National Groundwater Monitoring Network Award Number 2000012392

Texas Water Development Board

# Final Report for Texas Water Development Board Expansion of Services and Well Maintenance Activities for the National Ground-Water Monitoring Network

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# Table of Contents


1.0 Background ... 1

2.0 Summary of Findings ... 2

3.0 Objective 1: Wells Added to the NGWMN ... 5

4.0 Objective 4: Well Maintenance Activities ... 12

3.1 Discussion ... 14

3.2 Detailed activities at each site ... 17

Burnet 5809303 ... 17

Comal 6807407 ... 20

Dallas 3319101 ... 22

Karnes 7910406 ... 25

Milam 5911621 ... 28

Presidio 5129805 ... 30

Reeves 4661201 ... 33

Williamson 5829603 ... 35

Zavala 7702509 ... 39


# List of Figures


Figure 1. Locations of NGWMN wells with oil investigated under this project. ... 3

Figure 2. Blaine Aquifer wells added to NGWMN. ... 9

Figure 3. Rio Grande Aquifer Complex wells added to the NGWMN. ... 10

Figure 4. High Plains Aquifer wells added to the NGWMN. ... 11

Figure 5. Location map for Burnet County recorder well 5809303. ... 18

Figure 6. Absorbent pad after deployment in Burnet 5809303. ... 19

Figure 7. Oil and water recovered from Burnet 5809303. ... 20

Figure 8. Location map for Comal County recorder well 6807407. ... 21

Figure 9. Comal recorder well head ... 22

Figure 10. Absorbent pads after soaking in Comal recorder well. ... 22

Figure 11. Location map for Dallas County recorder well 3319101. ... 23

Figure 12 (left). Dallas recorder well, showing uncovered well opening ... 24

Figure 13 (right). Oil sample collected from Dallas recorder. 24
Figure 14. Location map for Karnes County recorder well 7910406. 26
Figure 15. Karnes recorder well location. 27
Figure 16. Float from the Karnes well 27
Figure 17 (left). Used pads and recovered oil. 27
Figure 18 (right) Modified bailer with 3-inch orifice. 27
Figure 19. Tarry material on the transducer from the Milam recorder well. 28
Figure 20. location map for Milam County recorder well 5911621. 29
Figure 21. Location map for Presidio County Recorder well 5129805. 31
Figure 22. Presidio recorder well location. 32
Figure 23 (left). Dark oil on the interface meter tape. 32
Figure 24 (right). 3-inch bailer with oil recovered from the Presidio recorder well. 32
Figure 25. location map for Reeves County recorder well 4661201. 34
Figure 26. Reeves well head completion 35
Figure 27. Oil recovered from Reeves well. 35
Figure 28. Diesel engine previously used on Reeves well. 35
Figure 29. Location map for Williamson County recorder well 5829603. 36
Figure 30 to 33. Absorbent pads after and before deployment in the well, modified bailer coated in oil; and oil water mixture recovered from the well. 38
Figure 34 and 35. Absorbent pads cut into mop configuration (left) and oil film on water recovered after oil removal (right). 39
Figure 36. Location map for Zavalla County recorder well 7702509. 40
Figures 37 (left) and 38 (right). Oil recovered on 5/5/21 using product-only bailer and oil recovered on 7/7/21 using 3-inch bailer. 42

## List of Tables

Table 1. NGWMN wells with floating oil 4
Table 2. Summary data on Blaine Aquifer wells added to the NGWMN. 6
Table 3. Summary data on Rio Grande Aquifer Complex wells added to the NGWMN. 8
Table 4. Summary of oil type and condition by well. 13

## 1.0 Background

As part of National Groundwater Monitoring Network (NGWMN) Award Number 2000012392, the Texas Water Development Board (TWDB) conducted activities under Objective 1, adding new wells to the network, and under Objective 4, performing maintenance work on existing wells in the network.

Under Objective 1, TWDB reviewed records for observation wells in the Blaine and Rio Grande system aquifers and selected representative locations for the NGWMN water level and water quality subnetworks. Previously, there were no Texas wells in the Blaine Aquifer in the NGWMN and only the Hueco Bolson portion of the Rio Grande Aquifer system was represented. In addition, we added 1,629 High Plains Aquifer wells to the NGWMN registry to support the U.S. Geological Survey (USGS) High Plains Aquifer water level study.

Under Objective 4, Well Maintenance, we investigated nine NGWMN wells that contain floating oil-phase product. The initial scope of the Objective 4 work was to measure the oil thickness in each well, evaluate what type of oil was present, and attempt to remove the oil from the wells. A map showing the location of all wells where field work was conducted as part of the project is included as Figure 1. Detailed location maps for each well that was investigated are included with the discussion of activities at each site in Section 3.2.

Database queries indicated that several NGWMN wells contained floating oil-phase product, which may impact water level and/or water quality measurements. The oil thickness and origins were unknown. We assumed in the proposal that the product was lubricating oil that was released from pump bearings directly into the well and that it does not indicate more extensive groundwater contamination in the aquifer. We proposed a minimal level of effort to identify the nature and volume of the oil and remove floating oil from the affected wells so that we could continue to collect valid data from these sites as part of the NGWMN. If the floating product was found to be anything other than lubricating oil, maintenance activities would be discontinued at that well, the owner informed that potentially hazardous materials are present in their well, and the well was to be removed from TWDB and NGWMN networks.

As we planned field activities, we discovered that five of the proposed wells were not suitable for further investigation. The wells that were part of the water quality network were all equipped with pumps and had a sealed well-head. We could not get interface probes, bailers, or absorbent pads into the wells. Access ports were limited to ½ inch diameter openings that were too small to even fit the interface probe. This eliminated Willacy 8834301, Wharton 6647904, and Wharton 6662313 from further investigation. In addition, we found that Wood County well 3413601 also had only a ½ inch access port and could not be evaluated. Finally, further review of Reeves 4609901 found that it was reported to be dry on the last two measurement attempts and did not in fact have any record of oil in the well. These five wells are indicated by shaded rows in Table 1.

After discussing the situation with the NGWMN staff, we identified five substitute wells where oil had been noted. Three of these are recorder wells and were already part of the NGWMN. Two additional recorder wells, Presidio 5129805 and Burnet 5809303, were added to the NGWMN as part of this project. Finally, recorder well Milam 5911621 is included in this report although it had no previous notation of oil in the well. Small amounts of tarry material were found in the well during recent maintenance activities. We will continue to monitor conditions in this well to determine if additional oil shows up and if more clean-up work is needed.

## 2.0 Summary of Findings

Under Objective 1, wells added to the NGWMN registry include 45 Blaine Aquifer wells and 24 Rio Grande Aquifer Complex wells identified by TWDB staff. Another 1,629 High Plains Aquifer wells were added from a list provided by the USGS. Approximately 700 additional High Plains wells are pending action to allow bulk loading of data for wells without well depth records.

Activities under Objective 4 resulted in a better understanding of the quantity and type of oil present; the impact of the oil on water level measurements; and preliminary data on cleanup effectiveness. Our findings include the following:

- The presence of oil generally has a minimal effect on the accuracy of water level measurements and water level measurements from recorder wells containing oil should be classified as Publishable.
- In most cases, the oil appears to be lubricating oil, but crude oil and oil/fuel mixtures are present in some wells.
- Our efforts to remove the oil from wells were only partially successful; more robust equipment will be needed to remove the volumes of oil identified in some wells.
- The number of water wells in Texas that contain oil remains poorly defined; the TWDB is working to improve identification and tracking of wells that contain oil.

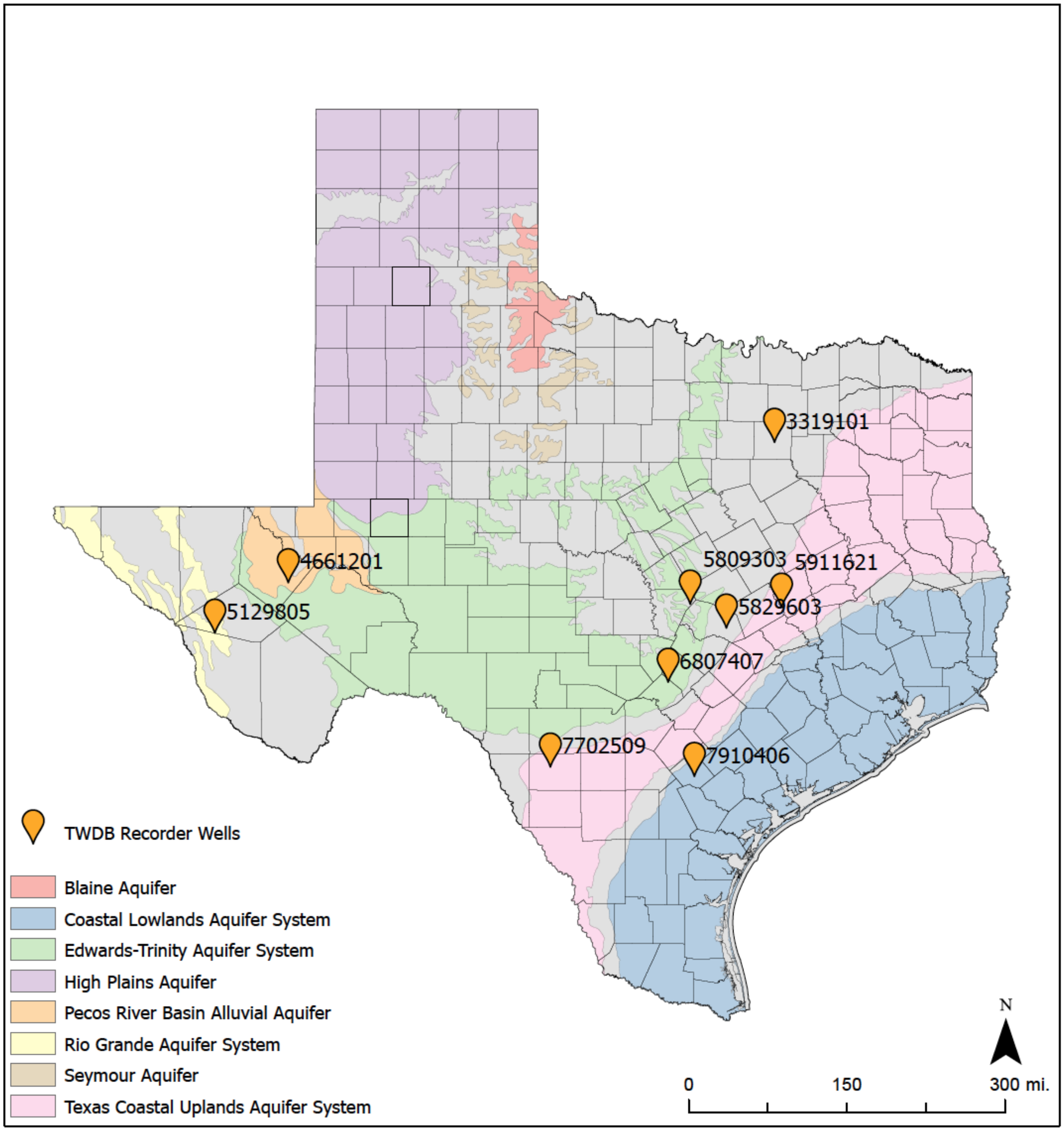


*Figure 1. Locations of NGWMN wells with oil investigated under this project.*

*Table 1. NGWMN wells with floating oil*

| NGWMN Well Number | County | Principal Aquifer | TWDB network | Sub-network | | Casing diameter, inches | Approximate depth to water, feet | Description |
|---|---|---|---|---|---|---|---|---|
| | | | | Level | Quality | | | |
| 5809303 | Burnet | Texas coastal uplands aquifer system | Recorder well | Yes | No | 4 | 460 | Crude oil in well. Added to network as part of project |
| 6807407 | Comal | Edwards-Trinity aquifer system | Recorder well | Yes | No | 8 | 345 | Oil noted on one occasion only. No oil detected on further investigation. |
| 3319101 | Dallas | Edwards-Trinity aquifer system | Recorder Well | Yes | No | 20 | 500 | City of Dallas well |
| 7910406 | Karnes | Coastal lowlands aquifer system | Recorder Well | Yes | No | 12 | 225 | City of Kenedy well #5 |
| 5911621 | Milam | Texas coastal uplands aquifer system | Recorder well | Yes | No | 6 | 45 | Oil not previously noted; tar present on equipment |
| 5129805 | Presidio | Rio Grande aquifer system | Recorder well | Yes | No | 16 | 351 | Added to network as part of this project |
| 4609901 | Reeves | Pecos River basin alluvial aquifer | Observation Well | Yes | No | 5 | 45 | Unused private well. Dry hole, no record of oil in well |
| 4661201 | Reeves | Edwards-Trinity aquifer system | GCD Observation well | Yes | No | 12 | 185 | Open hole, unused. Records list 16-inch casing but is actually 12-inch. |
| 6647904 | Wharton | Coastal lowlands aquifer system | Observation Well | No | Yes | 4 | 60 | City of Wharton airport well; no access to casing |
| 6662313 | Wharton | Coastal lowlands aquifer system | Observation Well | No | Yes | 14 | 80 | Greenleaf Nursery irrigation well; no access to casing |
| 8834301 | Willacy | Coastal lowlands aquifer system | Observation Well | Yes | Yes | 8 | 30 | City of Raymondville north well; no access to casing |
| 5829603 | Williamson | Texas coastal uplands aquifer system | Recorder well | Yes | No | 16 | 208 | City of Taylor well #3 |
| 3413601 | Wood | Texas coastal uplands aquifer system | Observation Well | Yes | No | 10 | 190 | Unused private well; no access to casing |
| 7702509 | Zavala | Texas coastal uplands aquifer system | Recorder Well | Yes | No | 10 | 400 | Unused private well |

*Note: shaded rows indicate wells that were originally proposed for assessment but were not evaluated because the surface completion did not permit access.*

## 3.0 Objective 1: Wells Added to the NGWMN

A total of 45 Blaine Aquifer wells and 24 Rio Grande Aquifer Complex wells were added to the NGWMN registry. These wells are all current observation wells measured by local groundwater conservation districts (GCD) or the TWDB. General locations of the added wells are shown in Figures 2 and 3, while summary information on the wells is listed in Tables 2 and 3, for the Blaine and Rio Grande aquifers, respectively. Detailed information on these wells has been loaded into the NGWMN registry.

