

6.0 EXPANSION OF MONITORING WELL NETWORK WITH CONSIDERATION FOR SUPPORTING GEOSTATISTICAL ANALYSIS OF DATA

6.1 BACKGROUND

The construction and maintenance of a comprehensive groundwater monitoring network is among the more costly activity that GCDs perform. Identifying favorable monitoring well locations is time consuming. Installation of wells is expensive. Securing leasing is resource intensive. And, obtaining and analyzing data is the trifecta: it is time-consuming, expensive, and resource intensive. Consequently, GCDs should have a well-reasoned and thought monitoring objectives and approach for accomplishing the said objectives before embarking on expansion of their monitoring well network.

This section is to provide a framework with CCGCD, TGCD, RFGCD, and VCGCD to expand their monitoring network. For convenience of brevity, these four GCDs will be referred to in the collective as the Districts. The framework will include identifying monitoring objectives based on a stakeholder based process and a systematic process for prioritizing the locations for additional monitoring wells.

6.2 CONSIDERATIONS FOR EXPANSION OF MONITORING WELL NETWORK

The considerations for the monitoring well expansion includes the monitoring responsibilities identified in Section 5.2 and a stakeholder-based evaluation of project priorities (Young, 2013). Among the GCDs management responsibilities related to monitoring water levels is evaluating compliance to the GCD's DFC. The importance of evaluating DFC compliance was echoed in the responses from a Groundwater Advisory Committee (GWAC) that was created by VCGCD that consisted of stakeholders that represented different groups of groundwater users in Victoria County. Young (2013) present the results of two surveys regarding groundwater issues, discussion and selection of potential projects, and a ranking of thirteen projects that were developed as one-page descriptions that included an estimated cost for the project.

Table 6-1 lists the ranking of 13 projects evaluated by the GWAC. The three bolded projects are associated with the collection and analysis of water level data from a monitoring well network. The 13 projects were ranked by each GWAC member with a score of 1, 2, 3, or 4, which represented a resource utilization of poor, fair, good, and excellent respectively. The final ranking for each project was based on the average of the rankings assigned to the project by the stakeholders. Table 6-1 provides the average scores for the projects. The average scores ranged between 3.75 to 1.75. Five projects were assigned a high resource utilization ranking. Three projects were assigned a moderate resource utilization ranking. Four projects were assigned a low resource utilization score

Out of the three projects involving the collecting and analyzing groundwater water level data, one project was rated as high and two projects were rated as low. The project with a high-priority rating was titled: "Project 6: Methodology for Analyzing Monitoring Data to Document Changes in Aquifer Conditions, Address District Concerns, and Evaluate Conformance with Desired Future Conditions (DFCs)." The two projects with low-priority ratings were titled: "Project 10. Measurement of Water Levels in Vertically-staged Monitoring Wells to help estimate Vertical Groundwater Flow and to help

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Monitor/Analyze Water Level Data” and “Project 11. Conceptualization and Characterization of Groundwater-Surface Water Interactions Based on Changes in Monitored Water Levels and Water Quality Measurements.” The two low-rated projects have appreciable overlap with four of the eight water level related issues discussed in Section 5.2 that involve monitoring groundwater levels.

Table 6-1 Groundwater Advisory Committee Stakeholder Ranking of Proposed Project from Young, (2013) . The three bolded projects are associated with the collection and analysis of water level data from a monitoring well network.

Resource Utilization		Proposed Project
Group	Score	
High	3.5	Project 1. Assessment of the GMA 15's GAM and Recommendations to Improve the GAM Capabilities to Help GCDs achieve their Goals and Objectives.
	3.5	Project 2. Literature Search for Hydraulic Test Data in Victoria County to Help Estimate Aquifer Hydraulic Properties to Improve Predictions of Pumping Impacts and Sustainability
	3.5	Project 3. Large-Scale Aquifer Test(s) to Characterize Aquifer Properties and Improve the Conceptualization of Groundwater Flow System in Victoria County
	3.75	Project 5. Development of Pumping-Impact Assessment Tool(s) Capable of Evaluating Water Level Change and Zone of Capture Associated with High-capacity Wells, Injection Wells, ASR operations, and Development of Brackish Water
	3.5	Project 6. Methodology for Analysing Monitoring Data to Document Changes in Aquifer Conditions, Address District Concerns, and Evaluate Conformance with Desired Future Conditions (DFCs)
	3.5	Project 12. Evaluation of Recharge Rates Estimated from Previous Field Studies and Collection and Analysis of Additional Field Data
Moderate	3	Project 4. Data-Gap Analysis of Well Construction Information and Identification of Wells Most Susceptible to Drawdown Impacts
	3	Project 8. Evaluation of the Sustainability of Groundwater Resources Using the GAM 15 GAM
	2.75	Project 9. Development of Adaptive Monitoring Practices to Achieve Sustainability of Groundwater Resources
Low	1.75	Project 7. Assessment of the Potential for Injection and Disposal Wells to Adversely Impact Groundwater Resources
	2.25	Project 10. Measurement of Water Levels in Vertically-staged Monitoring Wells to help estimate Vertical Groundwater Flow and to help Monitor/Analyze Water Level Data
	1.75	Project 11. Conceptualization and Characterization of Groundwater-Surface Water Interactions Based on Changes in Monitored Water Levels and Water Quality Measurements
	2.25	Project 13. Characterization of the Water Quality Based on Analysis of Well Monitoring and Analysis of Geophysical Logs

Based on GCD responsibilities in the TWC and responses from the GWAC created by VCGCD, the primary objective of the monitoring program should be to document changes in aquifer conditions over time and to evaluate compliance with DFCs. Additional objectives that should be deemed of considerably less

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importance would be to monitor groundwater levels near river gauges and to monitor water levels in vertically staged monitoring wells.

6.3 GENERAL APPROACH FOR IDENTIFYING CANDIDATE MONITORING WELL LOCATIONS

INTERA has assisted numerous GCDs with expanding their groundwater wells monitoring locations (Young, 2013, Young, 2014, Young, 2015a,b,c; Oliver and Piemonti, 2018; INTERA, 2012a,b; Young and others, 2015). Although each of these applications are different in their monitoring well selection criteria, the general approach used for each application is similar. The process involves the three following steps:

- Step 1. Define the objectives of the GCD monitoring well program and identify the GCD's current set of monitoring well locations
- Step 2. Identify candidate wells that appear suitable for use as monitoring wells by searching the GCD database of exempt wells and/or the TWDB database of submitted driller reports (SDRs).
- Step 3. Identify areas where additional monitoring wells would provide beneficial water level information for accomplishing the district goals.
- Step 4. Overlap the location of candidate wells with the monitoring areas of interest and select a set of candidate wells for each monitoring area.
- Step 5. Prioritize the monitoring area of interest and prioritize and select the candidate wells per monitoring area based on available well specifications and the GCD monitoring objectives
- Step 6. Tabulate the selected candidate wells by monitoring area and include relevant well information. Identify areas where new wells would provide the most beneficial areas if no candidate wells exist.

