Transportation Impacts of Marcellus Shale Development

The Marcellus Shale Impacts Study Wave 2: Chronicling Social and Economic Change in Northern and Southwestern Pennsylvania

March 2017

Executive Summary

Traffic concerns, especially truck traffic and road safety, have been identified in a number of studies in the Marcellus Shale region (Brasier et al., 2011). By some estimates, a single well in the Marcellus Shale region requires approximately 1,500 truck trips (Graham et al., 2015). In addition, motor vehicle deaths among workers in oil and gas industry are a leading cause of fatalities in the industry (Retzer et al., 2013). The number of additional trucks on the roads and the increased traffic due to gas worker transportation has raised significant concerns about the increased potential for accidents. This report supplements recently published findings on traffic impacts by providing the crash rates for four study counties in the project (Bradford, Lycoming, Washington, and Greene) in comparison to neighboring counties and for all counties in relation to the total number of wells drilled.

Two recently published studies directly related to traffic and road safety are reviewed. Food and Water Watch (2013) found that the number of heavy-truck crashes had been declining in Pennsylvania since 2000, but that this trend was seemingly curtailed with the onset of natural gas extraction. It found that rural counties with large numbers of wells saw a 7 percent increase in heavy truck crashes in the period just after wells were completed, while counties without wells showed a 12 percent decrease in heavy truck crashes. It also found that, from 2005 to 2010, there was a 9 percent annual increase in heavy truck crashes in counties with a high number of wells; conversely, there was a 3 percent annual decrease in other counties. Graham et al. (2015) found that counties with a high number of wells in the northern tier of Pennsylvania had 15-23 percent higher total crash rates in 2010-2012 and 61-65 percent higher heavy truck crash rates in 2011 and 2012 than other counties. They also found a 5-23 percent increase in crash rates was found for drilling counties. Finally, they found a 45-47 percent increase in fatal and major injury crashes in the southwest region in drilled counties for 2012.

This research describes three indicators of traffic – total crashes, heavy truck crashes, and crashes with fatalities. The trends over time are described in years prior to (2000-2007) and during (2008-2012/13) active well development periods. The study used annual data provided to the public by the Pennsylvania Department of Transportation (PennDOT) and the National Highway Traffic Safety Administration (NHTSA) for the years 2000-2013 and 2000-2012[1] respectfully. The data are provided as both the raw counts – as the total volume has importance for the provision of public services – and as rates for comparisons across counties.

Total Crashes: In Bradford County, the number of total crashes increased from 585 in 2009 to 848 in 2011 before declining again the next 2 years. Similarly, Lycoming County experienced an increase from 1,165 crashes in 2009 to 1,330 in 2011 before a decline in 2012-2013. Several counties in the northern

[1] At the time of the analysis, fatality data from the NHTSA was only available through 2012.

tier region also had substantial increases in the number and rates of total crashes, including Tioga, Sullivan, Clinton, and Potter counties in 2009 and 2010. Greene County experienced an increase from 356 crashes in 2009 to 420 in 2012 before declining again in 2013. Washington County held relatively steady during this time period, and annual averages of 1,994 crashes for 2000-2007 and 2,006 crashes for 2008-2013. The southwestern region had little observable change in crash rates. The analysis of total crashes for all counties in the state suggest that, on average, the counties with 226 or more wells had a slightly higher increase in rates (16 percent) from 2009 to 2011, in comparison to counties with 1-225 wells, which averaged an 8 percent increase and counties with no activity that averaged a 5 percent increase.

Heavy Truck Crashes: Bradford and Lycoming ounties experienced dramatic increases in the number and rate of heavy truck crashes from 2009 to 2011. There was a 344 percent increase in the number of heavy truck crashes in Bradford County and a 132 percent increase in Lycoming County. Other northern tier counties also experienced substantial increases: Tioga County experienced a 292 percent increase, Susquehanna County a 61 percent increase and Clinton County a 157 percent increase in the number of heavy truck crashes from 2009 to 2011. Greene County experienced a 74 percent increase, and Washington County a 24 percent increase in the number of heavy truck crashes between 2009 and 2011. The rates for other southwestern region counties show only slight increases. The analysis of the heavy truck crash data in relation to the number of wells drilled across all Pennsylvania counties indicates that while the overall trends of the three types of counties are similar, the years 2009-2011 show a larger increase for counties with high drilling activity compared to the other counties. Counties with the highest number of wells (226 or more) had a 56 percent increase, on average, in the number of crashes between 2009 and 2011. In contrast, counties with 1-225 wells had a 19 percent increase and counties with no wells had a 16 percent increase in the number of crashes. Similarly, the rate increased 75 percent in counties with a high number of wells, compared to 36 percent for those with fewer wells and 27 percent for those with no wells.

Crashes with Fatalities: The numbers of crashes with fatalities in all study counties is quite small, so small changes can lead to very dynamic patterns that are difficult to interpret. No apparent trends for the study counties or for the study counties in relation to neighboring counties were identified. However, the analysis for all counties as classified by the number of wells suggests that counties with the highest number of wells have steady or increasing numbers and rates of crashes with fatalities, while other counties experienced decreasing numbers and rates for the period of most active well development.

Although the information presented in this report is descriptive, it provides a means to understand traffic trends both prior to and during the heaviest phases of well development to date. Overall, the findings suggest that the most rural counties in the northern tier experiencing the highest levels of development – particularly Bradford, Tioga, Susquehanna, Clinton, and Lycoming – had increased absolute numbers and rates of total crashes and heavy truck crashes. The years of greatest impact appear to be 2009-2011, when activity was at its peak. The data for crashes with fatalities do not show any patterns. These findings are consistent with previous studies (Graham et al., 2015). For the 2012-

2013 time period, and potentially in recent years, the number of crashes declined. This is likely due to two factors: decreased natural gas extraction due to low natural gas prices, and adaptations by operators and well servicing companies (such as using more piping for transporting water, recycling wastewater, and using rail to transport supplies). Both factors have likely led to a decline in the total number of trucks and oil and gas workers on the roads.

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This project was sponsored by a grant from the Center for Rural Pennsylvania, a legislative agency of the Pennsylvania General Assembly.

The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania's rural and small communities.

Information contained in this report does not necessarily reflect the views of individual board members or the Center for Rural Pennsylvania. For more information, contact the Center for Rural Pennsylvania, 625 Forster St., Room 902, Harrisburg, PA 17120, telephone (717) 787-9555, email: info@rural.palegislature.us, www.rural.palegislature.us.

About this Project

The Marcellus Shale Impacts Project chronicles the effects of shale-based energy development in Pennsylvania by focusing on the experiences of four counties with significant extraction and production activity – Bradford, Lycoming, Greene, and Washington counties. Wave 1 of the project was completed in 2013 and Wave 2 began in early 2014. Wave 1 focused predominantly on data collection and the use of descriptive statistics to present changes in various outcomes over time. Wave 2 focused on developing statistical models to describe relationships between Marcellus Shale development and a set of social and economic indicators, identifying change in social and economic outcomes that are associated with Marcellus Shale development, and identifying the characteristics of people and places associated with the magnitude and types of impact experienced. A particular focus of Wave 2 was to explore the heterogeneity in Marcellus Shale development with respect to the intensity of drilling activity. This research focused on three indicators of traffic – total crashes, heavy truck crashes, and crashes with fatalities – to identify and describe changes in these outcomes over time and compare these trends with those in neighboring counties.

Study Counties

This study focused on the same four counties examined in Wave 1 of the Marcellus Shale Impacts Study: Bradford, Lycoming, Greene, and Washington. These counties experienced among the highest levels of Marcellus Shale development in Pennsylvania over the past 8 years, and they have diverse populations, histories, economic bases, and geographic locations. These differences allow comparisons that facilitate understanding of the potential associations between Marcellus Shale development and various social, economic, and health outcomes. Regional comparisons are also made based on adjacency to the study counties. The northern tier counties include Bradford, Lycoming, Clinton, Columbia, Montour, Northumberland, Potter, Sullivan, Susquehanna, Tioga, Union, and Wyoming. The southwestern counties include Greene, Washington, Allegheny, Beaver, Fayette, and Westmoreland.

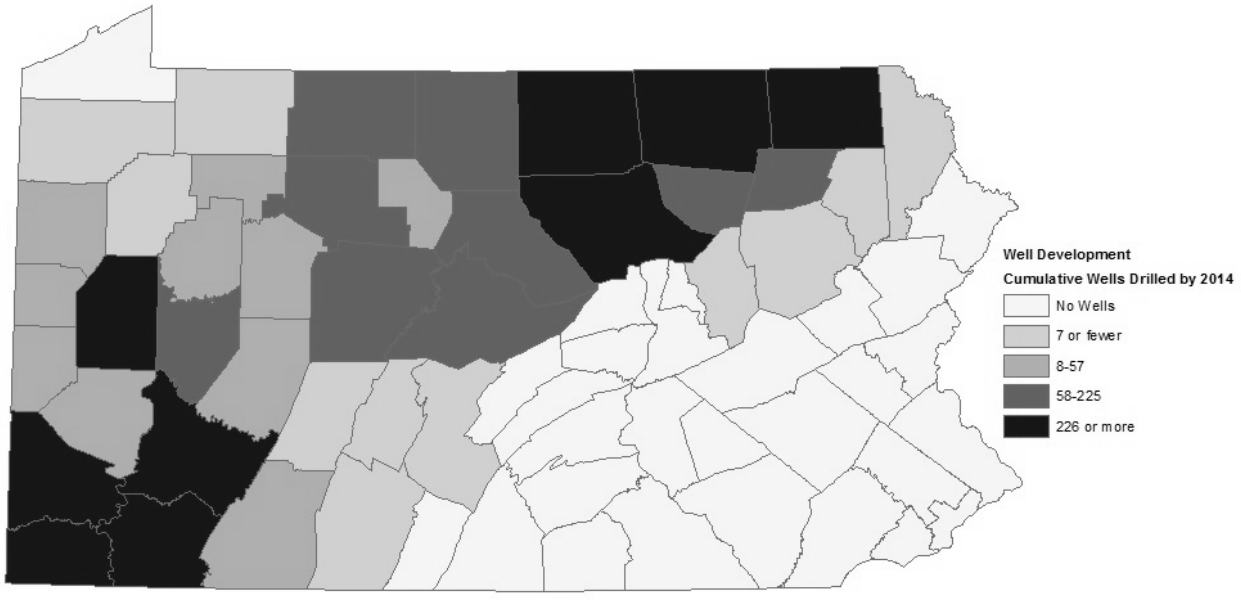
All four study counties are classified as rural by the Center for Rural Pennsylvania with population densities of less than 284 people per square mile. However, the U.S. Department of Agriculture's (USDA) Economic Research Service and the U.S. Census Bureau classify Lycoming and Washington counties as metropolitan counties. Lycoming County is in the Williamsport metropolitan area, and Washington County is part of the Pittsburgh metropolitan area. Bradford and Greene counties are classified by the USDA ERS as nonmetropolitan counties with small urban populations of less than 20,000 people. Both are adjacent to metropolitan areas.

Marcellus Shale Activity

Figure 1 presents the distribution of the cumulative number of wells drilled in each county in Pennsylvania through August of 2014. The cut points represent quintiles (intervals of 20 percent). Well development is concentrated in the northeast, northcentral, and southwestern portions of the state. In the northern tier, Bradford, Lycoming, Tioga, and Susquehanna counties have all experienced similar high levels of development. This suggests that comparisons of outcomes among these counties will be particularly useful. Similarly, the most useful comparisons will be between the neighboring southwestern counties with the most natural gas well development. These include Greene, Washington,

Fayette, and Westmoreland, although Greene and Washington counties have had substantially more wells drilled than Fayette and Westmoreland counties.

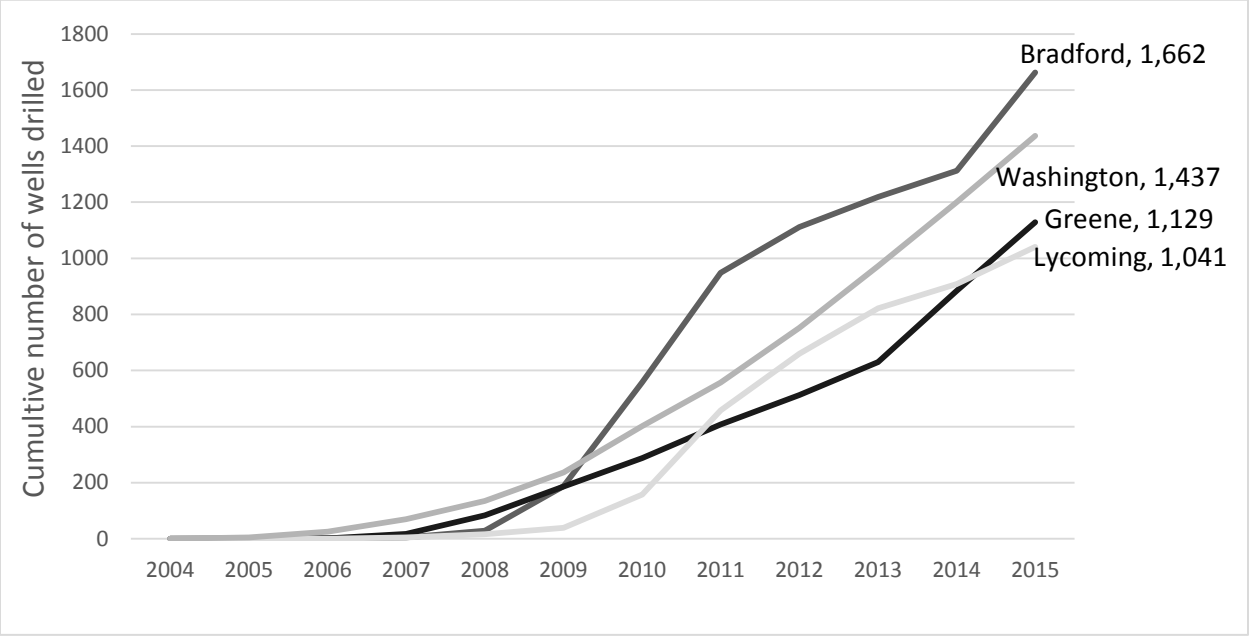
Figure 1. Cumulative Number of Unconventional Gas Wells Drilled, 2005-2014



Source: PA Department of Environmental Protection, Office of Oil and Gas Management

Figure 2 shows the cumulative number of unconventional wells drilled in the Marcellus Shale in the four study counties since 2005. Although some wells that were drilled early in the period may no longer be in production, and some new wells have not yet been put into production, the lines reveal overall trends in the study counties. The increase in wells drilled since 2009 has been substantial in all four counties, with Bradford and Washington counties experiencing the most pronounced increases. The increase in Bradford County was particularly robust between 2009 and 2011 and then leveled off to a slower growth rate after 2011. Lycoming experienced its steepest increase between 2010 and 2011, with steady but slightly lower growth rates after 2011. Development began earlier in the southwestern counties than in the northern tier counties, but growth in Washington and Greene counties has been relatively constant throughout the period with no dramatic spikes like those seen in the northern tier counties. Finally, although the pace of drilling appears to be leveling off in Bradford, Washington, and Lycoming counties, Greene County is continuing to experience an upward trend in development.

Figure 2. Cumulative number of wells drilled in four study counties, 2005-2015*

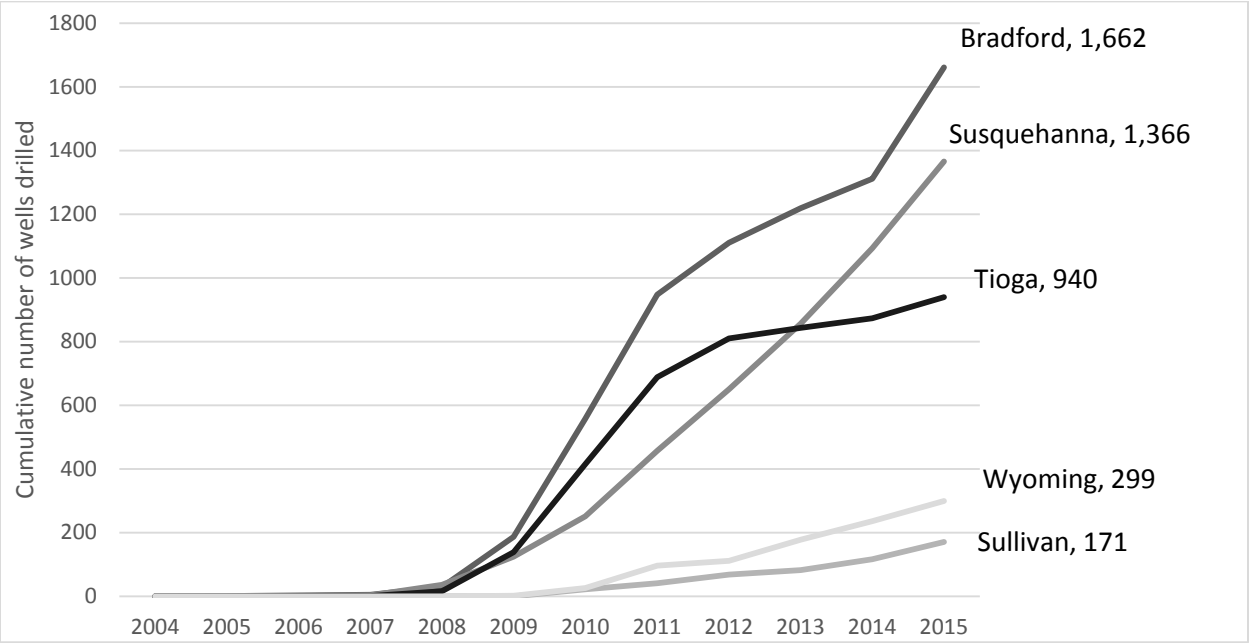


Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management. *through June 1, 2015

The next group of figures compares the cumulative number of wells drilled in the four study counties with their neighboring counties. Neighboring counties are defined as those that share a border or vertex (corner) with the study county. Although this report focuses on potential associations between Marcellus Shale development and traffic outcomes in the four study counties, counties do not exist in isolation. They are impacted by their neighbors, and given the spatial dependence of Marcellus Shale development (development is spatially clustered along the Marcellus Shale formation), traffic and traffic accidents may be affected not only by development in one county, but also by development in neighboring counties.

Due to the large number of neighboring counties, figures for the northern tier study counties are displayed separately to maintain visual ease. Figure 3 displays the cumulative number of wells drilled between 2005 through June 1, 2015 in Bradford County and its neighboring counties (Sullivan, Susquehanna, Tioga, and Wyoming). As can been seen from the figure, at 1,662, Bradford County has substantially more wells drilled than any of its neighboring counties. However, Susquehanna County has also experienced a rather large increase in drilling activity since 2008, and, if current trends continue, it could converge with Bradford County in the coming years.

