Truck Traffic and Truck Loads Associated with Unconventional Oil and Gas Development in Texas

Implementation Report RR-16-01

Prepared for Texas Department of Transportation
Maintenance Division

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INTRODUCTION

Energy developments that rely on horizontal drilling and hydraulic fracturing (also called fracking) technologies generate enormous amounts of truck traffic on state, county, and local roads. Secondary roads, in particular, were never designed to carry such high truck traffic volumes and heavy loads. The result has been accelerated degradation of pavements and roadside infrastructure, as well as increases in congestion and crash and fatality rates.

Quantifying the number of truck trips and resulting 18-kip equivalent single axle loads (ESALs) associated with the development and operation of oil and gas wells is a critical requirement for designing and maintaining pavement structures on energy sector roads. However, this is not enough. In order to implement roadway design, construction, and maintenance plans in energy sector areas, it is necessary to document the location, number, and characteristics of existing and planned well developments. It is also important to map out the routes that trucks are likely to use during the development and operation of those wells.

Research Report RR-15-01, submitted to the Texas Department of Transportation (TxDOT) in August 2015, described the work completed by the Texas A&M Transportation Institute (TTI) to characterize truck traffic and truck loads associated with unconventional oil and gas developments in Texas. Activities that TTI completed included, but were not limited to, the following:

- Obtain and process data from the Railroad Commission of Texas (RRC).
- Obtain and process data from the Department of Public Safety (DPS).
- Obtain and process data from the Texas Department of Motor Vehicles (TxDMV).
- Obtain and process weigh-in-motion (WIM) data from the Transportation Planning and Programming (TPP) Division at TxDOT.
- Reach out to the oil and gas industry to obtain information about typical numbers of trucks needed to develop oil and gas wells.
- Collect video data at selected WIM stations and correlate these data with corresponding WIM station data.
- Prepare county-level maps to document oil and gas well developments.
- Understand and document how the RDTEST68 computer program works.
- Estimate truck axle weights and equivalent single axle loads (ESALs).
- Prepare average ten heaviest wheel load daily (ATHWLD) estimates.

This report provides an update to several analyses completed in 2015, particularly in relation to data received from the Railroad Commission, descriptive statistics and county maps, and estimation of ESALs for individual wells. The report also describes a geographic information system (GIS)-based methodology to estimate truck volumes and ESALs at the individual roadway segment level for any number of oil or gas wells that are developed and operated in a geographic area.

DESCRIPTIVE STATISTICS AND COUNTY MAPS

INTRODUCTION

TTI gathered and processed data from the Railroad Commission to document locations and trends of oil and gas energy developments in the state. The outcome of this task was an updated geodatabase of oil and gas developments, which included GIS files of oil and gas permit locations as well as drilling permit attribute data. Table 1 provides an overview of the various datasets received from the Railroad Commission.

Table 1. Overview of Datasets Received from the Railroad Commission.

RRC Data Collection	RRC Dataset	Dataset Description	Date Range	Size	File Format
Digital Map Data	API Data	Oil and gas well attribute data	1900-01/2016	0.28 GB	*.dbf* and *.txt*
	Wells	Surface/bottom/directional oil and gas well locations	1977-02/2016	1.8 GB	*.shp* (and related)
	Spatial Pipeline Data	Location of inter- and intrastate pipelines	1990-01/2016	1.97 GB	*.shp* (and related)
Drilling Permit Data	Permit Master & Trailer & Lat/Long	Data about drilling permits including location	03/1922-02/2016	1.14 GB	*.dat*
Oil and Gas Production Data	Production Data Query	Oracle dump of the production data	01/1993-04/2016	2.82 GB	*.dmp* (Oracle dump)
Oil and Gas Regulatory Data	Underground Injection Control	Information about underground injection wells: inventory, permit, monitoring pressure testing, and enforcement action data	10/1970-01/2016	0.21 GB	*.txt*

With the data gathered from the Railroad Commission, TTI prepared a series of updated tables, figures, and maps to document locations and trends of oil and gas energy developments, with a focus on the Barnett Shale, Eagle Ford Shale, and Permian Basin regions (Figure 1).

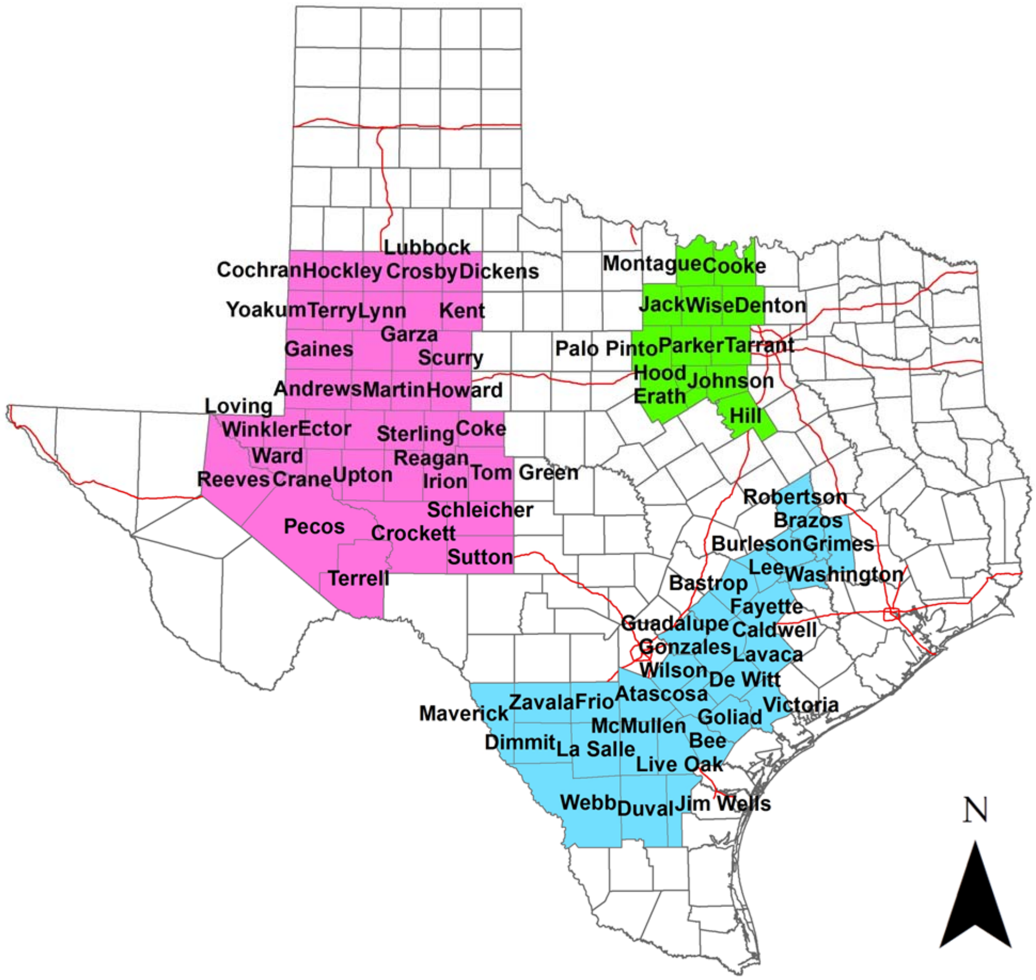


Figure 1. Counties Analyzed in the Eagle Ford Shale, Permian Basin, and Barnett Shale Regions.

Some of the reported RRC data from 2015 may be incomplete and therefore are not as reliable as data from previous years. The reason is the lag between when certain events occur and when RRC updates the corresponding database records. For example, there is lag between the date that an operator completes a well, the date the operator submits the completion report to the Railroad Commission, and the date the RRC database officially registers a well as completed and ready for production. Although the Railroad Commission has allowed operators to submit completion reports online since February 2011, the completion date lag causes the inventory of completed wells to lag behind the actual number of completed wells in the field.

DESCRIPTIVE STATISTICS

Oil and Gas Well Locations

This section includes a small sample of maps that illustrate major trends in recent years. The appendix provides a more extensive sample of county-level tables that document oil and gas developments in the state. The sample in this section includes the following maps:

- Figure 2 shows the location of 431,309 completed oil and gas wellheads in the state from 1977-2015. The figure also shows the location of 79,093 completed oil and gas wells from 2010-2015.

- Figure 3 shows the location of 32,123 uncompleted oil and gas wells with expired drilling permits from 2010-2015. The figure also shows the location of 21,420 uncompleted oil and gas wells with active drilling permits as of December 31, 2015.

- Figure 4 shows the location of wells that are used to inject liquids, air, or gas into non-productive zones. Wells that inject liquids into non-productive zones (also called disposal wells) are of particular interest because they are used to dispose unwanted fluids that result from the development or operation of active production wells.

  Figure 4 also shows the location of wells that are used to inject liquids, air, or gas into productive zones. In most cases, the purpose of injecting fluids into a field is to increase pressure that causes oil and gas to migrate toward adjacent active production wells.

- Figure 5 shows the number of completed oil and gas wells by county from 2005-2008.

- Figure 6 shows the number of completed oil and gas wells by county from 2009-2012.

- Figure 7 shows the number of completed oil and gas wells by county from 2013-2015.

- Figure 8 shows the cumulative number of oil and gas wells by county from 2009-2011.

- Figure 9 shows the cumulative number of oil and gas wells by county from 2009-2013.

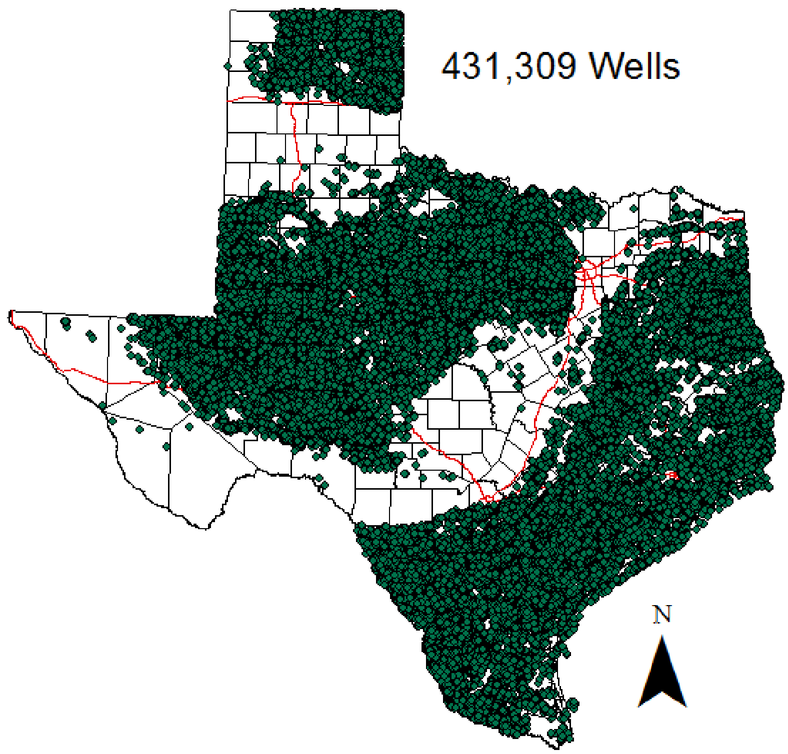
- Figure 10 shows the cumulative number of oil and gas wells by county from 2009-2015.

- Figure 11 shows the cumulative number of horizontal oil and gas wells by county from 2009-2011.

- Figure 12 shows the cumulative number of horizontal oil and gas wells by county from 2009-2013.

- Figure 13 shows the cumulative number of horizontal oil and gas wells by county from 2009-2015.

1977-2015



2010-2015

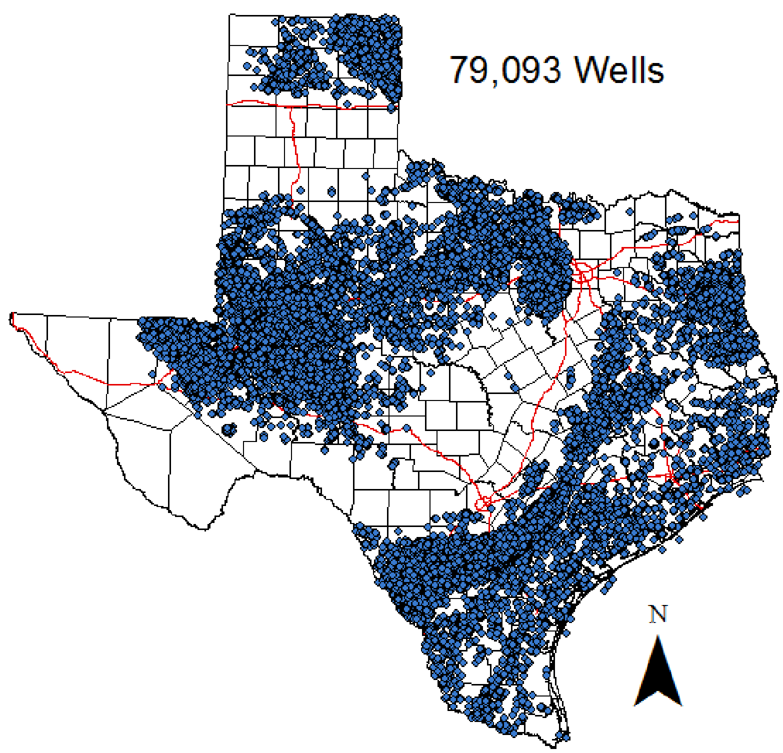


Figure 2. Completed Oil and Gas Wells in Texas (1977-2015).

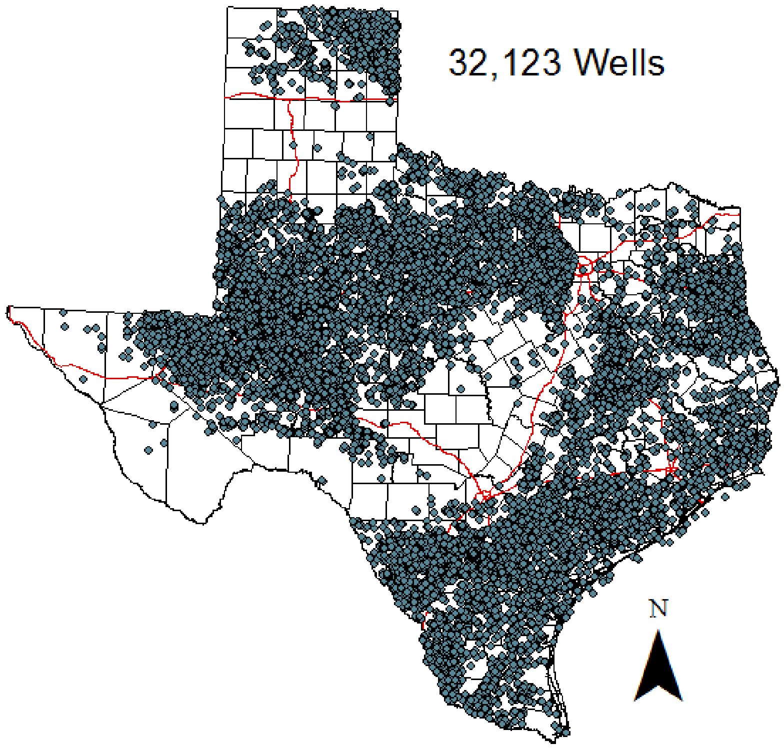
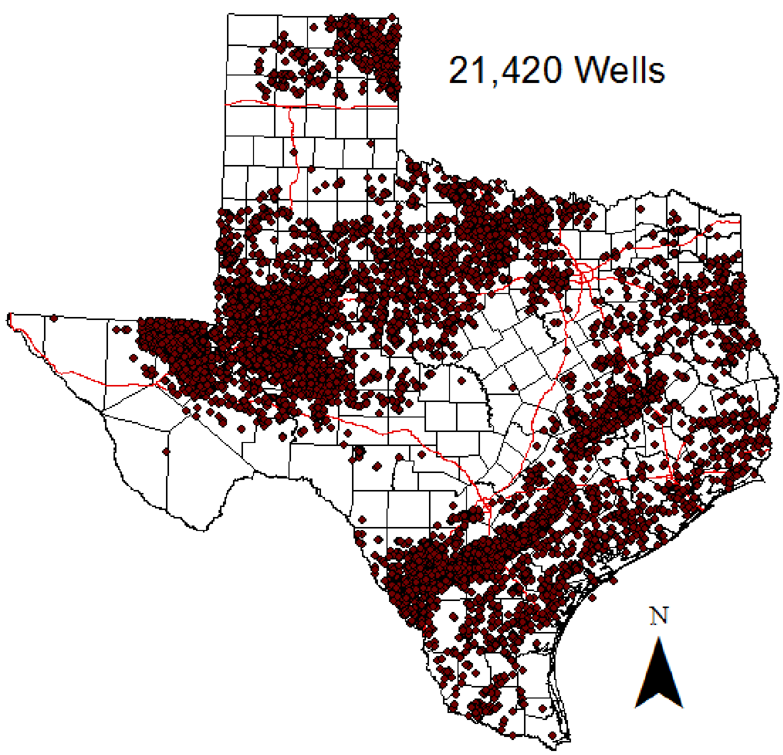
Expired Permits (2010-2015)	
Active Permits as of December 2015	

Figure 3. Uncompleted Oil and Gas Wells.

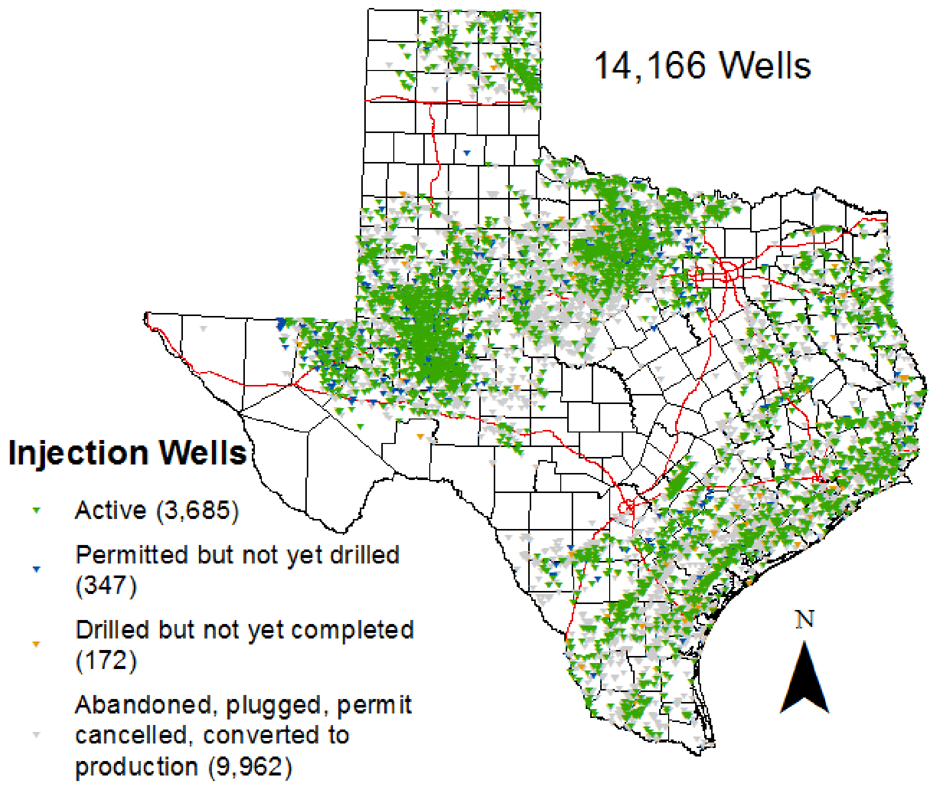
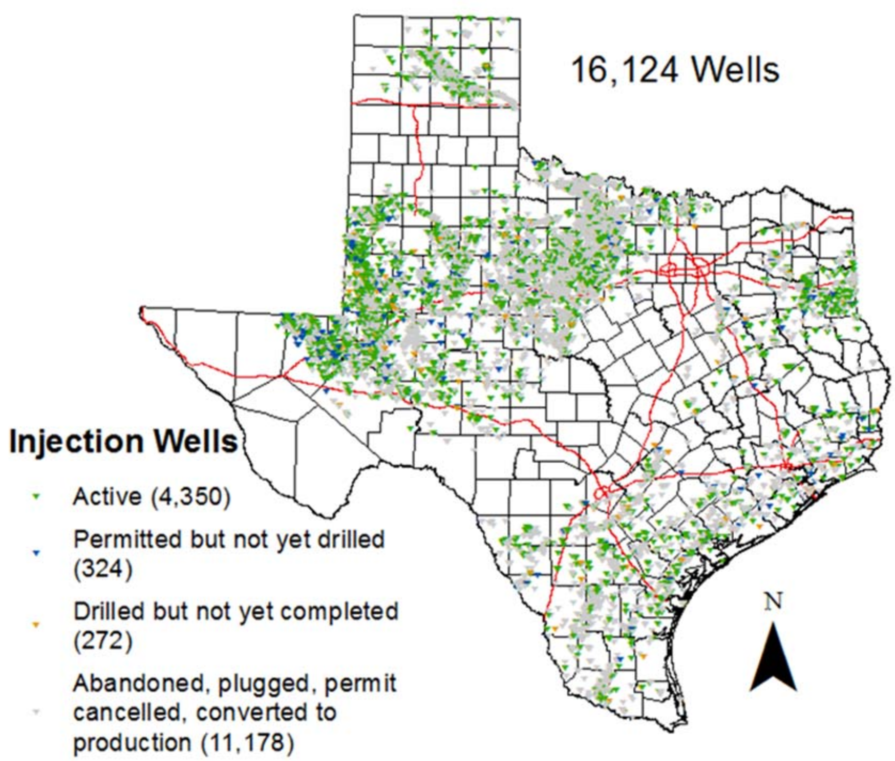
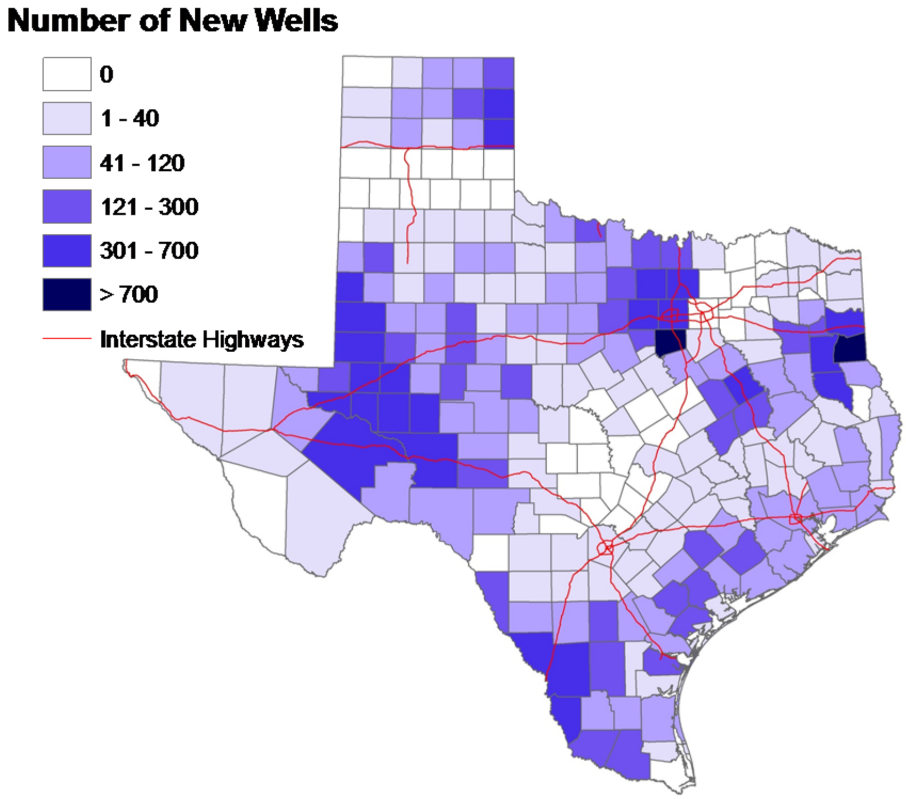
Injection wells into non-productive zones	
Injection wells into productive zones	

Figure 4. Wells Injecting Liquids, Air, or Gas (1983-2015).

<table>
<tr><td>2005-2006</td><td>
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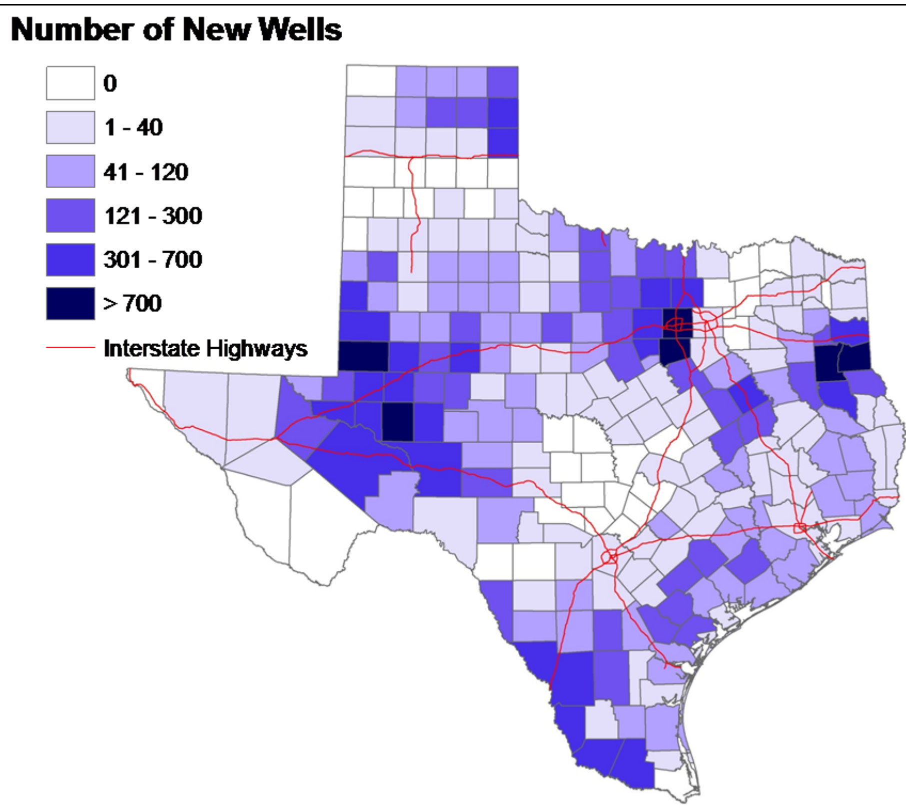
<tr><td>2007-2008</td><td>
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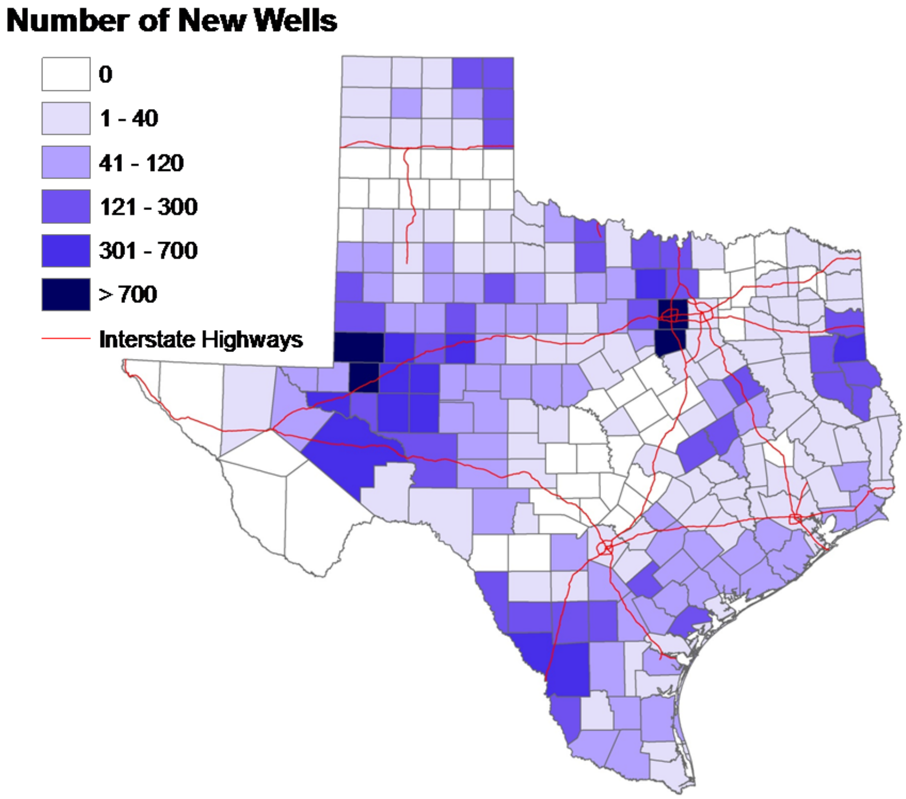
Figure 5. Completed Oil and Gas Wells (2005-2008).

2009-2010



2011-2012

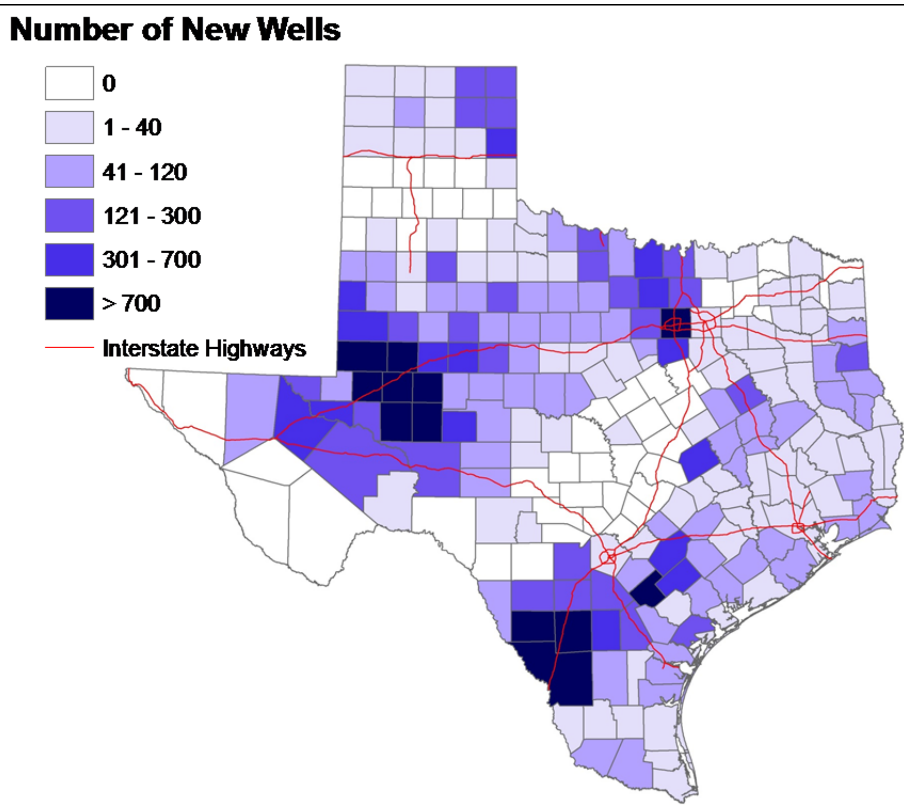
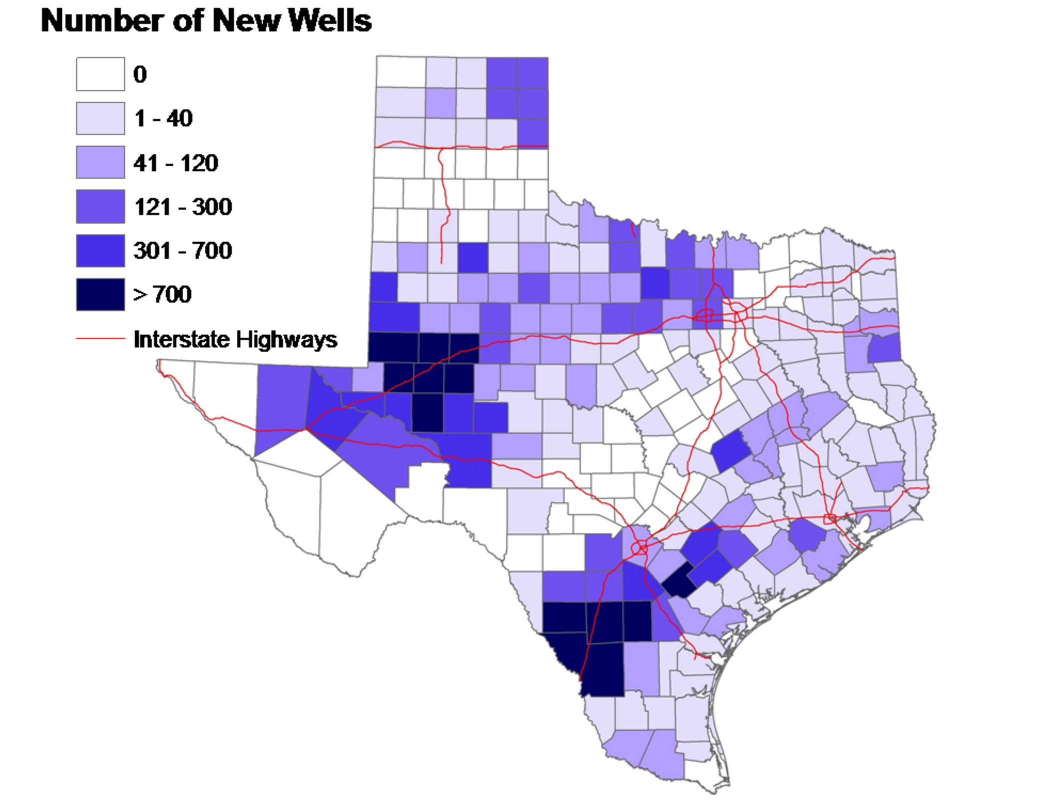


Figure 6. Completed Oil and Gas Wells (2009-2012).

2013-2014



2015

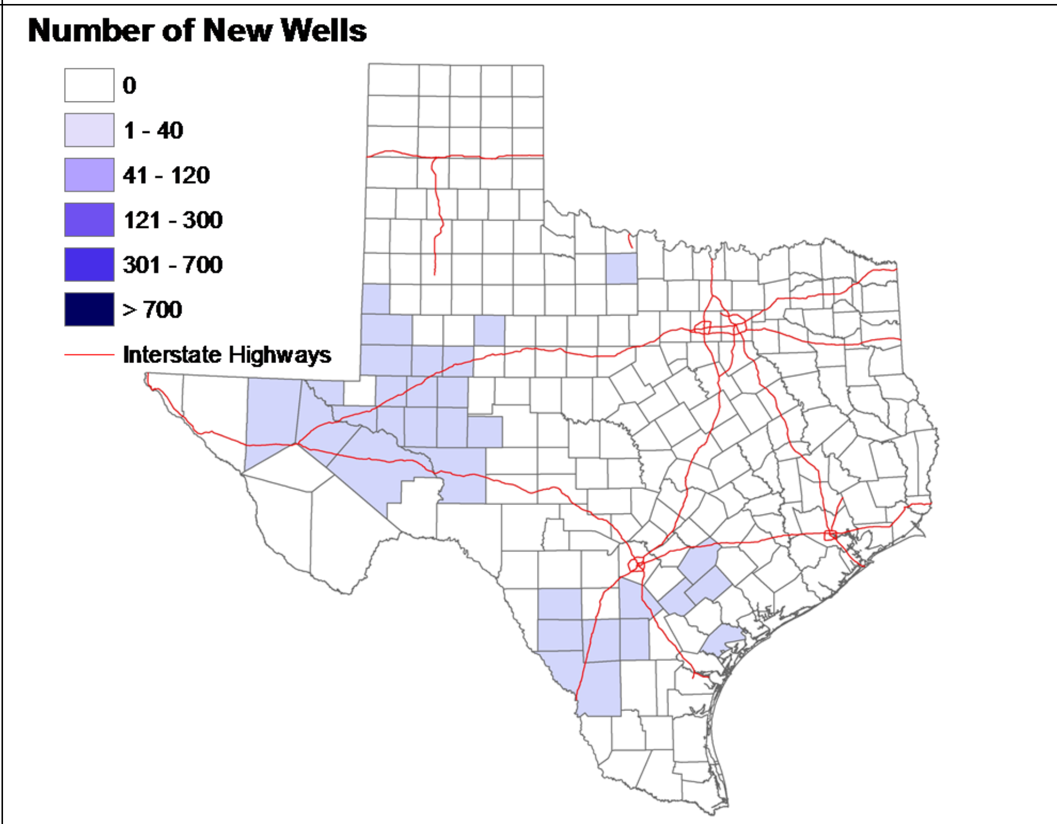


Figure 7. Completed Oil and Gas Wells (2013-2015).

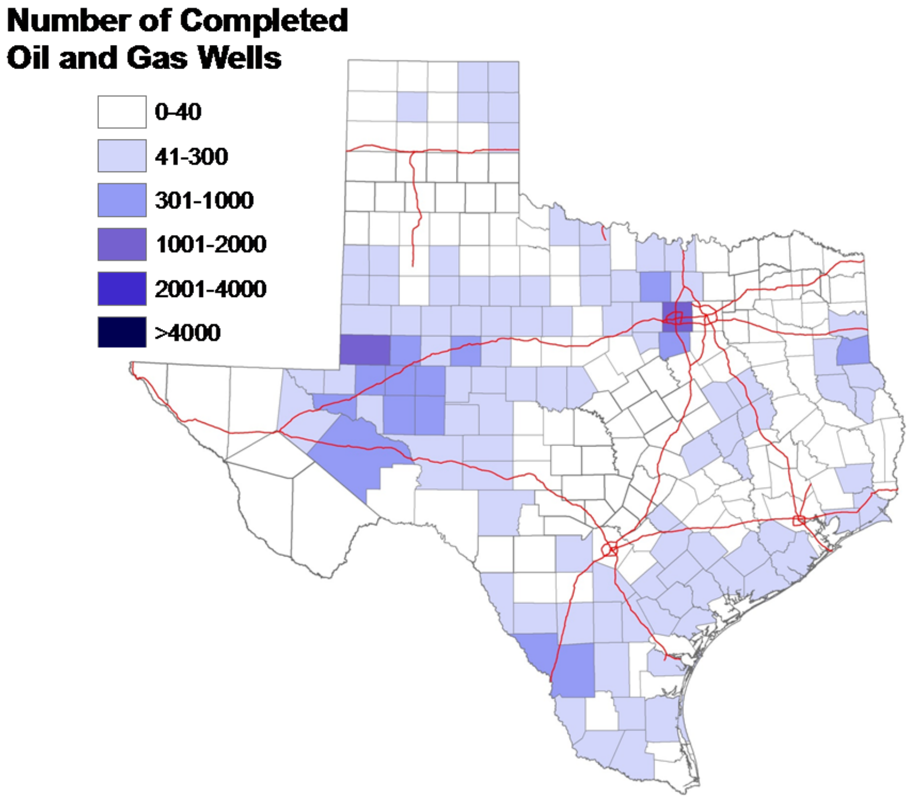
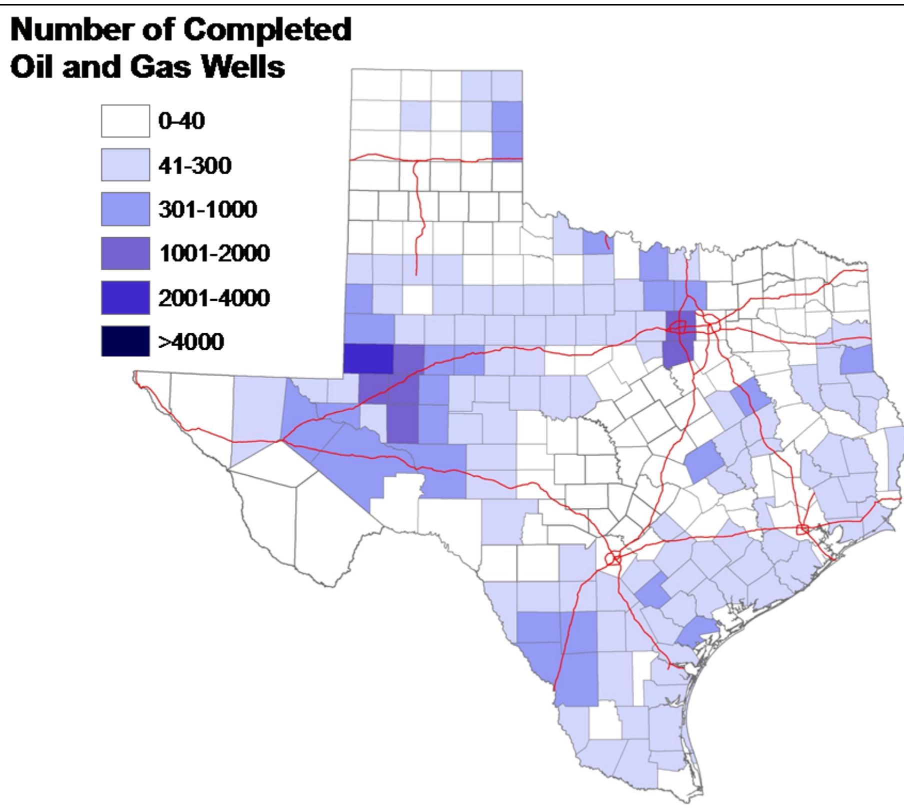
2009-2010	
2009-2011	

Figure 8. Cumulative Number of Oil and Gas Wells (2009-2011).