Among the key factors that affect how the six steps are implemented are the complexity of the site geology, the monitoring objectives, and the GCD area extent. A high-level summary of the approach can be visualized using results from its application for the Coastal Plains GCD in Matagorda County. The upper image in Figure 6-1 summarizes several key features, which include the locations of candidate wells with and without screen information, 11 monitoring areas of interest, and the locations of four existing monitoring wells. The monitoring areas of interest were delineated based on differences in production types and amounts. The candidate wells were based on water use type, aquifer assignment, installation date, screen interval, and well diameter. After culling the candidate wells based on selection criteria, the highest rated candidate wells kept for final consideration by the GCDs for their monitoring program. Final selection of the additional monitoring well was required a obtaining a candidate well or drilling a new well.

6.4 IDENTIFICATION OF CANDIDATE WELLS AND WELL LOCATIONS

6.4.1 Current Well Monitoring Network and Candidate Wells for Expanding the Network

The candidate wells for wells for the monitoring network for the Districts consists of three groups of wells. Wells in each of these groups were assigned to either the Chicot or the Evangeline Aquifer based on their well depth and the aquifer surfaces associated with the GMA 15 current GAM (Chowdhury and others, 2004). **Figure 6-1** shows the location of the wells belonging to each group for the Chicot and the

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Evangeline aquifers. Well Group 1 consists of wells that have been monitored for at least one water level from 2016 to 2021. These wells are shown as red squares. Well Group 2 consists of wells that were monitored at least once from 2000 to 2015 but were not monitored from 2016 to 2021. These wells are shown as black dots. Well Group 3 consists of wells that have been installed since 2021 and are a part of the TWDB SDR database. These wells are represented as gray dots.

For each of the four counties that comprise the Districts, we have assumed that the initial monitoring network can be reasonably represented by wells in Well Group 1 and Well Group 2. The working assumption is that the GCDs will have about a 90% and about a 70% chance of obtaining permission to monitor Well Group 1 and Well Group 2, respectively.

Well Group 3 are the location of candidate wells that could be used to expand the monitoring well network. The presumption is that there is about a 20% chance that a GCD will be able to reach a monitoring agreement with an owner of a Group 3 well. SDR wells that were considered as candidate wells include those with well use types of domestic, livestock, rig supply, and irrigation. SDR wells that were not considered as candidate wells include those with municipal, mining, and industrial use.

6.4.2 Monitoring Areas Where Beneficial Water Levels Can be Measured

Three priority levels were used to categorize the proposed locations for new monitoring wells. **Table 6-2** provides a brief explanation of the three levels. Level 1 is the highest priority. Level 3 is the lowest priority and Level 2 is an intermediate priority.

Table 6-2 Description of the Three Monitoring Levels that are Assigned to Proposed Areas for Expansion of the Monitoring Network

Monitoring Level		Purpose
Level 1	Highest Priority	Fill in gaps in well coverage to support geostatistical analysis that produce continuous water level surfaces that can be used to estimate temporal changes in water levels and flow directions and to check DFC compliance.
Level 2	Intermediate Priority	Obtain access to a former rig supply well that is located in an area where a Group 2 well may not be accessible or where monitoring a rig supply well would be preferred over a Group 2 well. In some cases, to monitor an area where no wells are in the current monitoring well network.
Level 3	Low Priority	Provide the opportunity to monitor groundwater -surface water interaction by measuring water level in a shallow groundwater well located in the vicinity of a stream gauge.

Figure 6-2 shows the shows circular areas in which the addition of a monitoring well is proposed. All of the monitoring areas in Figure 6-2 have a Level 1 priority. A Level 1 priority is assigned to areas where the closest existing monitoring well is no less than 5 miles away. In general, the Level 1 monitoring areas are located in areas where the kriging variance are relatively high (see Section 5.3.1). The addition of a new well in a Level 1 monitoring areas should have a much greater impact on decreasing the uncertainty associated with the calculated average water level across the county than a randomly placed monitoring well.

The candidate wells contained in the Level 1 monitoring areas are listed in the Texas Water Development Board Submitted Driller (SDR) database. The SDR wells have been installed after 2000 and include wells used for different water uses. The SDR wells with municipal, industrial, or mining use are

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not shown in Figure 6-2 or any subsequent files. They were deemed undesirable because they typically have relatively high productions and pumping all year round. The SDR candidate wells shown in have the preferred priority of rig supply wells, then domestic/livestock wells, and then irrigation wells. The final decision regarding which candidate well would serve as the best monitoring well should be made after inspection of local conditions including the well condition, nearby pumping, and local access.

Figure 6-3 shows monitoring areas that have a Level 2 priority. A Level 2 priority area contains one or more rig wells of interest. Rig wells were installed primarily to provide water for drilling a large and deep well such as an oil exploration borehole/well. After the well or borehole has been completed, the owners of the rig wells tend to be more cooperative than owners of other types of well owners in terms of providing a GCD access for monitoring the water well. Besides often being easier to gain monitoring access, rig wells have the additional benefit of not being pumped after they have fulfilled their purpose. The Level 2 monitoring areas provide an opportunity to reenforce an/or provide duplication in an area where a Group 2 well already exist. In these areas, additional water level data would help to help to reduce the kriged variance at the well location and provide for a better variogram analysis.

Figure 6-4 shows monitoring areas that have a Level 3 priority. The Level 3 monitoring areas are located close to stream gauges and include wells that are less than 100 feet deep. The monitoring areas have the potential to serve as a field site to collect information on groundwater – surface water interactions.

6.4.3 Proposed Well Monitoring Network

Figures 6-5, 6-6, 6-7, and 6-8 show the proposed well monitoring network for Calhoun, Jackson, Refugio, and Victoria counties, respectively. Each county's well network consists of previously monitored wells and proposed new well locations. The existing monitoring wells are comprised of two well groups: Group 1 and Group 2. Group 1 wells have been monitored since 2016. Group two wells have been monitored between 2000 and 2016. The proposed areas for new locations are designated by priority levels 1 to 3. Only one new monitoring well per monitoring area I proposed. Table 6.2 explains the purpose for the different priority levels. As mentioned previously, a primary reason for the Level 2 wells is to provide redundancy for the Group 2 wells, which may not be available for future use by a GCD.

Table 6.3 lists the number of wells that have been previously used to monitor water levels and the number of proposed new locations for monitoring wells by county and by aquifer. We anticipate that at several existing and proposed well locations, no well may be available for the GCD to monitor. In a few of these situations, the GCD may chose not to lease a well but to drill a new well. One of the problems associated with drilling a new well will be securing the right to drill. Among the options to drill is obtain access to land associated with TXDOT right aways, lands associated with state and federal lands.

