FINAL REPORT

State of Wyoming

Department of Transportation

Mitigating Impacts of Oil and Gas Traffic on Southeastern Wyoming County Roads

By:
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Abstract:
The county roads of southeastern Wyoming are experiencing considerable impacts from oil and gas drilling. These impacts may increase substantially in the near future. The Wyoming Department of Transportation contracted with the Wyoming Technology Transfer Center (WY T^2/LTAP) at the University of Wyoming to assess current conditions and evaluate current impacts from oil and gas drilling on county roads in four southeastern Wyoming counties, Converse, Goshen, Laramie and Platte.

This assessment includes: evaluating the current conditions of the four counties' paved and unpaved roads and cattleguards; measuring the roads' current traffic; predicting the roads' drilling traffic based on their proximity to oil and gas wells; compiling and assessing the counties' maintenance records; assessing the adequacy of the counties' road and bridge departments' resources; evaluating oversize and overweight vehicle permitting processes; and compiling safety and bridge data. In addition, the four counties were asked to identify those roads they believed were currently being or might soon be impacted by oil and gas-related traffic.

Based on the compiled information, improvements to the four counties' paved and unpaved roads are recommended. The counties' maintenance practices are assessed, as is their ability to maintain their roads in the event that they are impacted by substantial increases in oil and gas-related traffic.

Recommendations are made for future monitoring and management efforts on Wyoming's county roads. Procedures for assessing bridges are recommended for both those over 20 feet long currently monitored by WYDOT and for those under 20 feet long. Two options for monitoring paved roads are proposed, one of which involves continuous monitoring of county roads in southeastern Wyoming, while the other involves monitoring paved county roads throughout the entire state on a rotating basis. Finally, it is recommended that unpaved roads' maintenance tasks and costs are monitored and recorded similarly throughout the state. Each of these recommendations is proposed to both assess oil and gas drilling impacts on county roads and to allow them to be maintained and managed as efficiently as practical.

Key Words
Wyoming, oil, gas, drilling, county, roads, permits, resources, safety, impacts.

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SI* (Modern Metric) Conversion Factors

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

Approximate Conversions to SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

Mass

g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T

Temperature (exact)

°C	Centigrade temperature	1.8 C + 32	Fahrenheit temperature	°F

Illumination

lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl

Force and Pressure or Stress

N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

Mass

oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg

Temperature (exact)

°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C

Illumination

fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2

Force and Pressure or Stress

lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

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1. INTRODUCTION

This study was conducted at the behest of the Wyoming state legislature. They recognized that southeast Wyoming may soon experience, and in some cases is already experiencing, dramatic increases in oil- and gas-related traffic. They decided to assist several southeastern Wyoming counties with preparations for the potential impacts of oil and gas activities on their roads. They determined that necessary first steps were to document the current condition of the four counties' roads and to evaluate the current impacts of oil and gas activities on these roads.

Many parts of the State of Wyoming, along with other oil and natural gas producing regions, are currently experiencing a dramatic increase in exploratory and production drilling. The oil and natural gas industry has recently improved the processes of horizontal drilling and fracturing underground formations to recover more oil and gas. These advancements are making it possible to extract oil and gas from southeastern Wyoming's Niobrara Shale. County roads that once handled very low traffic volumes will be expected to carry hundreds of vehicles per day with a high proportion of heavy trucks. A typical example of such a county road is shown in Figure 1.1. These county roads were not originally designed for heavy truck traffic. Therefore, it is important that these roads are evaluated, and often upgraded, to keep them in serviceable condition.

Figure 1.1 Crooks Gap Road, Sweetwater County, Wyoming

To document and evaluate oil and gas impacts on county road networks, the legislature through the Wyoming Department of Transportation (WYDOT) contracted with the Wyoming Technology Transfer Center (WY T^2/LTAP), Wyoming's local technical assistance program at the University of Wyoming, to document and analyze the condition and performance of Converse (CO), Goshen (GO), Laramie (LA) and Platte (PL) Counties' road networks.

1.1 Objectives

The primary objective of this study and report is to assess the current conditions of Converse, Goshen, Laramie and Platte Counties' road networks. The emphasis is on roads impacted by oil and gas activities. Traffic counts and assessments, maintenance costs, and surface conditions are gathered and analyzed to evaluate these counties' road networks and the degree to which they are affected by oil and gas traffic. This report provides an overall evaluation of the condition of the counties' road networks and an assessment of how these conditions have been altered by oil and gas operations.

1.2 Background

1.2.1 Contributions to the Wyoming State Economy

The oil and gas industry has been doing business in Wyoming for over 100 years while making significant contributions to the State's economy. According to the Petroleum Association of Wyoming, in 2010 Wyoming ranked 7th in the nation in crude oil production and 2nd in natural gas production. During the same year, the petroleum industry employed approximately 21,000 people with a payroll of over $1.1 billion, and oil and gas production contributed $1.9 billion to state and local governments as taxes and royalties. It is essential that the State of Wyoming continues to work closely with the petroleum industry to insure the adequacy of the transportation infrastructure. Such cooperation will be beneficial to the Wyoming economy, to the driving public, and to the oil and gas industry.

1.2.2 Oil and Gas Impacts: Texas Paved Roads in the Early 1980's

Though most would agree that oil and gas activities significantly impact county roads, quantifying these impacts is difficult for a number of reasons. Roads will need increased maintenance, repairs, and in some cases rehabilitation or reconstruction due to substantial increases in traffic, particularly heavy truck traffic. A report published in 1983 evaluated oil field impacts on low volume paved roads in Texas *(Mason and Scullion 1983)*. This report estimated that drilling a single well takes about 60 days and that 1,365 trucks larger than a pickup are needed during preparation and drilling. Additionally they estimated that production typically lasts about three years and that 150 large trucks serve each well per month.

Since typical traffic characteristics and usual vehicle distributions are not applicable to roadways that carry oil field traffic, there is a need to determine the definitive elements of oil field traffic demand.

1.2.3 Oil and Gas Impacts: Wyoming Unpaved Roads in the Mid-2000's

The WY T^2/LTAP Center conducted a project from 2004 through 2006 examining oil and gas impacts on Wyoming's Carbon, Johnson, and Sheridan Counties' road networks. Many of the methods used in the current project were developed during this earlier project. An analysis of these three counties' unpaved roads concluded that those roads impacted by oil and gas drilling activities needed an average of $13,434 per mile in improvements while their unpaved, non-impacted roads needed an average of $2,048 per mile in improvements. Potholes were the main distress that necessitated these improvements, with 69% of the improvements on drilling roads and 62% of the improvements on non-drilling roads recommended because of potholes. Additionally, rutting was the distress necessitating 20% of the improvements on drilling roads and 30% of the improvements on non-drilling roads. Finally, only 10% of the improvements recommended were due to other distresses – drainage, dust or washboards *(Huntington and Ksaibati 2009a)*.

1.2.4 Oil and Gas Impacts: North Dakota in the Late 2000's

North Dakota has been experiencing oil and gas impacts similar to Wyoming. The North Dakota legislature funded a study to evaluate oil and gas impacts in 2010. The Upper Great Plains Transportation Institute (UGPTI) at North Dakota State University (NDSU) submitted a report to the North Dakota Department of Commerce titled 'Additional Road Investments Needed to Support Oil and Gas Production and Distribution in North Dakota' *(Tolliver and Dybing 2010)*. The report focused on forecasting the investment needed for efficient transportation of oil while maintaining an acceptable roadway for travelers in the oil producing counties of North Dakota over the next 20 years.

Prior to 2005, North Dakota had 3,300 producing oil wells. As of November 2010, that number had risen to 5,200. The number of producing wells is expected to increase substantially in the future. With this increasing oil-related traffic, the study estimated investment needs of $340 million for paved roads and an additional investment of $567 million for unpaved roads over the next 20 years.

The following sections summarize the North Dakota study including its main findings, and how some of these findings can help the Wyoming effort in evaluating the impacts of oil and gas drilling activities on county roads.

1.2.4.1 Objectives of the North Dakota Study

The purpose of the North Dakota study was to forecast road investment needs in oil and gas producing counties of North Dakota over the next 20 years due to the expected increase in traffic. The essential objective was to quantify the additional investments necessary for efficient year-round movement of oil-related traffic while providing the general public with acceptable roadways. The focus was on roads owned or maintained by local governments.

1.2.4.2 Principles of the North Dakota Study

The study was performed with the following principles in mind:

- Impacts and funding needs are analyzed for three types of roads: paved, graveled, and graded and drained.
- The analysis is based on three main data sources:
  - Oil production forecasts
  - Traffic data on selected roads
  - County road surveys to identify road conditions
- The forecasted output of wells is routed over the road network to pipelines using a detailed Geographic Information System (GIS) model in which oil movements are represented as equivalent tractor-semitrailer trips that follow least-cost paths.
- The county surveys provided information about the condition of each impacted segment.
- Typical thicknesses of surface and base layers were used.
- The future locations of drilling rigs were estimated from lease data obtained from the North Dakota Land Department. Estimates from the North Dakota Industrial Commission's Oil and Gas Division suggest that a total of 21,250 wells will be drilled in the next 10 to 20 years.

1.2.4.3 North Dakota Data Collection and Analysis

The North Dakota study followed a number of steps, as listed below and described in the following sections:

- Production forecasting from the North Dakota Land Department
- Trips forecasting and traffic analysis
- County road pavement structural assessments
- County road pavement service lives
- County roadway widths

1.2.4.3.1 Trips Forecast and Traffic Analysis

Oil traffic consists primarily of five types of movements:

1) Inbound movements of sand, water, cement, scoria/gravel, drilling mud, and fuel
2) Inbound movements of chemicals
3) Outbound movements of oil and byproducts
4) Outbound movements of saltwater
5) Rig-related movements of specialized vehicles such as workover rigs, fracturing rigs, cranes, and utility vehicles

Traffic counters were deployed at 100 locations in 15 of the 17 oil and gas producing counties. At each of the selected sites, a count of no less than 24 hours was taken and adjusted to represent the traffic over a 24-hour period. These raw counts were adjusted for monthly variation in traffic to estimate the average daily traffic (ADT) for each segment. The average traffic on these segments was 145 vehicles per day, with an average of 61 trucks, 26 of which are multi-units – semitrailer or multi-trailer trucks. Perhaps the road system that most closely resembles the major county roads is the rural collector network of the state highway system. The average daily traffic on state collectors was 277 vehicles per day, of which 17 are multi-unit trucks and 14 are single-unit trucks. Monitored North Dakota county roads had lower ADT but higher percentages of trucks – 34 single-unit and 27 multi-unit trucks per day. The paved roads in the 100 surveyed locations had 99 trucks per day, compared to 31 trucks per day on the state collectors.

1.2.4.3.2 Paved County Roads Structural Assessments

The capability of a road to accommodate additional truck traffic is measured by its structural number (SN) which is a function of the thickness of the surface and base layers and of the materials that make up these layers. Paved county roads are generally light-duty structures designed for farm-to-market and manufactured goods movements. They are often built with six-inch aggregate bases topped with asphalt. Total asphalt layer thicknesses usually range from 2½ to 6 inches. County roads in the oil and gas producing counties have an average SN of 1.6 for collectors and 1.1 for local county roads, while the average SN on state collectors in oil-producing counties is 2.8.

Each road in the study was analyzed for potential improvements. The four types of improvements for paved roads in this study were: reconstruction; normal resurfacing; structural overlay; and renewal. Each road that was a candidate for improvement was analyzed to determine what type of improvement was needed and an estimate of the investment was made. A structural overlay is a cost effective solution for pavements with substantial but lower increases in traffic, while on roads experiencing greater increases in traffic, reconstruction enables minor widening and shoulder improvements in addition to increasing structural capacity.

1.2.4.3.3 Paved County Roads Service Lives

The pavement design equations of the American Association of State Highway and Transportation Officials are used in this study *(AASHTO 1993)*. Using design equations and equivalent single-axle load (ESAL) factors, the service life of each impacted road is projected with and without oil traffic. The average reduction in life due to oil and gas traffic is estimated to be five years.

1.2.4.3.4 Roadway Width

According to surveys, the graded width of approximately half of the county roads in the oil and gas producing counties is 28 feet or less.

1.2.4.4 North Dakota Study Recommendations

The North Dakota study resulted in the following improvement recommendations:

- Reconstruction of Paved Roads
    - Approximately 256 miles of county road are selected for possible reconstruction.
- Structural Overlays
    - An additional 249 miles of paved road are candidates for structural overlays.
- Estimated Paved Road Funding Needs
    - The estimated paved road investment needs will cost about $340 million over the next 20 years. Most of these needs – 75% – are attributable to reconstruction, while 12% correspond to overlays and annual maintenance.
- Estimated Unpaved Road Funding Needs
    - Approximately 12,718 miles of impacted unpaved roads have been identified. The projected cost of oil-related traffic on these roads is $567 million over the next 20 years.
- Overall Needs
    - When the unpaved and paved road costs are added together, the projected investment needed for all roads is $907 million which implies an average annual cost of $45 million over the 20 year period from 2011 to 2030.

1.2.4.5 Implications for the Current Wyoming Study

The North Dakota study clearly demonstrated that the impact of oil and gas drilling activities on local roads is very significant. If a similar planning study were to be performed in Wyoming, forecasted needs would probably be of a similar magnitude to those in North Dakota.

Instead of duplicating the North Dakota study's approach, it makes more sense to concentrate the efforts in Wyoming on helping impacted counties develop their own pavement management systems (PMS). Such systems would enable them to collect condition data on their roadways so that they can measure actual rather than projected drilling impacts. Maintenance and rehabilitation strategies should be based on actual rather than projected conditions. WYDOT and other DOTs in the region follow a similar approach with their PMS. Continuous monitoring of road condition is a good management tool which will help impacted Wyoming counties for years to come. These systems require ongoing data collection and analysis to achieve the intended benefit of more efficient county road networks.

1.3 Study Justifications

As oil and gas drilling activities increase in southeastern Wyoming's Converse, Goshen, Laramie, and Platte Counties (see Figure 1.2), more trucks will travel their county roads. Many of the paved roads in these counties were built over 40 years ago. In the past, they served local traffic adequately without major upgrades. As these light duty roads are damaged by heavy oil and gas traffic, maintenance and rehabilitation costs will increase significantly. Unpaved roads in these counties will be impacted as well. Many of them lack adequate structural capacity, while others are not wide enough to safely carry local and truck traffic. Increased traffic on unpaved roads may necessitate both more maintenance and more dust control treatment. Proper maintenance and upgrades to paved and unpaved county roads would ensure meeting the needs of both the general public and the oil and gas industry.

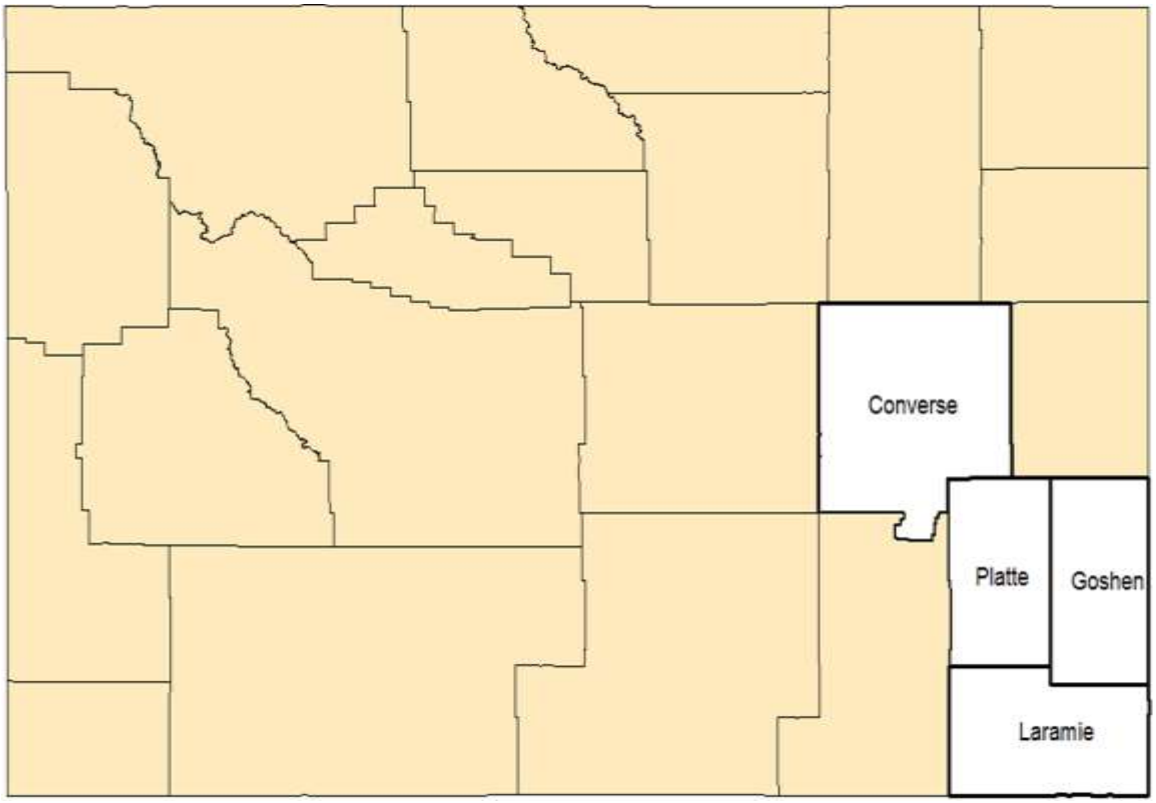


Figure 1.2 Wyoming counties in this study: Converse, Goshen, Laramie and Platte

The Wyoming legislature allocated $610,000 to evaluate oil and gas impacts and formulate mitigation strategies associated with mineral exploration and production in southeastern Wyoming. The Governor allocated a portion of these funds to the State Engineer's Office to ensure that water rights and usage compliance issues are adequately addressed. The rest of the fund, about $200,000, was allocated to WYDOT to evaluate road impacts. A small portion of the WYDOT funds were used in the first phase of this project to develop a standard methodology for mitigating the impact of oil and gas drilling activities. It is expected that the implementation of this methodology will help provide impacted counties with additional resources so that they can maintain and upgrade their road and bridge networks. Keeping local roads in acceptable condition is essential to both county residents getting their products to markets and to oil and gas companies which need to get their equipment to drilling sites. It may become increasingly difficult for both the companies and the impacted counties to keep up with rapidly increasing drilling traffic on the counties' roads without the support of the Wyoming legislature.

1.4 Project Organization

This project consists of three phases. The first phase has already been completed. This report describes the second phase. The third phase will address future needs more thoroughly and comprehensively. These phases are described in the following sections.

1.4.1 Previous Study: Phase I

The main objective of the first phase of this project *(Ksaibati 2011)* was to outline a methodology which will help counties develop strategies to effectively and efficiently serve the needs of the driving public and the oil and gas industry. This should help the counties adjust their maintenance and rehabilitation strategies so that they can allocate their limited resources effectively and efficiently. Recommended documentation will be very useful for legislators and others allocating funds to compensate counties for the impacts to their roads. The methodology developed will not only identify needed improvements on local roads, but it will also help rank the various improvements within each county. Such ranking will insure that funding is invested cost-effectively. The ultimate goal is to provide an effective tool for allocating scarce resources to ensure that road conditions are acceptable for all potential local and industrial users.

1.4.2 This Study: Phase II

Phase II, the subject of this report, is the implementation of the methodology developed in Phase I in Converse, Goshen, Laramie, and Platte Counties. The implementation concentrates on roads with predominantly drilling traffic as identified by the participating counties. Roads with inadequate surface conditions for their service level are recommended for improvements. Phase II addresses the immediate needs of the counties to mitigate the oil and gas impacts in the near-term. These recommendations can be used by lawmakers to allocate additional resources to improve heavily impacted county roads.

1.4.3 Future Study: Phase III

The third phase of this project will concentrate on identifying future needs in the four counties. Ongoing measurement and evaluation of road conditions and tracking maintenance efforts are both essential in determining future needs. Some of the counties included in this study may not have experienced the full impact of drilling activities yet. Therefore, Phase II may not show the full impact on their infrastructure. The proposed activities for Phase III will ensure the continuous monitoring of county roads so that resources are allocated not only *where* they are needed but also *when* they are needed. The Wyoming state legislature should be presented with information from the third phase so that they can allocate appropriate resources for its implementation.

1.5 Report Organization

This report describes the results of a broad and comprehensive assessment of the road and bridge networks of four Wyoming counties – Converse, Goshen, Laramie and Platte – with an emphasis on impacts to these networks from oil and gas-related activities and traffic.

This chapter, Chapter *1. Introduction,* provides a brief description of why the project was undertaken and of other efforts to assess oil and gas impacts on road networks. Chapter *2. Methodology* briefly describes the overall efforts that resulted in this report, including data collection, management, and analysis.

Subsequent chapters, listed below, provide more detailed descriptions of the efforts undertaken in this study along with additional background information. They also include detailed results of the analyses performed. These chapters are:

- *3. Traffic Counts*
- *4. Oil and Gas Trip Generation*
- *5. Paved Roads*
- *6. Unpaved Roads*
- *7. Cattle Guards*
- *8. Bridges*
- *9. Safety*
- *10. Permitting*
- *11. County Resources*

Chapter *12. Summary and Conclusions* summarizes the information presented in the topic-specific chapters listed above. Chapter *13. Phase III: Recommendations and Plans* suggests processes that will continue to provide the state and the counties with specific information that will allow the counties' road and bridge networks to be managed and funded as effectively and efficiently as possible. It also provides details on implementing Phase III, suggesting efforts to further improve operations of Wyoming counties' road and bridge departments while also generating information that will allow for equitable distribution of funds throughout the state.

Finally, Chapter *14. References* and the appendices provide readers with additional resources and information that supports the rest of this report.

2. METHODOLOGY

In simplest terms, this study consists of four main elements: planning; data collection; data analysis; and report preparation. The initial planning phases involved the overall process of determining goals and how they would be achieved. Two basic components of a county road network – maintenance costs and surface conditions – were evaluated to identify and quantify the impacts of oil and gas activities on county roads. The data collection phase consisted of two separate elements, one consisting of gathering costs and other data, and the other consisting of condition assessments. Data analysis combined these two elements to provide an overall evaluation of the counties' road networks and of the impacts to them caused by oil and gas activities. This report describes the results of these analyses in each of the four counties and in the four counties as a whole.

2.1 Planning

Plans for this element of the study were developed in Phase I *(Ksaibati 2011)*. This document describes proposed data collection, management and analysis techniques. It proposes methods by which the WY T^2/LTAP Center would assist counties by helping them establish pavement and other asset management systems so that they may document the performance of their road networks. One focus of these systems would be to document the impacts of oil and gas activities on the counties' road networks.

2.2 Data Collection, Management and Storage

Eight different types of data were collected for this study: unpaved road ratings; paved road ratings; traffic counts; cattle guard ratings; bridge data; oil and gas activities; maintenance records; and crash data. Field data was collected for unpaved road conditions, paved road conditions, cattle guard conditions, and traffic counts. Al these elements are related to each other with the location-specific capabilities of the geographical information system (GIS).

2.2.1 Preliminary Oil and Gas Impacts Inventory

In order to assess the impacts of oil and gas activities on county roads, the counties were consulted. Roads currently experiencing impacts were identified by each county's road and bridge supervisor. Since the degree and type of oil and gas impacts vary considerably from county to county, the standards by which the supervisors assigned roads as impacted or non-impacted also varied considerably. Figure 2.1 shows the locations of the roads identified as impacted and other, non-impacted roads in the four counties. Table 2.1 shows the mileages and the number of segments identified as impacted and non-impacted for each county for both paved and unpaved roads.