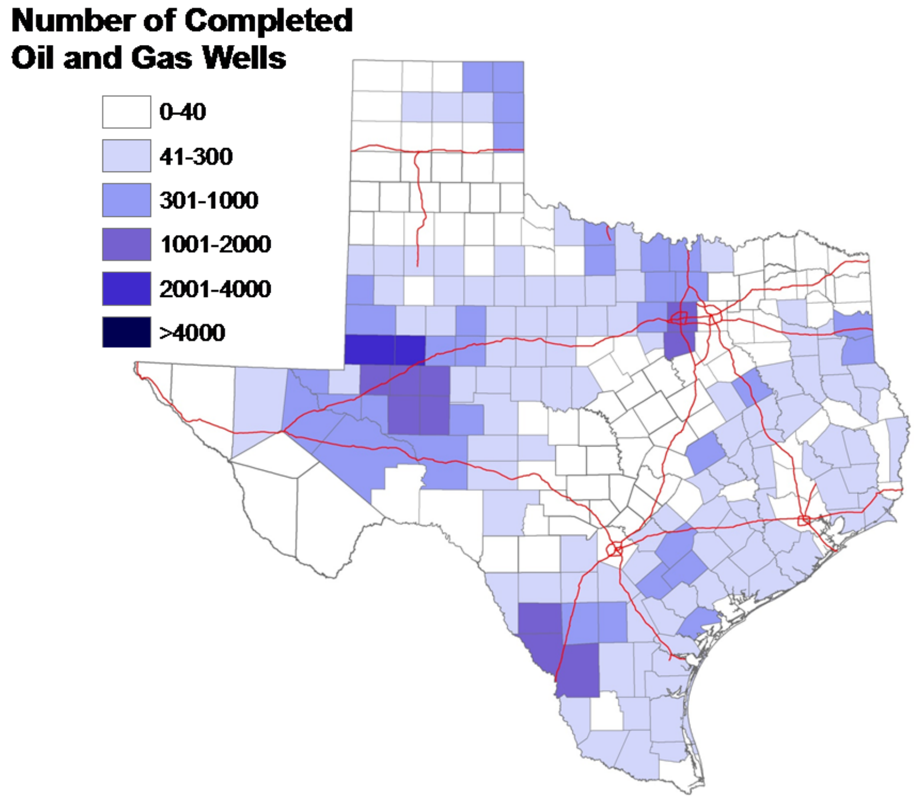
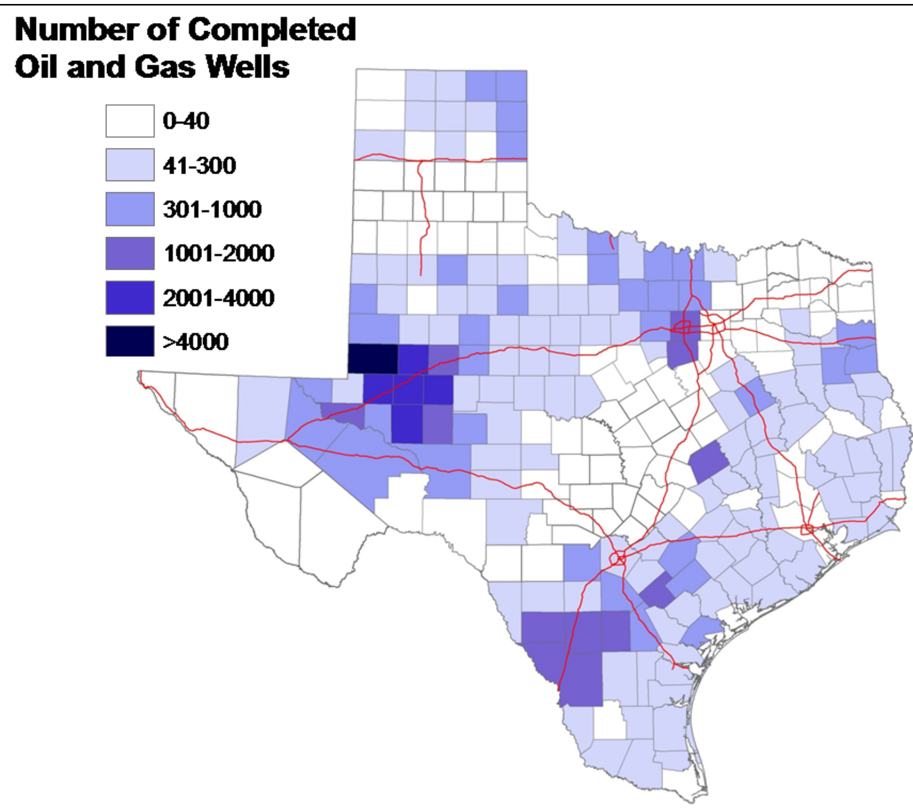
2009-2012	
2009-2013	

Figure 9. Cumulative Number of Oil and Gas Wells (2009-2013).

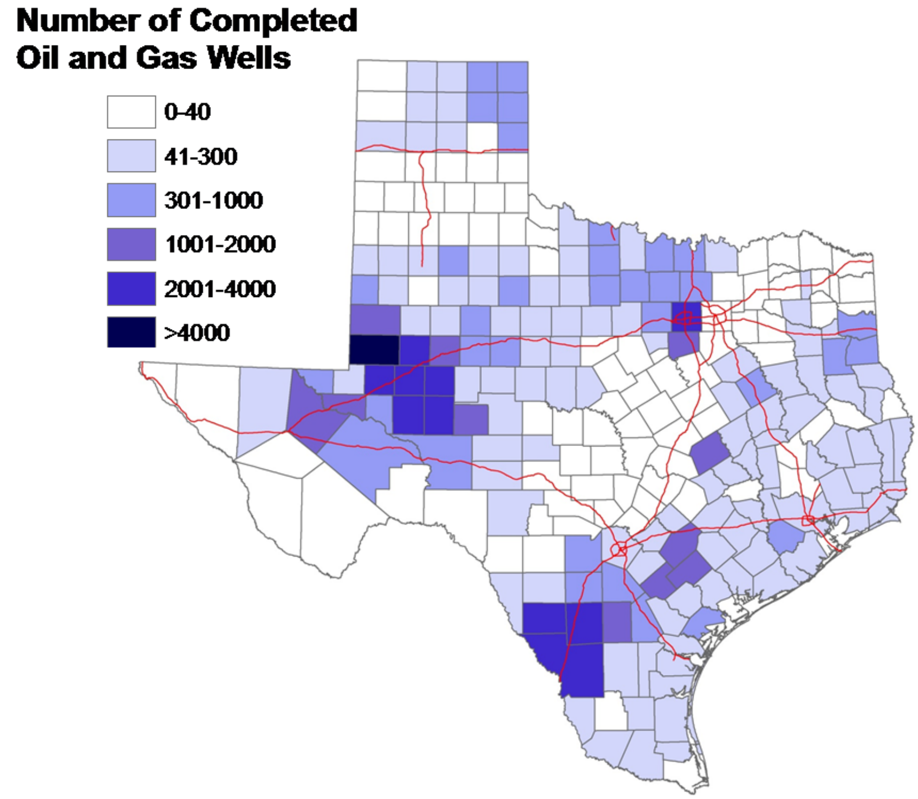
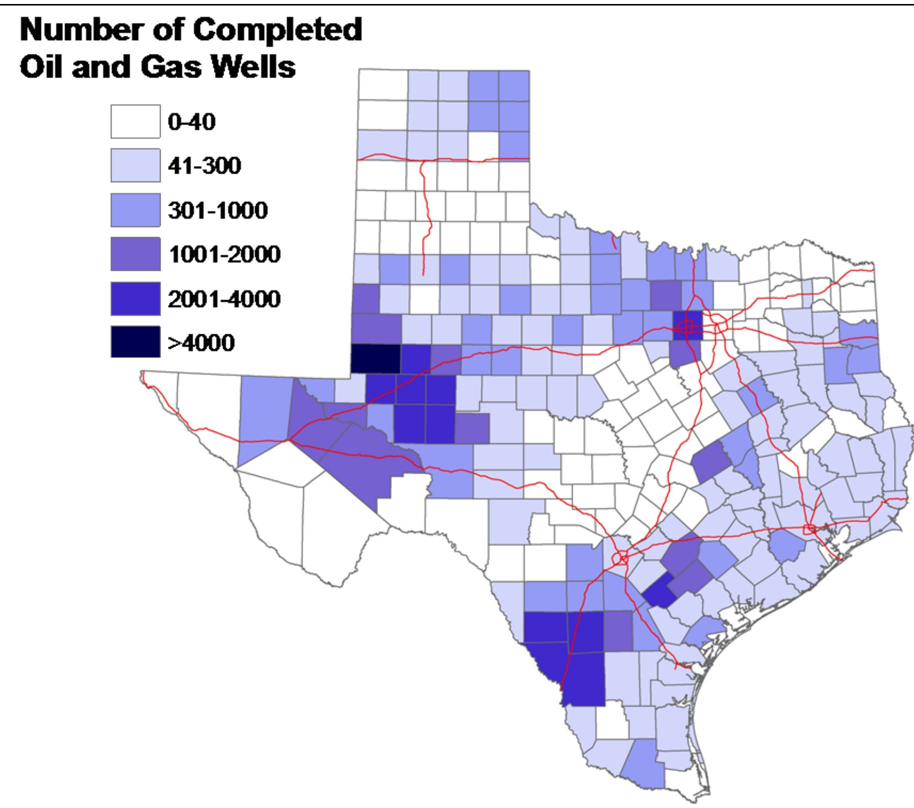
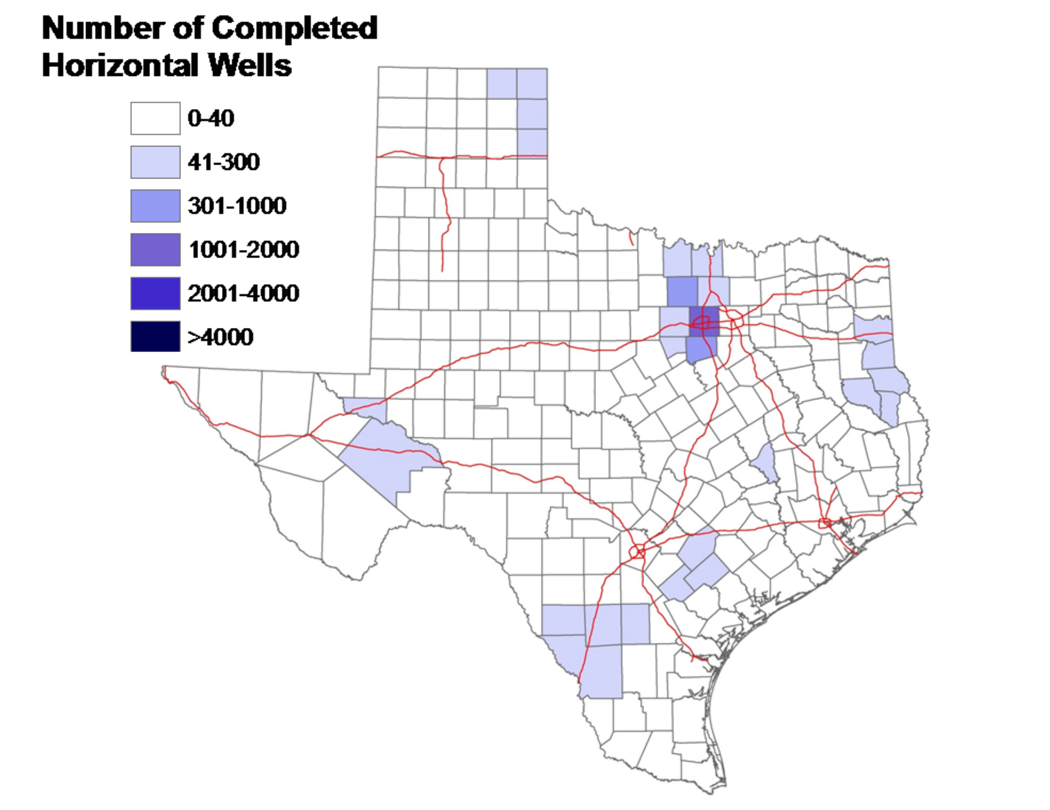
2009-2014	
2009-2015	

Figure 10. Cumulative Number of Oil and Gas Wells (2009-2015).

2009-2010



2009-2011

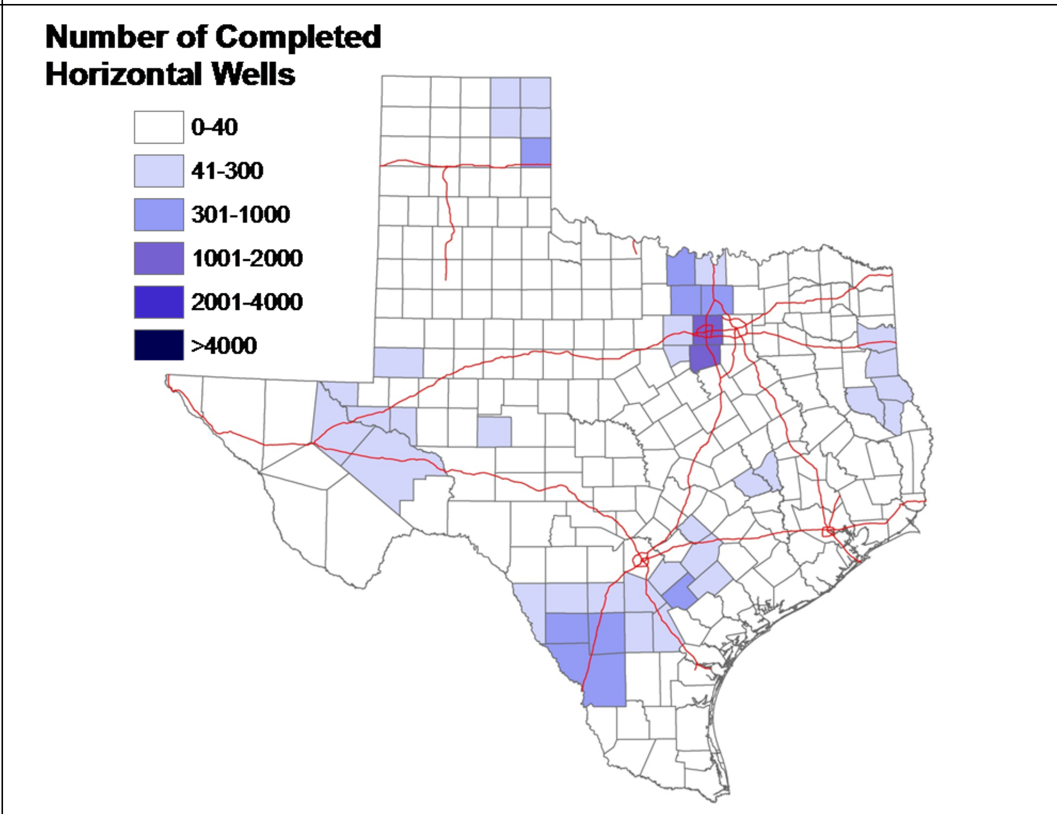
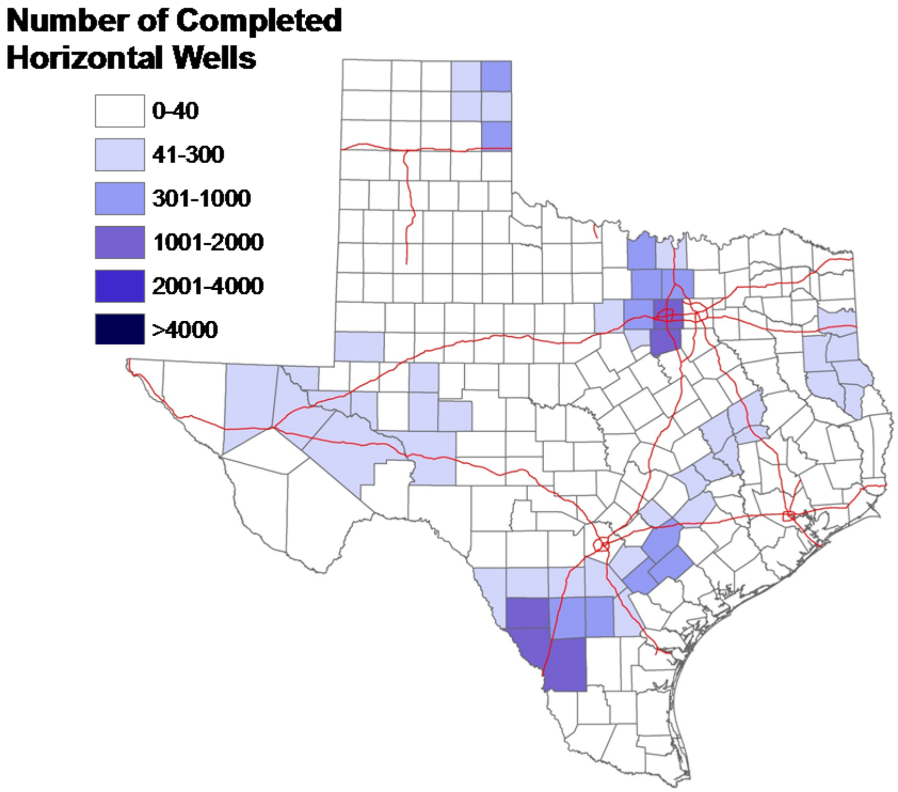


Figure 11. Cumulative Number of Horizontal Oil and Gas Wells (2009 2011).

<table>
<tr><td>2009-2012</td><td>
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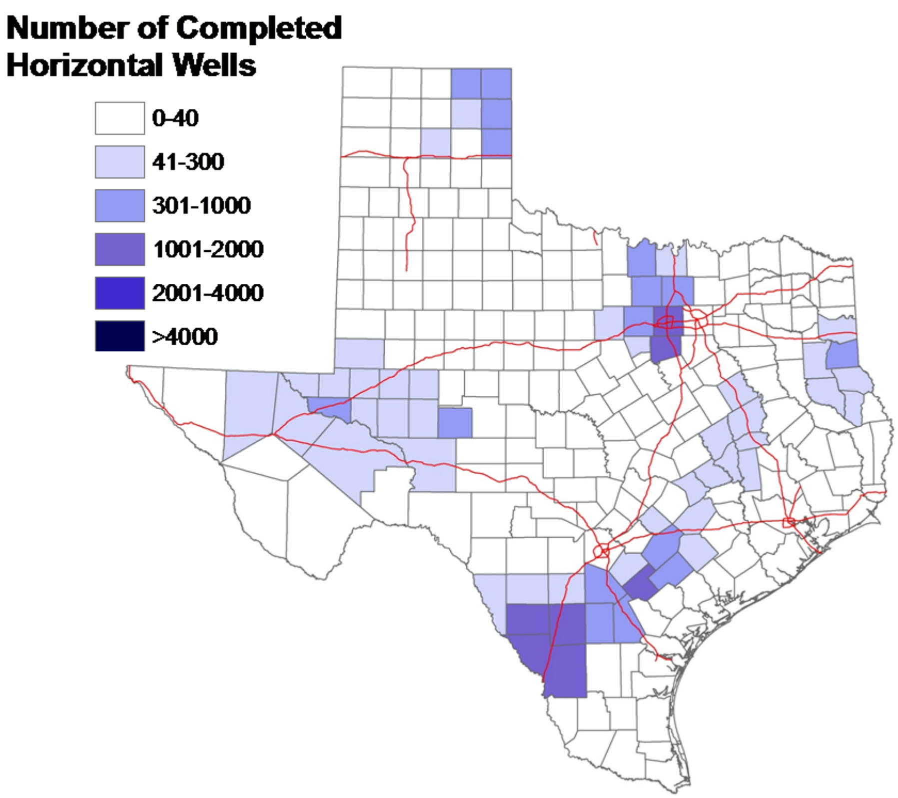
<tr><td>2009-2013</td><td>
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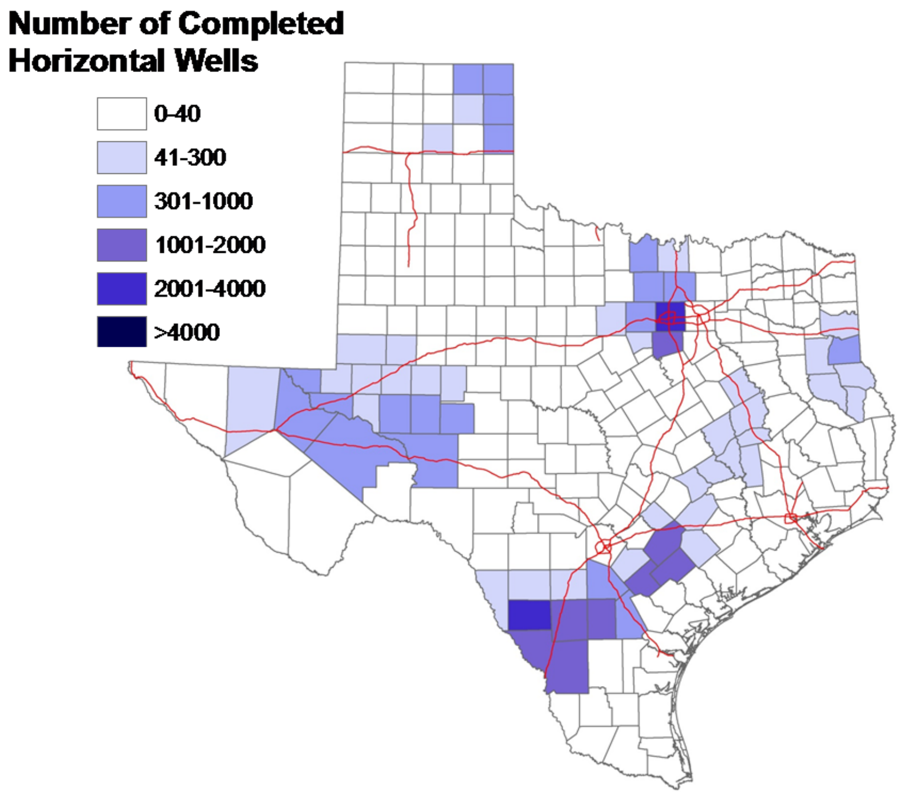
Figure 12. Cumulative Number of Horizontal Oil and Gas Wells (2009-2013).

2009-2014



2009-2015

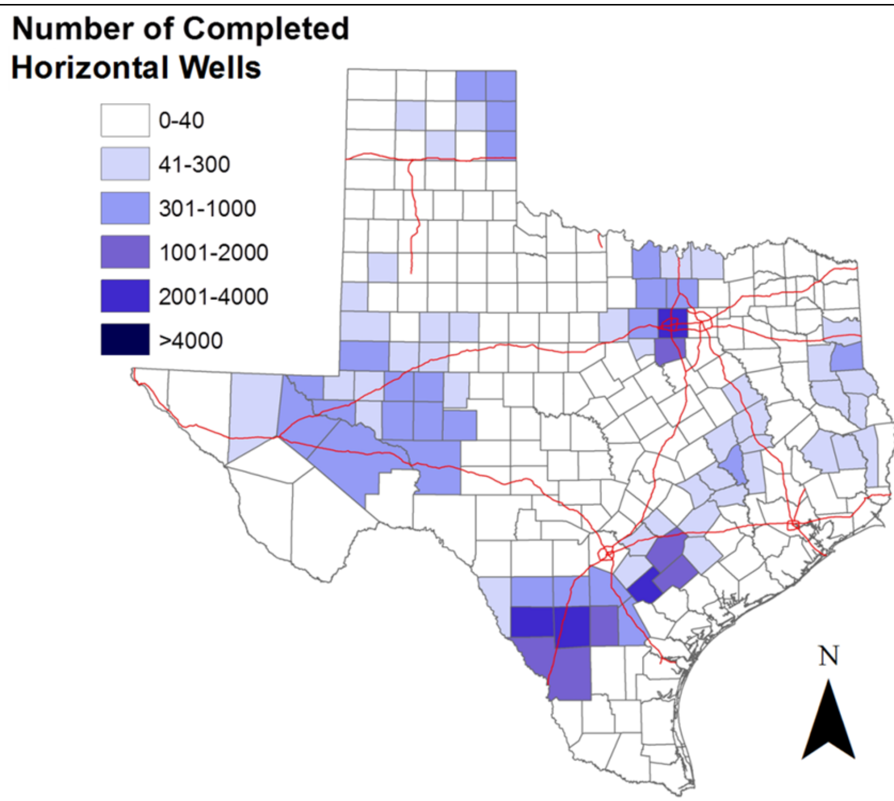


Figure 13. Cumulative Number of Horizontal Oil and Gas Wells (2009-2015).

Historical Evolution of Oil and Gas Wells

Figure 14 provides a historical view of the price of imported oil since 1974. In the late 1970s, oil prices were high due in part to instability in the oil supply that resulted from the Iranian Revolution of 1979 and the beginning of the Iraq-Iran War in 1980. High oil prices encouraged energy conservation, which, in turn, resulted in lower consumption. The resulting oversupply in oil caused a significant reduction in oil prices in the mid-1980s. The price of oil remained low until the mid-2000s. Oil prices accelerated quickly from around 2004 until July 2008, when the economic recession hit. In response, oil prices collapsed. In five months, the price of imported oil decreased from $127.77/barrel (or $139.23/barrel in May 2016 dollars) to $35.59/barrel (or $40.18/barrel in May 2016 dollars). After that, prices recovered quickly until reaching another peak in April 2011 ($113.02/barrel or $120.37/barrel in May 2016 dollars). Prices remained above $100/barrel until June 2014. However, by January 2015, the price of oil had decreased to $44.74/barrel (or $45.45 in May 2016 dollars). Since the beginning of 2015, the price of oil has fluctuated around $50/barrel. The current short-term Energy Information Administration (EIA) forecast is that the price of oil will remain between $40-$50/barrel through the end of 2017.

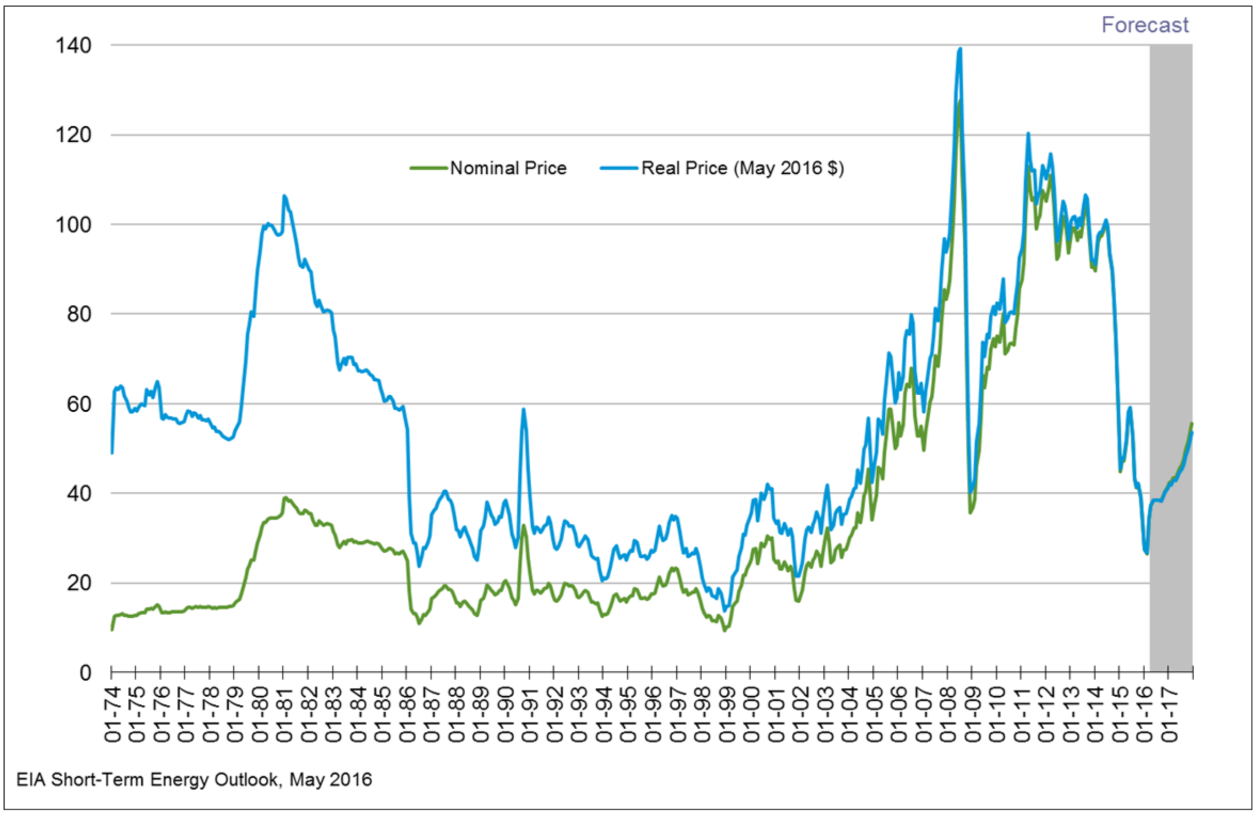


Figure 14. Price of Average Monthly Imported Crude Oil Price (adapted from [*1*]).

Figure 15 shows the number of permitted oil and gas wells from 1977-2015. Figure 16 shows the number of oil and gas wells completed during the same period. The Railroad Commission differentiates between "surface" wells (which correspond to the X,Y locations of the wellheads) and "bottom" wells (which correspond to the X,Y locations of the bottom end of the wells). Generally speaking, a "surface" well corresponds to the location of a wellhead (in the case of vertical wells) or a placeholder for all the wellheads that are connected to horizontal wells at the same pad location, all of which share the same American Petroleum Institute (API) number. For vertical wells, the relationship between "surface" well and "bottom" well locations is one-to-one. For horizontal wells, the relationship can be one-to-one (if there is only one lateral) or, increasingly, one-to-many. In 2015, for the first time, the number of new horizontal wells was higher than the number of new vertical wells. Industry insiders anticipate the number of new horizontal wells to continue to grow at a higher rate than the number of new vertical wells.

The amount of time needed to develop wells is increasing. As Figure 17 shows, the median duration between permit approval and well completion increased from about one month in 1977 to almost three months in 2014. The mean duration increased from a month and a half in 1977 to more than four months in 2014. There was also a significant increase in the median and mean durations from 2014 to 2015, which is consistent with a recent trend reported in the mass media about energy developers drilling wells but not immediately fracking those wells until oil prices become more favorable. Figure 17 also shows the 10th and 90th percentile durations. In particular, the 90th percentile duration increased from approximately three months in 1977 to more than ten months in 2015. The volatility of this duration is probably associated with uncertainties that some individual operators experience, e.g., delays in drilling equipment deliveries or truck shortages.

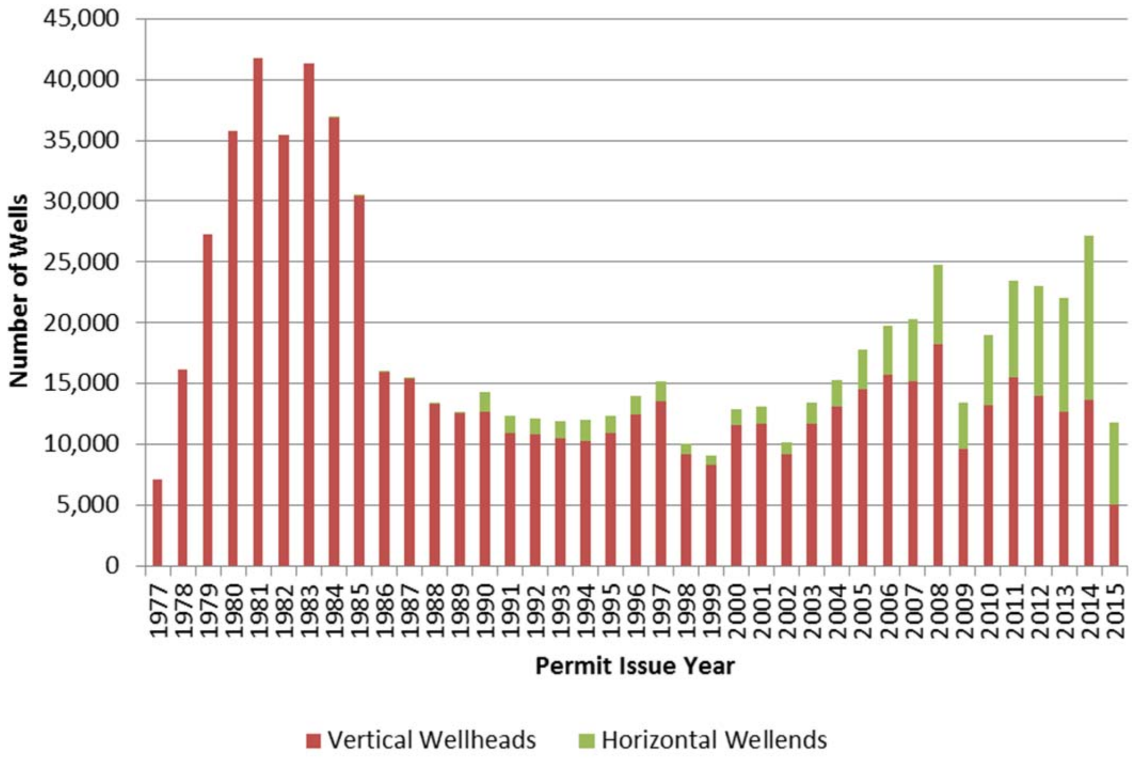


Figure 15. Permitted Oil and Gas Wells.

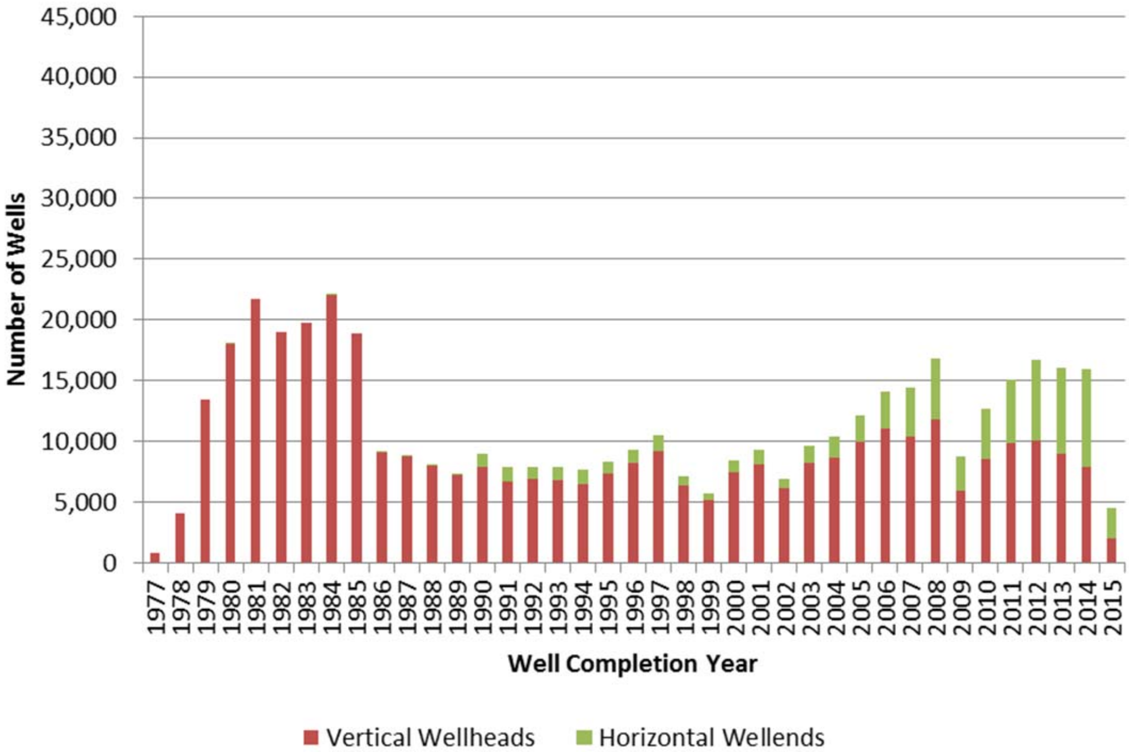


Figure 16. Completed Oil and Gas Wells.

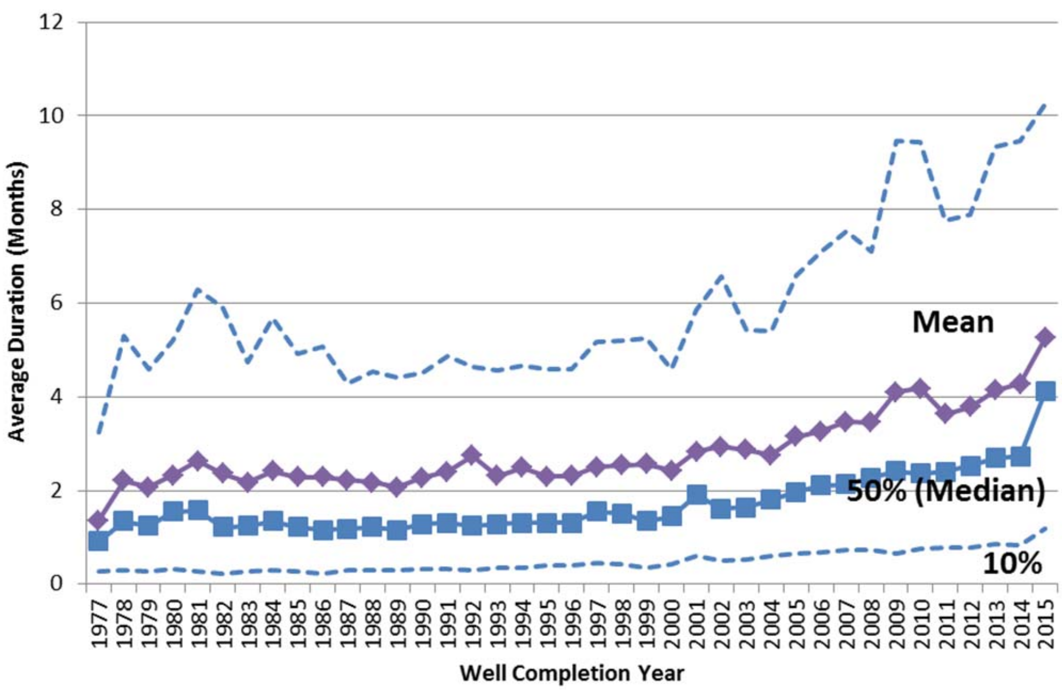
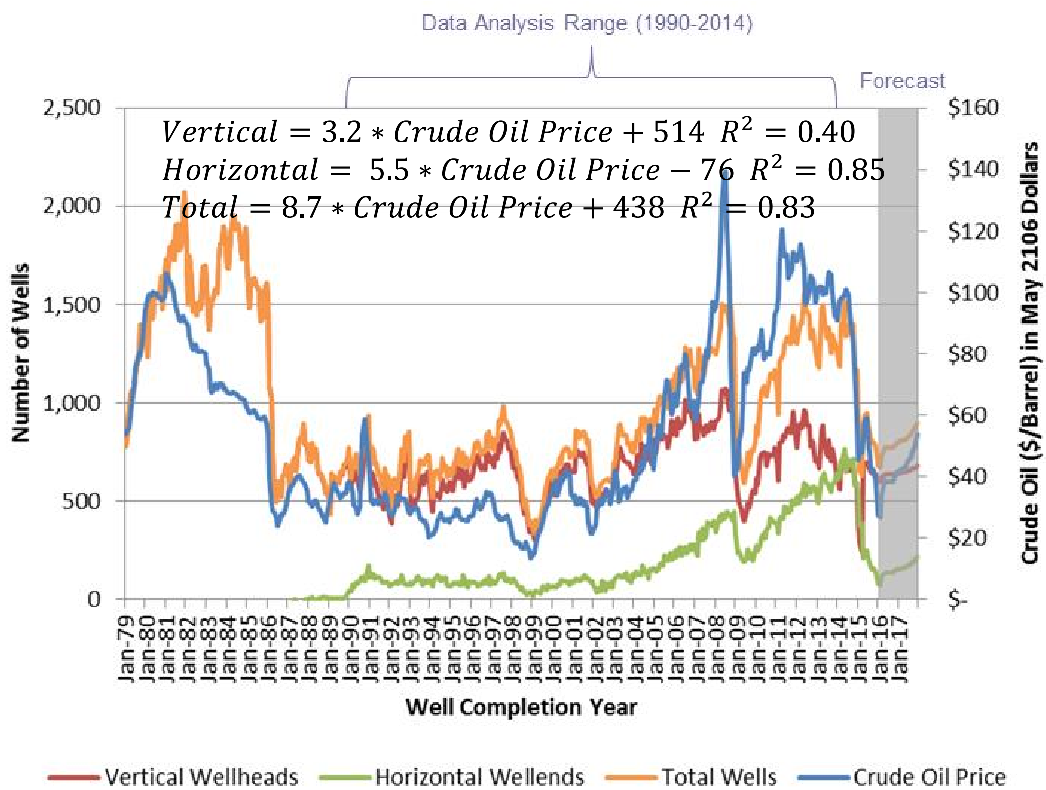


Figure 17. Duration between Permit Approval and Well Completion.