Appendices 7A, 7B, 7C, and 7D list the candidate wells associated with the proposed monitoring areas. These four appendices provide the latitude and longitude, the SDR number, and well use, well depth, aquifer, and the well owner's name for each well. Appendix 2A lists the wells that have been previously monitored. Appendix 2A lists the latitude and longitude, the SWN number, and well use, well depth, and aquifer. Table 6.4 lists the number of candidate wells associated with the monitoring areas for Calhoun, Jackson, Refugio, and Victoria counties.

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Table 6-3 Distribution of Existing and Proposed New Well Location for the Monitoring Network for Calhoun, Jackson, Refugio, and Victoria Counties

County	Aquifer	Existing Wells		Proposed New Well Locations (SDR)			Total	
		Group 1	Group 2	Level 1	Level 2	Level 3	Existing	Proposed
Calhoun	CH	11	9	4	3	1	20	8
	EV	0	0	0	0	0	0	0
Jackson	CH	58	22	3	4	3	80	10
	EV	5	3	5	0	0	8	5
Refugio	CH	13	14	4	3	0	27	7
	EV	2	7	3	2	0	9	5
Victoria	CH	39	45	2	2	2	84	5
	EV	16	26	5	3	2	42	10
Total	CH	121	90	12	12	6	211	30
	EV	23	36	13	5	2	59	20

Table 6-4 Number of Candidate Wells associated with the Monitoring Areas for Calhoun, Jackson, Refugio, and Victoria Counties

County	Aquifer	Proposed New Well Locations (SDR)			Total
		Level 1	Level 2	Level 3	
Calhoun	CH	28	10	8	46
	EV				0
Jackson	CH	27	27	7	61
	EV	7	--		7
Refugio	CH	18	34	--	52
	EV	14	4	--	18
Victoria	CH	25	8	11	44
	EV	36	13	6	55
Total	CH	88	79	26	193
	EV	57	17	6	80

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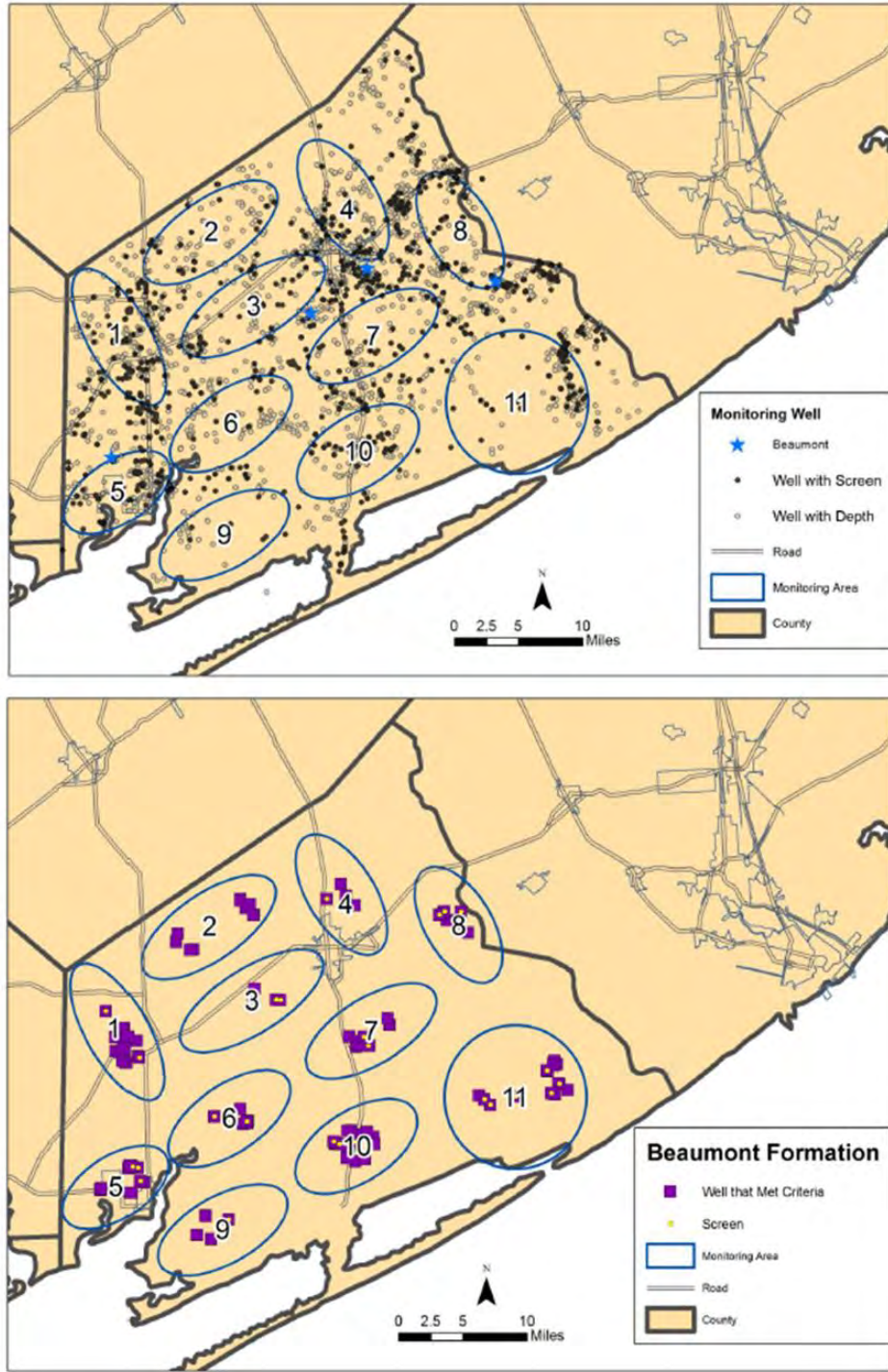


Figure 6-1 Location of eleven monitoring areas where addition monitoring wells would benefit the monitoring network for Coastal Plains GCD with locations of exempt wells that could server as monitoring wells (top image) and with five to ten wells proposed for per monitoring area as the preferred candidates for the single monitoring well to represent that monitoring area.