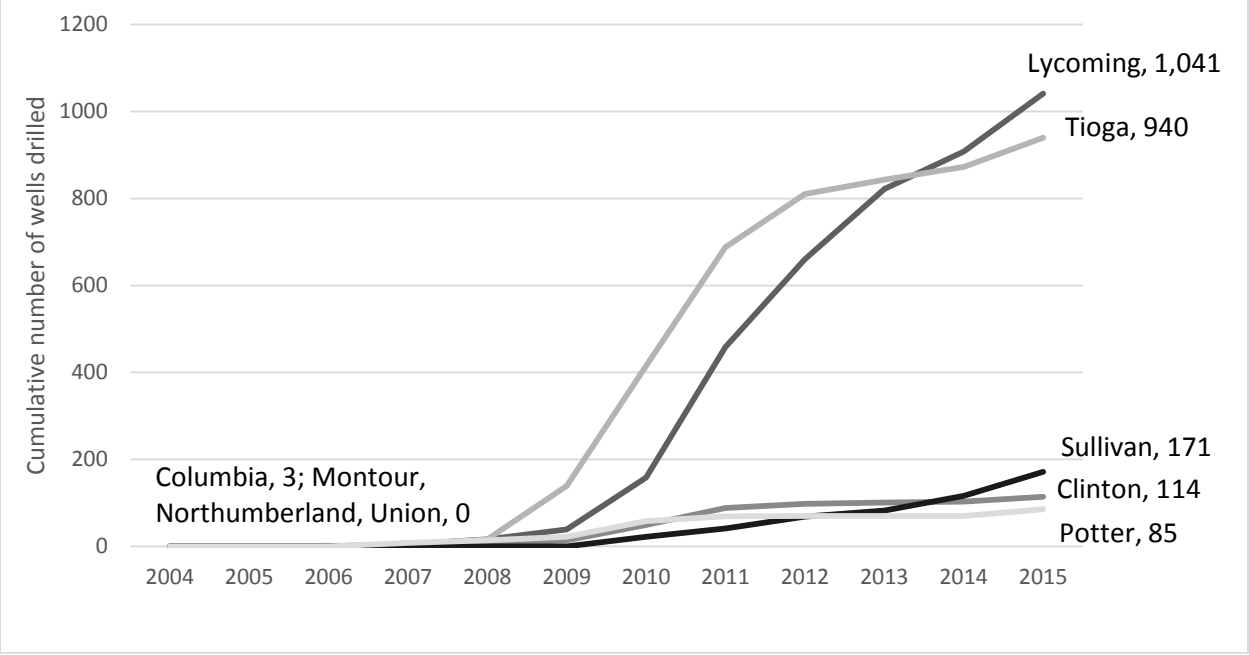
Figure 3. Cumulative number of wells drilled in Bradford and neighboring counties, 2005-2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management. *through June 1, 2015.

Figure 4 displays the cumulative number of wells for Lycoming County and its neighbors (Clinton, Columbia, Montour, Northumberland, Potter, Sullivan, Tioga, and Union). No wells have been drilled in Montour, Northumberland, and Union, and only three wells have been drilled in Columbia County. Lycoming and Tioga have a similar cumulative number of wells drilled. Clinton, Sullivan and Potter all have similar numbers of wells, and growth rates appear stable.

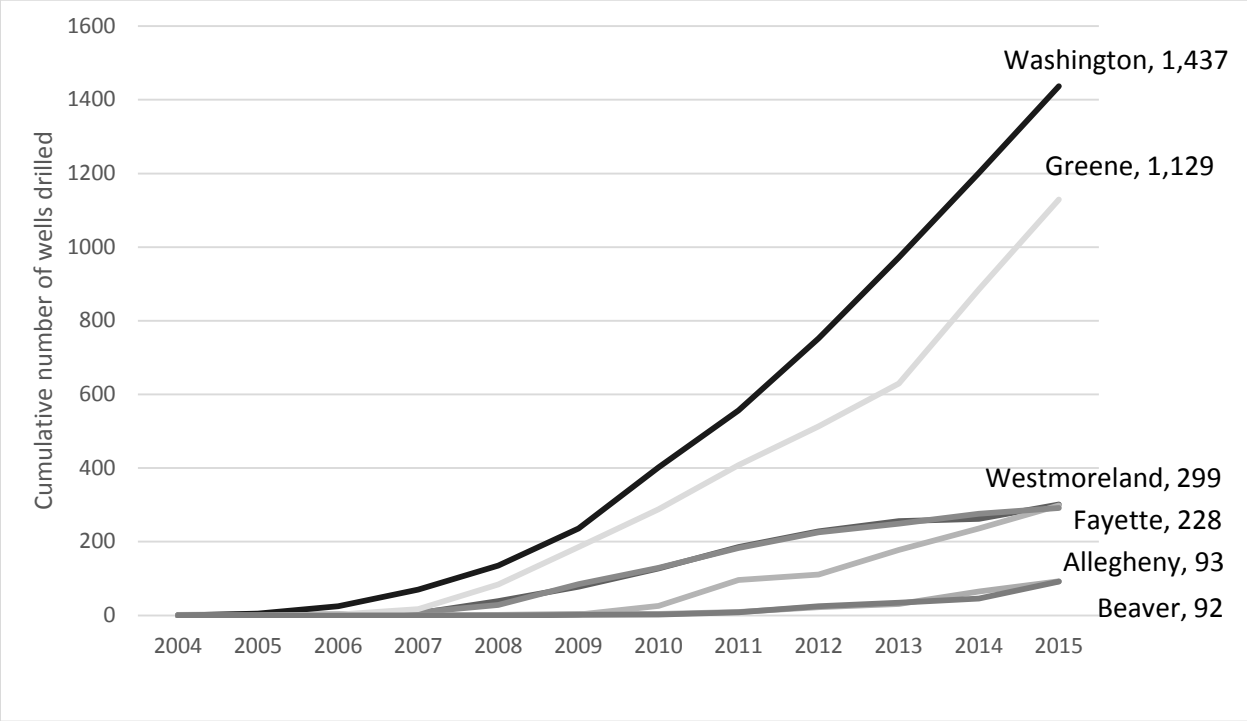
Figure 4. Cumulative number of wells drilled in Lycoming and neighboring counties, 2005-2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management. *through June 1, 2015.

Finally, Figure 5 displays the cumulative number of wells for the southwest study counties (Greene and Washington) and their neighbors (Allegheny, Beaver, Fayette, and Westmoreland). Washington and Greene have substantially more wells than their neighbors. Although Washington is showing signs of slight reduction in well growth rate, the growth rate for Greene continues to increase. Allegheny and Beaver counties both have low levels of development with low growth rates. Westmoreland and Fayette counties have 299 and 228 wells, respectively, with low growth rates.

Figure 5. Cumulative number of wells drilled in Greene, Washington and neighboring counties, 2005-2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management. *through June 1, 2015. Note: Lines for Fayette and Westmoreland overlap, as do lines for Allegheny and Beaver due to similar levels of drilling activity.

Previous Research

Traffic concerns, especially truck traffic and road safety, have been identified in a number of studies in the Marcellus Shale region (Brasier et al., 2011). By some estimates, a single well in the Marcellus Shale region requires approximately 1,500 truck trips (Graham et al., 2015), although some accounts suggest this number has decreased in recent years as the natural gas industry has moved toward technologies and practices that require fewer truck trips (e.g., piping freshwater from impoundments, on-site recycling of produced water). The number of additional trucks on the roads has raised significant concerns about traffic and safety due to increased potential for accidents. In addition, motor vehicle deaths among workers in oil and gas extraction are a leading cause of fatality in the industry (Retzer et al., 2013).

However, relatively few empirical studies of traffic and transportation impacts have been published. The project team found two recently published studies directly related to traffic and road safety: “The Social

Costs of Fracking," by Food and Water Watch (2013), and "Increased Traffic Accident Rates Associated with Shale Gas Drilling in Pennsylvania" by Graham and colleagues published in 2015.[2]

Food and Water Watch is an advocacy organization that opposes unconventional natural gas development. Its report, published on its website in 2013, discusses three areas in which the authors feel the "high social costs" of hydraulic fracturing are most apparent: rate increases in social disorder crimes (e.g., disorderly conduct), sexually transmitted diseases, and truck crashes. This research focuses solely on those findings related to truck crashes. Food and Water Watch (2013) used Pennsylvania Department of Transportation's (PennDOT) heavy-truck accident data as well as the number of total vehicle crashes per million miles. Crashes per million miles was used to control for total traffic volume when creating rates. Temporally, data were analyzed either as "pre-fracking" (2000-2005) or "post-fracking" (2005-2010) time periods. Counties were marked as metro, "unfracked rural," "fracked rural," and "heavily fracked rural" counties. Those counties designated as "heavily fracked" had at least 1 well per 15 square miles. Metro counties were not analyzed; thus, 35 Pennsylvania counties were included in the study, of which 12 had no fracking and 23 had fracking (of these, eight were considered heavily fracked).

Food and Water Watch (2013) reported two major findings concerning truck crashes. Generally speaking, the number of heavy-truck crashes had been declining in Pennsylvania since 2000; this effect was seemingly curtailed by the onset of unconventional natural gas extraction. Furthermore, in heavily fracked rural counties, an increase in heavy-truck crashes was found in the "post-fracking" period. It found a 7 percent increase in heavy truck crashes in the post-fracking period, while unfracked counties decreased 12 percent. The second major finding was that, from 2005 to 2010, heavy truck crashes increased annually 9 percent in heavily fracked counties; conversely, unfracked counties decreased annually 3 percent. The authors also included more qualitative findings reported by local newspapers in the fracked counties.

Graham et al. (2015) is a more comprehensive, peer-reviewed academic study of traffic accidents in correlation to Marcellus Shale drilling. The authors utilized traffic data gathered by the Pennsylvania Department of Transportation from 2005 to 2012; specifically, they used heavy-truck, fatal, major-injury, and total crashes. Additionally from PennDOT, million miles travelled was used in conjunction with Census Bureau population counts to create estimates of traffic volume. Graham et al. (2015) delineated 2005-2008 as a pre-drilling, baseline period; this timeframe was used to match what would become drilling counties with corresponding non-drilling counties based on population, traffic, and accident rates. Using drilling data from the Pennsylvania Department of Environmental Protection, Marcellus counties were analyzed on a monthly basis and marked as actively being drilled or not, based on well

[2] Other studies have estimated the economic costs of truck traffic. Abramzon et al. (2012) examined the costs of roadway maintenance from increased truck traffic, finding that "first-order costs of additional heavy truck traffic on Pennsylvania state-maintained roadways from Marcellus Shale natural gas development in 2011 were estimated at about $13,000–$23,000 per well for all state roadway types, or $5,000–$10,000 per well if state roads with the lowest traffic volumes are excluded" (4). Banerjee et al. (2012) estimated damages to highways in the Barnett region of Texas, finding that "the overall impacts of rig, construction, and saltwater traffic are about 1.6 percent, 13 percent, and 6 percent in additional damage, respectively, from a rutting perspective" (56).

drillings in the prior, current, or upcoming month. This method was chosen to compensate for the dynamic nature of natural gas well drilling and the heavy-truck traffic generated by it.

The authors used three separate statistical models to examine their data. First, they compared annual rates of crash events in drilling and non-drilling counties within two regional groupings of counties. Second, crash rates were compared in counties with drilling and match counties without drilling (regardless of region). Third, within drilling counties only, the numbers of new wells were analyzed in relation to the number of traffic accidents. The paper highlights three main findings. First, drilled counties in the northern region had 15-23 percent higher total crash rates in 2010-2012 and 61-65 percent higher *heavy truck crash rates* in 2011 and 2012 than control counties. Second, when comparing drilling and non-drilling counties regardless of region a 5-23 percent increase in *crash rates* was found for drilling counties. Finally, a 45-47 percent increase in *fatal and major injury crashes* was found in the southwest region in drilled counties for 2012; this was the only statistically significant finding regarding fatal and/or major injury crashes. They calculated that "the rate of heavy-truck crashes… was estimated to increase by approximately 10 percent for every 10 new wells drilled, for both the northern and southwestern counties…" (based on the analysis of counties with at least 20 wells drilled per month) (207).

This research supplements these findings by providing the crash rates for four study counties (Bradford, Lycoming, Washington, and Greene) in comparison to neighboring counties and for all counties in relation to the total number of wells drilled. The data here were provided as both the raw counts – as the total volume has importance for the provision of public services – and as rates for comparisons across counties. The focus here was on three indicators of traffic found to be of concern in previous studies – total crashes, heavy truck crashes, and crashes with fatalities. The trends over time are described, showing the trends in years prior to (2000-2007) and during (2008-2012/13) active well development periods.

Data Sources and Methods

This study used annual data provided to the public by PennDOT and the National Highway Traffic Safety Administration (NHTSA) for the years 2000-2013 and 2000-2012[3], respectfully. Three crash measurements were used:

- Total crashes. (PennDOT)
- Heavy truck crashes - crashes involving one or more single vehicle or tractor-trailer combination that is designed for carrying a heavy load of property on or in the vehicle. (PennDOT)
- Crashes resulting in one or more fatalities. (NHTSA)

[3] At the time of the analysis, fatality data from the NHTSA were only available through 2012.

These three measures were all analyzed annually at the county level as counts and as rates. The rates were calculated as the count divided by the number of daily vehicle miles traveled (DVMT). DVMT is a daily average estimate of traffic volume for all state-owned roads in a county. The DVMT is favorable over the million miles travelled measure used in Graham et al. (2015) and Food and Water Watch (2013) because it pertains only to the total volume of traffic in which an accident could occur, not the overall population. Due to this fact, this study's reported rates are less affected by potential changes in county populations; it does account for changes in total volume of traffic, which may be related to Marcellus Shale development. Additionally, this work reports both rates and raw counts; raw counts provide information about the overall frequency of events (which has implications for public services, emergency services, and safety), while rates provide a way to compare across places with differing levels of traffic and road networks (reflecting the base number of possibilities for accidents to occur).

Calculation of the Daily Vehicle Miles Traveled (DVMT)

DVMT is a daily estimate of the number of vehicles that travel on state owned roads. PennDOT calculates this figure using the following steps.

1. All state owned roads are broken down into designated segments that have traffic counts conducted every 1, 3, or 5 years. This count is done using an automated traffic counter or an actual observer.
2. These counts are compiled into a measure of the annual average daily traffic for each segment, then multiplied by the length of the road segments to calculate the vehicle miles traveled per year on state-owned roads.
3. This measure of vehicle miles traveled can be divided by 365 days to give a daily average: the DVMT.

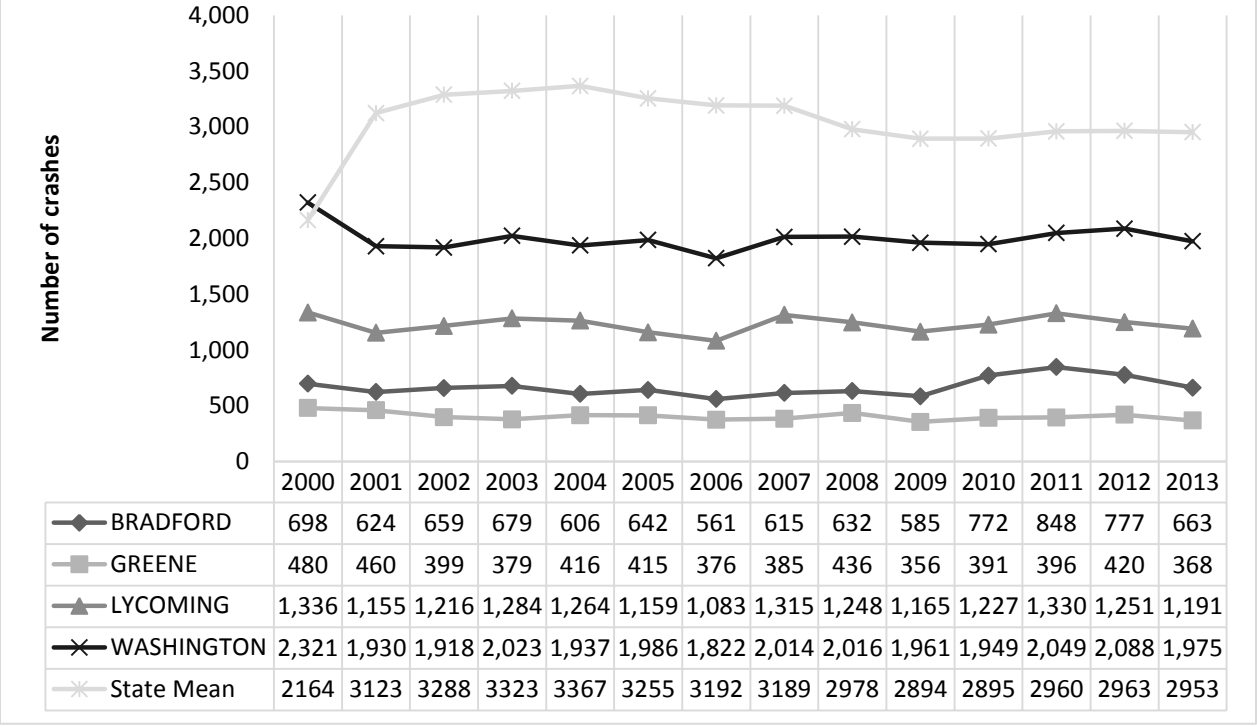
Results

Total Crashes

The first section of results focuses on the total crashes for the study counties, their surrounding counties, and all Pennsylvania counties categorized by the number of wells drilled. For the state as a whole, the total number of crashes had a slight downward trend over the study period (Figure 6). In 2001, the average number of crashes for all Pennsylvanian counties was 3,123; 12 years later that number was 2,953. A slight spike can be seen from 2009-2011 (when drilling activity rapidly increased) in three of the four study counties. In Bradford County, the number of total crashes increased from 585 in 2009 to 848 in 2011 before declining again the next 2 years. The average number of crashes in Bradford County from 2000-2007 was 636, whereas the average number 2008-2013 was 713. Similarly, Lycoming County experienced an increase from 1,165 crashes in 2009 to 1,330 in 2011 before a decline in 2012-2013. However, the average number of crashes was relatively similar between the two time periods, 1,227 in 2000-2007 and 1,235 in 2008-2013. In the southwest region, Greene County experienced an increase from 356 crashes in 2009 to 420 in 2012 before declining in 2013. The overall average for the two time periods shows a slight decrease, with 414 total crashes on average from 2000-

2007 and 395 from 2008-2013. Unlike the three other counties, the number of total crashes in Washington County held relatively steady during this time period, with annual averages of 1,994 crashes for 2000-2007 and 2,006 crashes for 2008-2013.