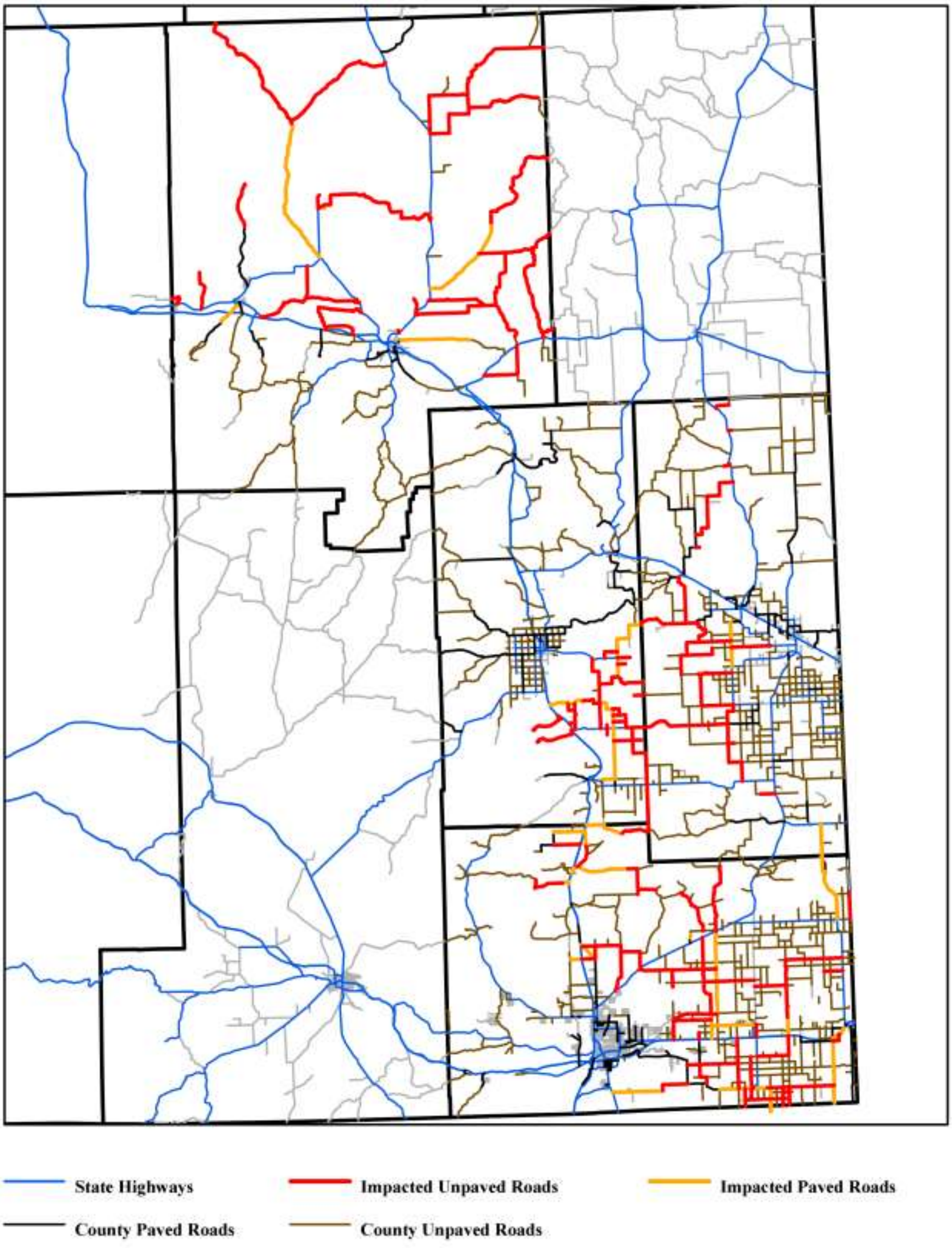


Figure 2.1 Roads identified by county personnel as impacted by oil and gas activities.

Table 2.1 Mileages and Segment Counts of Impacted and Non-Impacted County Roads as Identified by County Personnel

	Unpaved County Roads					
	Impacted		**Non-Impacted**		**Total**	
County	**Miles**	**Segments**	**Miles**	**Segments**	**Miles**	**Segments**
Converse	287.6	73	232.8	58	520.4	131
Goshen	188.4	57	616.2	207	804.6	264
Laramie	357.2	145	642.5	225	999.7	370
Platte	84.5	35	313.3	100	397.8	135
TOTAL	917.7	310	1,804.8	590	2,722.5	900
	Paved County Roads					
	Impacted		**Non-Impacted**		**Total**	
County	**Miles**	**Segments**	**Miles**	**Segments**	**Miles**	**Segments**
Converse	69.5	16	20.7	15	90.2	31
Goshen	42.6	9	80.4	41	123.0	50
Laramie	116.7	34	108.5	113	225.2	147
Platte	33.0	9	123.5	34	156.5	43
TOTAL	261.8	68	333.1	203	594.9	271
	All County Roads					
	Impacted		**Non-Impacted**		**Total**	
County	**Miles**	**Segments**	**Miles**	**Segments**	**Miles**	**Segments**
Converse	357.1	89	253.5	73	610.6	162
Goshen	231.0	66	696.6	248	927.6	314
Laramie	473.9	179	751.0	338	1,224.9	517
Platte	117.5	44	436.8	134	554.3	178
TOTAL	1,179.5	378	2,137.9	793	3,317.4	1,171

2.2.2 Features, Data Collection, Data Storage and GIS Map Layers

A geographical information system (GIS) database was used for the collection and analysis of all the data. A GIS is a database with a mapping function so it can map different data to help show trends with a network-based analysis. Table 2.2 shows which features were evaluated, the number of units for which data was collected, and the types of data collected. A total of 15 different layers were mapped in ArcGIS. They are:

- County roads
- All roads
- Impacted unpaved roads
- Non-impacted unpaved roads
- Paved roads with Pathway data

- Traffic counts
- County bridges
- Cattle guards
- Crashes
- Maintenance records
- OneOK pipeline
- Water haul sites
- Plan approved well sites in Laramie County
- Oil and gas wells in Wyoming since 1917

Table 2.2 Features and Data Collected

Feature	Quantity	Units	Data Types
Unpaved Roads	900	segments	number of lanes; inventory date; condition ratings; surface material type; location; photograph
Paved Roads	271	segments	IRI; PSI; RUT; PCI; PSR; location
Traffic Counts	172	counts	ADT; ADTT; 85th percentile speed; date; surface type; location; photograph
Cattle Guards	973	each	condition ratings; dimensions; location; photograph
Bridges	163	each	year built; design load; dimensions; deck rating; super rating; bridge condition; location
Maintenance Records	56,056	records	segment length; annual totals; grade and pull shoulders costs; build up and regravel costs; administration cost
Crashes	1,405	records	severity; first harmful event; manner of collision; roadway surface; location

2.2.3 Field Data Collection

Microsoft's *Streets and Trips®* software was used to collect data points in the field with a GPS unit connected to the computer. For each data collection step, a GPS point was stored so that it could be integrated into ArcGIS. The next step was to collect data in the field with specially developed spreadsheets for collection of each different type of data. Next, each spreadsheet was mapped with ArcGIS for quality control. Then the spreadsheets were prepared for analysis. Figure 2.2 shows the data collection process.

2.2.3.1 Paved Roads

The counties' paved roads were segmented by driving the road and determining any differences in the pavement types. A total of 271 paved road segments were established in the four counties. The segments begin and end where there are overlays, new construction, or other changes in the pavement. Each segment was mapped with ArcGIS as shown in Appendices *C.3. Converse County: Paved County Road Segments*, *C.11. Laramie County: Paved County Road Segments*, *C.19. Cheyenne MPO: Paved County Road Segments*, *C.26. Goshen County: Paved County Road Segments*, and *C.34. Platte County: Paved County Road Segments*. Data were collected specifically for this project by the WY T^2/LTAP Center and by Pathway Services Incorporated, the contractor which collects paved road data for WYDOT.

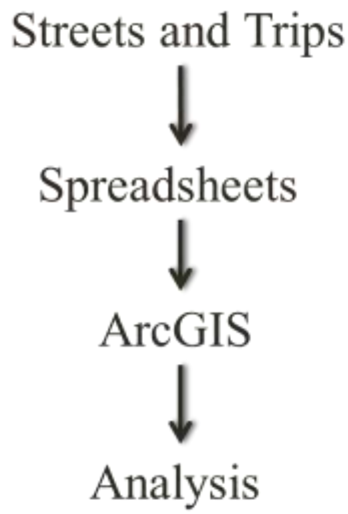


Figure 2.2 Data collection methodology.

2.2.3.2 Unpaved Roads

The four counties' unpaved roads were segmented by driving each road. Segment breaks were established at major intersections, at other significant traffic generators, at significant surfacing changes, at structural changes, or where maintenance practices changed. A total of 900 segments were rated and photographed. During the initial data collection events, the evaluator segmented the roads while also assessing and rating the unpaved roads' cross section (crown), roadside drainage, potholes, loose aggregate, rutting, dust, washboards, and ride quality. Road names, widths, and surface types were also recorded. All the unpaved roads in each county were rated in May 2012. In addition, the impacted roads in Goshen, Laramie and Platte Counties were rated in October 2011, June 2012 and August 2012, while those in Converse County were rated in June 2012 and August 2012. The segments were mapped as shown in Appendices *D.3. Converse County: Unpaved County Road Segments*, *D.13. Laramie County: Unpaved County Road Segments*, *D.29. Goshen County: Unpaved County Road Segments*, and *D.39. Platte County: Unpaved County Road Segments*.

Evaluation of current road conditions is more consistent from county to county since the WY T^2/LTAP Center performed the data collection. Still, maintenance practices vary, implying the need for different approaches to segmentation. Specifically, some counties and even areas within counties maintain their roads as a whole, surface blading or regraveling entire road segments, while in other areas, gravel is applied just where it is needed and isolated areas of roughness are bladed. These differences in how individual roads are maintained may be due to personal preferences of supervisors and operators, to logistical differences in the character of the roads, to varied availability of repair and maintenance materials, or to a combination of these. Real-world data collection must always adapt to the conditions as they are, not as one might like them to be in a rigorously designed scientific experiment. This project is no exception, so these variations were considered during analysis and interpretation of the results.

2.2.3.3 Cattle Guards

All 973 cattle guards in the four counties were evaluated. Their dimensions, base type, approach condition, base condition, grate condition, and wing condition were recorded. They were photographed and a GPS location was collected for each cattle guard. They were all mapped as shown in Appendix *E.1. Cattle Guard Locations in Southeastern Wyoming* and Figure 7.1 in Chapter 7 of this report.

2.2.3.4 Traffic Counts

A total of 172 traffic counts were conducted in the four counties. Traffic counts were performed on each impacted road. Additional counts were done at other locations to see how they compared to the impacted roads. All the traffic counts were entered into ArcGIS and mapped as shown in Appendix *A.1. Traffic Count Locations in Southeastern Wyoming* and in Figure 3.1 in Chapter 3 of this report.

2.2.4 Other Data Collection

2.2.4.1 Oil and Gas Wells

All the counties' oil well locations were obtained from the Wyoming Oil and Gas Conservation Commission (WOGCC). The oil well locations in western Nebraska and northern Colorado were also obtained to find the commuter roads between Wyoming and the adjacent states. The location of the new OneOK oil pipeline being built from the Bakken oil field in North Dakota through Goshen and Laramie counties to northern Colorado was obtained and mapped. Impacts to surrounding roads were monitored. Oil and gas activities in the four counties are shown in Appendix *B.1. Oil and Gas Activity Locations in Southeastern Wyoming*.

2.2.4.2 Water Haul Sites

A total of 85 temporary water haul sites were obtained from the Wyoming State Engineers Office. The temporary water haul site locations were entered in ArcGIS and mapped as shown in Appendix *B.1. Oil and Gas Activity Locations in Southeastern Wyoming*.

2.2.4.3 Bridges

WYDOT provided the WY T^2/LTAP Center with a spreadsheet containing data for the 163 bridges on the four counties' road networks. The spreadsheet includes location, year built, ratings and GPS points. The GPS points didn't map onto ArcGIS, so the bridges were located with route number and mile post. Google Earth was used to verify the locations of each bridge. All the bridges are mapped in ArcGIS and shown in Appendix *F.1. County Bridge Locations in Southeastern Wyoming*.

2.2.4.4 Safety and Crashes

A total of 702 crashes occurred on the four counties' roads between January 1, 2002 and June 30, 2012. The last ten-and-a-half years of crash data on the four counties' roads were mapped with ArcGIS and are shown in Appendix *G.1. Crash Locations on County Roads in Southeastern Wyoming*. The map shows the location of fatal, injury, and property damage only crashes.

2.2.5 Maintenance Records

Each of the four counties currently uses a computer-based maintenance and cost tracking software system, though no two collect them in the same way. Platte and Goshen Counties use the same software, but they segment their roads differently and they assign their work to somewhat different types of tasks. Additionally, maintenance records vary considerably in their quality and quantity. The degree to which the maintenance records are complete and useful for the analysis of historical maintenance practices varies not only from county to county, but also from employee to employee.

2.3 Data Analysis

2.3.1 Traffic Counts

Traffic count data were used in a variety of analyses throughout this project. Preliminary comparisons evaluated the average daily traffic (ADT) and the average daily truck traffic (ADTT) on the four counties' roads. Additionally, Goshen County data was analyzed over extended periods of time to evaluate seasonal effects on traffic volumes.

2.3.2 Oil and Gas Trip Generation

Data from the Wyoming Oil and Gas Conservation Commission (WOGCC) locating oil and gas wells drilled over the past several decades were entered into a GIS layer, as were water haul site locations from the State Engineer's office. These locations were used to estimate oil and gas-related traffic on county roads by counting the number of oil and gas wells and water haul sites within a buffer zone around county roads in all four counties. These counts were used to prioritize county roads based on their proximity to oil and gas activities.

2.3.3 Paved Roads

Once the paved county road data was collected and processed, it was analyzed in an attempt to shed light on the overall ability to service oil and gas traffic on the four counties' road networks. Preliminary analyses of the paved roads' condition data evaluated the current overall condition of the counties' pavements. Conditions on the county paved roads were compared to those on the state system. Based on the collected data and assumptions about the roads' histories, calibrations of the mechanistic-empirical design method were performed for paved county roads.

2.3.4 Unpaved Roads

Once the initial condition data was collected and compiled, several analytical procedures were performed, some on only the impacted segments and some on all unpaved road segments. The

May 2012 data was used for most of the analyses since this was the only data collection event that encompassed all the unpaved roads in all four counties.

Maintenance records provided by each county were compiled and presented. Since each county collects their data differently, no single procedure could be used to compile the maintenance records.

All roads were evaluated to determine whether improvements were needed based on the May 2012 data collection event. Each unpaved road segment was assigned a service level based on traffic counts when available and on road widths. Condition ratings were then used to determine if and what improvements were needed.

Impacted roads were assigned to a priority level. These assignments were made based upon the number of oil and gas wells and water haul sites near the road segment and on traffic counts.

2.3.5 Oil and Gas Impact Prioritization

Two methods were used to determine whether a given road segment was being impacted by oil and gas traffic. First, the counties were asked to identify the roads within their county that were being impacted by oil and gas traffic. Second, a method was developed to estimate the impacts using the average daily traffic (ADT), the average daily truck traffic (ADTT) and the proximity of oil or gas wells or water haul sites. The GIS software was able to determine an overlay within a given distance, two or four miles, of each road segment. From this, the number of wells and water haul sites were counted. Then, using this traffic and site proximity data and decision trees based on these inputs, impact priority numbers were generated for all roads identified by the counties as being impacted.

2.3.6 Cattle Guards

Initial costs for cattle guards were established based on the recommendations from the four counties' road and bridge supervisors. Based on assumed deterioration rates and the current condition ratings performed in 2012, the replacement and current values of all the cattle guards on each county's road network were estimated.

2.4 Report Preparation

This report compiles and describes the various elements of this project. Background research is discussed, methods are described, and results are quantified and evaluated. Summaries and recommendations were prepared, along with a brief discussion of possible future plans. The appendices provide extensive documentation of the data used to generate this report.

3. TRAFFIC COUNTS

The WY T^2/LTAP Center performed 160 traffic counts on the four counties' paved and unpaved, impacted and non-impacted roads. Goshen County provided an additional 12 continuous traffic counts that were included in the analysis. Trucks have a substantial impact on the durability and performance of roads, and proper planning is vital to the longevity of the road. Therefore, accurate traffic counts, particularly counts of heavy trucks, are essential to successfully planning road maintenance and construction activities. Detailed results from the traffic counts may be found in Appendix *A. Traffic Counts*.

3.1 Background

Traffic volume measurement provides data crucial to understanding the impact of heavy vehicle traffic on a roadway. However, if a traffic count is conducted during a lull or spike in truck traffic, inaccurate assumptions may be made, and the impacts misrepresented. Determining opportune times to collect traffic count data is vital to accurately monitoring heavy vehicle traffic.

The Federal Highway Administration (FHWA) published a Tech Brief about traffic volume that looked specifically at variations in truck volumes with time of day, day of the week, season of the year, and type of roadway. The section discussing seasonal variability was of special interest. The report states that truck volumes are higher in the summer than in the winter. The report goes on to discuss dramatic changes in truck volume from month to month, with an example of major construction for a short period of time *(FHWA 1998a)*.

The Wisconsin Department of Transportation studied seasonal traffic variations. Seasonal adjustment factors were generated to more accurately estimate average annual daily traffic (AADT). They focused on the months of the year when weather permitted traffic counts to be conducted which for them was between April and October. They found that by removing the winter months, the variation in seasonal traffic flow was reduced *(Aunet 2012)*.

The National Cooperative Highway Research Program *(NCHRP 2004)* published a report evaluating different equipment for collecting traffic data. It discusses various types of traffic count equipment, making recommendations as to when and where they should be used. It suggests methods for short-duration traffic counts, including road tubes, the technology used by the WY T^2/LTAP Center. It states that road tubes are not recommended for traffic counts conducted in snowy conditions due to snow plow damage and poor lane discipline by drivers. With Wyoming's geography and susceptibility to inclement weather, the accuracy could be greatly compromised if traffic counts are conducted during a period of inclement weather.

3.2 Methodology

The 160 traffic counts were performed between September 2011 and July 2012 in Converse, Goshen, Laramie and Platte Counties. The tube traffic counters were provided and operated by the WY T^2/LTAP except as described below. Each traffic count was in place for at least two days, with an average of three days at each location and longer as necessary. Most of the traffic counts were conducted on weekdays. Between October 2010 and August 2011, Goshen County collected 12 traffic counts using continuous traffic counters. The continuous traffic counts were conducted on ten roads throughout the county. The locations of all 172 traffic counts are shown in Figure 3.1.

3.2.1 Road Selection

To more accurately quantify the oil and gas-related traffic, the counties identified roads that were being impacted as described in Section *2.2.1 Preliminary Oil and Gas Impacts Inventory*. Traffic counters were placed on these roads. In addition to the impacted roads, traffic counters were distributed throughout the counties to quantify traffic throughout the counties' road networks.

3.3 Data Analysis

The traffic counts provided 13 different types of data and an additional 3 items were added to each count that included county, surface type, and whether the road was impacted.

3.3.1 General Analysis

Traffic counts were conducted on paved and unpaved roads, and on impacted and non-impacted roads. Each count yielded the average daily traffic (ADT), the average daily truck traffic (ADTT), the percent of trucks, and the 85th percentile speed. As shown in Table 3.1, the average ADT was 105 vehicles a day with 23% trucks. Paved roads had a higher ADT, ADTT and 85th percentile speed but a lower percentage of trucks. Impacted roads showed higher ADT, ADTT, and percentage of trucks than non-impacted roads.

Table 3.1 Traffic Count Four-County Averages

Road Type	**# of Counts**	**Average ADT**	**Average ADTT**	**Percent Trucks**	**85th Percentile Speed**
Paved	50	191	37	19%	62 mph
Unpaved	122	70	19	27%	49 mph
Impacted	115	117	29	25%	53 mph
Non-Impacted	57	80	14	18%	54 mph
Total/Average	172	105	24	23%	53 mph

Table 3.2 shows the traffic count values on paved roads for each county and Figure 3.2 graphs the recorded traffic volumes on county paved roads. Converse County has the highest average ADT and ADTT. All of the 85^{th} percentile speeds on paved roads are between 61 mph and 63 mph.

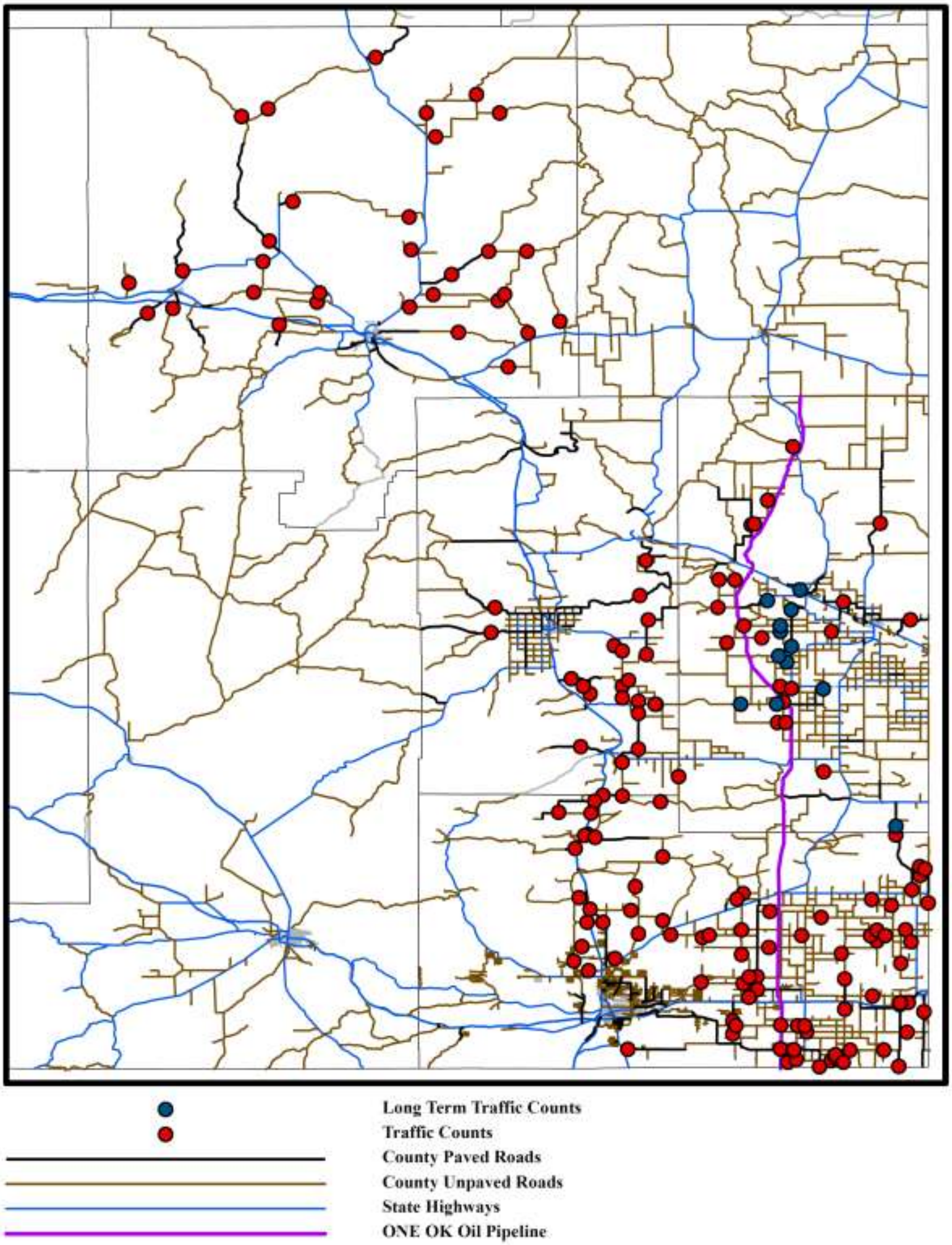


Figure 3.1 Traffic count locations in southeastern Wyoming.