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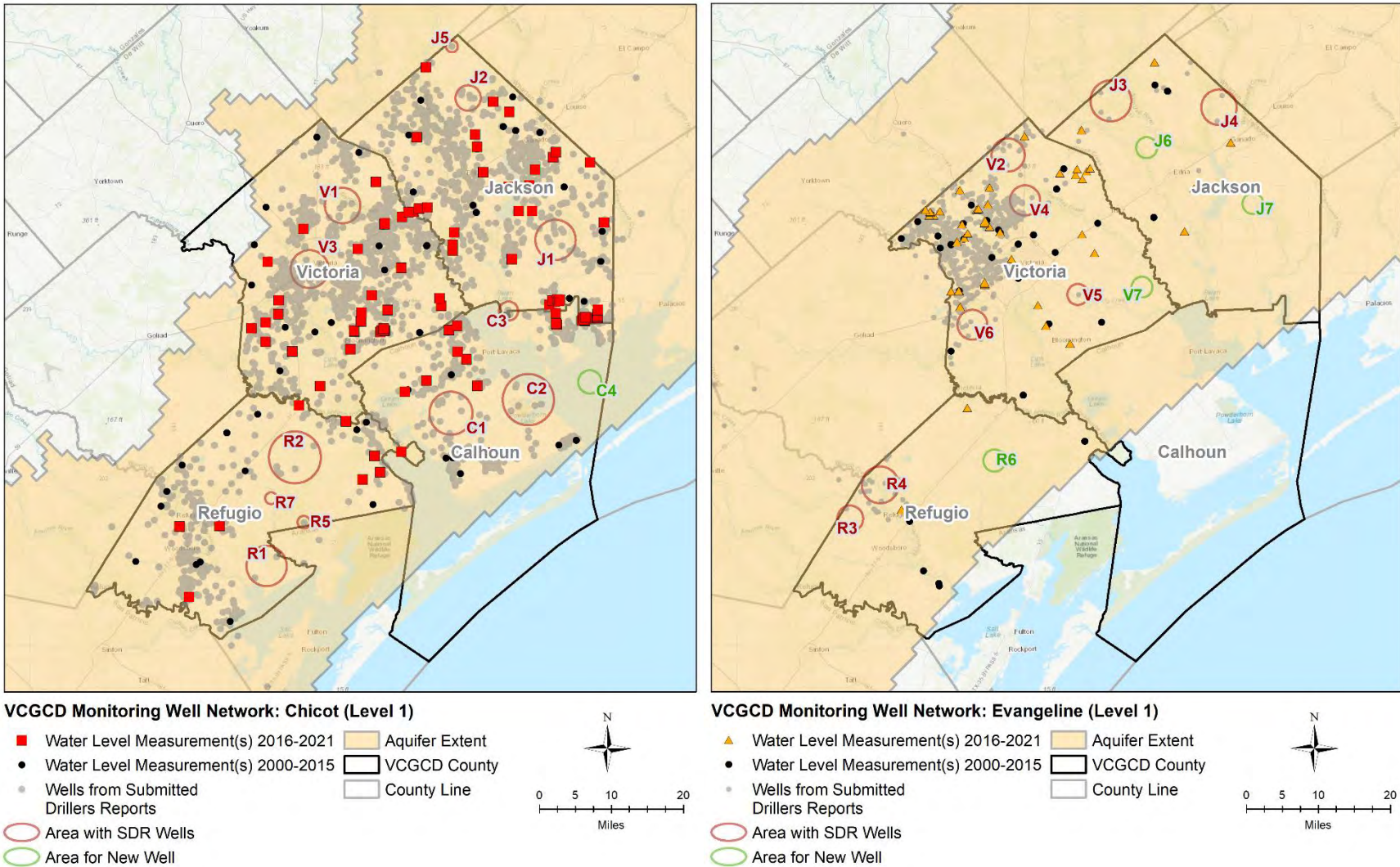


Figure 6-2 Proposed Level 1 Monitoring Areas for the Chicot and Evangeline aquifers in Calhoun, Jackson, Refugio, and Victoria counties with locations of wells with Submitted Drillers Reports.

