APPLICATION OF AN AREA OF REVIEW VARIANCE METHODOLOGY FOR UNDERGROUND INJECTION CONTROL REGULATIONS TO FIELDS IN GAINES COUNTY, TEXAS

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Abstract

When the Underground Injection Control Regulations were promulgated in 1980, existing oilfield (Class II) injection wells operating at the time that the regulations became effective were excluded from Area of Review requirements. The Environmental Protection Agency has expressed its intent to revise the regulations to include the requirement for Area of Reviews for such wells.

A methodology developed for obtaining Area of Review variances has been applied to oilfields in Gaines County, Texas. The work is part of a broader effort to apply the variance methodology throughout areas of the West Texas Permian basin. The work is being conducted under sponsorship of the American Petroleum Institute.

The general concept of the variance methodology which has been developed uses basic variance criteria that were agreed to by a Federal Advisory Committee, but expands upon those to provide a greater range of variance options.

In this study, the geology and hydrogeology of areas within Gaines County were defined with respect to petroleum production and groundwater occurrence. Oilfields were identified using several databases from the Texas Railroad Commission . Only fields with significant injection were investigated. Ten fields were identified for study. These included Cedar Lake, Flanagan, G-M-K, Harris, Riley North, Robertson North, Russell, Seminole, Seminole East, and Seminole West.

The results of the study with respect to the opportunity for variance for injection field in Gaines County are presented. The implications of the Gaines County study for other Permian basin counties are also discussed.

Introduction

An Area of Review (AOR) study is an analysis of all production, injection and abandoned wells that penetrate a Class II injection zone and are within 1/4 mile or within the calculated "zone of endangering influence" of a single injection well under consideration.[1] When the Underground Injection Control (UIC) Regulations were promulgated in 1980, existing Class II injection wells operating at the time that the regulations became effective were excluded from AOR requirements. The Environmental Protection Agency (EPA) has expressed its intent to revise the regulations to include the requirement for AORs for such wells and has initiated changes to that effect.

A Federal Advisory Committee (FAC) [2] has recommended that AORs for existing wells, not previously subject to that requirement, be performed within five years of promulgation of amended UIC regulations. The FAC has, however, recognized that conditions can exist that make it unnecessary to perform well-by-well AORs and that can allow wells in a basin, producing trend, region or field, or a portion of such areas to be exempted from an AOR through a variance program. The recognized conditions for which variances could be granted include:

1. the absence of USDWs
2. the reservoir is underpressured relative to the USDW
3. local geological condition preclude upward fluid movement that could endanger USDWs
4. other compelling evidence

If the FAC suggestion is adopted, oil and gas producing states will have only one year to formulate a variance program based on the criteria 1-4, and only five years in which to perform all necessary AORs, after revised EPA UIC regulations become effective. Recognizing the potential impact and urgency of this matter, the Underground Injection Control Issues Group of the American Petroleum Institute (API) sponsored development of a general AOR variance methodology which state regulatory agencies could use to fashion their own variance programs and which oil and gas operators could use in identifying areas most likely to qualify for AOR variance.

AOR Variance Methodology

A methodology for identifying areas that would be eligible for variance from AOR requirements based upon the FAC criteria has been developed and is shown in Figure 1. The methodology provides for evaluation of an area for variance based upon conditions 1-3 above or based upon the manner by which wells in the area were constructed and abandoned. These methods could be used in any order, singly or in combination, to exclude some or all wells from the AOR process. Wells not excluded by variance would be subject to well-by-well AORs.

In the methodology, variance condition 1 as listed by the FAC, has been extended from providing only the absence of USDWs as a variance criterion to also include the situation where the USDW is the producing formation and the situation where the USDW has been exempted under the Safe Drinking Water Act. A further extension is to provide variance for wells that penetrate through the USDWs but which do not reach the injection zone. These variance conditions are collectively categorized as lack of intersection with a USDW. An area would be evaluated for lack of intersection through hydrogeologic study.

Variance condition 2 refers to the situation where there is lack of potential for flow from a petroleum reservoir with active injection operations into an overlying USDW. Flow can only occur when the reservoir pressure is sufficient to raise a column of reservoir water to the base of the USDW and then still be sufficient to displace the water in the USDW. In the absence of such hydraulic flow potential, the area under evaluation would qualify for a variance. In the variance methodology, an area is evaluated for hydraulic flow potential by collection of USDW head data and petroleum reservoir pressure data and by comparison of those data sets, after appropriate conversions and adjustments have been made to the data to make them comparable.

Geological factors which preclude upward fluid movement are the third recognized variance criteria. Such mitigating geological factors include sloughing, squeezing and sink zones. A sloughing formation refers to any geological horizon which is highly incompetent and tends to fall or cave into the well. A squeezing formation is one with strata that flow plastically under the overburden stress to close an uncased bore hole or close the casing-formation annulus in a cased well.

The thief, or sink zone, refers to a geological horizon which has a flow potential less than the overlying USDWs and the petroleum reservoir which contains injection operations. Thief zones are intermediate formations (located between the petroleum reservoir with injection operations and an overlying USDW) which act to divert the fluids flowing up the wellbore. A thief zone can also be a normally pressured formation that is so permeable and thick that it diverts virtually all upward flowing fluid without experiencing significant pressure increase.

The only means of assessing the presence and the effectiveness of sloughing or squeezing zones may be qualitative evidence in the form of the experience by operators and of observations by regulatory agency personnel. The presence of sink zones may be known as a result of experience by operators with lost circulation during drilling or such zones may be known to geologists or engineers through basinal or regional studies of aquifer/reservoir fluid potentials.

Well construction and abandonment methods can also be considered as compelling evidence for an AOR variance. This is because the manner in which a well is constructed and abandoned may preclude fluid migration, even if a positive hydraulic flow potential does exist.

States which have oil and gas operations have historically set forth standards for well construction and abandonment. These standards detail the correct use or placement of casing, cement, bridge plugs, and other mechanical barriers in a wellbore. They have generally evolved from a series of accepted practices, adapted over the year to accommodate new technology and new regulatory practice.

On the basis of the historic sequence of development of construction and abandonment laws, regulations and practices, it is believed logical that well construction/abandonment based variances should be available through several different approaches, which are:

1. Field discovery and development post dates well construction and abandonment standards, providing adequate protection.