The U.S. Geological Survey provided the TWDB with a list of 2,394 High Plains Aquifer wells to add to the NGWMN registry in support of their investigations of the High Plains aquifer. TWDB staff initially loaded data for 1,700 of these wells to the NGWMN registry. A subset of 71 of these wells are classified as historical observation wells that are not visited on a regular basis by TWDB or GCD staff; we recommend deleting these wells from the registry since we will not be collecting additional data for these sites. Figure 4 shows the locations of the 1,629 wells that have been added. Because of the large number of wells, no well data table is included in the report. An Excel spreadsheet will be provided with this report.

The remaining 694 of the High Plains Aquifer wells on the list have null values for the well depth, which prevents bulk loading of data to the registry. TWDB staff located well depth data for 33 of these wells and manually entered the data in the registry. We will continue to try and track down well depths, but due to the large number of sites with null depths it will be time consuming to upload those sites manually. We hope that the USGS will be able to modify the portal to allow sites with null depths to be uploaded in bulk.

*Table 2. Summary data on Blaine Aquifer wells added to the NGWMN.*

| NGWMN Well Number | County | TWDB Aquifer | NGWMN Aquifer | Latitude | Longitude | Well Depth | Land Surface Elevation | Water Level Network | Water Quality Network |
|---|---|---|---|---|---|---|---|---|---|
| 0546704 | Wheeler | Blaine | Blaine | 35.2763889 | -100.3480556 | 200 | 2450 | Yes | No |
| 0555605 | Wheeler | Blaine | Blaine | 35.1886111 | -100.1375 | 87 | 2269 | Yes | No |
| 0556304 | Wheeler | Blaine | Blaine | 35.2286111 | -100.0369444 | 67 | 2141 | Yes | No |
| 0562202 | Collingsworth | Blaine | Blaine | 35.0855556 | -100.3027778 | 134 | 2256 | Yes | No |
| 0562805 | Collingsworth | Blaine | Blaine | 35.0122222 | -100.2969444 | 198 | 2117 | Yes | No |
| 0562904 | Collingsworth | Blaine | Blaine | 35.0022222 | -100.2744444 | 180 | 2108 | Yes | Yes |
| 0563407 | Collingsworth | Blaine | Blaine | 35.0511111 | -100.2175 | 150 | 2221 | Yes | Yes |
| 0563610 | Collingsworth | Blaine | Blaine | 35.0661111 | -100.1486111 | 60 | 2080 | Yes | No |
| 0563812 | Collingsworth | Blaine | Blaine | 35.0338889 | -100.1813889 | 120 | 2160 | Yes | No |
| 0563813 | Collingsworth | Blaine | Blaine | 35.0144444 | -100.1808333 | 105 | 2118 | Yes | No |
| 0564804 | Collingsworth | Blaine | Blaine | 35.0044444 | -100.0611111 | 179 | 2087 | Yes | No |
| 1208301 | Collingsworth | Blaine | Blaine | 34.9644444 | -100.0338889 | 111 | 1994 | Yes | No |
| 1208407 | Collingsworth | Blaine | Blaine | 34.9352778 | -100.0913889 | 193 | 1966 | Yes | No |
| 1214308 | Collingsworth | Blaine | Blaine | 34.8394444 | -100.2816667 | 245 | 1992 | Yes | No |
| 1214901 | Collingsworth | Blaine | Blaine | 34.7566667 | -100.2602778 | 174 | 1917 | Yes | No |
| 1214902 | Collingsworth | Blaine | Blaine | 34.7875 | -100.2516667 | 123 | 1912 | Yes | No |
| 1214916 | Collingsworth | Blaine | Blaine | 34.7786111 | -100.2877778 | 125 | 1923 | Yes | No |
| 1215501 | Collingsworth | Blaine | Blaine | 34.7941667 | -100.205 | 238 | 1940 | Yes | No |
| 1221301 | Childress | Blaine | Blaine | 34.7247222 | -100.3816667 | 225 | 1993 | Yes | No |
| 1223206 | Childress | Blaine | Blaine | 34.7116667 | -100.1877778 | 240 | 1778 | Yes | No |
| 1223210 | Childress | Blaine | Blaine | 34.7322222 | -100.1822222 | 305 | 1841 | Yes | No |
| 1223307 | Childress | Blaine | Blaine | 34.7172222 | -100.1561111 | 290 | 1821 | Yes | No |
| 1223603 | Childress | Blaine | Blaine | 34.6702778 | -100.1447222 | 177 | 1758 | Yes | No |
| 1224105 | Childress | Blaine | Blaine | 34.7412667 | -100.1179139 | 280 | 1853 | Yes | No |
| 1224207 | Childress | Blaine | Blaine | 34.7136111 | -100.0613889 | 212 | 1730 | Yes | No |
| 1224212 | Childress | Blaine | Blaine | 34.7302778 | -100.0775 | 227 | 1762 | Yes | No |
| 1224501 | Childress | Blaine | Blaine | 34.6986111 | -100.0816667 | 338 | 1783 | Yes | No |
| 1224702 | Childress | Blaine | Blaine | 34.6558333 | -100.0886111 | 150 | 1692 | Yes | No |
| 1224703 | Childress | Blaine | Blaine | 34.6427778 | -100.1227778 | 155 | 1696 | Yes | No |
| 1231305 | Childress | Blaine | Blaine | 34.5841667 | -100.1580556 | 148 | 1715 | Yes | No |
| 1232301 | Childress | Blaine | Blaine | 34.6052778 | -100.0055556 | 150 | 1605 | Yes | No |
| 1248803 | Cottle | Blaine | Blaine | 34.2897222 | -100.0616667 | 165 | 1701 | Yes | No |
| 1325902 | Hardeman | Blaine | Blaine | 34.505 | -99.9011111 | 250 | 1602 | Yes | No |
| 1333102 | Hardeman | Blaine | Blaine | 34.4919444 | -99.9602778 | 195 | 1790 | Yes | No |

*Table 2, continued.*

| NGWMN Well Number | County | TWDB Aquifer | NGWMN Aquifer | Latitude | Longitude | Well Depth | Land Surface Elevation | Water Level Network | Water Quality Network |
|---|---|---|---|---|---|---|---|---|---|
| 1333403 | Hardeman | Blaine | Blaine | 34.4338889 | -99.99 | 230 | 1686 | Yes | No |
| 1333501 | Hardeman | Blaine | Blaine | 34.4344444 | -99.9483333 | 200 | 1634 | Yes | No |
| 1342402 | Hardeman | Blaine | Blaine | 34.3270917 | -99.8583472 | 100 | 1561 | Yes | No |
| 1342804 | Hardeman | Blaine | Blaine | 34.2885139 | -99.7967944 | 120 | 1573 | Yes | No |
| 1342806 | Hardeman | Blaine | Blaine | 34.25735 | -99.81 | 136 | 1619 | Yes | No |
| 1358701 | Foard | Blaine | Blaine | 34.0027778 | -99.87 | 33 | 1678 | Yes | No |
| 2214504 | King | Blaine | Blaine | 33.8197222 | -100.3166667 | 230 | 1825 | Yes | No |
| 2231501 | King | Blaine | Blaine | 33.565 | -100.2058333 | 60 | 1791 | Yes | Yes |
| 2238301 | King | Blaine | Blaine | 33.4755556 | -100.2830556 | 25 | 1780 | Yes | No |
| 2915501 | Fisher | Blaine | Blaine | 32.8088889 | -100.1841667 | 60 | 1832 | Yes | No |
| 0564105 | Collingsworth | Blaine | Blaine | 35.1102806 | -100.0902833 | 201 | 1916 | Yes | No |

*Table 3. Summary data on Rio Grande Aquifer Complex wells added to the NGWMN.*

| NGWMN Well Number | County | TWDB Aquifer | NGWMN Aquifer | Latitude | Longitude | Well Depth | Land Surface Elevation | Water Level Network | Water Quality Network |
|---|---|---|---|---|---|---|---|---|---|
| 4760701 | Culberson | Salt Bolson | Rio Grande | 31.0344806 | -104.5912944 | 660 | 3907 | Yes | No |
| 5102926 | Culberson | Salt Bolson | Rio Grande | 30.8811639 | -104.7526889 | 417 | 3972 | Yes | Yes |
| 5110906 | Culberson | Salt Bolson | Rio Grande | 30.7656056 | -104.7807028 | 593 | 4056 | Yes | No |
| 5119101 | Jeff Davis | Salt Bolson | Rio Grande | 30.7361111 | -104.7280556 | 448 | 4094 | Yes | No |
| 5119203 | Jeff Davis | Salt Bolson | Rio Grande | 30.7448 | -104.6862028 | 447 | 4105 | Yes | No |
| 5127302 | Jeff Davis | Volcanics | Rio Grande | 30.5955139 | -104.64585 | 425 | 4262 | Yes | No |
| 5128303 | Jeff Davis | Salt Bolson | Rio Grande | 30.5904556 | -104.5146167 | 3422 | 4402 | Yes | No |
| 5128607 | Jeff Davis | Salt Bolson | Rio Grande | 30.5468889 | -104.5141028 | 1751 | 4374 | Yes | No |
| 5129805 | Presidio | Salt Bolson | Rio Grande | 30.518575 | -104.4297833 | 1648 | 4557 | Yes | No |
| 5148602 | Presidio | Volcanics | Rio Grande | 30.315 | -104.0211111 | 881 | 4710 | Yes | No |
| 5148603 | Presidio | Volcanics | Rio Grande | 30.3143444 | -104.0213417 | 1100 | 4709 | Yes | No |
| 5225305 | Jeff Davis | Igneous | Rio Grande | 30.58605 | -103.900275 | 303 | 4914 | Yes | No |
| 5225501 | Jeff Davis | Igneous | Rio Grande | 30.5448361 | -103.9276528 | 251 | 4959 | Yes | No |
| 5225603 | Jeff Davis | Volcanics | Rio Grande | 30.5785694 | -103.9070639 | 120 | 4951 | Yes | No |
| 5225604 | Jeff Davis | Volcanics | Rio Grande | 30.557625 | -103.8781806 | 300 | 4875 | Yes | Yes |
| 5225612 | Jeff Davis | Volcanics | Rio Grande | 30.5786028 | -103.881375 | 167 | 4938 | Yes | No |
| 5226802 | Jeff Davis | Volcanics | Rio Grande | 30.5245472 | -103.8222639 | 230 | 4703 | Yes | Yes |
| 5234301 | Jeff Davis | Igneous | Rio Grande | 30.4916667 | -103.7519444 | 409 | 4410 | Yes | No |
| 5235713 | Brewster | Volcanics | Rio Grande | 30.3849833 | -103.7219361 | 361 | 4595 | Yes | No |
| 5249402 | Presidio | Volcanics | Rio Grande | 30.1893278 | -103.9921139 | 800 | 4509 | Yes | No |
| 7406901 | Presidio | Alluvium and Tertiary Volcanics | Rio Grande | 29.8937278 | -104.2821944 | 380 | 4410 | Yes | No |
| 7415501 | Presidio | Igneous | Rio Grande | 29.8030222 | -104.2061111 | 600 | 4039 | Yes | No |
| 7430503 | Presidio | Presidio and Redford Bolsons | Rio Grande | 29.5421667 | -104.3261778 | 50 | 2557 | Yes | No |
| 7430605 | Presidio | Presidio and Redford Bolsons | Rio Grande | 29.5742389 | -104.2732889 | 530 | 2781 | Yes | No |