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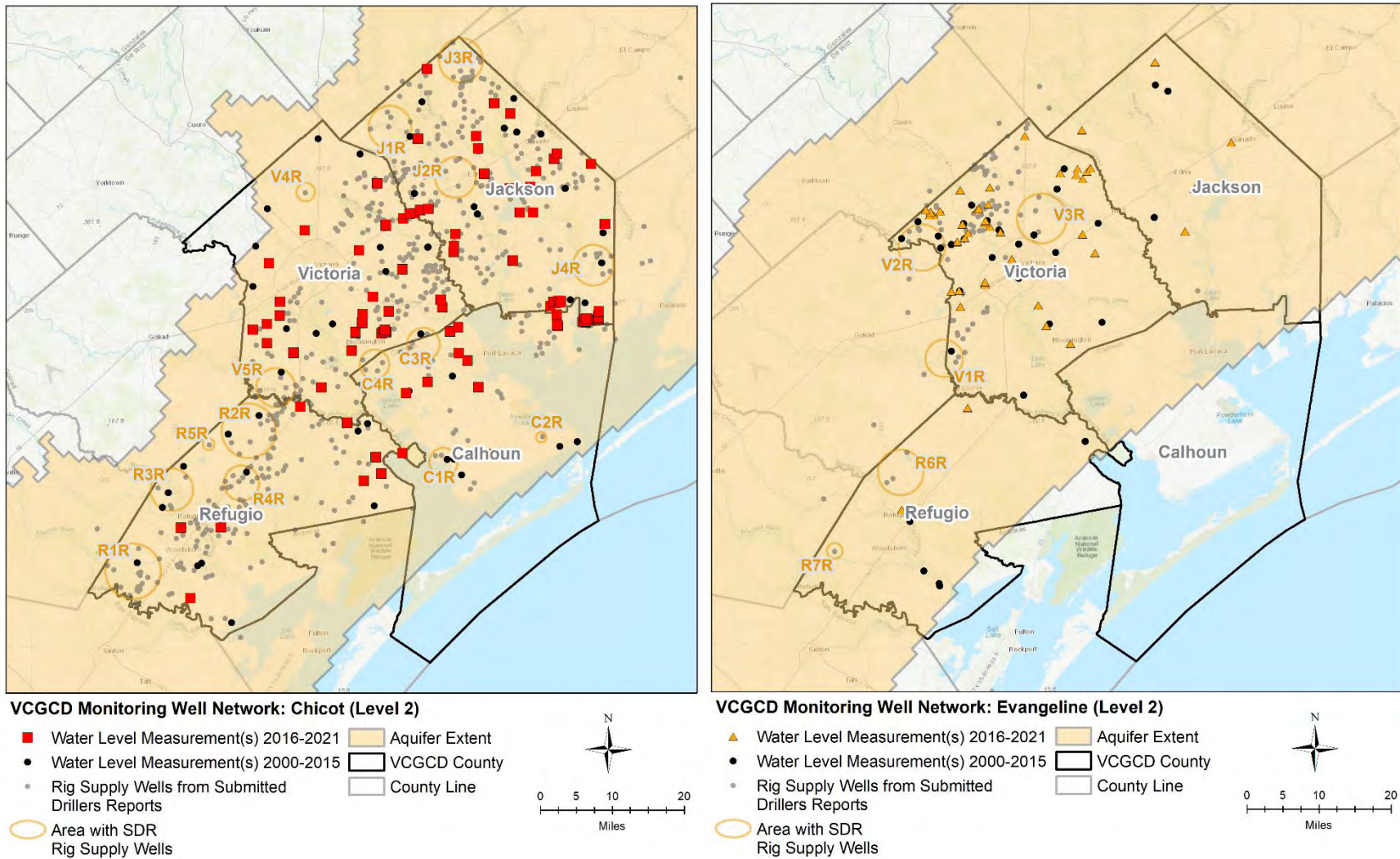
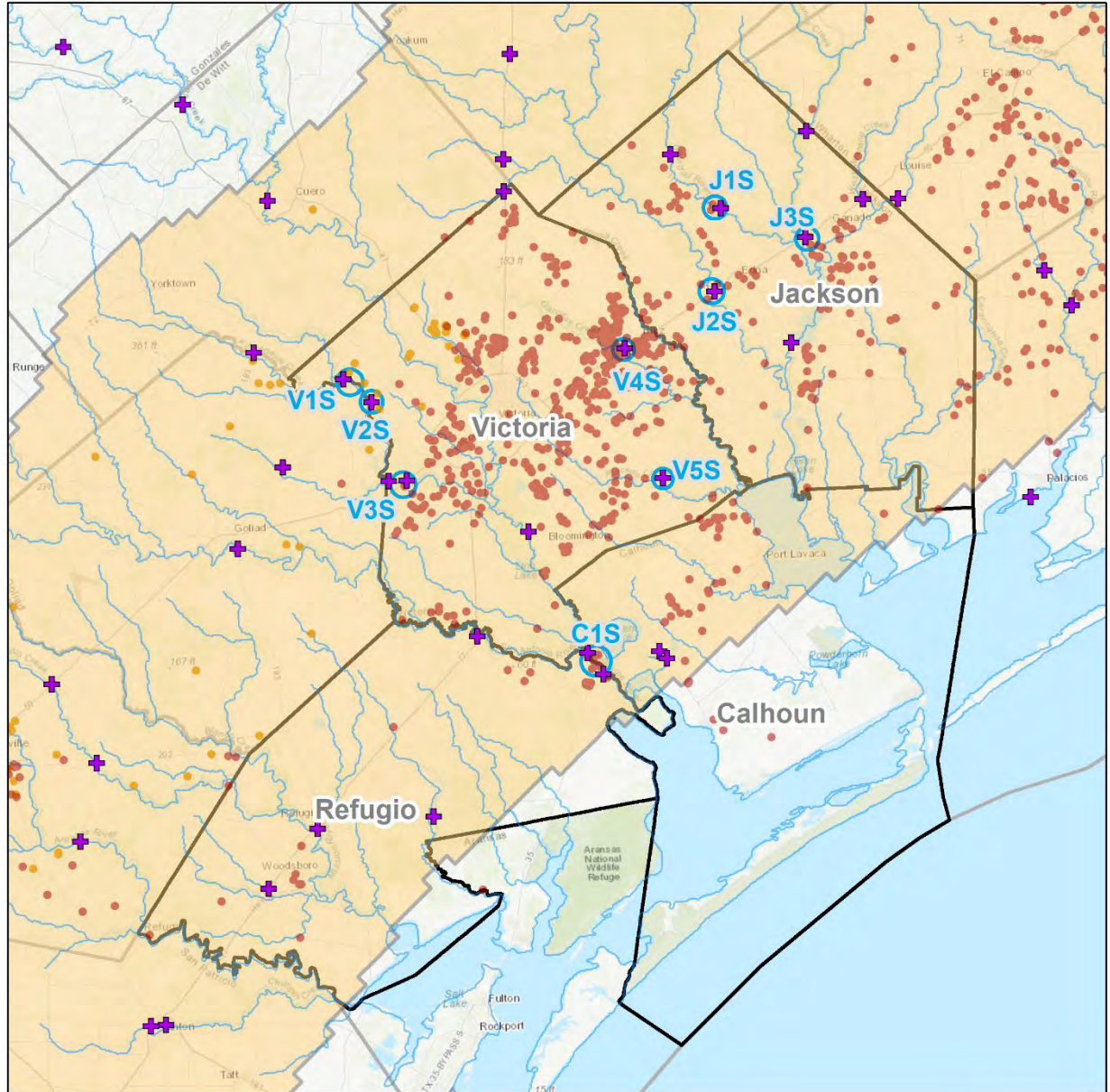


Figure 6-3 Proposed Level 2 Monitoring Areas for the Chicot and Evangeline aquifers in Calhoun, Jackson, Refugio, and Victoria counties with locations of wells with Submitted Drillers Reports.

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Groundwater Surface Water Interaction (Level 3)

- Shallow SDR Wells: Chicot
- Shallow SDR Wells: Evangeline
- ✚ Surface Water Gages
- Area with SDR Wells
- Rivers & Streams
- Evangeline Formation
- VCGCD County
- County Line