Figure 6. Total number of crashes in the four study counties and Pennsylvania's county average, 2000-2013

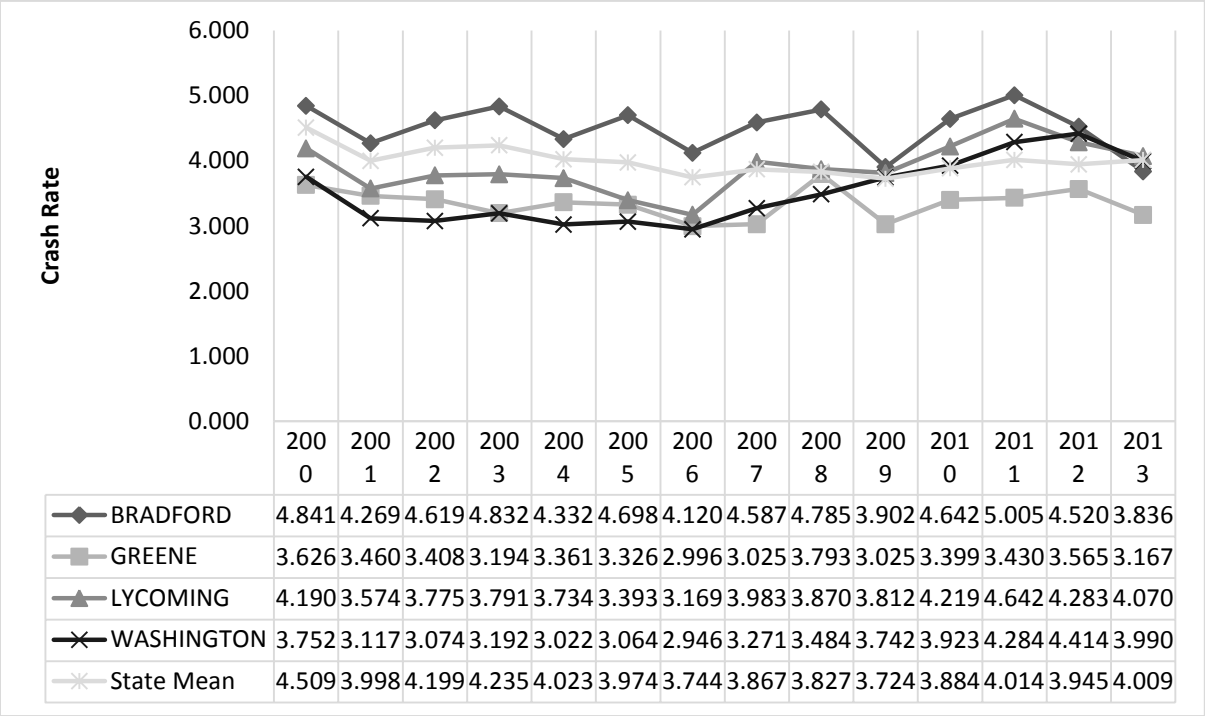


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	698	624	659	679	606	642	561	615	632	585	772	848	777	663
GREENE	480	460	399	379	416	415	376	385	436	356	391	396	420	368
LYCOMING	1,336	1,155	1,216	1,284	1,264	1,159	1,083	1,315	1,248	1,165	1,227	1,330	1,251	1,191
WASHINGTON	2,321	1,930	1,918	2,023	1,937	1,986	1,822	2,014	2,016	1,961	1,949	2,049	2,088	1,975
State Mean	2164	3123	3288	3323	3367	3255	3192	3189	2978	2894	2895	2960	2963	2953

Source: Pennsylvania Department of Transportation

Figure 7 provides the total crash rates (crashes/DVMT) for the four study counties and the Pennsylvania county average. The rates show greater annual volatility, so a particular pattern is hard to identify. Note that Bradford County had a rate that was higher than the state average throughout the period; the county experienced its lowest rate in 2013 and its highest rate in 2011. In contrast, the rate for Lycoming County had declined prior to 2007, when the rate jumped higher and remained higher throughout the rest of the study period, exceeding the county average for the state. Greene County experienced its highest rate in 2008, but returned to previous levels the next year; there was an upward trend in the rates from 2009-2012. Washington County experienced a rise in the rates beginning in 2007; the rate was 2.946 crashes/DVMT in 2006 and peaked at 4.414 crashes/DVMT in 2012.

Figure 7. Crash rates, using DVMT, in the four study counties and Pennsylvania's county average, 2000-2013.

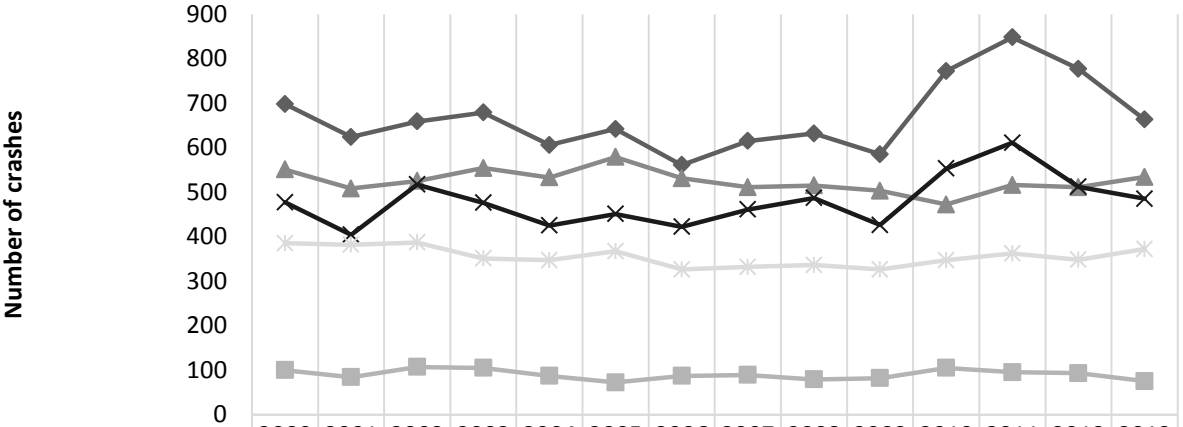


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	4.841	4.269	4.619	4.832	4.332	4.698	4.120	4.587	4.785	3.902	4.642	5.005	4.520	3.836
GREENE	3.626	3.460	3.408	3.194	3.361	3.326	2.996	3.025	3.793	3.025	3.399	3.430	3.565	3.167
LYCOMING	4.190	3.574	3.775	3.791	3.734	3.393	3.169	3.983	3.870	3.812	4.219	4.642	4.283	4.070
WASHINGTON	3.752	3.117	3.074	3.192	3.022	3.064	2.946	3.271	3.484	3.742	3.923	4.284	4.414	3.990
State Mean	4.509	3.998	4.199	4.235	4.023	3.974	3.744	3.867	3.827	3.724	3.884	4.014	3.945	4.009

Source: Pennsylvania Department of Transportation.

Figure 8 depicts the number of total crashes in Bradford and its surrounding counties. In addition to the previously mentioned increase from 2009-2011 in Bradford, there was a similar increase in Tioga County. Tioga County also experienced a dramatic increase in drilling activity during this time (see Figure 3). Additionally, in Figure 9, three counties experienced a dramatic increase in the rates of total crashes from 2009 to 2010: Bradford, Sullivan, and Tioga.

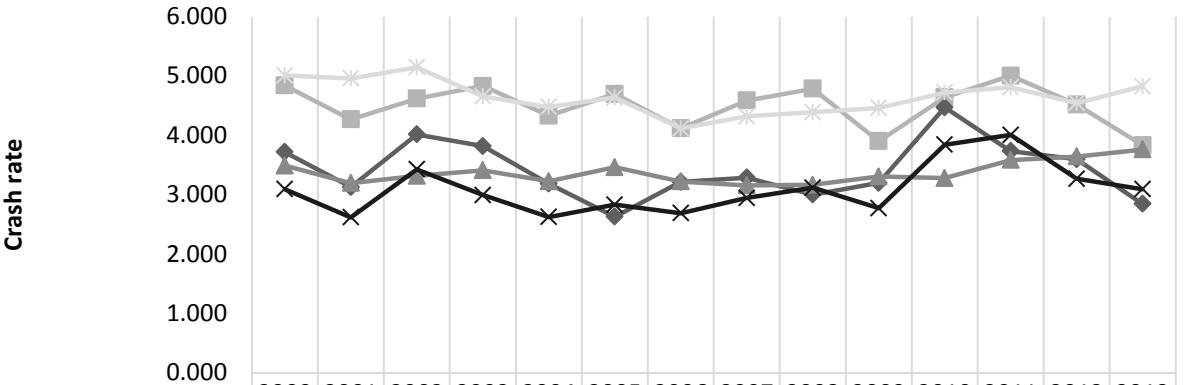
Figure 8. Number of crashes in Bradford and surrounding counties, 2000-2013



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	698	624	659	679	606	642	561	615	632	585	772	848	777	663
SULLIVAN	100	84	107	105	87	72	87	89	79	82	105	95	93	75
SUSQUEHANNA	551	508	525	554	533	579	531	511	515	503	472	516	511	534
TIOGA	477	404	517	476	425	451	422	461	487	426	553	611	512	485
WYOMING	385	382	387	351	347	367	326	332	336	326	347	362	348	372

Source: Pennsylvania Department of Transportation.

Figure 9. Crash rates, using DVMT, in Bradford and surrounding counties, 2000-2013

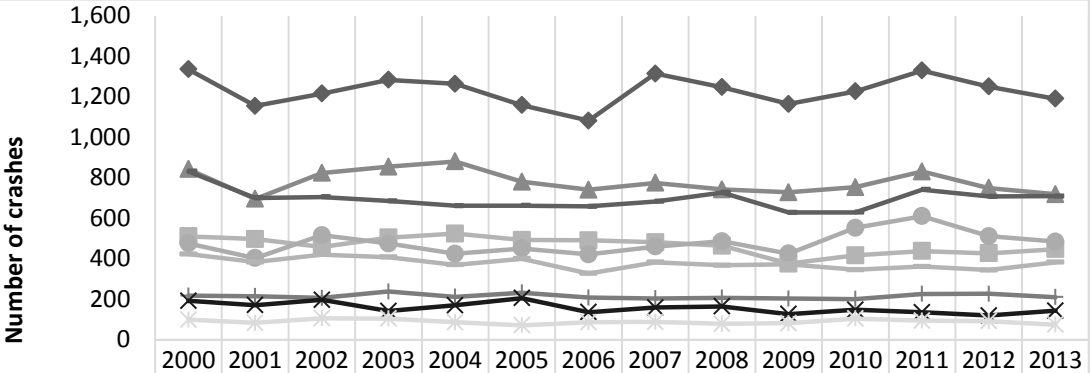


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	4.841	4.269	4.619	4.832	4.332	4.698	4.120	4.587	4.785	3.902	4.642	5.005	4.520	3.836
SULLIVAN	3.719	3.130	4.016	3.820	3.185	2.631	3.217	3.288	3.002	3.199	4.471	3.737	3.598	2.847
SUSQUEHANNA	3.491	3.196	3.318	3.411	3.225	3.464	3.222	3.160	3.168	3.307	3.281	3.584	3.643	3.763
TIOGA	3.095	2.619	3.429	2.996	2.626	2.832	2.690	2.945	3.118	2.775	3.844	4.007	3.268	3.094
WYOMING	5.011	4.958	5.147	4.658	4.479	4.637	4.115	4.320	4.391	4.464	4.722	4.811	4.543	4.826

Source: Pennsylvania Department of Transportation.

Looking at Lycoming and its surrounding counties (Figures 10 and 11), an increase in total crashes can be observed for Lycoming, Columbia, and Tioga counties. This increase becomes more apparent as a rate (Figure 11) for Lycoming, Clinton, Potter, Sullivan, and Tioga counties, which experienced a jump in the crash rates between 2009 and 2010.

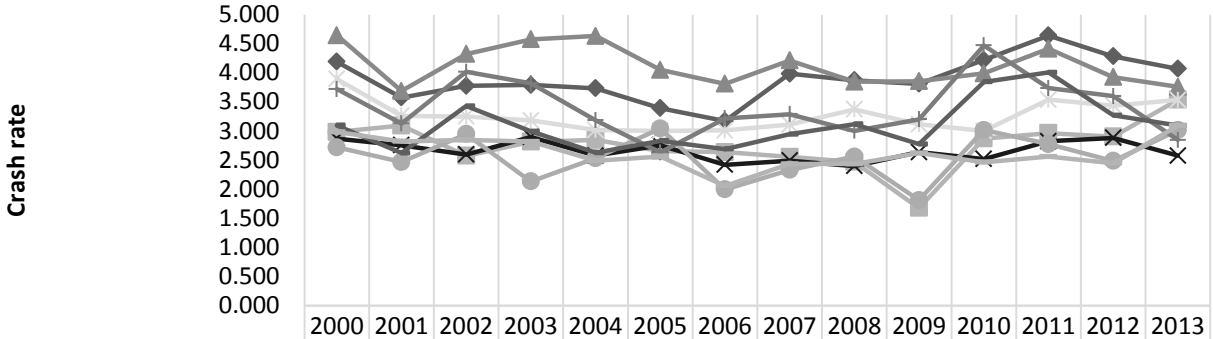
Figure 10. Number of crashes in Lycoming and surrounding counties, 2000-2013



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LYCOMING	1,336	1,155	1,216	1,284	1,264	1,159	1,083	1,315	1,248	1,165	1,227	1,330	1,251	1,191
CLINTON	511	498	459	505	525	493	492	482	465	376	417	439	428	448
COLUMBIA	843	696	824	855	881	781	741	775	743	729	754	831	750	719
MONTOUR	218	216	207	239	213	233	209	205	208	204	202	227	228	211
NORTHUMBERLAND	832	701	706	686	662	663	659	684	728	629	630	742	708	710
POTTER	193	172	198	142	171	206	137	160	165	127	149	136	120	144
SULLIVAN	100	84	107	105	87	72	87	89	79	82	105	95	93	75
TIOGA	477	404	517	476	425	451	422	461	487	426	553	611	512	485
UNION	424	384	421	409	371	401	328	383	368	373	346	362	345	383

Source: Pennsylvania Department of Transportation.

Figure 11. Crash rates, using DVMT, in Lycoming and surrounding counties, 2000-2013

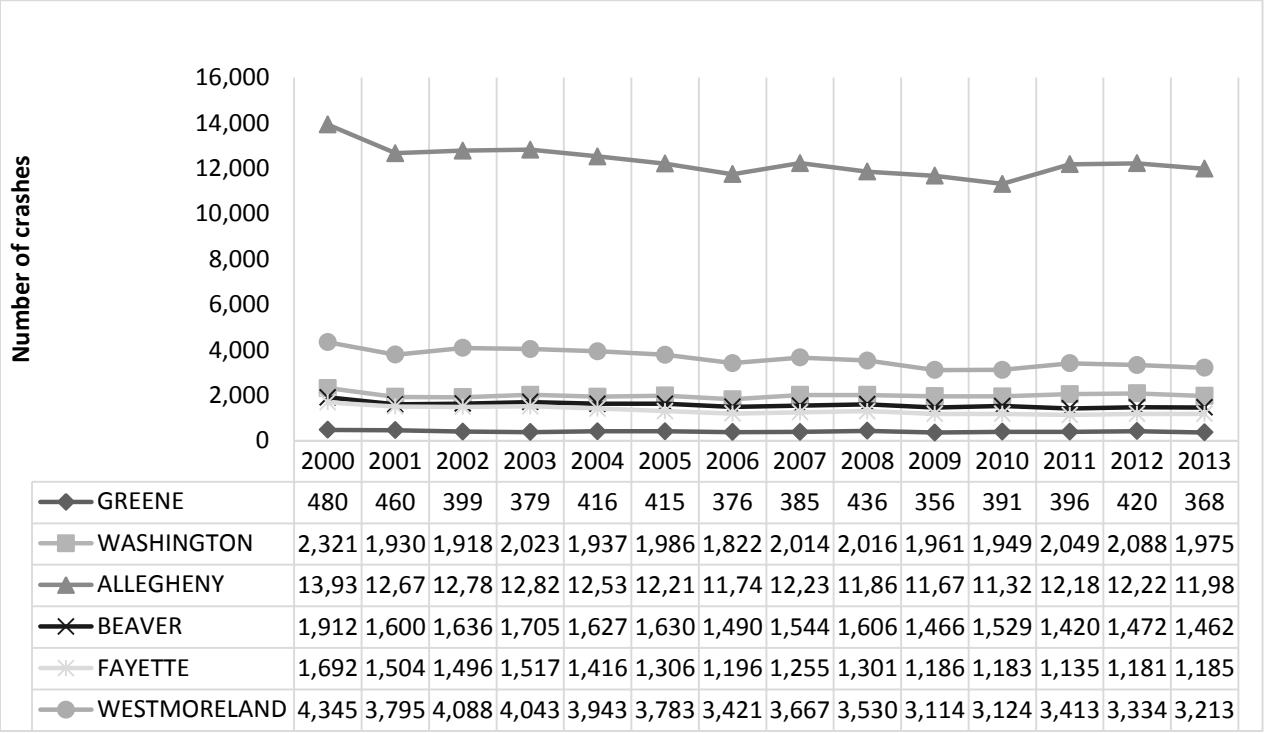


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LYCOMING	4.190	3.574	3.775	3.791	3.734	3.393	3.169	3.983	3.870	3.812	4.219	4.642	4.283	4.070
CLINTON	2.984	3.093	2.573	2.815	2.845	2.657	2.636	2.553	2.470	1.677	2.871	2.965	2.905	3.535
COLUMBIA	4.643	3.688	4.322	4.575	4.634	4.050	3.810	4.212	3.847	3.856	3.990	4.414	3.927	3.758
MONTOUR	2.872	2.755	2.595	2.898	2.575	2.755	2.419	2.491	2.397	2.637	2.517	2.825	2.883	2.575
NORTHUMBERLAND	3.892	3.260	3.249	3.182	3.015	3.001	3.010	3.109	3.371	3.114	3.000	3.540	3.436	3.533
POTTER	2.718	2.465	2.947	2.135	2.531	3.044	1.997	2.332	2.560	1.812	3.016	2.774	2.485	3.013
SULLIVAN	3.719	3.130	4.016	3.820	3.185	2.631	3.217	3.288	3.002	3.199	4.471	3.737	3.598	2.847
TIOGA	3.095	2.619	3.429	2.996	2.626	2.832	2.690	2.945	3.118	2.775	3.844	4.007	3.268	3.094
UNION	2.984	2.820	2.845	2.817	2.492	2.563	2.057	2.434	2.433	2.620	2.463	2.561	2.446	3.091

Source: Pennsylvania Department of Transportation.