2. Sufficient AORs exist and provide statistical evidence that all wells protect the USDWs.

3. Representative samples of wells are found to provide adequate protection to USDWs. Wells are evaluated with respect to flow barriers and plugs.

Variances could be justified through each of the approaches for all wells in an area or for only those wells in the area that meet the variance criteria. For example, under the first approach listed above, if a field was discovered and entirely developed after the date of adoption of construction and abandonment standards that provide adequate USDW protection, all wells would meet variance criteria. If the field was discovered and partially developed prior to such standards by part of the development post-dated such standards, then those wells constructed/abandoned after standards adoption would meet variance criteria and the older wells would have to be examined through another approach.

Under the second approach, it is conceived that older fields will exist where sufficient new injection wells have been drilled or sufficient production wells converted to injection since promulgation of UIC regulations to provide an adequate number of AORs and wells within those AORs to statistically characterize the entire field.

The third approach requires that a representative sample of wells be selected from the total population of area wells and that all wells in that sample be evaluated with respect to their construction/abandonment characteristics.

The evaluation process will provide data on the number of flow barriers in abandoned wells, producing wells and injection wells and the number of plugs in abandoned wells included in the selected sample of wells from the area under study.

Current AOR procedures require a well-by-well analysis of all production, injection and abandoned wells that penetrate the injection zone and are within 1/4 mile or within the calculated "zone of endangering influence" of the single injection well under consideration. If all wells are determined to have been satisfactorily constructed and/or abandoned, then the injection well has complied with present AOR requirements.

Evaluation of a statistically representative population of wells, through the procedures that have been developed, can substitute for the well-by-well process and can provide "other compelling evidence" for variance. If, for example, evaluation of the statistically selected random sample of wells shows that all wells provide adequate protection, then there is compelling evidence for variance since it would have been demonstrated that it is statistically probable that all wells have been constructed and/or abandoned by acceptable standards. This methodology can be applied to geographic areas much larger than a single AOR, for example, a producing basin, trend, region or field, or a portion of such areas.

The AOR variance methodology has been applied to oilfields in Gaines County, Texas. This work was intented as a test case of the methodology in the state of Texas, and is part of a broader effort to apply the variance methodology throughout areas of the West Texas Permian basin. The remainder of this paper details aspects of the Gaines Couty study.

Geology of the Oilfields in Gaines County, Texas

Gaines County is located in west Texas adjacent to the New Mexico state line (Figure 2). The county contains segments of several important geologic features including the southern extension of Early Permian Abo Reef trend, the western tip of the Pennsylvanian-Early Permian Horseshoe Atol complex, the northern extreme of the Central Basin Platform, and the southern extent of the Northwest Shelf area. In addition, the eastern part of the county is underlain by the Midland basin. [3]

Figure 3 is a generalized stratagraphic column showing principal hydrocarbon production horizons, waterflood horizons and USDW horizons for Gaines County, Texas. In Gaines County the vast majority of oil production and virtually all water injection is associated with the middle Permian (Leonard and Gaudalupe) Clear Fork and San Andres Formations. Other minor producing horizons include the Ordovician Ellenburger, Devonian, Pennsylvanian Canyon, Permian Wolfcamp, Permian Glorietta, and Permian Queen Formations.

The principal USDW in Gaines County is the High Plains aquifer (HPA), which is comprised by the Miocene age Ogallala Formation that consists of semiconsolidated gravel, sand, silt, caliche and clay. Available information indicates that the Ogallala occurs at the ground surface over much of the county and extends to a maximum depth of about 300 feet. The Cretaceous age Fredericksburg and Trinity Formations occur together as a minor near-surface aquifer underlying the Ogallala Formation in southern Gaines County. (Figure 3) The Fredericksburg is composed of limestone and the Trinity is composed of interbedded sand, shale and limestone.

The Triassic age Santa Rosa Formation occurs below the Ogallala over most of Gaines County and below the Edwards/Trinity elsewhere. The Santa Rosa is composed of gravel, sand, silt and shale red beds. Water in the Santa Rosa is probably not potable in Gaines County, but may be of limited use for irrigation and stock watering. The Santa Rosa apparently extends to a depth of as much as 2000 feet based on Texas Water Commission casing requirements in some oilfields.

In Gaines County, oil is trapped in all fields by simple anticlinal closure. The majority of the anticlines are associated with some sort of shelf edge, most are slightly asymmetric. Limits of the fields are typically defined generally by anticlinal closure, but these field limits are often modified by complex carbonate stratigraphy associated with the structures. Most fields have highest porosity and permeability near the crest of the structures with decreasing porosity and permeability toward the flanks. Although the Clear Fork and San Andres Formations are continuous across all fields, porosity and permeability zones within the formations are lenticular and irregular. Many fields have multiple pay zones with different and often tilted water contacts in different productive horizons.

For purposes of the study, ten fields with significant injection operations (25 or more injection wells) were selected for study. These fields included Cedar Lake, Flanagan, G-M-K, Harris, Riley North, Robertson North, Russell, Seminole, Seminole East, and Seminole West. (Figure 4) A summary of the geological characterization specific to these injection fields is given in Figure 5. Fields such as Wasson and Adair, which extend across county boundaries, were not studied but are included in an ongoing extension of the Gaines County work to other Permian Basin counties.

Application of AOR Variance Methodology to Gaines County, Texas

The four variance criteria embodied in the variance methodology were applied to the ten selected fields in Gaines County. However, certain observations were made which precluded a formal evaluation of variance criteria 1-3.

The principal USDW, the Ogallala, is present throughout the county and, consequently, variance criteria 1 could only apply in circumstances where the active or abandoned wells did not penetrate both the Ogallala and the petroleum reservoir with injection operations. Since most oilfields with multiple pay zones were developed with both deep and shallow completions, it would not be possible to exclude an entire field based on variance criteria 1.
Both variance criteria 2 and 3 could not be formally applied because there was insufficient data for analysis. These techniques have, however, been proven in a previous study of the San Juan Basin. [4]

For these reasons, the focus of the Gaines County study is the application of variance criteria 4, i.e. variance possibilities based on other compelling evidence such as well construction and abandonment practices.