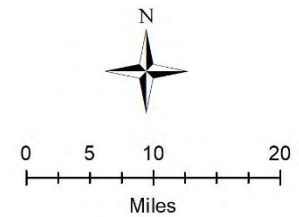
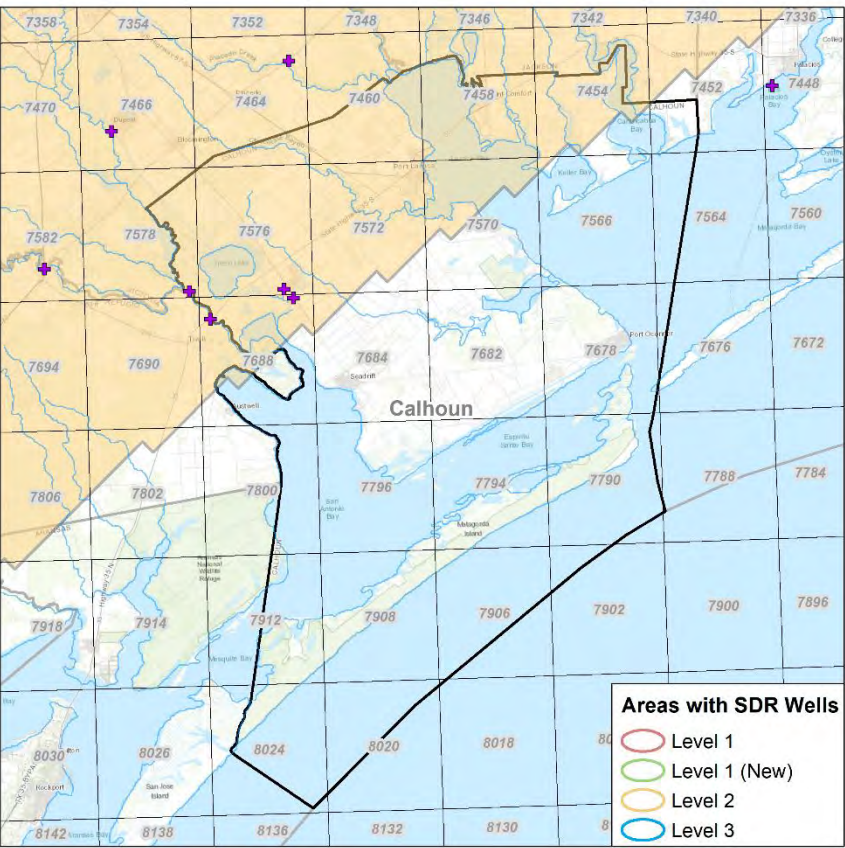
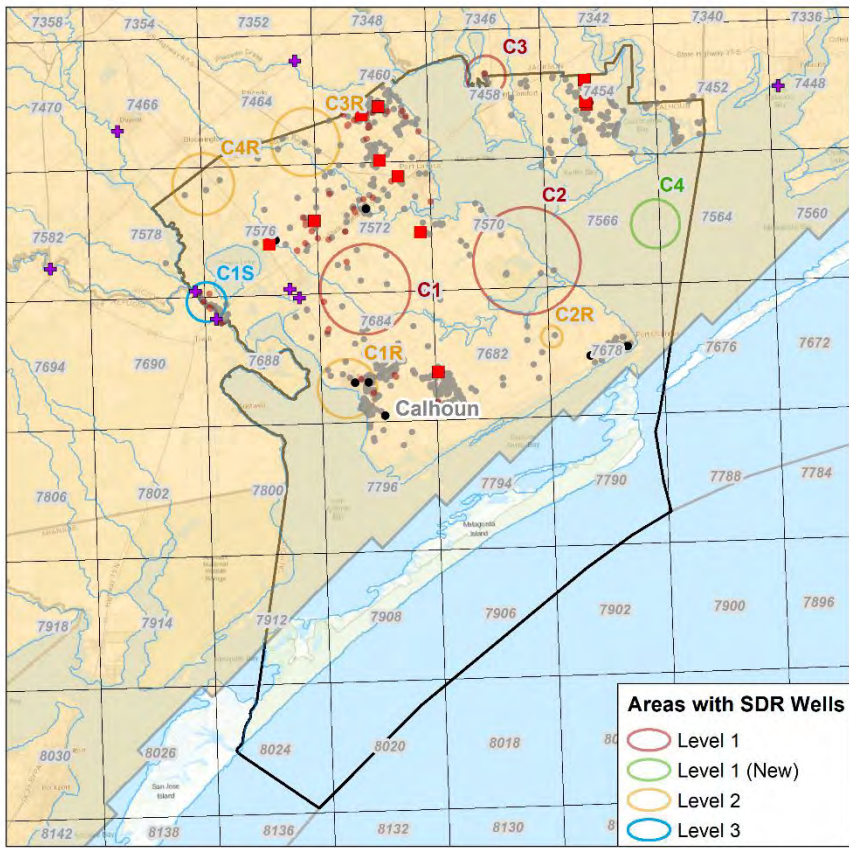
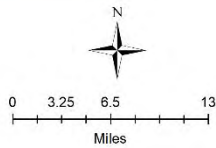


Figure 6-4 Proposed Level 3 Monitoring Areas for the Chicot and Evangeline aquifers in Calhoun, Jackson, Refugio, and Victoria counties with locations of wells with Submitted Drillers Reports



Calhoun Monitoring Well Network: Chicot

- Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ✚ Surface Water Gages
- Rivers & Streams
- Chicot Aquifer
- USGS 7.5 Minute Quadrangle
- Calhoun County
- County Line



Calhoun Monitoring Well Network: Evangeline

- ▲ Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ✚ Surface Water Gages
- Rivers & Streams
- Evangeline Aquifer
- USGS 7.5 Minute Quadrangle
- Calhoun County
- County Line

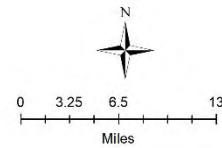
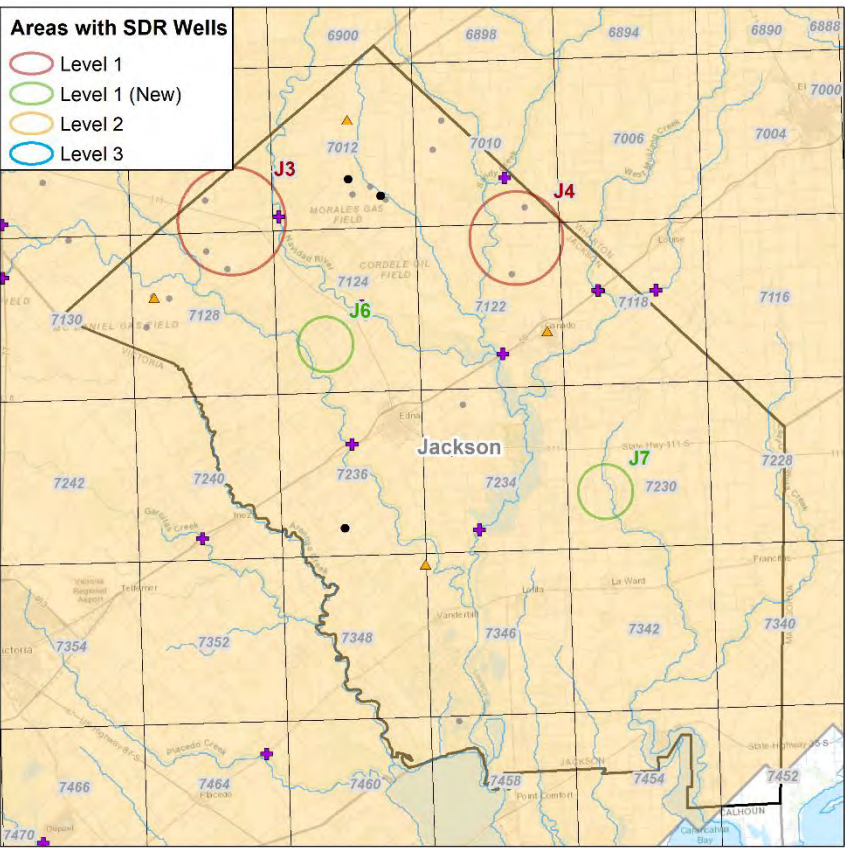
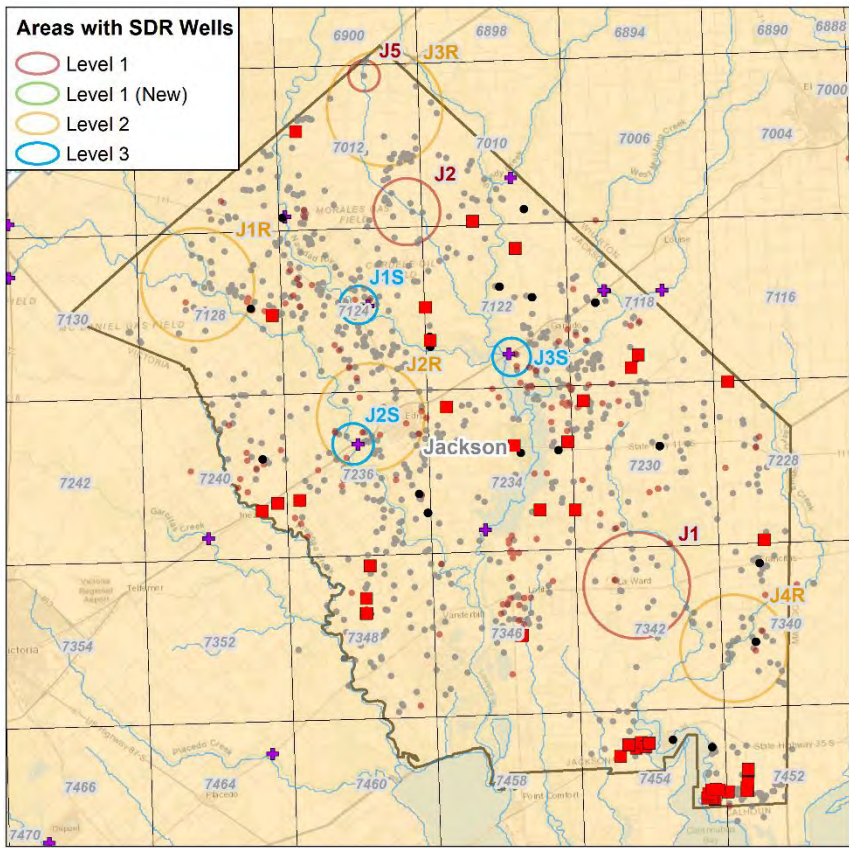
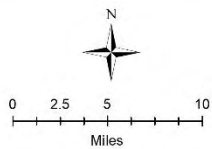