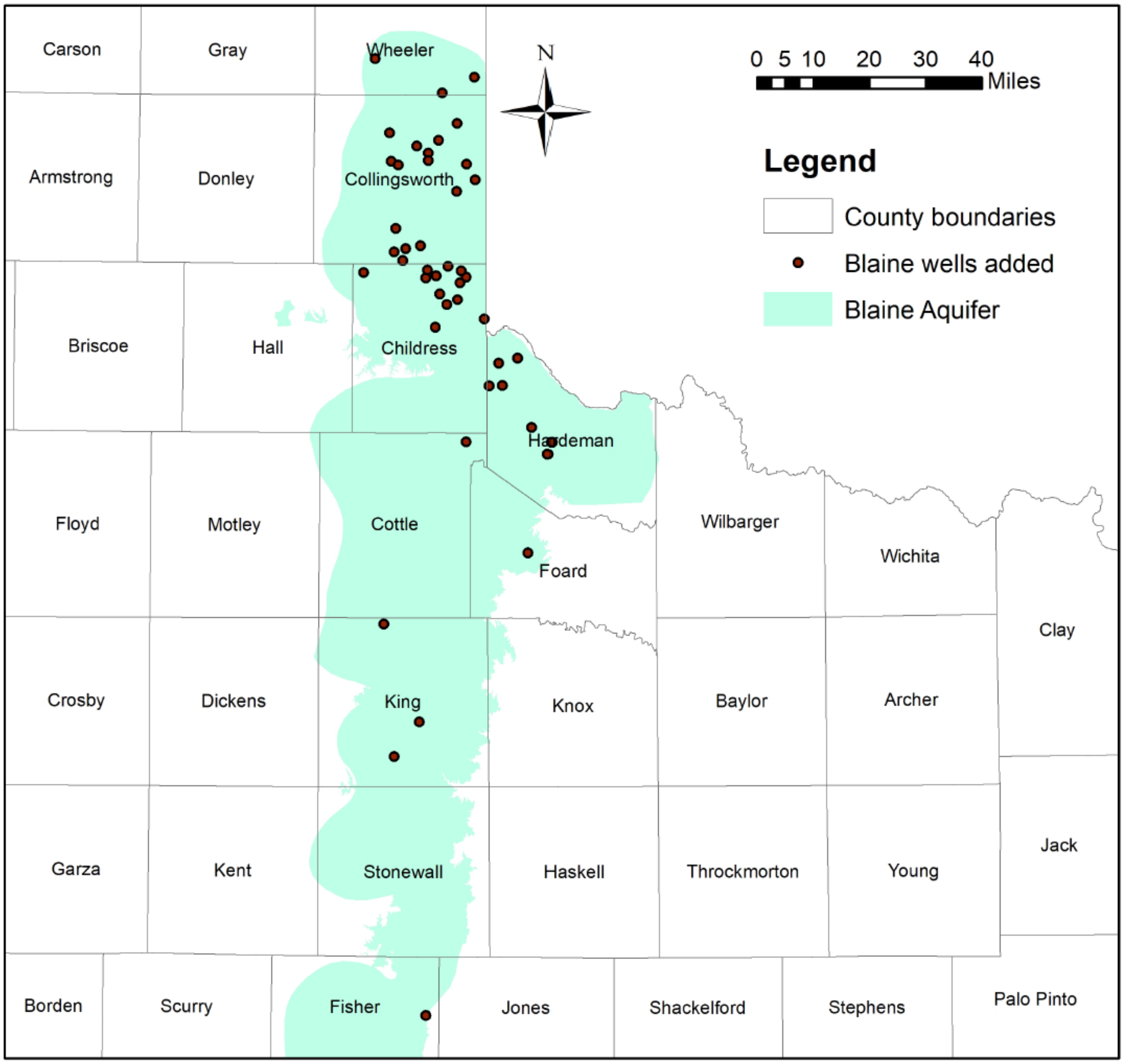


*Figure 2. Generalized location map for Blaine Aquifer wells added to NGWMN.*

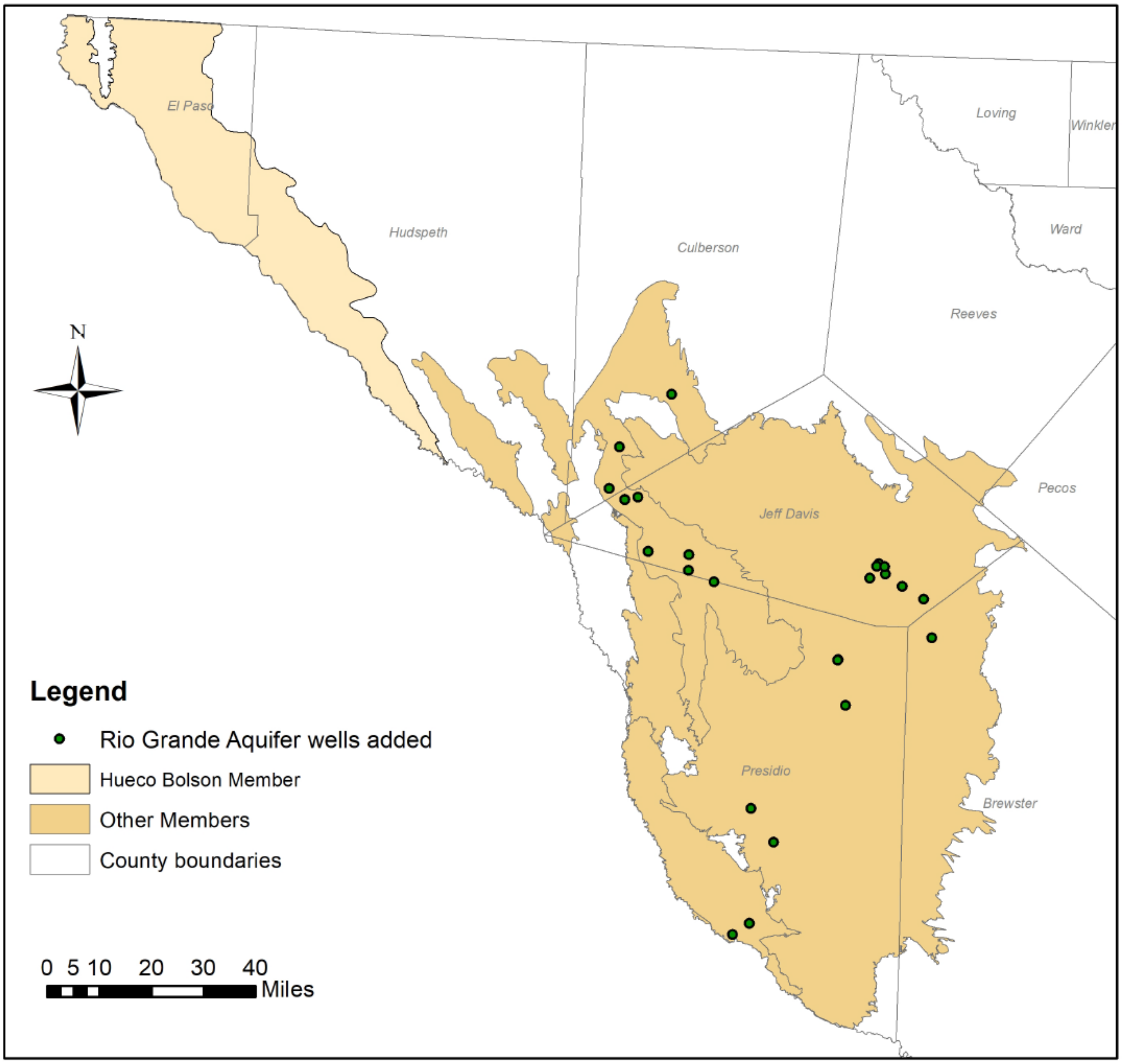


*Figure 3. Generalized location map for Rio Grande Aquifer Complex wells added to the NGWMN.*

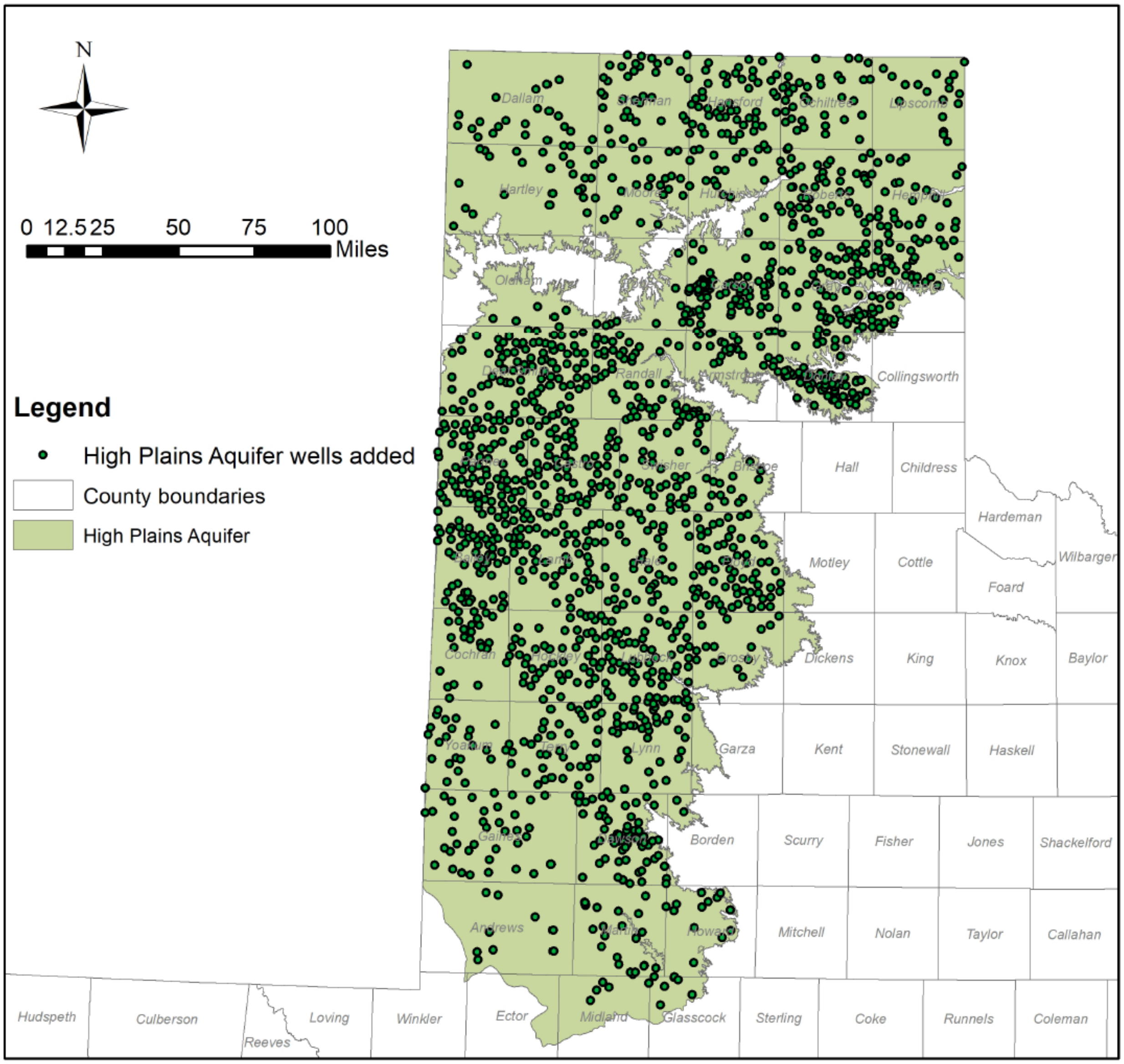


*Figure 4. Generalized location map for High Plains Aquifer wells added to the NGWMN.*

## 4.0 Objective 4: Well Maintenance Activities

Field work was conducted at nine NGWMN wells. The general workflow for each site visit was:

1. Measure the depth to the top of the oil layer and the depth to water with the interface probe and calculate the oil thickness.
2. Use bailers to remove oil from the well if more than a trace amount of oil is present.
3. If the oil thickness can be reduced to less than 0.1 foot, use oil-absorbent pads to remove the residual oil from the well.
4. Measure final oil thickness.

We fully completed this process at two wells – Karnes 7910406 and Williamson 5829603. Two additional wells either did not contain oil (Comal 6807407) or had very small quantities of oily material that will be monitored in the future (Milam 5911621). The remaining five wells had larger quantities of oil or different types of oil and could not be effectively cleaned-up. Table 3 summarizes activities at each of the sites that was evaluated.