The total crash counts and rates for the southwestern study counties, Greene and Washington, are shown in relation to their surrounding counties in Figures 12 and 13. Neither study county shows substantial changes in crash counts in comparison to surrounding counties. Washington County experienced a steady increase in crash rates from 2006 through 2012, as did Fayette County. Several counties in the region had increased crash rates in 2011 and 2012, making it difficult to identify a clear pattern.

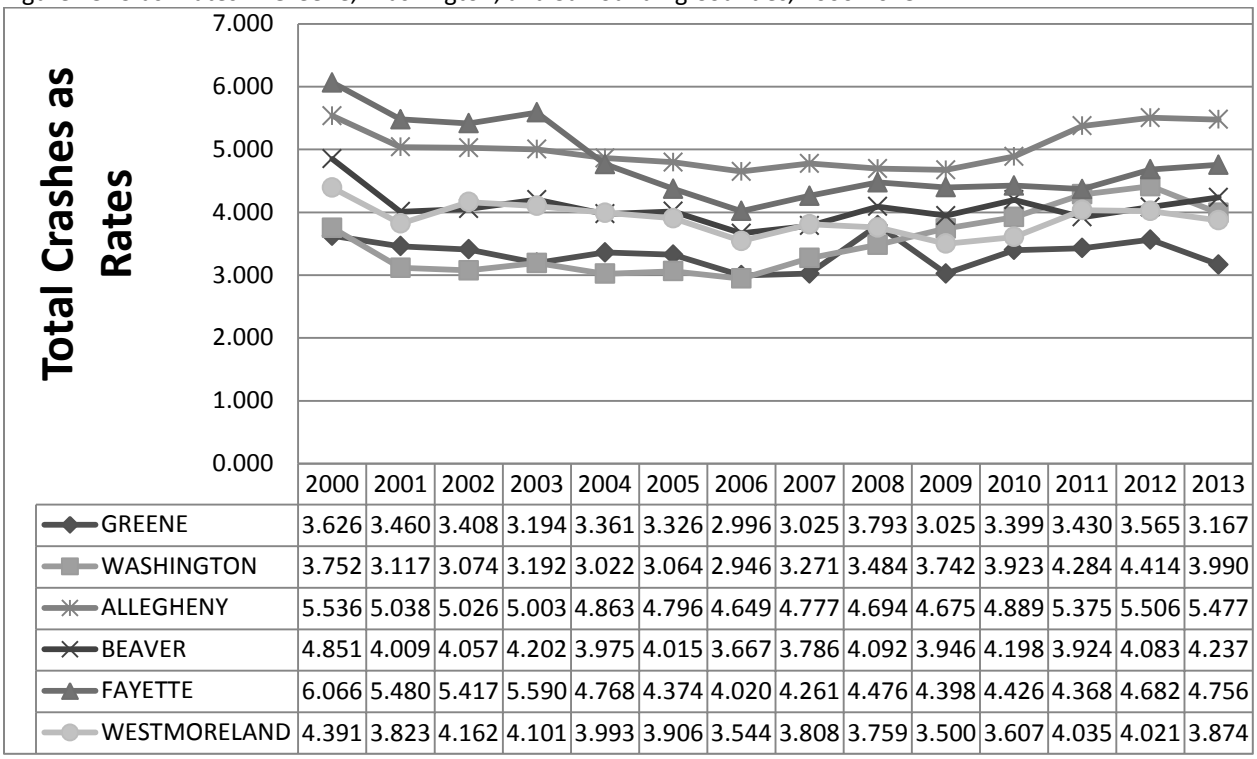
Figure 12. Number of crashes in Greene, Washington, and surrounding counties, 2000-2013.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GREENE	480	460	399	379	416	415	376	385	436	356	391	396	420	368
WASHINGTON	2,321	1,930	1,918	2,023	1,937	1,986	1,822	2,014	2,016	1,961	1,949	2,049	2,088	1,975
ALLEGHENY	13,93	12,67	12,78	12,82	12,53	12,21	11,74	12,23	11,86	11,67	11,32	12,18	12,22	11,98
BEAVER	1,912	1,600	1,636	1,705	1,627	1,630	1,490	1,544	1,606	1,466	1,529	1,420	1,472	1,462
FAYETTE	1,692	1,504	1,496	1,517	1,416	1,306	1,196	1,255	1,301	1,186	1,183	1,135	1,181	1,185
WESTMORELAND	4,345	3,795	4,088	4,043	3,943	3,783	3,421	3,667	3,530	3,114	3,124	3,413	3,334	3,213

Source: Pennsylvania Department of Transportation.

Figure 13. Crash rates in Greene, Washington, and Surrounding Counties, 2000-2013



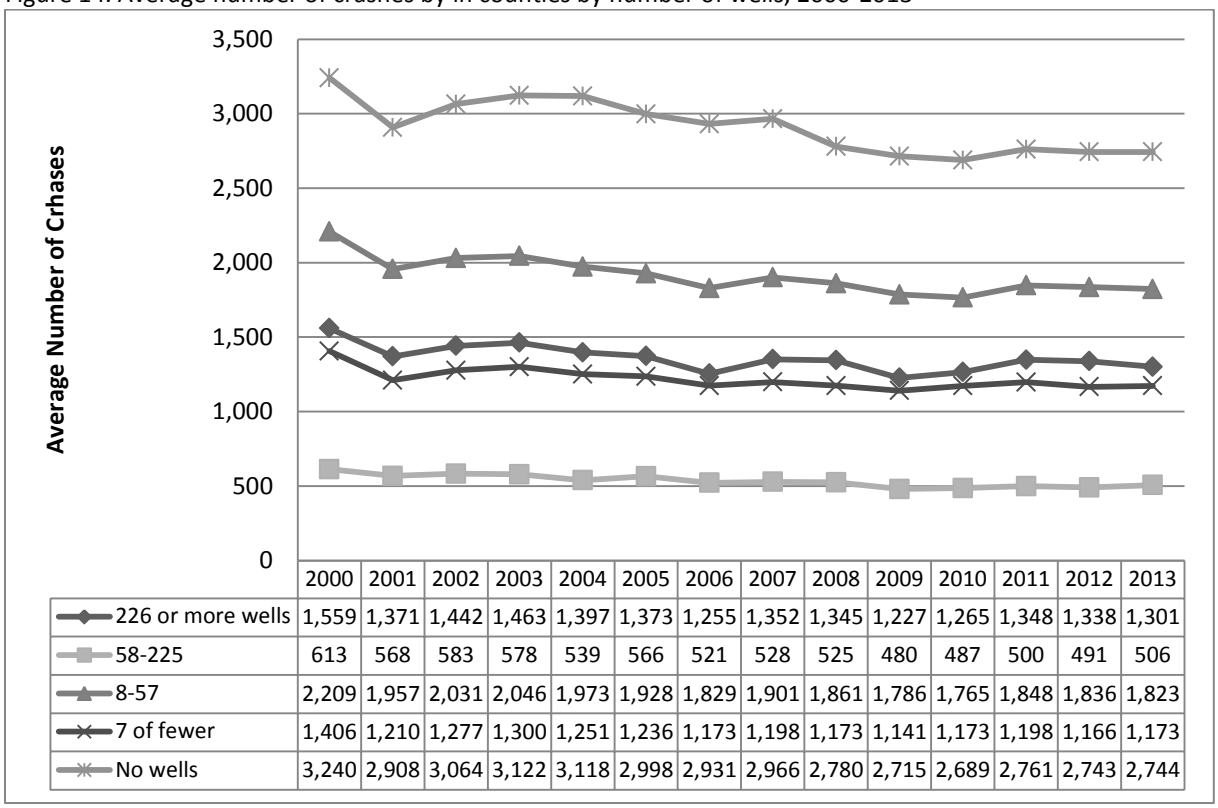
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GREENE	3.626	3.460	3.408	3.194	3.361	3.326	2.996	3.025	3.793	3.025	3.399	3.430	3.565	3.167
WASHINGTON	3.752	3.117	3.074	3.192	3.022	3.064	2.946	3.271	3.484	3.742	3.923	4.284	4.414	3.990
ALLEGHENY	5.536	5.038	5.026	5.003	4.863	4.796	4.649	4.777	4.694	4.675	4.889	5.375	5.506	5.477
BEAVER	4.851	4.009	4.057	4.202	3.975	4.015	3.667	3.786	4.092	3.946	4.198	3.924	4.083	4.237
FAYETTE	6.066	5.480	5.417	5.590	4.768	4.374	4.020	4.261	4.476	4.398	4.426	4.368	4.682	4.756
WESTMORELAND	4.391	3.823	4.162	4.101	3.993	3.906	3.544	3.808	3.759	3.500	3.607	4.035	4.021	3.874

Source: Pennsylvania Department of Transportation.

The next analysis divided Pennsylvania counties into five categories based on the total number of wells drilled between 2005 and 2013: counties with no wells, counties with 1-7 wells, with 8-57 wells, with 58-225 wells, and counties with 226 or more wells. The four categories with wells each represent about one-quarter of the counties in the state with drilling activity during this time period. To analyze crash counts and rates by these categories, the county averages were calculated.

Figure 14 shows the average number of crashes for counties in each category. Counties with 226 or more wells experienced, on average, a 10 percent increase in crashes between 2009 and 2011, whereas the other county categories increased 5 percent or less during that same time period.

Figure 14. Average number of crashes by in counties by number of wells, 2000-2013

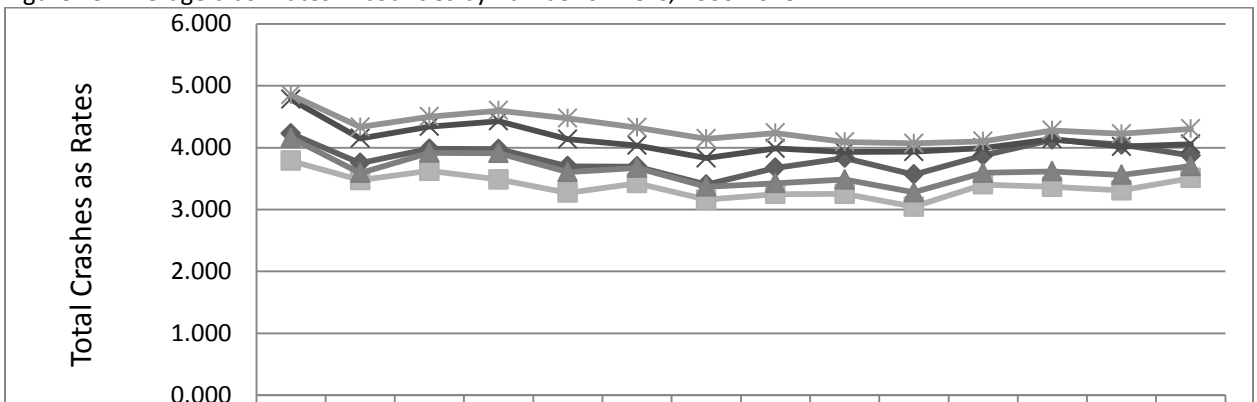


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
226 or more wells	1,559	1,371	1,442	1,463	1,397	1,373	1,255	1,352	1,345	1,227	1,265	1,348	1,338	1,301
58-225	613	568	583	578	539	566	521	528	525	480	487	500	491	506
8-57	2,209	1,957	2,031	2,046	1,973	1,928	1,829	1,901	1,861	1,786	1,765	1,848	1,836	1,823
7 of fewer	1,406	1,210	1,277	1,300	1,251	1,236	1,173	1,198	1,173	1,141	1,173	1,198	1,166	1,173
No wells	3,240	2,908	3,064	3,122	3,118	2,998	2,931	2,966	2,780	2,715	2,689	2,761	2,743	2,744

Source: Pennsylvania Department of Transportation.

Figure 15 provides the average rates by county type. For the counties in the top three well count categories, rates were declining in the beginning of the decade, reaching lows in 2006. In subsequent years, the rates increased. Counties with the most wells experienced a 21 percent increase in the rate of crashes, on average; in comparison, counties with no wells experienced a 3 percent increase, counties with 1-7 wells an 8 percent increase, counties with 8-57 wells a 7 percent increase, and counties with 58-225 wells a 7 percent increase.

Figure 15. Average crash rates in counties by number of wells, 2000-2013



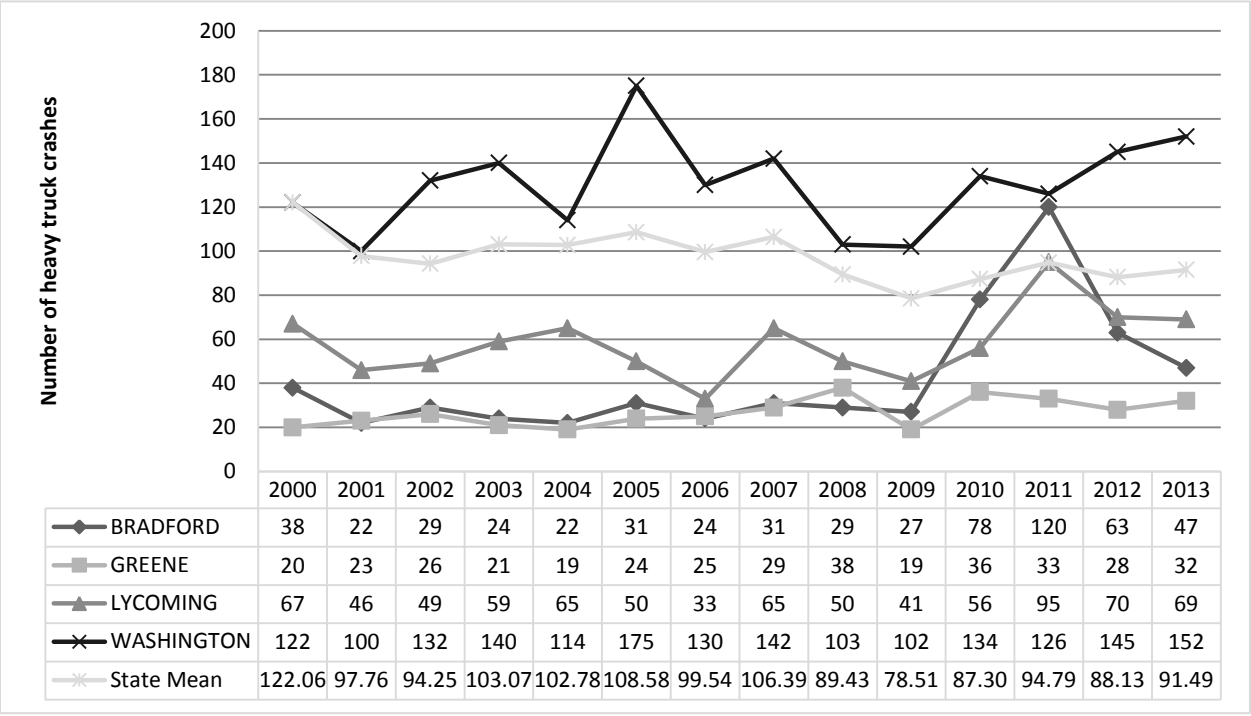
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
226 or more	4.227	3.752	3.982	3.977	3.698	3.695	3.401	3.673	3.834	3.565	3.873	4.128	4.048	3.874
58-225	3.788	3.473	3.624	3.486	3.270	3.426	3.158	3.249	3.252	3.045	3.405	3.366	3.309	3.507
8-57	4.156	3.591	3.917	3.912	3.604	3.675	3.368	3.426	3.485	3.278	3.593	3.617	3.560	3.703
7 or fewer	4.780	4.149	4.340	4.428	4.135	4.034	3.830	3.987	3.930	3.933	3.993	4.138	4.017	4.055
No wells	4.852	4.333	4.500	4.598	4.476	4.324	4.143	4.238	4.091	4.069	4.101	4.278	4.225	4.305

Source: Pennsylvania Department of Transportation.

Heavy Truck Crashes

This section of results focuses on the heavy truck crash figures for the study counties, their surrounding counties, and all counties in the state by the level of drilling activity. Crashes involving a heavy truck would be expected to be the most directly related to Marcellus drilling activity. There was relatively little change in the state-wide county average within the studied time period (Figure 16). However, when looking at the four study counties, a dramatic increase can be seen in Bradford and Lycoming counties from 2009-2011. There was a 344 percent increase in the number of heavy truck crashes in Bradford County, and a 132 percent increase in Lycoming County. Greene County experienced a 74 percent increase, and Washington County a 24 percent increase in the number of heavy truck crashes between 2009 and 2011. The rates in Figure 17 echo these dramatic increases for the northern tier study counties.

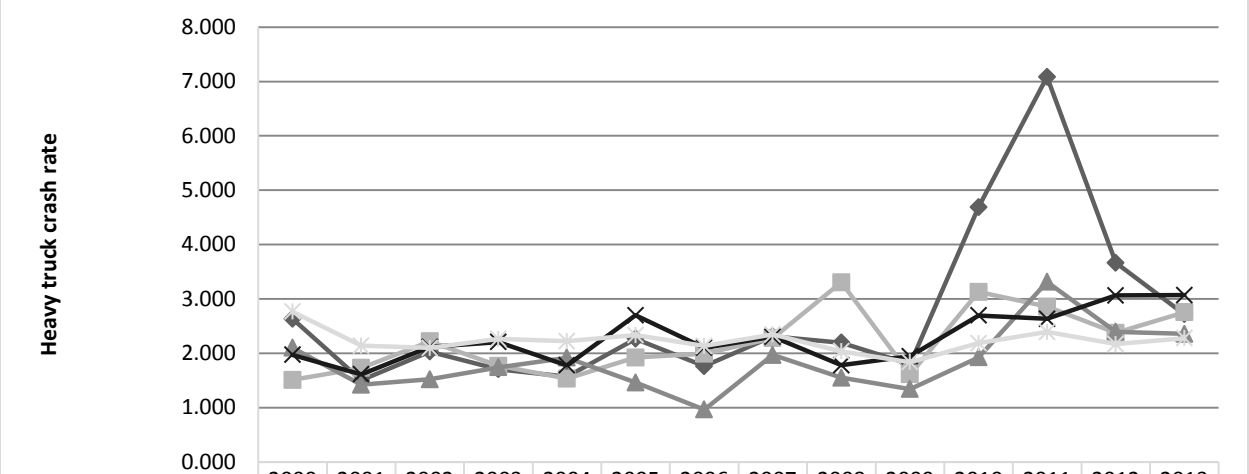
Figure 16. Number of heavy truck crashes in the four study counties and Pennsylvania's county average, 2000-2013



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	38	22	29	24	22	31	24	31	29	27	78	120	63	47
GREENE	20	23	26	21	19	24	25	29	38	19	36	33	28	32
LYCOMING	67	46	49	59	65	50	33	65	50	41	56	95	70	69
WASHINGTON	122	100	132	140	114	175	130	142	103	102	134	126	145	152
State Mean	122.06	97.76	94.25	103.07	102.78	108.58	99.54	106.39	89.43	78.51	87.30	94.79	88.13	91.49

Source: Pennsylvania Department of Transportation.