Figure 6-5 Proposed Level 1, 2 and 3 Monitoring Areas for the Chicot and Evangeline aquifers in Calhoun County with locations of wells with Submitted Drillers Reports



Jackson Monitoring Well Network: Chicot

- Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ⊕ Surface Water Gages
- Rivers & Streams
- Chicot Aquifer
- USGS 7.5 Minute Quadrangle
- Jackson County
- County Line



Jackson Monitoring Well Network: Evangeline

- ▲ Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ⊕ Surface Water Gages
- Rivers & Streams
- Evangeline Aquifer
- USGS 7.5 Minute Quadrangle
- Jackson County
- County Line

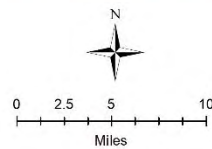
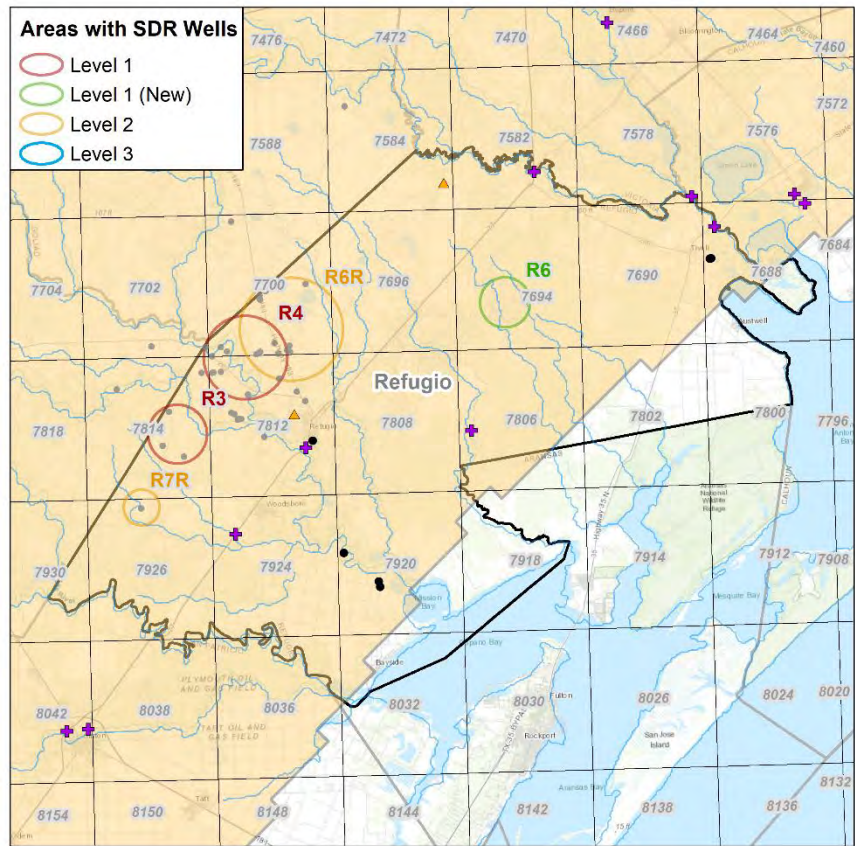
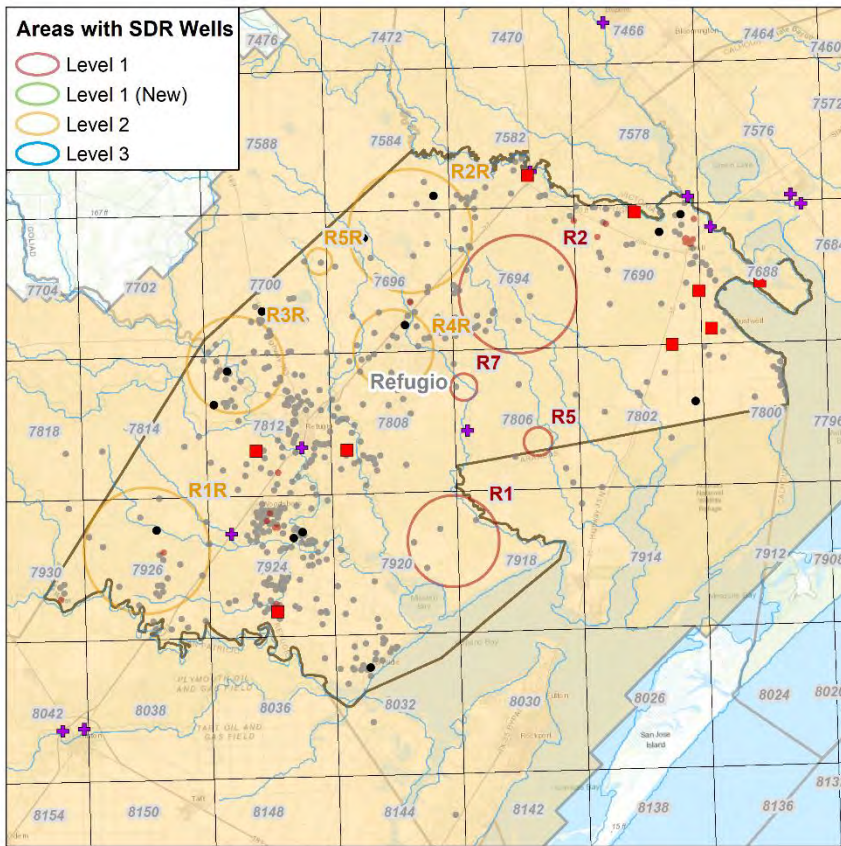
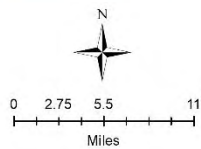