High-Level Forecasting

By combining EIA monthly crude oil price data with RRC well completion data, it is possible to estimate drilling activity as a function of the price of crude oil. Figure 18 shows the number of completed vertical wellheads, horizontal wellends, and total wells per month compared to the average monthly price of crude oil (adjusted to May 2016 dollars). At the state level, there is a strong correlation between the price of crude oil and the number of completed wells. The correlation is stronger for horizontal wellends than for vertical wellheads, and it is the highest after introducing a "lag" effect of three months (to account for the time it might take for energy developers to react to changes in oil prices). All correlations are positive, meaning that if the price of crude oil increases the number of wells completed increases.



Note: The regression analysis period covered years 1990 through 2014.

Figure 18. Number of Completed Wells as a Function of Crude Oil Prices.

Based on this information, TTI used several regression model to estimate the number of completed wells as a function of the price of crude oil. As an illustration, Figure 18 shows linear regression equations for vertical and horizontal wells. In Figure 19, linear, logarithmic, and power function trend lines are fit to the statewide dataset of monthly crude oil price versus total wells completed per month. Although the data exhibit a slightly curved pattern, the linear regression fit appears to be the most suitable based on the R^2 values. Notice in Figure 19 that different symbols and colors are used to highlight variations in the price of crude oil and the corresponding number of wells completed over time. The figure clearly shows data clusters that indicate specific trends in the industry.

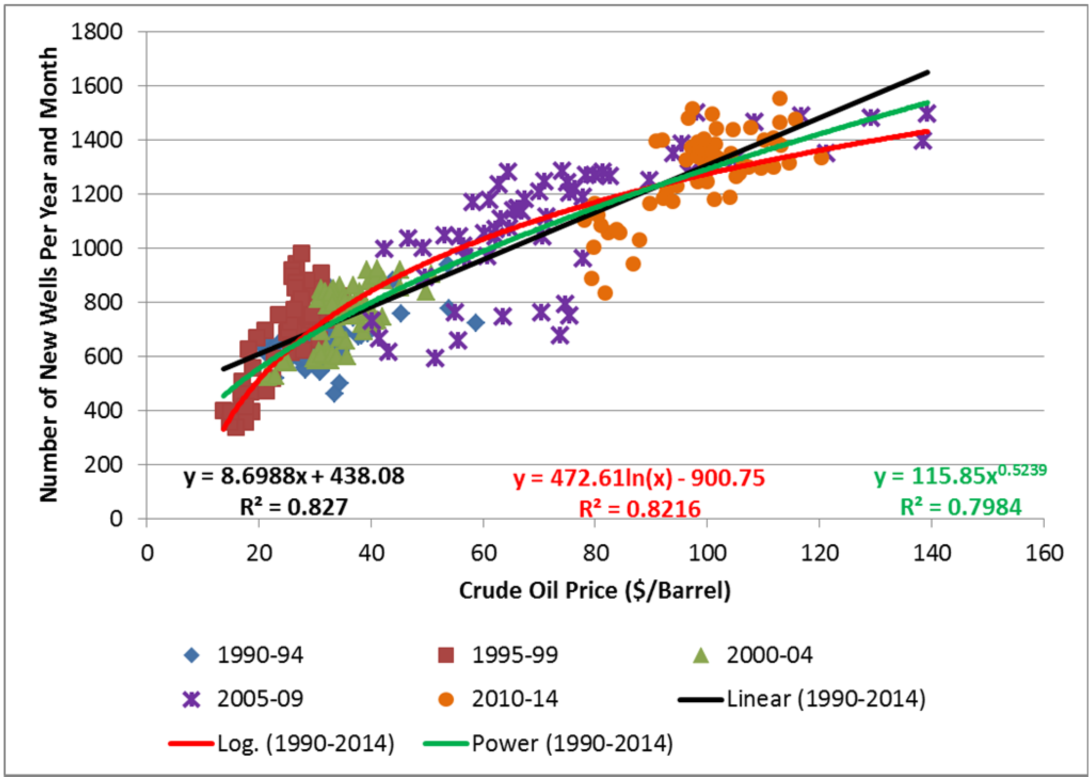


Figure 19. Crude Oil Price vs. Number of New (Vertical and Horizontal) Wells Statewide.

Figure 20 shows the number of new vertical and horizontal wells completed statewide. R^2 values were lower for vertical wells than for horizontal wells. When comparing the number of vertical and horizontal wells in Figure 20 (more specifically 2010-2014 data), the number of vertical wells is decreasing while the number of horizontal wells is increasing. In addition, when comparing the slopes of the linear regression trend lines, the slope for horizontal wells is greater than that of vertical wells, suggesting a faster response to price fluctuations for horizontal wells.

Figure 21 is similar to Figure 20, except the data points in Figure 21 are limited to the Eagle Ford Shale Region. In this region, the number of vertical wells completed remained roughly the same regardless of the price of crude oil. However, there was a noticeable trend beginning in 2010. From 2010-2014, the number of vertical wells decreased, while the number of horizontal wells increased rapidly. The price of crude oil had no effect on the number of horizontal wells completed prior to 2010. As shown, the number of horizontal wells completed was roughly constant even though prices ranged from $20-$140/barrel. Starting in 2010, the number of horizontal wells increased dramatically from less than 50 per month to over 300 per month, while the price of oil rose from $80/barrel to $120/barrel.

Figure 22 shows the annual average price of crude oil versus the number of wells completed per year in the Eagle Ford Region. The arrows are used to connect data from one year to the next. As such, the figure shows the evolution in the number of wells completed as the price of crude oil changes. For horizontal wells, the figure shows that, beginning in 2010, as the price of crude oil began to increase, the industry responded by drilling and completing an increasingly higher number of wells. Very quickly, the number of wells completed no longer was a function of the price of crude oil, i.e., the number of wells completed continued to increase, regardless of the price of crude oil. This trend should logically suggest a maximum point beyond which the number of wells would begin to decrease. More than likely, once data points for 2015 are included in the chart, this downward trend will become evident.

Figure 23 and Figure 24 show similar figures for the Barnett Shale Region. In this region, from 1990-1999, only a small number of vertical wells and nearly no horizontal wells were completed. Starting in 2000, the number of vertical wells and horizontal wells increased, although vertical wells increased at a greater rate than horizontal wells. This trend reversed from 2005 to 2009 as the number of horizontal wells outpaced the number of vertical wells completed. Starting in 2010, the number of both vertical and horizontal wells completed begins to decline each year, as the price of natural gas decreased substantially around that time.

The cyclical variations in the price of natural gas made it critical to use annualized data for the Barnett Shale Region, as shown in Figure 24. From 1990-1999, the price of natural gas was roughly constant and the number of vertical wells completed was very similar each year. Starting in 2000, a period of volatility started, with the number of vertical wells completed not well correlated with the price of natural gas. For example, from 2003-2008, the number of vertical wells decreased even though the price of natural gas increased. In recent years, the number of vertical wells has been nearly zero even though the price of natural gas has been higher than in other periods when the number of wells completed was substantially higher.

For horizontal wells, the annualized chart (Figure 24) reveals an interesting trend that illustrates how the industry has responded to changes in the price of natural gas. Beginning in 2003, the number of horizontal wells began to increase rapidly as the price of natural gas increased. At some point, the price of natural gas stopped increasing, but the number of wells continued to increase. This trend continued until about 2009 when the number of wells began to decrease rapidly. For forecasting purposes, this trend highlights the need to take into consideration both sides of the curve: when prices are moving from lower to higher and when prices are moving from higher to lower. When prices are moving from lower to higher, the number of horizontal wells completed per year is less than when prices are moving from higher to lower, even if the average annual price is the same.

Figure 25 shows the price of crude oil versus the number of vertical and horizontal wells per month in the Permian Basin Region. This analysis included the two highest producing counties because that is where most horizontal drilling took place in the region. Other counties in the Permian Region have many more wells, of which the majority are low-producing vertically drilled wells. The number of vertical and horizontal wells completed remained constant until 2011. Starting in 2012, the number of horizontal wells began to increase, but this number was still lower than the number of vertical wells. In 2013, the number of vertical wells and horizontal wells completed were similar, and in 2014, the number of horizontal wells completed was considerably greater than the number of vertical wells.

Figure 26 shows the annual average price of crude oil versus the number of vertical and horizontal wells completed per year. Although the numbers are specific to the Permian Basin Region, the overall trends are similar to those observed in the Eagle Ford Region.

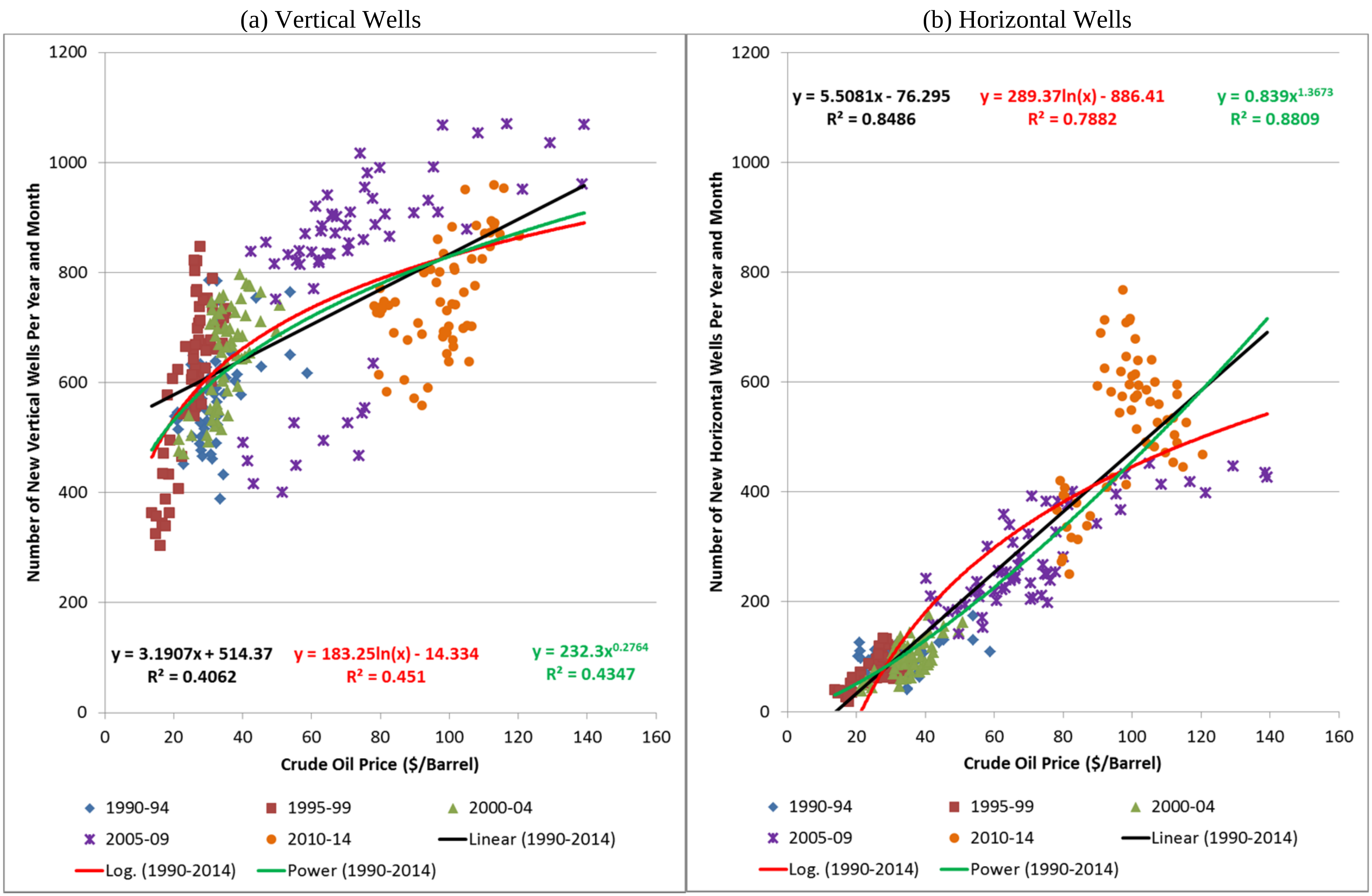


Figure 20. Price of Crude Oil vs. Number of New Wells Statewide.

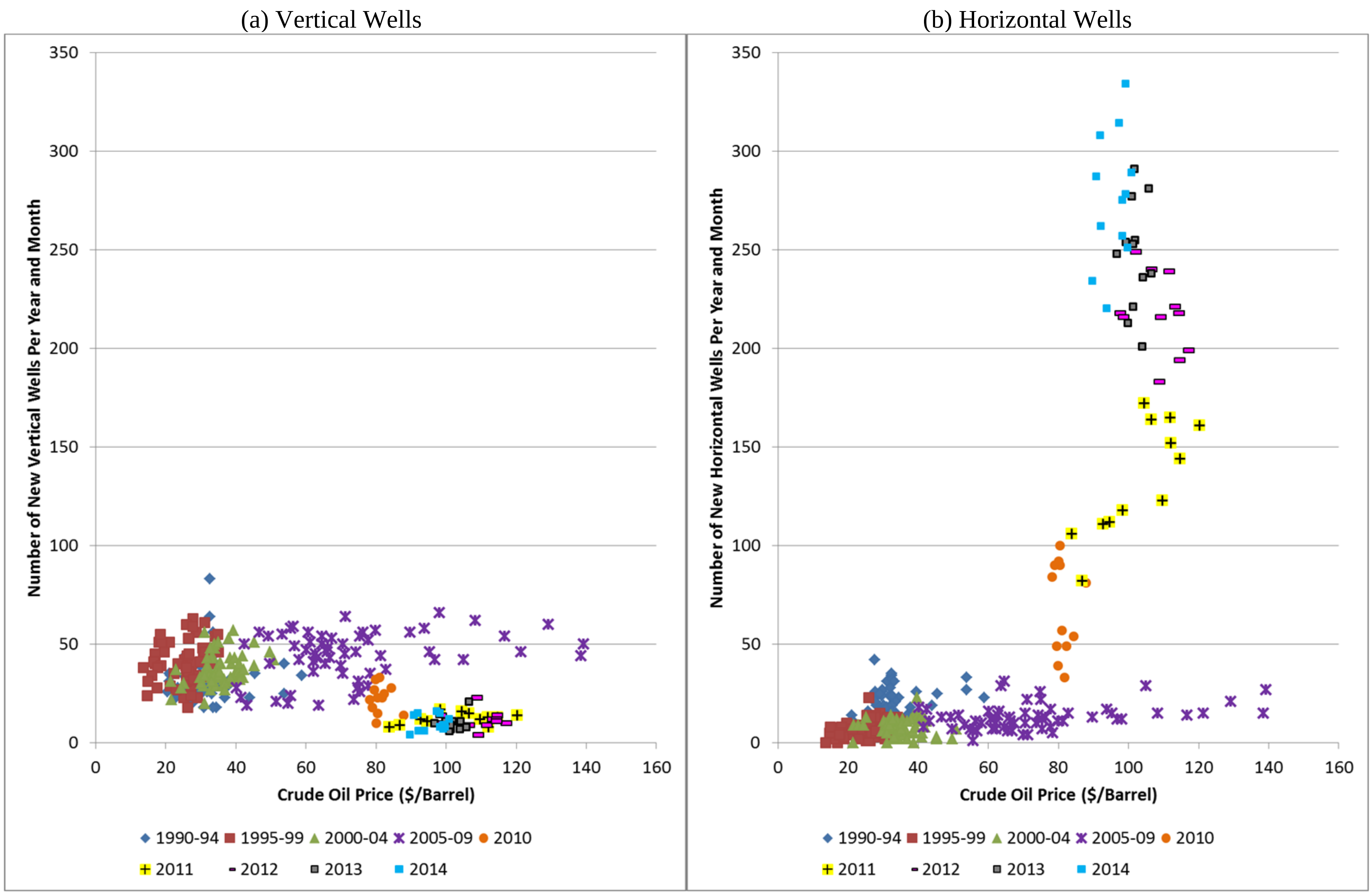


Figure 21. Price of Crude Oil vs. Number of New Wells in the Top 10 Producing Counties in the Eagle Ford Shale Region.

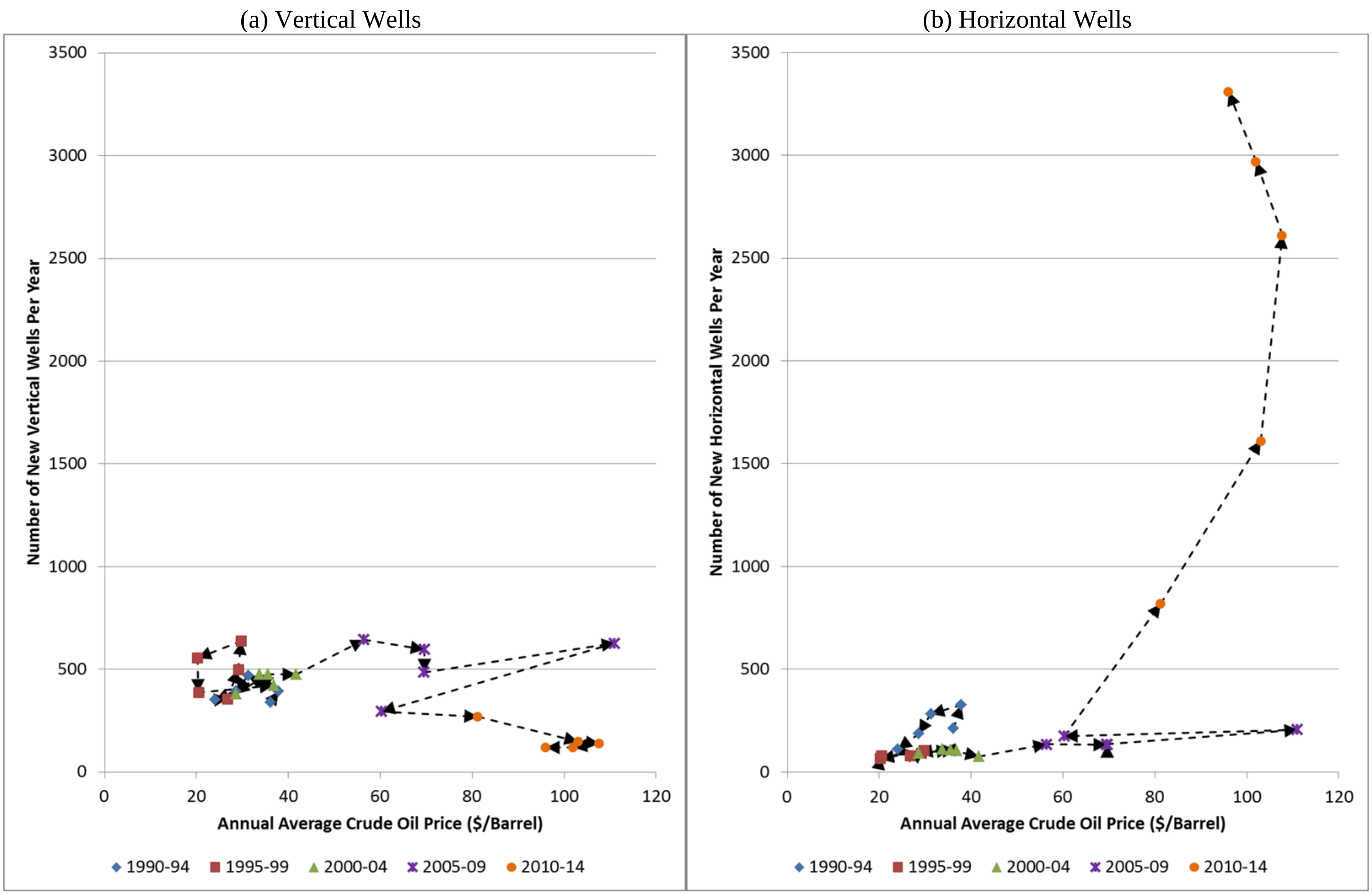
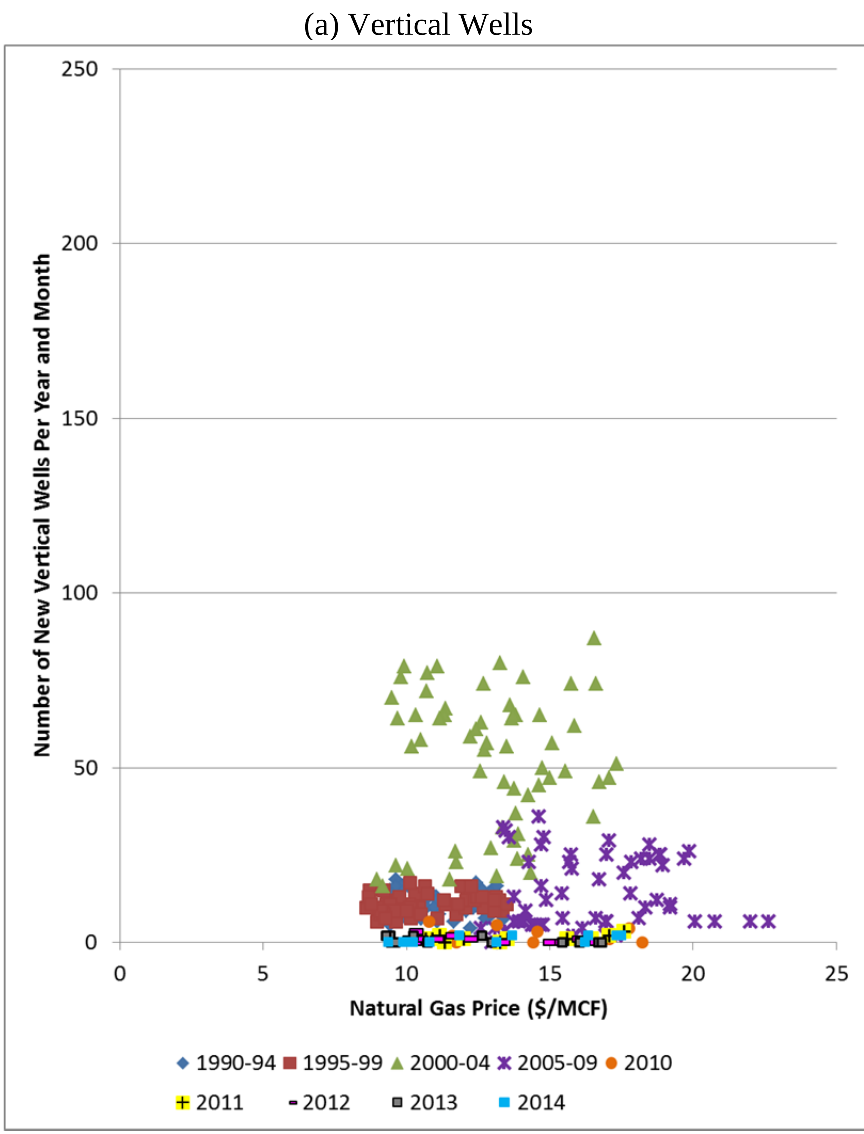


Figure 22. Annual Average Price of Crude Oil vs. Total (Annual) Number of New Wells in the Top 10 Producing Counties in the Eagle Ford Shale Region.



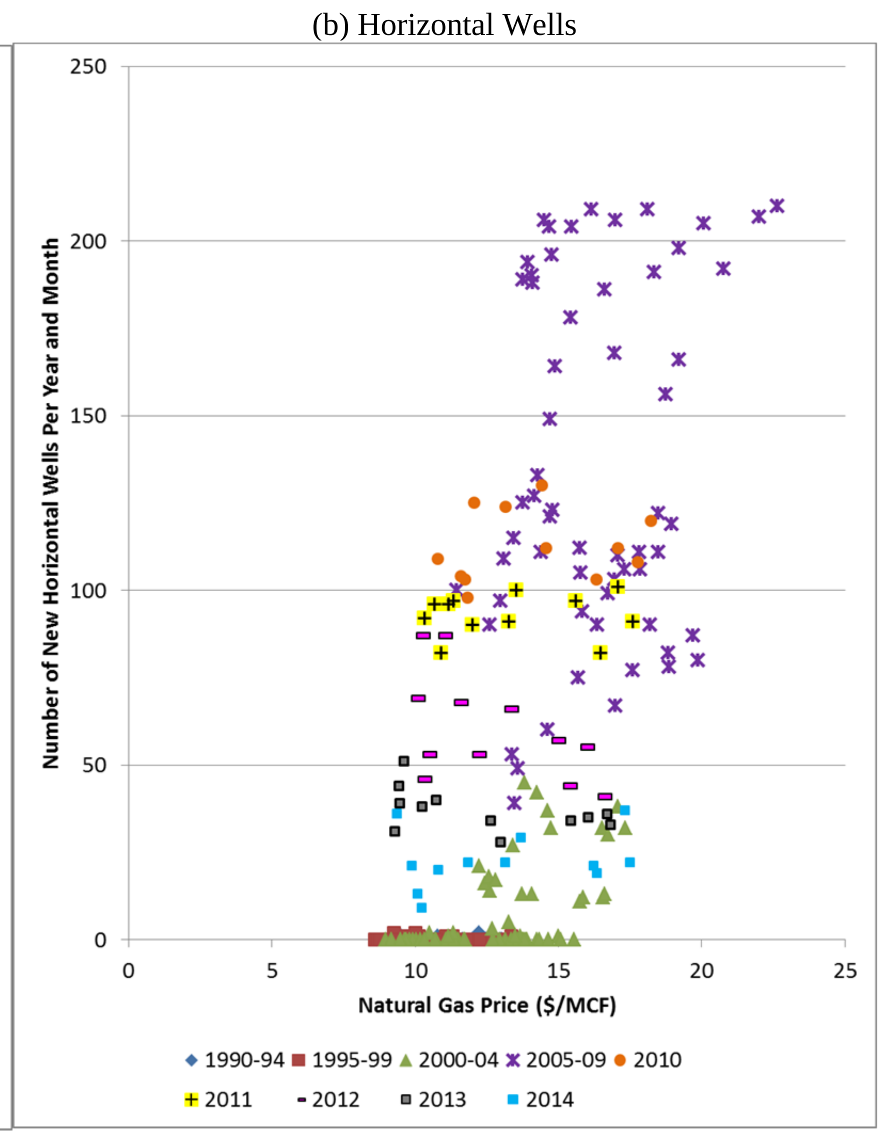
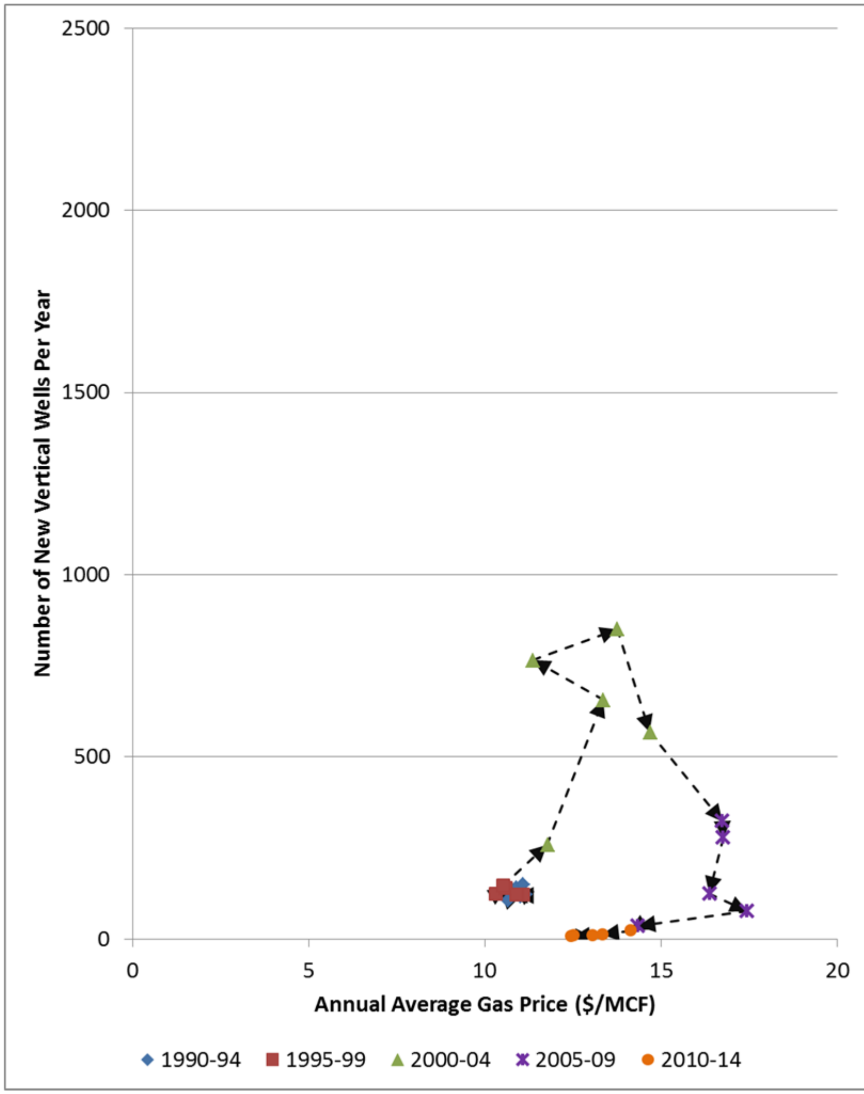


Figure 23. Price of Natural Gas vs. Number of New Wells in the Top 5 Producing Counties in the Barnett Shale Region.

(a) Vertical Wells



(b) Horizontal Wells

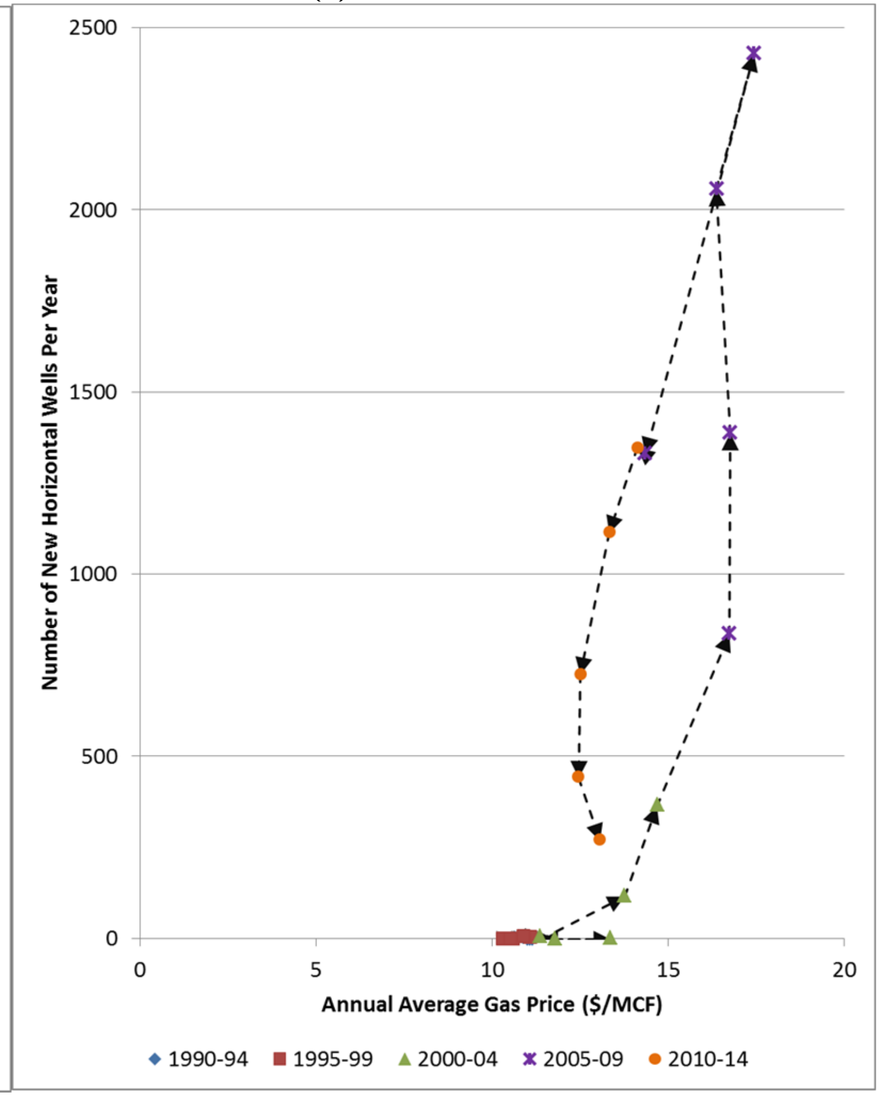


Figure 24. Annual Average Price of Natural Gas vs. Total (Annual) Number of New Wells in the Top 5 Producing Counties in the Barnett Shale Region.

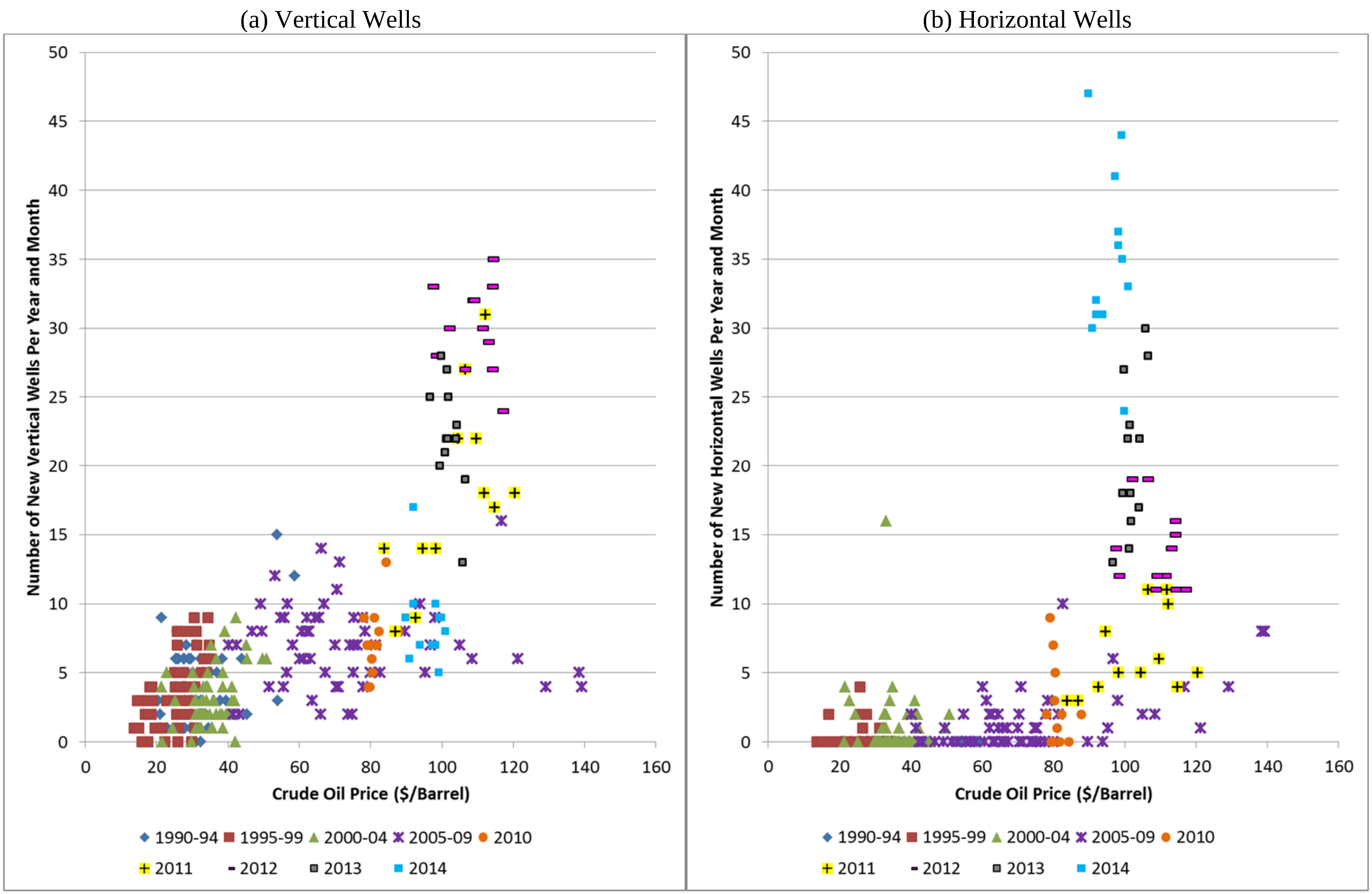


Figure 25. Price of Crude Oil vs. Number of New Wells in the Top 2 Producing Counties in the Permian Basin Region.