Table 3.2 Paved Road Traffic Counts by County

County	Number of Counts	ADT	ADTT	Percent Trucks	85th Percentile Speed
Converse	7	376	72	19%	61 mph
Goshen	10	133	15	11%	61 mph
Laramie	21	220	52	24%	63 mph
Platte	12	81	7	9%	62 mph

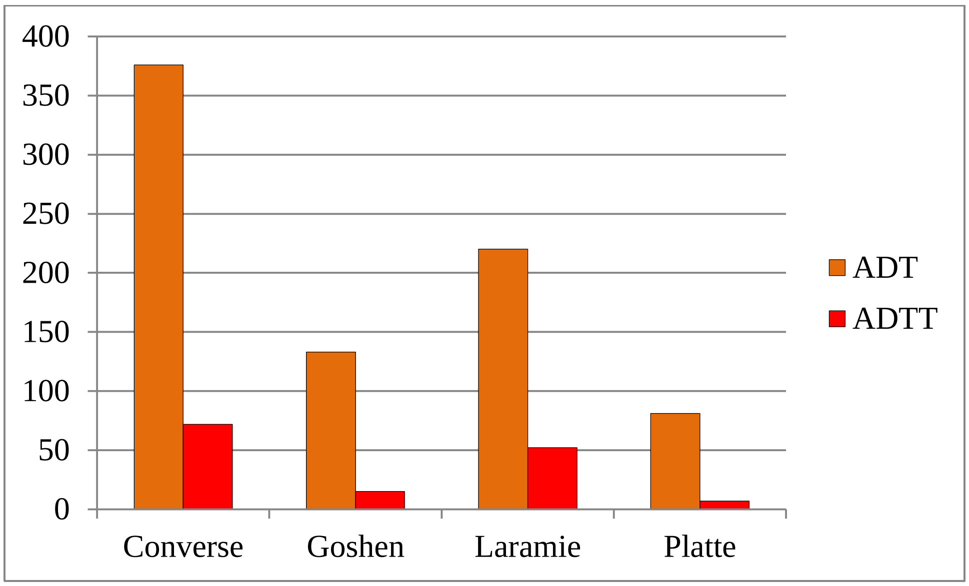


Figure 3.2 Paved road average daily traffic and truck traffic by county.

Table 3.3 shows the traffic counts on unpaved roads for each county while Figure 3.3 plots the recorded traffic volumes on county unpaved roads. Converse County had the highest average ADT, ADTT, and percentage of trucks on their unpaved roads. Laramie County had the second highest average ADT and ADTT, and the third highest percentage of trucks. Goshen County had almost the same average number of trucks as Laramie County.

3.4 Summary

The WY T^2/LTAP Center conducted 160 traffic counts with Goshen County providing another 12 counts from their continuous traffic counts. A total of 115 counts were performed on the roads the counties identified as being impacted, with the remaining 57 counts on non-impacted roads. Each county experiences different levels of truck traffic, with Laramie County having the highest average percentage of truck traffic on paved roads and Converse County having the highest average percentage of truck traffic on unpaved roads. Goshen County also had a high average percentage of truck traffic on unpaved roads with 23%. Average 85^{th} percentile speeds vary little from county to county, generally about 62 mph on paved roads and about 48 mph on unpaved roads. Overall, Converse County had the highest traffic and truck volumes on both unpaved and paved roads.

Table 3.3 Unpaved Road Traffic Counts by County

County	**Number of Counts**	**ADT**	**ADTT**	**Percent Trucks**	**85th Percentile Speed**
Converse	24	127	52	41%	45 mph
Goshen	23	47	11	23%	47 mph
Laramie	65	61	12	20%	52 mph
Platte	10	38	4	11%	47 mph

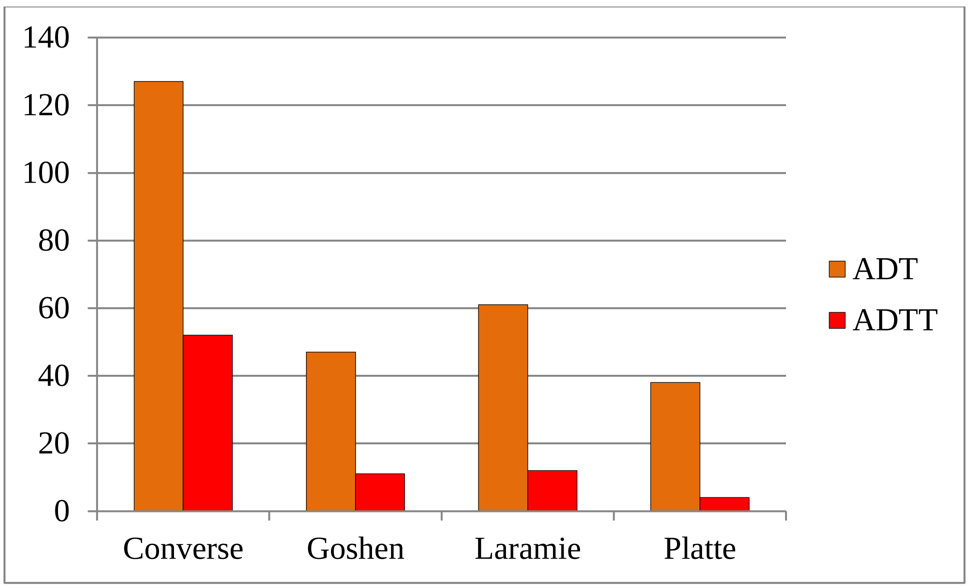


Figure 3.3 Unpaved road average daily traffic and truck traffic by county.

4. OIL AND GAS TRIP GENERATION

This chapter describes efforts to quantify the traffic generated by the oil and gas industry on the four counties' roads. The Wyoming Oil and Gas Conservation Commission (WOGCC) monitors the drilling permit process and ensures that the oil and gas industry complies with statewide oil and gas regulations. The WOGCC provided the WY T^2/LTAP Center with the locations of all oil and gas wells since 1917 along with permitted oil wells. The Wyoming State Engineer's office regulates Wyoming's water resources. They provided locations of all temporary water haul sites used by the oil and gas industry. Figure 4.1 shows the location of oil wells and temporary water haul sites in Wyoming, Colorado and Nebraska. Further details of the locations and types of oil and gas activities and of the analytical results from this study are shown in Appendix *B. Oil and Gas Activity*.

4.1 Oil Wells and Permits

Table 4.1 shows when the 1,917 wells drilled in the four counties since 1917 were drilled. The busiest decade was 1970 to 1979 when 567 wells were drilled. January 2000 through June 2012 was the second busiest period with 464 wells drilled. When analyzing each county individually, Converse County has had the majority of oil and gas wells drilled with a total of 1,565. The other three counties have seen an increase in the number of wells drilled in the last 12 years compared to previous time periods. Goshen County has seen 29 of its 30 wells drilled in the last 12 years, while Platte County has seen 6 of its 10 wells drilled during this period. The oil permits were acquired from WYDOT and only include Laramie County. Of the 52 permits, only 8 do not have current oil wells on them. Laramie County showed a continual increase in the number of wells drilled since 1970 with 164 wells between 2000 and June 2012. Figures 4.2, 4.3, 4.4 and 4.5 show all the wells since 1917, highlighting those since 2000, for each of the four counties.

Table 4.1 Oil and Gas Wells Drilled by Decade and County

	Converse	Goshen	Laramie	Platte	Total
1917 - 1949	16	0	17	0	33
1950 - 1959	130	0	10	2	142
1960 - 1969	40	1	15	0	56
1970 - 1979	555	0	12	0	567
1980 - 1989	425	0	32	0	457
1990 - 1999	135	0	62	2	199
2000 – June 2012	265	29	164	6	464
Total	1565	30	312	10	1917

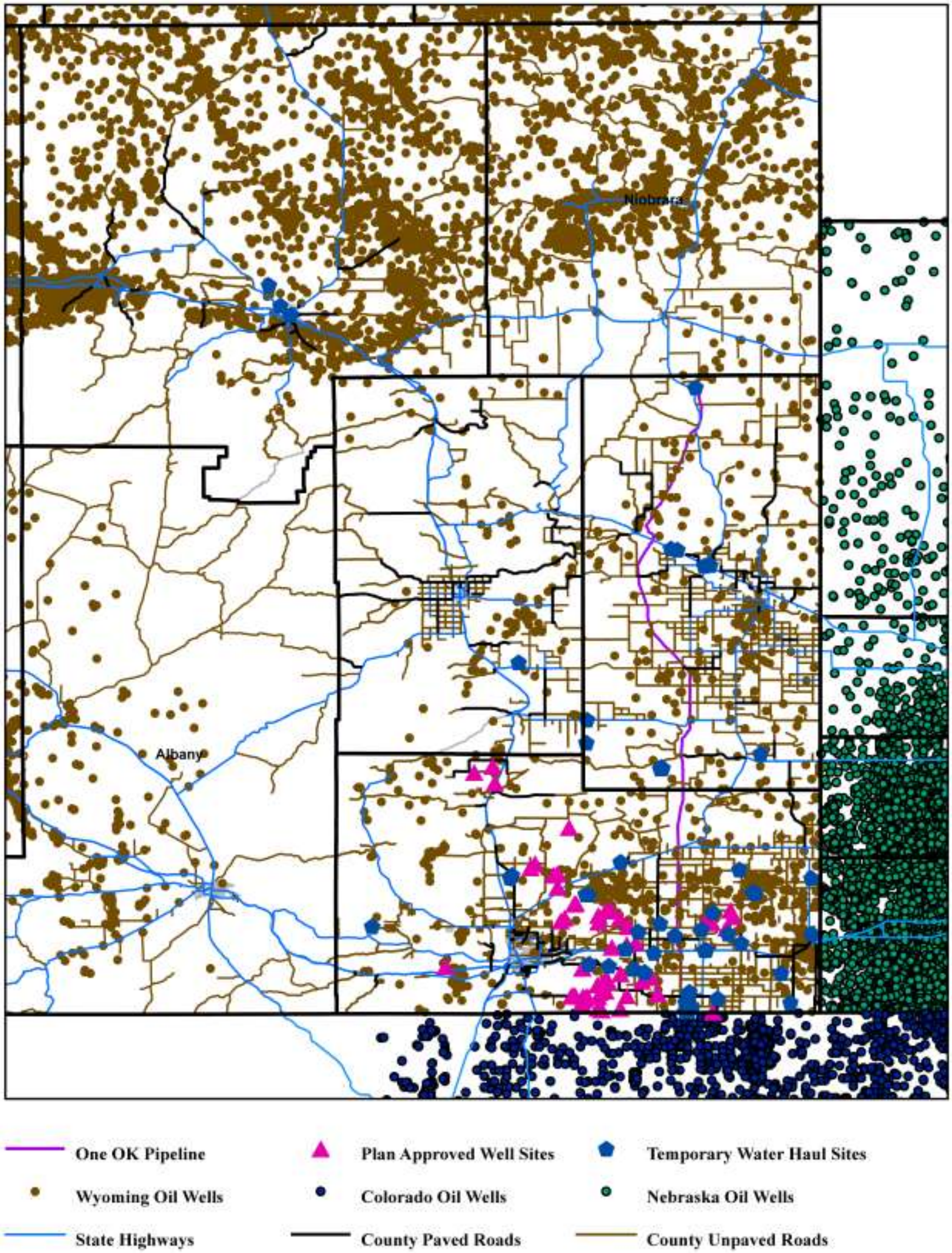


Figure 4.1 Wyoming and adjacent states oil, pipeline and water haul sites.

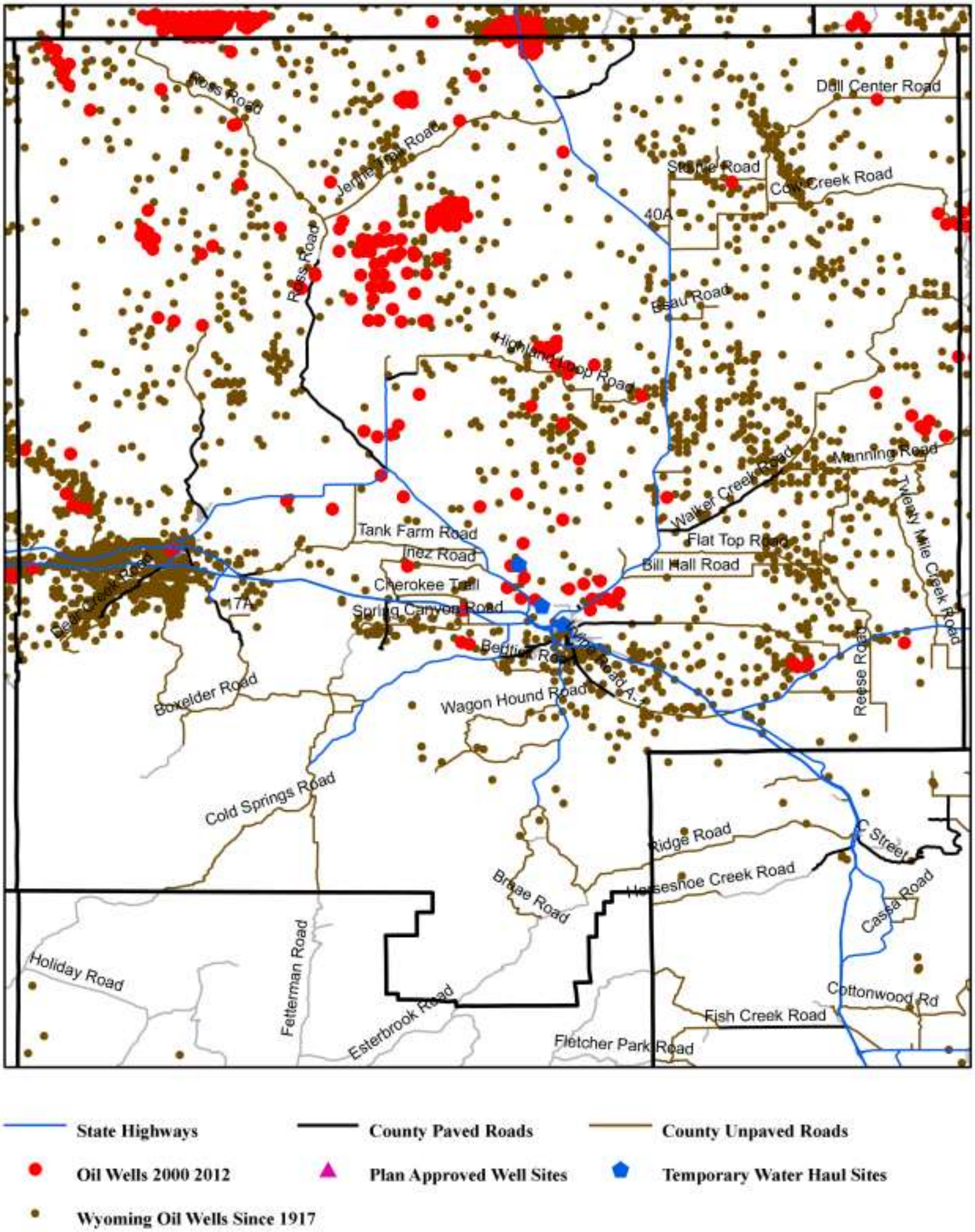


Figure 4.2 Converse County oil wells and water haul sites.

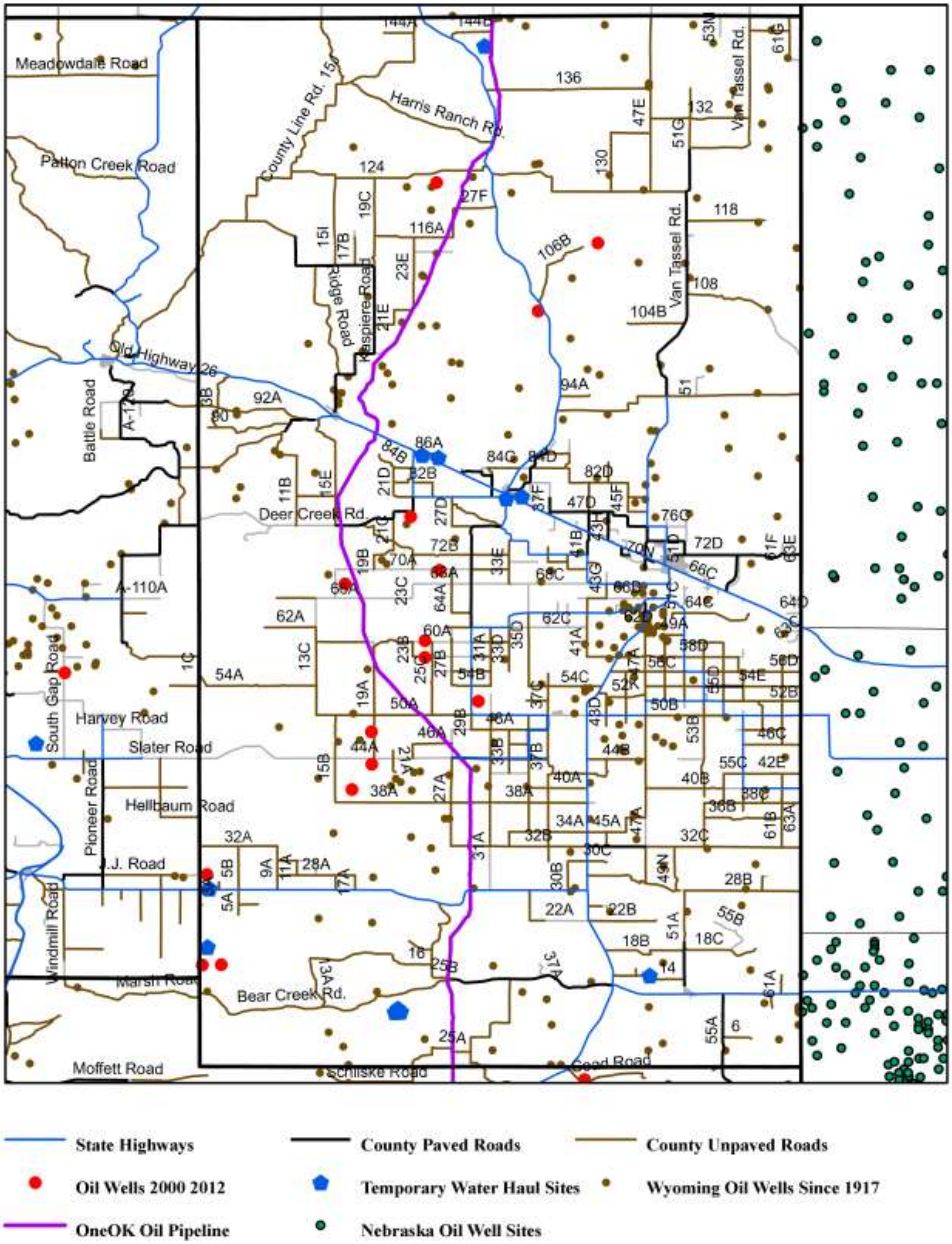


Figure 4.3 Goshen County oil wells, pipeline and water haul sites.

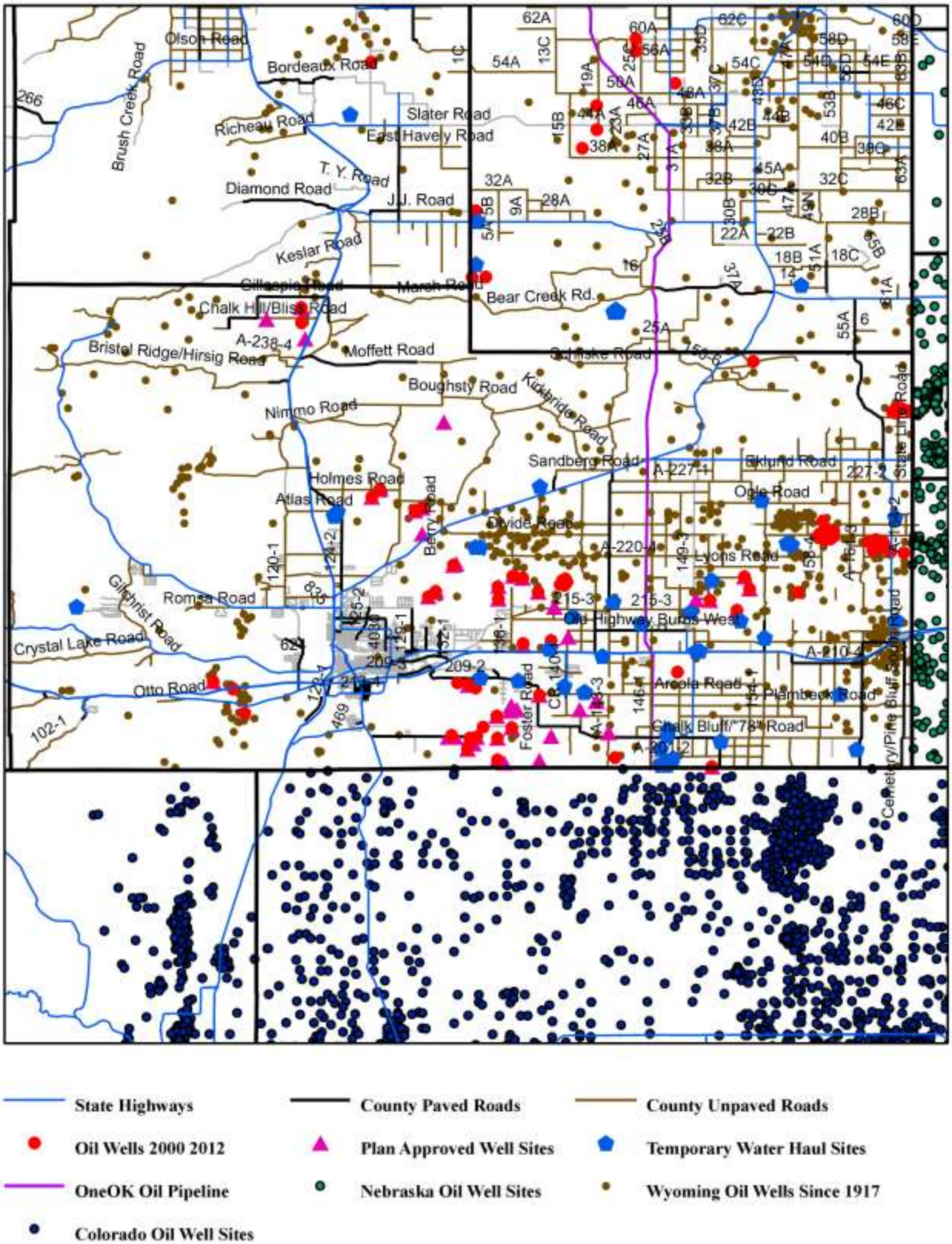
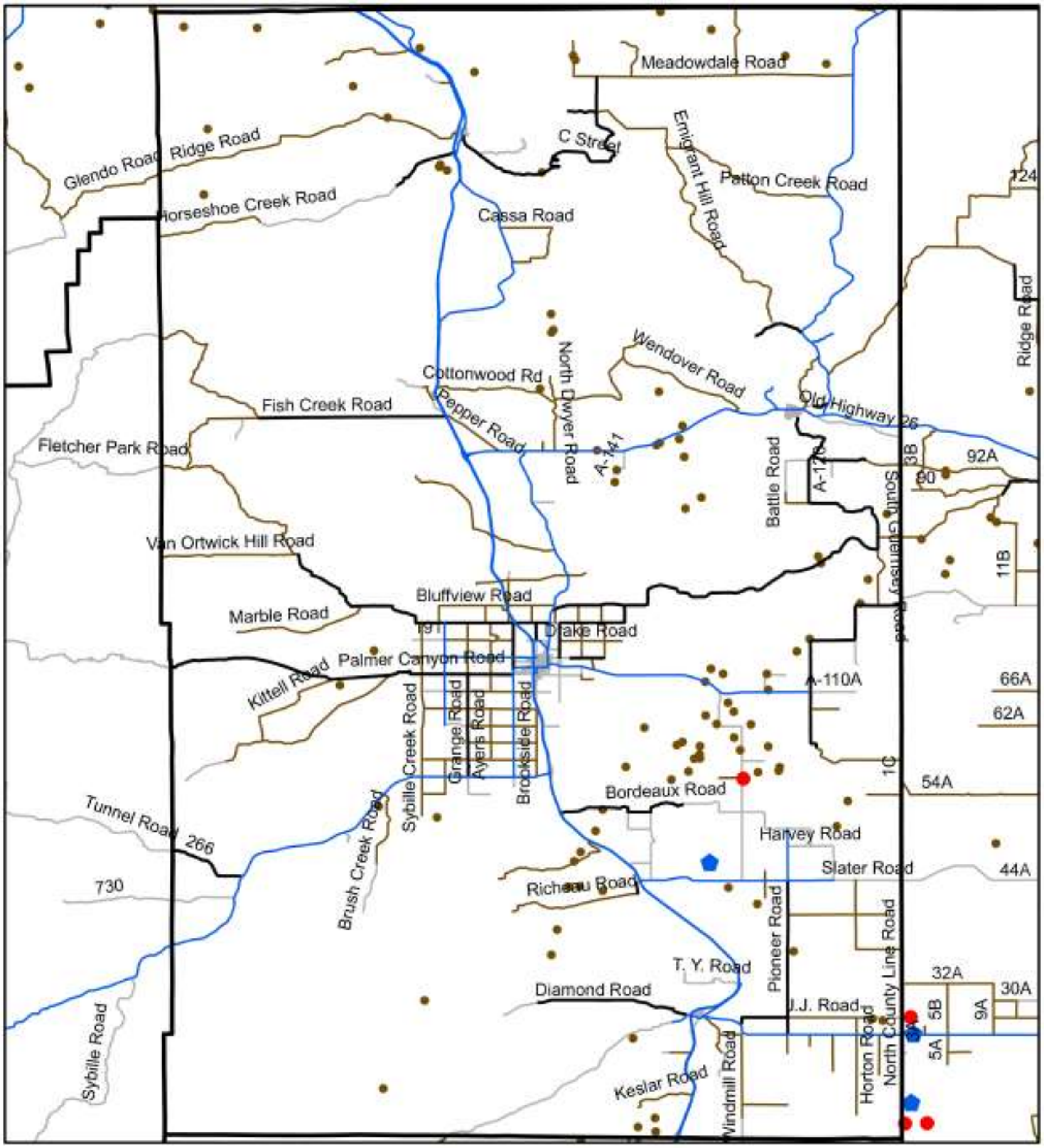


Figure 4.4 Laramie County oil wells, pipeline and water haul sites.