Well Construction and Abandonment Review of Principal Class II Injection Fields

A review of the Texas statewide well construction and abandonment regulations was conducted as part of the Gaines County study. The evolution of the rules was examined in an attempt to identify a time or period of time in which well construction and abandonment regulations required adequate protection to overlying USDWs. As noted previously, if such a date can be identified, and if all or portions of a fields are developed after this time, then it is logical to assume that these wells provide adequate protection to overlying USDWs.

For a several reasons (e.g. no formal definition of a USDW until 1980; lack of specificity in the well construction and abandonment regulations) it was not possible to identify a specific year (or period of time) in the regulations in which wells could uncategorically be considered to provide adequate to present day USDWs. Hence the Texas Railroad Commission (RRC) was queried regarding the time, or times, when it was felt that active and abandoned wells were required to provide adequate protection to USDWs.

Mr. Jerry Mullican, Assistant Director - Oil and Gas Division of the Texas RRC indicated that wells completed and abandoned prior to 1967 may or may not provide adequate protection, and those wells should be examined. Wells completed and abandoned from 1967 through 1982 should exhibit a high level of protection to USDWs and good compliace with the regulations, but should receive sufficient study to confirm their condition. Further, he indicated that wells completed and abandoned since 1982 would provide adequate protection and, therefore, one should not neeed to study these wells.

Mr. Mullican's age categorization of wells was reasonable when compared to the historical progression of the well construction and abandonment regulations. Although his categorization does not provide a single date for identifying fields which may qualify for variance, the time periods may be used in a similar manner. For example, wells constructed and/or abandoned after 1982 will almost certainly provide adequate protection to overlying USDWs. Hence, it was decided to adopt the time period categorization of wells (pre 1967; 1967-1982; post 1982) for sampling well populations in the study.

Wells within the ten selected injection fields were identified by merging data from a number of RRC databases. Once located, these wells were classified according to the age categories suggested by the Texas RRC. The grouping consisted of:

1. Wells drilled, completed or plugged prior to 1/1/67
2. Wells drilled, completed or plugged between 1/1/67 and 1/1/83
3. Wells drilled, completed or plugged after 1/183

For each of the age categories listed above, well counts were reported for the total number of wells available in the database, the number of wells with locations, the number of plugged wells, the number of injection wells and the number of producing wells. These well counts were used to select sample well populations for further study. Sampling was employed to limit the number of wells examined, since a valid sample of wells should represent the characterisitcs of the entire well population.

Wells were sampled according to the following scheme:

1. All pre-1967 abandoned and producing wells were included in the study, since the construction and abandonment methods used in older wells have greater uncertainty.

2. All abandoned wells with dates of 1967 through 1982 were included in the study to be conservative. A 10% sample size was used for producers with dates of 1967 through 1982.

3. A sample of five abandoned and five producing wells from each field was used for recent (post 1982) wells, since the construction and abandonment techniques were felt to be excellent in these wells.

Well construction and/or abandonment drawings were prepared for each of the sampled wells using data from the RRC databases. In some instances, the RRC database had incomplete information and well records were augmented by manual data searches at the Texas RRC in Austin, Texas. After these manual data searches, there remained wells for which either all necessary information was not obtained. However, it is believed that data for these wells does exist either in the RRC district offices or with the oil and gas operators.

Figures 6-8 depict typical well construction techniques used in the oilfields in Gaines, County. Figure 6 is a well in the Seminole West field completed in the San Andres formation. This well is an example of shallow completions seen in many of the other fields. In these wells, surface casing is normally set between 350 and 500 feet, but some wells have deeper set (e.g. 2000 feet) surface casing. This string is cemented back to the surface. Production casing is typically run either through or to the top of the reservoir. In the example shown in Figure 6 the production string is fully cemented back into the surface string. Many wells were completed in this manner, but there were also a large number of wells with approximately 1000' of cement above the reservoir. The difference in cementing technique was not necessarily related to the time the well was constructed. That is, wells which had fully cemented production casing strings included both old (pre-1967) and new (1988-1990) wells.

Many of the wells examined were deeper completions and an example of this type is shown in Figure 7. The deeper completions were frequently constructed with surface casing set between 1700 and 2000 feet. The surface string was cemented back to the surface. As in the shallower wells, production casing was again run either through the reservoir or to the top of the zone. The example shown in Figure 7 depicts a production string fully cemented into the surface casing, but many wells were constructed with cement tops 800-1200 feet above the reservoir.

A third construction style prevalent in deeper wells throughout Gaines County is shown in Figure 8. Wells of this type are constructed in a manner similar to the shallow completions, but include a string of intermediate casing normally set at a depth between 5200 and 6000 feet. The intermediate string was cemented back to the surface in some wells, althgough the example shown in Figure 8 has only a 600 foot cement column above the intermediate casing shoe.

Abandoned wells studied in the ten injection fields demonstrated a wider range of abandonment techniques than the construction methods seen in producing wells. However, there were similarities among the abandoned wells. The wells studied were typically abandoned by setting a bottom plug (either cement or a cast iron bridge plug (CIBP) with cement) across the perforations or immediately above the reservoir. (Figure 9) The borehole was filled with mud and one or more cement plugs were typically set in the wellbore. Where casing strings were retrieved, or where liners were run, the stub or the liner top was typically covered with cement. (Figure 10) Cement squeezes were also used in some wellbore abandonments. (Figure 11)

The sampled wells with sufficient data were evaluated with the Automated Borehole Evaluation (ABE) program according to the AOR variance methodology. [1] This evaluation determined the number of flow barriers present in active wells, and the number of flow barriers and plugs present in abandoned wells. An age distribution and well count for the wells evaluated in the study is presented in Table 1.

Interpretation of Results

Study of the evaluation of regulations governing well construction and abandonment indicated that wells constructed or abandoned after January 1, 1983, should, with certainty, provide USDW protection. Review of the regulations also suggested that wells constructed and abandoned after January 1, 1967, should provide adequate USDW protection. These conclusions were tested in the field-by-field analyses that were conducted.

Prior to detailed analysis, it was believed that 179 abandoned wells and 2151 producing wells were present in the 10 fields. It is now believed that there are 168 abandoned wells. Of these 168 abandoned wells, 142 wells were found to be abandoned after 1982 and 22 wells were abandoned during 1967-1982. Two wells were found to be abandoned prior to 1967 in the Seminole Field, and two other wells in this field could not be categorized with certainty although they could be pre-67 abandonments.

