-jetted well with product
5/2/2018	10:10am	induce product
5/2/2018	10:30am	ph level 2.71
5/2/2018	1:08pm	began surge
5/2/2018	1:57pm	end surge
5/2/2018	2:24pm	ph= 7.23
5/2/2018	2:40pm	ph= 2.97
5/2/2018	2:50pm	began brush
5/2/2018	4:15pm	end brush
5/2/2018	4:17 PM	ph= 5.70
5/3/2018	1:50pm	ph= 2.45
5/3/2018	2:00pm	began surge at screen
5/3/2018	2:15pm	end surge
5/3/2018	2:18pm	ph=3.75
5/3/2018	3:40pm	began brushing at the screen
5/3/2018	4:00pm	end brushing
5/3/2018	6:13pm	ph=4.65
5/3/2018	6:21pm	induced product
5/3/2018	6:26pm	ph=3.37

TerraFirma
Earth Technologies, Ltd

Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-5

Date	Time	Activity
5/3/2018	6:27pm	induce product
5/3/2018	6:32pm	3.31 (calibration off)
5/3/2018	6:36pm	began surge
5/3/2018	7:00pm	end surge
5/4/2018	8:30am	ph=4.22
5/4/2018	9:30am	airlift into tank
5/4/2018	10:34am	end airlift
5/4/2018	10:40am	ph= 6.6
5/7/2018	5:15PM	perform artesian flow test
5/7/2018	5:22pm	end flow test
5/7/2018	5:36pm	pump test start time
5/7/2018	6:10pm	test end time
5/8/2018	11:05am	induce product
5/8/2018	11.35am	end of inducing product
5/8/2018	12:30pm	began to agitate in screen
5/8/2018	12:41pm	end of agitation
5/8/2018	2:35pm	began swabbing at screen (5' for 5min.0
5/8/2018	3:00pm	end of swabbing
5/8/2018	3:05pm	top off with product
5/8/2018	4:50pm	began swabbing at screen (5' for 5min.0
5/8/2018	5:10pm	enf of swabbing
5/8/2018	5:13pm	top of with product
5/9/2018	10:13am	swab well
5/9/2018	10:45am	end swabbing
5/9/2018	11:13am	airlift into tank
5/9/2018	4:28pm	mixed chlorout into tank (approx 2lbs)
5/10/2018	8:00am	tested for chlorine levels in 1000 gallon tank (test strips not working)
5/10/2018	8:30am	let water settle in 2000 gal., tank for discharge
5/11/2018	10:00am	Shane tested, chlorine below threshold, discharge water into ditch as directed

TerraFirma
Earth Technologies, Ltd

Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-10

Date	Time	Activity
4/18/2018	12:50pm	opened manhole, took photographs. T.O.M.to static 5.62
4/18/2018	12:55pm	removed check valve
4/18/2018	1:03pm	sounded well- 48.115'=130.24
4/18/2018	1:15pm	started flow test. Top of riser to static 6.23'. Bailed 3x. Static recharged @5.30'per chuck FNI.
4/18/2018	1:23pm	go another round. 15 second intervals to 2 minutes
4/18/2018	1:58pm	started pump test
4/18/2018	2:28pm	ended pump test. Begin recovery recharge
4/18/2018	2:40pm	pump well to clear well from slime for video
4/18/2018	2:43pm	stop pumping
4/18/2018	2:45pm	replace check valve/manhole cover
4/19/2018	9:45am	began video inspection
4/19/2018	9:55am	end video inspection
4/19/2018	3:31pm	no airlift before brushing well
4/20/2018	9:19am	set-up brushing and disinfected brush
4/20/2018	9:29am	started brushing 5' for 5 mins.
4/20/2018	10:40am	end brushing
4/20/2018	11:35am	post brush sounding T.O.M. to B.O.M. 48.15'
4/20/2018	1:34pm	started airlift
4/20/2018	1:53pm	stop airlift. Per chuck, bail for well recovery and airlift more.
4/20/2018	2:10pm	resume airlift
4/20/2018	2:17pm	stop airlift
4/23/2018	11:00am	post mechanical test T.O.M.- 5.64'; D.T.W.- 48.22. static 3.89'
4/23/2018	11:15am	started artisan flow test
4/23/2018	11:20am	end artisan flow test
4/23/2018	11:40am	started pump test
4/23/2018	11:47am	end pump test
4/23/2018	11:48am	moved down to 10 gpm for pump test from 20 gpm back to 20 gpm.
4/23/2018	12:10pm	start pump test
4/23/2018	12:30pm	end pump test
4/30/2018	6:00pm	induced product into well
5/1/2018	8:30am	jetted well with product
5/1/2018	8:45am	end of jetting product
5/1/2018	9:00am	started surging
5/1/2018	9:23am	end of surge
5/1/2018	11:00am	added more product to well
5/2/2018	11:12am	began to surge well
5/2/2018	12:00noon	end of surge
5/2/2018	4:35pm	ph- 6.7
5/2/2018	4:39pm	induce product
5/2/2018	4:44pm	end of inducing product
5/2/2018	4:47pm	started brushing
5/2/2018	5:39pm	end of brushing
5/2/2018	5:41pm	induce product
5/2/2018	5:49pm	end of inducing products