State Highways
County Paved Roads
County Unpaved Roads
Oil Wells 2000 2012
Plan Approved Well Sites
Temporary Water Haul Sites
Wyoming Oil Wells Since 1917

Figure 4.5 Platte County oil wells and water haul sites.

4.2 Temporary Water Haul Sites

There are a total of 85 temporary water haul sites with the majority in Laramie County as shown in Table 4.2. Converse County has only two temporary water haul sites since most of the water that oil and gas companies use in the county comes from the Douglas city water pipeline.

Table 4.2 Temporary Water Haul Sites by County

County	**Temporary Water Haul Sites**
Converse	2
Goshen	13
Laramie	67
Platte	3
Total	85

4.3 Oil and Gas Activity Summary

The WOGCC provided the WY T^2/LTAP Center with a list of 1,917 oil and gas wells drilled since 1917. Of the four counties in this study, Converse County has had the most wells drilled but the other three counties have seen an increase in the number of wells drilled in the last 20 years. Laramie County has the most temporary water haul sites with 67, while Goshen County has 13. Converse County only has 2 temporary water haul sites since the oil and gas companies get most of their water from the Douglas city water pipeline.

There is considerable oil and gas traffic that serves operations outside of Wyoming, particularly in southern Laramie County where many county roads are used to access water haul sites for drilling activities in Colorado. Figure 4.1 shows the locations of oil and gas sites in southeastern Wyoming and adjacent parts of Colorado and Nebraska.

5. PAVED ROADS

5.1 Background

Intensified oil and gas drilling activities greatly increase the volume of heavy trucks present on local roads, especially paved roads that act as arterials throughout counties. It is important that paved local roads be capable of servicing any increase in traffic loads associated with oil and gas drilling activities. In general, county road systems are very old and have received less than adequate maintenance and treatment throughout their service life. Appendix *C. Paved County Roads* contains detailed results of the data collection and analysis performed as part of this study. This study analyzes the capabilities of local paved roads to accommodate the additional truck traffic that accompanies oil and gas development. It does so by evaluating the current condition and structural integrity of existing pavements. Data collection and analysis focused on road conditions, structural capacity, traffic counts, and oil and gas activities. Collectively, this information was processed to develop an understanding of how well paved roads across Converse, Goshen, Laramie, and Platte Counties are capable of servicing oil and gas activities. The results derive a strategy for investing necessary funds to ensure adequate serviceability is met and maintained in the future. The analysis was conducted on a single year of data collection. In order to better understand the impacts on local paved roads and to continually monitor local road serviceability and county necessities, additional years of data collection and evaluation will be necessary.

In order to analyze the current conditions and structural stability of county roadways, the WY T^2/LTAP Center developed a methodology based on the principles in the 1993 *AASHTO Guide for Design of Pavement Structures.* This allowed all data collection and analysis of road conditions to be conducted in a fashion similar to that used by the Wyoming Department of Transportation. The process provided a proven method of analysis for local paved roads while at the same time allowing results to be compared to paved roads in the state system. Within this project, the *1993 AASHTO Design Guide* was used to evaluate pavement rehabilitation options.

5.1.1 AASHTO Design Method

The AASHTO design method for paved roads has been the foundation of pavement design. The system began when the American Association of State Highway Officials (AASHO) sponsored a road test in the 1950's to study the performance of highway pavement structures with known thicknesses under moving loads of known magnitude and frequency. The study produced many concepts including the development of an equivalent single-axle load (ESAL), road serviceability, and pavement layer designs *(HRB 1962)*. Much of this information is the foundation of pavement design today. Overall, results from this study were used in developing the AASHTO design equation for flexible pavements and the nomographs used in the *1993 AASHTO Guide (AASHTO 1993).*

According to the AASHTO equation for flexible pavements, the condition and performance of highway pavements depends on several factors including:

- The quality of construction materials and practices
- Thickness of pavement layers
- Maintenance, and its effect on pavement condition
- Soil properties
- Traffic loads
- Environmental effects

The 1993 AASHTO Design Guide incorporates these variables into a simple relationship for the design of pavement structures. It also utilizes these factors in the analysis of current road conditions and determination of structural capacities.

One of the significant outcomes of the AASHO road test was the Present Serviceability Index (PSI) and Terminal Serviceability Index (P_t). The initial road test used the Present Serviceability Rating (PSR) to determine road quality. Determining the PSR required a panel of observers to travel across the road of interest and rate ride quality on a 0 - 5 scale, with 0 being extremely deteriorated pavement, and 5 being the best possible road quality. This rating system was not practical for large-scale use, demanding that a non-panel based system be developed. A new system was created correlating the panel's PSR ratings to various pavement measurements. This transitioned the rating system to PSI, which quantifies the behavior of pavement based on repeatable measurements such as cracking, roughness, and deformation. The road test determined that the PSI of a flexible pavement is a function of the roughness of the roadway, the extent, severity, and types of surface distresses, and permanent deformation. The scale is from 0 to 5 as with the PSR. The AASHO road test produced the following equation for estimating the PSI *(Carey and Irick 1960).*

$$PSI = 5.03 - \log(1 + SV) - 1.38(RD)^2 - 0.01(C + P)^{\frac{1}{2}}$$

Where:

- SV is the slope variance
- RD is the mean rut depth
- C is cracking density
- P is patching density

Since the development of this relationship, technology has advanced and now allows more accurate indices to be collected from paved road segments. Most users of the *1993 AASHTO Guide* have modified this equation in some form. Due to its high influence on the final PSI, some agencies evaluate PSI solely on the roughness of the road. WYDOT includes all three variables initially linked to pavement serviceability. The combination of rut depth, roughness, and the measurement of distresses not only allows for the PSI to be accurately calculated according to the *1993 AASHTO Guide* but also gives a history of the pavement being analyzed.

The present serviceability index (PSI) provides a single number on a scale from 0 to 5 that evaluates the overall condition of the pavement from the traveling public's perspective. The following equation is used by WYDOT to calculate the PSI of the state highway system.

$$PSI = 5.35e^{-0.0058*IRI} - 4RUT^2 - 3\left(1 - \left(\frac{PCI}{100}\right)\right)$$

Where:

- IRI is the International Roughness Index (inches/mile)
- RUT is the mean Rut Depth (inches)
- PCI is the Pavement Condition Index (based on ASTM D6433)

The equation was developed by WYDOT personnel in 1996 based on Wyoming state data with consideration to each variable's sensitivity. The PSI was calculated for every county paved road in Converse, Goshen, Laramie, and Platte Counties, excluding roads missing data, in both travelling directions and the overall road. Analysis on rural roads used all three inputs – IRI, rut depth and PCI. However, due to the frequent and inevitable stop-and-go movements when collecting data while driving urban roads, IRI was ignored during their evaluation and set to a standard number for calculations. The following rating scale is used by WYDOT to describe the condition of roads with a particular PSI value.

PSI > 3.5	-	**Excellent Condition**
3.0 < PSI < 3.5	**-**	**Good Condition**
2.5 < PSI < 3.0	**-**	**Fair Condition**
PSI < 2.5	**-**	**Poor Condition**

This scale is a state-modified version of the verbal rating scale developed by the FHWA *(TRB 1990)*. For consistency, the WYDOT scale was used in the analysis of local paved roads. Using the *1993 AASHTO Design Guide* and the procedure described above, the current conditions of local paved roads were analyzed. The *1993 AASHTO Design Guide* was also used in the determination of structural capabilities of local paved roads.

5.2 Paved Road Data Collection

Data collection for the analysis of local paved roads consisted of four primary sources: county meetings, oil/gas commission, traffic counts, and automated road data collection. Traffic counts and data from the WOGCC are discussed in Chapters *3. Traffic Counts* and *4. Oil and Gas Trip Generation*, respectively.

5.2.1 County Meetings

Meetings were arranged with each county to recover information regarding existing/past traffic counts, maintenance records, paved road information, and any recent oil and gas activity. Generally, the construction dates and layer thicknesses of paved roads is unknown to the county supervisors. Only roads constructed or rehabilitated most recently have detailed information. Because of this lack of information, each county was asked to roughly estimate the age and layer thicknesses of their paved roads. All four counties agreed that most roadways are about 40 to 50 years old and consist of approximately 2½ to 4 inches of pavement over 2 to 6 inches of base material. For this general data analysis, paved county roads with no information were given a pavement thickness of 3 inches and a base thickness of 4 inches when determining structural integrity. Along with this information, each county identified roads currently being most impacted by increased oil and gas activity. Of the 595 total miles of paved roads in the four counties, 262 miles were identified as being impacted by oil and gas truck traffic. Roads identified as most impacted by current oil and gas activity by county road and bridge supervisors can be seen in Figure 5.1.

Overall, 262 miles of paved county roads were identified as impacted as shown in Table 5.1. This allowed WY T^2/LTAP to focus traffic count collection efforts on areas most impacted by oil and gas development.

Additional meetings were held with county representatives throughout the course of the project to address additional issues and concerns.

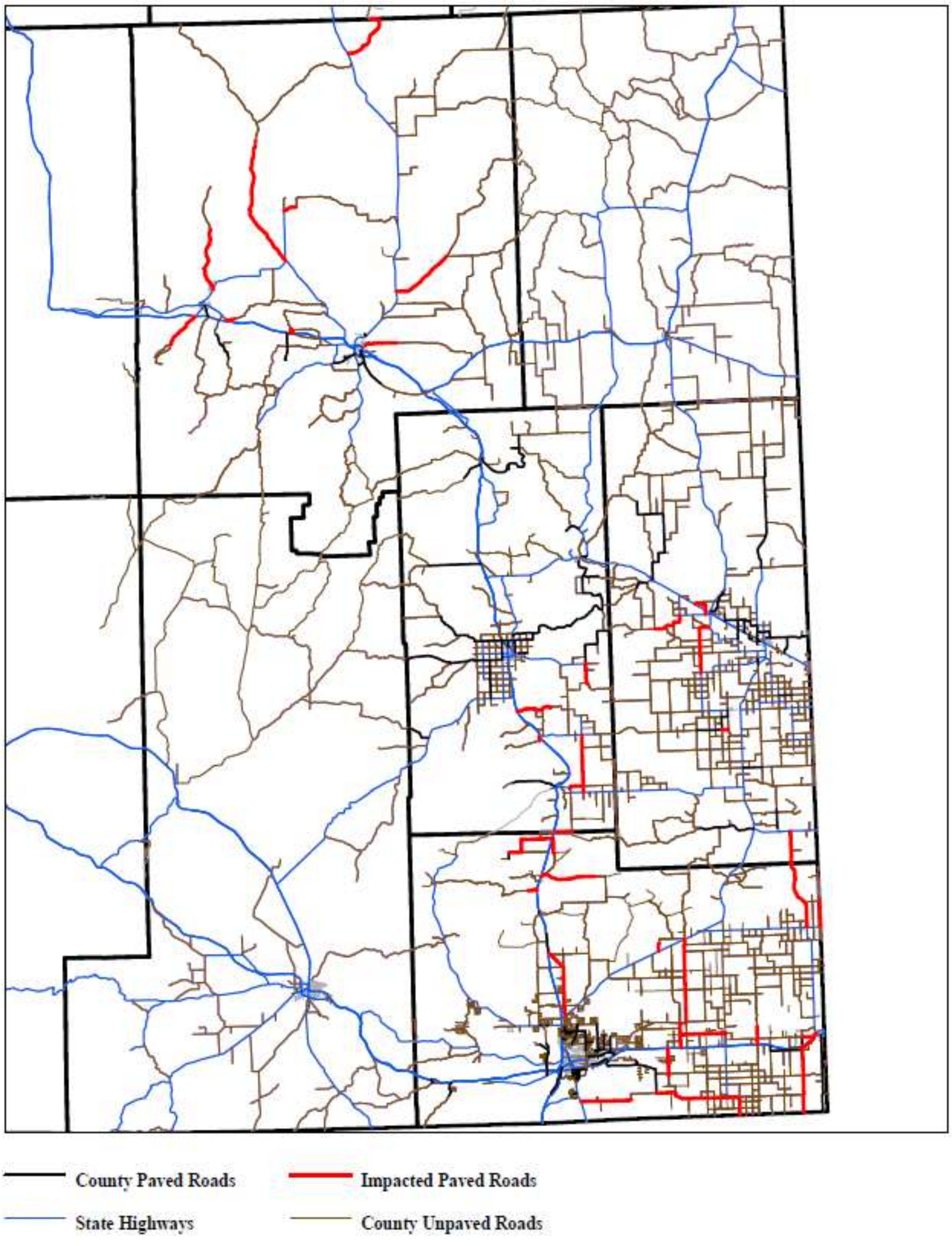


Figure 5.1 Impacted paved county roads.

Table 5.1 Impacted Paved County Roads

County	No. of Roads	No. of Segments	Total Paved Length (mi)	Impacted Segments	Impacted Length (mi)
Converse	25	31	90.2	16	69.5
Goshen	43	50	123	9	42.6
Laramie	122	147	225.2	34	116.7
Platte	31	43	156.5	9	33
TOTAL	**221**	**271**	**594.9**	**68**	**261.8**

5.2.2 Road Condition Data

WYDOT annually monitors, manages, and maintains approximately 2,400 miles of state secondary highways, 3,164 miles of state primary highways, and 1,836 miles of interstate highways. To properly manage this system, WYDOT utilizes an efficient method in determining where funds will be invested to improve the highway infrastructure. This process includes evaluating the current condition of the approximate 7,400 miles of state maintained roadways. WYDOT works in conjunction with Pathway Services Incorporated to collect data regarding this information, allowing them to analyze the current conditions of state roadways by estimating the PSI as described in Section *5.3.1 PSI – Pavement Condition*. Pathway specializes in automated road and pavement condition surveys. The company utilizes state of the art equipment to collect visual data regarding the roughness, distresses, and rutting of surveyed roadways.

WYDOT contracted with Pathway to collect data for local paved roads in Converse, Goshen, Laramie, and Platte Counties. The data and process were given to the WY T^2/LTAP Center for analysis. Pathway collected and delivered the following data to WYDOT:

- International Roughness Index, IRI, to measure slope variance/road roughness
- Rutting measurements, RUT, measure of permanent deformation
- Surface imaging, for use in analyzing pavement distresses, PCI

As noted earlier, the pavement serviceability was developed based on a panel rating system. Therefore, the roughness, or quality of ride, is the dominating factor in estimating the PSI of pavement. In order to accurately estimate pavement serviceability, a reliable method for measuring roughness is essential. Pathway accomplishes this by collecting data for IRI calculations using a South Dakota type laser profiler based on active class 1 ASTM E950 standards *(ASTM 2010a) (Pathway Services Inc.)*. After data collection is completed, the IRI can be calculated in accordance with ASTM E1926 *(ASTM 2010b).* Because this information is collected through inertial profiling equipment, IRI is repeatable and consistent across all roadways. Results from these data collection efforts are shown in Appendix *C. Paved County Roads*.

Rutting information is gathered using PathRunner Data Collection systems, designed to capture more than 1500 points up to three times per inch at highway speeds. The precise profile enables accurate RUT measurement to be extracted at any given point.

The Pavement Condition Index (PCI) is a numerical index quantifying the condition of a roadway based on surface distresses. The PCI is determined visually by monitoring surface defects present in pavements. The numerical scale ranges between 0 and 100, with 100 indicating the best possible condition and zero indicating the worst possible condition. The PCI is calculated by recording the extent and type of surface distresses present, and subsequently deducting values from the perfect condition of 100. The deduct values and calculation of the PCI is done in accordance with ASTM D6433 *(ASTM 2010c)*. Pathway simplifies the process for determining the PCI by providing continuous road surface videos, enabling the PCI to be calculated without requiring multiple trips to the field.

Working in coalition with WYDOT and determining the Present Serviceability Index as described in Section *5.1.1 AASHTO Design Method* validates the results found on paved county roads. It also allows comparisons to be made with the state-maintained system. WYDOT made information from their Pavement Management System (PMS) available to the WY T^2/LTAP Center. It includes IRI, RUT depth, PCI, layer thicknesses, construction dates, rehabilitation dates, and other useful data. This permitted the same analysis completed on the state system to be completed for the local paved roads.

5.2.3 Data Reduction

The surface images provided by Pathway Services Incorporated are generated by a continuous survey of the local paved roadways. When evaluating a road's PCI, it is impractical to evaluate the road's entire length. For instance, WYDOT breaks state roads into separate sections based on the date of construction. Each road section is considered a different entity which is evaluated separately from the other sections of the road. Once WYDOT divides a road into sections, they randomly sample 1000 foot test segments to represent the entire section. WYDOT works directly with Pathway to retrieve data that begins and ends at construction lines. Data on local roads was collected before construction segments were distinguished. The WY T^2/LTAP team manually drove each road to locate the exact position of segment breaks. Upon segmenting each road, the data provided by WYDOT was extracted in accordance with these segments. WYDOT personnel worked with the WY T^2/LTAP Center to develop a sampling method capable of producing valid results.

Pathway's profiling equipment continuously measures IRI and RUT depth, making data extraction possible at very small intervals. The information can be extracted in precise detail from every 100 feet to every mile. WYDOT evaluates this data at every one-tenth of a mile (0.10 mile). For consistency purposes, the IRI and RUT depth data were extracted at the same interval on paved county roads. Due to cattle guards, bridge decks, and other pavement interruptions, WYDOT uses a maximum IRI value of 400 inches per mile. Values in excess of 400 inches per mile are reduced to the maximum value. Average maximum RUT depths and half-car simulation IRI values were used during analysis.

5.2.4 Missing Data

The four counties consist of approximately 595 combined miles of local paved roads. This mileage is distributed across 221 roads consisting of 271 paved segments. Of these, 100 segments totaling 51 miles had no data collected by Pathway Services Incorporated. For the most part, this was a result of the short road lengths of several county roads. The majority of the 100 segments were not evaluated because they were shorter than 0.5 miles and very unlikely to experience increased traffic loads caused by the oil and gas industry. A few roads however, were collected erroneously or missed by the data collection process. This left 171 segments for analysis using the present serviceability index. Of these, four more segments were missing data regarding road widths. Overall, 167 segments were processed through the rehabilitation decision trees discussed later in this chapter.

5.2.5 Maintenance Records

Maintenance records for the paved county roads in the four counties are limited. Some counties have been collecting maintenance records for years; however, generic and inconsistent assignment of costs to a particular task or activity makes interpreting the maintenance data difficult. Current maintenance records on paved county roads are of limited use in analyzing oil and gas impacts and their effects. While one might expect the counties to increase maintenance on roads as they deteriorate faster due to oil and gas activities' impacts, practically speaking the amount of maintenance performed may be influenced as much by the availability of funds as by the condition of the roads. Maintenance on separate roads is currently not available; county wide maintenance records are described in Chapter *11. County Resources* of this report. It is recommended that counties begin to file maintenance records in accordance to the segmentation of paved roads in this analysis. This way, maintenance records may be of direct use in decision and rehabilitation processes.

5.3 Data Analysis

Once the paved county road data was collected and processed, it was analyzed in an attempt to shed light on the overall ability to service oil and gas traffic on the four counties' road networks. The following sections describe these analyses.

5.3.1 PSI – Pavement Condition

The 595 combined miles of county paved roads in the four counties consist of 221 roads split into 271 segments. Of this mileage, 539 miles split into 171 segments were evaluated while 100 segments totaling 51 miles were not evaluated because of missing data discussed earlier. Data analysis shows that the counties' paved roads are in poor condition. Of those analyzed, over 412 miles (just below 80%) are in poor condition. Appendices *C.6. Converse County: Pavement*

Serviceability Indexes (PSI), C.14. Laramie County: Pavement Serviceability Indexes (PSI), C.22. Cheyenne MPO: Pavement Serviceability Indexes (PSI), C.29 Goshen County: Pavement Serviceability Indexes (PSI), and *C.37. Platte County: Pavement Serviceability Indexes (PSI)* contain detailed PSI results for the four counties. Table 5.2 summarizes the results for the paved county roads analyzed in this study.