Figure 17. Heavy truck crash rates, using DVMT, in the four study counties and Pennsylvania's county average, 2000-2013



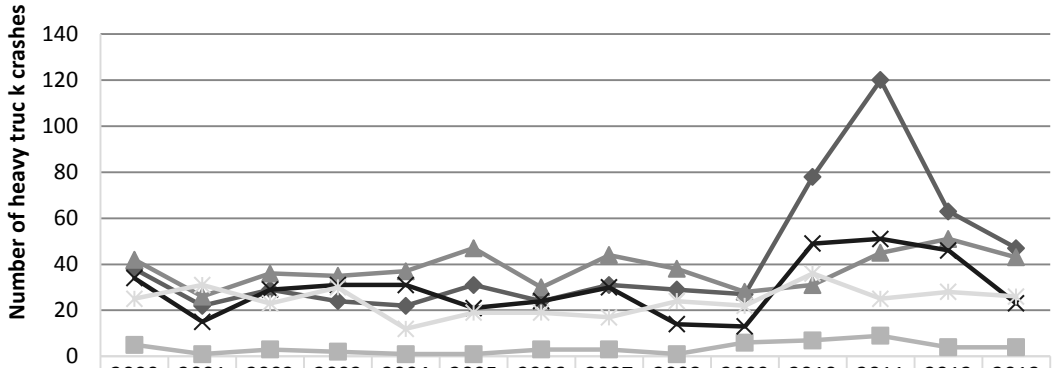
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	2.636	1.505	2.033	1.708	1.573	2.268	1.762	2.312	2.196	1.801	4.690	7.083	3.665	2.719
GREENE	1.511	1.730	2.221	1.770	1.535	1.923	1.992	2.278	3.306	1.614	3.130	2.859	2.377	2.754
LYCOMING	2.101	1.423	1.521	1.742	1.920	1.464	0.966	1.969	1.551	1.342	1.926	3.316	2.397	2.358
WASHINGTON	1.972	1.615	2.116	2.209	1.778	2.699	2.102	2.307	1.780	1.946	2.697	2.634	3.065	3.071
State Mean	2.77	2.14	2.10	2.27	2.22	2.33	2.14	2.35	2.04	1.84	2.19	2.39	2.17	2.28

Source: Pennsylvania Department of Transportation.

Figures 18 and 19 show that along with the increase in Bradford County, two of its neighbors, Tioga and Susquehanna, also experienced substantial increases. Tioga County experienced a 292 percent increase

and Susquehanna experienced a 61 percent increase in the number of heavy truck crashes from 2009-2011. The rates provided in Figure 19 echo these trends.

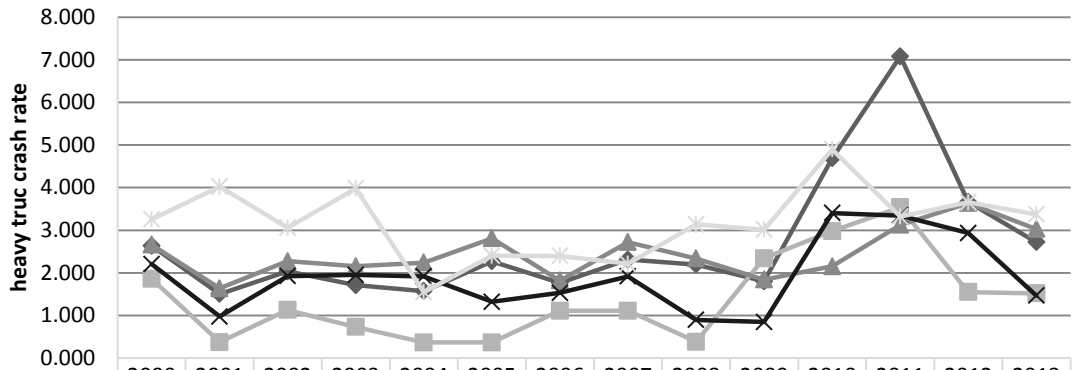
Figure 18. Number of heavy truck crashes in Bradford and surrounding counties, 2000-2013



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	38	22	29	24	22	31	24	31	29	27	78	120	63	47
SULLIVAN	5	1	3	2	1	1	3	3	1	6	7	9	4	4
SUSQUEHANNA	42	26	36	35	37	47	30	44	38	28	31	45	51	43
TIOGA	34	15	29	31	31	21	24	30	14	13	49	51	46	23
WYOMING	25	31	23	30	12	19	19	17	24	22	36	25	28	26

Source: Pennsylvania Department of Transportation

Figure 19. Heavy truck crash rates, using DVMT, in Bradford and surrounding counties, 2000-2013



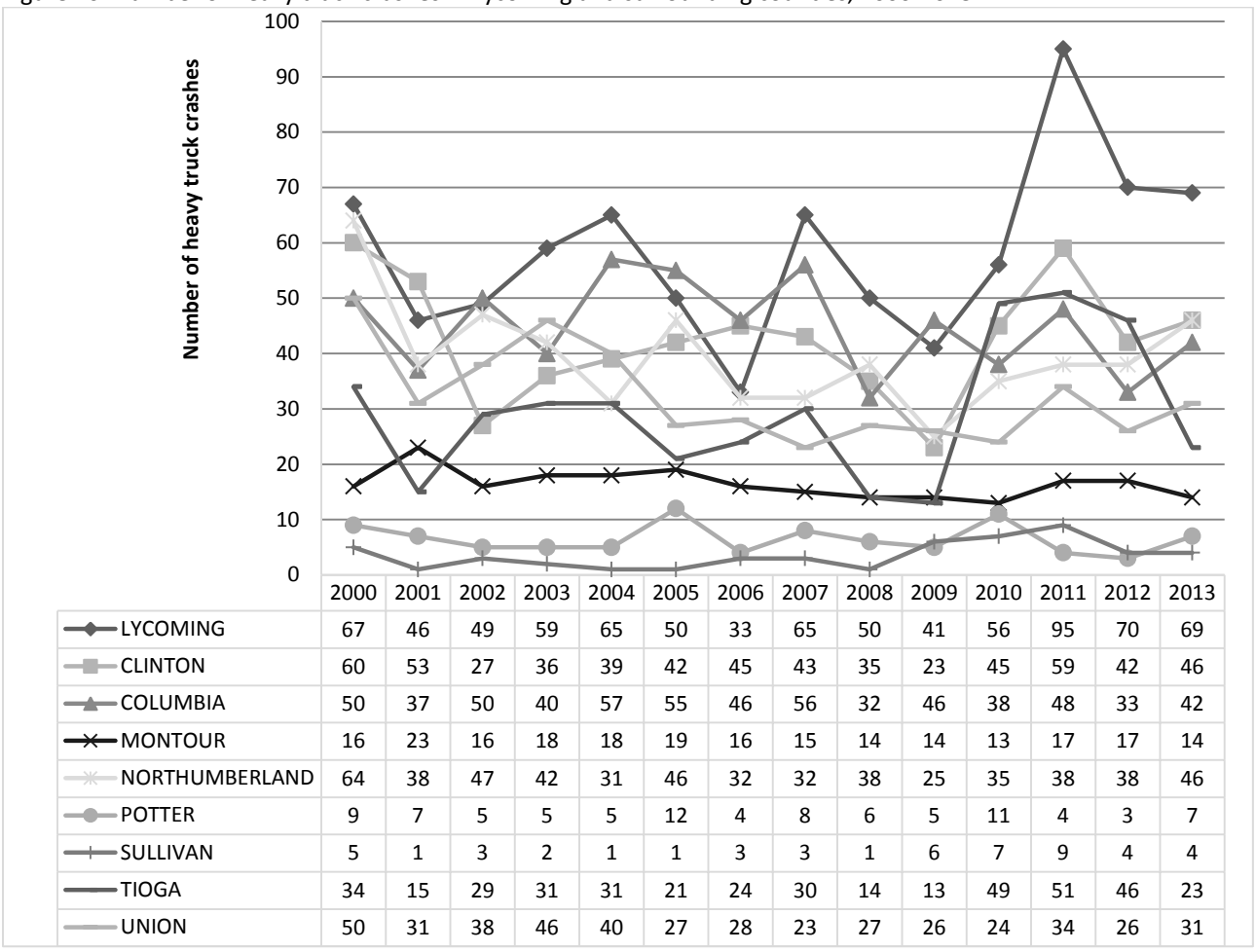
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BRADFORD	2.636	1.505	2.033	1.708	1.573	2.268	1.762	2.312	2.196	1.801	4.690	7.083	3.665	2.719
SULLIVAN	1.859	0.373	1.126	0.728	0.366	0.365	1.109	1.108	0.380	2.341	2.980	3.540	1.548	1.518
SUSQUEHANNA	2.661	1.636	2.275	2.155	2.239	2.812	1.821	2.721	2.338	1.841	2.155	3.126	3.636	3.030
TIOGA	2.206	0.972	1.923	1.951	1.916	1.319	1.530	1.917	0.896	0.847	3.406	3.345	2.936	1.467
WYOMING	3.254	4.023	3.059	3.981	1.549	2.401	2.398	2.212	3.136	3.013	4.899	3.322	3.655	3.373

Source: Pennsylvania Department of Transportation

The comparison of Lycoming County and its neighbors reveals a similar pattern. The increase in the number of heavy truck crashes in Lycoming County are mirrored by two of its neighbors, Clinton and

Tioga counties, whereas the rest of the counties (without drilling activity, such as Montour and Northumberland Counties) experienced relatively stable counts and rates of heavy truck crashes. As noted above, Tioga County experienced a 292 percent increase in heavy truck crashes between 2009 and 2011; Clinton County experienced a 157 percent increase during that same time period.

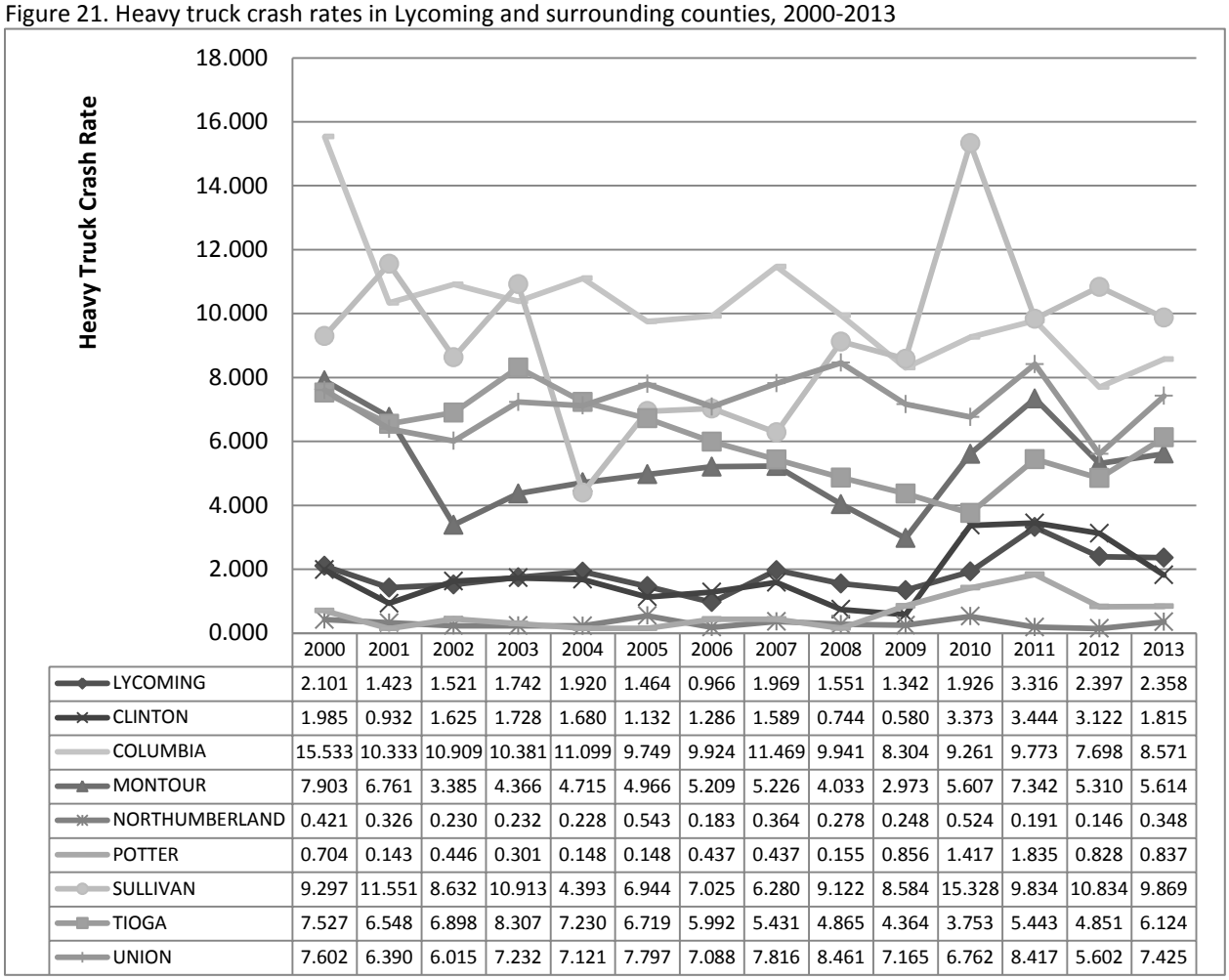
Figure 20. Number of heavy truck crashes in Lycoming and surrounding counties, 2000-2013.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LYCOMING	67	46	49	59	65	50	33	65	50	41	56	95	70	69
CLINTON	60	53	27	36	39	42	45	43	35	23	45	59	42	46
COLUMBIA	50	37	50	40	57	55	46	56	32	46	38	48	33	42
MONTOUR	16	23	16	18	18	19	16	15	14	14	13	17	17	14
NORTHUMBERLAND	64	38	47	42	31	46	32	32	38	25	35	38	38	46
POTTER	9	7	5	5	5	12	4	8	6	5	11	4	3	7
SULLIVAN	5	1	3	2	1	1	3	3	1	6	7	9	4	4
TIOGA	34	15	29	31	31	21	24	30	14	13	49	51	46	23
UNION	50	31	38	46	40	27	28	23	27	26	24	34	26	31

Source: Pennsylvania Department of Transportation.

Figure 21. Heavy truck crash rates in Lycoming and surrounding counties, 2000-2013

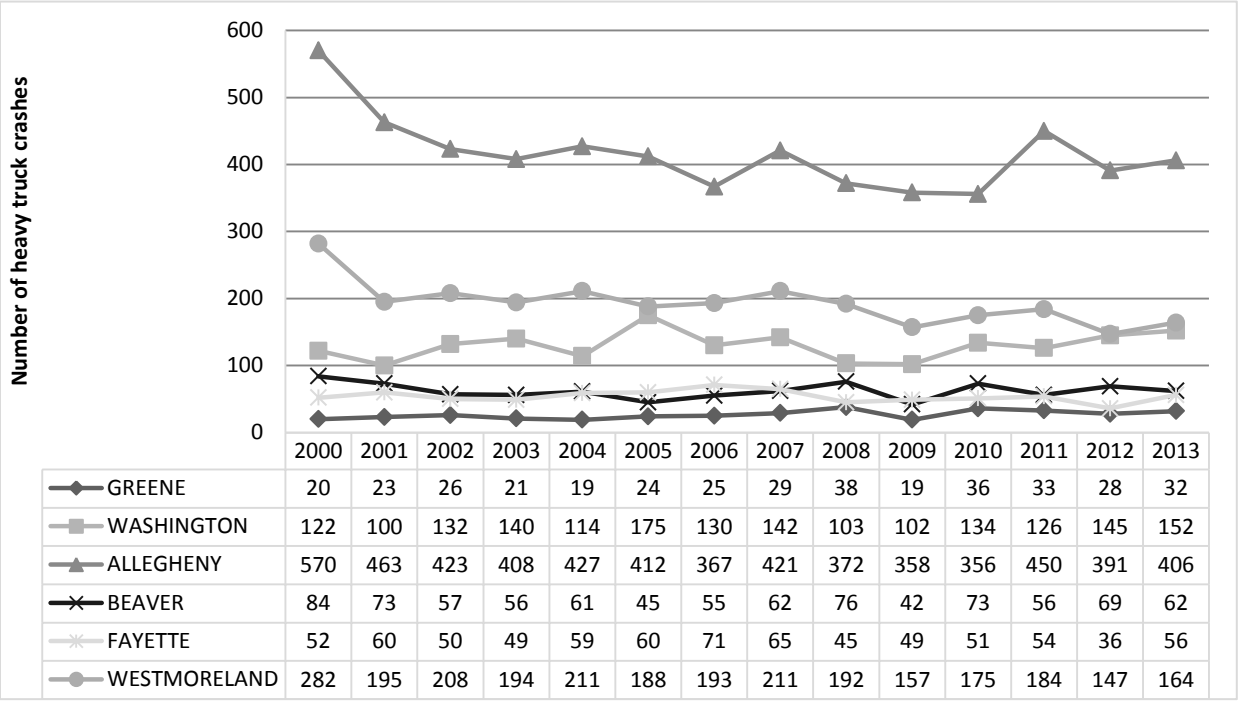


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LYCOMING	2.101	1.423	1.521	1.742	1.920	1.464	0.966	1.969	1.551	1.342	1.926	3.316	2.397	2.358
CLINTON	1.985	0.932	1.625	1.728	1.680	1.132	1.286	1.589	0.744	0.580	3.373	3.444	3.122	1.815
COLUMBIA	15.533	10.333	10.909	10.381	11.099	9.749	9.924	11.469	9.941	8.304	9.261	9.773	7.698	8.571
MONTOUR	7.903	6.761	3.385	4.366	4.715	4.966	5.209	5.226	4.033	2.973	5.607	7.342	5.310	5.614
NORTHUMBERLAND	0.421	0.326	0.230	0.232	0.228	0.543	0.183	0.364	0.278	0.248	0.524	0.191	0.146	0.348
POTTER	0.704	0.143	0.446	0.301	0.148	0.148	0.437	0.437	0.155	0.856	1.417	1.835	0.828	0.837
SULLIVAN	9.297	11.551	8.632	10.913	4.393	6.944	7.025	6.280	9.122	8.584	15.328	9.834	10.834	9.869
TIOGA	7.527	6.548	6.898	8.307	7.230	6.719	5.992	5.431	4.865	4.364	3.753	5.443	4.851	6.124
UNION	7.602	6.390	6.015	7.232	7.121	7.797	7.088	7.816	8.461	7.165	6.762	8.417	5.602	7.425

Source: Pennsylvania Department of Transportation.