TerraFirma
Earth Technologies, Ltd

Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-10

Date	Time	Activity
5/2/2018	5:50pm	ph=2.78
5/3/2018	1:00pm	induce product ph=6.61 before; 2.1 after
5/3/2018	1:14pm	begin surge at screen 15 mins,
5/3/2018	1:30pm	end surge
5/3/2018	3:04pm	ph=2.83
5/3/2018	3:11pm	begin brushing@screen for 20 mins.
5/3/2018	3:32pm	end brush
5/3/2018	3:35pm	ph=6.07
5/3/2018	5.26pm	ph=6.14
5/3/2018	5:29pm	induce product
5/3/2018	5:33pm	ph=2.58
5/3/2018	5:38pm	begin surge @ screen for 20 mins.
5/3/2018	6:04pm	end surge ph= 6.38
5/4/2018	10:48am	ph=6.9
5/4/2018	10:50am	begin airlift
5/4/2018	11:24am	end airlift
5/7/2018	1:20pm	Begin artesian flow test
5/7/2018	1:35pm	Begin pump test
5/7/2018	1:45pm	pump test ended, lost prime at 27.69'
5/8/2018	9:08am	video inspection
5/8/2018	9:36am	induce product
5/8/2018	10.23am	end of inducing product
5/8/2018	10:29am	begin swabbing
5/8/2018	10:45am	end of swabbing
5/8/2018	1:54pm	begin to swab @ screen
5/8/2018	2:24pm	end of swabbing
5/8/2018	4:10pm	begin swabbing @screen 5 for 5mins.
5/8/2018	4:35pm	end of swabbing
5/8/2018	4:40pm	top off with product
5/9/2018	9:32am	swab well
5/9/2018	10:03am	end swabbing
5/9/2018	12:45pm	airlift into tank
5/10/2018	8:00am	tested for chlorine levels in 1000 gallon tank (test strips not working)
5/10/2018	8:30am	let water settle in 2000 gal., tank for discharge
5/11/2018	10:00am	Shane tested, chlorine below threshold, discharge water into ditch as directed
5/14/2018	10:30am	redo pump test at 20gpm with suction hose set at 40'

TerraFirma
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Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-18

Date	Time	Activity
4/18/2018	2:59pm	remove cover, photograph manhole, remove check valve
4/18/2018	3:01pm	measuring depth to water (static) 5.86'
4/18/2018	3:03pm	depth to bottom from T.O.M. 56.45'
4/18/2018		bottom of well 122.1
4/18/2018	3:10pm	installed extension. Depth to water static 6.51'
4/18/2018	3:16pm	h20-3.45'. Riser 6.3 above T.O.M.
4/18/2018	3:17pm	begin artisian flow test. Bail 6x and record recovery rise every 15 sec.
4/18/2018	3:31pm	end of flow test
4/18/2018	3:35pm	set up pump test. T.O.C. .86' above T.O.M.
4/18/2018	4:05pm	pump test end, start recovery test
4/18/2018	4:15pm	end recovery measurements
4/19/2018	9:28am	begin video inspection
4/19/2018	9:35am	end video inspection
4/19/2018	1:30pm	ph test =7.33
4/19/2018	1:50pm	begin swabbing
4/19/2018	2:26pm	end swabbing
4/19/2018	2:30pm	decon airlift equipment
4/20/2018	9:40am	setup and decon equipment
4/20/2018	10:07am	started airlift
4/20/2018	10:12am	setup airlift, setup 2k tank on trailer
4/20/2018	12:01pm	restart airlift
4/20/2018	12:15pm	stop airlift
4/20/2018	1:16pm	start airlift with riser
4/20/2018	1:19pm	stop airlift, clean up per chuck
4/23/2018	1:52pm	started artisian flow test
4/23/2018	2:12pm	end of artisian flow test
4/23/2018	2:26pm	start of pump test; 5.88 T.O.M. 10 gpm; static 3.75'
4/23/2018	2:57pm	end of pump test
4/23/2018	2:58pm	start of recovery flow rate
4/23/2018	3:18pm	end of recovery flow rate
4/30/2018	8:30am	setup equipment
4/30/2018	11:00am	mixing product
4/30/2018	12:30pm	inducing product to well
4/30/2018	1:00pm	ph= 3.0
4/30/2018	1:10pm	surging well
4/30/2018	1:40pm	end of surging well
5/1/2018	12:01pm	inducing product to well
5/1/2018	12:30pm	end of jetting product in well
5/2/2018	8:00am	ph-6.74
5/2/2018	8:30am	mix product