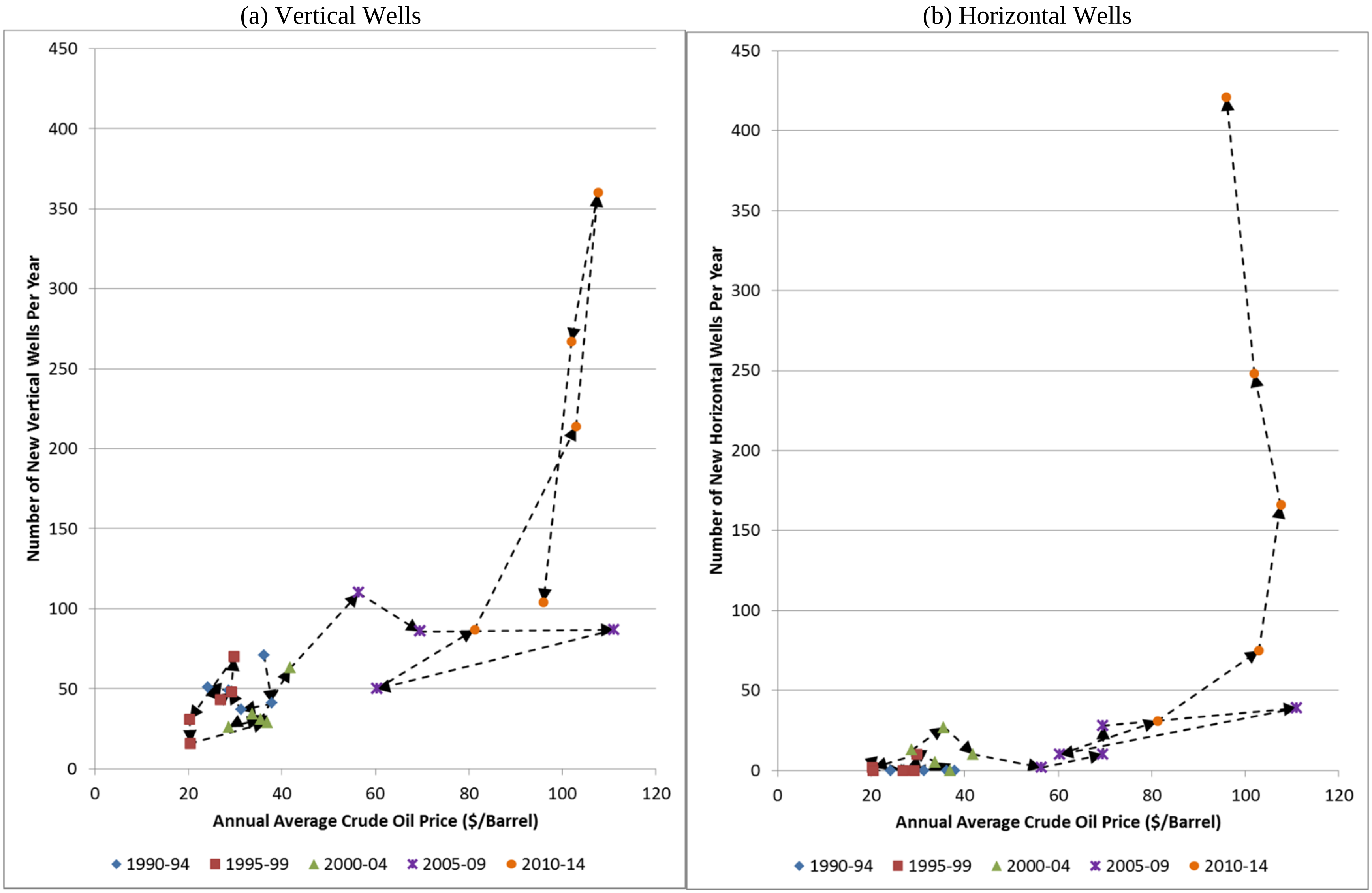


Figure 26. Price of Crude Oil vs. Number of New Wells in the Top 2 Producing Counties in the Permian Basin Region.

COUNTY MAPS

The geodatabase of oil and gas developments, which included GIS files of oil and gas permit locations as well as drilling permit attribute data, enabled the production of a wide range of maps to document locations and trends of oil and gas energy developments in the state. With the exception of the GIS files, processing the data involved activities, such as, but not limited to, processing the oil/gas production oracle data dump file, processing oil and gas master files, processing drilling permit master files, and processing the underground injection control file. As an illustration of the types of maps that are possible with the geodatabase, Figure 27 shows a map of completed wells in the Eagle Ford Shale region. Figure 28 shows a map of completed wells in Karnes County, with color codes representing the top oil well operators in the county. The figure shows both wellhead and horizontal drilling locations. Other types of maps, e.g., the county shaded maps shown in Figure 13, are also possible using the geodatabase.

TTI also prepared maps for each county located in the Barnett Shale region, Eagle Ford Shale region, and Permian Basin region. In total, 120 county maps in portable document format (PDF) were prepared. As an illustration, Figure 29 depicts the locations of the wellheads, wellends, and directional wells in Karnes County. The maps include completed wells, expired wells, and wells that are not expired and not completed as of December 31, 2015. The maps are accessible online at https://txdot.sharepoint.com/sites/division-MNT/SitePages/Home.aspx. Implementation Report IR-16-01 and Energy Sector Brief ESB-16-06 include instructions on how to use the maps.

To facilitate user understanding of the data, each PDF file contains layers that can be turned on or off, each layer representing a specific type of information, as shown in Figure 30. The layers panel is visible on the left side of the document. By clicking the eye next to each layer, the layers may be turned off or on. Completed wells are grouped by completion year as classified by the Railroad Commission. Not completed and not expired wells are shown individually. Several background layers are included in the maps, such as the roadways, railroads, pipelines, county lines, city limits, and geological formations. The labels for county, city, and major roadway names may be turned off and on from the layer panel. Energy Sector Brief ESB-16-16 provides additional instructions and information on how to use the maps.

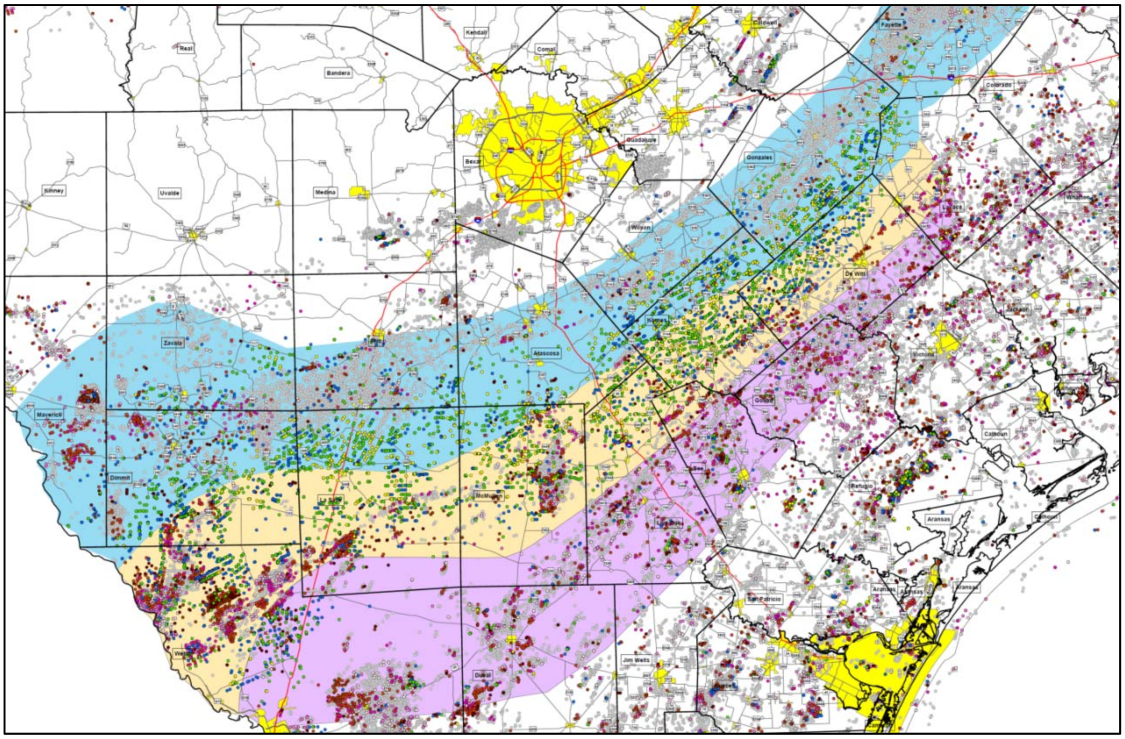


Figure 27. Map of Completed Wells in the Eagle Ford Shale Region.

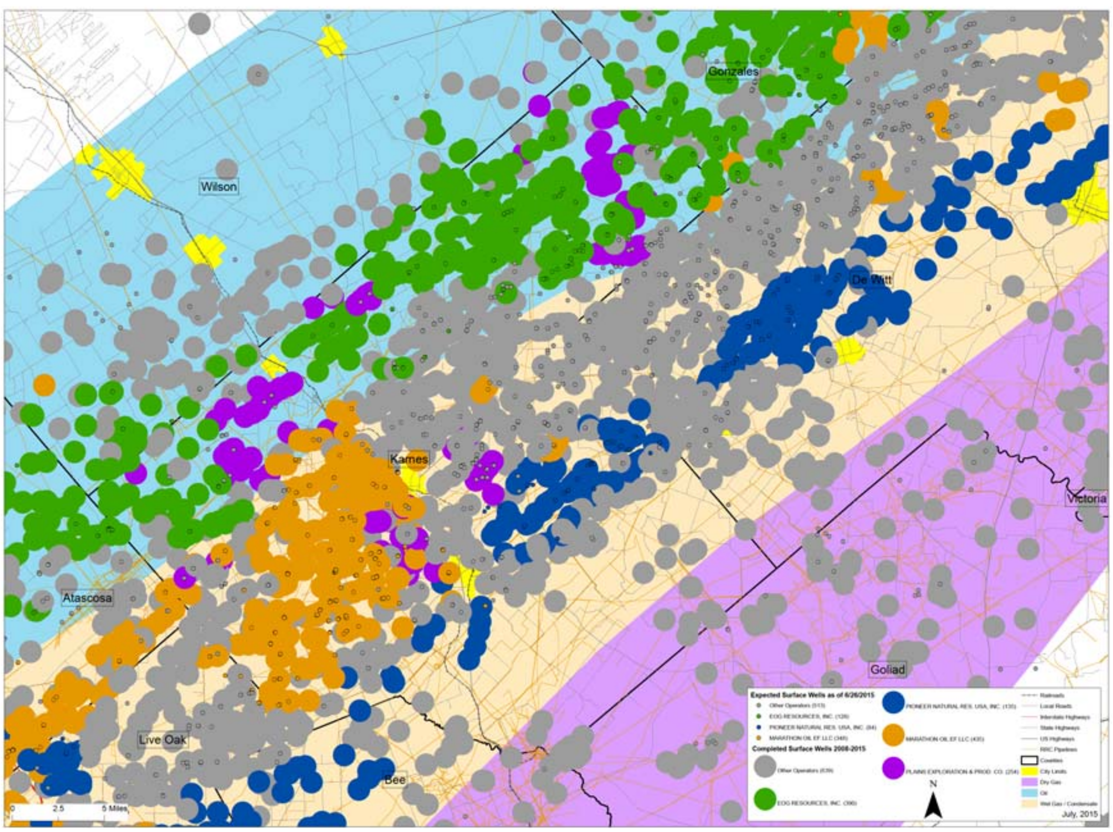


Figure 28. Wells Completed in Karnes County – Color Coded by Top Producers.

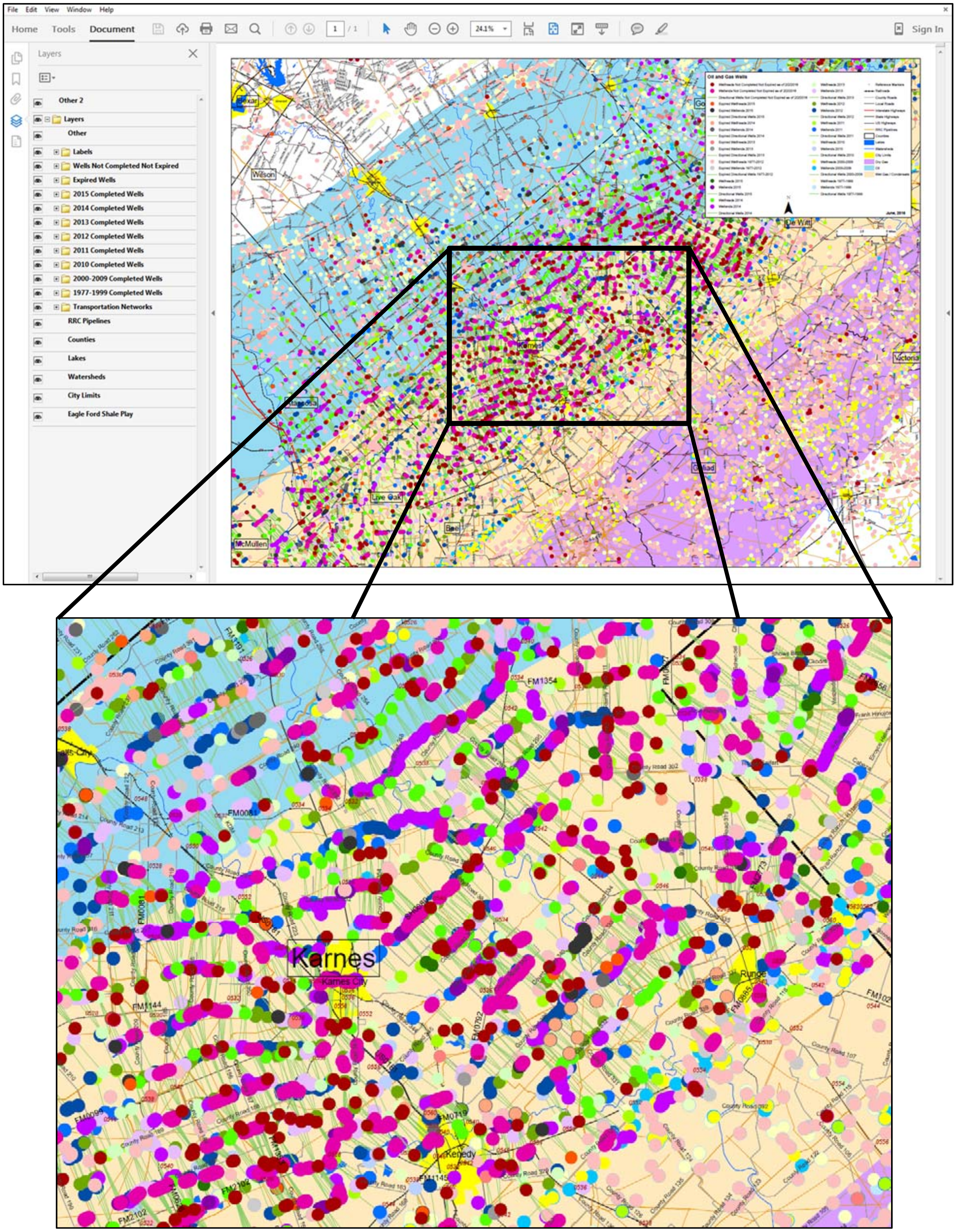


Figure 29. PDF Map Document for Karnes County with Layers.

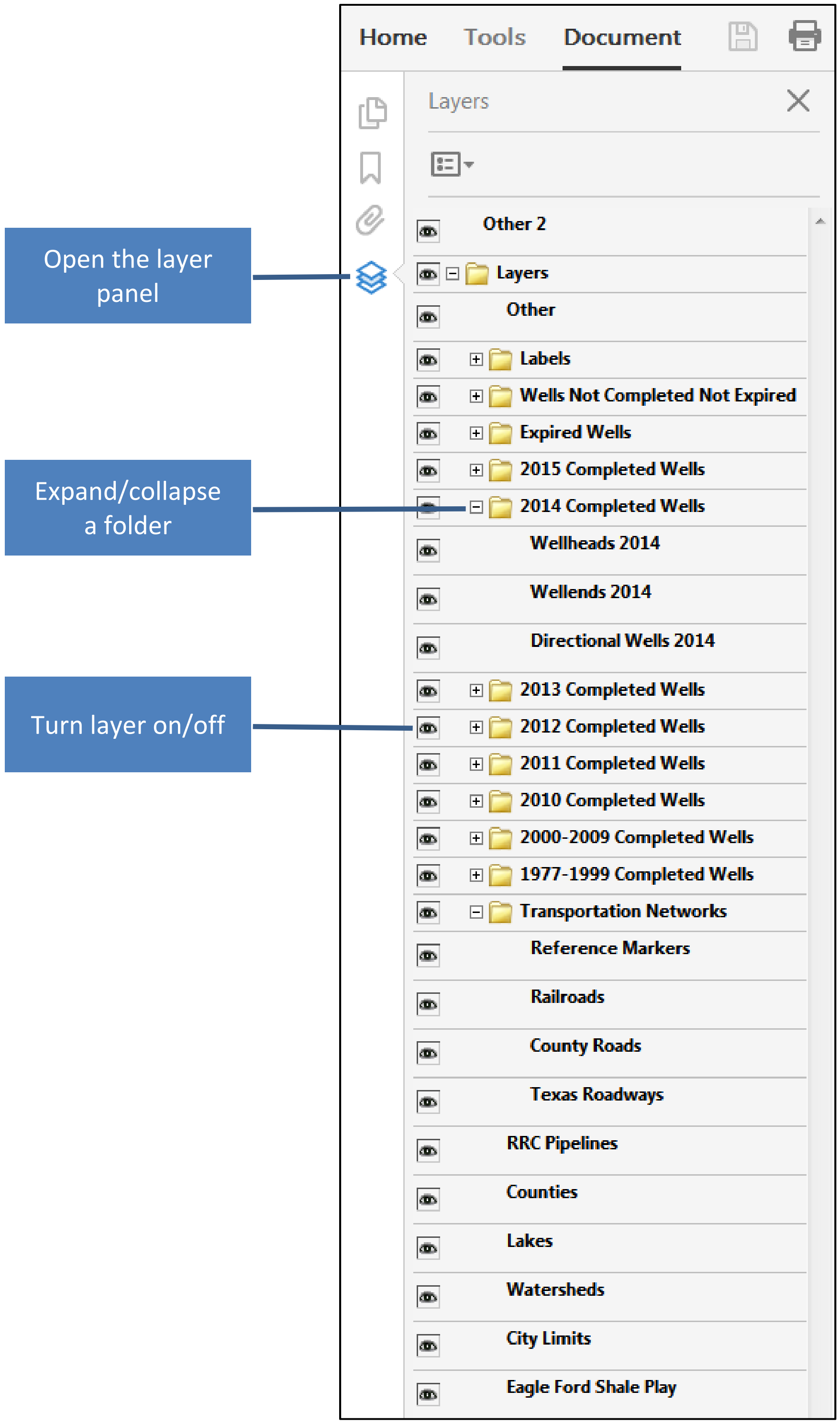


Figure 30. PDF Map Layer Menu.

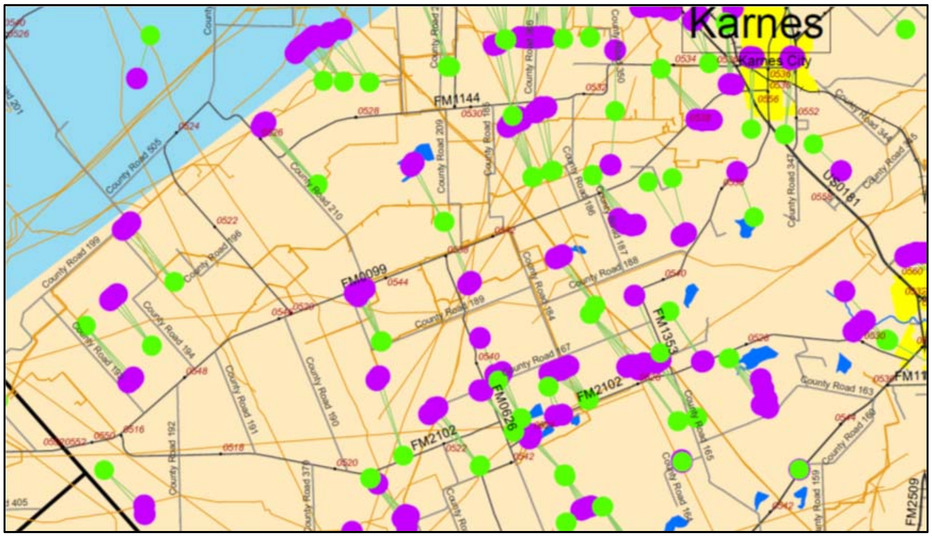
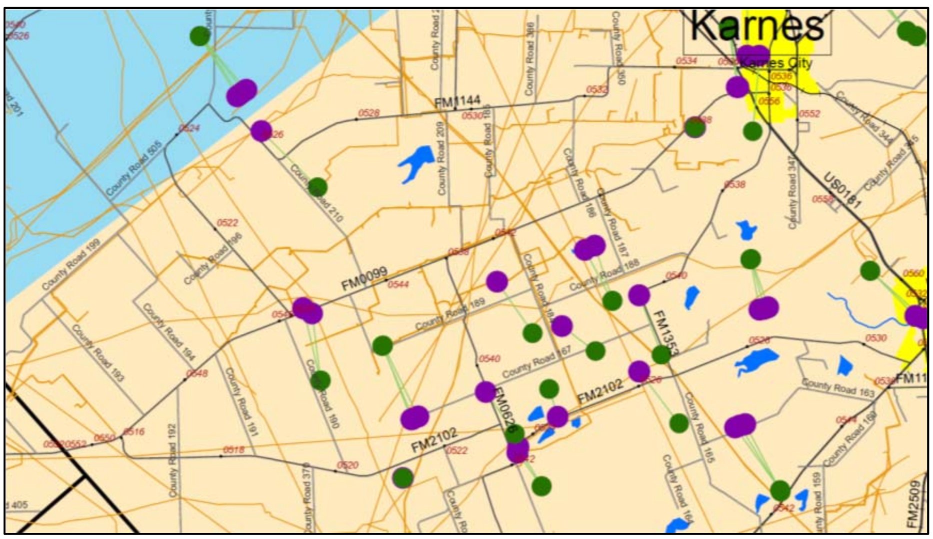
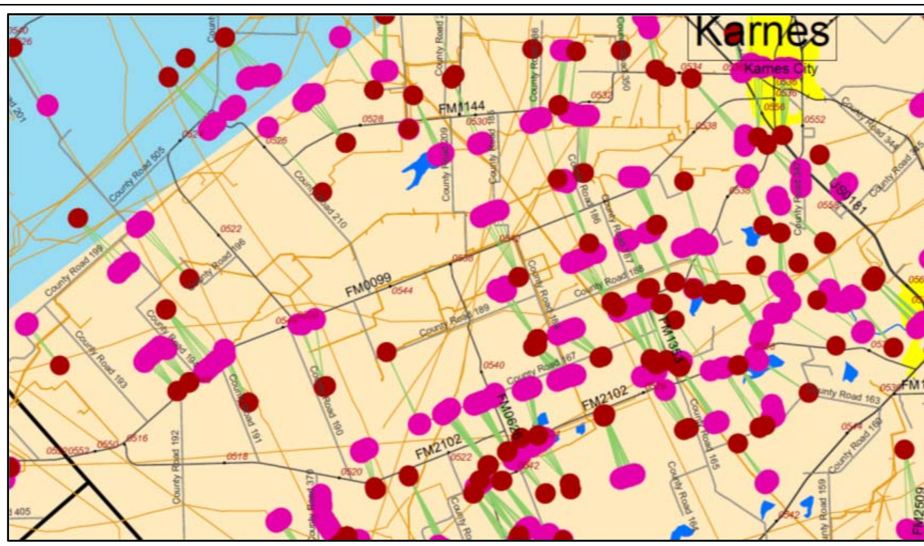
<table>
<tr><td>Wells completed in 2014</td><td>
</td></tr>
<tr><td>Wells completed in 2015</td><td>
</td></tr>
<tr><td>Permitted (non-completed) wells as of December 2015</td><td>
</td></tr>
</table>

Figure 31. Comparison between Completed Wells in 2014, Completed Wells in 2015, and Permitted (non-Completed) Wells.

TRAFFIC LOADS FOR DEVELOPING AND OPERATING INDIVIDUAL WELLS

INTRODUCTION

This chapter describes a methodology to determine truckloads (more specifically ESALs) in connection with the development and operation of a typical horizontal, hydraulically-fracked oil or gas well in the Eagle Ford Shale, Permian Basin, and Barnett Shale regions. Along with the results of an analysis of the anticipated number of wells that will use specific corridors in each of these regions, maintenance engineers and supervisors can use the ESAL estimates to design flexible pavements along those corridors.

PROCESS TO DETERMINE TRUCKLOADS

The general process to determine truckloads (more specifically ESALs) in connection with the development and operation of typical horizontal, hydraulically-fractured oil and gas wells in the Eagle Ford Shale, Permian Basin, and Barnett Shale regions of the state involved the following sets of activities:

- Determine well development and operation phases and activities. Well development involves pad preparation, drilling, and hydraulic fracturing. Well operation involves the continuous extraction of hydrocarbon products (oil, condensate, and/or gas) and water. Well operation also includes various maintenance activities. One such activity is re-fracking, which, if it happens, might conceivably occur at various times during the lifetime of a well. For the analysis, the researchers assumed that all oil and condensate production is moved by truck from a well to a designated truck off-load facility and all gas production is transported by pipeline.

- Determine the number of trucks per well phase activity, from pad construction to drilling, fracking, and operation of a typical well over a 20-year period. Because of the difficulty in obtaining direct, meaningful information from the industry, it became necessary to estimate truck volumes by relying on a literature review from around the country, information gathered by TxDOT officials, and well counts and other statistics from the Texas Railroad Commission (*3*). The researchers also used data from the FracFocus database (for the amount of water, sand, and additives used for fracking operations) (*4*). Specific analyses and assumptions included the following:

    - **Number of trucks per well activity during well operation in the Eagle Ford Shale and the Permian Basin region.** For oil production, the researchers analyzed February 2014 oil well counts by county from data provided by the Railroad Commission.
        - In the case of the Eagle Ford Shale region, the researchers analyzed data from 29 counties and calculated an average oil production per well based on the ten counties with the highest production of oil and condensate and the number of regular producing wells in that month. The researchers then calculated the number of trucks needed for oil production per well and

year assuming 306 lb/barrel as the unit weight of oil, a load capacity of 41,000 lb for steel tank trucks, a load capacity of 52,500 lb for aluminum tank trucks, and a fleet ratio of steel to aluminum tank trucks of 7/3.

    - For the Permian Basin region, the researchers analyzed 37 counties. However, the focus was on Reeves and Loving because these two counties experienced most of the unconventional energy development in the region and had a higher average oil production per well and month than all other counties. The researchers calculated an average oil production per well based on these two counties, assuming the same calculation parameters given above for the Eagle Ford Shale. This methodology filtered out counties that had higher total production levels, but relied primarily on a myriad of vertical wells that have been developed and operated using traditional techniques.
    - To estimate water during production, the researchers calculated an oil/condensate ratio for each county based on February 2014 oil production data from the Railroad Commission. The researchers then applied the county-based oil/condensate factor to estimate oil plus condensate production per county. Using county-based liquid injection data from the Railroad Commission, the researchers then established a ratio of liquids injected per oil plus condensate produced for the top 10 oil per well producing counties. This factor was then applied to the average amount of oil produced in the Eagle Ford Shale per well to estimate liquids that needed to be transported from each well and injected into the ground. The procedure for the Permian Basin region was similar, except that only the two highest producing counties in February of 2014 were used for the calculation of the disposal liquid ratio.

- **Number of trucks per well activity during well operation in the Barnett Shale region.** As mentioned, the researchers assumed that all gas would be transported via pipeline. To estimate the number of trucks needed to transport the small amount of oil and condensate production at each gas well, the researchers used the top five producing counties in the Barnett Shale region (under the assumption that all produced water from a well is transported by truck to a disposal facility within the same county). However, the researchers did not calculate the amount of produced water based on the liquid injected per oil produced ratio. Instead, the researches reviewed the number of active wells and liquids injected for the five highest producing counties in February of 2014 to calculate an average volume of liquids injected per well. With this information, the researchers then calculated the number of trucks needed to transport produced water per well and year.
- **Average number of water trucks per well during hydraulic fracturing operations.** For the three regions, the researchers used 2013, 2014, and 2015 data from the FracFocus database and converted the average water volume obtained from the database to trucks needed to move the water. To estimate the number of trucks needed, the researchers assumed that a steel tank truck could carry 130 barrels of water, aluminum tank trucks could carry 150 barrels of water, and that the fleet ratio of steel to aluminum tank trucks was 7/3.

- **Average number of sand and additive trucks per well.** For the three regions, the researchers used the FracFocus database to estimate the average mass of sand and additives used per well. The researchers converted the average mass of sand and additives into the number of trucks needed, assuming a capacity of 41,000 pounds for steel tank trucks, 52,500 pounds for aluminum tank trucks, and a fleet ratio of steel to aluminum tank trucks of 7/3.
- **Average number of flowback water trucks.** No reliable estimates were available to calculate this number. Based on anecdotal information, the research team assumed that 25 percent of water needed for hydraulic fracturing would need to be removed and transported away from each well.
- **Average number of trucks needed for re-fracking.** For all three regions, the number of trucks needed to re-frack a well was assumed to be the same as the number of wells needed for the fracking operation during the initial development of the well.

- Estimate the axle weight distribution for the truck types used for each phase of well development. Deploying portable weigh-in-motion (WIM) systems in the immediate vicinity of a well under development was not technically or financially feasible. For this reason, an indirect approach was implemented, which relied on WIM readings from the network of permanent WIM stations along major TxDOT corridors and concurrent video data collection at the WIM station locations. The researchers used more than 50,000 sample trucks that were captured via video screenshots and their corresponding WIM readings to develop aggregated axle weight distributions at 1,000-lb intervals. This approach involved some level of error because the truck traffic composition on major corridors was probably somewhat different from the truck traffic composition on secondary corridors in energy sector areas. However, the resulting characterization of the truck fleet provided at least a first-order approximation of the typical axle weight distributions that might occur on these corridors. For additional information, refer to Research Report RR-15-01, Implementation Report IR-16-02, and Energy Sector Brief ESB-16-08 (*3*, *5*, *6*).

- Determine a "typical" truck type and truck axle configuration for each well development, production, and re-fracking activity. The video screenshots from the WIM stations enabled the identification of multiple truck types. The researchers assigned one truck type to each well activity, e.g., truck type "rig truck" to the "drilling pad and construction equipment" activity and truck type "water truck" to the "hydraulic fracturing water" activity. Based on the related WIM data, the researchers analyzed the axle configurations of all truck types to determine the most prevalent axle configuration for each truck type. For example, of the 19 different axle configurations for rig trucks in the WIM station video screenshot sample, the most prevalent truck axle configuration was single-single-tridem (with 28 percent of all rig trucks). The researchers then assigned the most prevalent truck axle configuration to each truck type used for a well activity.

- Calculate empty truck weights. The researchers calculated the empty weights of each truck type based on the selected truck axle configuration and the following assumed axle weights of unloaded (empty) axle types:

- Single axle: 5,000 lbs.
- Tandem axle: 14,000 lbs.
- Tridem axle: 21,000 lbs.

- Calculate load equivalency factors (LEFs) for loaded and unloaded axles using industry-standard AASHTO road test equations (*7*). For *unloaded* axles, the researchers calculated the LEF for a particular axle type and weight given the unloaded axle weights above and the AASHTO road test equations. For *loaded* axle weights of a particular axle type and truck type, the researchers calculated LEFs in 1,000-pound intervals by multiplying the LEF for each weight group with the relative frequency of that weight group and then added all interval LEFs to arrive at an axle type LEF. This calculation only included counts of axle weights larger than the unloaded axle weights given above. Table 2 provides an example of the calculation for loaded single axles of equipment trucks, which resulted in an axle type LEF of 0.5288. The result of this process was an axle type LEF for each axle type of each truck type, both for loaded and unloaded trucks.

- Select trip load condition (loaded or empty) for each well activity in each well development phase. For example, during well development, the assumption was that drilling rig trucks would arrive loaded and leave loaded, while fracking water trucks would arrive loaded and leave empty.

- Estimate the number of ESALs for each phase. This process involved calculating loaded truck ESALs and empty truck ESALs and adding the ESALS for each well activity to arrive at a total number of ESALs for trips to the well and a total number of ESALs for trips leaving the well.

ASSUMPTIONS

Assumptions behind the calculations to estimate the number of ESALs after the completion of a well included the following:

- All fluids extracted from an oil or gas well are transported by truck from the well to a designated terminal facility. Oil and condensate are transported to a truck off-load terminal facility for transportation via pipeline to a midstream or downstream facility. Overtime, the industry might build a pipeline network to connect each well directly to the existing pipeline infrastructure, therefore bypassing the roadway infrastructure. However, it is not clear whether this would ever happen and over how many years. For the analysis, the researchers assumed that all oil and condensate are transported by truck to a designated truck off-load terminal facility over the 20-year period of analysis. For gas extraction, the assumption is that all gas is transported by pipeline from the well location.

Table 2. Distribution of Loaded Single Axles of Equipment Trucks.

Bin	Frequency	Relative Frequency	LEF	
1,000	-	0.00%	4.50487E-05	-
2,000	-	0.00%	0.000312777	-
3,000	-	0.00%	0.001229419	-
4,000	-	0.00%	0.003524391	-
5,000	-	0.00%	0.008243056	-
6,000	32	0.95%	0.016695976	0.0002
7,000	35	1.04%	0.030356254	0.0003
8,000	70	2.07%	0.050741157	0.0011
9,000	104	3.08%	0.079328454	0.0024
10,000	286	8.46%	0.117546161	0.0099
11,000	653	19.31%	0.16684122	0.0322
12,000	766	22.66%	0.228799497	0.0518
13,000	344	10.17%	0.305276017	0.0311
14,000	137	4.05%	0.398503072	0.0161
15,000	121	3.58%	0.51116283	0.0183
16,000	125	3.70%	0.646427202	0.0239
17,000	129	3.82%	0.807975392	0.0308
18,000	114	3.37%	1	0.0337
19,000	128	3.79%	1.227209588	0.0465
20,000	87	2.57%	1.49483216	0.0385
21,000	87	2.57%	1.808621405	0.0465
22,000	53	1.57%	2.174866035	0.0341
23,000	46	1.36%	2.600401822	0.0354
24,000	28	0.83%	3.09262573	0.0256
25,000	19	0.56%	3.659511559	0.0206
26,000	7	0.21%	4.309626595	0.0089
27,000	5	0.15%	5.052148904	0.0075
28,000	-	0.00%	5.896885017	-
29,000	1	0.03%	6.85428781	0.0020
30,000	1	0.03%	7.935474471	0.0023
31,000	2	0.06%	9.15224447	0.0054
32,000	-	0.00%	10.51709749	-
33,000	1	0.03%	12.04325125	0.0036
34,000	-	0.00%	13.74465933	-
35,000	-	0.00%	15.63602873	-
36,000	-	0.00%	17.73283753	-
37,000	-	0.00%	20.05135223	-
38,000	-	0.00%	22.60864517	-
39,000	-	0.00%	25.4226117	-
40,000	-	0.00%	28.51198738	-
Total	**3,381**			**0.5288**

- All water extracted from a well is transported by truck to a disposal facility where the water is injected into the ground. It is not clear whether the industry would ever build a pipeline network to connect each well to a disposal facility and, if so, at what point. The assumption is that the pipeline network is not built, forcing all the produced water to be transported by truck from the well location. Because of the cost to transport the water, the assumption is that water extracted from a well is hauled a relatively short distance, typically within the same county.

- As wells age, hydrocarbon production decreases. At the same time, the proportion of produced water increases. At this point, it is not clear how the total volume of fluids extracted from the ground (including oil, condensate, and water) would evolve over time. For simplicity, the researchers assumed the total volume to remain approximately constant over time. To develop an estimate, the researchers queried the total oil and condensate production per county from the Railroad Commission database, queried the total amount of water injected into non-productive wells (i.e., disposal wells) from the Railroad Commission database, and then divided the total volume by the number of horizontal wells in the county.

Input variables assumed in the calculations included the following:

- Pavement Structural Number (SN) = 3.0.

- Pavement Terminal Serviceability Index (P_t) = 2.5.

- Analysis period = 20 years.

- Number of re-fracking events per analysis period = 4.

- Disposal liquid ratio (or ratio of the volume of disposed water to the volume of oil and condensate):

    - Eagle Ford Shale: 0.26.
    - Barnett Shale: Not applicable because most of the hydrocarbon production is gas.
    - Permian Basin: 2.29.

- Ratio of steel to aluminum tank trucks = 7:3 (or 2.33).

- Flowback water volume during fracking = 25% of the water used for fracking.

RESULTS

Table 3 summarizes the number of trucks needed to develop, operate, and re-frack a well in the Eagle Ford Shale, Barnett Shale, and Permian Basin regions. Table 4 through Table 6 summarize the results of the ESAL calculation analysis for each region.

Table 3. Number of Trucks Needed to Develop, Operate, and Re-Frack a Well.

Well Development	Number of Trucks		
	Barnett Shale	Eagle Ford Shale	Permian Basin
Drilling pad and construction equipment	70	70	70
Drilling rig	4	4	4
Drilling fluid and materials	59	59	59
Drilling equipment: casing, drilling pipe	54	54	54
Fracking equipment: pump trucks, tanks	74	74	74
Fracking water:	533	1,021	527
Fracking water (steel tank)	373	715	369
Fracking water (aluminum tank)	160	306	158
Fracking sand:	57	147	66
Fracking sand (steel tank)	40	103	46
Fracking sand (aluminum tank)	17	44	20
Other additives and fluids	4	24	11
Flowback water removal	133	255	132
Total	**988**	**1,708**	**997**

Well Production Activity	Number of Trucks per Year		
	Barnett Shale	Eagle Ford Shale	Permian Basin
Produced water (steel tank)	41	65	181
Produced water (aluminum tank)	14	22	62
Oil and condensate production (steel tank)	8	249	79
Oil and condensate production (aluminum tank)	3	83	27
Total	**66**	**418**	**349**

Well Re-Fracking Activity	Number of Trucks per Event		
	Barnett Shale	Eagle Ford Shale	Permian Basin
Fracking equipment: pump trucks, tanks	74	74	74
Fracking water (steel tank)	373	715	369
Fracking water (aluminum tank)	160	306	158
Fracking sand (steel tank)	40	103	46
Fracking sand (aluminum tank)	17	44	20
Other additives and fluids	4	24	11
Flowback water removal	133	255	132
Total	**801**	**1,521**	**810**

Table 4. Number of Trucks and ESALs per Well (Barnett Shale Region).

Item	Development	Production		Re-Fracking		Total
		Per Year	Total	Per Event	Total	
Number of trucks	988	66	1,320	801	3,205	5,513
ESALs (trip to well)	1,363	5	98	1,070	4,281	5,742
ESALs (trip from well)	474	93	1,864	423	1,694	4,031

Table 5. Number of Trucks and ESALs per Well (Eagle Ford Shale Region).

Item	Development	Production		Re-Fracking		Total
		Per Year	Total	Per Event	Total	
Number of trucks	1,708	418	8,366	1,521	6,085	16,160
ESALs (trip to well)	2,261	31	625	1,968	7,871	10,757
ESALs (trip from well)	689	591	11,815	639	2,555	15,059

Table 6. Number of Trucks and ESALs per Well (Permian Basin Region).

Item	Development	Production		Re-Fracking		Total
		Per Year	Total	Per Event	Total	
Number of trucks	997	349	6,975	810	3,239	11,211
ESALs (trip to well)	1,381	26	519	1,089	4,354	6,254
ESALs (trip from well)	472	492	9,850	422	1,689	12,011

Overall, the results indicate the following:

- The total number of trucks per well over a 20-year period in the Eagle Ford Shale region is almost three times as high as in the Barnett Shale region and almost 50% higher than in the Permian Basin region. One of the reasons is that wells in the Eagle Ford Shale region are using considerably more water and sand than in the other two regions. In addition, hydrocarbon production in the Eagle Ford Shale region is primarily oil and condensate (requiring truck transportation to an off-loading facility), whereas in the Barnett Shale, hydrocarbon production is mainly dry gas (and the assumption is that all this gas is transported by pipeline).

- Although the number of re-fracking events over 20 years is unknown, the anticipated impact is that, all other things being equal, the number of trucks needed to re-frack a well in the Eagle Ford Shale region would be higher than in the Barnett Shale or Permian Basin regions. The reason, as mentioned above, is that the amount of water and sand needed to frack a well in the Eagle Ford Shale region is higher than in the other two regions.

- For both the Eagle Ford Shale and Permian Basin regions, the number of ESALs for trips leaving the well over 20 years is considerable higher than the corresponding number of ESALs for trips going to the well. The reason is the cumulative effect of operating the well over 20 years (more specifically by transportation oil and condensate by truck). By comparison, in the Barnett Shale region, the cumulative effect of operating the well is relatively minor, by re-fracking would have the highest impact on the number of ESALs.

EXCEL TEMPLATE TO CALCULATE TRUCKLOADS

An Excel spreadsheet template enables users to calculate the following for each well:

- Total number of trucks needed by phase activity and analysis period.
- Total amount of ESALs for trips to the well by phase activity and analysis period.
- Total amount of ESALs for trips leaving the well by phase activity and analysis period.