Figures 22 and 23 show the heavy truck crash data for both Greene and Washington counties and their neighboring counties. The counts for Greene and Washington counties appear to be relatively similar to neighboring counties both with and without well development. The rates of heavy truck crashes are highly variable in more rural counties, but indicate generally increasing trends for Greene, Washington, Fayette, and Beaver counties. Westmoreland and Allegheny counties had relatively steady rates throughout the period.

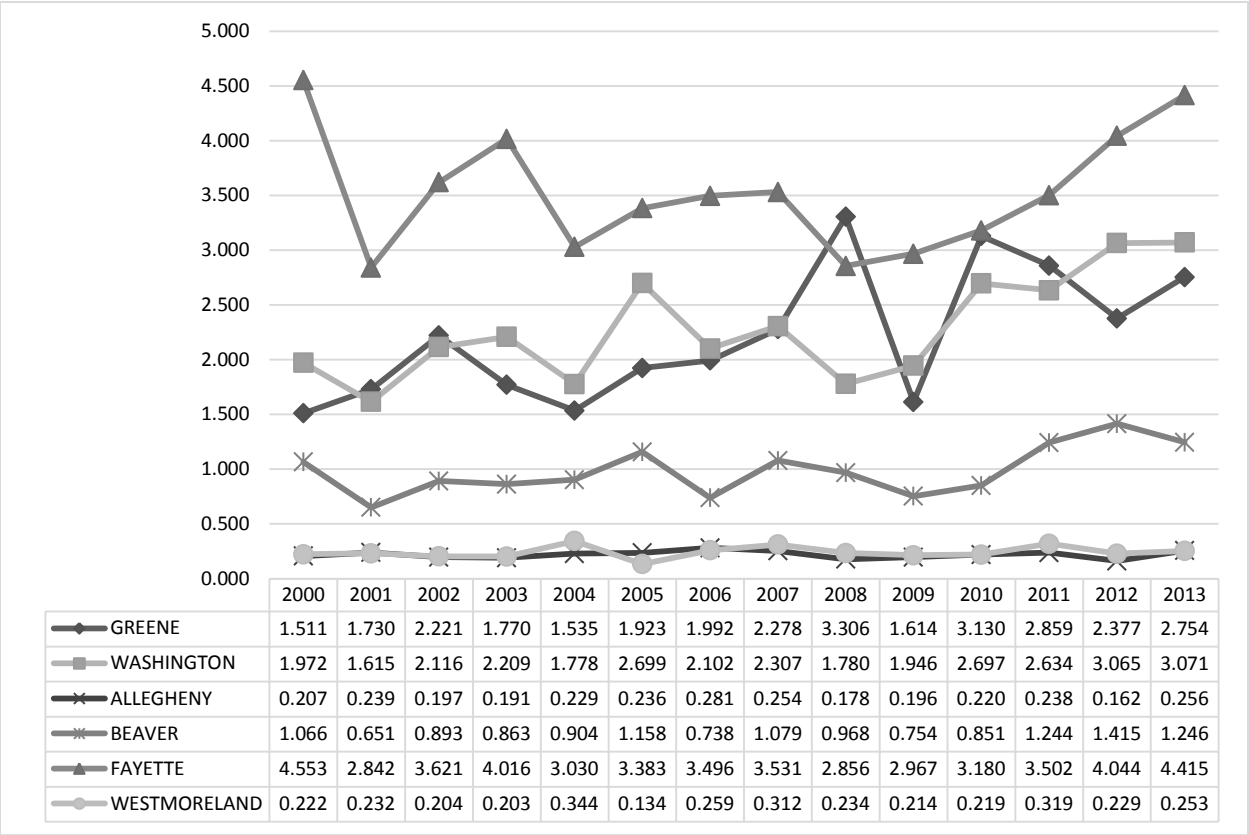
Figure 22. Number of heavy truck crashes in Greene, Washington, and surrounding counties, 2000-2013



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GREENE	20	23	26	21	19	24	25	29	38	19	36	33	28	32
WASHINGTON	122	100	132	140	114	175	130	142	103	102	134	126	145	152
ALLEGHENY	570	463	423	408	427	412	367	421	372	358	356	450	391	406
BEAVER	84	73	57	56	61	45	55	62	76	42	73	56	69	62
FAYETTE	52	60	50	49	59	60	71	65	45	49	51	54	36	56
WESTMORELAND	282	195	208	194	211	188	193	211	192	157	175	184	147	164

Source: Pennsylvania Department of Transportation.

Figure 23. Heavy truck crash rates in Greene, Washington, and surrounding counties, 2000-2013.

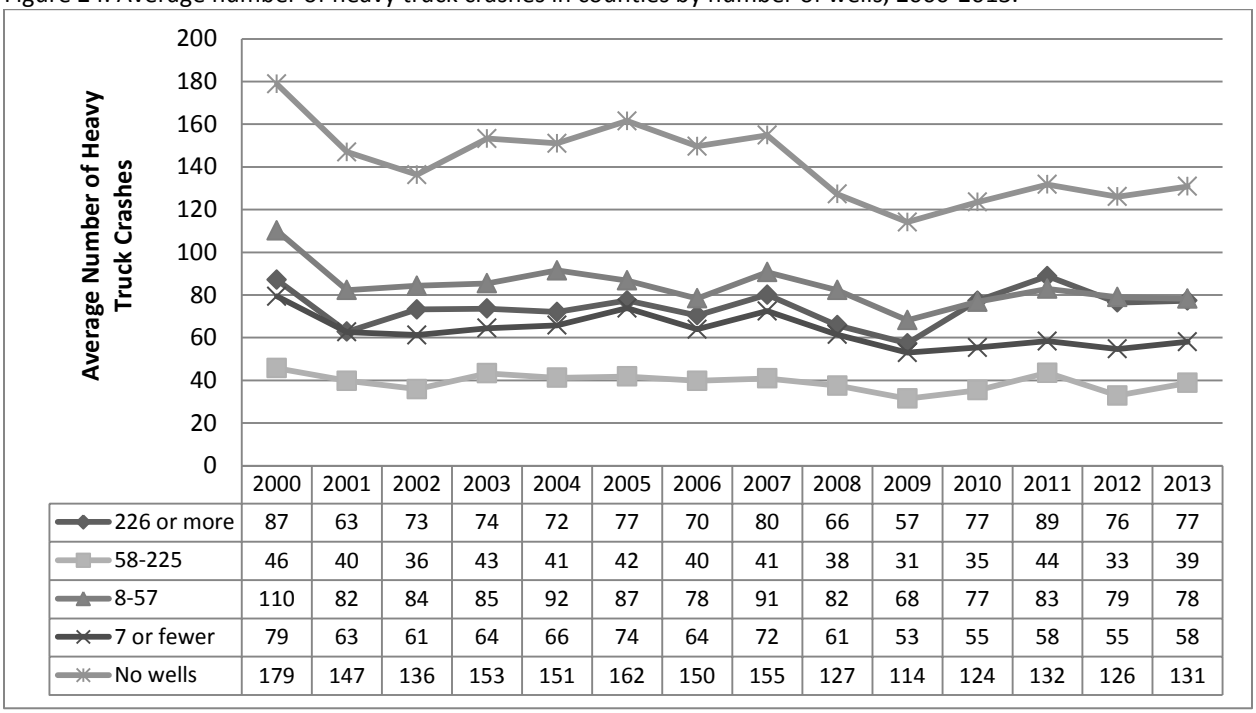


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GREENE	1.511	1.730	2.221	1.770	1.535	1.923	1.992	2.278	3.306	1.614	3.130	2.859	2.377	2.754
WASHINGTON	1.972	1.615	2.116	2.209	1.778	2.699	2.102	2.307	1.780	1.946	2.697	2.634	3.065	3.071
ALLEGHENY	0.207	0.239	0.197	0.191	0.229	0.236	0.281	0.254	0.178	0.196	0.220	0.238	0.162	0.256
BEAVER	1.066	0.651	0.893	0.863	0.904	1.158	0.738	1.079	0.968	0.754	0.851	1.244	1.415	1.246
FAYETTE	4.553	2.842	3.621	4.016	3.030	3.383	3.496	3.531	2.856	2.967	3.180	3.502	4.044	4.415
WESTMORELAND	0.222	0.232	0.204	0.203	0.344	0.134	0.259	0.312	0.234	0.214	0.219	0.319	0.229	0.253

Source: Pennsylvania Department of Transportation.

The analysis of the heavy truck crash data in relation to the number of wells drilled in the counties indicates that the years 2009-2011 show a larger increase for counties with high drilling activity compared to the other counties (Figures 24 and 25). Counties with the highest number of wells (226 or more) had a 55 percent increase, on average, in the number of crashes between 2009 and 2011. Counties with 58-225 wells had increased heavy truck crashes, on average, by 39 percent; those with 8-57 wells increased 22 percent, and those with 7 or fewer increased 10 percent. In contrast, counties with no wells increased 15 percent in the number of heavy truck crashes, on average. Similarly, the rates of heavy truck crashes between 2009 and 2011 (Figure 25) increased, on average, 75 percent in counties with the highest number of wells (226 or more), 15 percent in counties with 58-225 wells, 52 percent in counties with 8-57 wells, 16 percent in counties with 7 or fewer wells. In contrast, the rate of heavy truck crashes increased 27 percent for counties with no wells. The large difference in the increases between the counties with the highest number of wells and all others suggests that counties with the most wells experienced substantially higher rates of heavy truck crashes than others. However, since the percent change does not decrease as the number of wells decreases, this suggests that there is not a clear relationship between the number of wells and the rate of truck crashes.

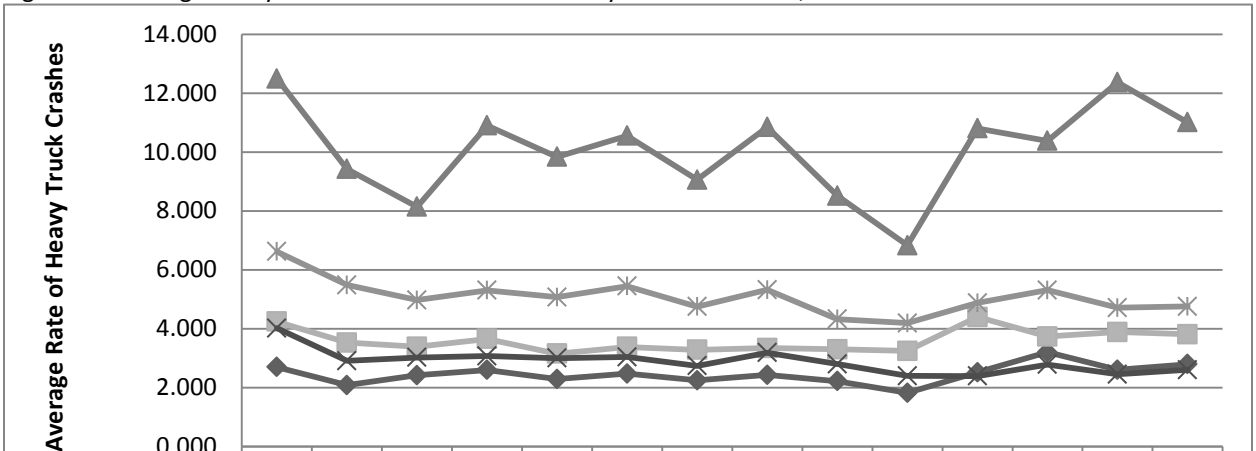
Figure 24. Average number of heavy truck crashes in counties by number of wells, 2000-2013.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
226 or more	87	63	73	74	72	77	70	80	66	57	77	89	76	77
58-225	46	40	36	43	41	42	40	41	38	31	35	44	33	39
8-57	110	82	84	85	92	87	78	91	82	68	77	83	79	78
7 or fewer	79	63	61	64	66	74	64	72	61	53	55	58	55	58
No wells	179	147	136	153	151	162	150	155	127	114	124	132	126	131

Source: Pennsylvania Department of Transportation.

Figure 25. Average heavy truck crash rates in counties by number of wells, 2000-2013



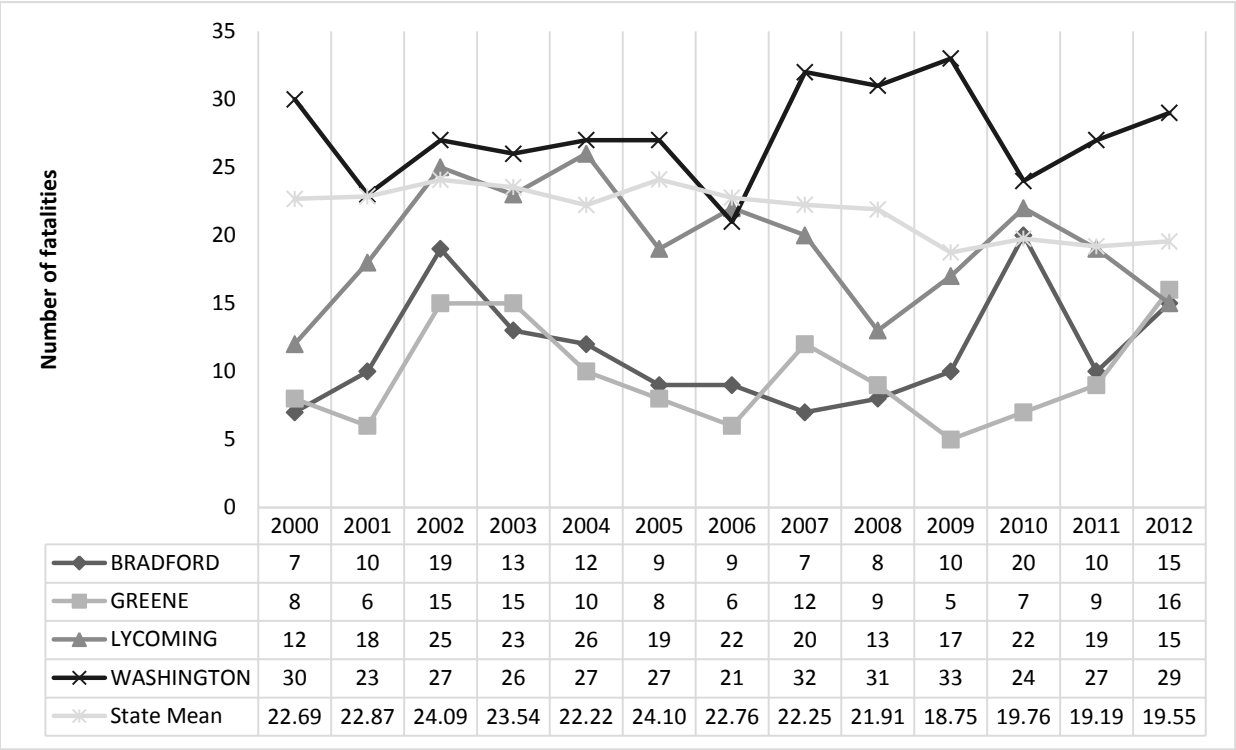
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
226 or more	2.698	2.083	2.424	2.603	2.289	2.475	2.246	2.431	2.223	1.823	2.520	3.206	2.609	2.797
58-225	4.239	3.531	3.386	3.655	3.156	3.383	3.285	3.346	3.299	3.248	4.401	3.739	3.888	3.811
8-57	12.494	9.424	8.142	10.902	9.838	10.555	9.059	10.849	8.516	6.831	10.802	10.381	12.367	11.011
7 or fewer	4.017	2.913	3.027	3.073	3.003	3.043	2.743	3.186	2.805	2.401	2.393	2.786	2.453	2.607
No wells	6.621	5.484	4.975	5.305	5.072	5.449	4.753	5.322	4.329	4.191	4.879	5.310	4.715	4.760

Source: Pennsylvania Department of Transportation.

Traffic Fatalities

This final section examines fatality figures for the study counties, their surrounding counties, and all counties according to their number of wells drilled during the study period. The numbers of fatalities in all counties is quite small, so small changes can lead to very dynamic patterns (Figures 26 and 27). Accordingly, it is difficult to identify patterns. Bradford County experienced peaks in 2002 and 2010; Greene County similarly experienced peaks in 2002, 2003, and 2012. Of the four study counties, Greene County's rate in 2012 was the highest rate of traffic fatalities during the study period. Lycoming and Washington counties had slightly less volatile rates over the study period.

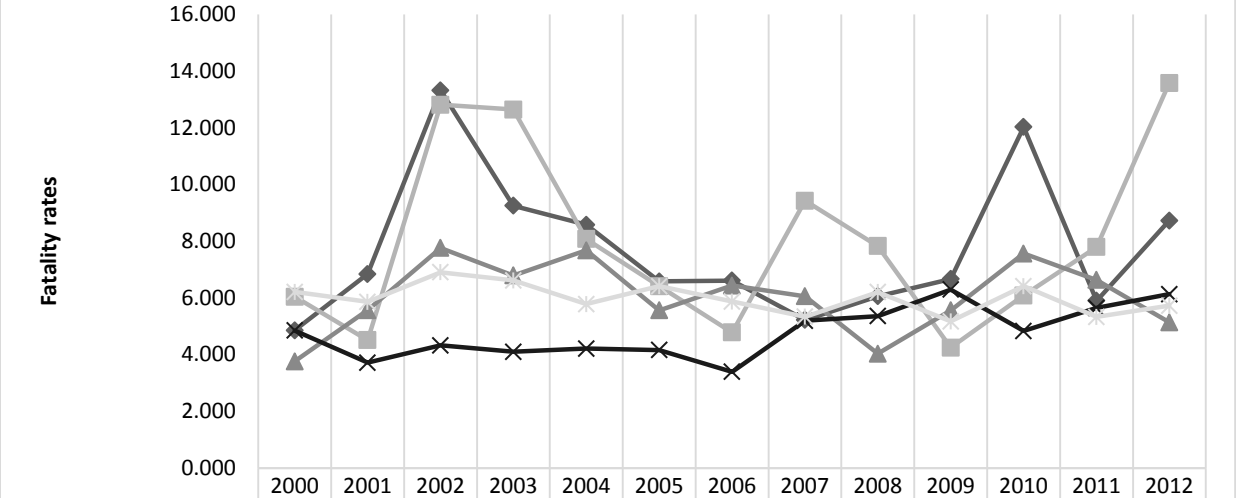
Figure 26. Total number of vehicle crashes with one or more fatalities in the four study counties and Pennsylvania's county average, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BRADFORD	7	10	19	13	12	9	9	7	8	10	20	10	15
GREENE	8	6	15	15	10	8	6	12	9	5	7	9	16
LYCOMING	12	18	25	23	26	19	22	20	13	17	22	19	15
WASHINGTON	30	23	27	26	27	27	21	32	31	33	24	27	29
State Mean	22.69	22.87	24.09	23.54	22.22	24.10	22.76	22.25	21.91	18.75	19.76	19.19	19.55

Source: National Highway Traffic Safety Administration.