The TWDB proposed using 1.5-inch product-only bailers to recover the bulk of the oil if more than a trace amount was present and then use oil absorbent pads to clean up any residual amounts. These tools quickly proved ill-suited to remediate the volumes of oil present at some project locations. Most of the wells investigated are between 8 and 20 inches in diameter. Measured oil thickness ranged up to nearly 18 feet, with estimated oil volumes up to more than 70 gallons.

Special product-only bailers designed to collect just oil and not water were purchased for this project using in-kind funds. The 1.5-inch product-only bailers were suspended on 2-millimeter Kevlar cord and lifted using a cordless electric drill to wind the cord onto a spool. The product-only bailers are designed for low viscosity distillates such as gasoline and do not work well for heavier lube oil or crude oil. The ball valve on the bottom of the bailer frequently fails to seat properly, especially with more viscous oil or where large amounts of scale and other debris are present in the oil, so that both water and oil drain out of the bailer as it is raised back to the surface. At several sites, staff were only able to bail a few ounces of oil per attempt; at these sites the absorbent pads were used instead if the total volume of oil was estimated at less than a few gallons. We did recover 5-gallons of oil with the product-only bailers at the Zavala site, but it took several hours of work.

*Table 4. Summary of oil type and condition by well*

| NGWMN Well Number | County | Oil thickness, feet | Oil volume, gallons | Oil removed, gallons | Oil description | Notes |
|---|---|---|---|---|---|---|
| 5809303 | Burnet | Unknown; probably <1.0 feet | Unknown | <0.1 | Crude oil. Weathers to sticky tar. Semi-solid lump floating in well. | Oil viscosity too high for interface meter. Tarry material won't go into bailer or soak up on pads. |
| 6807407 | Comal | 0 | 0 | 0 | No oil present. Transducer cable is weathering, producing a slimy coating on the cable. | |
| 3319101 | Dallas | 1.64 | 26.7 | 2.5 | light relatively clear lube oil, no odor | Site fencing limits access to well-head. |
| 7910406 | Karnes | 0.5 | 2.9 | 2.9 | Dark, smelly lube oil | Well effectively cleaned up. Sample collected for TPH fractions |
| 5911621 | Milam | 0 | <0.1 | 0 | Small amount of tar present on transducer and cable. No measurable oil thickness. | Frack rig operating immediately across highway from well site. |
| 5129805 | Presidio | ~4 | 52.8 | 3 | Dark, smelly, crude odor, higher viscosity; sludgy. Density 0.872 g/cc. | Oil sticks to interface probe; can't get good reading. Estimated thickness |
| 4661201 | Reeves | 7.16 | 42.0 | 3 | Lube oil with diesel odor. Density 0.879 g/cc. | GCD analysis indicates 'used motor oil' |
| 5829603 | Williamson | 0.1 | 1.3 | 4.5 | Lube oil; dark, low to medium viscosity, no odor | Site effectively cleaned up. Thickness measurement suspect given volume of oil recovered. |
| 7702509 | Zavala | 17.8 | 72.6 | 10 | Dark, clear, low odor; low to medium viscosity. Density 0.88 g/cc. | |

After trying the product-only bailers at several wells, we tried fabricating larger diameter bailers to collect more oil at a time. We used a 24-inch length of 3-inch PVC pipe, a 1.5-inch diameter plastic ball, and various PVC fittings to construct a bailer that could remove over ½-gallon of oil per attempt. But the 3-inch bailer was too heavy to lift using the cordless drill. Pulling the bailer up several hundred feet by hand was slow and tedious, especially once the cord got covered in oil, which made it extremely slippery and hard to grip.  We concluded that any volume of oil beyond about 10 gallons is impractical to remove with small bailers. An electric winch, lifting gear, and bailers sized to the well being cleaned are needed to efficiently remove floating oil from the wells.

The absorbent pads worked better than the bailers for removing oil from wells with an oil thickness less than a few inches but takes 10 to 15 attempts to remove the final traces of oil. The pads absorb oil fairly rapidly. Initially, we wrapped several feet of the absorbent mat around a 3-foot length of 1-inch PVC pipe and fixed it in place with hose clamps to create a long swab. The PVC provides some support for the pads and decreases their buoyancy, so that as the pads become saturated with oil they gradually sink so that the entire length of the swab collects oil from the interface.  In wells with more than a couple of inches of oil, the pads get saturated within a few minutes. When there is only a trace of oil in the well the pads need to be left in the well for 30 minutes to one hour to collect as much oil as possible. After experimenting with different amounts of time and different ways to wrap the pads on the PVC, we determined that cutting the pads up to create a 'mop-head' configuration increases surface area and picks up oil from the interface more quickly, especially when only traces of oil are left in the well.

Because the absorbent pads picked up oil quickly, and because we could not leave the pads in the wells that were equipped with float-and-weight recorders, we did not try leaving the pads in the wells for longer periods of time.

The oil recovered from the wells was collected for disposal in a DOT-approved 55-gallon drum. Oil and oily pads will be disposed of at a commercial recycling facility in Austin, Texas.

## 3.1 Discussion

The purpose of the well maintenance task was to determine what type of oil is present in the wells, assess the extent to which the oil is interfering with water level measurements, evaluate the effectiveness of simple oil removal techniques, and overall get a better idea of the nature and extent of oil contamination in water wells in Texas. We made progress on all of these questions but have not found easy answers to any of them.

The working hypothesis at the start of this project was that the oil was a byproduct of turbine pump operations at the wells, most of which had formerly been used as municipal supply or irrigation wells. In theory, turbine pumps were supposed to be lubricated using a food-grade oil but in general, no records of what type or volume of oil was used are available. All of the wells evaluated have been out of service for groundwater production for at least 20 years.

The well maintenance task did not include any funding to analyze oil samples. The initial idea was that visual and olfactory inspection would be sufficient to distinguish lubricating oil from lighter distillates such as diesel or gasoline that could be present in the aquifer as environmental contaminants. The planning process did not address the potential presence of crude oil in the wells or propose methods to distinguish food-grade oil from standard motor oil, or address the possibility that some mixture of hydrocarbon types might be present.

Anecdotal evidence from GCD managers and landowners indicates that food-grade oils are light-colored to white in contrast to the dark to black oil that was recovered from the NGWMN wells. Crude oil contains more volatile fractions than refined lubricating oils so that it weathers and becomes tarry over time whereas refined lubricating oils are more environmentally stable. Crude oil also typically contains some amount of hydrogen sulfide, giving it a characteristic rotten egg smell. None of these general properties are sufficient to unambiguously identify the oil recovered from the NGWMN wells. Total Petroleum Hydrocarbon (TPH) analysis of an oil sample from the Karnes well is consistent with lubricating oil but does not rule out some crude oil component.

Project results are consistent with a lubricating oil origin for most of the sites but cannot rule out other sources. At least one site appears to be affected by an on-going source of crude oil and a crude oil component at other sites is possible.

The number of water wells in Texas that contain oil remains poorly defined. None of the landowners and only one of the GCD managers associated with the wells included in this project were aware that the wells contained oil. Since the wells have been out of service for years and may have changed ownership since they were last operational any knowledge of oil in the wells may have been lost. The well owners may never have been aware that their wells contained oil since under normal operations the oil layer is typically hundreds of feet above the pump inlet and no oil is produced with the water.

The TWDB groundwater monitoring program tracks wells where oil is noted, but only to the extent that it is a nuisance problem in obtaining good water level measurements. The remark code “16,” indicating “Inconsistent or spotty tape mark due to oil or gasoline” has not been applied consistently to all wells containing oil. Field staff interpreted the remark code to apply primarily to the measurement quality rather than the presence of oil. As long as a clear mark was readable on the steel tape the code was not used and no notation was made to indicate that a well contained oil. In some instances, field staff have written the word "Oil" on the recorder well shelter to let other field staff know not to use an e-line to measure water levels in a well, but the code 16 is only occasionally recorded. As a result, we have a very poor understanding of how common oil contamination is in Texas water wells.

The volume of oil present in monitoring wells and the effect of the oil layer on water level measurements is better defined as a result of project activities. Prior to this project, the TWDB had no tools to measure the thickness of the oil layer in contaminated wells. Groundwater monitoring staff typically use a steel tape to measure water levels. The tape only indicates the depth to the top of the fluid layer in the well. Standard electric water level meters do not function in wells with an oil layer. The electrical contacts get coated with oil as the probe goes through the floating oil layer and do not complete the electrical circuit when the probe enters the water layer. The Solinst interface probe purchased as part of this project gives a clear signal for the top of the oil layer, representing the potentiometric surface of the groundwater. The interface probe does not work as well for measuring the top of the water surface. Lubricating oils and crude oil are much more viscous than the light distillates such as gasoline or diesel that the interface probe is designed for. The oil tends to stick to the sensor even after it is lowered into the water below the oil. In most of the wells the depth to the water surface could be measured with some patience but in other cases no consistent water level was measurable.

In most cases, the presence of oil has a minimal effect on the accuracy of water level measurements and water level measurements from recorder wells containing oil should be classified as Publishable. Because the oil has a lower density than water, at equal pressure heads wells with oil will have a higher level than wells that contain only water. Since the oil density averages about 0.88 g/cc, the measured potentiometric surface will be off by approximately one inch for every foot of oil in the well. For most of the wells investigated this results in an error of a few inches. Even for the Zavala recorder, with nearly 18 feet of oil, the potentiometric surface error is only 1.5 feet. This error is comparable to the uncertainty in well-head elevations, which are typically estimated from Google Earth or paper maps. More importantly, the oil does not affect measured trends in water levels as long as a consistent signal can be obtained using a transducer, float and weight, steel tape, or interface probe. Measurements from wells with oil should be classified as Questionable only in cases where steel tape measurements are uncertain and other methods of measurement are not feasible because of well construction or other constraints.

The effectiveness of the simple oil removal techniques assessed as part of this project has been limited. Where the initial oil layer was only a few inches thick, absorbent pads proved effective at removing all measurable oil from wells, although trace amounts of oil remain in the wells and may require further remediation. As previously noted, bailers were only partially effective at cleaning up wells where larger amounts of oil were present. The 1.5-inch diameter product-only bailers were too small for the volumes of oil present in the large diameter irrigation or production wells and the valves tended to leak when used with relatively viscous lubricating oils, resulting in small volumes of oil removed. Larger diameter bailers removed more oil per attempt but were too heavy to lift with the power equipment available and were difficult to handle manually. Larger bailers and a powered winch are needed to effectively remove the oil and larger tanks are needed to contain it for disposal. While project activities were not successful at cleaning up all of the wells investigated, we now have a better idea of the volume of oil present in each well and are better positioned to develop plans to remove it.

## 3.2 Detailed activities at each site

The following sections summarize field activities at the nine wells where the oil contamination was investigated as part of this project.

### Burnet 5809303

The Burnet County recorder was specifically drilled as a groundwater conservation district (GCD) monitoring well, in July 2009. The well is completed in the Trinity Aquifer in the southeastern part of the county, near the Williamson County line (Figure 5). It has a 5-inch Schedule 40 PVC casing to 520 feet depth and 5-inch PVC screen intervals from 520 to 540 feet and from 620 to 640 feet, with blank casing extending to a total depth of 780 feet. The well has never been equipped with a pump and there is no commercial development within a mile of the well location. Groundwater conservation district staff have noted that oil gradually accumulated in the well over the last 12 years. Based on the appearance of the oil and the lack of any local source for it, GCD staff concluded that it was naturally occurring crude oil.

The oil in the Burnet recorder well is dark and sticky, with a slight crude odor. As it loses volatile fractions or oxidizes the oil becomes more viscous and turns into a tarry semi-solid material on the transducer cable and in the well. TWDB staff were unable to get interface meter readings on the depth to the water/oil interface. The oil sticks on the probe so that it is impossible to get reproducible readings for the depth to water. The total thickness of liquid oil in the well appears to be less than six inches, based on recovery of an oil-water mixture in the bailer.