The spreadsheet calculates these values based on inputs the user provides in various places of the spreadsheet, as shown in the red cells in Table 7 and Table 8. Once all the cells shaded in red are populated, the spreadsheet calculates the number of trucks and ESALs per well for the selected analysis period, both for trips to the well and trips leaving the well, as show in Table 9. If needed for further analysis, the Excel file also includes all the data and details used for the calculations.

Table 7. Input Parameters to Determine Number of Trucks and ESALs.

Input	
Pavement Structural Number (**SN**) =	3.0
Pavement Terminal Serviceability Index (**P_t**) =	2.5
Analysis Period (Years) =	20
Number of Re-Fracking Events per Analysis Period =	4
Disposal Liquid Ratio =	0.26
Ratio of Steel to Aluminum Tank Trucks =	2.33
Flowback water ratio =	0.25

The pavement structural number and terminal serviceability index are flexible pavement design parameters that affect the calculation of load equivalency factors.

The analysis period covers the development, operation, and maintenance phases of an oil or gas well for pavement design purposes. It assumes continuous operation of the well. A well could operate past the analysis period.

The number of re-fracking events per analysis period represents the number of times a well is re-fracked during the analysis period.

The disposal liquid ratio represents the ratio of produced water to oil and condensate (by volume), which must be transported by truck to a disposal facility.

The ratio of steel to aluminum tank trucks is the ratio of the number of steel tank trucks to the number of aluminum tank trucks.

The flowback water ratio is the ratio of the volume of water recovered to the volume of water injected during fracking.

Table 8. Trucks Needed to Develop, Operate, and Maintain an *Oil* Well (Note: Users populate cells in red; other cells are calculated automatically).

Trucks Needed to Develop and Complete a Well	
Well Development Activity	**Truck Volume (per Well)**
Drilling pad and construction equipment	70
Drilling rig	4
Drilling fluid and materials	59
Drilling equipment: casing, drilling pipe	54
Fracking equipment: pump trucks, tanks	74
Fracking water	1,021
Fracking water (steel tank)	715
Fracking water (aluminum tank)	306
Fracking sand	147
Fracking sand (steel tank)	103
Fracking sand (aluminum tank)	44
Other additives and fluids	24
Flowback water removal	255
Total	**1,708**

Trucks Needed for Oil Production	
Well Production Activity	**Truck Volume (per Well and Year)**
Produced water (steel tank)	65
Produced water (aluminum tank)	22
Oil production (steel tank)	249
Oil production (aluminum tank)	83
Total	**418**

Trucks Needed for Re-Fracking	
Well Re-Fracking Activity	**Truck Volume (per Well and Event)**
Fracking equipment: pump trucks, tanks	74
Fracking water (steel tank)	715
Fracking water (aluminum tank)	306
Fracking sand (steel tank)	103
Fracking sand (aluminum tank)	44
Other additives and fluids	24
Flowback water removal	255
Total	**1,521**

Table 9. Volume of Trucks and Number of ESALs per Well.

Output						
	Development	Production		Re-Fracking		Total
	Per Analysis Period	Per Year	Per Analysis Period	Per Event	Per Analysis Period	Per Analysis Period
Total volume of trucks per well	1,708	418	8,366	1,521	6,085	**16,160**
Total ESALs per well, trip *to* well	2,261	31	625	1,968	7,871	**10,757**
Total ESALs per well, trip *from* well	689	591	11,815	639	2,555	**15,059**

As mentioned previously, the liquid disposal ratio is not applicable in the Barnett Shale region because most of the corresponding hydrocarbon production is gas. For this region, the volume of produced water is based on the amount of water injected into the ground at disposal facilities at the top five gas producing counties. Table 10 shows the corresponding number of trucks needed to carry the water. The table also shows a small number of trucks needed to haul oil and condensate, based on average production levels as reported by the Texas Railroad Commission.

Table 10. Trucks Needed to Operate a *Gas* Well in the Barnett Shale Region (Note: Users populate cells in red; other cells are calculated automatically).

Trucks Needed for Gas Production	
Well Production Activity	**Truck Volume (per Well and Year)**
Produced water (steel tank)	41
Produced water (aluminum tank)	14
Oil and condensate production (steel tank)	8
Oil and condensate production (aluminum tank)	3
Total	**66**

TRAFFIC LOADS FOR SEGMENT AND CORRIDOR-LEVEL ANALYSES

INTRODUCTION

This chapter describes a GIS-based methodology to estimate truck volumes and ESALs at the individual roadway segment level for any number of oil or gas wells that are developed and operated in a geographic area. The methodology uses inputs such as, but not limited to, locations of anticipated wells; identification and location of equipment, materials, and other supplies needed to develop and operate the wells; number and type of trucks needed for each development and operation activity; evaluation of loaded and unloaded number of ESALs for each truck type, and length of the analysis period.

The methodology described in this report uses four-step travel demand modeling principles that were adapted to take into account specific trip generation, trip distribution, and route assignment characteristics of typical unconventional energy developments in the state. Anticipated applications of the methodology include, but are not limited to, estimation of truck volumes and ESALs at the roadway segment and corridor levels, determination of roadway and roadside maintenance needs, prioritization of pavement maintenance and rehabilitation projects, evaluation of truck route plans, analysis of traffic operations and safety impacts, and analysis of congestion and access management requirements. The report documents the results of a case study in Karnes County using wells that were completed in 2013.

TRAVEL DEMAND MODELING APPROACH AND ASSUMPTIONS

Four-step travel demand modeling is a commonly used procedure for urban transportation planning, which typically includes trip generation, trip distribution, mode choice, and route assignment components (*8*). Examples of application of these components for energy-sector truck traffic analysis are available in the literature (*8, 9, 10*). The analysis presented in this paper also adopted the four-step travel demand modeling process to determine truck volumes and ESALs for pavement maintenance and design purposes. However, the modeling approach was specifically adapted to take into account unique trip generation, trip distribution, and route assignment characteristics of typical unconventional energy developments.

Because the main focus was on truck traffic, trips requiring non-truck vehicles (e.g., pickup trucks, utility trucks, and personal vehicles) were not included in the analysis. Although the number of non-truck trips needed to develop and operate oil and gas wells could be quite significant (some estimates place the number of these trips as being of the same of magnitude as the number of truck trips), the corresponding impact on the total number of ESALs would be very small. Further refinements of the modeling approach could include non-truck trips for applications such as emergency evacuations and traffic and congestion management.

Specific assumptions and modeling approach for the trip generation, trip distribution, and trip assignment components follow.

- **Trip Generation**. Wells are trip producers, making well locations the origin of all trips (whether trucks arrive at or leave well locations). Locations that provide or receive equipment, materials, and other supplies are trip attractors. For trip productions, the number of trips corresponds to the number of trucks needed for each well development or operation activity, making trip productions constrained. The number of trucks needed for each activity was obtained through parallel efforts based on a comprehensive literature review from around the county, information gathered by TxDOT officials, well counts and other statistics from the Railroad Commission of Texas (RRC), and data from the FracFocus database (*11*). For trip attractions, individual supplier capacity can limit the number of attracted trips. For simplicity, suppliers were not assumed to be capacity-constrained, i.e., suppliers have sufficient materials and supplies to address the needs of the well developments they serve.

- **Trip Distribution**. A number of methods are available to estimate trips between trip productions and attractions, including growth factor methods, gravity models, and destination choice models (*12*). Growth factor methods require an existing trip distribution matrix to be available. Gravity models rely on short path calculations and impedance measures between trip productions and attractions, such as travel time or travel cost. Commonly used impedance functions include exponential, inverse power, and gamma. Destination choice models are a generalization of gravity models, which use a wider range of explanatory variables and are, therefore, more data intensive. Because posted speed limit data and other roadway characteristics were available for all roadway segments, the researchers selected a gravity model to determine the number of trips between trip productions and trip attractions. The researchers also used an inverse power impedance function because this kind of function only required the estimation of one parameter (*13*).

- **Route Assignment**. Several methods are available to assign routes, e.g., all-or-nothing, user equilibrium, and system optimum (*14*). All-or-nothing assignment allocates trips to single, minimum-cost paths without considering roadway capacity or impact of traffic on travel cost. This method is frequently unrealistic in urban areas where congestion is common, but it may be more suitable for rural and relatively uncongested areas. Both user equilibrium assignment and system optimum assignment consider roadway capacity and impact of traffic on travel cost. User equilibrium assignment assumes that all travelers strive to find a path with minimum travel time. System optimum assignment assumes that travelers cooperate with each other to minimize total system travel time.

  For the analysis, the researchers used an all-or-nothing assignment because most energy developments occur in rural areas with sparse transportation networks and occasional congestion. With truck trips assigned to routes, the last step was to convert the assigned number of trips on each roadway segment to ESALs using the ESAL calculations for individual truck types. It is worth mentioning that this study used ESAL factors based on weigh-in-motion (WIM) data collected along energy-sector corridors (*11*). Specifically, the researchers captured over 50,000 snapshots of energy-related trucks through video data collected at four selected WIM stations and matched each snapshot to its corresponding WIM record. Nine truck types of interest were identified and the axle load distributions for each truck type were developed, including single axle, tandem, tridem, and quadrem axles for each truck type. Based on these axle load distributions, truck type-specific ESAL factors were then prepared using existing AASHTO formulations as described in Chapter 3.

CASE STUDY

The researchers conducted a case study using wells completed in Karnes County in 2013 to evaluate the feasibility of the modeling approach. The researchers conducted the analysis using TransCAD 7.0. To obtain input data such as well locations or material supplier locations, the researchers reached out to TxDOT officials, explored various databases, and conducted extensive Google searches to collect comprehensive information. Table 11 provides a listing of the various datasets used for the analysis. Figure 32 shows the location of wells completed in Karnes County. Figure 33 shows the locations of the suppliers listed in Table 11. As Figure 33 shows, although all the wells used for modeling were located in Karnes County, the researchers included a large number of surrounding counties to account for a wide range of material or service supplier locations.

Table 11. Data Used in Case Study.

Dataset	Number of Records	Source of Information
Completed wells (2013)	493	Railroad Commission of Texas
Aggregate suppliers	14	TxDOT Corpus Christi District Office
Drilling rig and equipment suppliers	3	TxPROS oversize/overweight permit database
Water suppliers	9	TxDOT Karnes City Area Office
Pipe and casing suppliers	4	Google search
Fracking sand suppliers	2	TxDOT Karnes City Area Office
Chemical suppliers	9	Google search
Injection disposal wells (as of 2014)	615	Railroad Commission of Texas
Crude oil terminals	2	TxDOT Karnes City Area Office

For the modeling effort, the researchers used wellhead locations. As Figure 32 shows, most wells completed in Karnes County are horizontal wells in which the lateral component is approximately one mile long. Although Figure 32 suggests one wellhead location for several laterals, in reality each wellhead has its own lateral (with its own API number). This characteristic facilitated modeling of the number of trucks and ESALs at the individual lateral level.

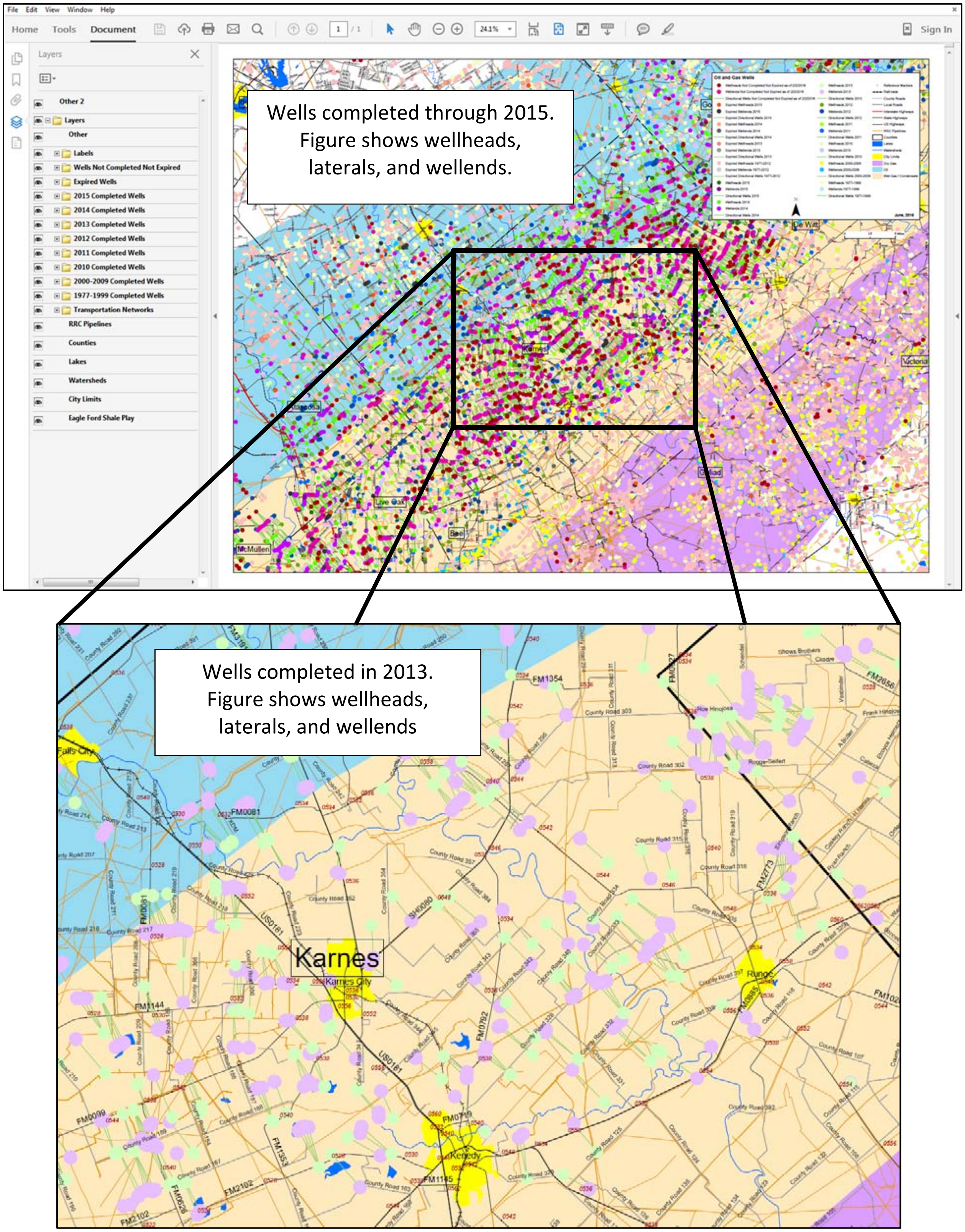


Figure 32. Wells Completed in Karnes County.

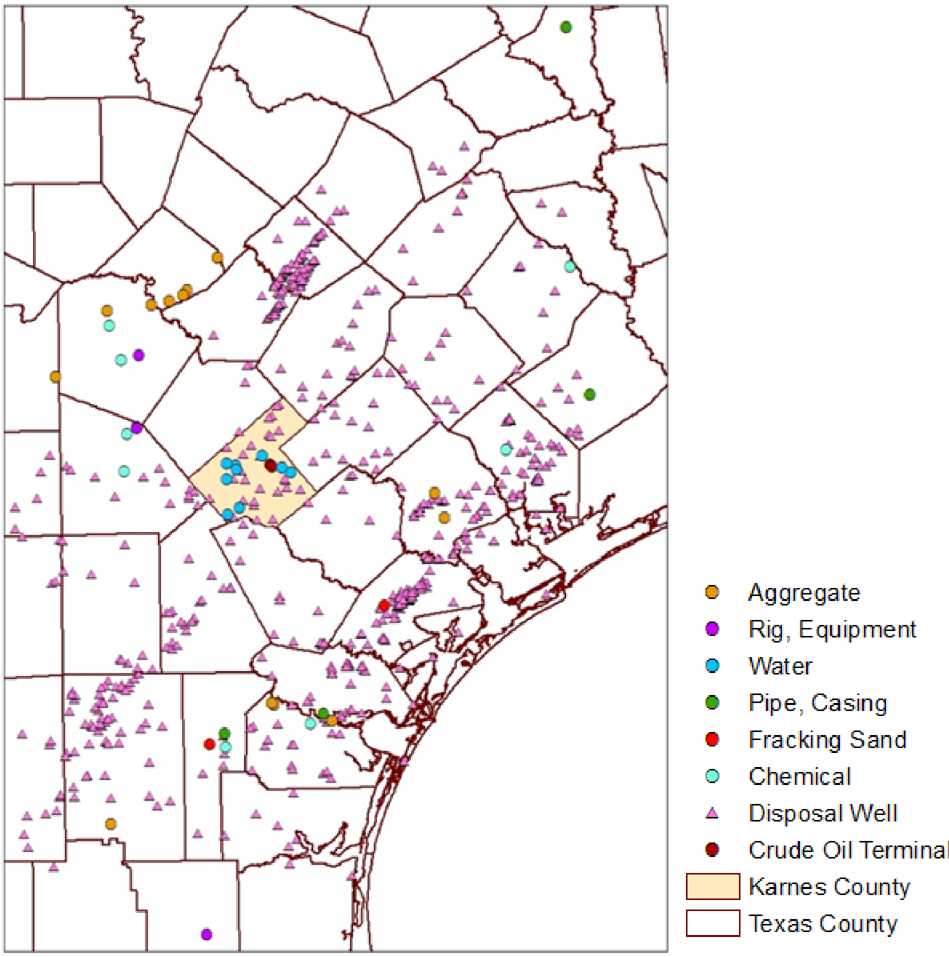


Figure 33. Location of Potential Suppliers Used for the Analysis.

Trip Generation

The researchers prepared a trip generation table showing the number of trips generated by trip productions and attractions. Trip generation calculations involved the following assumptions:

- Trips are loaded or unloaded depending on the trip purpose and direction. For example, for fracking water, the trip from a supplier to a well is loaded while the return trip is empty. For flowback or produced water disposal, the trip to the well is empty while the trip to the disposal facility is loaded.

- All wells need the same amount of resources and number of trucks for each activity regardless of operator or number of wellheads developed at the same pad location. The activities considered in this study include well development activities (e.g., pad preparation, drilling), well operation activities (e.g., production), and well re-fracking. Table 12 shows the number of trucks needed for each development, operation, and re-fracking activity based on results described in Chapter 3. The use of temporary water lines was not considered in this analysis. However, a sensitivity analysis is possible in order to examine the impact of variations in resources needed, e.g., in relation to the use of temporary water lines to decrease the number of trucks needed to carry fracking water, or in relation to the impact due to multiple wells developed at the same pad location within a short duration. The researchers are currently conducting a separate research project (TxDOT Research Project 0-6886) to evaluate the use of temporary water lines and their impact on the transportation network, including both pavement structures and roadside infrastructure.

Table 12. Truckloads Needed for Individual Wells in the Eagle Ford Shale Region.

Well Development Activity	**Truck Volume (per well)**	**Supplier**
Drilling pad and construction equipment	70	Aggregate suppliers
Drilling rig	4	Drilling rig and equipment suppliers
Drilling fluid and materials	59	Water suppliers
Drilling equipment: casing, drilling pipe	54	Pipe and casing suppliers
Fracking equipment: pump trucks, tanks	74	Drilling rig and equipment suppliers
Fracking water (steel tank)	715	Water suppliers
Fracking water (aluminum tank)	306	Water suppliers
Fracking sand (steel tank)	103	Fracking sand suppliers
Fracking sand (aluminum tank)	44	Fracking sand suppliers
Other additives and fluids	24	Chemical suppliers
Flowback water removal	255	Injection disposal wells
Total	1,708	
Well Production Activity	**Truck Volume (per well and year)**	**Supplier**
Produced water (steel tank)	65	Injection disposal wells
Produced water (aluminum tank)	22	Injection disposal wells
Oil production (steel tank)	249	Crude oil terminals
Oil production (aluminum tank)	83	Crude oil terminals
Total	418	
Well Re-fracking Activity	**Truck Volume (per well and event)**	**Supplier**
Fracking equipment: pump trucks, tanks	74	Drilling rig and equipment suppliers
Fracking water (steel tank)	715	Water suppliers
Fracking water (aluminum tank)	306	Water suppliers
Fracking sand (steel tank)	103	Fracking sand suppliers
Fracking sand (aluminum tank)	44	Fracking sand suppliers
Other additives and fluids	24	Chemical suppliers
Flowback water removal	255	Injection disposal wells
Total	1,515	

- All suppliers have sufficient capacity to address the needs of individual wells. Because suppliers are not capacity-constraint and information about pricing of materials and services from various suppliers was not available, the choice of suppliers for each well is only based on travel time. In some cases, there was information that suggested specific trip characteristics or trends. For example, many water trucks use steel tanks. However, WIM data records indicated a substantial number of aluminum tank trucks (*15*). Using WIM data records as a guidance, the researchers assumed a 7/3 split between the number of steel tank trucks and aluminum tank trucks.

- Pavement impact is assumed to be linearly dependent on the amount of traffic, e.g., doubling the number of trucks of the same type and loaded similarly would result in twice the number of ESALs. This characteristic made it possible to simplify the modeling effort considerably by only having to run TransCAD models once for each trip purpose assuming a normalized number of trips per development or operation activity: 100. During the route assignment step, the researchers multiplied the resulting number of assigned trips per roadway segment by the corresponding number of trucks in Table 12 and then divided by 100 to obtain the correct number of assigned trucks per roadway segment for each development or operation activity.

Trip Distribution

In the absence of any additional information about factors that contribute to the selection of material or service suppliers, this selection was only based on travel time considerations. More specifically, the researchers assumed that the impedance between a well and a supplier location was only a function of the shortest travel time between them. Posted speed limit data from the TxDOT Road–Highway Inventory Network (RHiNo) database was used to provide a measure of travel time between origins and destinations. A literature review on the specific connection between pavement conditions and traveling speeds, which would have provided additional insight about travel times on energy sector corridors, particularly secondary roads such as farm-to-market (FM) roads, was inconclusive. Nevertheless, the modeling environment enables users to modify speed data either for entire groups of roadway segments or for individual roadway segments to conduct sensitivity analyses. With this approach, it is possible to evaluate, for instance, the conditions under which trucks would begin to drive more often on unpaved county roads instead of on-system state roads.

The production-constrained gravity model used to determine the number of trips between each well and each supplier location was as follows:

$$T_{ij} = P_i \frac{A_j \times f(d_{ij})}{\sum_{k=1}^{z} A_k \times f(d_{ik})}$$

where:

T_{ij} = Truck flow produced by trip production i and attracted to trip attraction j.
P_i = Number of trips produced by trip production i.
A_j = Number of trips attracted to trip attraction j.
$f(d_{ij})$ = Friction factor between trip production i and trip attraction j.
z = Number of trip attractions.

The output was an origin-destination matrix showing the choice of suppliers for each well and the associated number of trips for each choice of supplier.

The friction factor is calculated by using the following inverse power impedance function:

$$f(d_{ij}) = d_{ij}^{-b}$$

where:

d_{ij} = Impedance between trip production i and trip attraction j.
b = Model parameter.

In the absence of real-world data to calibrate the b parameter, the researchers tried several values ranging from 0.5 to 1.5 in addition to the default value of 0.02 in TransCAD. A previous study in Canada suggested the value of b could range from 0.48 to 1.39 for different census areas in Canada (*13*). Although the study is dated and based on work-related trips in urban areas, it could be used as a reference to select b values for sensitivity analysis purposes.

In an effort to replicate the decreasing likelihood of a trip as a function of travel time in rural areas, the default value of 0.02 in TransCAD was considered unrealistic because the likelihood of a trip would depend very little on the travel time between an origin and a destination. A b value of 0.5 would more likely represent the relationship between travel times and the corresponding likelihood of trips. For example, for one well and nine water suppliers located in the study area, a b value of 0.02 would result in an approximately even distribution of trips among the nine water sources regardless of travel time (Table 13). By increasing the value of b to 0.5, the distribution of trips between the well and the various water sources would change significantly, resulting in more trips to water sources that have a shorter travel time. This effect would be even more noticeable by using a b value of 1 or 1.5 (Table 13). Calibration based on field data would further reduce the level of uncertainty associated with b.

Table 13. Example Trip Distribution Based on Different *b* Values.

Water Supplier	Travel Time between Well and Water Supplier (minute)	Percentage of Total Water Trips			
		b = 0.02	b = 0.5	b = 1	b = 1.5
1	4.7	11.3%	17.9%	26.9%	37.7%
2	8.0	11.2%	13.7%	15.8%	16.9%
3	10.8	11.2%	11.8%	11.7%	10.7%
4	13.1	11.1%	10.7%	9.6%	8.0%
5	13.4	11.1%	10.6%	9.4%	7.8%
6	14.2	11.1%	10.3%	8.8%	7.1%
7	16.2	11.1%	9.6%	7.8%	5.8%
8	23.3	11.0%	8.0%	5.4%	3.4%
9	27.2	10.9%	7.4%	4.6%	2.7%
Total		100%	100%	100%	100%

Route Assignment

As mentioned, the researchers used an all-or-nothing assignment method to complete the route assignment step. In essence, this method assigned all the trips between each origin-destination pair to the shortest path between that pair, regardless of roadway capacity or congestion. The output was segment-based truck flow for each direction of travel.

ESAL Calculations

For the conversion of truck volumes to ESALs, the researchers used the results of an analysis that estimated ESALs for each truck type based on axle weight distributions from WIM station readings. Details of this analysis are available in Implementation Report IR-16-03. Table 14 shows the number of ESALs for each truck type.

The researchers then calculated the total number of ESALs for each segment (in each direction) by multiplying the number of assigned trucks for each activity by the corresponding number of ESALs per truck, by adding the number of ESALs for each phase, and by aggregating the three phases of development, operation, and re-fracking. Assuming an analysis period of 20 years and four re-fracking events during this period, the cumulative number of ESALs for each direction of segment *i* was as follows:

$$Total\_ESAL_i = Dev\_ESAL_i + 20 \times Prod\_ESAL_i + 4 \times Refrc\_ESAL_i$$

where:

$Total\_ESAL_i$ = Total cumulative ESALs for one direction of segment *i*
Dev_ESAL_i = Cumulative ESALs from development activities for one direction of segment *i*
$Prod\_ESAL_i$ = Cumulative ESALs from production activities for one direction of segment *i*
$Refrc\_ESAL_i$ = Cumulative ESALs from re-fracking activities for one direction of segment *i*.

Results

The first set of runs involved determining ESAL values due to the development and operation of one well over 20 years. Because the number of ESALs depends on the direction of travel (to the well or away from the well), the researchers prepared three sets of results for each roadway segment: ESALs for trips to the well, ESALs for trips from the well, and higher directional ESALs (i.e., the higher ESAL value between the two directions of travel). Figure 34 shows the total number of ESALs for trips to the well, Figure 35 shows the total number of ESALs for trips from the well, and Figure 36 shows higher directional ESALs. As expected, roadway segments near the well had a much higher number of ESALs than segments farther away from the well. In the immediate vicinity of the well, the total number of ESALs was 10,757 for trips to the well and 15,059 for trips from the well. The total number of ESALs decreased as the roadway segments were farther away from the well.

Notice in Figure 35 that FM 81 southeast of the well would be expected to have over 10,000 ESALs for trips from the well during the 20-year analysis period. Part of the reason is the location of two crude oil truck off-load terminals on FM 81 approximately four miles southeast of the well.

The second set of runs involved increasing the numbers of wells. The following scenarios were completed: 10 wells, 100 wells, 200 wells, and 493 wells (i.e., the same number of wells completed in 2013). The 10-well, 100-well, and 200-well scenarios involved a random selection of wells from the total population of 493 wells completed in 2013.

Table 14. ESALs per Truck Type in the Eagle Ford Shale Region.

Well Development Activity	Truck Type	ESALs per Truck (Trip to Well)	ESALs per Truck (Trip from Well)
Drilling pad and construction equipment	5-axle dump	1.177	0.092
Drilling rig	5-axle rig	8.676	8.676
Drilling fluid and materials	5-axle water	1.412	0.092
Drilling equipment: casing, drilling pipe	5-axle flatbed	1.709	0.066
Fracking equipment: pump trucks, tanks	5-axle equipment	2.606	2.606
Fracking water (steel tank)	5-axle water	1.412	0.092
Fracking water (aluminum tank)	5-axle water	1.412	0.023
Fracking sand (steel tank)	5-axle water	1.876	0.092
Fracking sand (aluminum tank)	5-axle sand	1.876	0.023
Other additives and fluids	5-axle sand	1.412	0.092
Flowback water removal	5-axle sand	0.092	1.412

Well Production Activity (per year)	Truck Type	ESALs per Truck (Trip to Well)	ESALs per Truck (Trip from Well)
Produced water (steel tank)	5-axle water	0.092	1.412
Produced water (aluminum tank)	5-axle water	0.023	1.412
Oil and condensate production (steel tank)	5-axle water	0.092	1.412
Oil and condensate production (aluminum tank)	5-axle water	0.023	1.412

Well Re-Fracking Activity (per event)	Truck Type	ESALs per Truck (Trip to Well)	ESALs per Truck (Trip from Well)
Fracking equipment: pump trucks, tanks	5-axle equipment	2.606	2.606
Fracking water (steel tank)	5-axle water	1.412	0.092
Fracking water (aluminum tank)	5-axle water	1.412	0.023
Fracking sand (steel tank)	5-axle sand	1.876	0.092
Fracking sand (aluminum tank)	5-axle sand	1.876	0.023
Other additives and fluids	5-axle water	1.412	0.092
Flowback water removal	5-axle water	0.092	1.412

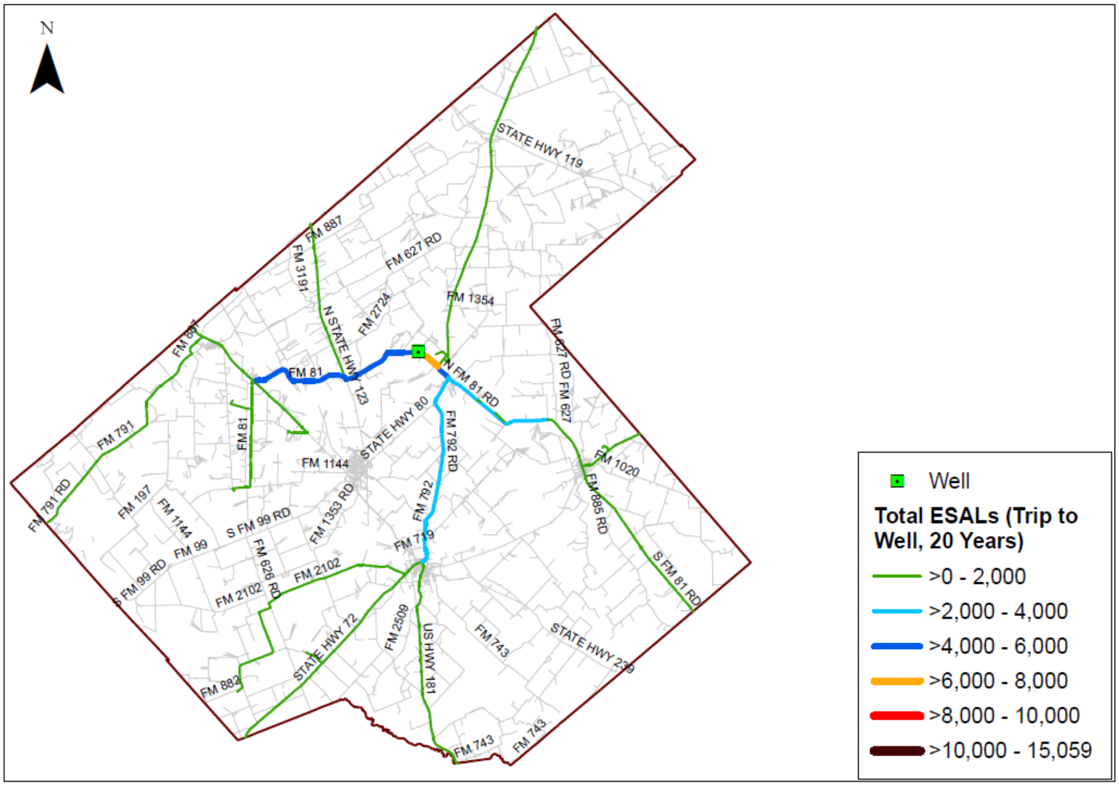


Figure 34. Total Number of ESALs (Trips *to* the Well) – One Well.

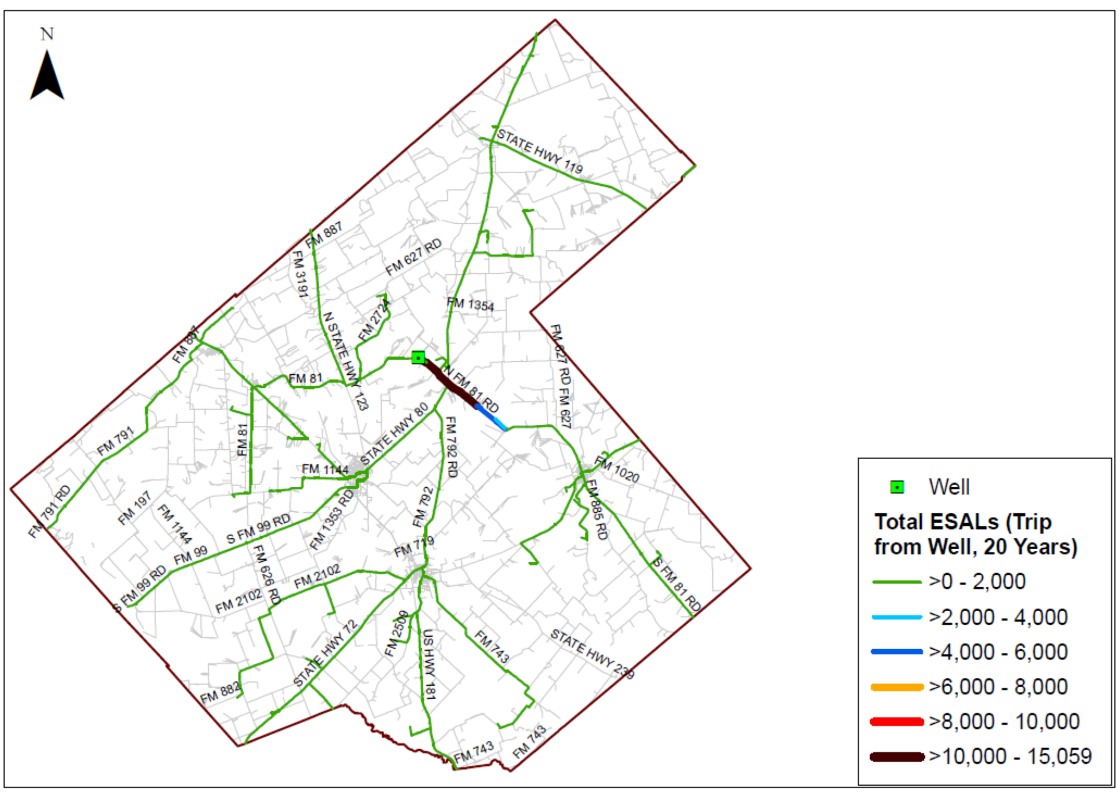


Figure 35. Total Number of ESALs (Trips *from* the Well) – One Well.

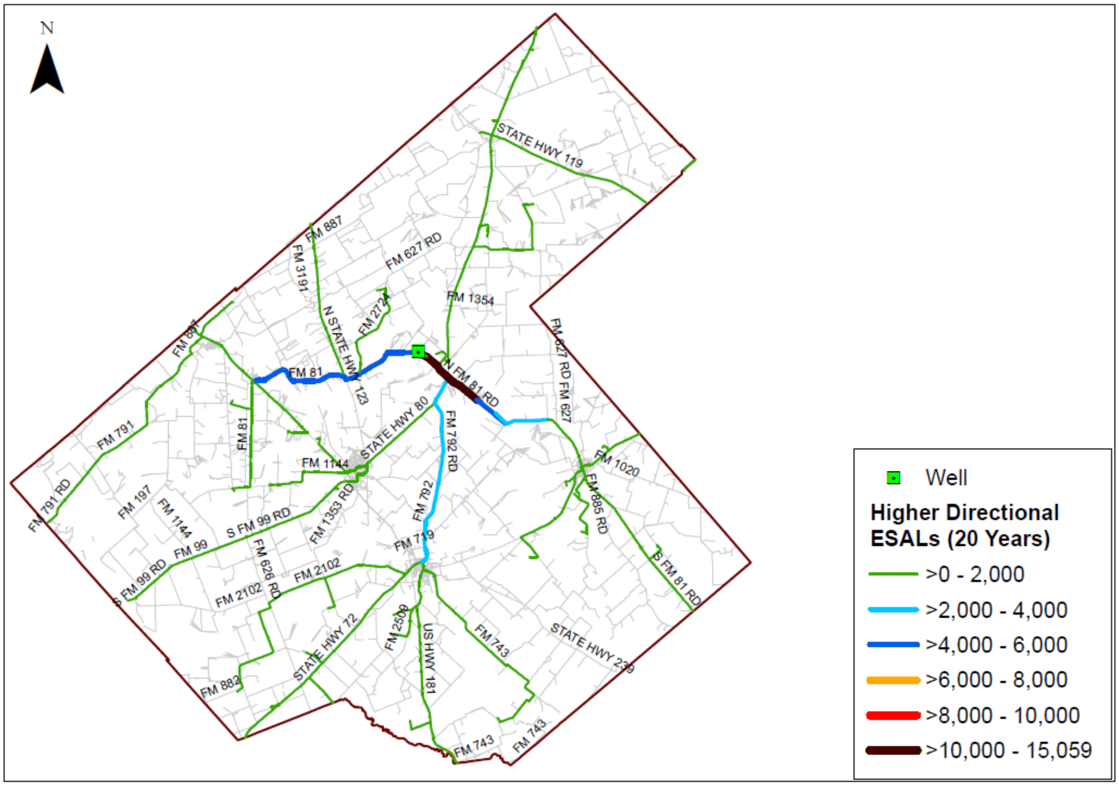


Figure 36. Total Number of ESALs (Higher Directional ESALs) – One Well.

Figure 37 through Figure 40 show the spatial distribution of higher directional ESALs for the four scenarios analyzed. The figures clearly show that the number and extent of roadway segments affected increase as the number of wells increases and their location is more widely spread out throughout Karnes County. FM 81 southeast of SH 80 had the highest number of ESALs. In the 493-well scenario (Figure 40), the number of directional ESALs on FM 81 southeast of SH 80 was higher than 4.4 million.

Table 15 provides a summary of the number of miles involved for each scenario and ESAL interval, as well as the corresponding percentage with respect to the total number of network miles. For example, for the 100-well scenario, approximately 37 miles (or 11% of the on-system network) would have 250,000-500,000 ESALs over 20 years. By comparison, for the 493-well scenario, approximately 67 miles (or 20% of the on-system network) would have 250,000-500,000 ESALs over 20 years.