TerraFirma
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Well Maintenance Log

Project: Lake Conroe Dam Relief Well Rehabilitation Pilot Study
Client: San Jacinto River Authority
Well: RW-18

Date	Time	Activity
5/2/2018	8:45am	begin inducing product to well
5/2/2018	9:10am	ph=2.79
5/2/2018	10:35am	begin to surge well; 5 for 5mins.
5/2/2018	11:00am	end of surge
5/3/2018	11:02am	induce product
5/3/2018	11:07am	end of inducing product
5/3/2018	11:10am	ph=2.50
5/3/2018	11:18am	begin swabbing @ screen 5 for 5mins.
5/3/2018	11:34am	end of swabbing
5/3/2018	11:39am	ph=6.45
5/3/2018	2:34pm	ph=6.6
5/3/2018	2:38pm	begin brush @screen 20' for 15mins.
5/3/2018	2:55pm	end of brush
5/3/2018	4:23pm	ph-7.0
5/3/2018	4:33pm	inducing product to well
5/3/2018	4:36pm	end of inducing product
5/3/2018	4:45pm	begin surge @screen 15 mins.
5/3/2018	5:07pm	end of surge
5/4/2018	12:30pm	ph-7.17
5/4/2018	12:35pm	induce product
5/4/2018	1:00pm	end of inducing product
5/4/2018	2:00pm	ph 6.5
5/4/2018	2:05pm	began swabbing
5/4/2018	2:55pm	end of swabbing
5/4/2018	3:00pm	began swabbing @screen
5/4/2018	3:00pm	end of swabbing @screen
5/4/2018	3:30pm	began swabbing @screen
5/4/2018	3:35pm	top off with prduct
5/4/2018	3:45pm	began airlift
5/4/2018	4:20pm	end of airlift into 2k gallon tank
5/7/2018	10:00am	began video inspection
5/7/2018	10:15am	began artisian flow test
5/7/2018	10:55am	began pump test
5/7/2018	11:25am	end of pump test
5/8/2018	6:30am	mixed product (approx 620gal water, 1gal sod hyp, 2.5qt nuwell 410)
5/8/2018	7:30am	began inducing product
5/8/2018	8:30am	end inducing product (test strips dot working or reading ppm.)
5/8/2018	8:45am	began swabbing/agitate/surge
5/8/2018	8:50am	end swabbing
5/8/2018	12:52pm	began swabbing 5 min for 5 ft. (30mins.)

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Well Maintenance Log

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Date	Time	Activity
5/8/2018	1:44pm	end swabbing
5/8/2018	1:45pm	top off with product (chiorine)
5/8/2018	3:21pm	began swabbing (30 mins)
5/8/2018	4:01pm	end swabbing
5/9/2018	8:46am	swab well
5/9/2018	9:16am	end swabbing
5/9/2018	2:36pm	airlift into tank
5/9/2018	4:28pm	mixed chlorout into tank (approx 2lbs)
5/10/2018	8:00am	tested for chlorine levels in 1000 gallon tank (test strips not working)
5/10/2018	8:30am	let water settle in 2000 gal., tank for discharge
5/11/2018	10:00am	Shane tested, chlorine below threshold, discharge water into ditch as directed