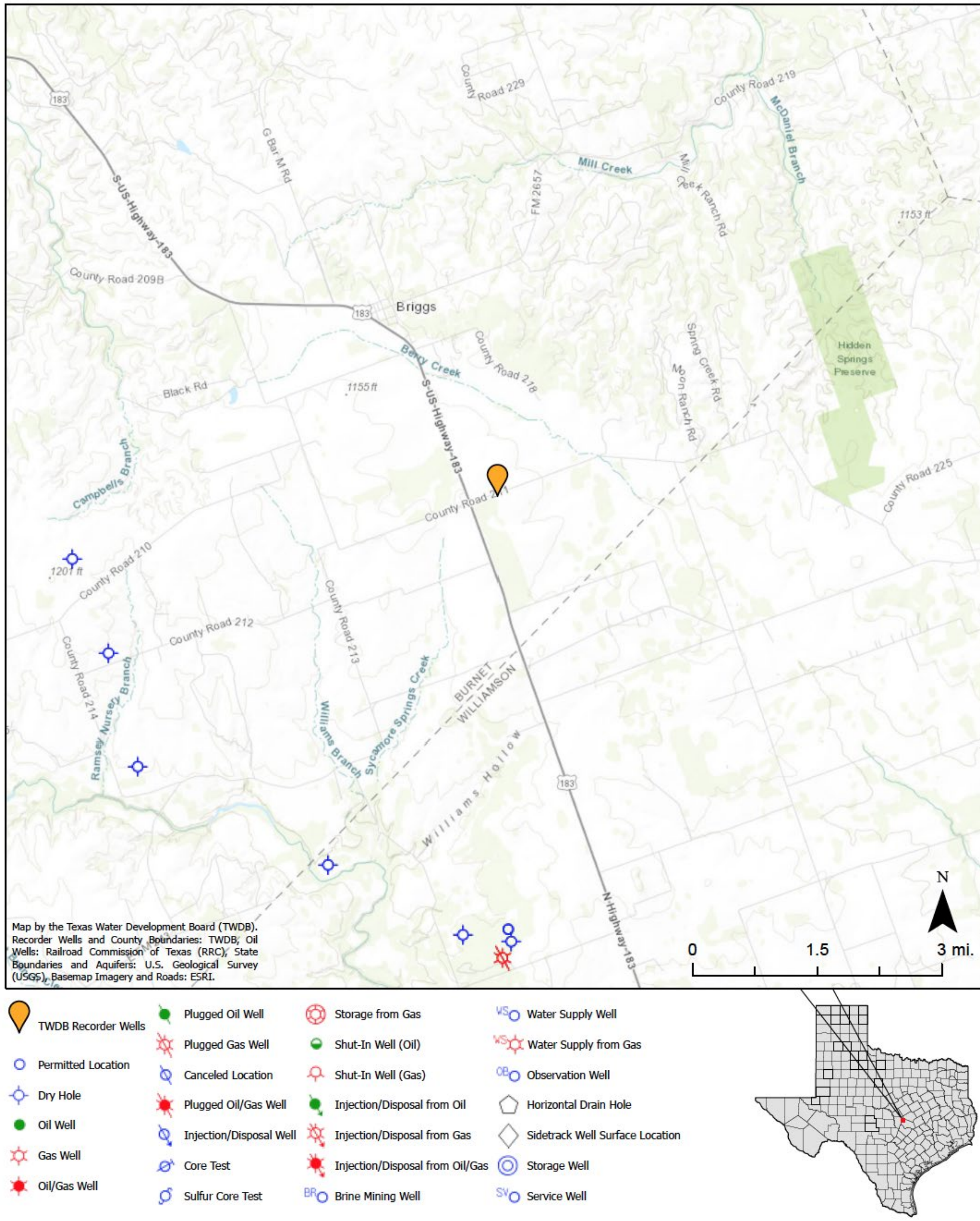


*Figure 5. Location map for Burnet County recorder well 5809303.*

The crude oil presumably leaks into the formation from deeper formations along fractures or unmapped faults. The water temperature in the well is elevated approximately 20 degrees Celsius above normal for the Trinity, suggesting a significant contribution from deeper fluids. The Ott PLS transducer installed in the well in 2021 reports a water temperature of about 46 degrees Celcius and equipment pulled from the well is noticeably warm to the touch.

TWDB staff visited the Burnet recorder well on two occasions, on November 2, 2020 and July 6, 2021, to assess the amount of oil in the well and to attempt to recover oil out of it. We found that both the bailer and absorbent pads were ineffective for removing oil from the Burnet well. Both devices tend to get stuck in the 'tar ball' of weathered oil floating at the oil-water interface. The absorbent pads got stuck on the tar ball so that only the bottom five or six inches of the swab absorbed any oil, as shown in Figure 6. Oil coated the outside of the bailer but only a small amount of mixed oil and water was recovered inside the bailer (Figure 7), suggesting that the oil layer is probably less than about one foot thick since the bailer was only lowered about one foot below the top of the oil.

Using the interface meter, we were able to get an accurate measurement of the depth to the top of the oil, at 461.75 feet on July 6, 2021. This was about four feet different from previous readings using a steel tape. The oil sticks to the inside of the casing as the water level changes and tends to coat the steel tape, making it hard to get an accurate measurement of depth to water. The interface probe seems to be more reliable at detecting the actual liquid surface.

*Figure 6. Absorbent pad after deployment in Burnet 5809303. Only the bottom eight inches of the pad made contact with the oil layer.*

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*Figure 7. Oil and water recovered from Burnet 5809303, showing high viscosity of recovered oil.*

TWDB staff are evaluating potential methods for removing the semi-solid tar-ball from the Burnet recorder, such as a weighted net that can be dropped down below the tar-ball in a closed configuration and then opened as it is pulled up to catch the tar-ball. The GCD is also evaluating options for potentially replacing the well. In the meantime, following calibration to the interface meter readings, the water level measurements from the well are not significantly affected by the small thickness of oil that is present. But this location may not accurately represent regional conditions because of the apparent effects of circulation from deeper formations in the immediate vicinity of the Burnet recorder.

### Comal 6807407

TWDB records include one comment indicating that oil was detected in Comal County recorder well 6807407. This well is completed in the Trinity Aquifer and is used as a monitoring well by the Canyon Lake Water Supply Corporation. It has never been used as a production well. No active oil or gas wells are located nearby (Figure 8).

TWDB staff visited the location on May 4, 2021 to assess site conditions. When we pulled the transducer, we found that, below the water line, the cable was coated with a slimy substance that may have been mistaken for oil. The slimy material was clear to slightly green and appeared to be the result of deterioration of the green plastic cable jacket (Figure 9). The interface meter detected no oil floating in the well and a swab of absorbent pads lowered into the water came up clean (Figure 10). We concluded that no oil is present in the Comal recorder.

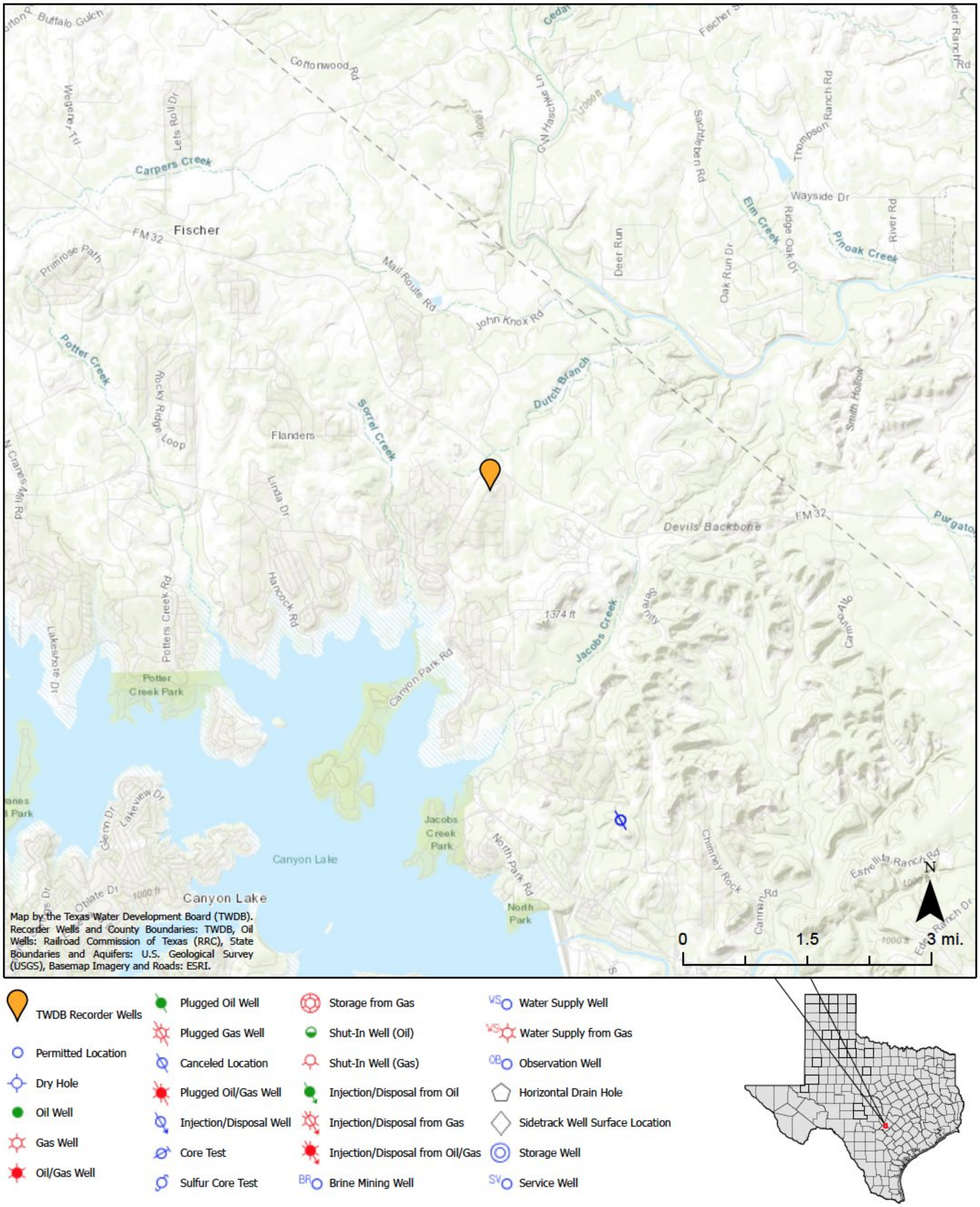


*Figure 8. Location map for Comal County recorder well 6807407.*

Figure 9. Comal recorder well head, showing excess cable coiled in shelter.


Figure 10. Absorbent pads after soaking in Comal recorder well.

### Dallas 3319101

The Dallas recorder is a former City of Dallas water supply well completed in the Trinity Aquifer in the southeastern part of Dallas (Figure 11). The well is located inside a fenced area and vehicle access from the road is restricted by a locked barricade so that all equipment has to be hand carried several hundred feet to the site. No oil or gas wells are located nearby.

The well is constructed with a 20-inch steel casing to a depth of 840 feet, 14-inch steel casing from 840 to 2,842 feet, 10-inch steel casing from 2,643 to 2,843 feet and 10-inch steel screen from 2,843 to 3,063 feet below ground surface. The well-head is set in an open brick-lined vault that extends approximately four feet below the current ground surface (Figure 12). There are no bars or grating covering the well, creating a hazardous condition and significant risk for dropping tools or equipment into the well.