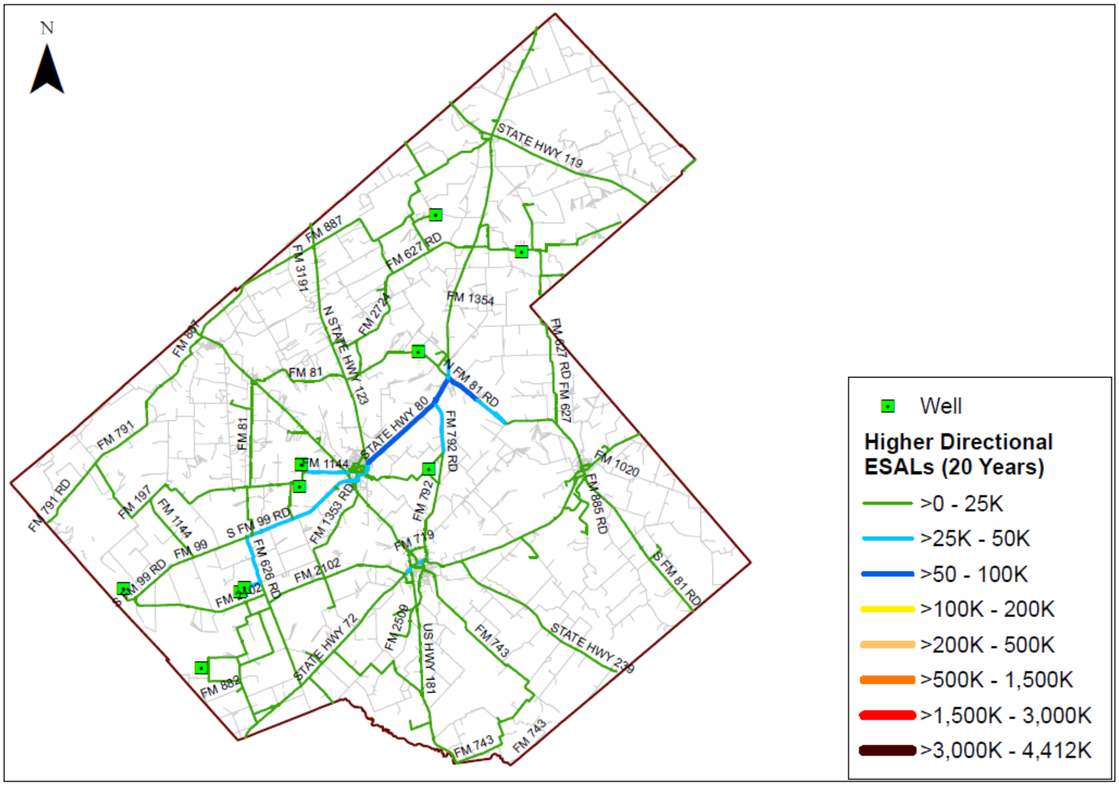


Figure 37. Total Number of ESALs (Higher Directional ESALs) – 10 Wells.

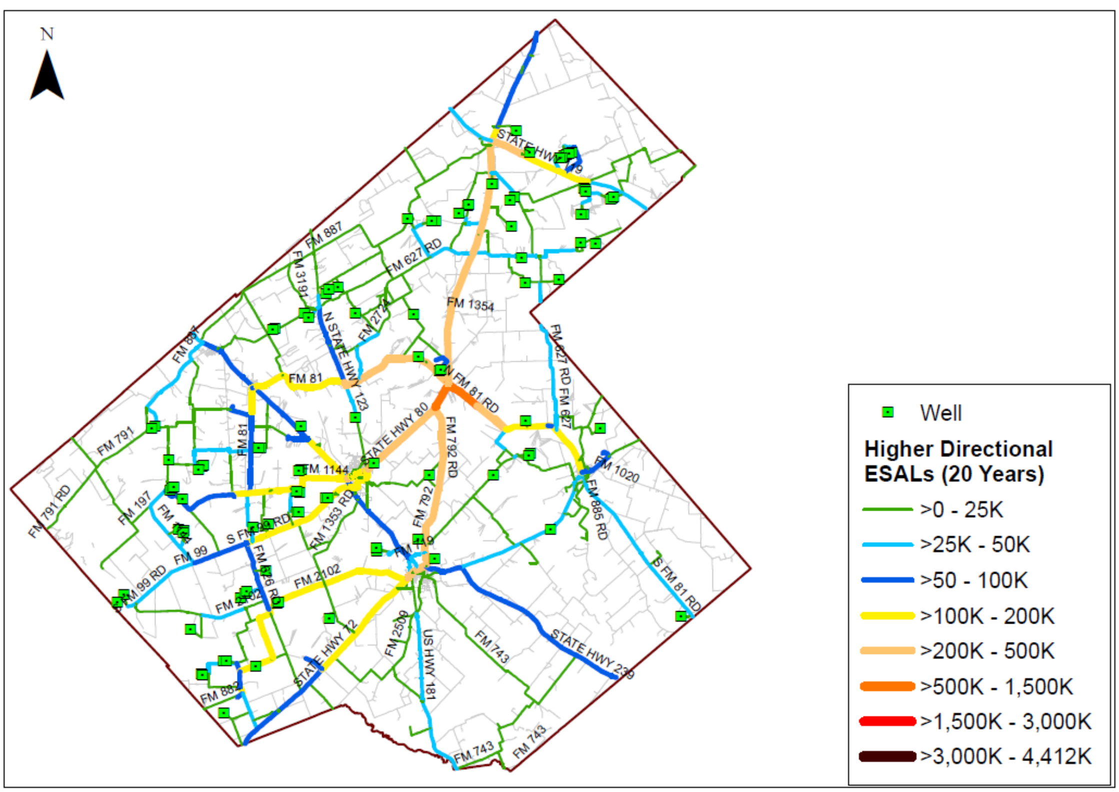


Figure 38. Total Number of ESALs (Higher Directional ESALs) – 100 Wells.

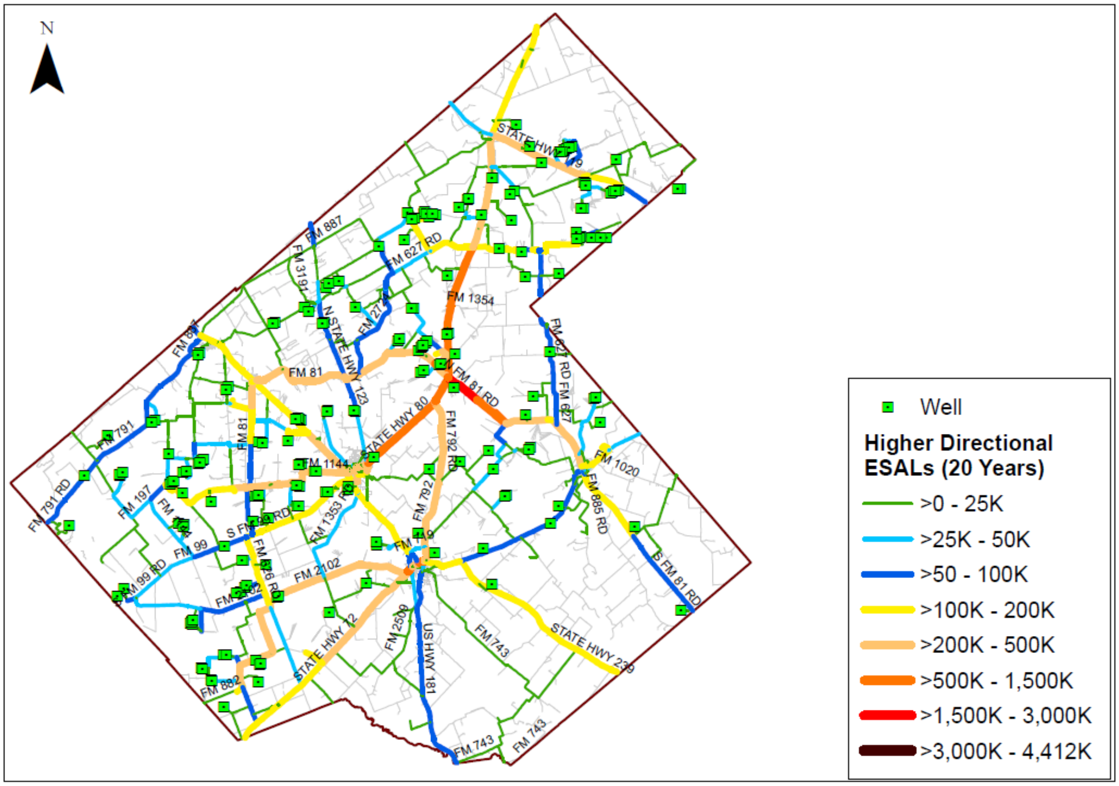


Figure 39. Total Number of ESALs (Higher Directional ESALs) – 200 Wells.

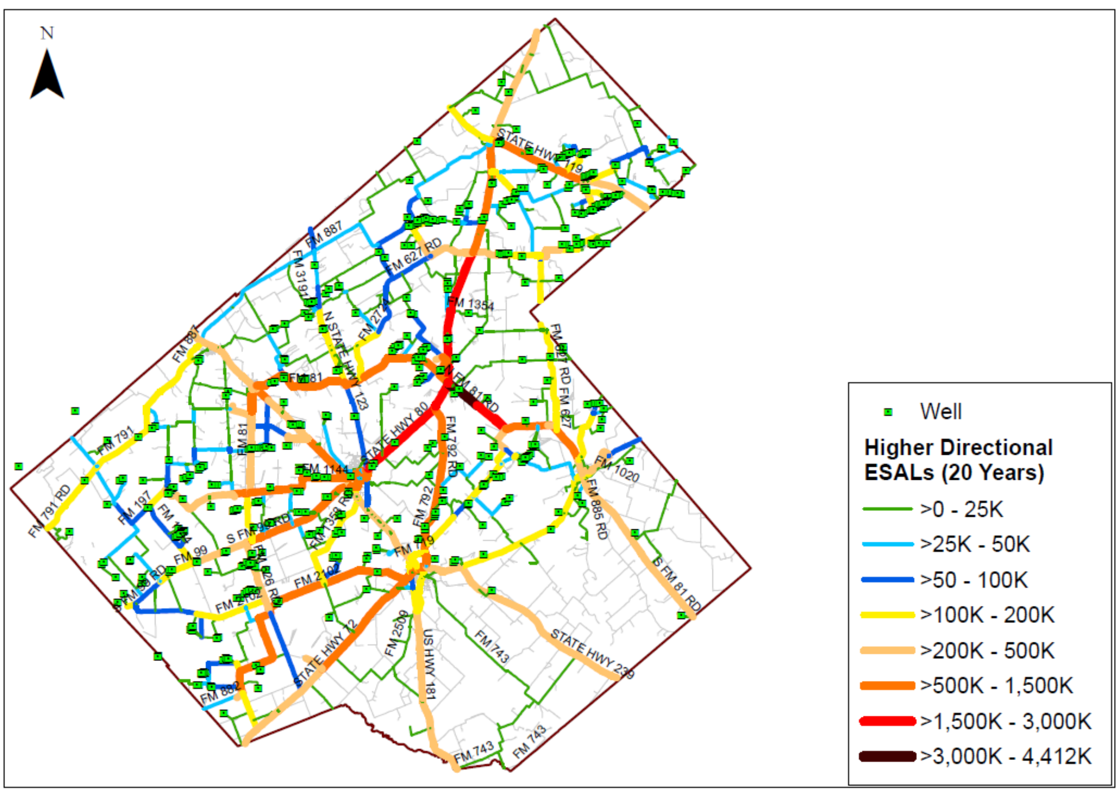


Figure 40. Total Number of ESALs (Higher Directional ESALs) – 493 Wells.

Table 15. Miles of On-System and Off-System Roads Used to Develop and Operate Wells.

Higher Directional ESALs (20 Years)	1 Well				10 Wells			
	On-System Roads Used		Off-System Roads Used		On-System Roads Used		Off-System Roads Used	
	Miles	Percent*	Miles	Percent**	Miles	Percent	Miles	Percent
>0 – 25,000	198	59%	31	2%	274	81%	88	7%
>25,000 – 50,000	-	-	-	-	18	5%	3	0.2%
>50,000 – 100,000	-	-	-	-	8	2%	-	-
>100,000 – 200,000	-	-	-	-	-	-	-	-
>200,000 – 500,000	-	-	-	-	-	-	-	-
>500,000 – 1,500,000	-	-	-	-	-	-	-	-
>1,500,000 – 3,000,000	-	-	-	-	-	-	-	-
>3,000,000 – 4,412,000	-	-	-	-	-	-	-	-
Total	**198**	**59%**	**31**	**2%**	**300**	**88%**	**91**	**7%**

Higher Directional ESALs (20 Years)	100 Wells				200 Wells			
	On-System Roads Used		Off-System Roads Used		On-System Roads Used		Off-System Roads Used	
	Miles	Percent*	Miles	Percent**	Miles	Percent	Miles	Percent
>0 – 25,000	104	31%	215	17%	61	18%	260	21%
>25,000 – 50,000	71	21%	26	2%	38	11%	45	4%
>50,000 – 100,000	54	16%	11	0.8%	75	22%	12	1%
>100,000 – 200,000	51	15%	3	0.2%	63	19%	14	1%
>200,000 – 500,000	37	11%	1	0.1%	67	20%	2	0.2%
>500,000 – 1,500,000	3	0.9%	-	-	16	5%	1	0.1%
>1,500,000 – 3,000,000	-	-	-	-	2	0.6%	-	-
>3,000,000 – 4,412,000	-	-	-	-	-	-	-	-
Total	**320**	**95%**	**255**	**21%**	**321**	**95%**	**333**	**27%**

Higher Directional ESALs (20 Years)	493 Wells			
	On-System Roads Used		Off-System Roads Used	
	Miles	Percent	Miles	Percent
>0 – 25,000	61	18%	260	21%
>25,000 – 50,000	38	11%	45	4%
>50,000 – 100,000	75	22%	12	1%
>100,000 – 200,000	63	19%	14	1%
>200,000 – 500,000	67	20%	2	0.2%
>500,000 – 1,500,000	16	5%	1	0.1%
>1,500,000 – 3,000,000	2	0.6%	-	-
>3,000,000 – 4,412,000	-	-	-	-
Total	**321**	**95%**	**333**	**27%**

* Percentage of the total of 337 miles of on-system (i.e., state-maintained) roads in Karnes County.
** Percentage of the total of 1,243 miles of off-system (i.e., county or local) roads in Karnes County.

For comparison purposes, Figure 41 shows the spatial distribution of ESALs listed in the TxDOT Road-Highway Inventory Network (RHiNo) database. Of particular interest are corridors where the cumulative ESALs in Figure 40 are higher than the corresponding ESALs listed in the RHiNo database. Examples include FM 81, SH 80 south of FM 627, FM 1144, FM 1353, and FM 2102.

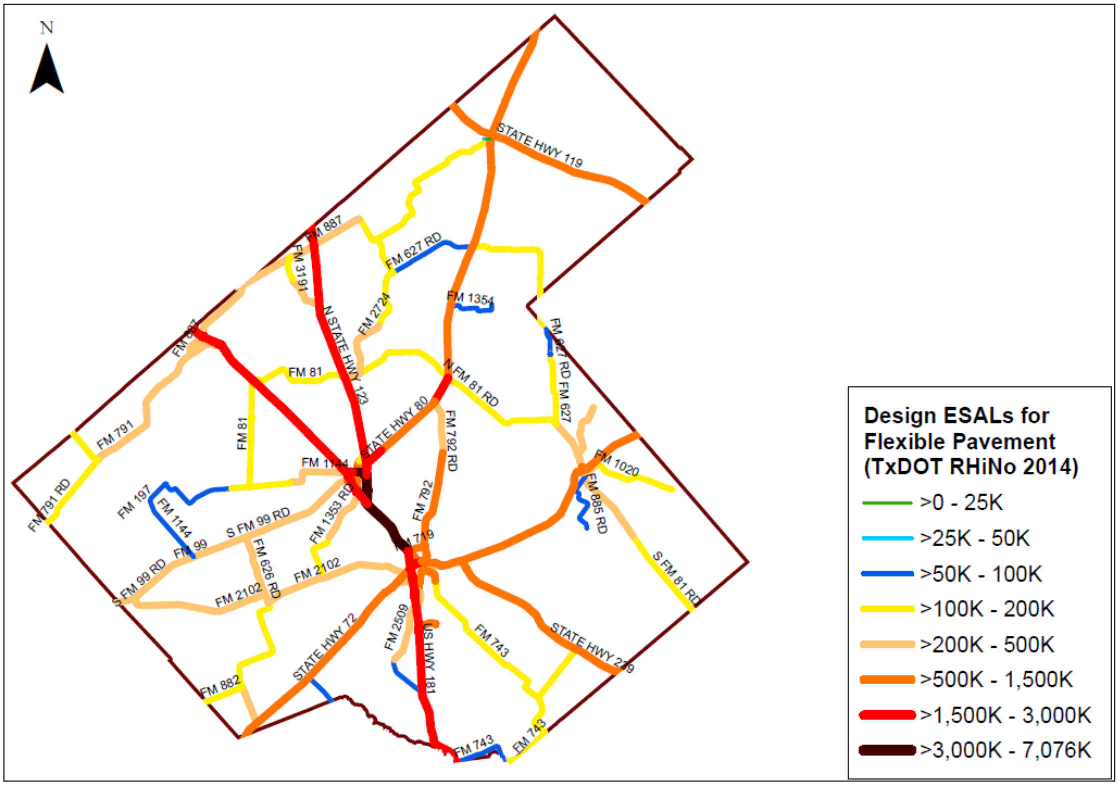


Figure 41. ESALs According to the TxDOT RHiNo Database.

TTI researchers also estimated the number of ESAL-miles for all five scenarios. ESAL-miles are frequently used to measure the combined effect of ESALs at any given location and distance driven to provide an overall measure of the amount of pavement "consumed." The results indicate that for roads in Karnes County, developing and operating one well over 20 years could result in 0.308 million ESAL-miles. As the number of wells increases, the total number of ESAL-miles also increases: 4.35 million ESAL-miles for 10 wells, 46.3 million ESAL-miles for 100 wells, 90.7 million ESAL-miles for 200 wells, and 223 million ESAL-miles for 493 wells.

The number of ESAL-miles could be used for a variety of applications, including the estimation of a marginal cost that reflects the additional use of the pavement structure due to the development and operation of any number of oil and gas wells in a geographic area. Depending on the specific application, the marginal cost estimation could vary drastically, which highlights the need for a careful assessment of the assumptions behind the calculation. For example, a cursory review of data from several states could suggest a unit cost of approximately 3 cents per ESAL-mile, which, for one well in Karnes County, would translate into a total marginal cost of approximately $9,000. For 493 wells, the cost would be $6.7 million (*16*). However, the information gathered did not shed light as to what was included in the unit cost assessment. By comparison, assuming 74 cents per ESAL-mile (*16*), the cost for one well in Karnes County would be approximately $228,000. For 493 wells, the cost would be $165 million.

APPLICABILITY OF THE METHODOLOGY

The methodology described in this report enables users to map truck traffic in connection with energy developments to the surface transportation network in the state. The methodology uses the four-step travel demand modeling approach. A case study was conducted to evaluate the feasibility of the methodology using data for well development and operation in Karnes County located in the Eagle Ford Shale area in South Texas. The spatial distribution of ESALs due to development and operation of a number of wells in Karnes County over an analysis period was obtained as the output of methodology. Examples of potential applications of the methodology include, but are not limited to, the following:

- Forecast the spatial distribution of ESALs due to the development and operation of any number of wells. For wells that are in the development stage, analysis can be conducted to evaluate the future impact due to well development, operation, and re-fracking on the transportation network. For wells that are in production, the analysis can focus on future impact due to well production and re-fracking activities. The resulting ESAL distribution can also be used to estimate the total cost of pavement damage by multiplying the total number of ESAL-miles by a marginal pavement cost.

- Forecast the spatial-temporal distribution of ESALs due to the development and operation of any number of wells. For example, it may be of interest to determine how the spatial distribution of ESALs evolves over time during the development, production, and re-fracking phases of multiple wells. The methodology enables users to forecast spatial-temporal distributions of ESALs by aggregating ESALs associated with each well during the analysis period.

- Evaluate alternative scenarios by conducting sensitivity analyses. One potential application could be to evaluate the reduction in truck traffic impact on the transportation network resulting from various temporary water pipe implementations. Another application could be to calibrate various assumptions to improve the simulation procedure. For example, in the step of trip distribution, the researchers assumed the impedance was travel time and the *b* parameter of inverse power impedance function was 0.5. A previous study in Canada suggested the value of *b* ranged from 0.48 to 1.39 for different census areas in Canada based on the impedance of trip length (*13*). Although the study is dated and based on work-related trips in urban area, it may be used as a reference to select values for *b* to conduct sensitivity analyses.

  Keeping all the other assumptions the same as in the scenario shown in Figure 36, the researchers used *b* values of 0.02, 1.0, and 1.5 to simulate different alternative scenarios. Figure 42, Figure 43, and Figure 44 show the distribution ESALs due to one well in Karnes County based on different values of *b*. In relation to Figure 36, the number of affected segments is the same across all four scenarios because the change in *b* only affects the amount of trips assigned between an origin and a destination, but not the choice of routes. According to the figures, the *b* parameter was found to be sensitive to the ESAL distribution on segments that are in vicinity of the well.

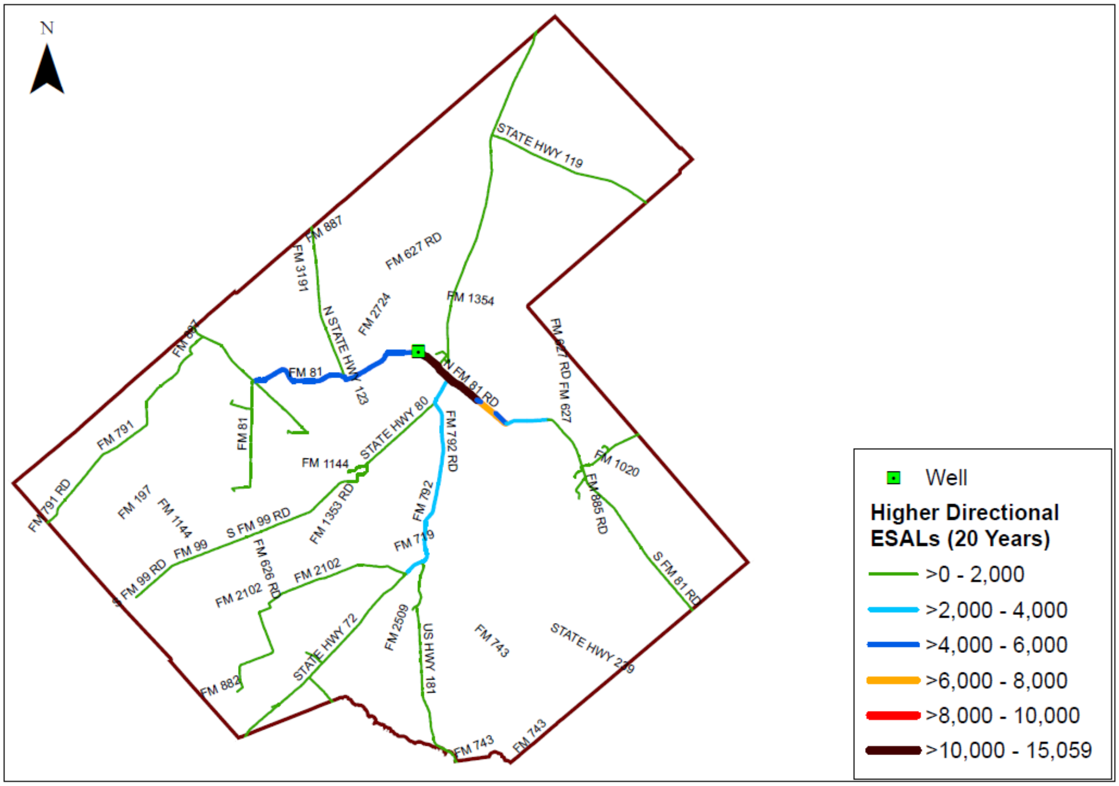


Figure 42. Total Number of ESALs (Higher Directional ESALs) – One Well (*b*=0.02).

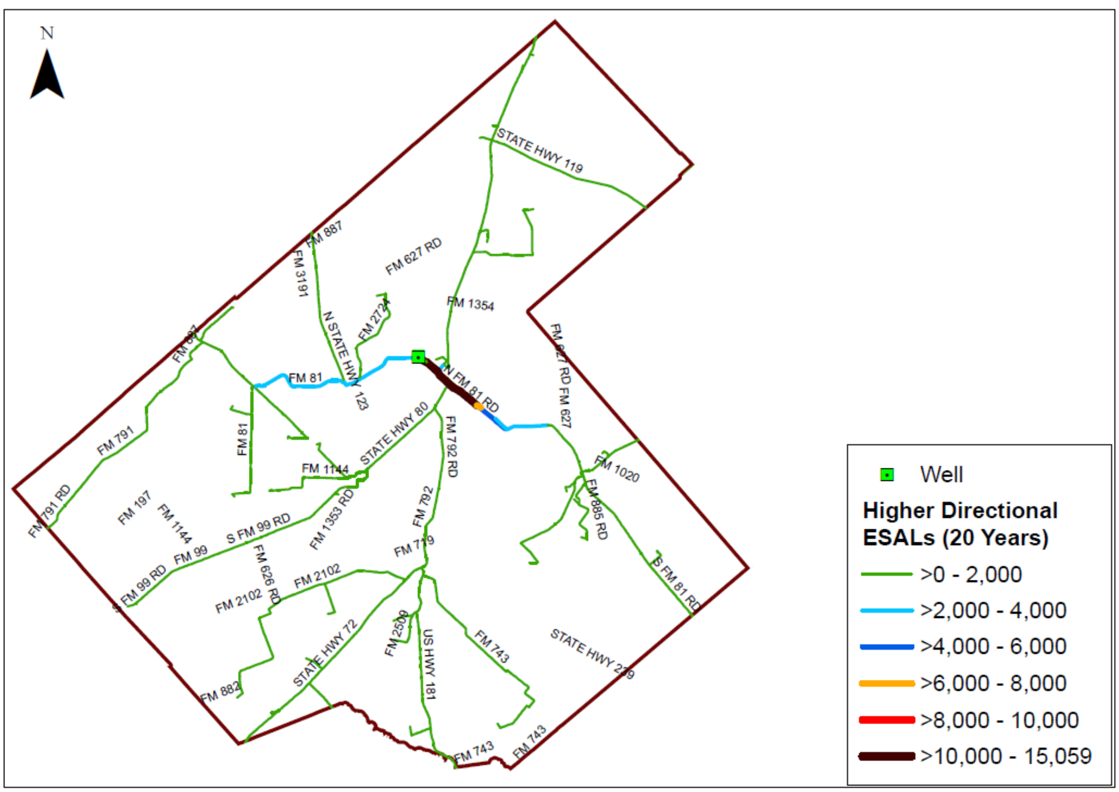


Figure 43. Total Number of ESALs (Higher Directional ESALs) – One Well (*b*=1).

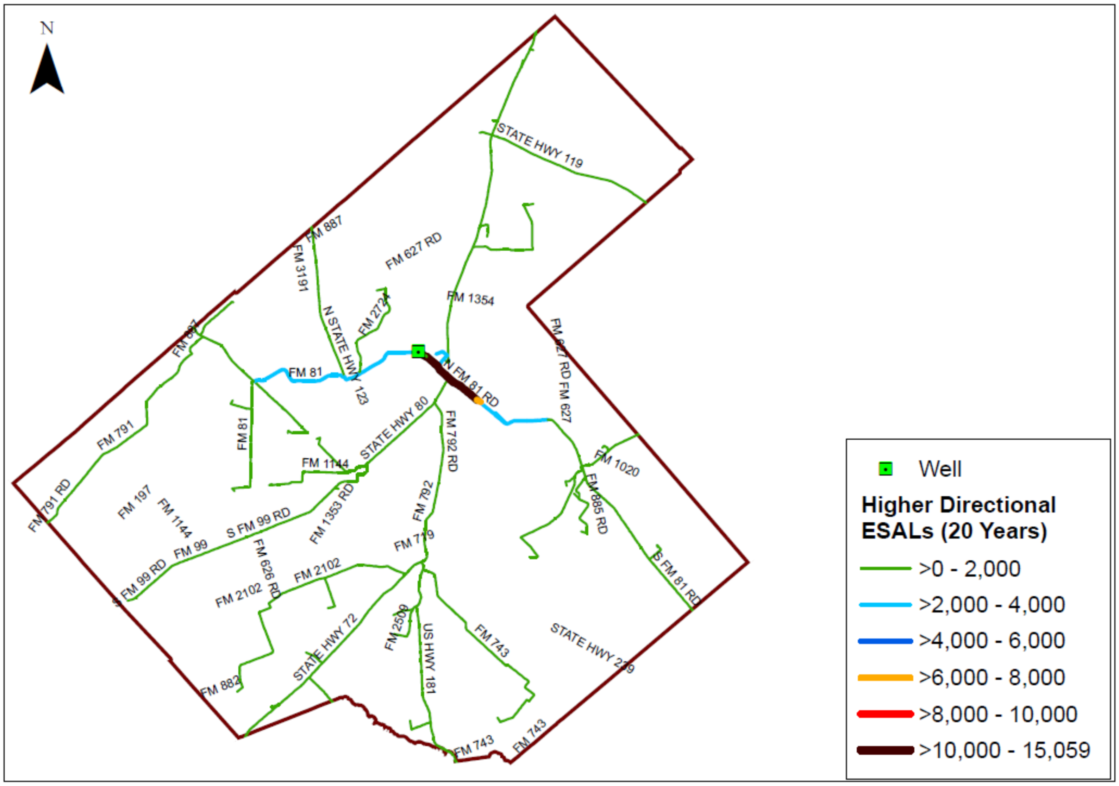


Figure 44. Total Number of ESALs (Higher Directional ESALs) – One Well (*b*=1.5).

In addition to the ESAL maps, TTI calculated the total number of ESAL-miles for one-well scenario and 493-well scenario by summing up the multiplication of ESALs for both directions of a segment and segment length. The results provide a high-level aggregate measure to quantify pavement damage due to truck traffic for either study area or Karnes County.

Figure 45 shows the total ESAL-miles on roads in the study area and in Karnes County due to one well based on different *b* values, while Figure 46 shows total ESAL-miles due to 493 wells. The results indicate that *b* became less sensitive to total ESAL-miles in the smaller area (i.e., Karnes County) compared to the larger area (i.e., the study area). In addition, *b* was less sensitive to the total number ESAL-miles in the 493-well scenario compared to the one-well scenario.

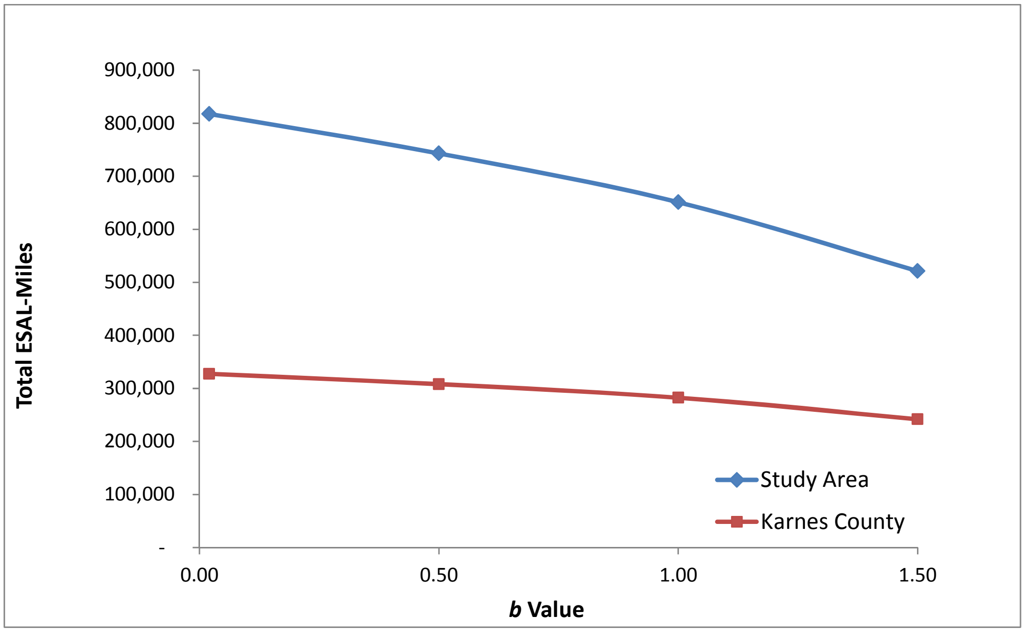


Figure 45. ESAL-Miles vs. b Parameter – One Well.

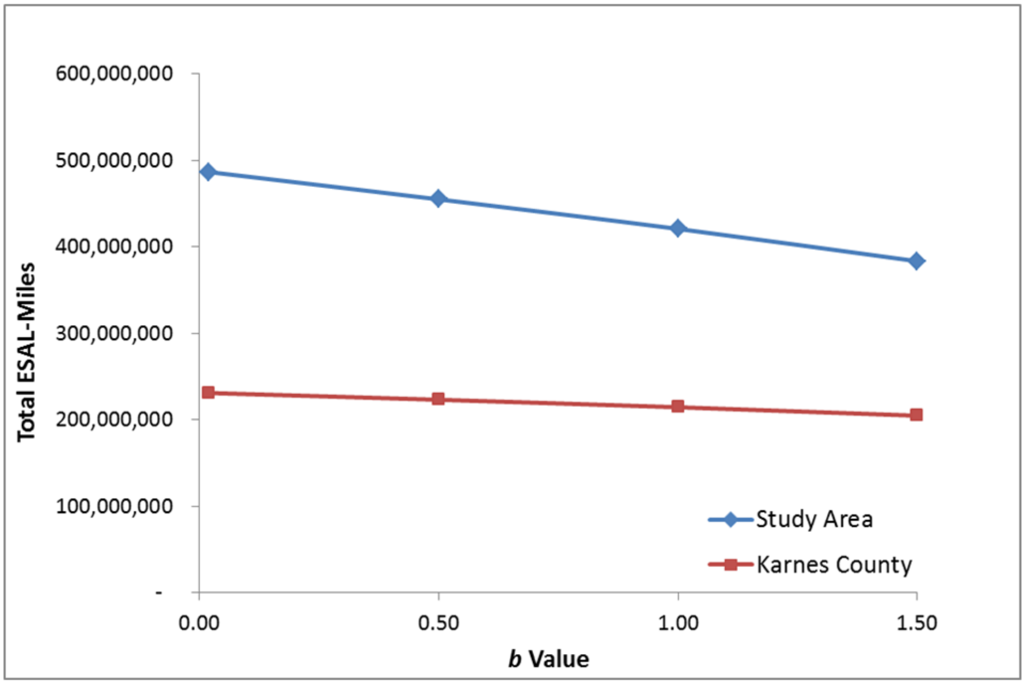


Figure 46. ESAL-Miles vs. *b* Parameter – 493 Wells.

- Forecast the spatial distribution of ESALs in urban areas due to well developments that take place in rural areas. One potential application could be to determine the need and feasibility of alternative truck routes. As an illustration, Figure 47 provides a zoomed-in view of Figure 40 around Karnes City. With all 493 wells developed throughout the county, there would be a substantial amount of truck traffic within city limits. The results of the simulation could shed some light as to expected truck volumes and traffic patterns, which could be used to determine whether (and when) alternative truck routes may be warranted.

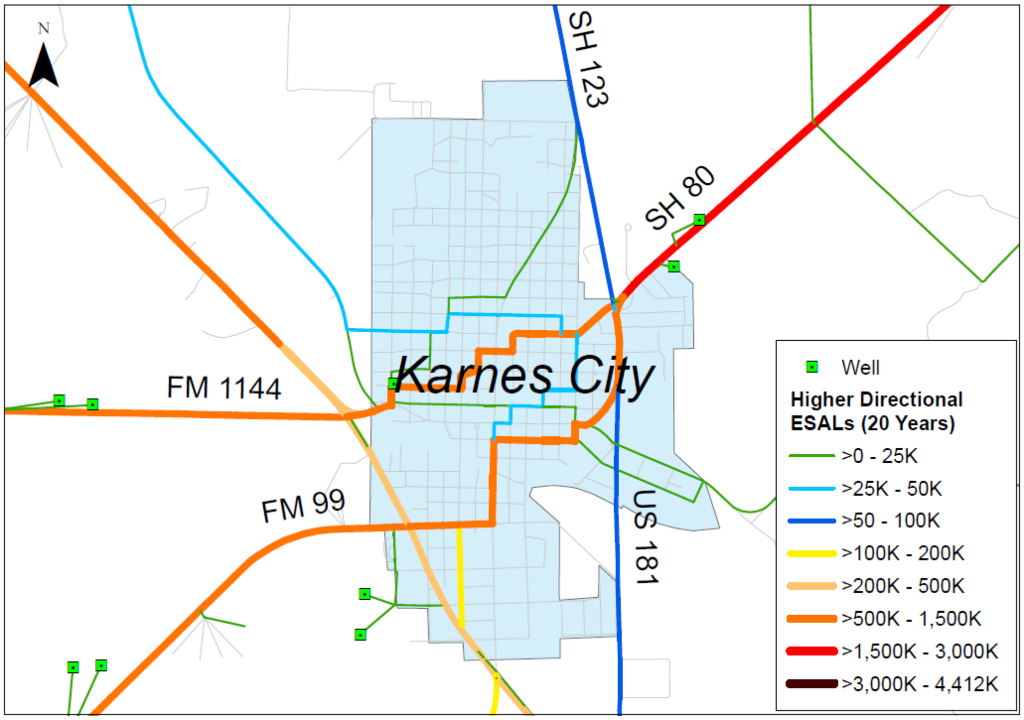


Figure 47. ESAL Distributions in Karnes City Due to 493 Wells in Karnes County.

In reality, traffic that travels on state roads tends to stay on those roads even within city limits. The modeling software enables users to manage this characteristic by modifying impedance functions or altering certain parameters, e.g., posted speed limits along certain corridors. As an illustration, Figure 48 shows the spatial distribution of ESALs in Karnes City with modified speed limit for local roads to ensure that most traffic traveling within city limits stays within state highways.

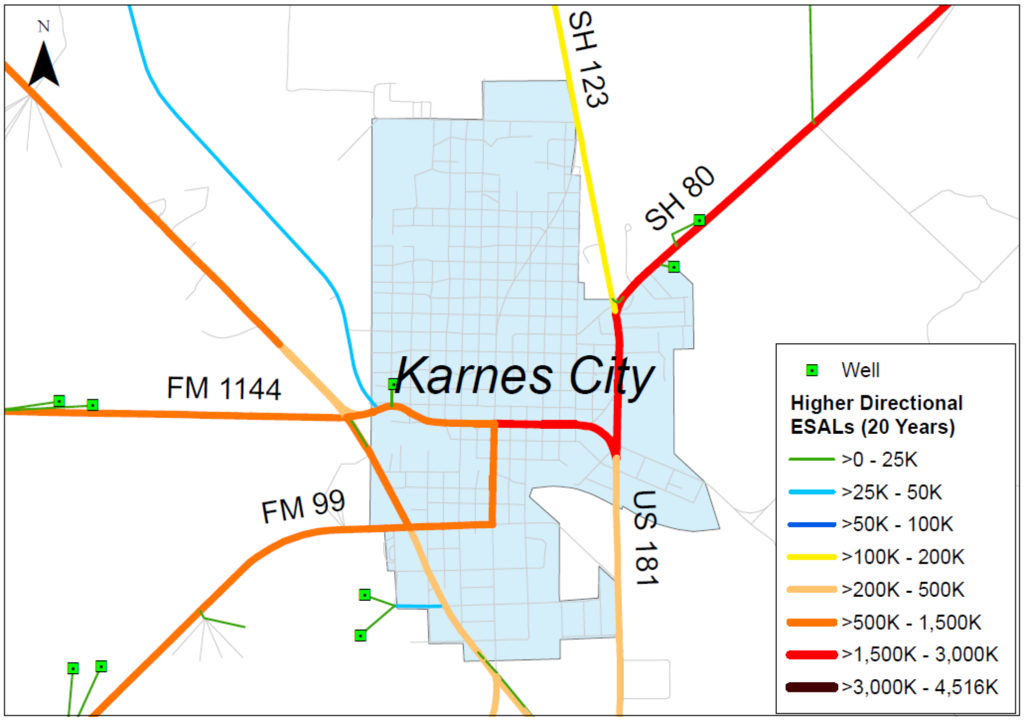


Figure 48. ESAL Distributions in Karnes City Due to 493 Wells in Karnes County (Alternative Scenario).

Anticipated enhancements of the methodology include the following:

- The methodology did not take into account economies of scale that operators implement when developing multiple wells within a short period, which would result in a lower number of trucks per well. Future enhancements would enable a variety of logistical assumptions, e.g., by combining trips involving multiple wells for a number of development or production activities. These wells could be located either on the same pad or on different pads.

- The methodology assumed that the water and sand needed for fracking operations were uniform throughout the region. Through a separate initiative, TTI researchers are currently conducting an analysis to determine spatial and temporal variations in the amount of water and sand used. These results could be used to fine tune the estimates, which could have an impact on trip modeling results.

- The methodology did not consider non-truck trips needed to develop and operate oil and gas wells because these trips would likely result in a very small number of ESALs. Future refinements could include non-truck trips for applications such as emergency response and congestion management.