Twenty-one of the 22 wells abandoned during 1967-1982 had wellbore drawings and ABE analyses generated, and all wells for which complete information was available were found to have been abandoned according to RRC rules and regulations. At this writing, one well in the 1967-1982 category had insufficient data for analysis. This well will be researched using district RRC files and, possibly, operator records, to absolutely confirm the level of USDW protection provided by this age category.

Wellbore drawings and ABE analyses were produced for 57 post-1982 wells. All of these for which complete information was obtained were found to have been abandoned according to RRC rules and regulations. Six wells located in four fields had insufficient data for analysis. These wells will be researched further using district RRC files and, possibly, operator records.

None of the four known or suspected older abandoned wells had sufficient data for analysis. These data are currently being sought from RRC district offices and from operators.

All of the abandoned wells studied were found to be plugged according to RRC rules and regulations. However, some of the wells lacked casing cementing information and these data are currently being sought. It is expected the information does exist, and that all of these wells will be found to provide adequate USDW protection.

A total of 272 active wells were sampled from the initial producing well population and 3 active wells were included from reclassification of abandoned wells. Of these 275 active wells, 228 were found to be producing wells, 46 wells had been converted for injection service, and one well was being used for salt water disposal. 6 shut-in wells were identified and were excluded from the active well population.

Wellbore drawings and ABE analyses were generated for 250 of the 275 active wells; twenty five of the active wells sampled had insufficient data for analysis. 133 of the wells analyzed were found to have been constructed prior to 1967, 70 wells were constructed during 1967-1982, and 47 wells were constructed after 1982. All wells which had sufficient data for analysis were found to be constructed according to RRC rules and regulations. Cementing records were missing for some of the active wells sampled. It is expected the information does exist, and that all of these wells will be found to provide adequate USDW protection.

The preliminary results of the Gaines County study suggest that all of the abandoned wells in the ten injection fields that were studied will be found to have been constructed and abandoned according to Texas RRC rules and regulations and that all producing wells will be found to have been constructed according to the rules and regulations. These results should provide a substantial basis for consideration of these fields by the RRC for variance from future AORs.

Future Work

The methodology that has been applied to Gaines County is currently being extended to a number of other Permian Basin counties. In that continuing work, the Gaines County results are being used to minimize the effort needed to evaluate fields for AOR variance consideration.

Acknowledgments

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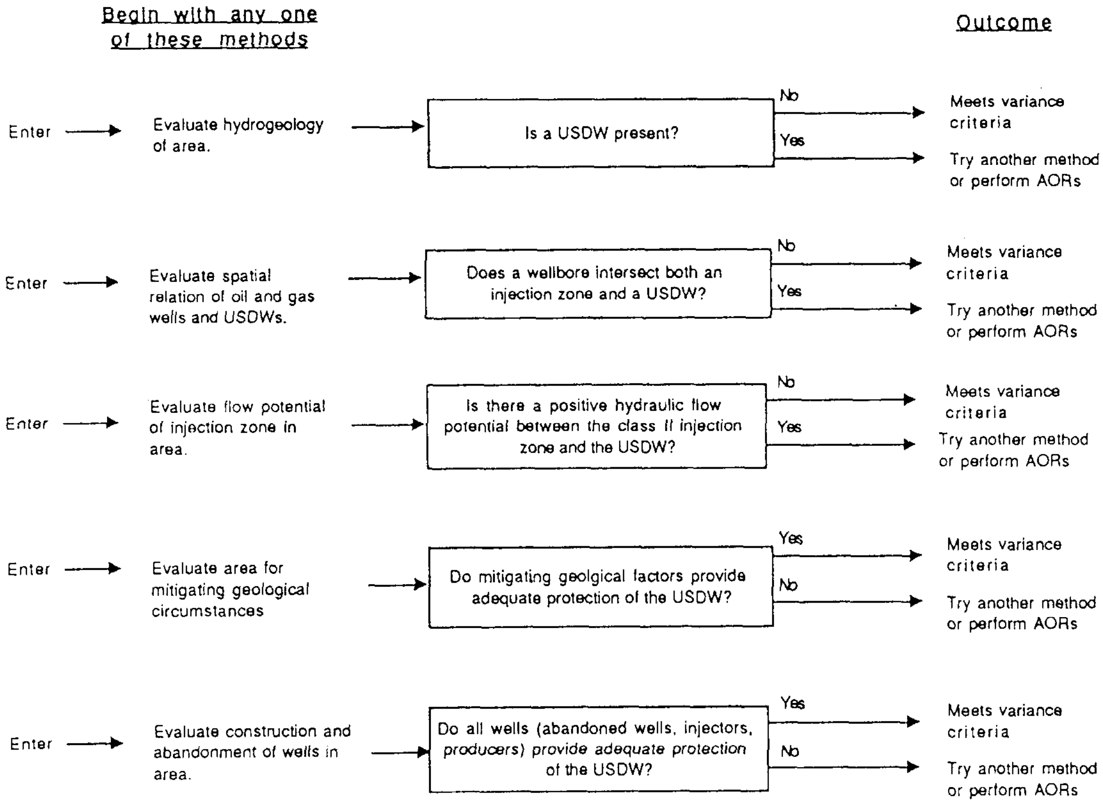
References

1. 40 CFR, Part 146

2. Warner, D. L., L.F. Koederitz, S. Dunn-Norman, and R.C. Laudon, "An Area of Review Variance Methodology", April 1993, Final Report to the American Petroleum Institute, Washington D.C.

3. Warner, D. L., L.F. Koederitz, S. Dunn-Norman, and R.C. Laudon, "Application of an AOR Variance Methodology to the Permian Basin - Gaines County, Texas", October 1993, Interim report to the American Petroleum Institute, Washington D.C.

4. Warner, D. L., L.F. Koederitz, S. Dunn-Norman, and R.C. Laudon, "Application of an Area of Review Methodology to the San Juan Basin of New Mexico", June 1993, Report to the American Petroleum Institute, Washington D. C.



Five general methods are available for obtaining variance from revised EPA Area of Review requirements. These methods can be used in any order, singly or in combination, to exclude some or all wells from the AOR process. Wells not excluded by variance would be subject to well-by-well AORs.