Figure 27. Rates of vehicle crashes with one or more fatalities in the four study counties and Pennsylvania's county average, 2000-2012

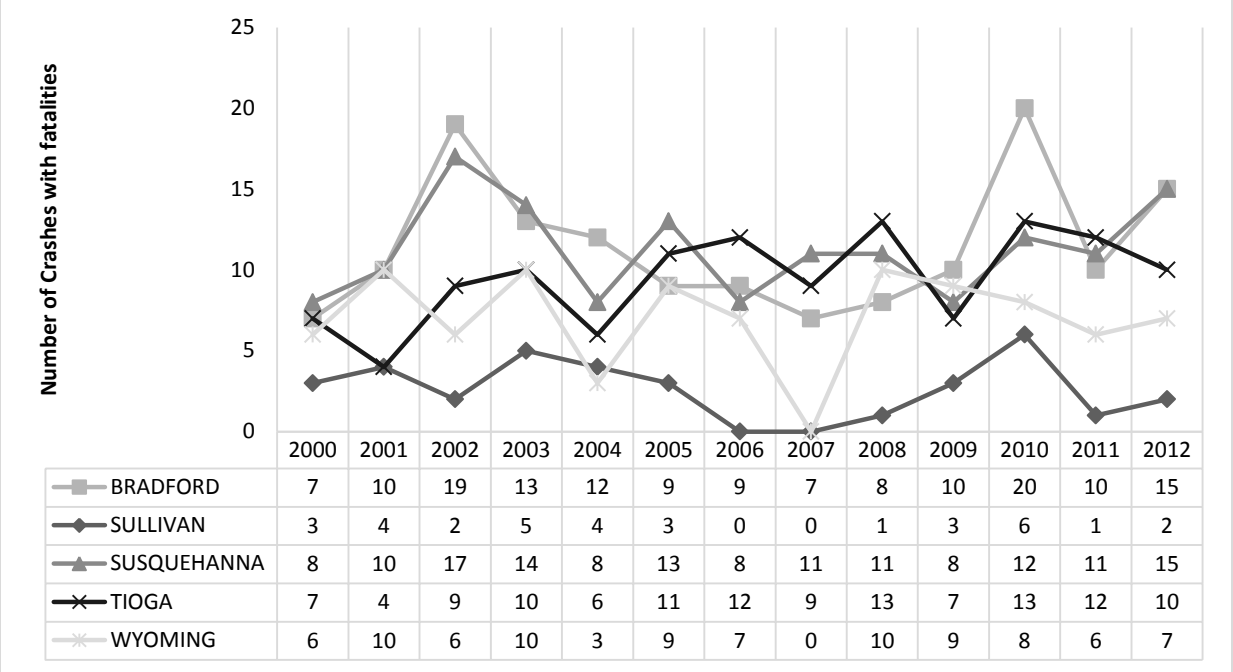


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BRADFORD	4.855	6.841	13.318	9.252	8.578	6.585	6.609	5.221	6.057	6.670	12.025	5.903	8.727
GREENE	6.044	4.513	12.811	12.641	8.079	6.411	4.781	9.428	7.830	4.249	6.086	7.796	13.580
LYCOMING	3.763	5.570	7.760	6.791	7.680	5.562	6.438	6.058	4.031	5.562	7.565	6.632	5.136
WASHINGTON	4.850	3.714	4.328	4.103	4.212	4.165	3.395	5.198	5.357	6.297	4.831	5.645	6.130
State Mean	6.211	5.860	6.905	6.616	5.781	6.415	5.875	5.334	6.202	5.170	6.416	5.331	5.728

Source: National Highway Traffic Safety Administration.

The fatality numbers for the study counties and their surrounding counties also appear to have no pattern; given the low numbers in each county, small changes can have a dramatic impact on the trend line and on the rates.

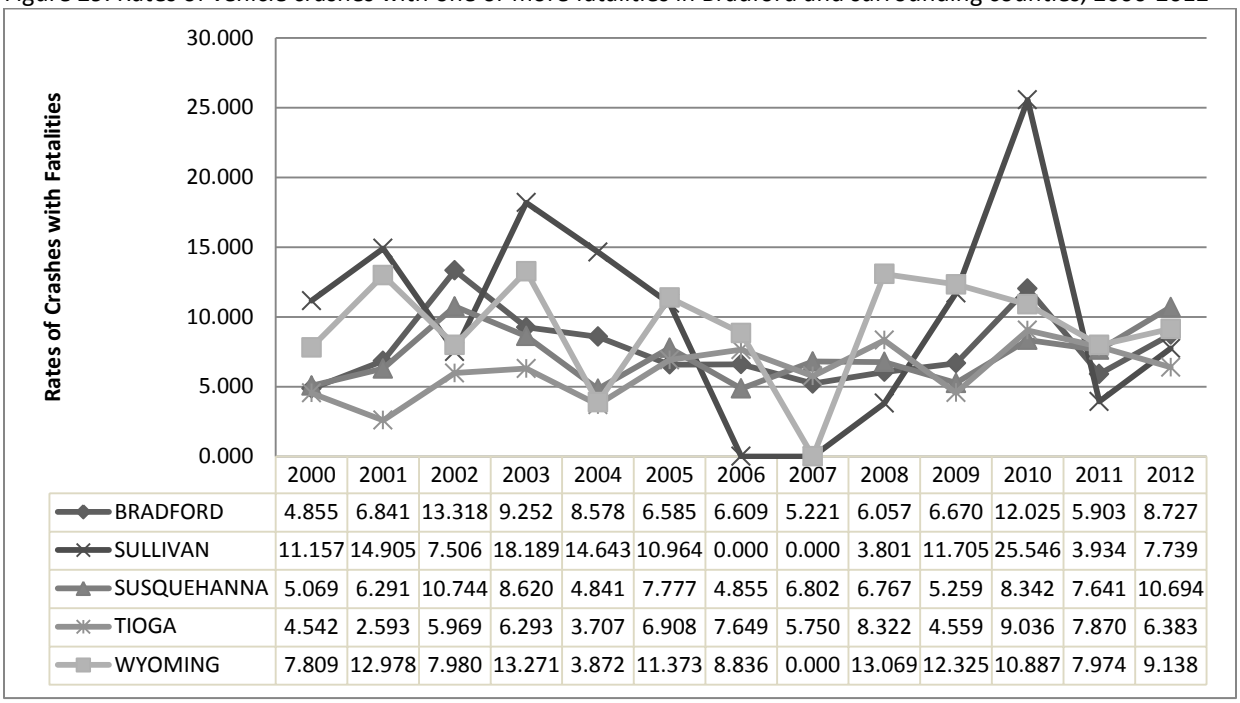
Figure 28. Total number of vehicle crashes with one or more fatalities in Bradford and surrounding counties, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BRADFORD	7	10	19	13	12	9	9	7	8	10	20	10	15
SULLIVAN	3	4	2	5	4	3	0	0	1	3	6	1	2
SUSQUEHANNA	8	10	17	14	8	13	8	11	11	8	12	11	15
TIOGA	7	4	9	10	6	11	12	9	13	7	13	12	10
WYOMING	6	10	6	10	3	9	7	0	10	9	8	6	7

Source: National Highway Traffic Safety Administration.

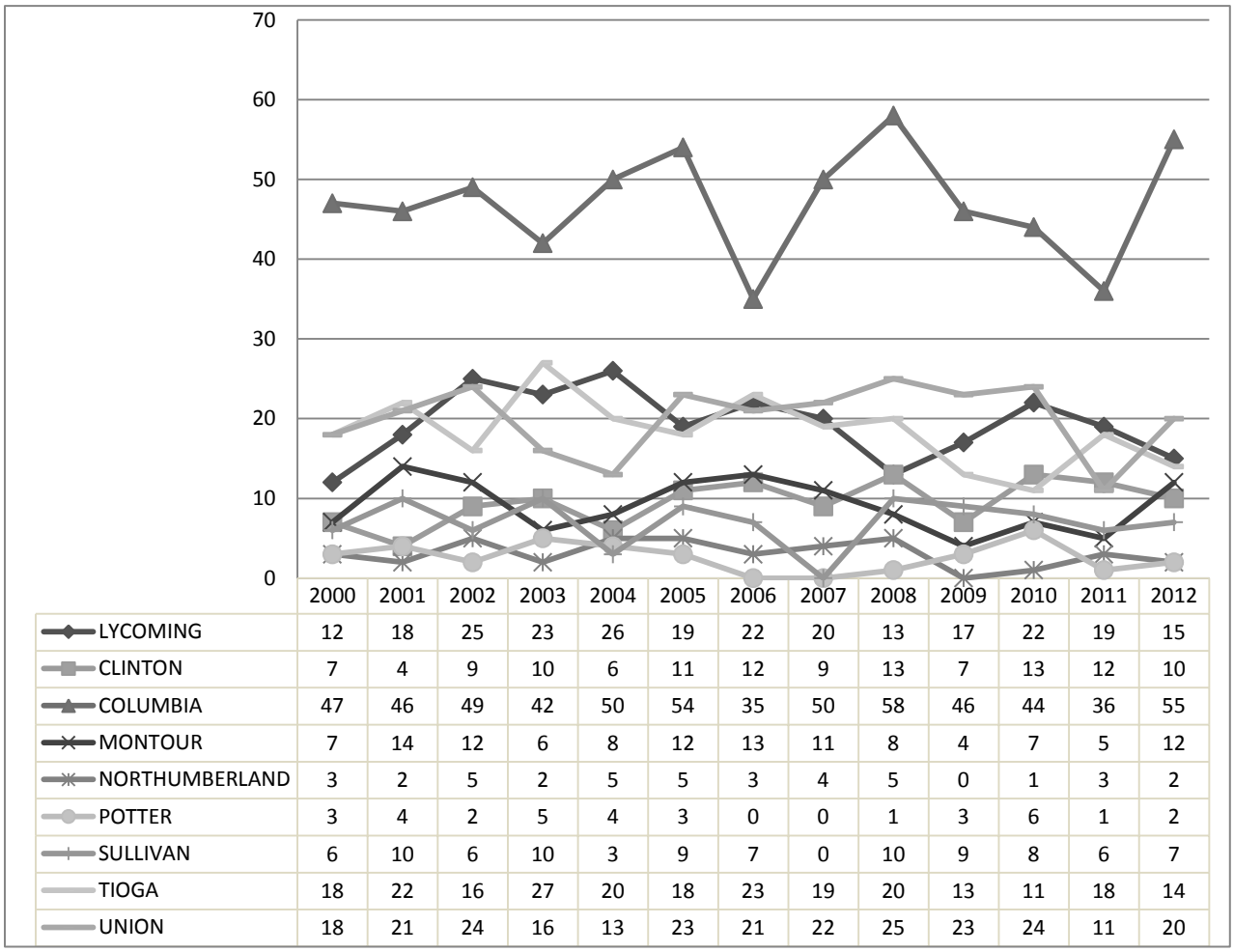
Figure 29. Rates of vehicle crashes with one or more fatalities in Bradford and surrounding counties, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BRADFORD	4.855	6.841	13.318	9.252	8.578	6.585	6.609	5.221	6.057	6.670	12.025	5.903	8.727
SULLIVAN	11.157	14.905	7.506	18.189	14.643	10.964	0.000	0.000	3.801	11.705	25.546	3.934	7.739
SUSQUEHANNA	5.069	6.291	10.744	8.620	4.841	7.777	4.855	6.802	6.767	5.259	8.342	7.641	10.694
TIOGA	4.542	2.593	5.969	6.293	3.707	6.908	7.649	5.750	8.322	4.559	9.036	7.870	6.383
WYOMING	7.809	12.978	7.980	13.271	3.872	11.373	8.836	0.000	13.069	12.325	10.887	7.974	9.138

Source: National Highway Traffic Safety Administration.

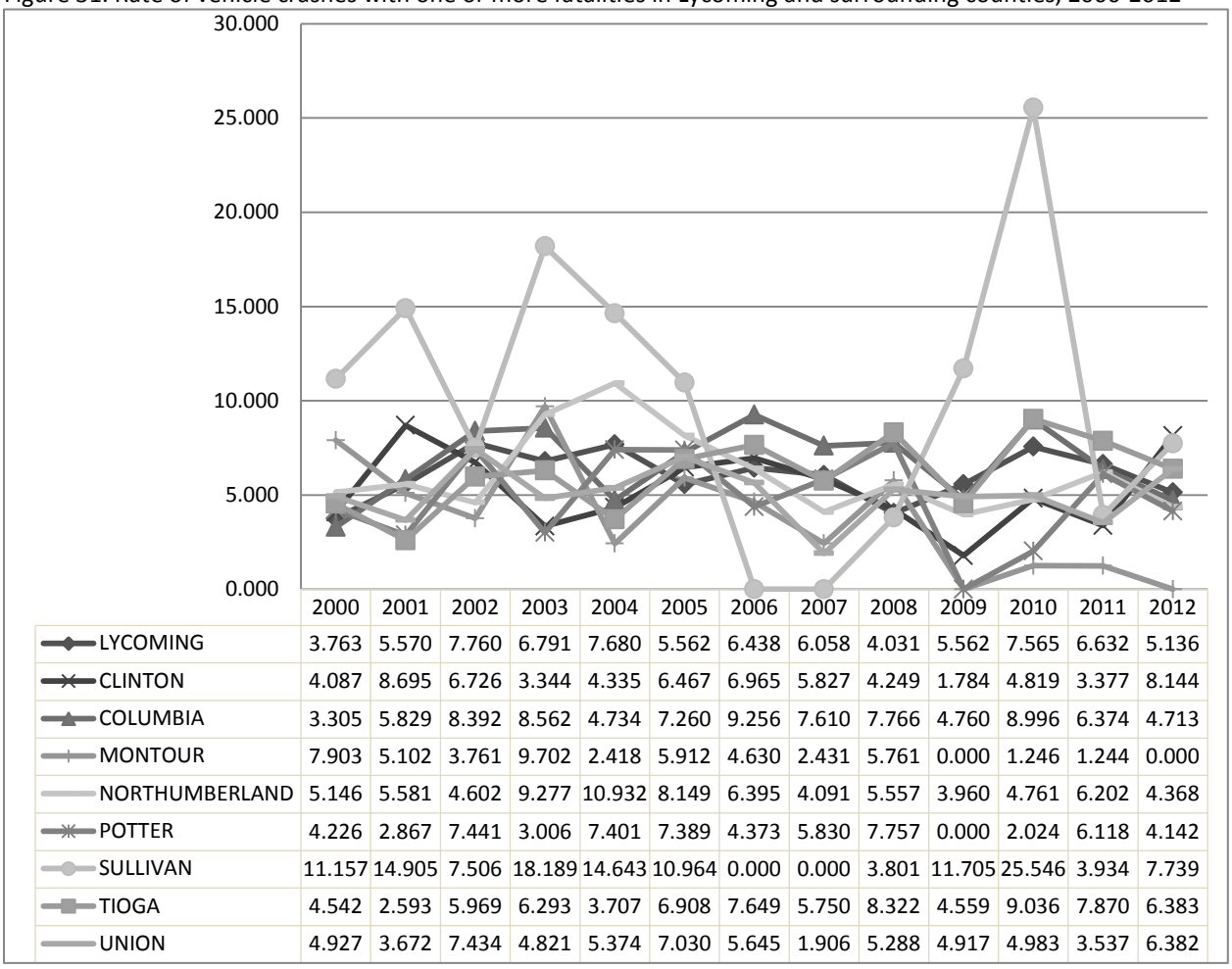
Figure 30. Total number of vehicle crashes with one or more fatalities in Lycoming and surrounding counties, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
LYCOMING	12	18	25	23	26	19	22	20	13	17	22	19	15
CLINTON	7	4	9	10	6	11	12	9	13	7	13	12	10
COLUMBIA	47	46	49	42	50	54	35	50	58	46	44	36	55
MONTOUR	7	14	12	6	8	12	13	11	8	4	7	5	12
NORTHUMBERLAND	3	2	5	2	5	5	3	4	5	0	1	3	2
POTTER	3	4	2	5	4	3	0	0	1	3	6	1	2
SULLIVAN	6	10	6	10	3	9	7	0	10	9	8	6	7
TIOGA	18	22	16	27	20	18	23	19	20	13	11	18	14
UNION	18	21	24	16	13	23	21	22	25	23	24	11	20

Source: National Highway Traffic Safety Administration

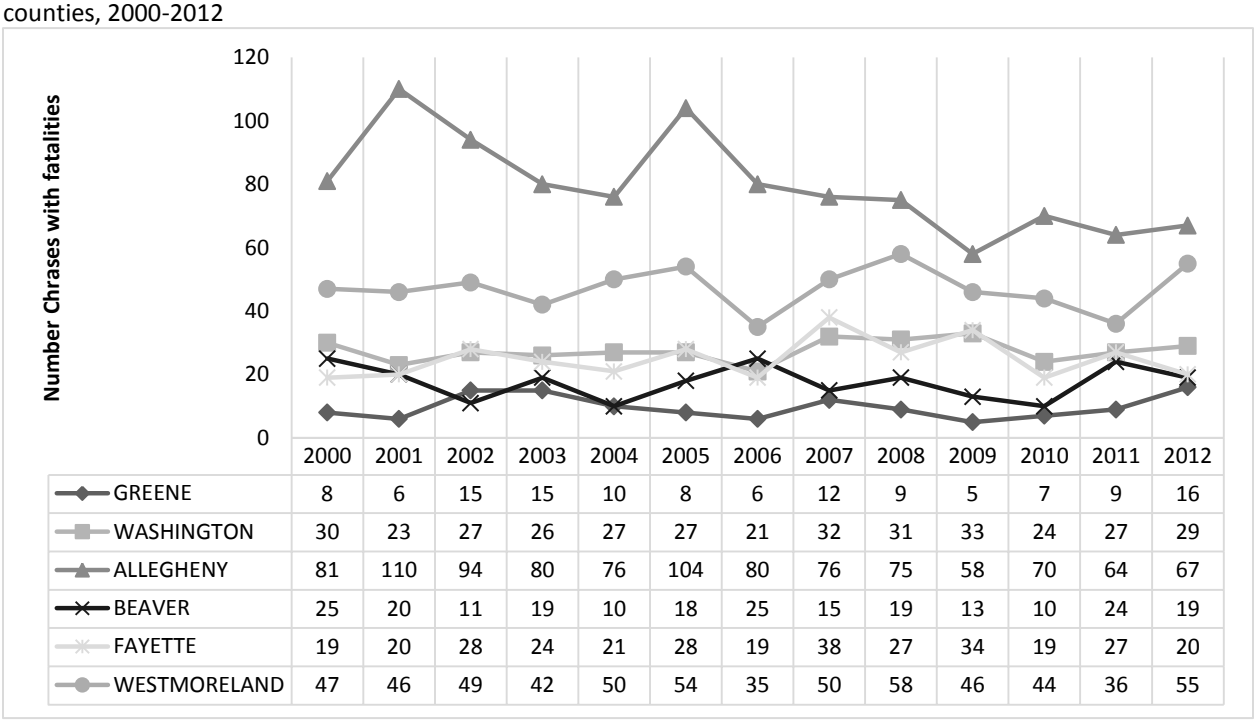
Figure 31. Rate of vehicle crashes with one or more fatalities in Lycoming and surrounding counties, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
LYCOMING	3.763	5.570	7.760	6.791	7.680	5.562	6.438	6.058	4.031	5.562	7.565	6.632	5.136
CLINTON	4.087	8.695	6.726	3.344	4.335	6.467	6.965	5.827	4.249	1.784	4.819	3.377	8.144
COLUMBIA	3.305	5.829	8.392	8.562	4.734	7.260	9.256	7.610	7.766	4.760	8.996	6.374	4.713
MONTOUR	7.903	5.102	3.761	9.702	2.418	5.912	4.630	2.431	5.761	0.000	1.246	1.244	0.000
NORTHUMBERLAND	5.146	5.581	4.602	9.277	10.932	8.149	6.395	4.091	5.557	3.960	4.761	6.202	4.368
POTTER	4.226	2.867	7.441	3.006	7.401	7.389	4.373	5.830	7.757	0.000	2.024	6.118	4.142
SULLIVAN	11.157	14.905	7.506	18.189	14.643	10.964	0.000	0.000	3.801	11.705	25.546	3.934	7.739
TIOGA	4.542	2.593	5.969	6.293	3.707	6.908	7.649	5.750	8.322	4.559	9.036	7.870	6.383
UNION	4.927	3.672	7.434	4.821	5.374	7.030	5.645	1.906	5.288	4.917	4.983	3.537	6.382

Source: National Highway Traffic Safety Administration.