REFERENCES

1. Real Prices Viewer. U.S. Energy Information Administration, Washington, D.C., August 2015. http://www.eia.gov/forecasts/steo/realprices/. Accessed August 01, 2016.
2. Texas Administrative Code Title 16, Part 1, Chapter 3, Rule §3.29. Hydraulic Fracturing Chemical Disclosure Requirements.
3. C.A. Quiroga, E. Kraus, I. Tsapakis, J. Li, W. Holik. *Truck Traffic and Truck Loads Associated with Unconventional Oil and Gas Developments in Texas*. Report RR-15-01. Texas A&M Transportation Institute, Texas Department of Transportation, College Station, Texas, August 2015.
4. Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission (IOGCC). 2014. FracFocus Chemical Disclosure Registry. FracFocus Data Download. https://fracfocus.org/data-download. Accessed July 21, 2016.
5. *Truck Axle Weight Distributions*. Implementation Report IR-16-02. Texas A&M Transportation Institute, Texas Department of Transportation, College Station, Texas, July 2016.
6. *Traffic Loads for Developing and Operating Individual Wells*. Energy Sector Brief ESB-16-08. Texas A&M Transportation Institute, Texas Department of Transportation, College Station, Texas, July 2016.
7. AASHTO Guide for Design of Pavement Structures, Fourth Edition. American Association of State Highway and Transportation Officials, Washington, D.C., 1998.
8. Gutekunst, J., Motamed, M., Alrashidan, A., & Machemehl, R. B. (2016). *Pavement Maintenance Prioritization Tool for Effects of Hydraulic Fracturing.* Transportation Research Record: Journal of the Transportation Research Board, (2580), 65-70.
9. Dybing, A., Lee, E., DeHaan, C., & Dharmadhikari, N. (2013). *Impacts to Montana State Highways Due to Bakken Oil Development (No. FHWA/MT-13-002/8219).*
10. Bratlien, A., Dybing, Alan., Holt, L., Horner, T., Kazemi, Y., Lee, E., Lu, P., Mielke, J., Tolliver, D., Wentz, B., Dang, V., DeHaan, C., Dharmadhikari, N., Ifepe, C., Park, Y., Yuan, F., and Zheng, Z. (2014). *Infrastructure Needs: North Dakota's County, Township and Tribal Roads and Bridges: 2015-2034*.
11. Quiroga, C., Tsapakis, I., Li, J., Holik, W., Kraus, E. *Truck Traffic and Truck Loads Associated with Unconventional Oil and Gas Developments in Texas*. 2016 Update. Report RR-16-01. Texas A&M Transportation Institute, Texas Department of Transportation, College Station, Texas, August 2016.
12. Meyer, M. D., & Miller, E. J. (2000). Urban transportation planning Second Edition.
13. Hutchinson, B. G., & Smith, D. P. (1979). Empirical studies of the journey to work in urban Canada. *Canadian Journal of Civil Engineering*, 6(2), 308-318.
14. Patriksson, M. (2015). *The traffic assignment problem: models and methods*. Courier Dover Publications.

15. Quiroga, C., Kraus, E., Tsapakis, I., Li, J., Holik, W. (2015) *Truck Traffic and Truck Loads Associated with Unconventional Oil and Gas Developments in Texas*. Report RR-15-01. Texas A&M Transportation Institute, Texas Department of Transportation, College Station, Texas.

16. Murillo, J., Ahmed, A., Labi, S. (2014). *Using Regional Freight Traffic Assignment Modeling to Quantify the Variability of Pavement Damage for Highway Cost Allocation and Revenue Analysis.* Final Report, USDOT Region V Regional University Transportation Center.

APPENDIX. OIL AND GAS WELL INFORMATION BY COUNTY

This appendix includes supplemental information pertaining to the completion of oil and gas wells in Texas. The tables included in this appendix are as follows:

Table 16 shows the total number of new wellheads completed per county.

Table 17 shows the total number of new wellends completed per county.

Table 18 shows the total number of new directional well completed per county.

Table 19 shows the total number of new vertical wellheads completed per county.

Table 20 shows the total number of new horizontal wellends completed per county.

Note that the number of wells in Table 16, Table 17, and Table 18 corresponds to actual wells, i.e., multiple permits may be issued for a single well location and have subsequently been removed from this well count. The number of wells in Table 19 and Table 20 corresponds to the number of completed permits associated with the wells since wells may be active for multiple time periods resulting in additional truck traffic.

Table 16. Total Number of New *Wellheads* Completed per County.

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Anderson	23	25	38	21	5	7	10	10	9	2
Andrews	278	286	497	399	834	1153	1100	705	821	191
Angelina	18	32	29	12	2	2	4	0	0	0
Aransas	9	11	11	2	2	2	1	3	1	2
Archer	60	77	104	91	80	93	101	95	110	49
Armstrong	0	0	0	0	0	0	0	0	0	0
Atascosa	11	3	6	16	36	52	147	175	293	72
Austin	8	6	28	14	9	9	8	9	5	2
Bailey	0	0	0	0	0	0	0	0	0	0
Bandera	0	2	1	0	0	0	0	0	0	0
Bastrop	0	4	15	1	5	3	2	3	1	0
Baylor	3	3	6	1	1	5	12	12	16	4
Bee	59	52	61	30	36	21	40	29	15	1
Bell	0	0	0	0	0	0	0	0	0	0
Bexar	0	2	1	2	4	0	5	47	14	0
Blanco	0	0	0	0	0	0	0	0	0	0
Borden	19	42	20	8	28	41	43	55	45	9
Bosque	13	3	2	0	0	0	0	1	0	0
Bowie	1	1	1	1	1	0	0	0	1	0
Brazoria	20	20	30	8	32	38	53	31	30	21
Brazos	18	17	24	23	42	26	27	71	76	12
Brewster	1	0	0	0	0	0	0	0	0	0
Briscoe	0	1	0	0	0	0	0	0	0	0
Brooks	29	24	50	14	23	22	16	15	14	3
Brown	7	15	11	5	43	45	10	5	7	2
Burleson	9	8	36	3	33	14	5	14	78	12
Burnet	0	0	0	0	0	0	0	0	0	0
Caldwell	15	42	15	14	30	39	35	15	30	9

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Calhoun	10	11	9	7	3	2	3	2	1	0
Callahan	17	16	22	15	14	7	10	8	17	7
Cameron	0	0	0	1	0	3	0	0	0	0
Camp	0	1	0	1	1	0	1	4	2	0
Carson	3	5	7	5	0	15	18	10	19	0
Cass	1	0	0	4	3	5	4	5	6	1
Castro	0	0	0	0	0	0	0	0	0	0
Chambers	14	2	13	8	30	33	41	32	42	7
Cherokee	44	54	76	22	10	12	5	8	15	9
Childress	0	0	3	0	0	0	0	0	0	0
Clay	24	18	40	6	14	18	25	17	11	3
Cochran	14	9	41	21	19	44	13	29	12	2
Coke	31	14	20	13	29	32	35	25	17	3
Coleman	4	12	13	8	45	42	40	44	23	11
Collin	0	0	0	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	4	0	0	0
Colorado	29	33	28	11	24	18	7	4	7	1
Comal	0	0	0	0	0	0	0	0	0	0
Comanche	3	4	2	2	2	4	1	4	8	2
Concho	19	23	27	7	4	11	5	5	4	2
Cooke	71	70	71	38	105	130	69	38	33	10
Coryell	0	3	3	0	0	0	0	0	0	0
Cottle	9	7	12	2	5	4	1	2	5	1
Crane	159	175	148	58	83	116	144	213	160	76
Crockett	290	287	311	64	168	94	148	210	214	54
Crosby	1	37	24	25	41	95	121	127	187	34
Culberson	9	7	9	8	18	47	42	65	85	48
Dallam	0	0	0	1	0	0	1	0	0	0
Dallas	0	7	10	8	9	1	2	4	0	0
Dawson	27	37	36	17	36	61	57	48	53	8
Deaf Smith	0	0	0	0	0	0	0	0	0	0
Delta	0	0	0	0	0	0	0	0	0	0
Denton	225	229	291	128	167	99	67	88	53	17
DeWitt	40	46	63	28	60	174	226	359	317	97
Dickens	25	23	24	11	11	10	6	6	9	0
Dimmit	59	36	55	29	137	332	583	524	612	244
Donley	0	0	0	0	0	0	0	0	0	0
Duval	58	80	74	26	32	24	35	56	40	16
Eastland	23	52	12	7	4	6	4	4	4	4
Ector	229	151	225	235	453	488	689	668	494	102
Edwards	31	26	20	19	49	7	9	4	6	3
Ellis	3	15	21	10	9	4	0	0	0	0
El Paso	0	0	0	0	0	0	0	0	0	0
Erath	56	64	77	12	4	2	0	0	0	0
Falls	0	0	1	1	1	2	4	4	4	2
Fannin	0	0	0	0	0	0	2	0	0	0
Fayette	14	6	12	8	14	15	27	14	39	9
Fisher	12	18	35	22	30	36	40	41	38	18
Floyd	1	1	0	0	1	0	1	0	0	0
Foard	0	28	9	1	2	0	4	3	1	0
Fort Bend	42	35	34	23	38	61	43	78	87	7
Franklin	0	2	9	1	2	4	10	11	29	4
Freestone	215	241	213	165	124	96	45	16	16	5
Frio	11	55	42	18	20	73	82	70	99	18
Gaines	215	164	162	64	208	211	160	180	231	94
Galveston	14	13	8	1	7	7	7	5	2	1
Garza	46	42	50	39	29	27	29	39	45	11

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gillespie	0	0	0	0	0	0	0	0	0	0
Glasscock	70	78	79	67	217	588	732	579	526	114
Goliad	88	53	58	12	26	16	7	1	4	1
Gonzales	2	3	6	7	41	171	287	381	252	57
Gray	54	8	7	3	1	10	14	10	1	0
Grayson	10	9	5	6	13	16	20	23	23	9
Gregg	66	62	59	19	11	18	15	26	25	5
Grimes	6	8	11	9	10	9	19	14	20	1
Guadalupe	4	2	7	3	7	13	17	20	4	2
Hale	22	12	13	2	7	0	1	0	1	0
Hall	0	0	0	0	0	0	0	0	0	0
Hamilton	3	3	0	0	0	0	0	0	0	0
Hansford	26	16	31	16	4	7	8	8	7	2
Hardeman	11	8	10	3	5	6	11	9	6	8
Hardin	41	35	47	39	43	55	51	56	25	13
Harris	12	12	15	7	14	8	2	7	22	5
Harrison	266	302	293	128	93	64	45	35	72	8
Hartley	4	3	4	2	7	8	10	4	6	1
Haskell	9	6	10	15	26	39	34	19	37	4
Hays	0	0	0	0	0	0	0	0	0	0
Hemphill	272	255	295	112	121	132	115	119	117	37
Henderson	14	15	19	11	5	3	4	5	13	6
Hidalgo	135	152	135	51	45	47	39	37	54	12
Hill	44	49	114	28	10	0	0	0	0	0
Hockley	115	90	79	40	57	50	32	41	57	3
Hood	144	269	200	38	25	42	47	5	7	0
Hopkins	0	1	0	1	0	1	3	1	2	1
Houston	16	19	11	6	11	19	21	32	34	3
Howard	42	72	96	60	129	219	312	429	397	133
Hudspeth	1	3	4	0	0	0	0	0	0	0
Hunt	0	0	0	0	0	0	0	0	0	0
Hutchinson	41	145	91	10	15	13	22	12	17	3
Irion	27	22	69	41	50	168	237	263	262	66
Jack	67	129	55	32	33	70	126	122	254	19
Jackson	37	31	53	23	21	15	20	16	23	7
Jasper	5	9	16	12	9	9	8	9	3	0
Jeff Davis	1	1	1	0	0	0	0	0	0	0
Jefferson	26	36	30	23	35	26	35	26	17	5
Jim Hogg	29	15	8	2	3	2	3	6	4	0
Jim Wells	6	9	18	10	17	8	6	5	5	2
Johnson	531	839	898	423	360	241	102	18	5	1
Jones	44	50	53	38	40	41	37	52	38	10
Karnes	9	13	21	18	105	276	490	492	611	112
Kaufman	0	0	0	0	0	0	1	2	0	1
Kendall	0	0	0	0	0	0	0	0	0	0
Kenedy	25	22	35	20	17	13	0	6	5	2
Kent	12	21	32	24	28	21	22	35	20	2
Kerr	0	0	0	0	0	0	0	0	0	0
Kimble	3	1	0	1	1	0	0	0	0	0
King	21	24	27	10	14	13	12	29	36	9
Kinney	0	0	0	0	0	0	0	0	0	0
Kleberg	18	21	14	5	13	26	21	18	13	7
Knox	3	4	8	2	1	5	8	7	6	0
Lamar	0	0	0	0	0	0	0	0	0	0
Lamb	3	2	8	4	4	3	3	0	0	1
Lampasas	1	6	5	1	1	0	1	1	0	0
La Salle	58	45	55	32	102	239	513	605	637	238

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Lavaca	99	58	57	26	35	26	36	61	128	19
Lee	11	8	17	8	14	16	14	12	26	0
Leon	74	73	60	36	42	67	41	39	25	4
Liberty	36	35	32	13	15	17	14	14	9	0
Limestone	87	121	156	57	50	26	19	14	10	4
Lipscomb	121	98	145	56	69	116	118	113	130	16
Live Oak	45	35	49	25	52	74	110	181	162	35
Llano	0	0	0	0	0	0	0	0	0	0
Loving	41	47	44	27	52	56	171	156	150	99
Lubbock	8	7	12	21	19	8	8	4	5	4
Lynn	2	5	3	3	3	11	9	7	3	2
McCulloch	1	0	0	3	0	0	1	1	6	4
McLennan	0	2	3	0	0	0	0	0	0	0
McMullen	50	57	84	40	81	148	305	411	476	135
Madison	12	5	9	7	18	24	42	61	69	2
Marion	12	6	12	1	3	3	9	7	8	4
Martin	118	176	191	119	402	635	786	612	672	145
Mason	0	0	0	0	0	0	0	0	0	0
Matagorda	37	36	59	24	25	15	14	10	8	1
Maverick	65	46	184	104	26	34	14	12	5	0
Medina	1	4	18	16	45	54	100	114	47	11
Menard	9	8	9	6	6	22	16	6	3	3
Midland	227	153	225	166	347	565	545	484	593	217
Milam	22	8	3	54	81	222	331	319	39	0
Mills	0	1	0	0	0	0	0	0	0	0
Mitchell	122	199	228	160	154	164	162	107	46	9
Montague	97	67	124	70	190	207	214	167	105	1
Montgomery	12	1	7	4	5	7	5	10	3	0
Moore	49	42	36	27	20	27	46	20	47	26
Morris	0	0	0	0	0	0	0	0	0	0
Motley	0	0	1	0	0	0	0	0	1	1
Nacogdoches	209	227	229	87	71	70	36	2	3	1
Navarro	37	14	28	10	10	6	11	11	7	2
Newton	21	6	7	11	15	13	4	5	7	2
Nolan	21	35	49	18	40	70	72	66	47	26
Nueces	39	44	40	29	23	33	14	18	10	7
Ochiltree	43	36	72	47	84	85	123	142	157	30
Oldham	3	4	6	2	7	10	12	24	9	3
Orange	13	11	6	4	11	5	11	7	5	0
Palo Pinto	77	61	105	64	30	13	35	51	76	18
Panola	366	372	336	178	146	117	127	154	103	38
Parker	352	291	240	83	63	105	135	50	30	6
Parmer	0	0	0	0	0	0	0	0	0	0
Pecos	193	270	374	163	225	117	102	114	112	77
Polk	11	22	28	13	16	16	17	12	5	0
Potter	34	3	5	2	11	16	3	4	15	8
Presidio	0	0	0	0	0	0	0	0	0	0
Rains	0	1	0	1	0	0	0	0	0	0
Randall	0	0	0	0	0	0	0	0	0	0
Reagan	207	169	252	141	440	385	381	320	392	155
Real	0	0	1	1	0	0	1	0	0	0
Red River	0	0	1	1	0	2	1	1	1	0
Reeves	46	48	58	30	56	220	330	346	369	156
Refugio	78	77	70	79	84	71	62	46	60	42
Roberts	116	99	120	31	41	58	72	61	85	20
Robertson	100	116	165	98	53	43	38	32	14	3
Rockwall	0	0	0	0	0	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Runnels	79	40	46	10	28	26	18	24	18	12
Rusk	332	349	308	90	50	39	55	54	57	22
Sabine	1	1	1	1	6	6	4	1	1	0
San Augustine	0	8	31	52	73	65	25	11	12	1
San Jacinto	4	19	10	16	12	16	9	3	2	0
San Patricio	30	21	19	8	13	24	17	19	9	2
San Saba	0	0	0	0	0	0	0	0	0	0
Schleicher	52	19	31	18	29	45	45	32	25	5
Scurry	105	58	109	85	78	100	79	141	133	55
Shackelford	42	48	85	48	59	48	41	56	36	12
Shelby	53	80	121	66	91	44	21	10	14	0
Sherman	18	15	79	10	5	8	10	14	1	6
Smith	104	51	20	13	11	10	11	12	18	5
Somervell	19	34	55	6	5	4	3	0	0	0
Starr	127	127	165	51	41	35	40	25	43	6
Stephens	32	36	55	13	24	50	41	47	79	15
Sterling	53	71	53	52	41	22	50	50	43	3
Stonewall	17	24	40	40	80	81	75	59	68	11
Sutton	167	60	124	40	59	29	26	13	0	0
Swisher	0	0	0	0	0	0	0	0	0	0
Tarrant	314	615	785	540	540	516	243	117	92	30
Taylor	15	17	15	18	8	20	19	34	32	10
Terrell	66	45	38	2	6	2	2	0	1	1
Terry	54	51	41	30	24	30	31	19	11	9
Throckmorton	21	22	26	10	15	16	32	58	60	18
Titus	8	0	2	0	0	1	5	5	21	2
Tom Green	26	26	18	46	14	16	25	17	13	3
Travis	0	0	0	0	0	0	0	0	0	0
Trinity	3	2	2	1	0	3	0	0	3	0
Tyler	26	29	25	18	12	16	12	9	2	1
Upshur	40	48	24	7	4	10	1	3	14	6
Upton	230	298	476	194	489	581	620	524	552	191
Uvalde	1	0	0	0	0	0	0	0	0	0
Val Verde	16	10	1	9	0	0	0	2	0	0
Van Zandt	4	18	10	6	5	5	8	4	6	0
Victoria	48	34	51	36	28	20	20	22	15	1
Walker	7	0	3	0	0	0	1	7	5	0
Waller	32	34	26	16	17	7	7	11	4	2
Ward	339	203	232	101	234	281	306	298	283	61
Washington	7	4	3	2	3	1	2	11	12	0
Webb	282	239	352	196	313	385	445	369	457	50
Wharton	57	29	65	30	50	48	45	36	33	7
Wheeler	173	196	238	75	132	200	204	209	92	5
Wichita	108	125	160	135	118	162	136	135	147	35
Wilbarger	55	32	28	21	35	39	67	34	39	20
Willacy	12	17	16	15	14	9	7	6	8	0
Williamson	0	1	0	1	0	0	0	1	2	0
Wilson	3	2	2	4	10	46	39	53	27	1
Winkler	98	161	127	16	27	31	49	68	61	23
Wise	219	189	283	186	234	161	181	156	91	8
Wood	15	7	4	12	8	9	18	6	12	13
Yoakum	231	125	177	35	121	147	163	220	222	88
Young	41	55	76	37	54	45	68	64	65	18
Zapata	274	235	246	91	48	33	5	14	14	2
Zavala	16	14	7	7	11	46	75	66	78	44

Table 17. Total Number of New *Wellends* Completed per County.

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Anderson	26	27	39	22	5	7	10	10	12	2
Andrews	291	294	506	411	868	1169	1113	710	827	191
Angelina	19	32	29	12	2	2	5	0	0	0
Aransas	9	11	13	3	2	2	1	3	1	2
Archer	60	77	104	91	80	95	102	95	110	49
Armstrong	0	0	0	0	0	0	0	0	0	0
Atascosa	11	3	6	17	42	52	147	176	293	72
Austin	8	7	28	15	9	9	8	9	6	2
Bailey	0	0	0	0	0	0	0	0	0	0
Bandera	0	2	1	0	0	0	0	0	0	0
Bastrop	0	4	20	1	6	3	2	3	1	0
Baylor	3	3	6	1	1	5	12	12	16	4
Bee	62	56	63	30	36	21	42	29	15	1
Bell	0	0	0	0	0	0	0	0	0	0
Bexar	0	2	1	2	4	0	5	47	14	0
Blanco	0	0	0	0	0	0	0	0	0	0
Borden	21	49	21	8	33	50	44	56	46	9
Bosque	13	3	2	0	0	0	0	1	0	0
Bowie	1	2	1	1	1	0	0	0	1	0
Brazoria	24	22	30	12	35	44	55	34	31	21
Brazos	41	36	51	41	106	41	34	75	82	12
Brewster	1	0	0	0	0	0	0	0	0	0
Briscoe	0	1	0	0	0	0	0	0	0	0
Brooks	29	25	52	15	24	24	19	16	14	3
Brown	7	15	11	5	43	45	10	5	7	2
Burleson	19	19	70	6	102	38	8	21	78	12
Burnet	0	0	0	0	0	0	0	0	0	0
Caldwell	15	43	15	15	30	43	49	19	34	9
Calhoun	10	11	10	7	3	2	3	2	1	0
Callahan	17	16	22	15	14	7	10	8	17	7
Cameron	0	0	0	3	0	3	0	0	0	0
Camp	0	1	0	2	1	0	1	4	2	0
Carson	4	9	15	15	0	22	28	16	19	0
Cass	1	0	0	4	3	6	4	5	6	1
Castro	0	0	0	0	0	0	0	0	0	0
Chambers	14	2	16	10	37	38	48	36	45	8
Cherokee	45	55	78	22	10	12	6	8	16	10
Childress	0	0	3	0	0	0	0	0	0	0
Clay	24	18	41	6	14	18	25	17	11	3
Cochran	18	10	43	22	22	45	15	31	12	2
Coke	31	14	20	13	29	33	35	25	17	3
Coleman	4	12	13	8	46	42	41	44	23	11
Collin	0	0	0	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	4	0	0	0
Colorado	29	34	32	11	24	18	7	4	7	1
Comal	0	0	0	0	0	0	0	0	0	0
Comanche	3	4	2	2	2	4	1	4	8	2
Concho	19	23	27	7	4	11	5	5	4	2
Cooke	71	70	71	38	106	131	69	38	34	10
Coryell	0	3	3	0	0	0	0	0	0	0
Cottle	9	7	13	2	5	4	1	2	5	1
Crane	160	184	151	59	85	118	147	213	160	76
Crockett	293	297	314	64	169	98	150	210	215	54
Crosby	1	37	24	26	41	96	122	127	187	34
Culberson	10	7	9	9	18	47	42	65	85	48

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dallam	0	0	0	1	0	0	1	0	0	0
Dallas	0	8	10	8	9	1	2	4	0	0
Dawson	32	42	38	18	36	62	57	48	53	8
Deaf Smith	0	0	0	0	0	0	0	0	0	0
Delta	0	0	0	0	0	0	0	0	0	0
Denton	228	231	292	129	168	101	70	104	54	17
DeWitt	40	47	72	31	61	175	226	359	322	97
Dickens	25	23	24	11	11	10	6	6	9	0
Dimmit	92	62	84	38	166	344	596	540	637	256
Donley	0	0	0	0	0	0	0	0	0	0
Duval	59	80	74	28	33	25	35	57	41	16
Eastland	23	54	12	7	4	6	4	4	4	4
Ector	239	157	237	236	458	496	698	672	498	106
Edwards	31	30	21	19	50	7	9	4	6	3
Ellis	3	16	21	10	9	4	0	0	0	0
El Paso	0	0	0	0	0	0	0	0	0	0
Erath	56	64	77	13	5	2	0	0	0	0
Falls	0	0	1	1	1	2	4	4	4	2
Fannin	0	0	0	0	0	0	2	0	0	0
Fayette	38	13	21	16	29	20	34	20	46	9
Fisher	12	20	35	22	30	38	41	42	38	18
Floyd	1	2	0	0	1	0	1	0	0	0
Foard	0	28	9	1	2	0	4	3	1	0
Fort Bend	44	35	34	23	40	61	44	78	88	7
Franklin	0	3	9	1	2	4	10	11	29	4
Freestone	217	243	214	166	128	97	46	16	16	5
Frio	20	62	52	21	29	80	88	81	128	18
Gaines	216	171	172	70	229	218	163	182	235	95
Galveston	14	15	10	1	7	7	7	7	2	1
Garza	46	42	50	39	29	29	29	39	46	11
Gillespie	0	0	0	0	0	0	0	0	0	0
Glasscock	71	79	79	69	220	589	733	581	526	114
Goliad	91	53	58	12	26	17	7	1	4	1
Gonzales	2	7	8	10	49	187	297	386	254	58
Gray	54	9	7	3	1	10	14	10	1	0
Grayson	11	9	6	6	14	16	22	24	24	9
Gregg	66	62	60	19	11	18	16	26	26	5
Grimes	11	15	17	16	17	10	23	14	21	2
Guadalupe	4	3	8	3	7	18	20	27	6	3
Hale	24	15	17	7	8	0	1	0	1	0
Hall	0	0	0	0	0	0	0	0	0	0
Hamilton	3	3	0	0	0	0	0	0	0	0
Hansford	31	16	31	16	4	7	8	8	7	2
Hardeman	13	11	12	3	5	6	11	11	6	10
Hardin	42	35	48	39	46	56	51	56	25	13
Harris	12	12	16	9	16	9	3	10	23	5
Harrison	268	302	297	133	93	64	46	35	72	8
Hartley	5	3	4	2	7	8	10	4	6	1
Haskell	9	6	10	15	26	39	34	19	37	4
Hays	0	0	0	0	0	0	0	0	0	0
Hemphill	273	256	298	112	121	134	116	120	119	37
Henderson	14	15	19	11	5	3	4	5	13	6
Hidalgo	139	159	138	51	47	50	40	37	56	12
Hill	45	51	117	28	10	0	0	0	0	0
Hockley	136	117	112	45	65	54	36	44	57	3
Hood	146	270	200	38	25	42	47	5	7	0
Hopkins	0	1	0	1	0	1	4	1	2	1

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Houston	17	24	13	6	11	19	21	34	35	4
Howard	43	73	96	61	130	220	314	429	397	133
Hudspeth	1	3	4	0	0	0	0	0	0	0
Hunt	0	0	0	0	0	0	0	0	0	0
Hutchinson	45	156	103	22	18	13	22	12	17	3
Irion	27	22	69	41	50	170	237	264	267	66
Jack	67	131	55	32	33	71	128	123	254	19
Jackson	38	31	54	23	21	15	21	16	23	7
Jasper	5	21	37	26	12	21	16	12	3	0
Jeff Davis	2	1	1	0	0	0	0	0	0	0
Jefferson	29	41	31	24	38	34	39	28	18	5
Jim Hogg	29	15	8	2	3	2	3	9	4	0
Jim Wells	6	9	18	10	17	8	6	5	5	2
Johnson	535	841	898	426	360	241	102	19	6	2
Jones	44	50	53	38	40	41	37	52	38	10
Karnes	9	13	23	18	109	276	492	494	613	112
Kaufman	0	0	0	0	0	0	1	3	0	1
Kendall	0	0	0	0	0	0	0	0	0	0
Kenedy	26	24	38	20	18	14	0	6	5	3
Kent	13	21	33	24	28	21	22	35	20	2
Kerr	0	0	0	0	0	0	0	0	0	0
Kimble	3	1	0	1	1	0	0	0	0	0
King	22	24	27	10	14	13	12	29	36	9
Kinney	0	0	0	0	0	0	0	0	0	0
Kleberg	20	24	15	5	15	26	21	19	13	7
Knox	3	4	8	2	1	5	8	7	6	0
Lamar	0	0	0	0	0	0	0	0	0	0
Lamb	3	3	9	4	6	3	3	0	0	1
Lampasas	1	6	5	1	1	0	1	1	0	0
La Salle	64	50	55	33	105	239	515	611	638	238
Lavaca	102	61	57	26	38	28	36	63	129	19
Lee	35	19	33	18	21	37	39	21	27	0
Leon	75	74	60	38	43	69	43	39	25	4
Liberty	36	39	34	14	16	18	14	15	13	0
Limestone	87	121	156	57	51	26	20	14	10	4
Lipscomb	128	101	170	57	70	116	118	114	132	16
Live Oak	47	39	54	25	52	74	111	185	162	35
Llano	0	0	0	0	0	0	0	0	0	0
Loving	42	50	44	29	54	56	177	161	152	100
Lubbock	8	7	15	25	23	9	13	4	5	4
Lynn	3	6	3	3	3	11	11	7	3	2
McCulloch	1	0	0	3	0	0	1	1	6	4
McLennan	0	2	3	0	0	0	0	0	0	0
McMullen	50	57	85	40	86	148	305	413	477	135
Madison	19	6	12	8	20	26	46	62	71	2
Marion	12	6	12	1	3	3	9	7	8	4
Martin	120	178	191	119	402	635	788	612	673	145
Mason	0	0	0	0	0	0	0	0	0	0
Matagorda	40	39	59	25	25	17	14	11	9	1
Maverick	79	68	210	109	27	34	14	12	7	0
Medina	1	4	18	16	45	54	100	114	47	11
Menard	9	8	9	6	6	22	16	6	3	3
Midland	227	161	233	170	348	565	548	489	593	218
Milam	22	9	3	54	84	224	333	319	39	0
Mills	0	1	0	0	0	0	0	0	0	0
Mitchell	122	199	228	160	154	164	162	108	46	9
Montague	97	69	127	70	190	208	217	167	105	1

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Montgomery	12	1	7	7	11	9	5	10	3	0
Moore	56	44	39	31	21	35	73	20	47	26
Morris	0	0	0	0	0	0	0	0	0	0
Motley	0	0	1	0	0	0	0	0	1	1
Nacogdoches	228	233	241	87	71	71	36	2	3	1
Navarro	37	14	28	11	10	6	11	11	7	2
Newton	24	6	7	15	26	14	4	6	7	2
Nolan	21	35	49	18	42	70	72	67	47	26
Nueces	40	47	40	30	26	35	14	19	10	7
Ochiltree	43	36	75	48	84	86	124	142	158	30
Oldham	3	4	6	2	7	10	12	24	9	3
Orange	13	12	6	5	13	5	11	7	6	0
Palo Pinto	77	61	109	64	31	13	36	52	76	19
Panola	366	374	337	179	149	120	128	155	103	38
Parker	357	295	242	84	63	105	137	50	30	8
Parmer	0	0	0	0	0	0	0	0	0	0
Pecos	274	360	445	253	308	176	148	178	185	154
Polk	13	44	52	22	22	25	22	12	5	0
Potter	62	6	5	4	19	17	3	4	15	8
Presidio	0	0	0	0	0	0	0	0	0	0
Rains	0	1	0	2	0	0	0	0	0	0
Randall	0	0	0	0	0	0	0	0	0	0
Reagan	208	169	252	141	440	385	381	321	394	156
Real	0	0	2	1	0	0	1	0	0	0
Red River	0	0	1	1	0	2	1	1	1	0
Reeves	48	52	71	31	60	224	332	354	374	163
Refugio	78	77	70	80	84	71	62	48	60	42
Roberts	117	99	122	32	42	58	73	63	86	20
Robertson	120	148	203	117	67	71	44	34	15	3
Rockwall	0	0	0	0	0	0	0	0	0	0
Runnels	79	40	46	10	28	26	18	24	18	12
Rusk	332	349	311	90	50	39	55	54	57	23
Sabine	3	4	1	1	6	6	4	1	1	0
San Augustine	0	12	32	53	74	65	26	11	12	1
San Jacinto	4	19	10	16	13	16	9	3	2	0
San Patricio	30	22	19	10	13	25	18	19	9	3
San Saba	0	0	0	0	0	0	0	0	0	0
Schleicher	52	19	31	18	29	45	45	32	25	5
Scurry	107	58	115	94	78	101	80	143	134	56
Shackelford	42	48	85	48	60	48	41	56	37	12
Shelby	71	124	179	79	100	44	22	17	15	0
Sherman	18	15	79	19	5	8	10	14	1	6
Smith	104	51	20	13	11	11	11	12	21	5
Somervell	19	34	55	6	5	4	3	0	0	0
Starr	129	128	167	51	43	35	41	27	45	6
Stephens	32	39	55	13	25	50	41	50	80	16
Sterling	56	71	53	52	41	22	50	51	44	3
Stonewall	17	24	40	40	81	81	75	59	68	11
Sutton	167	61	124	40	59	29	27	14	0	0
Swisher	0	0	0	0	0	0	0	0	0	0
Tarrant	316	616	787	540	540	516	243	118	92	30
Taylor	15	17	15	19	8	20	19	34	32	11
Terrell	71	48	39	2	6	2	2	0	1	1
Terry	66	55	51	32	27	31	34	24	13	12
Throckmorton	21	23	26	10	15	16	32	58	60	18
Titus	8	0	2	0	0	1	5	5	21	2
Tom Green	26	26	18	46	14	16	25	17	13	3

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Travis	0	0	0	0	0	0	0	0	0	0
Trinity	3	2	2	1	0	3	0	0	3	0
Tyler	59	69	62	50	32	30	17	11	2	1
Upshur	40	48	24	7	4	10	1	3	14	6
Upton	233	303	477	194	493	589	622	530	557	192
Uvalde	1	0	0	0	0	0	0	0	0	0
Val Verde	16	11	1	9	0	0	0	2	0	0
Van Zandt	4	18	10	6	5	5	8	4	6	0
Victoria	48	34	51	38	28	20	20	22	15	1
Walker	7	0	3	0	0	0	1	7	5	0
Waller	32	34	26	17	17	7	7	11	4	2
Ward	347	222	250	105	240	288	308	300	284	62
Washington	26	8	10	3	10	1	4	26	12	0
Webb	287	241	361	198	321	389	447	369	457	50
Wharton	57	29	68	30	51	50	46	37	33	7
Wheeler	175	197	241	75	134	202	206	212	92	5
Wichita	108	125	160	135	118	162	136	135	147	35
Wilbarger	55	32	28	21	35	39	67	35	39	20
Willacy	12	18	16	15	16	9	7	6	9	0
Williamson	0	1	0	1	0	0	0	1	2	0
Wilson	9	7	2	6	10	52	40	63	28	2
Winkler	106	164	132	19	27	34	50	70	62	24
Wise	220	190	287	187	238	164	184	161	100	8
Wood	21	7	4	14	9	11	20	6	12	13
Yoakum	238	132	183	36	122	156	163	221	223	89
Young	41	55	76	37	54	45	68	64	65	18
Zapata	277	239	250	92	48	37	5	14	14	2
Zavala	32	34	18	17	11	60	98	83	104	49

Table 18. Total Number of New Directional Wells Completed per County.