Table 5.2 Present Serviceability Index (PSI) of All Paved County Roads

PSI	**Segments**	**Length (miles)**	**% of Segments***	**% of Length**	**% of Length***
Poor	117	412.0	68.4%	69.3%	76.4%
Fair	24	47.3	14.0%	8.0%	8.8%
Good	26	65.8	15.2%	11.1%	12.2%
Excellent	4	14.1	2.3%	2.4%	2.6%
NA	100	55.5	--	9.3%	--
TOTAL	271	594.8	100.0%	100.0%	100.0%

* Excluding segments with no available data

Figure 5.2 shows the mileage in each condition for each county's paved roads. All four counties are characterized by a majority of roads in poor condition. Three of the four counties contain nearly or over 100 miles of paved roads in poor condition with the lone exception being Converse County which contains only 90 miles of paved roads. Still, over 80% of Converse County's paved roads are in poor condition. Maps of RUT depth, IRI, PCI, and PSI are shown in Appendices *C.5* through *C.8* for Converse County, *C.13* through *C.16* and *C.21* through *C.24* for Laramie County, *C.29* through *C.32* for Goshen County, and *C.37* through *C.40* for Platte County.

To further investigate the sensitivity of county roads to increased oil and gas drilling activities, those roads identified as being currently impacted by the oil and gas industry were further examined. Table 5.3 presents information regarding these impacted roads. Overall, 50 roads were identified across the four counties as being impacted by oil and gas traffic, totaling 68 segments and 262 miles. Of these, only 18 segments totaling 19.3 miles had no data available. Of the remaining 243 miles, 184 miles, just above 75% of the analyzed mileage, are in poor condition.

During the AASHO road test, it was determined that the initial PSI of flexible pavement was 4.2. During the course of the study and as increased volumes of traffic were subjected to the pavement, the PSI would decline. Once it dropped below 1.5, the section of pavement was taken out of service and deemed incapable of fully servicing traffic. The Terminal Serviceability Index, P_t, represents the lowest PSI that can be experienced before rehabilitation is required. The *1993 AASHTO Guide* suggests using a terminal PSI for major highways of 2.5 and 2.0 for local roads. It is important to note that terminal serviceability is directly related to the motorist's satisfaction with the quality of ride. Following the general guidelines for minimum levels of P_t obtained from the studies of the AASHO Road Test, 85% of people believe a PSI of 2.0 is unacceptable. At the same time, 55% of people believe a PSI of 2.5 to be unacceptable *(AASHTO 1993) (Lavin 2003).*

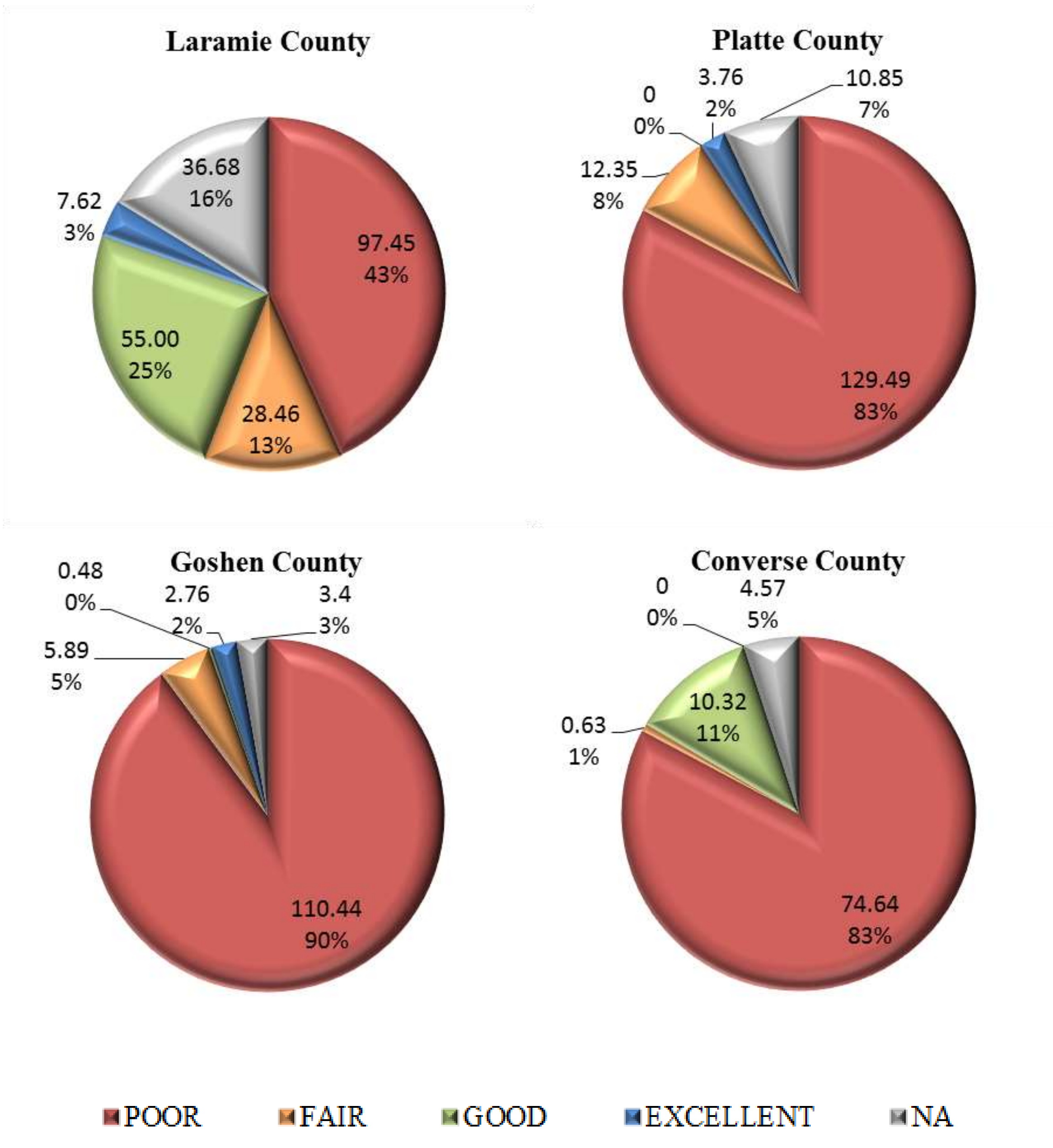


Figure 5.2 Paved county road conditions.

Table 5.3 Present Serviceability Index (PSI) of Impacted Paved County Roads

PSI	Segments	Length (miles)	% of Segments*	% of Length	% of Length*
Poor	36	184.2	72.0%	70.3%	75.9%
Fair	6	25.1	12.0%	9.6%	10.3%
Good	7	28.5	14.0%	10.9%	11.7%
Excellent	1	4.9	2.0%	1.9%	2.0%
NA	18	19.3	--	7.4%	--
TOTAL	68	261.9	100.0%	100.0%	100.0%

* Excludes segments with no available data

As shown in Table 5.4, of the 539 miles of county roads analyzed, 317 miles, or 59% of the total road miles examined, have a PSI less than the suggested terminal serviceability index of 2.0. Looking at the impacted roads in the same manner reveals that 151 miles, or 62% of the analyzed roads, have reached the end of their serviceable life. The FHWA rating scale for PSI further distinguishes from the WYDOT scale by designating any PSI less than 1.0 to be in very poor condition where the "pavements are in an extremely deteriorated condition and may even need complete reconstruction" *(TRB 1990)*. A total of 147 miles of paved county roads have a PSI less than 1.0, 79 miles of which were identified by the counties as being impacted by oil and gas activity. Table 5.4 quantifies the mileage of paved roads in each county that is below the terminal serviceability recommended by the *1993 AASHTO Guide* and by the FHWA.

Table 5.4 Paved County Roads Exceeding Terminal Serviceability

County	PSI < 2.0	Miles	% PSI < 2.0	PSI < 1.0	Miles	% PSI < 1.0
	All Paved County Roads					
Converse	14	64.1	74.8%	8	39.7	46.3%
Goshen	24	85.0	71.1%	9	23.6	19.7%
Laramie	23	78.0	41.4%	15	57.8	30.6%
Platte	26	90.2	62.0%	8	26.3	18.1%
TOTAL	87	317.3	58.8%	40	147.3	27.3%
County	**Impacted Paved County Roads**					
Converse	9	48.4	71.5%	6	33.5	49.5%
Goshen	5	28.5	67.5%	1	0.6	1.5%
Laramie	10	56.7	54.9%	8	44.5	22.6%
Platte	5	17.3	58.3%	1	0.6	1.9%
TOTAL	29	150.8	62.2%	16	79.2	32.6%

5.3.2 State and County Road Comparison

Using WYDOT's PMS updated in 2012, the conditions of state secondary, primary, and interstate systems were compared to those of paved county roads being analyzed. The conditioning procedure of the two systems is identical, making this comparison possible. The results are summarized in Figure 5.3. Each graph depicts the mileage and percentage of total length classified under each condition.

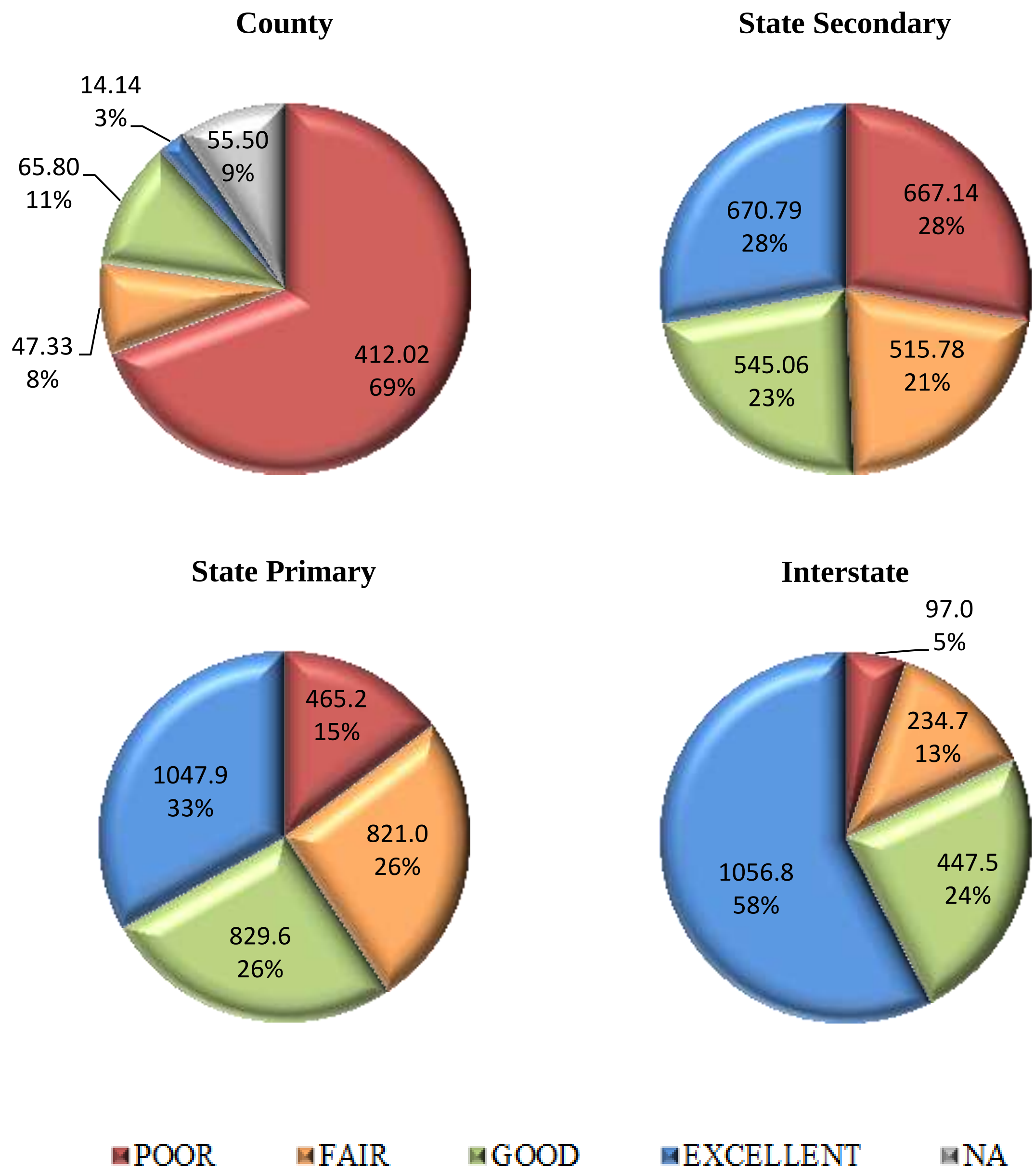


Figure 5.3 Present serviceability index (PSI) by functional group.

The results show that roads classified as a higher functional group are primarily in much better condition. Although it is common knowledge that roads of greater functional group are better designed to withstand heavy loads, it is still alarming to see the almost universally poor condition of local roads. This suggests that these roads are very vulnerable to increased traffic loads. In order to identify the cause of such poor conditions on the paved county roads, the three components contributing to the Present Serviceability Index were compared. Table 5.5 presents the average IRI, RUT, and PCI data for state and county roads, along with the average PSI for each classification of road completed in this study.

Table 5.5 Paved State and County Average IRI, RUT, PCI and PSI

Functional Group	**IRI, inches per mile**	**RUT, inches**	**PCI**	**PSI**
County	144.4	0.25	85	1.69
State Secondary	86.1	0.18	93.7	2.95
State Primary	76.5	0.18	93.6	3.12
Interstate	62.8	0.17	96.1	3.48

The IRI of paved county roads is substantially worse than any of the state maintained roads, over double the value of both primary and interstate routes. The *1993 AASHTO Guide* stresses the importance of roughness in determining a paved road’s serviceability. Because roughness is the primary controller of road quality, it controls the life cycle of the pavement. Therefore, the overall age of the pavement on county roads has subjected the pavement to years of wear and tear caused by both traffic and the environment. The age alone has caused significant damage to the overall roughness of paved county roads. Along with pavement age, the roughness of a paved road is directly related to the quality of construction.

Based on the construction techniques at the time most of these roads were built and the lack of guidelines for current construction on county roads, the initial PSI of a paved county road will not be as good as state roads. The initial PSI directly impacts the life cycle of a pavement. For instance, take a newly designed road with a 4” asphalt layer and 6” structural base layer designed for a SN of 2.5. Assume all material properties are constant and only the quality of construction differs so that one segment has an initial PSI of 4.2 (40 IRI, 0 RUT, 100 PCI) and the other has an initial PSI of 3.3 (83 IRI, 0 RUT, 100 PCI). Using the AASHTO design equation for flexible pavements, the segment with better initial quality is estimated to carry approximately 30% more ESAL’s during its serviceable life. This represents three years in a ten-year design or six years in a twenty-year design.

The presence of rutting on paved roadways raises safety concerns regarding the potential of traveling vehicles to hydroplane. WYDOT identifies any roads with rutting greater than 0.3 inches as potentially hazardous. Table 5.5 presents rut depth averages in all four functional groups analyzed. Rutting depths are on average 40% greater in depth on paved county roads than on the other three road classifications. In fact, 43 of the 171 county road segments analyzed have an average rut depth greater than 0.3 inches, and 130 of the 171 have a maximum rut depth greater than 0.3 inches. Correlating this information back to the overall serviceability of the roads, all 43 (100%) segments with rut depth averages of 0.3 inches or greater and 115 of the 130 (88%) with maximum rut depths of 0.3 inches or more are in poor condition. Ruts are formed due to permanent deformation of the pavement and underlying sub base caused by loading over time. Years of wear and tear is a definite factor in explaining the large ruts characterizing local roads; however, other causes include poor road and hot mix asphalt design. Considering that these rural roads historically service agricultural areas, they were never designed to carry significant traffic loads. It raises the question, with such permanent deformation already present, what effects would accompany increased oil and gas traffic?

Along with the IRI and rutting characteristics, the paved county roads contain inferior PCI values to that of state roads. The PCI is directly related to three deteriorating properties: age, maintenance, and road design. The age of these county roads has negatively affected each characteristic of the pavement. Decreased PCI values also suggest insufficient maintenance. The counties do not have the funding to maintain their infrastructure. Lastly, the extensive distresses in the asphalt suggest that road design, from the base to the asphalt, was insufficient.

5.3.3 Potential Impact of Oil and Gas Activities

Overall, the local road systems of Converse, Goshen, Laramie and Platte Counties are in poor condition and vulnerable to increased traffic loads. The extent of damage expected with increased impact should be considered. The AASHTO design equation for flexible pavements is regularly used to relate the structural integrity of a road to its predicted traffic load for the design period. This analysis utilizes the structural number of roads to predict the remaining life in total Equivalent Single Axle Loads (ESALS).

The *1993 AASHTO Guide* outlines three different methods for determining the effective structural number for existing paved roadways. These are the effective structural number, SN_{eff}, from non-destructive testing (NDT) the SN_{eff} from the Condition Survey, and the SN_{eff} from the Remaining Life of asphalt concrete (AC) pavements. Ideally, the SN_{eff} would be determined by utilizing all three of these methods; however, do to the lack of information regarding the roads of interest, this is not possible. Utilizing common information for both county and state roadways, the SN_{eff} presented in this analysis is calculated using the Condition Survey method. The condition survey method of determining the SN_{eff} involves a component analysis using the structural number equation from the *AASHTO Guide (AASHTO 1993).* The condition survey method requires the use of Table 5.2 of the *1993 AASHTO Guide* to determine layer coefficients for pavement and granular base or subbase *(AASHTO 1993).* In order to efficiently determine the coefficients for the approximate 8,000 miles being evaluated, a simple function was constructed to mirror the subjective results from the *1993 AASHTO Guide*.

If,

- LT = 0, and AC = 0
  - $a_1 = 0.4$
- LT < 5, and AC =0
  - $a_1 = 0.4 - 0.025*LT$
- LT < 10, or AC < 10
  - $a_1 = 0.35 - 0.01 * (LT - 2) - 0.007*AC$
- LT > 10, and AC > 10
  - $a_1 = 0.08$

Where:

- a_1 is the layer coefficient for pavement
- LT is Longitudinal Cracking Density ($ft/1000\ ft^2$)
- AC is Alligator Cracking Density ($ft^2/1000\ ft^2$)

The layer coefficient for the structural base (a_2) was determined by the presence of alligator cracking. As a distress that is caused by movement and pumping in the base and progresses upward through the pavement, the presence of alligator cracking provides a fair indication of the base layer's condition. Roads without alligator cracking were given a base layer coefficient of 0.14 while roads with alligator cracking were given a base layer coefficient of 0.10.

Drainage coefficients (m) are also necessary to complete this calculation. Since the material and drainage abilities of each road are unknown, a value of 1.0 was used for all roads. Using this criteria and the information from WYDOT's PMS, the SN_{eff} could be estimated for each state segment. County segments are a little more complicated due to the lack of information available on individual segments. For simplification purposes, county roads with no data were given an asphalt thickness of 3" with a structural base layer of 4" as discussed previously.

Figure 5.4 shows the distribution of structural numbers by percentage of miles for each functional group studied. On average, the local paved roads have a structural number estimated at 1.43. If the 59% (317 miles) of paved county roads beyond their serviceable life as defined in Section *5.3.1 PSI – Pavement Condition* are eliminated, the remaining 41% (222 miles) have a structural number estimated at 1.65.

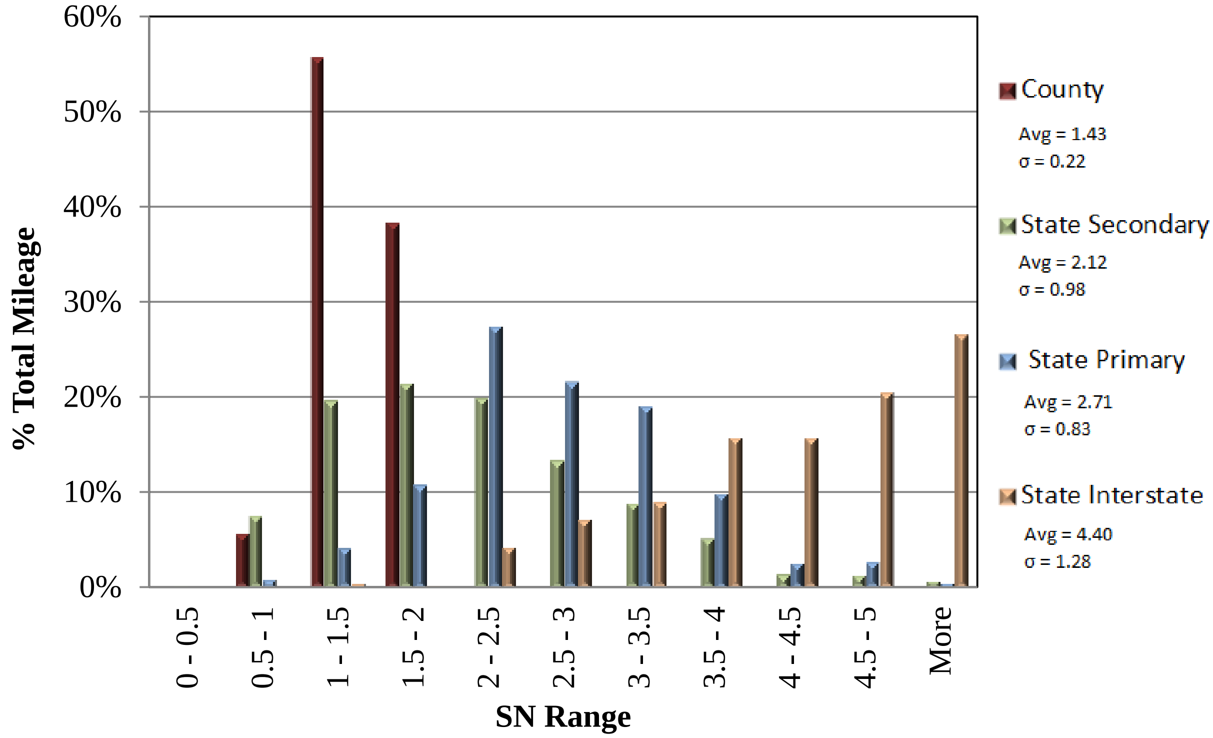


Figure 5.4 SN distribution by functional group.

In order to determine the county road system's ability to withstand increased traffic, a sensitivity study was conducted on the AASHTO design equation for flexible pavements. The analysis eliminated the effects of variables within the equation to examine how individual variables affect the estimated service life in ESALS of a pavement. Analyzing the equation to determine the effects of structural integrity, a pattern was found independent of soil resilient modulus, reliability, and standard deviation. This pattern relates structural number to the estimated traffic load for the design period and is only altered by the design serviceability loss. By AASHTO recommendation, this was set at 2.2 (P_o = 4.2 and P_t = 2.0). In order to analyze the remaining life and sensitivity of local roads, only roads within their serviceable life were considered. The 317 miles of roads with a serviceability index less than 2.0 are considered to be incapable of servicing traffic properly and any additional impact on such roads will be extremely damaging. Using the structural number of 1.65 as a base, Figure 5.5 presents the traffic multiplication factor for like design and increasing structural numbers. The average estimated structural numbers of each functional group along with their multiplier are shown in the Figure 5.5. For instance, the interstate system (with an average SN of 4.40) is capable of carrying an estimated 563 times the amount of traffic before the end of its serviceable life than local roads.