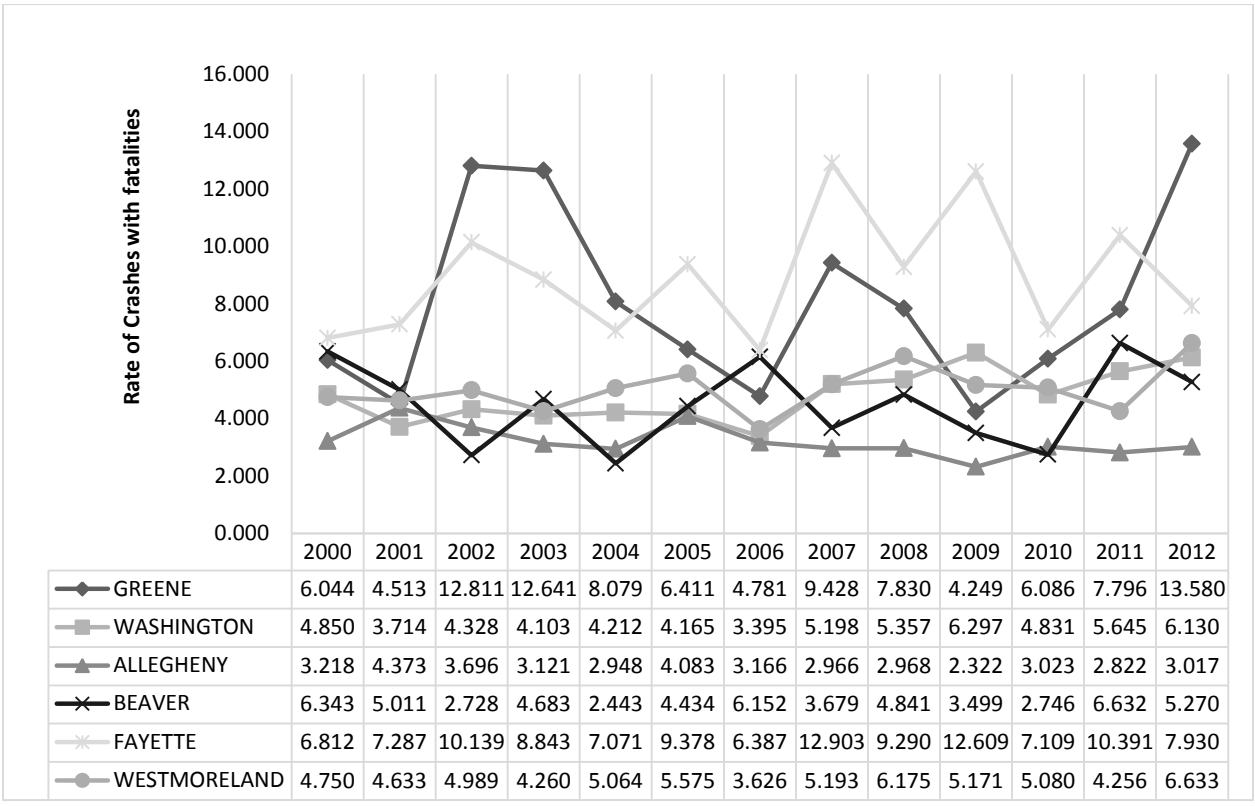
Figure 32. Total number of vehicle crashes with one or more fatalities in Greene, Washington, and surrounding counties, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GREENE	8	6	15	15	10	8	6	12	9	5	7	9	16
WASHINGTON	30	23	27	26	27	27	21	32	31	33	24	27	29
ALLEGHENY	81	110	94	80	76	104	80	76	75	58	70	64	67
BEAVER	25	20	11	19	10	18	25	15	19	13	10	24	19
FAYETTE	19	20	28	24	21	28	19	38	27	34	19	27	20
WESTMORELAND	47	46	49	42	50	54	35	50	58	46	44	36	55

Source: National Highway Traffic Safety Administration.

Figure 33. Rate of vehicle crashes with one or more fatalities in Greene, Washington, and surrounding counties, 2000-2012

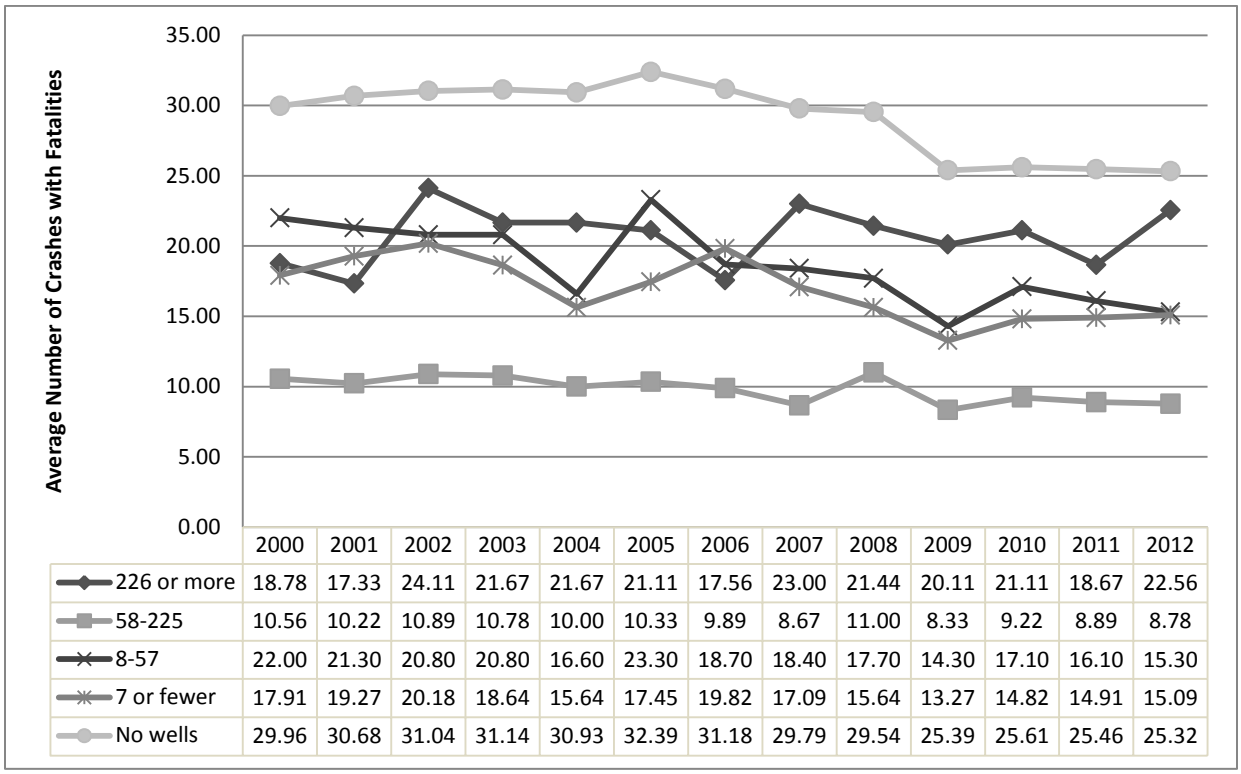


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GREENE	6.044	4.513	12.811	12.641	8.079	6.411	4.781	9.428	7.830	4.249	6.086	7.796	13.580
WASHINGTON	4.850	3.714	4.328	4.103	4.212	4.165	3.395	5.198	5.357	6.297	4.831	5.645	6.130
ALLEGHENY	3.218	4.373	3.696	3.121	2.948	4.083	3.166	2.966	2.968	2.322	3.023	2.822	3.017
BEAVER	6.343	5.011	2.728	4.683	2.443	4.434	6.152	3.679	4.841	3.499	2.746	6.632	5.270
FAYETTE	6.812	7.287	10.139	8.843	7.071	9.378	6.387	12.903	9.290	12.609	7.109	10.391	7.930
WESTMORELAND	4.750	4.633	4.989	4.260	5.064	5.575	3.626	5.193	6.175	5.171	5.080	4.256	6.633

Source: National Highway Traffic Safety Administration.

Finally, fatality figures across the categories of counties based on number of wells does not reveal a clear pattern. The number of crashes with fatalities for the counties with the highest number of wells is higher than counties with fewer wells during the period of the highest levels of development (from 2007-2012); in contrast, counties in all other categories had declining numbers. The number of crashes with fatalities was at its highest point (about 24, on average) in 2002, with other peaks in 2007 and 2012. The annual average number of crashes for counties with the highest number of wells was the same for the period prior to (2000-2007) and during (2008-2012) development (20.7 and 20.8, respectively). In contrast, the annual averages for these same time periods declined for all the other categories of counties: counties with 58-225 wells declined slightly from 10.2 to 9.2 crashes, on average; counties with 8-57 wells declined from 20.2 to 16.1, on average; counties with 1-7 wells declined from 18.3 to 14.7 crashes, on average; and counties with no wells declined from 30.9 to 26.3 crashes, on average.

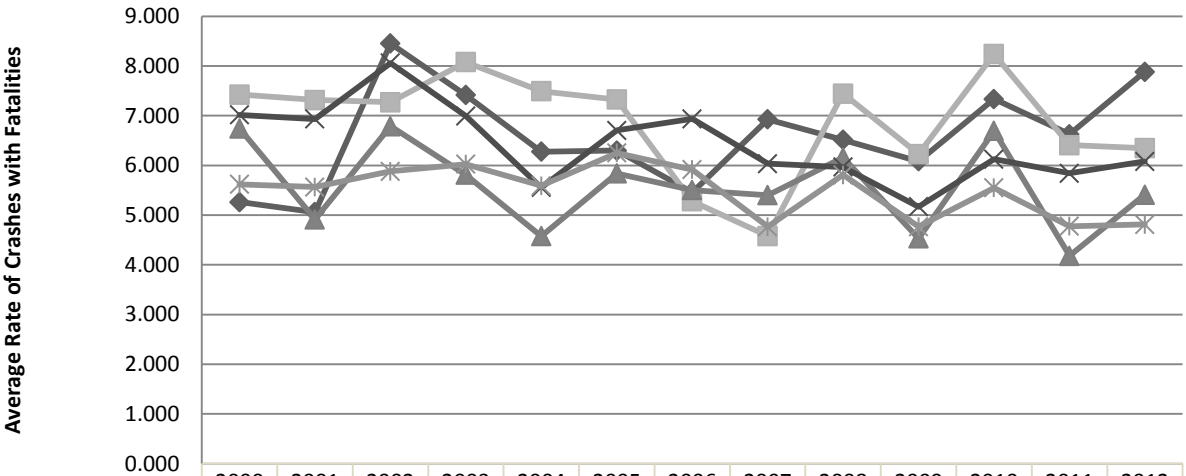
Figure 34. County average of number of vehicle crashes with one or more fatalities in counties by number of wells, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
226 or more	18.78	17.33	24.11	21.67	21.67	21.11	17.56	23.00	21.44	20.11	21.11	18.67	22.56
58-225	10.56	10.22	10.89	10.78	10.00	10.33	9.89	8.67	11.00	8.33	9.22	8.89	8.78
8-57	22.00	21.30	20.80	20.80	16.60	23.30	18.70	18.40	17.70	14.30	17.10	16.10	15.30
7 or fewer	17.91	19.27	20.18	18.64	15.64	17.45	19.82	17.09	15.64	13.27	14.82	14.91	15.09
No wells	29.96	30.68	31.04	31.14	30.93	32.39	31.18	29.79	29.54	25.39	25.61	25.46	25.32

Source: National Highway Traffic Safety Administration.

Figure 35. County average rate of vehicle crashes with one or more fatalities in counties by number of wells, 2000-2012



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
226 or more	5.262	5.061	8.453	7.416	6.278	6.300	5.458	6.928	6.515	6.082	7.336	6.628	7.883
58-225	7.424	7.317	7.272	8.078	7.493	7.327	5.277	4.579	7.445	6.228	8.239	6.409	6.348
8-57	6.744	4.916	6.789	5.812	4.576	5.840	5.502	5.402	6.159	4.531	6.693	4.182	5.409
7 or fewer	7.018	6.934	8.059	6.994	5.555	6.703	6.936	6.035	5.967	5.169	6.125	5.843	6.082
No wells	5.618	5.564	5.879	6.027	5.590	6.252	5.917	4.766	5.810	4.766	5.549	4.777	4.811

Source: National Highway Traffic Safety Administration.

The rates of crashes with one or more fatalities (Figure 35) also show a highly variable annual average rate. Counties in the top category of well counts (226 or more) have slightly higher average rates in 2007-2012 (6.9) than in the period prior to well development (6.4). In comparison, the other categories of counties had steady or declining rates, on average. Counties with 58-225 wells had on average 6.8 crashes with fatalities per daily vehicle mile traveled from 2000-2007 and 6.9 from 2008-2012. Counties with 8-57 wells had a decline in the rate from 5.7 to 5.4, counties with 7 or fewer wells declined from 6.8 to 5.8, and counties with no wells declined from 5.7 to 5.1 crashes per DVMT.

Conclusions

This research examined three indicators of traffic accidents – total crashes, heavy truck crashes, and crashes with one or more fatalities – in relation to Marcellus Shale development. Although the information presented here is only descriptive, it reveals traffic trends both prior to and during the heaviest phases of well development to date for several of the most active counties in the state. Overall, the findings are consistent with other studies (Graham et al., 2015) and suggest that the most rural counties in the northern tier experiencing the highest levels of development – particularly Bradford, Tioga, Susquehanna, and Lycoming – had increased absolute numbers and rates of total crashes and heavy truck crashes. The years of greatest impact appear to be 2009-2011, when the well drilling and completion activity was at its height. In subsequent years, as production declined due to low natural gas prices and as production companies have adapted their practices (such as using more piping for transporting water, recycling wastewater, and using rail to transport supplies), the total number of trucks and oil and gas workers on the roads may have declined, resulting in fewer crashes. The data for

crashes with fatalities also suggests that counties with the highest number of wells experienced steady rates whereas other counties experienced a decline in these crashes.

Together these findings suggest the need to closely monitor and address traffic safety concerns in areas of particularly high development, especially in more rural counties. Other measures that encourage road safety, including speed reductions, signage, enforcement, and traffic calming, should also be considered in these regions. Policies that encourage alternative systems of transportation, that rely less on heavy trucks, also should be considered.

Report Authors

Kathryn Brasier, PhD – Associate Professor of Rural Sociology
Joshua Perchinski – MS Student in Rural Sociology

Other Research Team Members
Leland Glenna, PhD – Associate Professor of Rural Sociology
Timothy Kelsey, PhD – Professor of Agricultural Economics
Kai Schafft, PhD – Associate Professor of Educational Leadership & Director of Center on Rural Education and Communities
Shannon M. Monnat, PhD – Assistant Professor of Rural Sociology, Demography, and Sociology
Mark Suchyta – MS Student in Rural Sociology
Raeven Faye Chandler – PhD Student in Rural Sociology and Demography
Max Pohlman – Undergraduate Student

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Appendix A: County Typology

Well Count Typology	***Counties***
No Wells	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Erie, Franklin, Fulton, Juniata, Lancaster, Lebanon, Lehigh, Mifflin, Monroe, Montgomery, Montour, Northumberland, Perry, Philadelphia, Pike, Schuylkill, Snyder, Union, York
Bottom Quartile (7 or fewer)	Bedford, Blair, Cambria, Columbia, Crawford, Huntingdon, Lackawanna, Luzerne, Warren, Wayne
Second Quartile (8-57)	Cameron, Centre, Clarion, Forest, Indiana, Jefferson, Mercer, Potter, Somerset, Venango
Third Quartile (58-225)	Allegheny, Armstrong, Beaver, Clearfield, Clinton, Elk, Fayette, Lawrence, McKean, Sullivan
Top Quartile (More than 226)	Bradford, Butler, Greene, Lycoming, Susquehanna, Tioga, Washington, Westmoreland, Wyoming

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The Center for Rural Pennsylvania
625 Forster St., Room 902
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