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Anderson	7	5	3	1	0	0	0	2	3	0
Andrews	15	10	11	16	47	156	315	140	158	42
Angelina	4	12	6	2	1	0	3	0	0	0
Aransas	7	10	6	2	2	0	0	1	1	1
Archer	0	0	0	0	0	4	2	0	1	0
Armstrong	0	0	0	0	0	0	0	0	0	0
Atascosa	0	0	0	2	27	47	138	167	290	70
Austin	2	2	2	4	4	1	2	2	2	0
Bailey	0	0	0	0	0	0	0	0	0	0
Bandera	0	0	0	0	0	0	0	0	0	0
Bastrop	0	0	10	0	1	0	2	2	1	0
Baylor	0	0	0	0	0	3	0	0	2	0
Bee	12	11	20	1	5	1	15	5	4	0
Bell	0	0	0	0	0	0	0	0	0	0
Bexar	0	0	0	0	0	0	0	0	0	0
Blanco	0	0	0	0	0	0	0	0	0	0
Borden	3	14	5	0	6	11	9	7	16	0
Bosque	13	3	2	0	0	0	0	1	0	0
Bowie	0	1	1	1	1	0	0	0	0	0
Brazoria	15	8	5	7	10	13	30	23	18	3
Brazos	37	31	43	40	99	33	33	73	80	12
Brewster	0	0	0	0	0	0	0	0	0	0
Briscoe	0	0	0	0	0	0	0	0	0	0
Brooks	7	4	12	2	8	7	4	4	2	1

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brown	0	0	0	0	0	0	0	0	0	0
Burleson	12	13	49	4	92	37	7	19	77	12
Burnet	0	0	0	0	0	0	0	0	0	0
Caldwell	2	3	5	9	19	25	41	16	24	4
Calhoun	3	3	5	0	0	0	2	1	0	0
Callahan	0	0	0	0	0	0	0	0	0	0
Cameron	0	0	0	3	0	3	0	0	0	0
Camp	0	0	0	1	0	0	0	0	1	0
Carson	2	5	10	11	0	17	18	10	12	0
Cass	0	0	0	0	0	1	1	1	1	0
Castro	0	0	0	0	0	0	0	0	0	0
Chambers	9	0	10	5	15	14	28	30	18	5
Cherokee	6	23	20	2	3	2	1	2	7	4
Childress	0	0	0	0	0	0	0	0	0	0
Clay	1	1	6	0	0	4	2	5	3	0
Cochran	4	1	2	1	5	7	3	3	6	0
Coke	1	0	0	1	0	2	3	2	1	0
Coleman	0	0	0	0	1	0	1	0	0	0
Collin	0	0	0	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	0	0	0	0
Colorado	5	3	7	0	1	2	3	1	0	0
Comal	0	0	0	0	0	0	0	0	0	0
Comanche	0	1	0	0	0	0	0	0	0	0
Concho	0	0	0	0	0	0	0	0	0	0
Cooke	1	4	4	15	65	106	52	15	9	1
Coryell	0	0	0	0	0	0	0	0	0	0
Cottle	0	0	1	0	0	0	0	0	0	0
Crane	3	15	10	3	16	46	70	70	22	1
Crockett	13	20	18	2	4	36	95	157	183	40
Crosby	0	0	0	2	2	1	3	1	0	0
Culberson	3	2	4	3	9	16	19	52	80	46
Dallam	0	0	0	0	0	0	0	0	0	0
Dallas	0	7	10	8	9	1	2	4	0	0
Dawson	6	5	2	1	0	1	0	2	13	0
Deaf Smith	0	0	0	0	0	0	0	0	0	0
Delta	0	0	0	0	0	0	0	0	0	0
Denton	167	211	278	126	165	99	63	89	53	17
DeWitt	6	16	38	16	52	169	218	351	316	96
Dickens	0	0	0	0	1	1	0	0	0	0
Dimmit	47	35	44	29	156	336	589	531	620	249
Donley	0	0	0	0	0	0	0	0	0	0
Duval	3	7	11	6	7	2	2	2	1	0
Eastland	2	16	0	0	0	0	0	0	0	0
Ector	27	14	22	5	20	55	176	147	76	32
Edwards	2	12	7	1	1	0	0	0	0	0
Ellis	3	15	21	10	9	4	0	0	0	0
El Paso	0	0	0	0	0	0	0	0	0	0
Erath	40	56	73	9	1	0	0	0	0	0
Falls	0	0	0	0	0	0	0	0	0	0
Fannin	0	0	0	0	0	0	0	0	0	0
Fayette	29	10	14	13	24	16	30	16	41	9
Fisher	0	2	0	2	1	2	4	4	1	0
Floyd	0	1	0	0	0	0	0	0	0	0
Foard	0	0	0	0	0	0	0	0	0	0
Fort Bend	18	7	13	1	8	19	9	5	7	0
Franklin	0	1	0	0	1	3	7	5	7	0
Freestone	36	34	33	46	46	40	13	5	5	1

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Frio	14	11	17	6	26	70	78	76	125	17
Gaines	7	11	12	10	26	29	15	32	65	16
Galveston	12	13	6	0	6	6	4	7	2	1
Garza	2	0	1	1	3	2	1	5	3	0
Gillespie	0	0	0	0	0	0	0	0	0	0
Glasscock	1	1	1	2	6	30	29	72	156	48
Goliad	15	12	11	1	2	2	0	0	0	0
Gonzales	0	4	3	4	47	169	278	381	251	55
Gray	0	1	0	0	0	0	0	0	0	0
Grayson	2	3	3	0	4	7	17	14	16	6
Gregg	26	16	21	10	7	5	4	4	5	0
Grimes	11	14	15	15	17	8	19	11	19	1
Guadalupe	2	3	4	2	4	12	11	14	4	3
Hale	8	3	4	5	2	0	0	0	0	0
Hall	0	0	0	0	0	0	0	0	0	0
Hamilton	1	1	0	0	0	0	0	0	0	0
Hansford	16	0	4	0	2	4	4	4	2	1
Hardeman	3	5	4	0	3	4	6	6	2	2
Hardin	8	7	9	3	7	8	1	3	0	1
Harris	3	8	7	3	10	2	2	6	13	3
Harrison	29	39	110	80	86	46	33	22	41	2
Hartley	1	0	0	0	0	0	1	0	1	0
Haskell	0	0	0	0	0	0	0	1	0	0
Hays	0	0	0	0	0	0	0	0	0	0
Hemphill	13	10	53	14	62	115	107	112	113	35
Henderson	2	1	4	2	2	0	0	0	4	6
Hidalgo	34	35	34	11	21	14	17	10	11	0
Hill	44	49	116	28	10	0	0	0	0	0
Hockley	25	31	39	10	14	14	10	13	13	0
Hood	133	267	197	38	25	42	47	5	7	0
Hopkins	0	0	0	0	0	0	1	1	0	0
Houston	6	12	8	3	0	0	5	6	21	1
Howard	2	6	0	1	2	2	6	11	33	18
Hudspeth	0	0	0	0	0	0	0	0	0	0
Hunt	0	0	0	0	0	0	0	0	0	0
Hutchinson	7	15	13	15	5	0	0	0	0	0
Irion	0	0	0	2	3	36	109	166	165	49
Jack	28	50	21	3	4	9	16	2	1	0
Jackson	3	1	3	3	4	2	2	5	4	1
Jasper	4	16	35	24	11	19	11	6	2	0
Jeff Davis	1	0	0	0	0	0	0	0	0	0
Jefferson	13	24	13	10	25	23	22	11	7	0
Jim Hogg	1	1	3	1	0	1	0	4	0	0
Jim Wells	0	0	0	0	0	0	0	0	0	0
Johnson	522	835	890	425	359	241	102	19	5	2
Jones	0	0	1	0	0	0	0	1	0	0
Karnes	2	5	15	11	96	260	476	489	610	108
Kaufman	0	0	0	0	0	0	1	1	0	1
Kendall	0	0	0	0	0	0	0	0	0	0
Kenedy	9	8	11	3	4	4	0	1	1	2
Kent	1	1	6	1	7	0	1	15	3	0
Kerr	0	0	0	0	0	0	0	0	0	0
Kimble	0	0	0	0	0	0	0	0	0	0
King	1	0	0	0	1	2	2	0	4	1
Kinney	0	0	0	0	0	0	0	0	0	0
Kleberg	9	14	11	2	7	5	4	2	2	0
Knox	0	0	0	0	0	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Lamar	0	0	0	0	0	0	0	0	0	0
Lamb	0	2	2	0	2	0	0	0	0	0
Lampasas	0	0	0	0	0	0	0	0	0	0
La Salle	8	8	2	26	100	231	505	599	625	237
Lavaca	16	12	19	2	6	15	25	46	107	16
Lee	24	12	22	16	13	29	34	19	26	0
Leon	9	11	18	13	18	36	29	21	13	4
Liberty	17	13	9	5	7	8	3	6	8	0
Limestone	12	17	33	13	21	17	5	0	1	0
Lipscomb	101	76	136	50	64	110	114	108	127	15
Live Oak	10	16	16	10	26	60	92	166	142	32
Llano	0	0	0	0	0	0	0	0	0	0
Loving	1	6	3	4	16	26	115	132	130	89
Lubbock	0	0	3	4	4	1	6	0	0	4
Lynn	1	1	0	0	0	0	3	2	0	0
McCulloch	0	0	0	0	0	0	0	0	0	0
McLennan	0	0	0	0	0	0	0	0	0	0
McMullen	5	0	5	12	58	131	284	391	456	128
Madison	10	4	7	6	14	18	31	36	51	1
Marion	1	0	5	0	1	0	2	2	2	0
Martin	2	2	1	1	1	3	9	24	136	63
Mason	0	0	0	0	0	0	0	0	0	0
Matagorda	13	8	10	5	6	6	0	6	1	1
Maverick	33	61	65	18	22	23	14	11	6	0
Medina	0	0	0	0	0	1	0	0	0	0
Menard	0	0	0	0	0	0	0	0	0	0
Midland	3	14	13	8	3	7	18	62	189	111
Milam	0	2	0	0	4	6	7	4	0	0
Mills	0	0	0	0	0	0	0	0	0	0
Mitchell	0	0	0	0	0	4	9	10	3	0
Montague	4	18	42	56	171	195	196	147	90	0
Montgomery	4	1	2	4	10	4	0	5	3	0
Moore	7	2	5	4	1	14	35	0	0	0
Morris	0	0	0	0	0	0	0	0	0	0
Motley	0	0	0	0	0	0	0	0	0	0
Nacogdoches	53	57	72	23	41	66	23	0	2	0
Navarro	0	0	1	1	1	0	2	4	0	0
Newton	17	3	4	9	19	9	3	3	2	1
Nolan	0	0	0	0	9	20	10	8	5	0
Nueces	4	13	6	7	6	10	2	5	1	1
Ochiltree	11	7	43	32	67	66	111	129	131	29
Oldham	0	0	0	0	0	1	1	5	5	2
Orange	8	9	5	3	11	3	8	4	5	0
Palo Pinto	4	23	62	31	4	4	11	6	1	2
Panola	51	94	122	104	92	80	97	104	81	29
Parker	328	278	237	79	63	103	137	45	29	6
Parmer	0	0	0	0	0	0	0	0	0	0
Pecos	90	106	157	129	178	69	51	70	93	93
Polk	5	35	41	15	13	17	9	4	3	0
Potter	33	3	0	2	9	2	0	0	10	8
Presidio	0	0	0	0	0	0	0	0	0	0
Rains	0	0	0	2	0	0	0	0	0	0
Randall	0	0	0	0	0	0	0	0	0	0
Reagan	1	0	0	1	1	14	63	166	301	134
Real	0	0	1	0	0	0	1	0	0	0
Red River	0	0	0	1	0	1	0	0	0	0
Reeves	7	15	35	5	10	43	50	131	301	141

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Refugio	1	0	0	1	4	1	1	3	0	1
Roberts	16	22	25	11	27	41	64	47	74	18
Robertson	44	53	70	46	34	47	36	30	15	2
Rockwall	0	0	0	0	0	0	0	0	0	0
Runnels	0	0	1	0	0	1	0	0	0	0
Rusk	22	39	37	23	21	14	27	25	36	16
Sabine	2	3	0	1	5	5	4	0	0	0
San Augustine	0	12	30	50	71	64	24	11	12	1
San Jacinto	0	6	2	2	6	5	2	1	1	0
San Patricio	1	8	5	8	4	6	4	4	1	2
San Saba	0	0	0	0	0	0	0	0	0	0
Schleicher	1	0	0	0	0	3	3	13	10	1
Scurry	15	7	24	33	10	8	7	29	42	19
Shackelford	0	1	2	0	3	0	0	1	1	0
Shelby	32	92	129	55	82	36	19	11	13	0
Sherman	1	0	0	9	0	0	0	1	0	0
Smith	65	32	14	4	2	2	6	3	8	2
Somervell	16	33	54	6	5	4	3	0	0	0
Starr	19	15	15	11	2	1	3	6	15	2
Stephens	0	3	5	3	1	1	6	6	6	1
Sterling	3	0	0	0	1	1	11	17	12	0
Stonewall	0	0	0	0	6	1	1	0	2	0
Sutton	3	2	1	0	1	1	1	3	0	0
Swisher	0	0	0	0	0	0	0	0	0	0
Tarrant	311	605	779	530	539	516	243	117	92	30
Taylor	0	0	2	1	0	0	0	1	0	1
Terrell	17	9	7	1	0	0	0	0	0	0
Terry	15	4	16	4	4	2	7	7	5	3
Throckmorton	0	1	0	0	0	0	2	12	23	2
Titus	0	0	0	0	0	1	3	4	8	1
Tom Green	0	0	0	0	0	0	0	0	0	0
Travis	0	0	0	0	0	0	0	0	0	0
Trinity	1	1	0	0	0	2	0	0	1	0
Tyler	56	63	56	47	29	21	8	5	2	1
Upshur	1	2	4	0	2	0	1	0	3	2
Upton	17	20	22	11	27	18	21	93	235	109
Uvalde	0	0	0	0	0	0	0	0	0	0
Val Verde	2	4	0	0	0	0	0	0	0	0
Van Zandt	0	1	0	1	1	0	0	0	1	0
Victoria	1	0	3	3	0	0	0	3	1	0
Walker	0	0	1	0	0	0	1	3	2	0
Waller	7	6	1	3	4	3	3	2	1	1
Ward	12	32	46	12	42	95	118	119	122	28
Washington	22	6	9	2	10	1	4	20	4	0
Webb	35	33	61	56	209	345	425	355	444	45
Wharton	3	3	9	3	4	5	3	2	1	0
Wheeler	28	38	47	32	114	186	192	201	83	3
Wichita	0	0	0	0	0	0	0	0	0	1
Wilbarger	0	0	0	0	1	0	3	4	4	2
Willacy	4	5	2	8	6	3	0	0	2	0
Williamson	0	0	0	0	0	0	0	0	0	0
Wilson	6	5	1	3	5	40	36	59	26	1
Winkler	14	9	10	7	4	9	13	20	28	8
Wise	116	158	256	175	218	153	176	154	84	8
Wood	11	0	4	7	3	3	8	2	4	9
Yoakum	31	22	35	3	21	46	64	89	141	50
Young	0	1	0	0	0	1	2	2	2	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Zapata	87	82	82	29	11	10	1	5	0	0
Zavala	22	30	17	15	8	52	87	74	97	48

Table 19. Total Number of New Vertical Wellheads Completed per County.

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Anderson	23	23	37	21	6	7	10	11	8	2
Andrews	289	293	504	413	837	1154	1063	659	718	152
Angelina	19	34	28	11	1	2	1	0	0	0
Aransas	12	12	12	3	5	4	1	4	1	2
Archer	60	78	105	92	83	94	99	95	109	49
Armstrong	0	0	0	0	0	0	0	0	0	0
Atascosa	14	3	6	15	16	5	10	9	3	2
Austin	8	7	34	18	9	10	11	9	5	2
Bailey	0	0	0	0	0	0	0	0	0	0
Bandera	0	2	1	0	0	0	0	0	0	0
Bastrop	0	8	8	1	4	3	0	1	0	0
Baylor	3	3	6	1	1	4	12	12	14	4
Bee	56	56	54	36	41	26	29	26	12	1
Bell	0	0	0	0	0	0	0	0	0	0
Bexar	0	2	1	2	4	0	5	47	14	0
Blanco	0	0	0	0	0	0	0	0	0	0
Borden	23	41	19	9	28	33	39	51	40	9
Bosque	0	0	0	0	0	0	0	0	0	0
Bowie	1	1	1	1	0	0	0	0	1	0
Brazoria	22	26	35	10	35	38	51	32	30	21
Brazos	2	3	7	0	1	4	0	0	1	0
Brewster	1	0	0	0	0	0	0	0	0	0
Briscoe	0	1	0	0	0	0	0	0	0	0
Brooks	33	27	51	14	29	24	17	16	15	3
Brown	7	17	12	5	45	45	10	5	7	2
Burleson	4	4	16	1	0	0	2	1	1	0
Burnet	0	0	0	0	0	0	0	0	0	0
Caldwell	13	42	11	6	11	18	8	3	10	5
Calhoun	11	12	10	7	4	2	3	3	1	0
Callahan	17	16	24	15	14	7	10	8	17	8
Cameron	0	0	0	1	1	3	0	0	0	0
Camp	0	1	0	0	1	0	1	4	2	0
Carson	2	2	2	0	0	2	3	0	12	0
Cass	1	0	1	4	3	5	3	4	6	1
Castro	0	0	0	0	0	0	0	0	0	0
Chambers	20	4	19	13	34	37	41	34	44	7
Cherokee	46	55	72	20	11	11	5	6	8	7
Childress	0	0	3	0	0	0	0	0	0	0
Clay	24	18	37	6	14	14	24	12	8	3
Cochran	12	8	39	20	16	38	10	27	6	2
Coke	33	16	22	14	30	33	35	23	17	3
Coleman	4	12	15	8	45	44	40	46	24	11
Collin	0	0	0	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	4	0	0	0
Colorado	38	40	29	11	25	20	6	4	7	1
Comal	0	0	0	0	0	0	0	0	0	0
Comanche	3	3	2	2	2	4	1	4	9	2
Concho	20	24	27	7	4	12	5	5	4	2
Cooke	72	72	78	31	61	30	18	23	24	9
Coryell	0	3	3	0	0	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cottle	9	7	12	2	6	4	1	2	5	1
Crane	170	170	155	63	76	84	80	160	145	75
Crockett	297	277	312	66	165	62	55	53	37	20
Crosby	1	37	24	24	41	94	121	127	188	34
Culberson	6	9	7	5	9	31	23	13	5	2
Dallam	0	0	0	1	0	0	1	0	0	0
Dallas	0	0	0	0	0	0	0	0	0	0
Dawson	28	37	35	17	39	63	59	47	46	8
Deaf Smith	0	0	0	0	0	0	0	0	0	0
Delta	0	0	0	0	0	0	0	0	0	0
Denton	92	45	17	5	3	2	4	0	0	0
DeWitt	40	40	42	20	11	8	9	11	7	1
Dickens	26	26	25	11	11	10	7	6	9	0
Dimmit	44	32	39	8	8	8	8	9	16	7
Donley	0	0	0	0	0	0	0	0	0	0
Duval	60	82	75	27	26	27	35	57	41	16
Eastland	22	40	12	7	4	6	4	4	4	4
Ector	228	157	225	254	490	523	666	648	463	96
Edwards	29	15	17	20	49	7	9	4	6	3
Ellis	0	0	0	0	0	0	0	0	0	0
El Paso	0	0	0	0	0	0	0	0	0	0
Erath	17	9	4	6	4	2	0	0	0	0
Falls	0	0	1	1	1	2	4	4	4	2
Fannin	0	0	0	0	0	0	2	0	0	0
Fayette	6	1	4	2	5	5	4	4	4	0
Fisher	12	17	38	20	31	38	36	41	39	18
Floyd	2	0	0	0	1	0	1	0	0	0
Foard	0	28	9	1	2	0	4	3	1	0
Fort Bend	44	33	32	25	38	61	43	77	87	7
Franklin	0	2	10	1	3	1	3	6	29	4
Freestone	235	248	212	156	111	89	46	13	12	4
Frio	10	52	33	15	4	10	10	5	2	1
Gaines	222	165	162	60	195	209	162	179	226	93
Galveston	14	13	9	1	7	8	9	6	2	1
Garza	46	43	50	38	26	27	29	34	43	11
Gillespie	0	0	0	0	0	0	0	0	0	0
Glasscock	76	85	81	72	231	593	717	516	376	67
Goliad	107	57	77	16	30	17	7	1	4	1
Gonzales	2	2	4	5	2	7	12	4	3	3
Gray	54	7	7	3	1	10	14	10	1	0
Grayson	12	9	5	7	13	12	11	13	10	6
Gregg	68	68	62	18	9	15	12	24	26	5
Grimes	1	1	3	1	2	3	3	3	2	1
Guadalupe	2	0	4	1	3	6	10	13	2	1
Hale	21	10	10	1	6	0	1	0	1	0
Hall	0	0	0	0	0	0	0	0	0	0
Hamilton	2	2	0	0	0	0	0	0	0	0
Hansford	16	17	28	18	2	3	4	4	5	1
Hardeman	10	6	8	3	3	2	7	4	6	7
Hardin	45	35	53	41	48	55	51	56	25	13
Harris	14	12	15	7	15	8	3	7	22	5
Harrison	279	303	259	67	12	21	16	14	31	6
Hartley	3	4	4	3	7	8	10	4	5	1
Haskell	9	7	10	16	26	41	36	19	38	4
Hays	0	0	0	0	0	0	0	0	0	0
Hemphill	276	257	261	106	66	19	11	8	5	2
Henderson	15	15	20	11	5	3	4	5	10	2

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Hidalgo	152	171	153	57	54	48	39	37	55	12
Hill	1	3	0	0	1	0	0	0	0	0
Hockley	99	69	55	37	53	48	29	36	54	3
Hood	12	4	2	0	0	0	0	0	0	0
Hopkins	0	1	0	1	0	1	3	0	2	1
Houston	12	17	9	4	12	21	18	30	26	3
Howard	43	75	99	71	147	229	315	423	368	115
Hudspeth	1	3	4	0	0	0	0	0	0	0
Hunt	0	0	0	0	0	0	0	0	0	0
Hutchinson	44	138	84	3	12	14	23	12	17	3
Irion	27	24	78	44	53	133	128	98	100	17
Jack	44	83	38	32	32	65	121	130	256	19
Jackson	40	36	65	31	23	19	23	17	24	7
Jasper	6	5	4	3	7	5	3	9	2	0
Jeff Davis	0	1	1	0	0	0	0	0	0	0
Jefferson	34	44	40	25	38	26	34	26	17	5
Jim Hogg	32	16	8	1	3	2	3	5	4	0
Jim Wells	7	11	27	12	19	8	6	5	6	2
Johnson	14	7	8	1	1	0	0	0	1	1
Jones	47	54	53	39	43	45	37	52	38	10
Karnes	8	10	13	7	14	16	17	4	5	4
Kaufman	0	0	0	0	0	0	1	2	0	1
Kendall	0	0	0	0	0	0	0	0	0	0
Kenedy	27	31	39	23	18	13	0	6	5	2
Kent	12	22	33	26	26	21	21	35	21	2
Kerr	0	0	0	0	0	0	0	0	0	0
Kimble	4	1	0	1	1	0	0	0	0	0
King	21	24	28	10	14	13	12	29	35	9
Kinney	0	0	0	0	0	0	0	0	0	0
Kleberg	17	22	16	5	13	29	21	18	13	7
Knox	3	4	8	2	1	5	8	7	6	0
Lamar	0	0	0	0	0	0	0	0	0	0
Lamb	3	1	6	4	3	3	3	0	0	1
Lampasas	1	6	5	1	1	0	1	1	0	0
La Salle	59	45	54	8	4	8	10	9	13	3
Lavaca	112	72	60	28	37	14	13	19	26	5
Lee	4	5	9	1	3	2	2	1	1	0
Leon	78	72	61	36	34	44	18	18	12	1
Liberty	42	37	34	13	19	17	15	15	9	0
Limestone	98	134	153	55	42	18	19	14	10	4
Lipscomb	27	24	13	6	5	6	4	6	5	1
Live Oak	46	29	43	19	30	15	21	20	23	3
Llano	0	0	0	0	0	0	0	0	0	0
Loving	42	45	47	24	38	31	61	29	20	11
Lubbock	9	7	9	17	16	7	2	4	5	0
Lynn	1	4	4	3	3	11	8	5	3	2
McCulloch	1	0	0	3	0	0	1	1	6	4
McLennan	0	2	3	0	0	0	0	0	0	0
McMullen	54	61	85	28	30	19	23	23	21	7
Madison	7	3	7	1	8	9	16	27	37	1
Marion	12	6	8	1	3	3	8	7	6	4
Martin	124	179	199	137	453	652	797	599	542	82
Mason	0	0	0	0	0	0	0	0	0	0
Matagorda	48	44	62	25	28	18	14	9	9	1
Maverick	48	4	149	92	4	11	1	2	1	0
Medina	1	4	19	16	45	53	100	114	47	11
Menard	9	8	9	7	6	22	16	6	3	3

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Midland	228	150	226	161	368	583	555	443	425	108
Milam	22	8	3	55	80	218	326	315	39	0
Mills	0	1	0	0	0	0	0	0	0	0
Mitchell	146	216	230	161	156	166	160	100	43	9
Montague	96	54	89	17	20	17	23	21	16	1
Montgomery	12	2	7	4	3	7	5	10	3	0
Moore	44	40	33	25	19	20	23	20	47	26
Morris	0	0	0	0	0	0	0	0	0	0
Motley	0	0	1	0	0	0	0	0	1	1
Nacogdoches	202	223	216	81	37	6	14	2	1	1
Navarro	37	14	28	9	10	6	10	7	7	2
Newton	25	6	8	9	9	6	4	5	7	2
Nolan	23	35	55	19	38	72	71	64	45	30
Nueces	49	62	48	37	28	34	14	18	11	7
Ochiltree	40	35	33	17	19	20	13	14	29	1
Oldham	3	4	6	2	8	10	12	23	6	2
Orange	14	11	6	4	12	6	12	7	5	0
Palo Pinto	80	41	51	36	27	10	27	64	77	17
Panola	396	374	322	137	118	65	36	55	27	9
Parker	25	13	5	6	0	3	1	5	2	2
Parmer	0	0	0	0	0	0	0	0	0	0
Pecos	138	193	315	100	169	72	69	80	57	22
Polk	10	10	17	10	13	12	17	13	5	0
Potter	20	1	6	1	7	15	3	4	6	0
Presidio	0	0	0	0	0	0	0	0	0	0
Rains	0	1	0	1	0	0	0	0	0	0
Randall	0	0	0	0	0	0	0	0	0	0
Reagan	209	170	253	140	441	374	319	155	92	22
Real	0	0	1	1	0	0	0	0	0	0
Red River	0	0	1	0	0	1	1	1	1	0
Reeves	44	41	40	26	49	183	299	238	84	21
Refugio	137	137	114	112	111	95	73	62	64	42
Roberts	110	93	105	25	17	17	9	19	12	2
Robertson	102	116	157	92	48	30	13	4	0	1
Rockwall	0	0	0	0	0	0	0	0	0	0
Runnels	83	41	47	12	29	26	23	24	20	12
Rusk	417	445	327	87	39	26	30	30	21	8
Sabine	1	1	1	0	2	1	0	1	1	0
San Augustine	0	0	2	3	2	1	2	0	0	0
San Jacinto	4	19	10	16	15	16	10	2	1	0
San Patricio	35	28	23	9	13	25	17	20	12	2
San Saba	0	0	0	0	0	0	0	0	0	0
Schleicher	52	23	31	18	31	42	43	20	16	4
Scurry	106	54	100	72	77	96	79	134	127	51
Shackelford	42	49	83	50	58	50	41	55	37	12
Shelby	45	39	61	32	26	13	2	1	4	0
Sherman	17	15	79	8	5	8	11	13	1	6
Smith	101	52	17	14	11	11	11	11	14	3
Somervell	3	1	1	0	0	0	0	0	0	0
Starr	134	131	171	53	44	36	40	26	45	6
Stephens	34	38	55	10	25	52	35	47	79	15
Sterling	54	75	60	56	43	22	40	33	31	3
Stonewall	17	24	40	40	82	83	78	59	67	11
Sutton	168	61	123	40	59	29	26	12	0	0
Swisher	0	0	0	0	0	0	0	0	0	0
Tarrant	12	17	13	12	3	1	0	0	0	0
Taylor	15	18	13	18	8	23	20	36	34	10

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Terrell	62	39	32	1	7	2	2	0	1	1
Terry	46	48	28	30	23	32	24	14	10	9
Throckmorton	21	22	26	10	16	17	32	47	39	16
Titus	8	0	2	0	0	0	2	1	21	2
Tom Green	30	28	22	47	16	16	25	17	13	3
Travis	0	0	0	0	0	0	0	0	0	0
Trinity	2	1	2	1	0	3	0	0	2	0
Tyler	6	10	9	3	6	14	12	7	2	1
Upshur	43	49	23	7	2	10	0	3	11	4
Upton	219	299	472	195	489	578	614	464	330	83
Uvalde	1	0	0	0	0	0	0	0	0	0
Val Verde	15	10	1	9	0	0	0	2	0	0
Van Zandt	4	19	10	5	5	5	8	4	6	0
Victoria	69	50	67	45	39	21	22	21	14	1
Walker	7	0	2	0	0	0	0	6	3	0
Waller	32	36	27	16	18	7	7	11	4	2
Ward	340	186	202	94	200	204	201	196	193	41
Washington	2	2	1	2	0	0	0	4	8	0
Webb	274	233	327	164	121	52	26	21	15	6
Wharton	74	45	83	34	65	67	47	47	33	7
Wheeler	195	219	250	47	27	15	13	13	9	2
Wichita	111	127	160	138	119	164	136	138	147	34
Wilbarger	56	32	32	22	35	40	64	30	35	18
Willacy	16	19	21	18	17	9	8	6	10	0
Williamson	0	1	0	1	0	0	0	1	2	0
Wilson	1	0	2	3	6	11	3	3	2	0
Winkler	92	155	125	12	27	24	37	49	35	16
Wise	135	43	34	12	17	8	5	3	7	0
Wood	8	8	1	7	11	8	15	5	12	8
Yoakum	232	124	177	37	122	146	161	215	205	77
Young	41	59	84	37	55	47	68	67	63	18
Zapata	284	239	251	89	50	34	4	11	14	2
Zavala	9	6	1	1	5	8	12	8	6	1

Table 20. Total Number of New Horizontal Wellends Completed per County.

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Anderson	5	5	2	0	0	0	0	0	2	0
Andrews	36	23	18	29	51	23	49	57	118	39
Angelina	4	1	4	1	1	0	4	0	0	0
Aransas	0	0	0	0	0	0	0	0	0	0
Archer	0	0	0	0	0	2	3	0	1	0
Armstrong	0	0	0	0	0	0	0	0	0	0
Atascosa	0	0	0	1	29	47	138	166	290	70
Austin	0	0	0	0	0	0	0	0	0	0
Bailey	0	0	0	0	0	0	0	0	0	0
Bandera	0	0	0	0	0	0	0	0	0	0
Bastrop	0	0	12	0	2	0	2	2	1	0
Baylor	0	0	0	0	0	1	0	0	2	0
Bee	10	11	17	1	5	1	14	4	3	0
Bell	0	0	0	0	0	0	0	0	0	0
Bexar	0	0	0	0	0	0	0	0	0	0
Blanco	0	0	0	0	0	0	0	0	0	0
Borden	3	12	5	0	11	17	9	7	6	0
Bosque	13	3	2	0	0	0	0	1	0	0
Bowie	0	0	0	0	1	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brazoria	0	0	0	0	0	0	4	0	0	0
Brazos	45	37	48	41	102	37	36	75	79	12
Brewster	0	0	0	0	0	0	0	0	0	0
Briscoe	0	0	0	0	0	0	0	0	0	0
Brooks	0	0	0	0	0	0	0	0	0	0
Brown	0	0	0	0	0	0	0	0	0	0
Burleson	15	15	55	5	104	38	7	19	77	12
Burnet	0	0	0	0	0	0	0	0	0	0
Caldwell	2	1	8	11	21	29	43	14	24	4
Calhoun	0	0	0	0	0	0	0	0	0	0
Callahan	0	0	0	0	0	0	0	0	0	0
Cameron	0	0	0	0	0	0	0	0	0	0
Camp	0	0	0	2	0	0	0	0	0	0
Carson	2	7	13	15	0	20	24	16	7	0
Cass	0	0	0	0	0	0	1	1	0	0
Castro	0	0	0	0	0	0	0	0	0	0
Chambers	0	0	0	0	0	0	0	2	0	0
Cherokee	2	5	12	2	3	1	0	4	8	2
Childress	0	0	0	0	0	0	0	0	0	0
Clay	0	1	6	0	0	4	2	5	3	0
Cochran	7	2	4	2	8	7	5	4	6	0
Coke	0	0	0	0	0	0	1	2	0	0
Coleman	0	0	0	0	2	0	0	0	0	0
Collin	0	0	0	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	0	0	0	0
Colorado	0	0	0	0	0	0	1	0	0	0
Comal	0	0	0	0	0	0	0	0	0	0
Comanche	0	1	0	0	0	0	0	0	0	0
Concho	0	0	0	0	0	0	0	0	0	0
Cooke	1	2	2	7	47	101	51	15	10	1
Coryell	0	0	0	0	0	0	0	0	0	0
Cottle	0	0	0	0	0	0	0	0	0	0
Crane	2	17	7	0	11	36	71	57	19	1
Crockett	2	22	6	0	4	34	97	157	177	34
Crosby	0	0	0	2	0	2	0	0	0	0
Culberson	4	0	3	4	9	16	19	53	80	46
Dallam	0	0	0	0	0	0	0	0	0	0
Dallas	0	8	10	8	9	1	2	4	0	0
Dawson	9	10	4	0	0	0	0	1	7	0
Deaf Smith	0	0	0	0	0	0	0	0	0	0
Delta	0	0	0	0	0	0	0	0	0	0
Denton	137	184	274	123	166	99	66	104	54	17
DeWitt	2	12	36	13	64	187	226	352	314	96
Dickens	0	0	0	0	0	0	0	0	0	0
Dimmit	54	40	47	33	161	343	608	535	618	249
Donley	0	0	0	0	0	0	0	0	0	0
Duval	0	0	3	2	6	0	0	0	0	0
Eastland	2	14	0	0	0	0	0	0	0	0
Ector	16	6	13	0	3	12	36	24	35	7
Edwards	2	19	5	0	0	0	0	0	0	0
Ellis	3	16	21	10	9	4	0	0	0	0
El Paso	0	0	0	0	0	0	0	0	0	0
Erath	44	55	73	8	0	0	0	0	0	0
Falls	0	0	0	0	0	0	0	0	0	0
Fannin	0	0	0	0	0	0	0	0	0	0
Fayette	32	15	17	16	21	16	30	16	42	9
Fisher	0	3	0	2	0	0	5	4	1	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Floyd	0	2	0	0	0	0	0	0	0	0
Foard	0	0	0	0	0	0	0	0	0	0
Fort Bend	0	2	2	0	0	0	0	1	0	0
Franklin	0	0	0	0	0	3	7	5	0	0
Freestone	6	7	15	12	21	8	3	3	4	1
Frio	18	7	20	10	27	77	81	77	129	17
Gaines	17	30	22	11	37	11	6	2	8	1
Galveston	0	0	0	0	0	0	0	0	0	0
Garza	0	0	1	1	3	2	1	5	2	0
Gillespie	0	0	0	0	0	0	0	0	0	0
Glasscock	0	2	0	2	7	26	26	66	153	48
Goliad	0	0	0	0	0	0	0	0	0	0
Gonzales	0	6	6	6	47	182	290	388	251	54
Gray	0	2	0	0	0	0	0	0	0	0
Grayson	0	0	0	0	3	4	11	14	14	3
Gregg	0	1	1	2	3	4	4	2	0	0
Grimes	11	14	15	15	14	8	21	11	18	0
Guadalupe	2	5	4	2	6	14	10	14	6	2
Hale	2	5	14	7	2	0	0	0	0	0
Hall	0	0	0	0	0	0	0	0	0	0
Hamilton	1	1	0	0	0	0	0	0	0	0
Hansford	14	0	5	0	2	4	4	4	2	1
Hardeman	2	4	2	0	2	6	4	6	1	2
Hardin	0	0	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0	0	0
Harrison	3	8	44	67	87	44	33	21	41	2
Hartley	2	0	0	0	0	0	1	0	1	0
Haskell	0	0	0	0	0	0	0	1	0	0
Hays	0	0	0	0	0	0	0	0	0	0
Hemphill	0	2	38	9	58	118	107	112	114	35
Henderson	0	0	0	0	0	0	0	0	3	4
Hidalgo	0	0	0	0	0	0	1	0	0	0
Hill	44	49	117	28	9	0	0	0	0	0
Hockley	38	61	72	8	13	6	7	8	3	0
Hood	134	265	197	38	25	42	47	5	7	0
Hopkins	0	0	0	0	0	0	0	1	0	0
Houston	7	12	4	2	0	0	5	3	9	0
Howard	1	3	0	0	0	1	0	7	29	18
Hudspeth	0	0	0	0	0	0	0	0	0	0
Hunt	0	0	0	0	0	0	0	0	0	0
Hutchinson	9	22	20	19	6	0	0	0	0	0
Irion	0	0	0	3	6	38	109	165	164	49
Jack	30	55	21	3	5	8	11	0	1	0
Jackson	0	0	0	1	0	1	0	2	0	0
Jasper	0	16	33	23	8	18	13	0	1	0
Jeff Davis	2	0	0	0	0	0	0	0	0	0
Jefferson	0	0	0	0	0	0	1	0	0	0
Jim Hogg	0	0	1	1	0	0	0	5	0	0
Jim Wells	0	0	0	0	0	0	0	0	0	0
Johnson	524	838	890	425	360	241	102	19	4	0
Jones	0	0	1	0	0	0	0	0	0	0
Karnes	2	5	11	11	104	263	479	496	612	108
Kaufman	0	0	0	0	0	0	0	0	0	0
Kendall	0	0	0	0	0	0	0	0	0	0
Kenedy	0	0	0	0	0	0	0	0	0	0
Kent	0	0	0	0	2	0	1	0	0	0
Kerr	0	0	0	0	0	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kimble	0	0	0	0	0	0	0	0	0	0
King	0	0	0	0	0	0	0	0	3	0
Kinney	0	0	0	0	0	0	0	0	0	0
Kleberg	4	2	0	0	4	2	0	0	0	0
Knox	0	0	0	0	0	0	0	0	0	0
Lamar	0	0	0	0	0	0	0	0	0	0
Lamb	0	2	3	0	2	0	0	0	0	0
Lampasas	0	0	0	0	0	0	0	0	0	0
La Salle	4	8	2	33	108	237	507	605	626	235
Lavaca	3	5	10	1	1	13	25	45	102	15
Lee	29	14	23	17	18	37	37	20	26	0
Leon	3	6	4	4	11	25	23	21	13	3
Liberty	0	2	0	0	0	0	0	0	0	0
Limestone	1	4	7	2	9	8	1	0	1	0
Lipscomb	102	77	160	51	64	110	116	107	128	15
Live Oak	6	9	12	9	26	61	92	164	142	32
Llano	0	0	0	0	0	0	0	0	0	0
Loving	0	7	2	4	17	29	118	134	132	89
Lubbock	0	0	6	8	6	2	11	0	0	4
Lynn	2	2	0	0	0	0	1	2	0	0
McCulloch	0	0	0	0	0	0	0	0	0	0
McLennan	0	0	0	0	0	0	0	0	0	0
McMullen	0	4	3	12	61	133	292	398	459	128
Madison	14	3	8	7	12	16	30	35	32	1
Marion	1	0	4	0	1	0	1	1	2	0
Martin	4	2	0	0	0	3	4	24	139	63
Mason	0	0	0	0	0	0	0	0	0	0
Matagorda	0	0	0	0	0	0	0	1	0	0
Maverick	55	93	75	19	23	23	13	10	5	0
Medina	0	0	0	0	0	1	0	0	0	0
Menard	0	0	0	0	0	0	0	0	0	0
Midland	3	17	13	6	1	1	3	50	172	113
Milam	0	2	0	0	4	6	7	4	0	0
Mills	0	0	0	0	0	0	0	0	0	0
Mitchell	0	0	0	0	0	0	2	10	3	0
Montague	4	18	36	55	170	192	194	147	89	0
Montgomery	0	1	0	4	7	0	0	0	0	0
Moore	12	7	6	6	2	15	50	0	0	0
Morris	0	0	0	0	0	0	0	0	0	0
Motley	0	0	0	0	0	0	0	0	0	0
Nacogdoches	32	17	31	7	36	66	22	0	2	0
Navarro	0	0	0	2	0	0	3	4	0	0
Newton	4	0	6	7	12	9	2	0	0	0
Nolan	0	0	0	0	3	2	2	4	4	0
Nueces	0	0	0	0	4	2	0	0	0	0
Ochiltree	9	7	47	33	68	65	111	130	129	29
Oldham	0	0	0	0	0	0	0	1	3	1
Orange	0	0	0	0	0	0	0	0	0	0
Palo Pinto	5	25	66	31	3	4	9	5	1	2
Panola	4	15	33	47	44	58	93	103	78	29
Parker	333	284	237	78	63	102	135	45	28	4
Parmer	0	0	0	0	0	0	0	0	0	0
Pecos	242	210	169	168	152	125	86	110	132	132
Polk	5	35	38	12	11	13	7	0	0	0
Potter	47	5	0	3	18	2	0	0	9	8
Presidio	0	0	0	0	0	0	0	0	0	0
Rains	0	0	0	0	0	0	0	0	0	0

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Randall	0	0	0	0	0	0	0	0	0	0
Reagan	0	0	0	1	1	15	63	168	303	133
Real	0	0	0	0	0	0	2	0	0	0
Red River	0	0	0	1	0	1	0	0	0	0
Reeves	10	21	37	6	14	46	48	114	289	151
Refugio	0	0	0	0	0	0	0	0	0	0
Roberts	15	11	19	9	28	41	66	44	74	18
Robertson	46	36	50	25	19	45	32	30	15	2
Rockwall	0	0	0	0	0	0	0	0	0	0
Runnels	0	0	1	0	0	1	0	0	0	0
Rusk	0	2	7	11	14	15	26	26	36	14
Sabine	0	0	0	1	5	5	4	0	0	0
San Augustine	0	12	31	51	73	64	24	11	12	1
San Jacinto	0	0	0	0	0	0	0	1	1	0
San Patricio	0	0	0	0	1	1	3	2	0	0
San Saba	0	0	0	0	0	0	0	0	0	0
Schleicher	1	0	0	0	0	3	3	13	10	1
Scurry	1	5	16	20	1	4	1	8	6	4
Shackelford	0	1	2	0	3	0	0	1	0	0
Shelby	31	89	123	52	80	34	20	15	10	0
Sherman	1	0	0	10	0	0	0	1	0	0
Smith	6	1	3	0	0	0	0	1	4	2
Somervell	16	33	54	6	5	4	3	0	0	0
Starr	0	0	4	2	0	0	0	0	0	0
Stephens	0	2	5	3	0	0	6	2	2	0
Sterling	5	0	0	0	0	1	11	20	13	0
Stonewall	0	0	0	0	0	0	0	0	1	0
Sutton	0	0	1	0	0	1	0	2	0	0
Swisher	0	0	0	0	0	0	0	0	0	0
Tarrant	305	601	776	530	539	515	244	118	92	30
Taylor	0	0	2	0	0	0	0	0	0	0
Terrell	7	7	7	1	0	0	0	0	0	0
Terry	22	6	24	3	4	1	10	8	1	0
Throckmorton	0	0	0	0	0	0	2	11	23	2
Titus	0	0	0	0	0	1	3	4	0	0
Tom Green	0	0	0	0	0	0	0	0	0	0
Travis	0	0	0	0	0	0	0	0	0	0
Trinity	1	1	0	0	0	0	0	0	1	0
Tyler	54	60	57	48	28	17	3	7	0	0
Upshur	0	0	1	0	2	0	1	0	3	2
Upton	20	16	22	6	2	7	17	75	235	109
Uvalde	0	0	0	0	0	0	0	0	0	0
Val Verde	1	0	0	0	0	0	0	0	0	0
Van Zandt	0	1	0	1	1	0	0	0	0	0
Victoria	0	0	0	0	0	0	0	2	1	0
Walker	0	0	1	0	0	0	3	1	2	0
Waller	0	0	0	0	0	0	0	0	0	0
Ward	18	47	72	23	43	87	106	103	92	22
Washington	24	6	9	0	10	1	4	22	4	0
Webb	20	16	32	46	223	344	425	349	442	44
Wharton	0	0	0	0	0	0	0	0	0	0
Wheeler	1	4	12	30	109	188	195	197	83	3
Wichita	0	0	0	0	0	0	0	0	0	1
Wilbarger	0	0	0	0	0	0	3	5	4	2
Willacy	0	0	0	0	0	0	0	0	0	0
Williamson	0	0	0	0	0	0	0	0	0	0
Wilson	16	7	0	3	5	37	37	62	26	2

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Winkler	19	9	9	6	2	9	15	23	26	8
Wise	89	150	252	174	220	158	179	157	93	8
Wood	14	0	4	5	0	2	5	1	0	5
Yoakum	0	7	7	0	0	8	2	5	18	11
Young	0	0	0	0	0	1	2	1	2	0
Zapata	1	2	5	4	1	0	1	3	0	0
Zavala	29	32	19	19	7	55	90	83	98	48