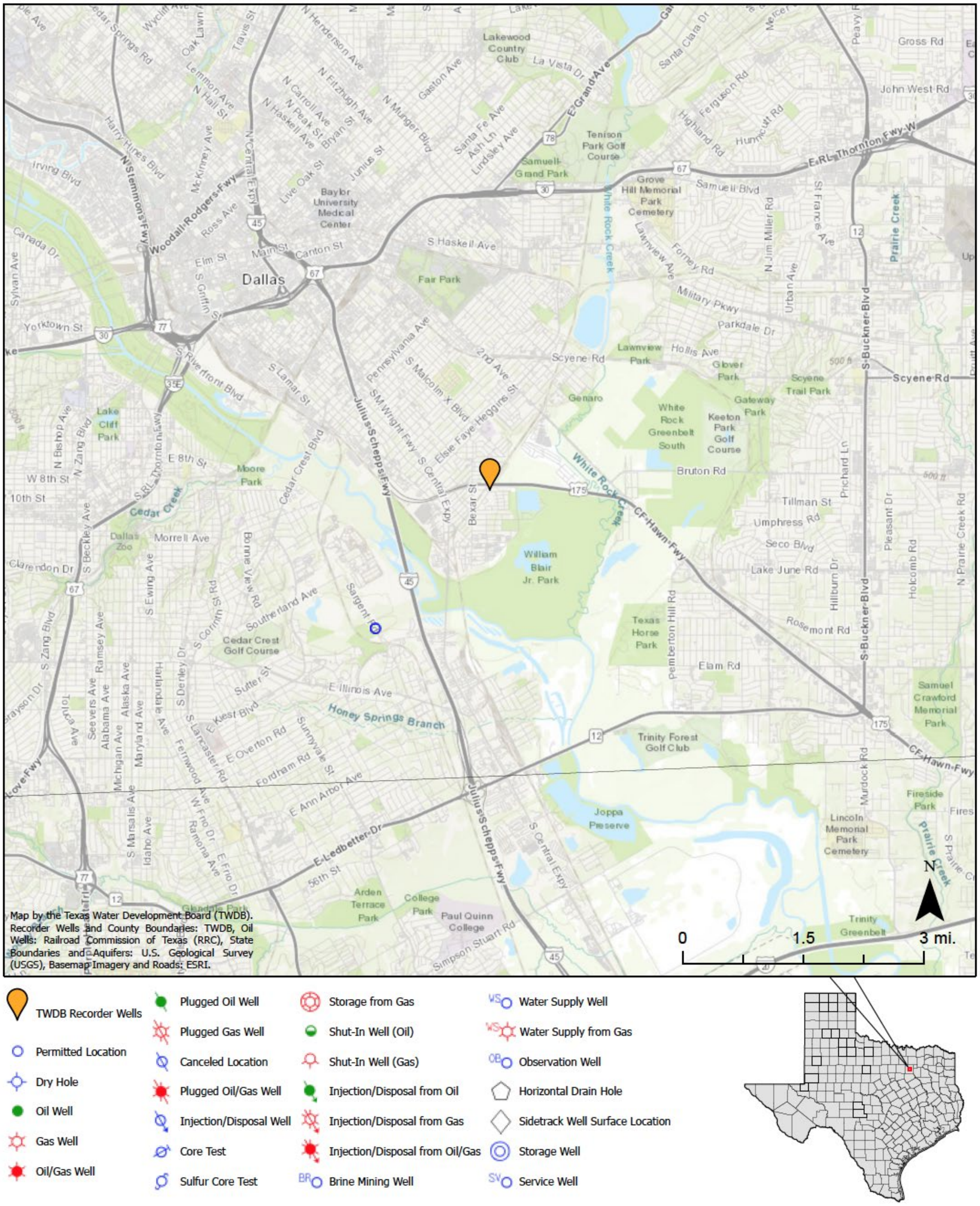


*Figure 11. Location map for Dallas County recorder well 3319101.*

TWDB staff visited the Dallas recorder site on June 30, 2021.  At that time, the depth to the top of the oil layer was 485.69 feet and the depth to the top of water was 487.53 feet, giving an oil thickness of 1.64 feet in the 20-inch casing. The estimated total oil volume was approximately 26 gallons. Samples of the oil collected in the product-only bailers (Figure 13) were a relatively light, clear lube oil with little or no odor. The float and weight system in use for measuring water levels accurately represented the fluid level in the well

Staff determined that it was not practical to remove the volume of oil that was present in the well with the tools and equipment on hand. Larger diameter bailers and lifting gear are needed to efficiently remove the oil. Additional site work would be needed to temporarily remove fencing and allow vehicle access to the well-head.


*Figure 12 (left). Dallas recorder well, showing uncovered well opening*
*Figure 13 (right). Oil sample collected from Dallas recorder.*

### Karnes 7910406

The Karnes recorder is the former City of Kenedy water supply well #5. The well was completed in the Jasper Aquifer within the Coastal Lowlands Aquifer System in 1948 with a 12-inch steel casing and an 8-inch steel screen to a total depth of 416 feet. Depth intervals for the screen were not recorded. Recent water levels are about 190 feet below ground surface. Numerous active oil and gas wells are located nearby (Figure 14). The well is located in a fenced but unlocked area (Figure 15).

An initial site visit to Recorder well 7910406 in the City of Kenedy, Karnes County, TX was completed in August 27, 2019. We made rough measurements of the oil thickness in the well, based on the thickness of the oil layer captured in a bailer, which indicated that less than a foot of oil was present, and collected samples of the oily material for Total Petroleum Hydrocarbon (TPH) analysis. The results of the TPH analysis showed that the oil was predominantly intermediate-weight fractions and did not include any light fractions, consistent with a presumed origin of the material as used lubricating oil. The oil density is 0.831 grams per cubic centimeter. The oil in the Kenedy well is clear, dark brown, and smelly, with a crude oil odor (Figure 16).

A second site visit was conducted on March 2, 2020 to evaluate the effectiveness of bailing and skimming techniques for removing the oil. The City of Kenedy had procured New Pigg Oil Only absorbent pads and the TWDB provided a standard bailer. The initial oil thickness was 0.5 ft. We recovered less than ½ gallon of free liquid oil by repeatedly bailing from the oil-water interface and approximately two gallons of oil with the absorbent pads (Figure 17) but did not succeed in removing all free oil within the time available. The standard bailers recovered at most a couple of ounces of oil per trip and were judged ineffective.

TWDB field staff visited the site again on November 11, 2020 with product-only bailers and more absorbent pads. We found that the product-only bailers don't work well with higher viscosity fluids such as lube oil. The ball does not seal firmly in the opening at the bottom of the bailer so that oil and water leaks out as the bailer is raised.

TWDB field staff visited the Kenedy well a third time on February 10, 2021. We modified the bailer by adding larger orifice at the bottom (Figure 18), which improved performance and allowed collection of approximately 8 ounces of oil per trip.  We removed 1 quart of oil using the bailer, then switched to the Newpigg absorbent pads. After soaking four sets of pads, the oil thickness was reduced to less than 0.01 foot in a discontinuous layer.

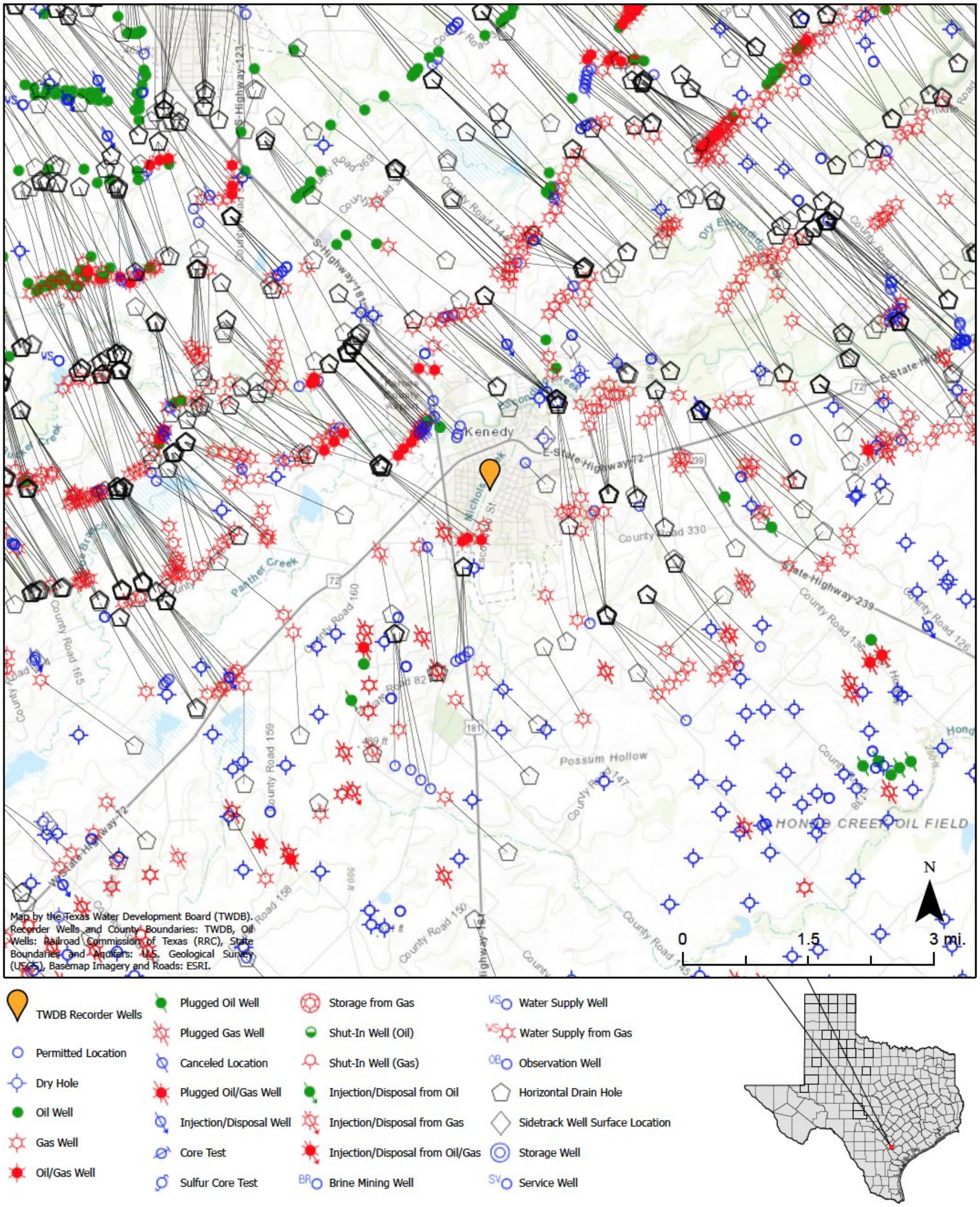


*Figure 14. Location map for Karnes County recorder well 7910406.*



*Figure 15. Karnes recorder well location.*

*Figure 16. Float from the Karnes well showing a coating of clear oil on the PVC.*

*Figure 17 (left). Used pads and recovered oil.*
*Figure 18 (right). Modified bailer with 3-inch orifice.*

## Milam 5911621

The Milam recorder well was not originally selected for evaluation as part of this project. It is included because small amounts of oily material were found in the well during regular maintenance activities on July 22, 2021, in the form of tarry deposits on the pressure transducer and cable (Figure 19). Oil has not been previously reported in the well and there is no record of it being used for irrigation or public supply purposes.

The Milam recorder is completed in the Texas Coastal Uplands Aquifer System near the Brazos River, with a total depth of 232 feet. Numerous oil wells are located nearby (Figure 20) and an active rig was present immediately across the highway from the recorder well during the July 2021 site visit.

There was not enough oil in the well to collect samples or to measure the thickness of any floating layer. TWDB staff will continue to monitor the Milam recorder site to determine if additional oil is entering the well.


*Figure 19. Tarry material on the transducer from the Milam recorder well.*

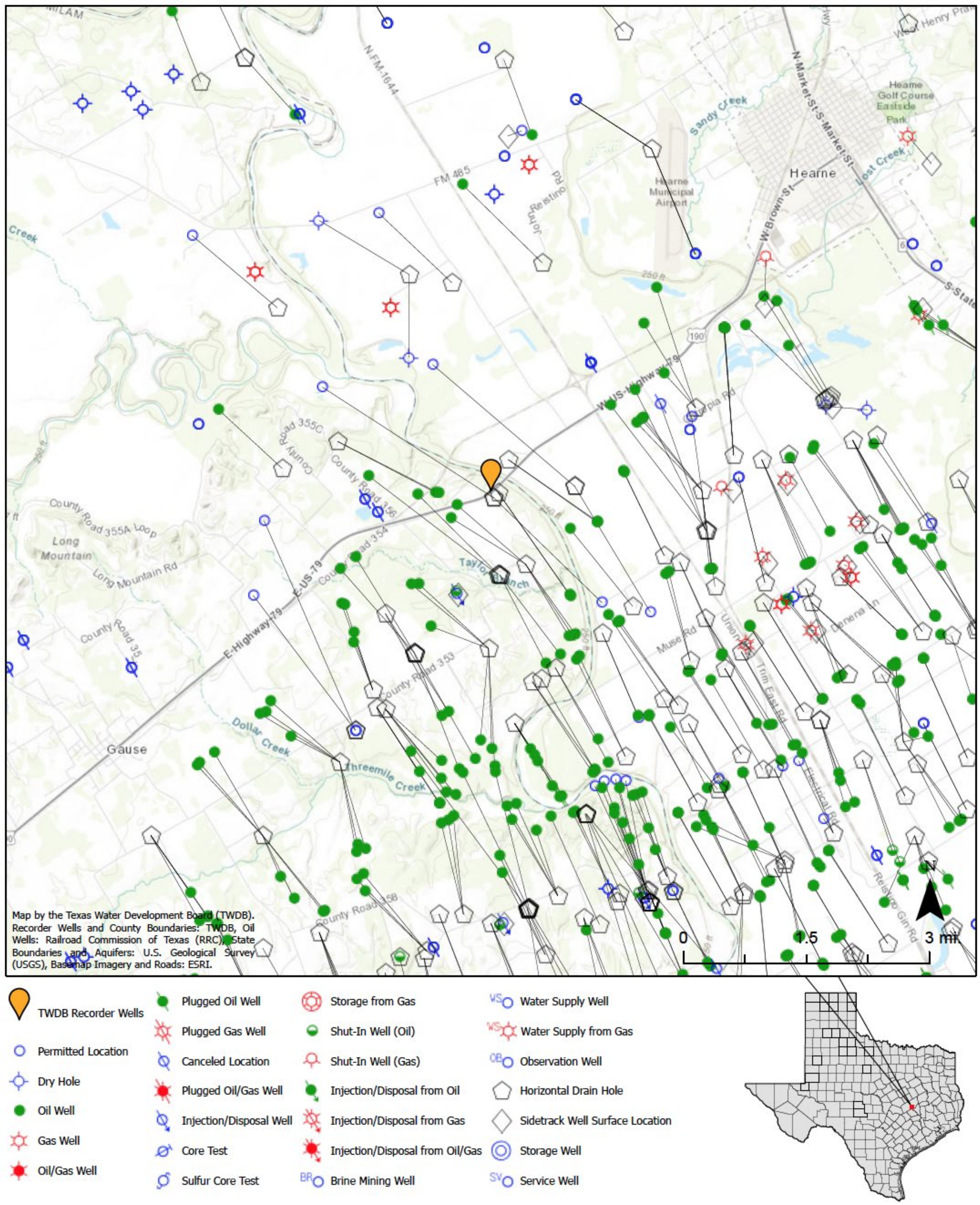


*Figure 20. Location map for Milam County recorder well 5911621.*

### Presidio 5129805

The Presidio County recorder well is located near the town of Valentine, Texas. The well was drilled in 1979 to a total depth of 1,648 feet in an area of the Rio Grande Aquifer System locally known as the Salt Bolson (Figure 21). No active oil or gas wells are located nearby.