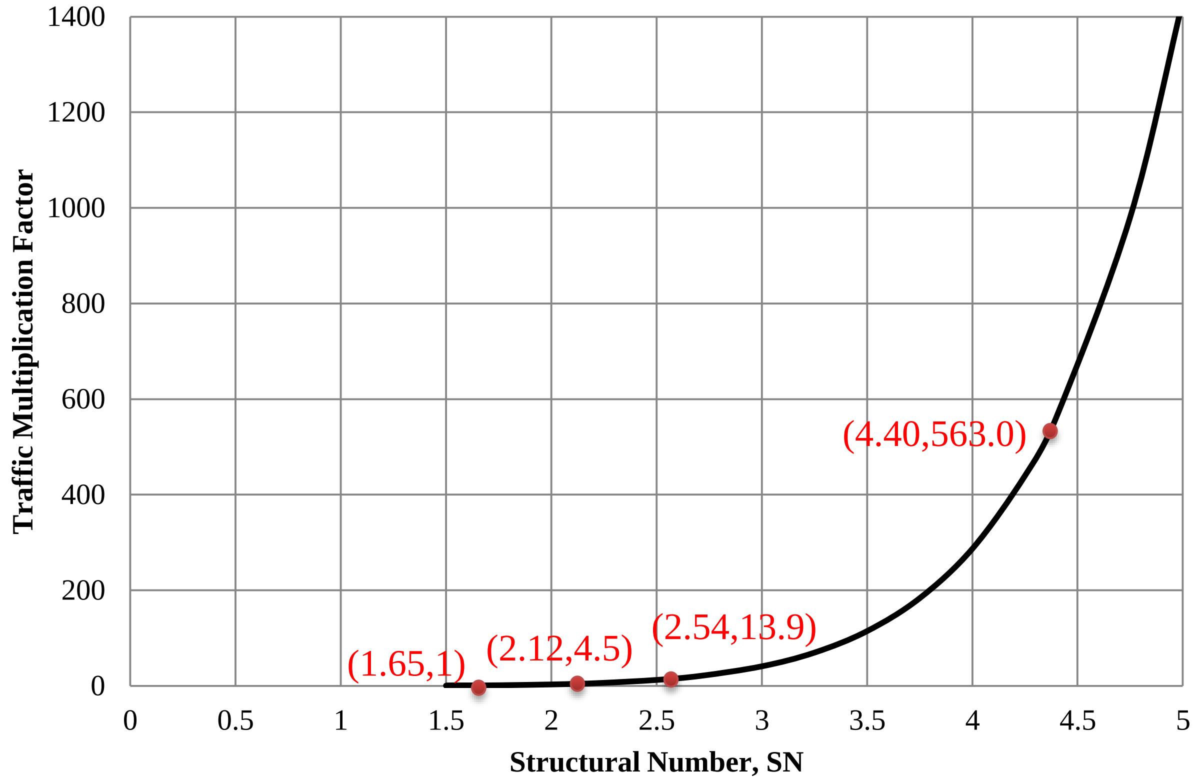


Figure 5.5 Traffic multiplication factors as a function of structural number (Base SN = 1.65).

Assuming a reliability equal to 80%, S_o = 0.45, and M_R = 6000 psi, a county road with a structural number of 1.65 would carry an estimated 11,650 ESAL's while state secondary, primary and interstate routes would carry an estimated 52,000, 178,600, and 6,560,000 ESAL's respectively. The assumed values for reliability, 80%, and variability, 0.45 = S_o, in this example were derived from the *1993 AASHTO Guide* while the M_R was a value estimated by WYDOT for typical subgrades in Wyoming.

The original AASHO study produced a set of tables presenting ESAL values for single and tandem axle trucks. Later, in 1986, AASHTO extended the test results to include load-equivalency factors for tridem axles. For flexible pavement design, the tables created relate the axle load with the structural number of the road to determine the corresponding ESAL for particular loads. The AASHTO tables were graphed to show the relationship discussed above. Figure 5.6 shows the relationship of ESAL's to structural number for single axles. The relationship found with tandem and tridem axles is very similar, demonstrating that an identical load has a greater impact on roads with smaller structural numbers. For instance, a single axle truck with an axle load of 40 kips, would have a load equivalency factor of 49.7 for a SN of 1 while at the same time, 31.2 for a SN of 6.

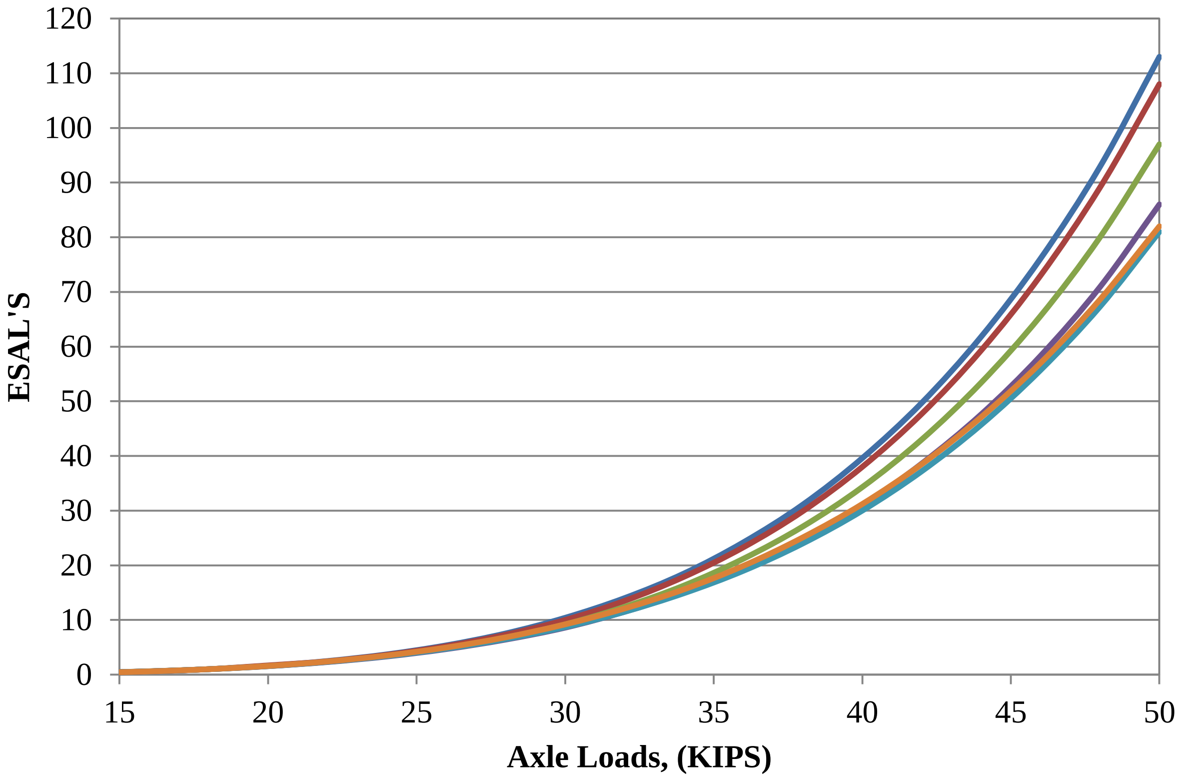


Figure 5.6 ESAL relationship for single axle loads.

Overall, not only are local paved county roads capable of carrying very little ESAL's compared to state maintained roads, but also are more extensively damaged by loads of equivalent weights. The effect of the nonlinear increase of ESAL's with axle loads results in a substantial reduction in pavement life with increased loads. The short remaining service life on these roads coupled with the fact that identical trucks induce more damage to roads of lesser design, suggests that local roads exposed to increased truck traffic will quickly deteriorate. Overall, upgrading local roads is required in order to service the profitable oil and gas industry in Wyoming.

5.4 Improvement Recommendations

The purpose of this project is to evaluate the local road system's ability to withstand the impacts of oil and gas traffic. Through analysis, Converse, Goshen, Laramie, and Platte Counties' paved roads are commonly in poor condition and are largely inadequate for the needs of the oil and gas industry. Additional county funding to aid in oil and gas impact relief should be justified by well-defined impacts. In order for each county to achieve the quality of roads necessary for both oil field and local traffic, a network level improvement strategy has been developed.

5.4.1 Improvement Criteria and Inputs

Oil and gas traffic levels, current road conditions, and road widths were all considered when evaluating each county's paved road improvement needs. The following discussions address issues relating to each of these three design inputs.

5.4.1.1 Quantifying Oil and Gas Impacts

In order to recommend appropriate treatments, quantifying impact levels is crucial. During initial data collection, each county was asked to identify roads impacted by increasing oil and gas activity. This process allowed the WY T^2/LTAP Center to proceed with traffic data collection efforts in a more focused manner, thus avoiding wasting time and resources on areas not currently being impacted by oil and gas traffic. Since the initial processes of identifying impacted roads were subjective and unique to each county, a consistent decision process was needed to quantify oil and gas impacts on paved roads in all four counties. Each road segment's impacts from oil and gas traffic were quantified using three variables: ADT, ADTT, and proximity to oil or gas wells or water haul sites. The process is consistent across all four counties, yielding a reliable quantification of the oil and gas impacts.

To measure each road segment's proximity to oil or gas wells and water haul sites, a GIS network was developed with wells and water haul sites since 2000. Buffer zones were developed around each road segment. Oil or gas wells and water haul sites were counted within each buffer zone. In Laramie, Platte, and Goshen counties, a two-mile buffer zone was applied since their road networks are well developed. A four-mile buffer zone was applied in Converse County since it has a more dispersed county road network. The buffer zones and sites within them are shown in Appendices *B.4. Converse County: Paved County Roads 4-Mile Buffer Zone*, *B.7. Laramie County: Paved County Roads 2-Mile Buffer Zones*, *B.10. Goshen County: Paved County Roads 2-Mile Buffer Zones*, and *B.13. Platte County: Paved County Roads 2-Mile Buffer Zones*.

To determine the level of impact for each road in each county, a priority decision tree was constructed. Table 5.6 contains verbal descriptions of the six priority levels, while Figure 5.7 shows the decision tree. The prioritization process uses each road segment's ADT, ADTT, and proximity to oil wells or water haul sites to yield an impact priority rank from 1 to 6, with 1 being the highest priority and 6 being the lowest.

Table 5.6 Impact Priority Level Descriptions

Impact Priority Level	Description
1	Extremely High energy related impact - immediate improvement concern
2	High energy related impact - high improvement concern
3	Moderately high energy related impact - moderately high improvement concern
4	Moderately low energy related impact - moderately low improvement concern
5	Low energy related impact - low improvement concern
6	Extremely low energy related impact - low to no improvement concern

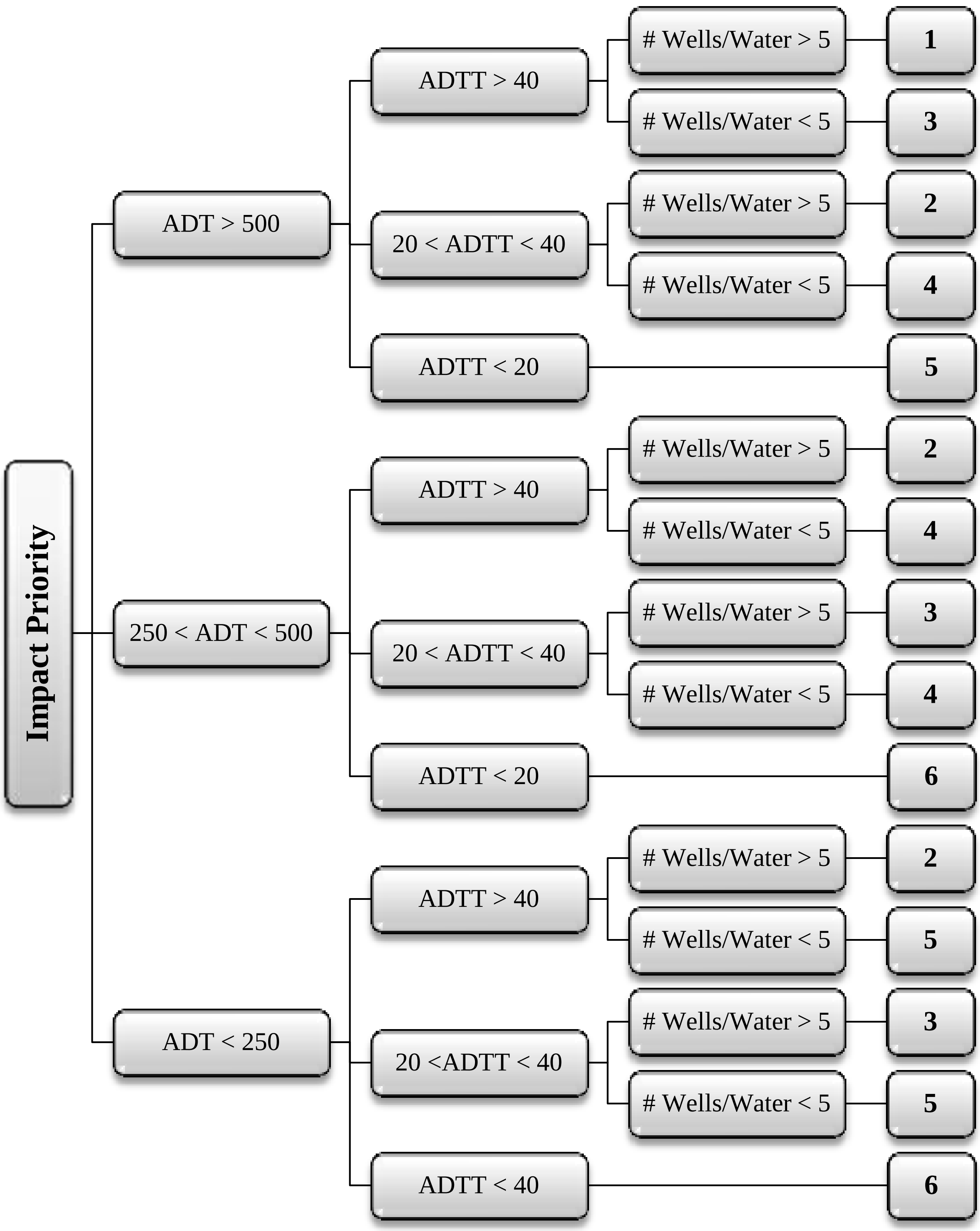


Figure 5.7 Impact priority decision process for paved roads.

The first decision is made based upon ADT with break points at 250 and 500. These values were selected based on the high volumes of non-truck oil field traffic that comes with oil and gas development.

The second decision is made based upon truck traffic, ADTT, with break points of 20 and 40. A report prepared by North Dakota State University examined oil and gas impacts in North Dakota. It derived an average ESAL factor per front-haul mile for oil and gas truck traffic of 1.77. With an ADTT of 40, this equates to roughly 25,000 ESALs/year. Based on the structural analysis considered earlier in this report, such an impact could have detrimental effects on the pavement structure. Many local paved roads would reach the end of their serviceable life within one year with these impacts. An ADTT of 20 implies roughly 12,500 annual ESALs. This would still have an impact on the paved infrastructure; however, based on earlier analysis many roads would be capable of servicing this volume for a short period of time. Any road segment with an ADTT less than 20 is currently not seeing significant truck traffic increases due to oil and gas activities.

The final decision evaluates the road segment's proximity to oil and gas activities. If no oil wells or water haul sites are near the road, it is unlikely that the trucks measured during traffic analysis are serving oil and gas operations.

5.4.1.2 Serviceability

Based on earlier analysis, it was discovered that 317 miles, or 59% of the total analyzed roads, have reached a present serviceability rating of less than 2.0 (deemed as terminal serviceability by the *1993 AASHTO Guide*). Clearly, many of the paved county roads in the four counties are in poor condition and many are in need of rehabilitation. Rehabilitation strategies must differ based on the current condition of each paved road segment. Road segments in poorer condition will require more intensive improvements than those in better condition. Also, the presence of rutting can control the rehabilitation process. Roads characterized by large rut depths will require surface preparation efforts before overlay placement. These two aspects shape how each road segment will be considered when identifying improvement options.

5.4.1.3 Road Widths

When considering rehabilitation efforts and total reconstruction of a roadway, the effects of lane width and road width warrant substantial consideration in design. The width of the road and its lanes plays a major role in the safety of drivers, future rehabilitation capabilities, and expected distresses.

Of the four counties being considered in this study, only Laramie County exhibited greater than 2 percent of their roadways with widths greater than 28 feet. Fourteen percent of Laramie County roads displayed widths greater than 28 feet, which is still a relatively small portion of the total amount considered. The paved county road widths for each county are shown in Figure 5.8. The effects of having roads with narrow lane widths and limited shoulders are discussed in the following sections.

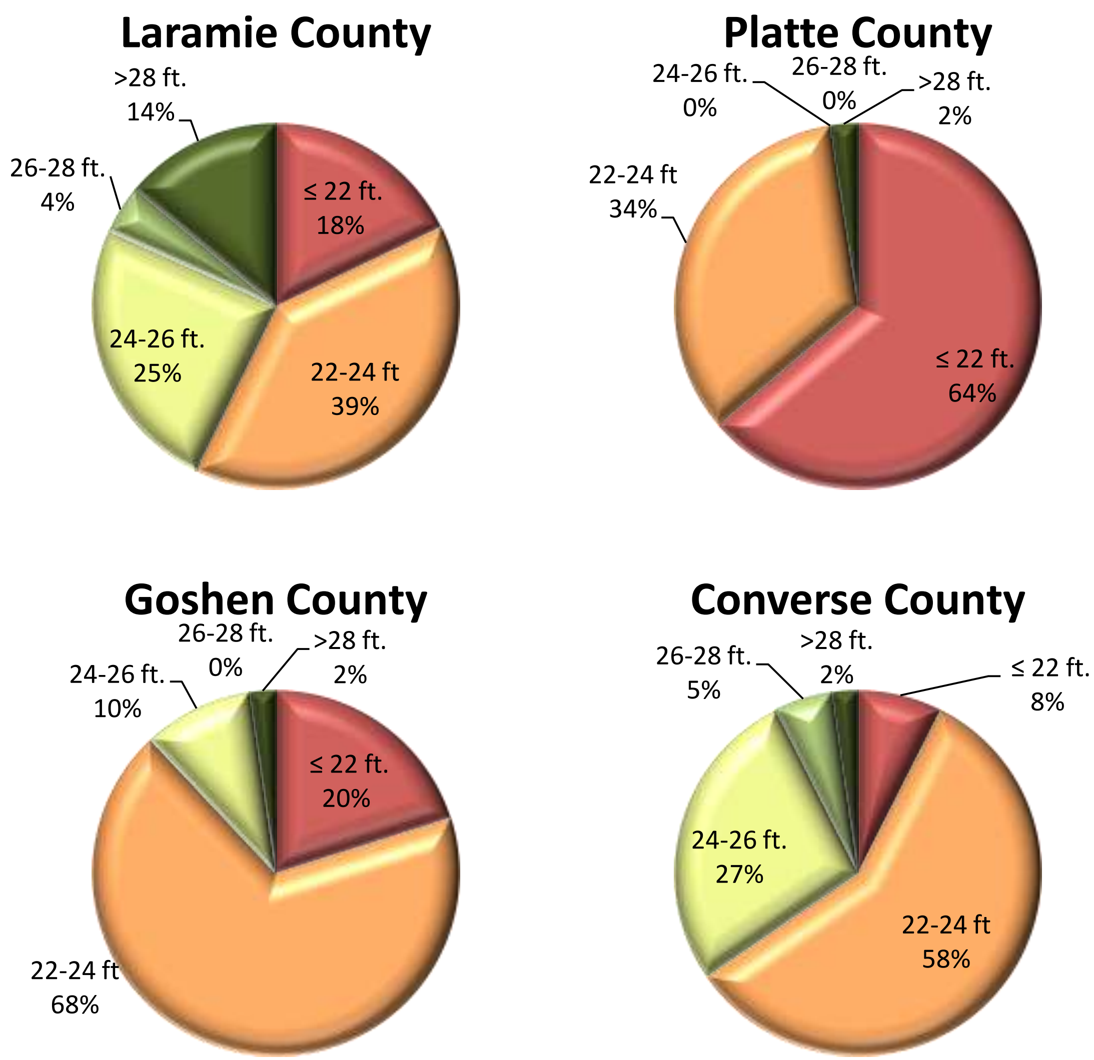


Figure 5.8 Paved county road widths.

5.4.1.3.1 Safety and Road Widths

Safety concerns that arise when considering lane width and shoulder width are the probabilities of crashes. To characterize the crash trends that occur with varying lane widths and shoulder widths, a model was developed for the Federal Highway Administration using Highway Safety Information System (HSIS) data from Minnesota and Washington State *(Tolliver 2010)*. This model considered a multitude of variables including lane width, shoulder width, roadway hazard rating, driveway density per mile, and other geometric design characteristics. To simplify the analysis process, this model was used to predict crashes on flat and straight roadways. Predicted crashes from the model were then used to develop the likelihood of crashes occurring given a certain lane width and shoulder width. Roadways with 12-foot lanes and 6-foot shoulders were considered to have ideal conditions and thus were normalized to 1.00. Table 5.7 shows the likelihood of crashes occurring on other roadway designs. For example, a 12-foot lane with no shoulder is 1.43 times more likely to have a crash on it then a 12-foot lane with 6-foot shoulders *(Tolliver 2010).*

Table 5.7 Crash Probabilities as a Function of Shoulder and Lane Widths

Shoulder	**Lane Width (ft.)**			
Width (ft.)	**9**	**10**	**11**	**12**
0	1.84	1.7	1.55	1.43
1	1.74	1.59	1.46	1.35
2	1.64	1.51	1.38	1.28
3	1.55	1.42	1.3	1.2
4	1.46	1.33	1.23	1.13
5	1.38	1.26	1.16	1.06
6	1.29	1.19	1.09	1

5.4.1.3.2 Overlay Feasibility

When considering the application of an overlay to a pavement structure, the graded width of the roadway plays a major role. Cross-sectional slope of the roadway must be maintained throughout the life of the pavement even if additional layers, such as overlays, are added. Consequently, when overlays are being considered, the existing graded width of the roadway is assessed to determine whether sufficient graded width for lanes and shoulders will be maintained after the overlay material is placed.

To illustrate this point, consider a cross-sectional slope of 4:1 ratio.   If the existing graded width of the roadway is 26 feet (12-foot lanes with 1-foot shoulders), and a 3-inch overlay is applied, the overall graded width of the road will decrease by 2 feet. This would eliminate the shoulders of the roadway. Thus, as Table 5.7 shows, in order to maintain safe roadway widths, overlays should not be applied to very narrow roads.

When considering the rehabilitation strategies proposed in this report, there are separate strategies for roads that warrant an overlay and those that warrant an overlay plus shoulder rehabilitation. A graded width of 28 feet is considered the breaking point between a road needing an overlay and a road needing an overlay and shoulder rehabilitation. If a roadway has 28 feet or more of graded width, it is considered able to receive an overlay, whereas any road less than 28 feet wide in need of an overlay also needs shoulder widening. When it comes to thin overlays in this study (more functional than structural), a breaking point of 26 feet was used.

5.4.2 Paved Road Rehabilitation Decision Process

In addition to continuously monitoring roadway conditions around the state, the Wyoming Department of Transportation (WYDOT) prepares an annual Pavement Management System

(PMS) Pavement Conditions and Project Candidates report. The report is designed to document and prioritize current and projected pavement needs through an eight-year period. The document includes a list of project candidates for each Wyoming district with treatment types and projected treatment year included. Due to the number of years and information available on the state maintained pavement system, WYDOT can look at the trends in pavement characteristics and predict future road needs. Since data is very limited, this is currently impossible for Wyoming's local paved roads. However, current needs can be estimated, and with future data collection, a similar pavement management process may be created on paved county roads.

In their annual report for the PMS Pavement Conditions & Project Candidates, WYDOT has developed a pavement preservation strategy prescribing four primary treatments.