Figure 6-6 Proposed Level 1, 2 and 3 Monitoring Areas for the Chicot and Evangeline aquifers in Jackson County with locations of wells with Submitted Drillers Reports



Refugio Monitoring Well Network: Chicot

- Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ⊕ Surface Water Gages
- Rivers & Streams
- Chicot Aquifer
- USGS 7.5 Minute Quadrangle
- ▭ Refugio County
- ▭ County Line



Refugio Monitoring Well Network: Evangeline

- ▲ Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ⊕ Surface Water Gages
- Rivers & Streams
- Evangeline Aquifer
- USGS 7.5 Minute Quadrangle
- ▭ Refugio County
- ▭ County Line

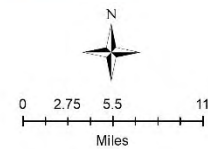
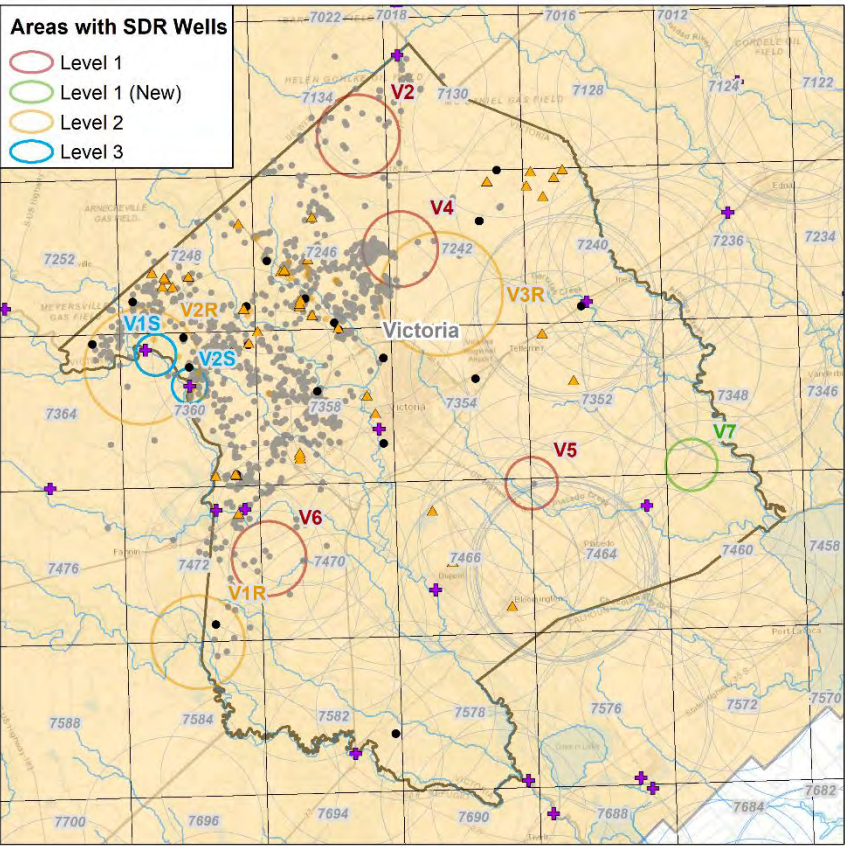
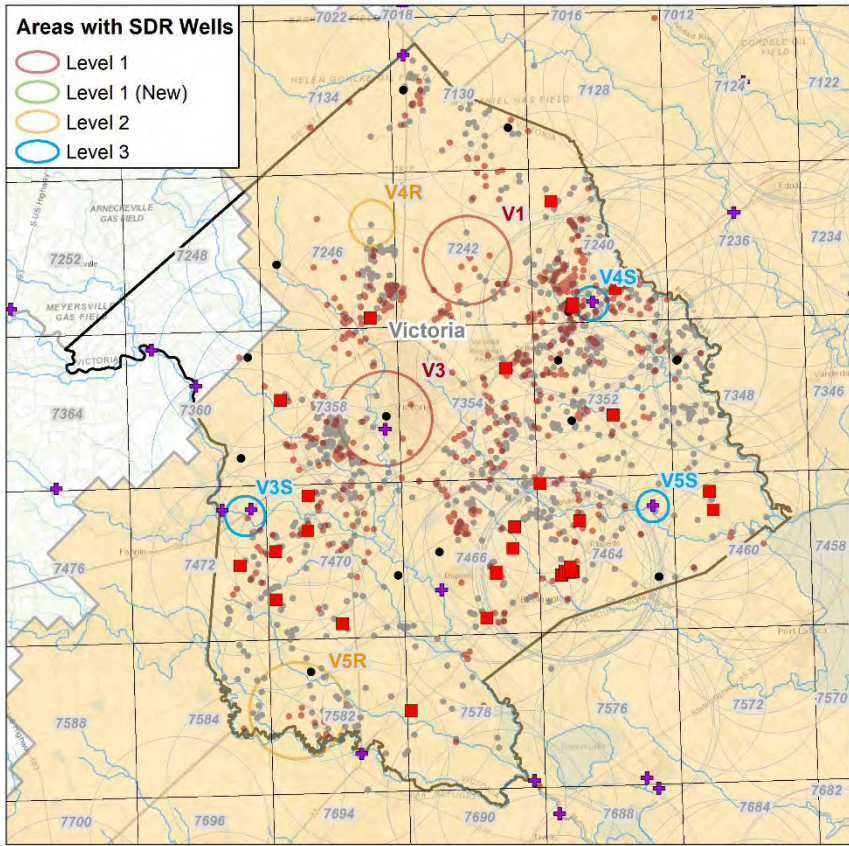
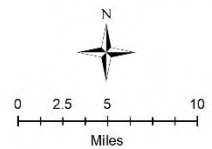


Figure 6-7 Proposed Level 1, 2 and 3 Monitoring Areas for the Chicot and Evangeline aquifers in Refugio County with locations of wells with Submitted Drillers Reports



Victoria Monitoring Well Network: Chicot

- Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ✚ Surface Water Gages
- Rivers & Streams
- Chicot Aquifer
- USGS 7.5 Minute Quadrangle
- Victoria County
- County Line



Victoria Monitoring Well Network: Evangeline

- ▲ Water Level Measurement(s) 2016-2021
- Water Level Measurement(s) 2000-2015
- SDR Wells
- Shallow SDR Wells
- ✚ Surface Water Gages
- Rivers & Streams
- Evangeline Aquifer
- USGS 7.5 Minute Quadrangle
- Victoria County
- County Line

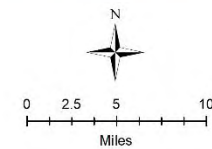


Figure 6-8 Proposed Level 1, 2 and 3 Monitoring Areas for the Chicot and Evangeline aquifers in Victoria County with locations of wells with Submitted Drillers Reports