Figure 1 - AOR evaluation methodology

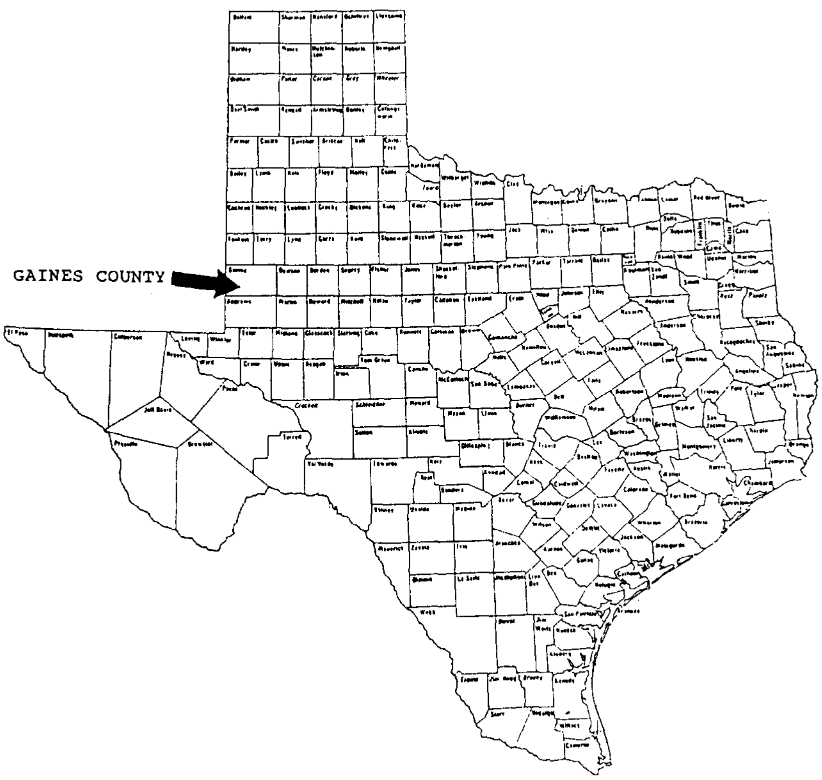


Figure 2 - Counties of Texas showing location of Gaines County, Texas

SYSTEM	SERIES	FORMATION	HYDROCARBON PRODUCTION HORIZONS	WATER FLOOD HORIZONS	USDWs
QUATERNARY	RECENT PLEISTOCENE	ALLUVIUM			Minor
TERTIARY	EOCENE-PLIO	OGALALLA			MAJOR
CRETACEOUS	COMANCHEAN	FREDRICKSBURG			Minor
TRIASSIC	UPPER	SANTA ROSA			Minor
PERMIAN	OCHOA				
	GUADALUPE	TANSILL			
		YATES			
		SEVEN RIVERS			
		QUEEN	Minor		
		GRAYBURG			
		SAN ANDRES	MAJOR	MAJOR	
		GLORIETTA	Minor		
	LEONARD	U CLEAR FORK	MAJOR		
		TUBB			
		L CLEAR FORK	MAJOR	MAJOR	
		ABO			
	WOLFCAMP	WOLFCAMP	Minor		
PENNSYLVANIAN	CISCO CANYON STRAWN ATOKA MORROW	CANYON	Minor		
MISSISSIPPIAN	CHESTER OSAGE KINDERHOOK				
DEVONIAN	UPPER MIDDLE LOWER	DEVONIAN	Minor		
SILURIAN	UPPER LOWER	FUSSELMAN			
ORDOVICIAN	CINCINNATIAN	MONTOYA			
	MOHAWKIAN	BROMIDE TULIP CREEK			
	CHAZYAN	McLISH OIL CREEK JOINS			
	CANADIAN	ELLENBURGER	Minor		
CAMBRIAN	UPPER LOWER				
PRECAMBRIAN					

Figure 3 - Generalized stratigraphic column showing principal hydrocarbon producing horizons, waterflood horizons and USDW horizons for Gaines County, Texas