- 1S – Preventative Rehabilitation
- 2S – Minor Rehabilitation
- 3S – Major Rehabilitation
- 4S – Full Reconstruction

In WYDOT's pavement preservation plan, rehabilitation strategies are selected utilizing decision trees including present serviceability index (PSI), rut depth (RUT), pavement condition index (PCI), and equivalent single axle loads (ESAL) depending on the road segment's functional class.

A pavement preservation strategy similar to the one used by WYDOT was created for local paved roads. Based on data collection for road widths on local paved roads, it is clear that treatment methods created on local paved roads need to include designs for widening as well. It was determined then that there are six primary treatments essential for a pavement preservation strategy on local paved roads. These include:

- No rehabilitation necessary
- Minor rehabilitation
- Minor rehabilitation with shoulder/widening needs
- Major rehabilitation
- Major rehabilitation with shoulder/widening needs
- Full reconstruction

These six treatments are summarized in Table 5.8 along with descriptions, applications, and estimated costs/mile. The costs of each treatment type were originally adopted from WYDOT information. During a discussion with the four county road and bridge superintendents, the cost estimates in Table 5.8 were adjusted to reflect typical construction costs on county projects. Treatment prices on local paved roads depend on several factors; these estimates are merely network level numbers for analysis purposes. For road specific road treatment costs, a project level analysis is necessary.

Table 5.8 Pavement Preservation Strategy for Paved County Roads

Treatment Type	Details and Applications	Est. Cost/Mile
GM General Maintenance	➢ General Maintenance Procedures ➢ Asphalt Patching ➢ Pothole Repair ➢ Crack Sealing ➢ Road Striping	$0
1-R Preventative Rehabilitation	➢ Chip Seal ➢ Micro-surface ➢ Thin overlay (<2")	$60,000
2-R Minor Rehabilitation	➢ Surface preparation (mill, level, full-depth reclamation, or combination thereof) ➢ Thick Overlay (>2") ➢ Seal Coat	$250,000
3-R Preventative Rehabilitation with Shoulder Needs	➢ 1-R plus shoulder or widening requirements ➢ Applicable on roads in good condition with shoulder needs	$350,000
4-R Major Rehabilitation	➢ 2-R plus shoulder or widening requirements ➢ Applicable on narrow roads with shoulder or widening needs	$650,000
5-R Full Reconstruction	➢ Complete Reconstruction	$1,200,000

Decision trees analogous to those used by WYDOT were constructed for both rural and urban paved county roads. Rural roads were analyzed utilizing PSI, RUT, and road width as decision criteria. Since IRI values are not valid on urban roads, the PSI is not used when analyzing urban roads. Also, due to the slower average speeds expected on urban roads and the low likelihood of increased truck traffic, road widths were not of concern in the urban road rehabilitation decision process. Therefore, urban roads were analyzed with PCI and RUT values only.

5.4.2.1 Rural Road Pavement Preservation

The PSI break points were established based on the *1993 AASHTO Guide* and WYDOT's ranking system. According to the *1993 AASHTO Guide*, local roads with a PSI < 2.0 have reached terminal serviceability and road segments with PSI < 1.0 are characterized by severely deteriorated pavement. Therefore, these roads are in need of more intense treatment. As the PSI increases, rehabilitation strategies are also determined based on rut depths and road widths. If the PSI is considered to be in good or better condition, PSI > 3.0, rehabilitation is warranted only when the surface should be widened to improve the road's safety characteristics.

Rut depth becomes a deciding factor when choosing between a thin overlay or a chip seal and a more intense surface treatment or a thicker overlay. The rut depth of 0.3 inches is utilized as the break point in this analysis since WYDOT deems rut depths in excess of 0.3 inches to be hazardous. Large rut depths, RUT > 0.3 inches, must be treated before any overlay can be placed on a road segment; therefore, large rut depths will warrant more extensive treatment methods. Roads with smaller rut depths, RUT < 0.3 inches, may be treated with a chip seal or a thin overlay.

Many of the paved county roads analyzed in this study are constructed with very narrow lanes and shoulders. Width affects many aspects of road performance including capacity, travel speed, and safety. The width of a road determines the feasibility of placing overlay pavements on existing surfaces. According to AASHTO's *A Policy on Geometric Design of Highways and Streets*, commonly referred to as the 'Green Book,' lane widths of 12 feet are generally provided in the design of two lane highways with expected high percentages of commercial vehicles, such as oil and gas trucks. In addition, shoulders on paved roadways increase lateral clearance and improve capacity, while at the same time accommodating stopped vehicles and emergency uses. They also provide lateral support for the subbase, base, and surface courses. Therefore the presence of a shoulder is essential on paved roadways. The 'Green Book' recommends a minimum two foot shoulder width on minor rural roads. It states that "roads with a narrow traveled way, narrow shoulders, and an appreciable traffic volume tend to provide poor service, have a relatively higher crash rate, and need frequent and costly maintenance." Based on design parameters regarding road width and shoulder presence, local paved roads should have enough width for 12-foot lanes with at least some shoulder in order to properly service the oil and gas industry. Therefore, thin overlays were recommended only for roads 26 feet wide or wider. Thick overlays were only recommended for roads 28 feet wide or wider. Setting these roadway width parameters ensures that road widths following treatment are adequate to safely and efficiently serve oil and gas traffic. The entire decision process is shown in Figure 5.9 *(AASHTO 2011)*.

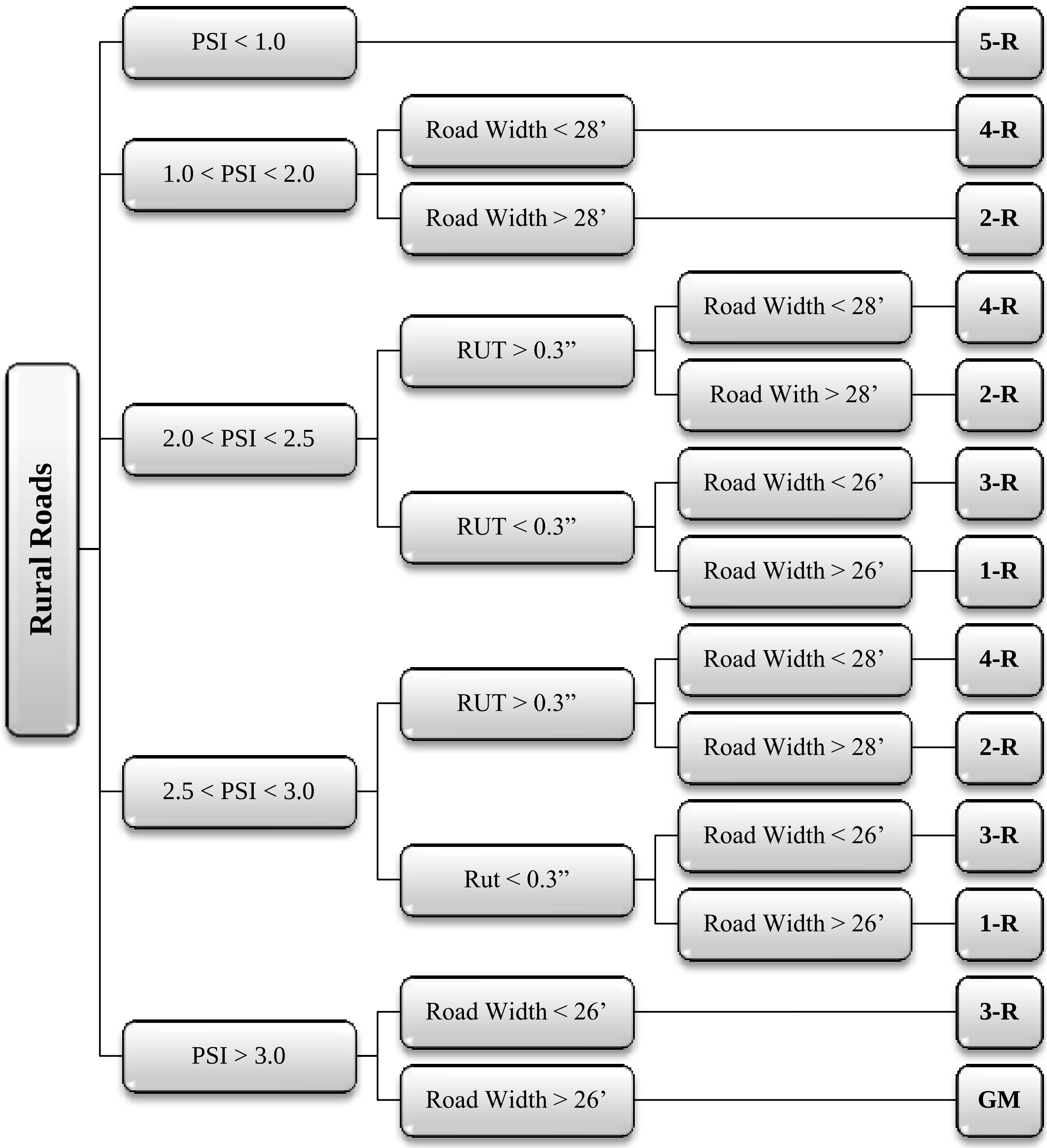


Figure 5.9 Paved rural road treatment decision process.

5.4.2.2 Urban Roads Pavement Preservation

Urban roads paved with asphalt are evaluated without the use of the International Roughness Index (IRI) because of the frequent stop and go movements of the data collection vehicles. Therefore, a decision process recommending treatments should not include an overall PSI that assumes a fixed IRI value. Instead the process should use known values from data collection –

PCI and RUT. Figure 5.10 shows the decision process for local paved urban roads. The process and derived treatment methods are similar to those from WYDOT's Urban Asphalt Decision Tree.

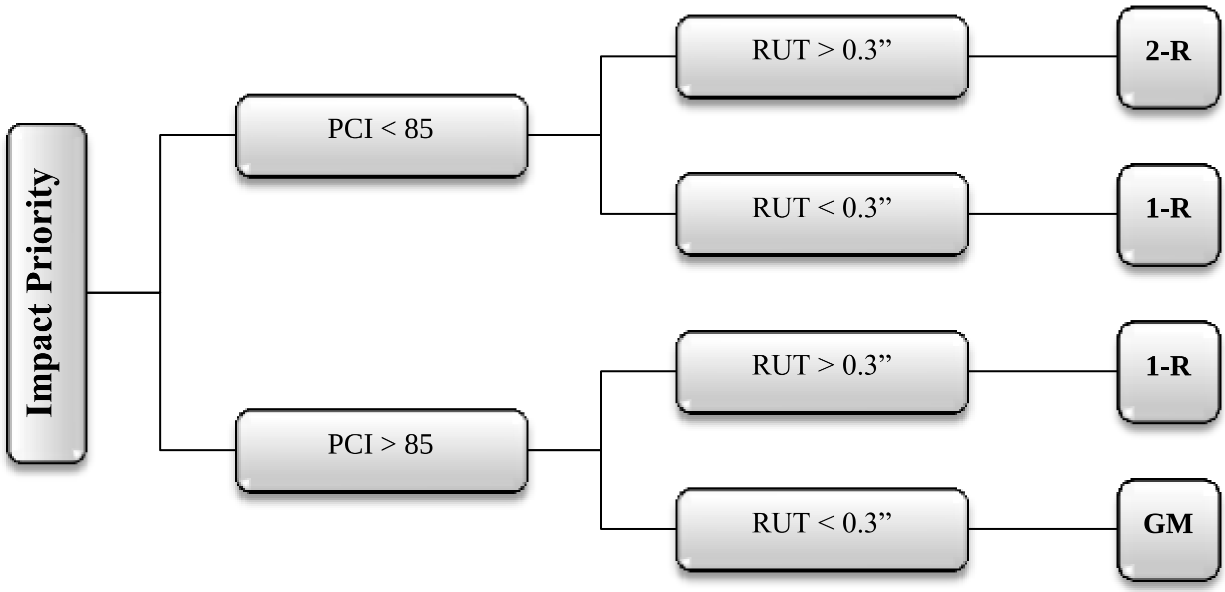


Figure 5.10 Paved urban road treatment decision process.

5.4.2.3 Generalized Results of Paved Impact Priority

All the paved segments identified by the counties as being impacted were assessed with the impact priority decision process. Generalized results are shown in Table 5.9. To view a complete list including impact priorities for specific roads, refer to Section *5.4.2.4 County Specific Results*.

Table 5.9 Paved Road Impact Priority Decision Process Results

	Impact Priority Number					
County	**1**	**2**	**3**	**4**	**5**	**6**
Converse	2	0	2	3	2	2
Goshen	0	0	0	0	1	5
Laramie	2	2	3	1	3	12
Platte	0	0	0	0	0	6
Total	4	2	5	4	6	25
Percentages	8.7%	4.3%	10.9%	8.7%	13.0%	54.3%

5.4.2.4 County Specific Results

The following sections contain information for each county containing the following:

- Road lists containing prescribed treatment types for impacted roads based on the pavement preservation treatment decision tree process.
- Road lists containing the impact priority levels for impacted roads based on the impact priority decision process.
- Road lists containing information on missing data on impacted local paved roads.

For a complete list of prescribed treatments for each county's roads, see Appendices *C.10. Converse County: Paved County Road Recommended Improvements, C.18. Laramie County: Paved County Road Recommended Improvements, C.25 Cheyenne MPO: Paved County Road Recommended Improvements, C.33. Goshen County: Paved County Road Recommended Improvements,* and *C.41. Platte County: Paved County Road Recommended Improvements*. This information is for county use only. It is important to note that all treatment levels are prescribed on network level analysis. It is recommended that project level analysis be completed before implementing designs on road segments.

5.4.2.4.1 Converse County Results

Converse County is responsible for the maintenance of 25 paved roads. These roads are broken down into 31 pavement segments totaling 90 miles. Of these, 16 segments (69 miles) were identified by the Converse County Road and Bridge Supervisor as being impacted by oil and gas development. Overall, nine segments were not evaluated due to missing data described in Section *5.2.4 Missing Data* of this report, five of which are considered "impacted." Table 5.10 shows the 11 segments with complete data sorted by treatment type.

Table 5.10 Converse County Impacted Paved Road Treatment List

Segment ID	Road Name	Begin MP	End MP	Length, miles	Top Width, ft	PSI	Treatment Type	Impact Priority	Estimated Cost
200	Walker Creek Rd	0.0	9.9	9.9	24	0.5	5-R	5	$11,904,000
197	***Ross Rd***	***0.0***	***7.7***	***7.7***	***26***	***0.4***	***5-R***	***1***	***$9,240,000***
195	Deer Creek Rd	0.0	6.1	6.1	24	0.6	5-R	6	$7,260,000
198	East Antelope Rd	0.6	5.7	5.1	24	0.7	5-R	6	$6,108,000
201-2	55 Ranch Rd	7.9	10.5	2.7	24	0.0	5-R	4	$3,192,000
196	Highland Loop Rd	0.0	2.0	2.0	26	0.0	5-R	5	$2,448,000
197-1	**Ross Rd**	**7.7**	**20.3**	**12.6**	**23**	**1.3**	**4-R**	**1**	**$8,216,000**
201	55 Ranch Rd	0.0	1.1	1.1	24	1.6	4-R	4	$682,500
201-1	55 Ranch Rd	1.1	7.9	6.8	24	3.0	3-R	4	$2,216,500
203	Antelope Coal Mine Rd	0.0	5.7	5.7	26	2.4	1-R	3	$342,000
203-1	Antelope Coal Mine Rd	5.7	9.2	3.5	28	3.3	GM	3	$0
	AVERAGE	--	--	5.7	25	1.3	--	--	--
	TOTAL	--	--	63.2	--	--	--	--	$51,609,000

Bold font: Roads that are clearly impacted by oil and gas traffic.
Bold italic font: Roads that have been rehabilitated since data collection and are clearly impacted by oil and gas traffic.

Table 5.11 contains the same paved segments sorted by the impact priority rank. Road segments were identified as "clearly impacted by oil/gas development" through natural breaking points in the data collection. In Table 5.11, Ross Road is by far the most impacted segment in Converse County with high levels of ADT and ADTT as well as several nearby rigs and water sites. Even though Antelope Coal Mine Road has a relatively high impact priority ranking, it was determined impact was caused by the nearby coal mines instead of oil and gas activity since no wells or water haul sites are nearby.

Since data collection has taken place for this project, Ross Road segment 197 has experienced rehabilitation. The PSI is no longer 0.4. It is encouraging to see that county officials have invested money in the most highly impacted segment. Ross Road segment 197-1 is still in very poor shape and experiencing high oil and gas impacts. This segment is at risk of severe deterioration with current impacts and should be of high priority in terms of future repairs. Table 5.12 summarizes the five impacted segments lacking data in Converse County. Included in the table is a short description of what data is missing. Through continued research, this information will be valuable in ensuring segments are not missed again.

Table 5.11 Converse County Paved Roads Impact Priorities

Segment ID	Road Name	Begin MP	End MP	Length, miles	ADT	ADTT	Serviceable Rigs/Water Haul Sites	PSI	Impact Priority
197	***Ross Rd***	***0.0***	***7.7***	***7.7***	***967***	***295***	***30***	***0.4***	***1***
197-1	**Ross Rd**	**7.7**	**20.3**	**12.6**	**967**	**295**	**24**	**1.3**	**1**
203	Antelope Coal Mine Rd	0.0	5.7	5.7	669	118	1	2.4	3
203-1	Antelope Coal Mine Rd	5.7	9.2	3.5	669	118	0	3.3	3
201	55 Ranch Rd	0.0	1.1	1.1	380	21	1	1.6	4
201-1	55 Ranch Rd	1.1	7.9	6.8	380	21	0	3	4
201-2	55 Ranch Rd	7.9	10.5	2.7	380	21	0	0	4
196	Highland Loop Rd	0.0	2.0	2.0	173	31	2	0	5
200	Walker Creek Rd	0.0	9.9	9.9	154	28	1	0.5	5
195	Deer Creek Rd	0.0	6.1	6.1	142	10	1	0.6	6
198	East Antelope Rd	0.6	5.7	5.1	56	4	14	0.7	6
	AVERAGE	--	--	5.7	449	87	6.7	1.3	--
	TOTAL	--	--	63.2	--	--	74	--	--

Bold font: Roads that are clearly impacted by oil and gas traffic.

Bold italic font: Roads that have been rehabilitated since data collection and are clearly impacted by oil and gas traffic.

Treatment methods for individual roads in Converse County, both impacted and non-impacted, are shown in Appendix *C.10. Converse County: Paved County Road Recommended Improvements*.

Table 5.12 Converse County Paved Roads Missing Data

Segment ID	Road Name	Begin MP	End MP	Length, miles	Comments
197-2	Ross Rd	20.8	21.1	0.3	Missing Pathway Data
209	Inez Rd	11.0	11.4	0.4	Missing Pathway Data
210	Irvine Rd	0.0	3.3	3.3	Missing Traffic Data
211	Irvine Rd	3.3	4.5	1.2	Missing Traffic Data
219	Tank Farm Rd	15.7	17.0	1.3	Missing Pathway Data
			TOTAL	6.4	

5.4.2.4.2 Goshen County Results

Goshen County is responsible for the maintenance of 43 paved roads. These roads are broken down into 50 pavement segments totaling 123.0 miles. Of these, 9 segments (42.6 miles) were identified by the Goshen County Road and Bridge Supervisor to be impacted by oil and gas development. Overall, 13 segments were not evaluated due to missing data described in Section *5.2.4 Missing Data* of this report, three of which are considered impacted. Table 5.13 shows the remaining six segments sorted by treatment method.

Table 5.13 Goshen County Impacted Paved Road Treatment List

Segment ID	Road Name	Begin MP	End MP	Length, miles	Top Width, ft	PSI	Treatment Type	Impact Priority	Estimated Cost
155	*Lingle Veteran Rd*	*0.0*	*8.6*	*8.6*	*24*	*2.5*	*3-R*	*5*	*$2,778,750*
153	CR 55A	0.0	5.1	5.1	26	2.0	3-R	6	$1,667,250
154	Deer Creek Rd	0.0	5.6	5.6	22	1.2	4-R	6	$3,620,500
157	Wyncote Rd	0.0	2.7	2.7	20	1.3	4-R	6	$1,768,000
184	Kaspiere Rd	0.0	17.7	17.7	24	1.1	4-R	6	$11,505,000
156	CR 31B	0.0	0.6	0.6	22	0.7	5-R	6	$768,000
	AVERAGE	--	--	6.7	23	1.5	--	--	--
	TOTAL	--	--	40.3	--	--	--	--	$22,107,500

Italic font: Road that has been rehabilitated since data collection.

Table 5.14 contains the same pave segments sorted by the impact priority rank. In Goshen County, no segments were identified as being impacted by oil and gas development. Lingle Veteran Road is the most impacted road in the county, receiving only a “5” in the priority ranking system. The other five paved road segments in Goshen County are ranked with impact priorities of “6”.

The Lingle Veteran Road has experienced rehabilitation since data collection for this project. Once again, county officials invested funds in the most needed place based on oil and gas impact. Table 5.15 shows the three impacted segments lacking data in Goshen County. Included in the table is a short description of what data is missing.

Treatment methods for individual roads in Goshen County, both impacted and non-impacted, are shown in Appendix *C.33. Goshen County: Paved County Road Recommended Improvements*.

Table 5.14 Goshen County Paved Roads Impact Priority

Segment ID	Road Name	Begin MP	End MP	Length, miles	ADT	ADTT	Serviceable Rigs/Water Haul Sites	PSI	Impact Priority
155	*Lingle Veteran Rd*	*0.0*	*8.6*	*8.6*	*203*	*39*	*2*	*2.5*	*5*
156	CR 31B	0.0	0.6	0.6	152	16	2	0.7	6
157	Wyncote Rd	0.0	2.7	2.7	152	16	3	1.3	6
153	CR 55A	0.0	5.1	5.1	115	16	0	2	6
154	Deer Creek Rd	0.0	5.6	5.6	88	9	3	1.2	6
184	Kaspiere Rd	0.0	17.7	17.7	82	1	0	1.1	6
	AVERAGE	--	--	6.7	132	16	1.7	1.5	--
	TOTAL	--	--	40.3	--	--	10	--	--

Italic font: Road that has been rehabilitated since data collection.

Table 5.15 Goshen County Paved Roads Missing Data

Segment ID	Road Name	Begin MP	End MP	Length, miles	Comments
151	CR 44A	--	--	0.4	Missing Pathway Data
152	CR 50A	--	--	0.1	Missing Pathway Data
182	Grayrock Rd	0.0	1.8	1.8	Missing Traffic Data
			TOTAL	2.3	

5.4.2.4.3 Laramie County Results

Laramie County is responsible for the maintenance of 122 paved roads. These roads are divided into 147 pavement segments totaling 225.2 miles. Of these, 34 segments (116.7 miles) were identified by the Laramie County Road and Bridge Supervisor to be impacted by oil and gas development. Overall, 72 segments were not evaluated due to missing data described in Section *5.2.4 Missing Data* of this report, 11 of which are considered "impacted". Table 5.16 shows the remaining 23 segments sorted by treatment method.

Table 5.16 contains the same paved segments sorted by the impact priority rank. Road segments were identified as "clearly impacted by oil/gas development" through natural breaking points in the data collection. In Table 5.17, seven roads stand apart from the rest and all have high levels of ADT and ADTT as well as several nearby rigs and water sites. In Laramie County, the impact priority of "3" was used as the breaking point.