The well has a 16-inch slotted screen from 628 feet to 1,202 feet and a 12.75-inch slotted screen from 1,237 feet to 1,648 feet depth. The well is owned by the City of El Paso but satellite imagery and water level records suggest that it was used briefly as an irrigation supply well in the late 1970s and early 1980s. the well has been unused since at least 1993, when recorder equipment was installed. The water level in recorder well 5129805 has been extremely consistent since the recorder equipment was installed, showing a gradual increase from 360 feet to 351 feet below ground surface over nearly 30 years. All pumps and piping have been removed from the vicinity of the well head (Figure 22).

TWDB staff visited the site on July 14, 2021. The depth to fluid in the well measured with the interface meter was 351.10 feet below ground surface, which is consistent with the most recent recorder readings. The interface meter did not give a reliable reading for the top of water in the well because of oil fouling on the probe tip. The oil was dark and sludgy (Figure 23) with a slight crude oil odor. Lowering a bailer 5-feet into the fluid recovered a mix of oil and water, resulting in an estimated oil thickness of approximately four feet. Based on a 4-foot oil thickness, an estimated 52.8 gallons of oil are present in the well. Several bailers of oil were recovered (Figure 24) and a sample was collected for density determination, but no attempt was made to remove all of the oil from the well.

The oil in recorder well 5129805 appears to be a weathered lubricating oil, possibly contaminated with other petroleum products. The oil density is 0.872 grams per cubic centimeter.

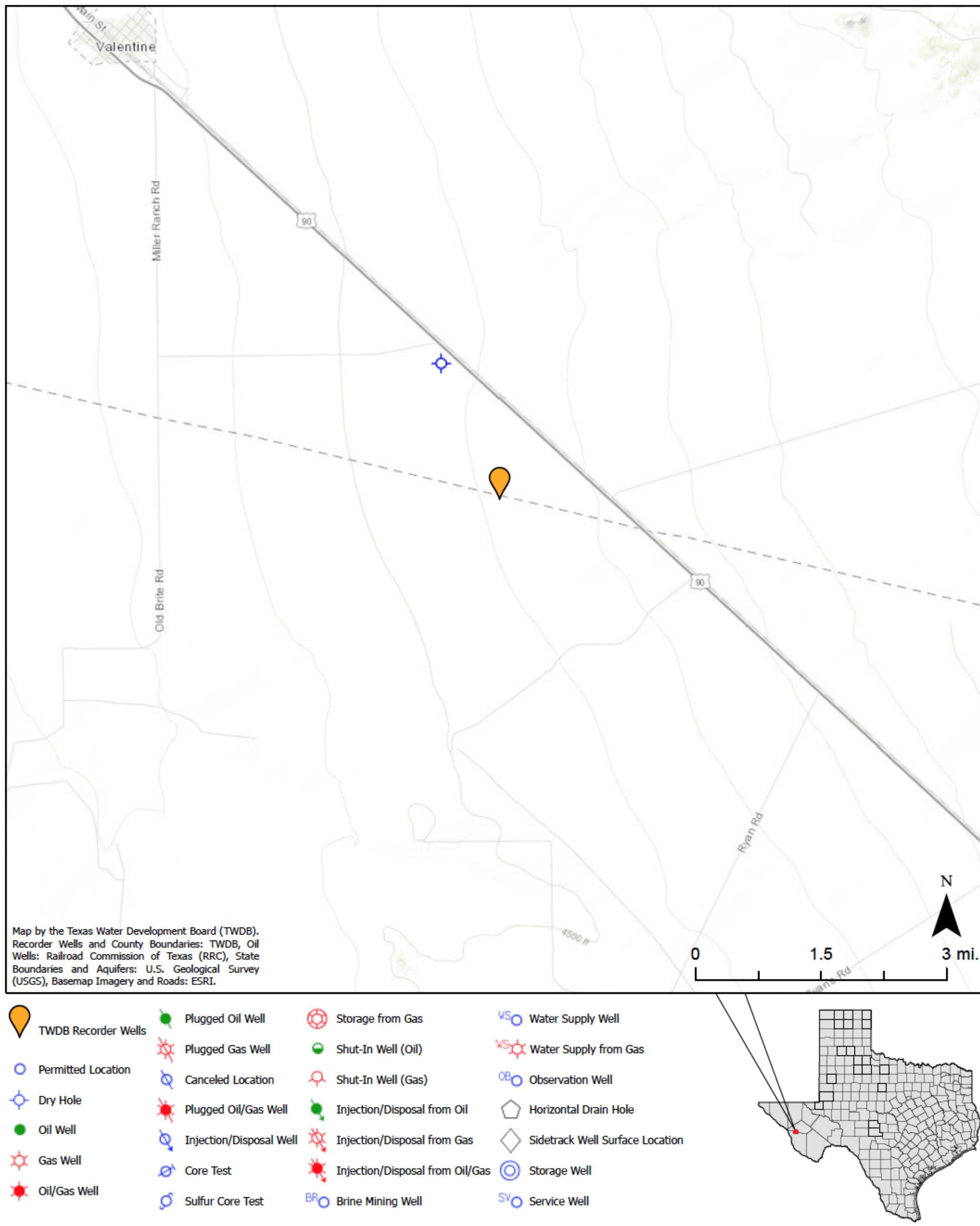


*Figure 21. Location map for Presidio County Recorder well 5129805.*

*Figure 22. Presidio recorder well location.*

*Figure 23 (left). Dark oil on the interface meter tape.*

*Figure 24 (right). 3-inch bailer with oil recovered from the Presidio recorder well.*

### Reeves 4661201

Reeves 4661201 is an unused irrigation well located approximately 20 miles south of Pecos, Texas (Figure 25). Staff had to climb a barbed wire fence and hand carry equipment approximately 200 yards to reach the well.

The Reeves well is not equipped for automatic water level measurement but is regularly monitored by the local groundwater conservation district. The Reeves well is completed to a total depth of 350 feet in the Antlers Sand member of the Edwards-Trinity Aquifer. The well is listed as having a 16-inch steel casing but field measurements indicate that the casing is 12-inch diameter. The top of the well casing is completed flush with the ground surface and the well is covered by two weathered 2 x 12 boards, which allow dirt and debris to be washed into the well (Figure 26). Numerous oil wells are located near the Reeves well, but TWDB records indicate that oil has been noted in this well since at least January 2006, before the most recent Permian Basin oil boom took off.

TWDB staff visited the site on July 13, 2021. The depth to the top of the oil surface was 185.72 feet, with the top of water at 192.88 feet, giving an oil thickness of 7.16 feet and an oil volume of approximately 42 gallons. Previous water level measurements at this well frequently have been flagged as “Questionable” because of the presence of oil in the well and difficulties in using an electric line in wells with oil. We removed approximately 3.5 gallons of oil from the well using a 3-inch bailer (Figure 27). The thickness of the floating oil layer was measured at 6.46 feet after the oil removal. Additional oil removal was not practical with the equipment on hand.

The oil has the appearance of used motor oil and has a diesel odor, with a density of 0.879 grams per cubic centimeter. An old diesel engine a short distance from the well, (Figure 28), apparently removed from mountings next to the well, is a likely source of diesel contamination in the lubricating oil used by the former irrigation pump.

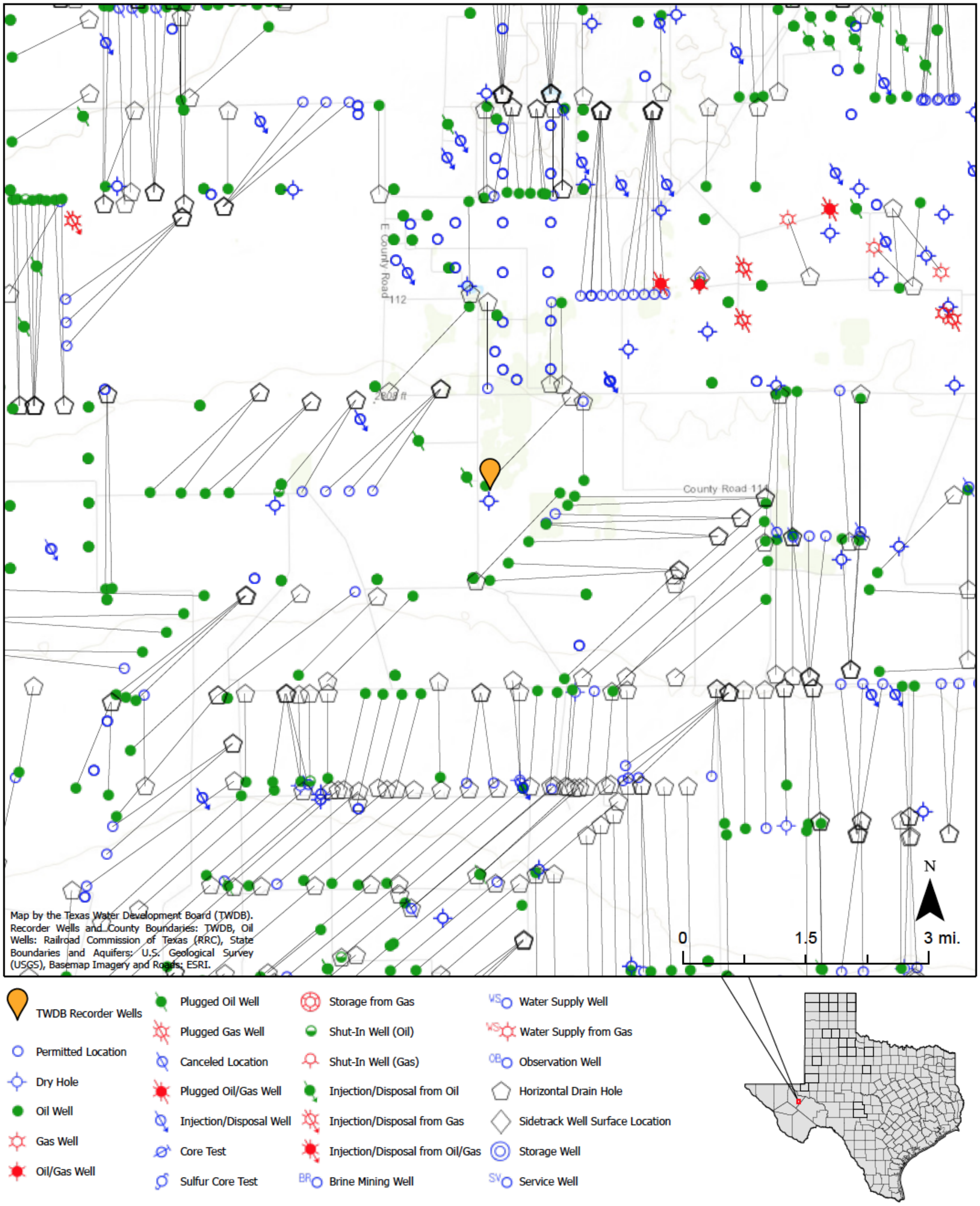


*Figure 25. Location map for Reeves County recorder well 4661201.*

*Figure 26. Reeves well head completion*
*Figure 27. Oil recovered from Reeves well.*
*Figure 28. Diesel engine previously used on Reeves well.*

### Williamson 5829603

The Williamson recorder is an old City of Taylor water supply well located in a city park (Figure 29). The well is completed in the Edwards-Trinity Aquifer Complex, with a 16-inch casing to 300 feet below ground surface, an 11-inch casing to 2,732 feet, and 7-inch casing and screen to a total depth of 3,335 feet. There are no active oil or gas wells in the vicinity.