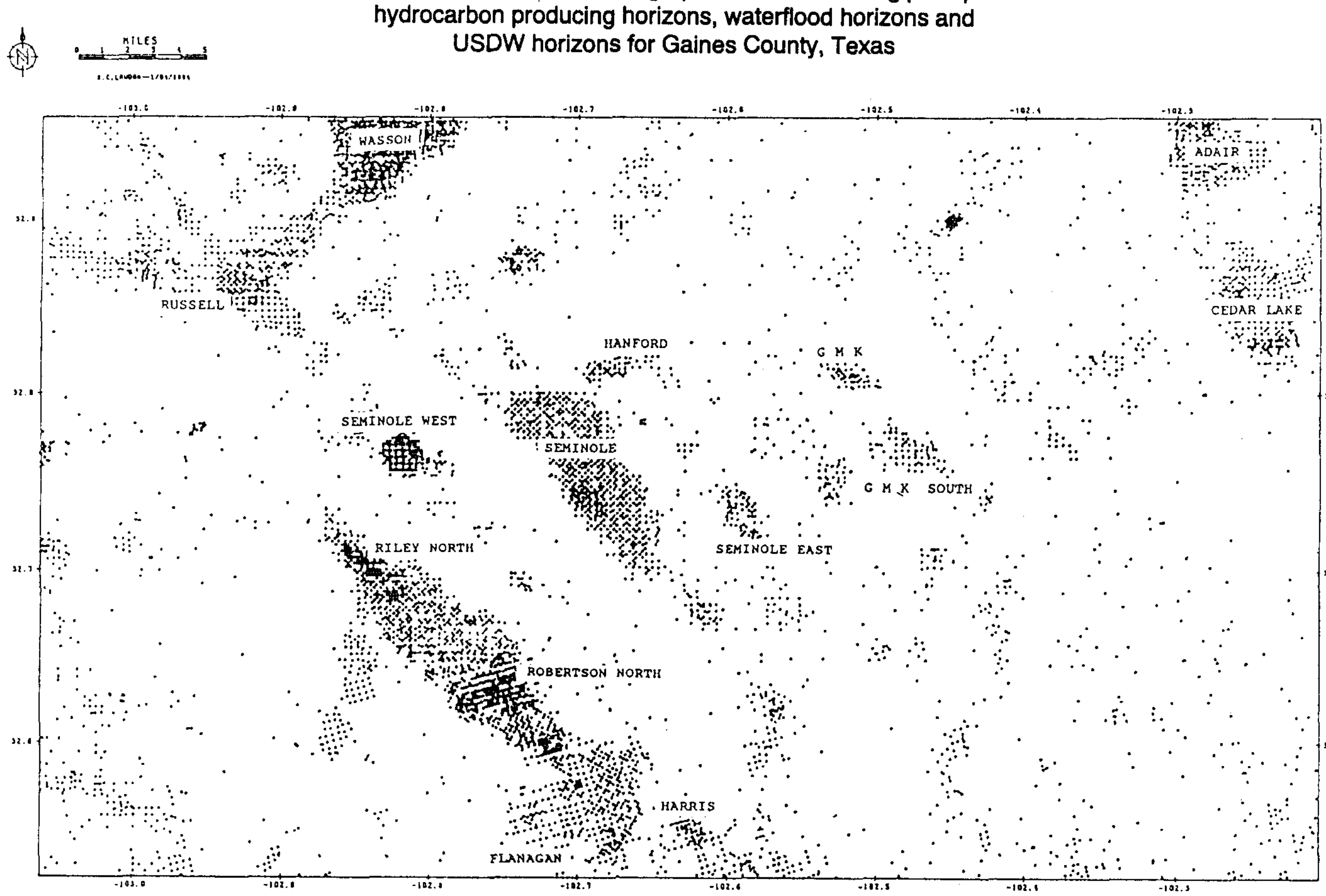


Figure 4 - Map of Gaines County, Texas, showing all oil and gas well locations plus names of major oilfields. Wells located by latitude and longitude from Texas Railroad Commission Well Location Datafiles.

Summary and Generalizations Pertinent to Injection

1. The geology of all fields in Gaines County, Texas is remarkably similar.

   A. All fields are in simple anticlines. The only exception is Seminole East and it is different only in that the anticline has a central depression.

   B. The vast majority of oil production and virtually all water injection is in two very similar formations, the middle Permian Clear Fork and San Andres Formations.

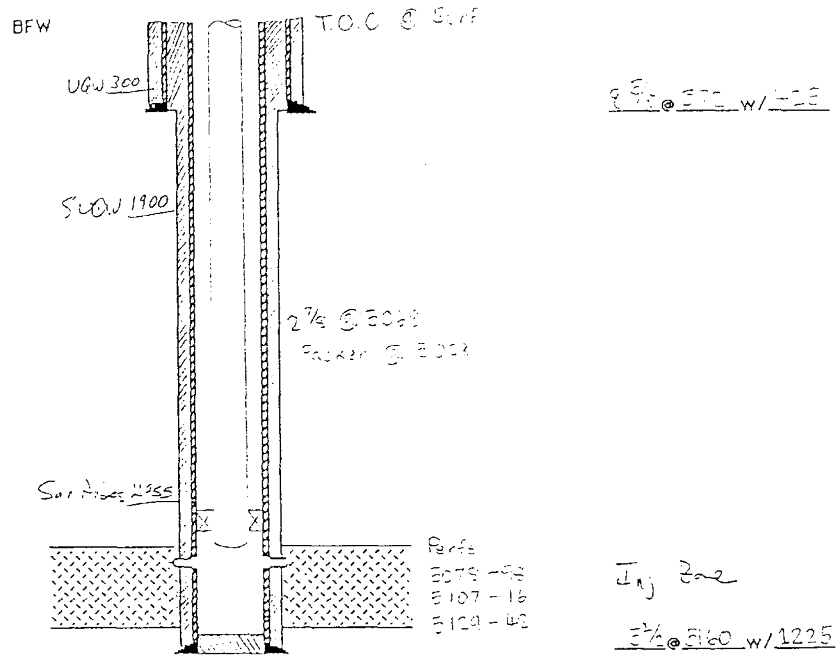
   C. The two formations are composed of thinly bedded, irregular and complex carbonates.

2. Fields were discovered in three general time periods. These are:

   1939-42: Fields draped over pre-existing reefs.
   1947-49: Fields associated with the northeast shelf edge of the Central Basin Platform. Three exceptions exist.
   1957-63: Small fields to the east of the shelf edge.

3. Several fields have minor production from deeper horizons. Further analysis will be required to determine the spatial location of these wells relative to Clear Fork and San Andres production and injection. Preliminary work on one field (Seminole West) indicates that deeper wells may be separate from the main Clear Fork-San Andres producing areas. This may not be true, however, for all fields.

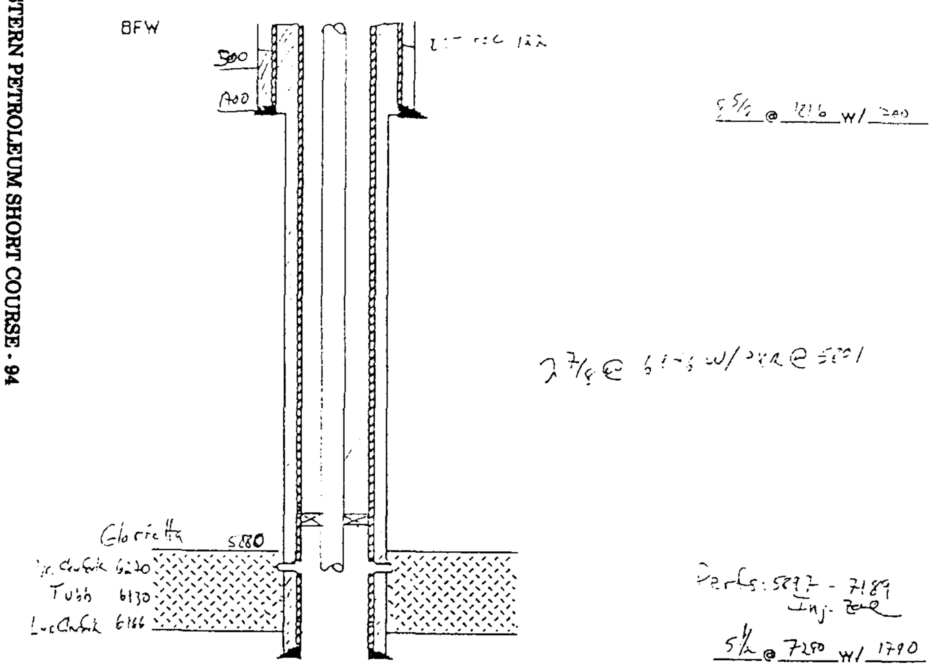
Figure 5 - Geological information regarding ten injection fields studied in Gaines County, Texas.