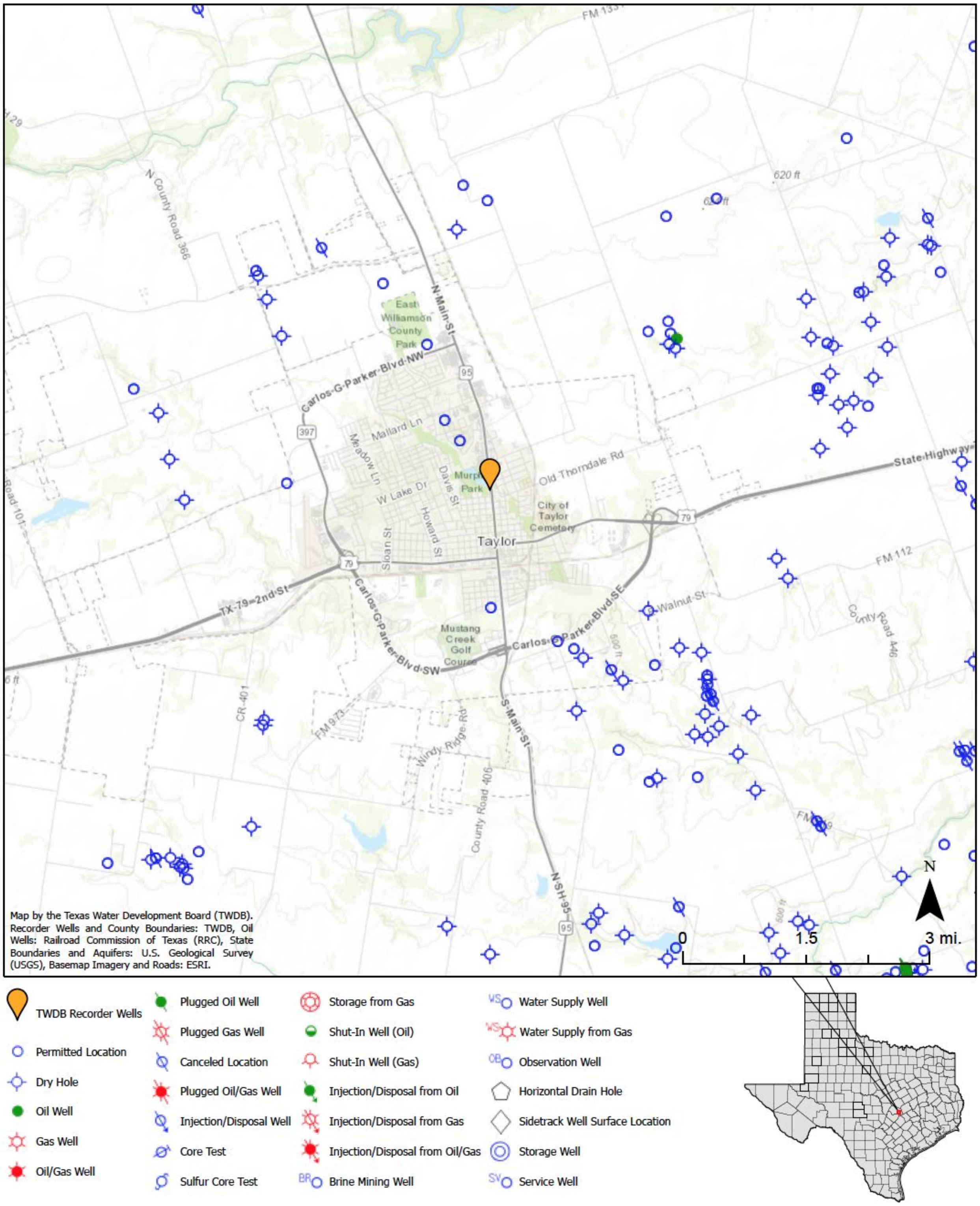


*Figure 29. Location map for Williamson County recorder well 5829603.*

TWDB staff visited the site three times to measure oil thickness and recover oil from the well. The first site visit was on October 20, 2020. No reliable product-thickness measurement could be obtained using the interface meter. Staff used the product-only bailers but recovered only small amounts of oil at a time. Approximately two gallons of oil were recovered using several sets of absorbent pads wrapped on a length of PVC pipe (Figures 30 and 31).

Staff visited the well a second time on March 8, 2021. The initial depth to oil measured with the interface meter was 214.60 feet, and the depth to water was 214.70 giving an oil thickness of 0.1 feet. This oil thickness measurement is suspect given that approximately two gallons of oil were subsequently removed on that site visit. A bailer was modified by adding a 3-inch PVC adapted onto the lower end of the bailer (Figure 32) in an attempt to recover a larger volume of oil from the oil-water interface each time the bailer was deployed. Even with this modification, the bailer recovered only a small amount of oil mixed with water on each deployment (Figure 33). The bailer was lost downhole on the third deployment when the plastic lifting ring broke. Absorbent pads were used to recover about two gallons of oil after the bailer was lost. The final depth to oil was 214.7 feet and depth to water was 214.84 feet, for an oil thickness of 0.14 feet

The third site visit took place on July 22, 2021. We tried using a 3-inch bailer but recovered only water in the bailer even though the exterior surface of the PVC was coated in oil. Two sets of pads wrapped around a length of 1-inch PVC pipe recovered small amounts of oil but did not get saturated with oil. Staff experimented with a 'mop' design, cutting the lower ends of the pads into thin strips, wrapping it around a short length of 1-inch steel pipe and clamping it in place with a hose clamp. The mop design resulted in better recovery of the remaining oil from well. We used three sets of pads cut into mop heads (Figure 34). Several weeks after the mop heads were recovered from the well, the dark discoloration turned to a red-orange rust color, suggesting that much of the material removed from the Taylor recorder during the final cleaning was iron oxide particles rather than oil. No measurable oil layer remained after the July 22 cleaning, although a discontinuous oil film was still present in recovered water (Figure 35).


*Figure 30 to 33, clockwise from upper right, showing absorbent pads after and before deployment in the well, modified bailer coated in dark oil; and oil water mixture recovered from the well.*

*Figure 34 and 35. Absorbent pads cut into mop configuration (left) and oil film on water recovered after oil removal (right).*

## Zavala 7702509

The Zavalla recorder well is a former irrigation well completed in the Texas coastal uplands aquifer system near the town of La Pryor (Figure 36). The well has a 10-inch steel casing and screen. The total depth of the well is 734 feet.  Several oil and gas wells have been drilled nearby but the closest active well is approximately one mile to the southeast.

TWDB staff first visited the Zavala recorder site on May 5, 2021. The depth to the top of the oil layer was measured with the interface probe at 421.05 feet. Staff could not obtain a reproducible reading for the depth to water. The oil layer was estimated to be at least several feet thick because bailers came up full of oil with no trace of water. The oil is dark and clear, with a low odor. It has a medium viscosity and appears to be lubricating oil.

We initially used the New Pigg absorbent pads to recover oil. After three attempts we decided to use the product-only bailer instead as the volume of oil was too much for the pads. We recovered 5 gallons of oil using the bailer (Figure 37).

We determined that the pressure transducer setting at the Zavalla recorder was off by about 41 feet because of a bad steel tape water level measurement from the previous year. The well has a leaky casing in addition to the oil, further complicating water level measurements with steel tape or electric line. The steel tape gets wet from the casing leak, giving a reading about 40 feet above the current water level. The electric line does not respond to the oil, which fouls the contacts so the meter does not give a reliable signal for the water layer either. The interface meter gives a clear signal for the top of the oil.

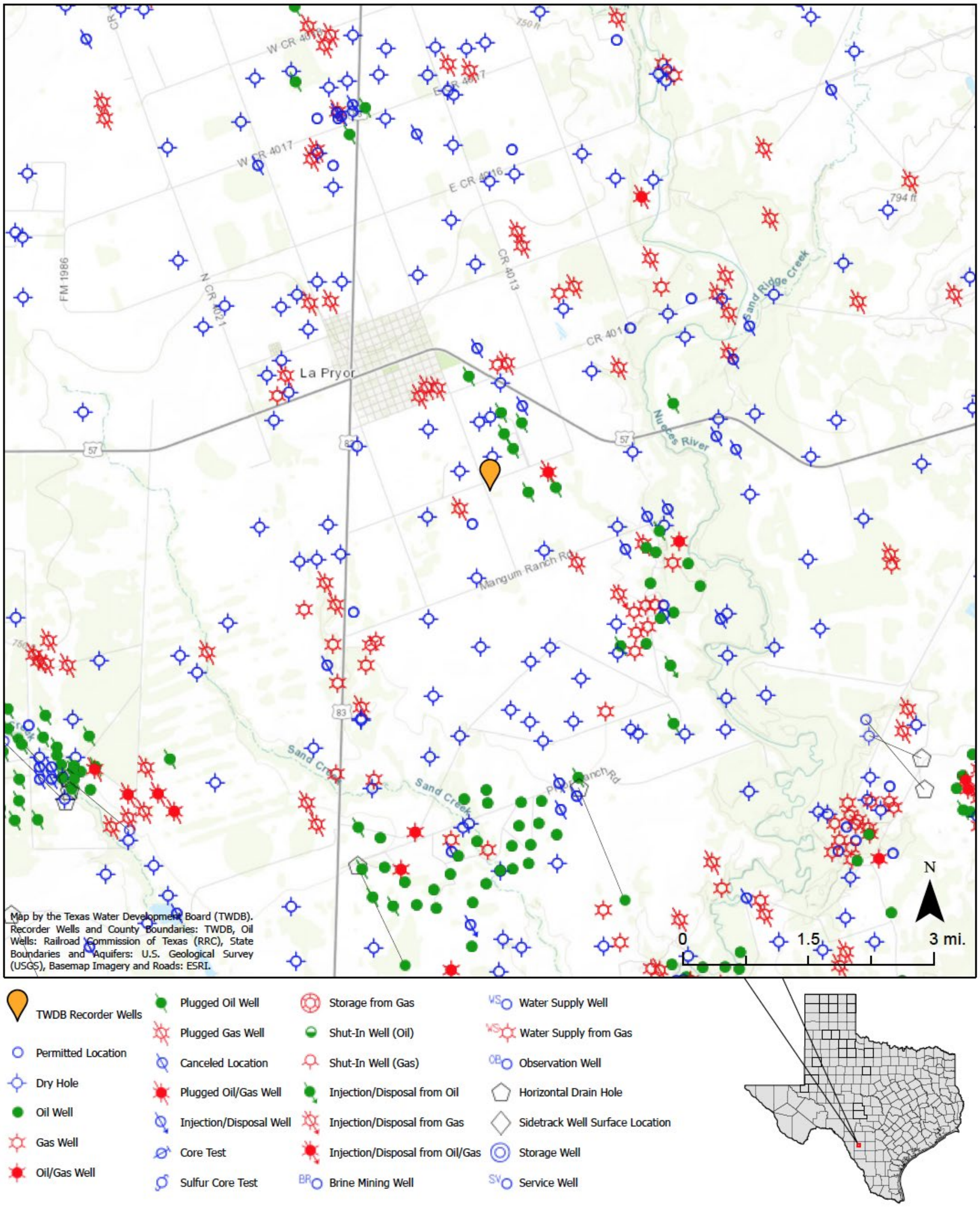


*Figure 36. Location map for Zavalla County recorder well 7702509.*

We visited the Zavalla site a second time on July 7, 2021. Depth to the top of the oil was 420.7 feet, and the depth to the top of the water was estimated at 438.5 using the interface meter, giving an oil thickness of 17.8 feet. It is hard to get a good water level reading even with the interface probe – the oil is fairly viscous and sticks to the optical sensor on the meter so that it doesn't give a reproducible oil-water interface reading. We recovered an additional five gallons of oil in 12 bailer runs using a three-inch bailer (Figure 38). A sample collected for density testing gave a value of 0.88 grams per cubic centimeter. Scale particles from the well casing and debris washed into the well get stuck in the ball valve on the bailer and let the oil leak out so that half of the bailer runs were mostly empty. The three-inch bailer is more efficient than the 1.5-inch product-only bailers, but it is too heavy to raise with the electric drill and pulling it by hand is difficult once the rope gets oiled up and slippery. Better equipment is need to remove the remaining oil in the Zavalla well.

The landowner reports that nearby irrigation wells on his property have a strong petroleum odor in produced water. Also, he reports that the Texas Railroad Commission plugged a couple of abandoned oil and gas wells nearby in the last few years. There does not appear to be any connection between these activities and the oil in the Zavala recorder.



*Figures 37 (left) and 38 (right). Oil recovered on 5/5/21 using product-only bailer and oil recovered on 7/7/21 using 3-inch bailer.*