TD: 5160
PB: 5159

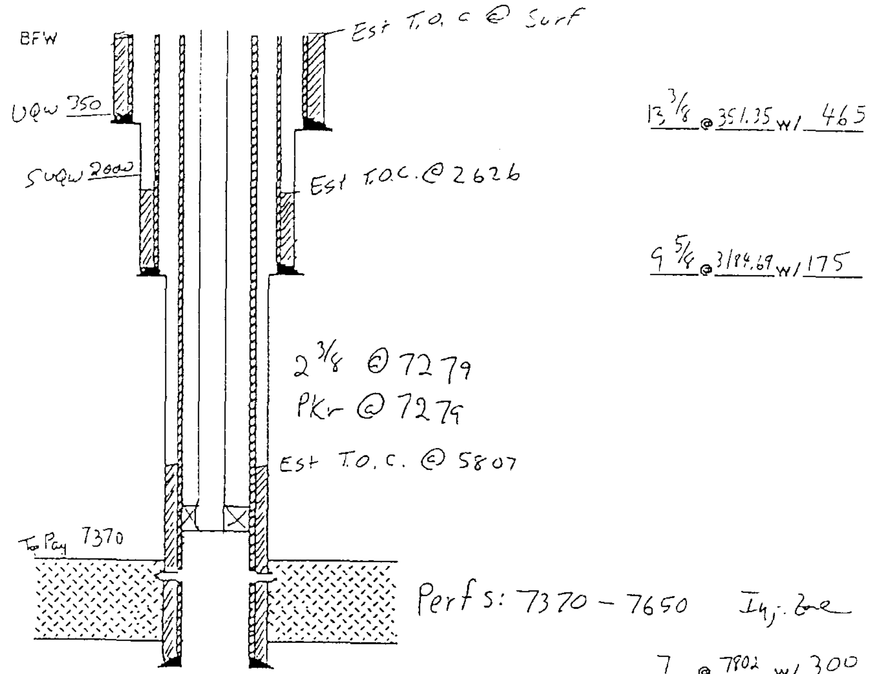
Field (Reservoir): West Seminole
Lease Name: West Seminole San Andres Unit
API Number: 165 - 30508
Location: Section 334 BLK G Survey CCSD&RGNG
FTGS: 1515 FSL 330 FEL
Completion Date: 10 / 29 / 75 Drilling Date: 10 / 17 / 75
Status At Completion: Oil
Conversions During Life: ____ / ___ / ___
Notes:

Figure 6 - Representative completion for shallow wells in Gaines County, Texas



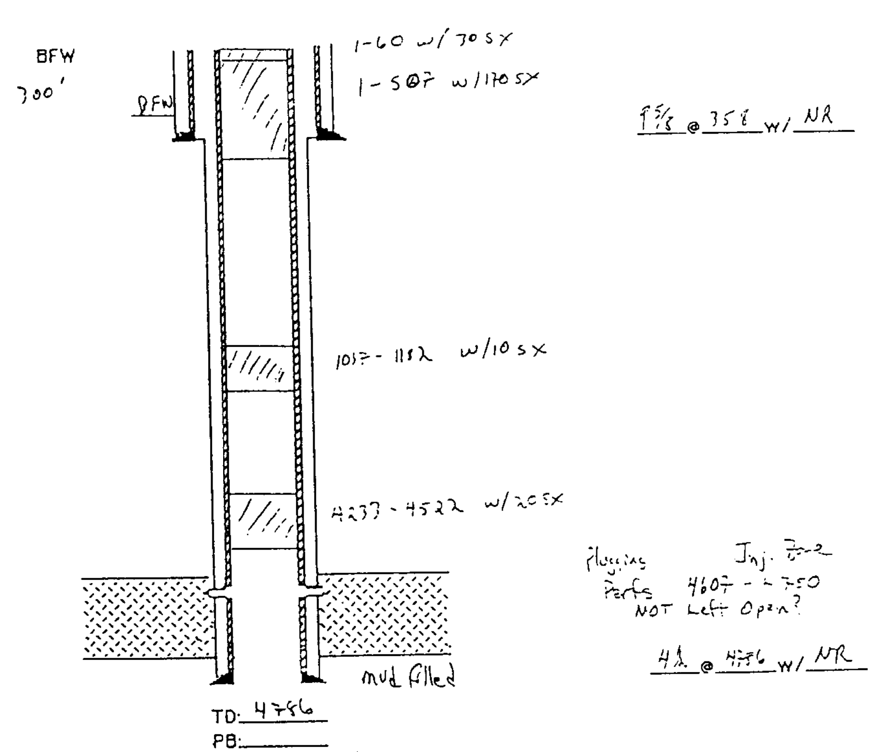
TD: 7380
PB:
Field (Reservoir): Robertson N (Clear Fork 7100)
Lease Name:
API Number: 165 - 33610
Location: Section 326 BLK G Survey CCSD + RGNG RR El: 3369
FTGS: ___ F__L ___ F__L
Completion Date: 6 / 26 / 82 Drilling Date: 6 / 5 / 82
Status At Completion: Oil
Conversions During Life: ___ / ___ / ___
Notes:

Figure 7 - Representative completion for deeper wells in Gaines County, Texas



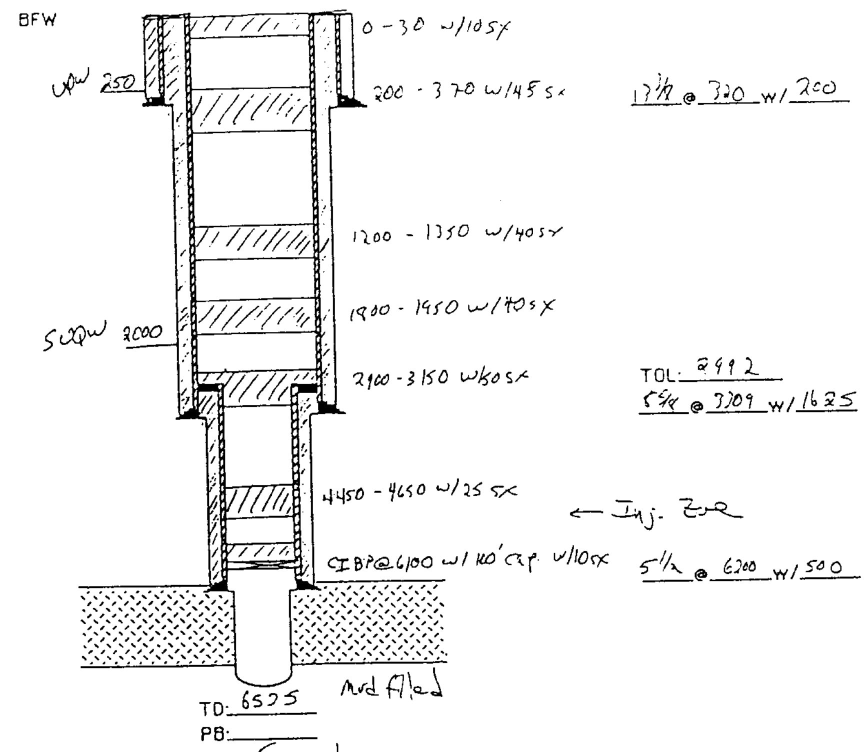
TD: 7802
PB:
Field (Reservoir): Russell (7000' Clearfork)
Lease Name: Russell 7000 Clearfork Unit
API Number: 165 - 01612
Location: Section 454 BLK 6 Survey CCSD & RGNG
FTGS: 1980 FWL 1980 FSL
Completion Date: ___ / ___ / ___ Drilling Date: ___ / ___ / ___
Status At Completion:
Conversions During Life: W.I.W 9 / 2 / 71
Notes:

Figure 8 - Representative completion for deeper wells with intermediate casing in Gaines County, Texas



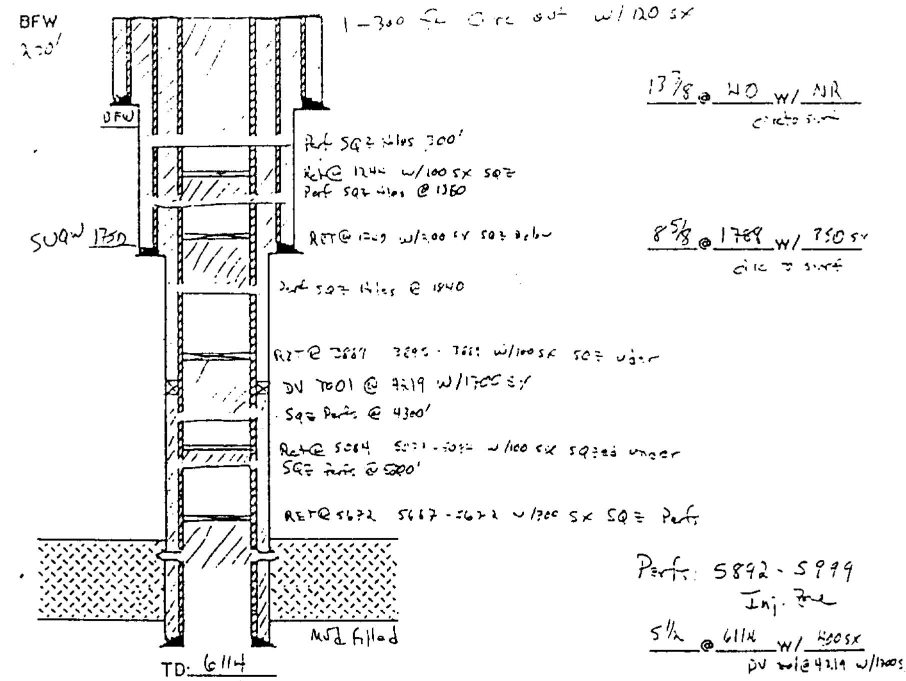
TD: 4756
PB:
Field (Reservoir): Cedar Lake
Lease Name:
API Number: 165 - 10270
Location: Section ____ BLK ____ Survey D+W RR EL: 3033 RT
FTGS: ____ F L ____ F L
Completion Date: __ / __ / __ Drilling Date: __ / __ / __
Status At Completion: Oil
Conversions During Life: Plugged 1 / 14 / 88
Notes:

Figure 9 - Example wellbore abandonment in Gaines County, Texas



TD: 6525
PB:
Field (Reservoir): Cowmale
Lease Name: SF Main
API Number: 165 - 2435
Location: Section 220 BLK G Survey WTRR EL: 3345
FTGS: 660 F NL 1650 F WL
Completion Date: 4 / 21 / 51 Drilling Date: 3 / 1 / 51
Status At Completion: Oil
Conversions During Life: Plugged 6 / 18 / 92
Notes:

Figure 10 - Example wellbore abandonment in Gaines County, Texas



TD: 6114
PB: 6045

Field (Reservoir): Harris
Lease Name: South Harris Unit
API Number: 165 - 32434
Location: Section 15 BLK A-22 Survey PSL EL: 3284 GL
FTGS: 1320 FNL 25 FEL
Completion Date: 12 / 17 / 82 Drilling Date: __ / __ / __
Status At Completion: oil
Conversions During Life: Injector __ / __ / __
Notes: plugged 3 / 2 / 86

Field notes @ 250'

SQZ under Retainers. Unsure if Retainer left in hole.

Figure 11 - Example wellbore abandonment in Gaines County, Texas

Table 1
Age Distribution and Well Counts for Sampled Wells Evaluated with ABE

Field	Abandoned Wells			Active Wells		
	Pre-1967	1967-1982	Post 1982	Pre-1967	1967-1982	Post 1982
Cedar Lake		1	7	6	3	6
Flanagan		1	3	9	5	4
G-M-K		3	1	6	2	4
Harris			7	16	6	5
Riley North		2	7	6	3	4
Robertson North		1	9	21	20	5
Russell		7	5	14	6	5
Seminole		1	7	48	13	4
Seminole, East		2	5		4	6
Seminole, West		3	6	7	8	4
Total		21	57	133	70	47