Table 5.16 Laramie County Impacted Paved Road Treatment List

Segment ID	Road Name	Begin MP	End MP	Length, miles	Top Width, ft	PSI	Treatment Type	Impact Priority	Estimated Cost
222-1	**Chalk Bluff/"78' Rd**	**18.2**	**24.3**	**6.1**	**25**	**0.3**	**5-R**	**2**	**$7,260,000**
3	**Albin/LaGrange Rd**	**0.0**	**10.7**	**10.7**	**25**	**0.9**	**5-R**	**3**	**$12,840,000**
6	Black Hills Rd	0.0	10.1	10.1	22	0.1	5-R	5	$12,060,000
19-1	Old Highway Burns West	0.0	6.5	6.5	22	0.3	5-R	5	$7,776,000
222	Chalk Bluff/"78' Rd	12.7	18.2	5.5	23	1.0	5-R	5	$6,600,000
21-2	Old Yellowstone Rd	4.9	7.6	2.7	20	0.2	5-R	6	$3,216,000
21-1	Old Yellowstone Rd	7.6	9.4	1.9	21	0.9	5-R	6	$2,220,000
21	Old Yellowstone Rd	9.4	10.6	1.2	21	0.0	5-R	6	$1,464,000
10	**Chalk Bluff/"78' Rd**	**0.0**	**7.7**	**7.7**	**24**	**1.4**	**4-R**	**3**	**$5,011,500**
18-1	Moffet Rd	3.5	8.0	4.5	23	1.3	4-R	6	$2,899,000
15	**Hillsdale Rd West**	**0.0**	**3.8**	**3.8**	**24**	**2.2**	**3-R**	**1**	**$1,238,250**
14-1	Hillsdale N Rd/Midway	11.9	17.0	5.1	24	2.8	3-R	4	$1,641,250
13	Gillaspie Rd	0.0	4.8	4.8	22	2.8	3-R	6	$1,547,000
18	Moffet Rd	0.0	3.5	3.5	23	3.1	3-R	6	$1,150,500
2	A-118-1	0.0	2.0	2.0	22	3.2	3-R	6	$663,000
11	Chalk Hill/Bliss Rd	4.2	6.2	2.0	23	3.2	3-R	6	$650,000
7	Bristol Ridge/Hirsig Rd	17.4	19.0	1.6	22	2.9	3-R	6	$533,000
8	Bruegman Rd	0.0	1.3	1.3	24	2.9	3-R	6	$422,500
1	**CR 140-1**	**0.2**	**4.4**	**4.3**	**26**	**2.4**	**1-R**	**3**	**$255,000**
5	Bear Creek/Marsh Rd	0.0	2.7	2.7	26	2.1	1-R	6	$160,200
9	**Carpenter Rd/Berger Rd**	**0.0**	**2.5**	**2.5**	**27**	**3.1**	**GM**	**1**	**$0**
14	**Hillsdale N Rd/Midway**	**3.8**	**11.9**	**8.1**	**26**	**3.5**	**GM**	**2**	**$0**
21-3	Old Yellowstone Rd	0.0	4.9	4.9	34	3.6	GM	6	$0
	AVERAGE	--	--	3.2	24	2.6	--	--	--
	TOTAL	--	--	35.5	--	--	--	--	$11,159,700

Bold font: Roads that are clearly impacted by oil and gas traffic.

No impacted roads in Laramie County have been rehabilitated since data collection has taken place for this study. The seven roads identified as “clearly impacted by oil/gas development” are at risk to increased oil and gas activity. These roads should be considered a priority in any future rehabilitation decision process. Table 5.18 summarizes the 11 segments with missing data in Laramie County.

Treatment methods for individual roads in Laramie County, both impacted and non-impacted, are shown in Appendices *C.18. Laramie County: Paved County Road Recommended Improvements* and *C.25. Cheyenne MPO: Paved County Road Recommended Improvements*.

Table 5.17 Laramie County Paved Roads Impact Priority

Segment ID	Road Name	Begin MP	End MP	Length, miles	ADT	ADTT	Serviceable Rigs/Water Haul Sites	PSI	Impact Priority
15	**Moffet Rd**	**0.0**	**3.8**	**3.8**	**603**	**59**	**10**	**2.2**	**1**
9	**Carpenter Rd/Berger Dr**	**0.0**	**2.5**	**2.5**	**518**	**243**	**12**	**3.1**	**1**
14	**Hillsdale Rd West**	**3.8**	**11.9**	**8.1**	**372**	**62**	**8**	**3.5**	**2**
222-1	**Chalk Bluff/"78" Rd**	**18.2**	**24.3**	**6.1**	**168**	**72**	**12**	**0.3**	**2**
10	**Chalk Bluff/"78" Rd**	**0.0**	**7.7**	**7.7**	**350**	**40**	**6**	**1.4**	**3**
1	**CR 140-1**	**0.2**	**4.4**	**4.3**	**328**	**40**	**10**	**2.4**	**3**
3	**Albin/LaGrange Rd**	**0.0**	**10.7**	**10.7**	**108**	**22**	**7**	**0.9**	**3**
14-1	Hillsdale N/Midway Rd	11.9	17.0	5.1	372	62	0	2.8	4
19-1	Old Highway Burns West	0.0	6.5	6.5	198	26	3	0.3	5
222	Chalk Bluff/"78" Rd	12.7	18.2	5.5	168	72	2	1.0	5
6	Black Hills Rd	0.0	10.1	10.1	114	36	3	0.1	5
13	Gillaspie Rd	0.0	4.8	4.8	37	7	1	2.8	6
21	Old Yellowstone Rd	9.4	10.6	1.2	36	6	2	0.0	6
21-1	Old Yellowstone Rd	7.6	9.4	1.9	36	6	2	0.9	6
21-2	Old Yellowstone Rd	4.9	7.6	2.7	36	6	2	0.2	6
21-3	Old Yellowstone Rd	0.0	4.9	4.9	36	6	0	3.6	6
2	A-118-1	0.0	2.0	2.0	34	7	0	3.2	6
11	Chalk Hill/Bliss Rd	4.2	6.2	2.0	34	7	0	3.2	6
7	Bristol Ridge/Hirsig Rd	17.4	19.0	1.6	31	0	0	2.9	6
18	Moffet Rd	0.0	3.5	3.5	26	1	0	3.1	6
18-1	Moffet Rd	3.5	8.0	4.5	26	1	0	1.3	6
8	Bruegman Rd	0.0	1.3	1.3	24	4	1	2.9	6
5	Bear Creek/Marsh Rd	0.0	2.7	2.7	15	0	0	2.1	6
	AVERAGE	--	--	4.5	160	34	3.5	1.9	--
	TOTAL	--	--	103.2	--	--	81	--	--

Bold font: Roads that are clearly impacted by oil and gas traffic.

Table 5.18 Laramie County Paved Roads Missing Data

Segment ID	Road Name	Begin MP	End MP	Length, miles	Comments
4	Atlas Rd	0.0	0.4	0.4	Missing Pathway Data
16	I-80 Service Rd	0.0	3.0	3.0	Missing Pathway Data
19	Old Highway Burnd West	6.5	7.0	0.5	Missing Pathway Data
20	Old Highway Pine Bluffs West	7.2	9.0	1.8	Missing Pathway Data
22	Stuckey Rd	0.0	0.0	0.0	Missing Pathway Data
12	Egbert N/Egbert S Rd	11.8	13.5	1.7	Missing Pathway Data
41244	Egbert N/Egbert S Rd	10.9	11.8	0.9	Missing Pathway Data
17	Little Bear Rd	0.0	0.6	0.6	Missing Pathway Data
17-1	Little Bear Rd	4.3	6.7	2.4	Missing Pathway Data
17-2	Little Bear Rd	6.7	6.9	0.3	Missing Pathway Data
222-2	Chalk Bluff/"78" Rd	24.3	26.3	2.0	Missing Pathway Data
			TOTAL	13.5	

5.4.2.4.4 Platte County Results

Platte County is responsible for the maintenance of 31 paved roads. These roads are broken down into 43 pavement segments totaling 156.5 miles. Of these, 9 segments (33.0 miles) were identified by the Platte County Road and Bridge Supervisor to be impacted by oil and gas development. Overall, six segments were not evaluated due to missing data described in Section *5.2.4 Missing Data* of this report, three of which are considered "impacted". Table 5.19 shows the remaining six segments sorted by treatment method, while Table 5.20 shows the same roads with their prioritization data.

Table 5.19 Platte County Impacted Paved Road Treatment List

Segment ID	Road Name	Begin MP	End MP	Length, miles	Top Width, ft	PSI	Treatment Type	Impact Priority	Estimated Cost
223-2	Bordeaux Rd	5.5	6.1	0.6	20	0.9	5-R	6	$660,000
123	Pioneer Rd	0.0	8.9	8.9	24	2.0	4-R	6	$5,785,000
223-1	Bordeaux Rd	2.4	5.5	3.1	20	1.1	4-R	6	$2,041,000
223	Bordeaux Rd	0.1	2.4	2.3	22	1.3	4-R	6	$1,495,000
124	Deer Creek Rd	0.0	8.8	8.8	24	2.9	3-R	6	$2,850,250
121	Dickenson Hill Rd	0.0	3.6	3.6	23	3.0	3-R	6	$1,163,500
	AVERAGE	--	--	4.5	22	1.9	--	--	--
	TOTAL	--	--	27.2	--	--	--	--	$13,994,750

Table 5.20 Platte County Paved Roads Impact Priority

Segment ID	Road Name	Begin MP	End MP	Length, miles	ADT	ADTT	Serviceable Rigs/Water Haul Sites	PSI	Impact Priority
223-2	Bordeaux Rd	5.5	6.1	0.6	85	15	0	0.9	6
123	Pioneer Rd	0.0	8.9	8.9	60	4	0	2.0	6
223-1	Bordeaux Rd	2.4	5.5	3.1	85	15	0	1.1	6
223	Bordeaux Rd	0.1	2.4	2.3	85	15	0	1.3	6
124	Deer Creek Rd	0.0	8.8	8.8	95	2	0	2.9	6
121	Dickenson Hill Rd	0.0	3.6	3.6	16	2	0	3.0	6
	AVERAGE	--	--	6.2	56	2	0.0	3.0	--
	TOTAL	--	--	12.4	--	--	0	--	--

Currently Platte County is not experiencing high impacts from oil and gas development. Through the priority ranking system developed in this report, all six roads in Platte County were rated as "6". This is a result of low levels of observed ADT, ADTT, and nearby rigs and water haul sites.

Looking at the conditions of these six roads, four currently have a PSI < 2.0 or terminal serviceability. The low quality of these segments indicates that any increase in oil and gas activity could have a detrimental effect on the serviceability of these segments. Continued monitoring is essential to ensure that these roads can be maintained in the event of increased impacts. Table 5.21 summarizes the three segments with missing data in Platte County.

Table 5.21 Platte County Paved Roads Missing Data

Segment ID	Road Name	Begin MP	End MP	Length, miles	Comments
223-3	Bordeaux Rd	9.3	12.2	2.9	Missing Pathway Data
122	JJ Rd	0.0	2.4	2.4	Missing Traffic Data
125	Rompoon Rd	0.0	0.5	0.5	Missing Pathway Data
			TOTAL	5.8	

Treatment methods for individual roads in Platte County, both impacted and non-impacted, are shown in Appendix *C.41. Platte County: Paved County Road Recommended Improvements*.

5.4.2.5 Pavement Preservation Results

All segments containing the necessary data, 167 segments in all, were evaluated using either the rural or urban paved decision tree. The summarized results are shown in Table 5.22 which includes all paved roads that would benefit significantly from upgrading assuming they are to be maintained as paved roads in the long term. The process resulted in a diverse range of treatments necessary across the study area. To view a complete list including treatment types for specific roads, see Appendices *C.10. Converse County: Paved County Road Recommended Improvements, C.18. Laramie County: Paved County Road Recommended Improvements, C.25 Cheyenne MPO: Paved County Road Recommended Improvements, C.33. Goshen County: Paved County Road Recommended Improvements,* and *C.41. Platte County: Paved County Road Recommended Improvements*. For a list of impacted roads only, refer to Section *5.4.2.4 County Specific Results*. The treatments prescribed by this method are recommended as part of a network level analysis. Therefore, if individual roads are selected for rehabilitation, a more detailed, project level analysis is needed to ensure that the proper treatment is applied.

Table 5.22 includes all recommended treatments derived from the decision processes described in Section *5.4.2 Paved Road Rehabilitation Decision Process* for the impacted, paved roads in the four counties. Table 5.23 shows the miles and costs for each of the six treatment types. To address the impacts of oil and gas activities, those treatments on the highest priority roads – priority level 1 – should be addressed first. As with any management system, the results of this network level analysis should be corroborated with more detailed, project level analysis before final construction and rehabilitation plans are undertaken.

5.4.3 Design Specifications

5.4.3.1 General Rehabilitation Efforts

For use in visualizing rehabilitation strategies, the *1993 AASHTO Design Guide* was used to create typical designs for both new and rehabilitated flexible pavements. These designs were made to incorporate the different rehabilitation strategies based on the roads' current conditions and widths. Within those rehabilitation strategies, designs for 2-R/4-R and 5-R scenarios were established. These typical designs include a thick overlay (greater than 2 inches) for 2-R/4-R and complete reconstruction or new construction for 5-R. Within these strategies, designs for high, medium, and low truck traffic volumes were also developed. The classifications were assigned these truck traffic levels:

- High: < 300 trucks/day
- Medium: 100 – 300 trucks/day
- Low: < 100 trucks/day

Table 5.22 Impacted Paved Road Treatment Costs and Mileages

Impact Priority Number	Segments	Miles	Estimated Cost
1	3	18.9	$9,454,250
2	2	14.2	$7,260,000
3	5	31.9	$18,448,500
4	4	15.6	$7,732,250
5	5	34.0	$40,788,000
6	25	103.2	$61,616,700
Subtotal	44	217.7	$145,299,700
Completed Projects	2	16.3	$12,018,750
Missing Data	22	28.0	NA
TOTAL	68	261.9	$157,318,450

For each design, reliability levels were selected using typical values that are used by WYDOT for secondary and miscellaneous roadways. Reliability indicates the level of certainty that the road will perform as designed. For secondary roads, reliability is not as critical as it is for interstate or primary roadways, so a 75% reliability level was used for these local road designs. Additional assumptions had to be made in accordance to the AASHTO design equation. These are listed below.

- Reliability: 75%

- Standard Deviation: 0.35 (standard practice on AC pavements in the *1993 AASHTO Guide*)
- M_R: 6,000 psi (estimated value WYDOT provided project area)
- Δ PSI: 2.2
- m_1,m_2: Drainage Coefficients: 1.25 (assumed good drainage on new construction)
- Design Life: 20 years

Based on the North Dakota State University report on oil and gas impacts in North Dakota, an average ESAL factor per front-haul miles was computed to be 1.77. Using this value, the total ESAL expectancy was calculated and applied for design. When considering overlay design, the average effective structural number (found earlier in this report) of 1.43 was utilized. The remainder of the structural number required for twenty year design had to be derived from asphalt overlay only. This resulted in large overlay thicknesses. The results are shown in Table 5.23.

Table 5.23 Typical Pavement Thickness Designs, Inches

	Reconstruction Thickness			Overlay
	Pavement	Base	Subgrade	Overlay Thickness
High	4	6	12	5.5
Medium	3.5	6	12	5
Low	3	6	12	4

5.5 Summary

In order to quantify the impact that the oil and gas industry will have on local paved roads, current local paved road conditions were analyzed. This analysis aimed at determining what type of serviceability remained within the design life of the roads, and also looked to gauge the ability of local paved roads to service the oil and gas industry and the increased heavy truck traffic associated with it. These analyses were conducted in conjunction with methodologies similar to those used by the Wyoming Department of Transportation. The current conditions of Laramie, Goshen, Platte, and Converse Counties' paved roads were determined using data collected through Pathway Services Incorporated. This included surface imaging (used to derive PCI), IRI, and RUT depth, all of which were used to determine the present serviceability index of each road. After determining the current condition of local paved roads, the structural integrity was estimated. Further details on the data inputs and analyses are presented in Appendix *C. Paved County Roads*. Overall it is evident that increased oil and gas activity will quickly deteriorate local pavements. This is believed to be due to a multitude of factors, including age, lack of maintenance, poor construction methods, and in some cases, increased heavy truck traffic.

After determining what condition the paved roads were currently in, rehabilitation strategies and prioritization rankings were determined. These methodologies are intended to guide the proper authorities in decisions being made regarding maintenance and rehabilitation procedures. The priority rankings indicate which roadway necessitates the most prompt attention regarding rehabilitation or reconstruction. The rehabilitation strategies indicate which remediation technique should be used. These indicator methodologies take into account the roadway's current condition, the present and future impact of the oil and gas industry, and roadway characteristics, such as road width. To provide typical designs for use in conjunction with the rehabilitation strategies, the AASHTO Design was used. Design values are completed on network level analysis and should only be considered for this report and decision processes. If chosen to be rehabilitated, actual project level analysis needs to be conducted.

5.6 Recommendations

In order to determine where funding needs to be allocated on county road projects, it is recommended that the priority rankings and rehabilitation strategies developed through this study be used. These methodologies are based on the current conditions of the road, the road's probability of being impacted by oil and gas activities, and traffic counts. Indicators used in these methodologies, such as PSI, PCI, rut depth, ADT, and ADTT, are telling factors if a road is currently meeting serviceability standards or will be able to in the future. Because of this fact, the rehabilitation strategy decision tree and priority rankings provide a reliable method for determining which roads need additional funding and maintenance work of some kind.

The design specifications that were developed during this study are representative of typical designs that can be used for the various rehabilitation options. It is recommended that these designs be used as possible starting points for project level designs of particular roadways. It is also recommended that additional resources be applied to collecting more years of pavement condition data for future research. This data would be extremely useful in determining the impacts of the oil and gas industry and quantifying the impacts of increased traffic loads. It will allow WY T^2/LTAP to better understand the effects of oil and gas impacts on local paved roads and provide insight into a more complete management program.

Table 5.24 Paved Impacted Road Treatments and Their Costs and Mileages

Impact Priority Number	Treatment Cost						
	GM	1-R	2-R	3-R	4-R	5-R	TOTAL
1	$0	$0	$0	$1,238,250	$8,216,000	$0	$9,454,250
2	$0	$0	$0	$0	$0	$7,260,000	$7,260,000
3	$0	$597,000	$0	$0	$5,011,500	$12,840,000	$18,448,500
4	$0	$0	$0	$3,857,750	$682,500	$3,192,000	$7,732,250
5	$0	$0	$0	$0	$0	$40,788,000	$40,788,000
6	$0	$160,200	$0	$10,647,000	$29,113,500	$21,696,000	$61,616,700
Impacted Subtotal	$0	$757,200	$0	$15,743,000	$43,023,500	$85,776,000	$145,299,700
Completed Projects	$0	$0	$0	$2,778,750	$0	$9,240,000	$12,018,750
TOTAL	$0	$757,200	$0	$18,521,750	$43,023,500	$95,016,000	$157,318,450

Impact Priority Number	Treatment Mileage						
	GM	1-R	2-R	3-R	4-R	5-R	TOTAL
1	2.5	0.0	0.0	3.8	12.6	0.0	18.9
2	8.1	0.0	0.0	0.0	0.0	6.1	14.2
3	3.5	10.0	0.0	0.0	7.7	10.7	31.9
4	0.0	0.0	0.0	11.9	1.1	2.7	15.6
5	0.0	0.0	0.0	0.0	0.0	34.0	34.0
6	4.9	2.7	0.0	32.8	44.8	18.1	103.2
Subtotal	19.0	12.6	0.0	48.4	66.2	71.5	217.7
Completed Projects	0.0	0.0	0.0	8.6	0.0	7.7	16.3
TOTAL	19.0	12.6	0.0	57.0	66.2	79.2	233.9

6. UNPAVED ROADS

Unpaved roads comprise about 82% of the centerline miles in the four counties. Though unpaved roads generally serve less traffic, they still need a large portion of the counties' budgets to remain in good enough condition to provide service at levels that are acceptable to the traveling public. The fundamental unpaved roads maintenance and management challenges faced by county road and bridge departments are to provide service at acceptable levels at an acceptable cost. Further details on the data collected and analyzed as part of this study may be found in Appendix *D. Unpaved County Roads*. This study attempts to provide some insights into how the four counties try to achieve this, and into how oil and gas activities influence and affect their efforts.

6.1 Background

Relative to the research and analysis effort that has gone into studying asphalt concrete and portland cement concrete roads, there is little documented research on the performance of unpaved roads. Much of the unpaved roads methodology used in this study was developed as part of earlier work performed by the Wyoming Technology Transfer Center and Local Technical Assistance Program (WY T^2/LTAP). In the most general terms, some of the overall approaches were outlined and described in the three volume report titled 'Gravel Roads Management' *(Huntington and Ksaibati 2010; Huntington and Ksaibati 2011b)*. The overall procedures for generating recommended improvements were developed for general assessments of deteriorated conditions *(Huntington and Ksaibati 2011a)* and applied to damage related to oil field traffic *(Huntington and Ksaibati 2009a)*. Preliminary service level assignments were based on methods presented in another report which described methods for estimating annual maintenance costs for unpaved roads *(Huntington and Ksaibati 2009b)*.

To rate many miles of unpaved roads in a short time as is done in this study, rapid data collection methods are necessary. The primary assessments of surface and drainage conditions performed as part of this study use a visual rating system based on the PASER method developed in Wisconsin and modified by the WY T^2/LTAP Center (see Appendices *H.1. Gravel Roads Rating Standards* and *H.2. Ride Quality Rating Guide* and *(WTTC 2010a)*). These methods are described in more detail in the following sections.

6.1.1 PASER Gravel Manual

The Pavement Surface Evaluation and Rating (PASER) manual for gravel roads provides the underlying system used for rating and evaluating the unpaved roads in this study. Due to the nature of unpaved roads, evaluation and rating requires a different perspective than for asphalt or concrete surfaced roads. According to the PASER manual, local heavy traffic can dramatically change the surface characteristics of gravel roads from one day to the next, and a single pass from a motor grader can greatly improve the surface conditions. The most important elements of a gravel road are the cross section, drainage and gravel layer *(Walker, 1989)*. In order to evaluate and rate the condition of unpaved roads, the PASER gravel manual describes five road conditions: (1) The crown of the roadway including the height and condition of the crown and the cross slope, (2) the road's drainage and the efficiency with which water is carried away, (3) the gravel layer's thickness and quality, (4) current surface roughness conditions – washboarding/corrugations, potholes and ruts, and (5) dust and loose aggregate. The rating of each unpaved road segment takes into account the different combinations and presence of these five conditions. Distresses such as ruts, potholes and washboards indicate a lack of strength of the road and are thus considered a secondary condition whose underlying cause is one of the primary conditions – cross section, drainage and gravel layer. The actual rating system from the PASER manual is a simple 1 to 5 scale with 5 being excellent and 1 failed.

6.1.2 RQRG – Ride Quality Rating Guide

The Ride Quality Rating Guide (RQRG) *(WTTC 2010a)* was developed by the WY T^2/LTAP Center and is shown in Appendix *H.2. Ride Quality Rating Guide*. It relies heavily on the approaches and standards defined in the gravel PASER manual *(Walker 1989)*. Unlike the PASER manual, the RQRG rates roads on a scale from 1 to 10, with 10 being excellent and 1 failed, rather than PASER's 1 to 5 scale. Otherwise, the scale of this system is based directly on that of the PASER system. For example, the cutoff between a fair and poor unpaved road in both systems is a reasonable traveling speed of 25 mph.

The fundamental difference between the RQRG and the PASER system is that PASER attempts to evaluate the overall quality of the road from a manager's viewpoint. Durability is a primary factor in its ratings as reflected by its consideration of drainage and gravel properties. On the other hand, the RQRG focuses strictly on the quality of the unpaved road from the traveling public's viewpoint. Table 6.1 summarizes the standards used for unpaved road evaluation with the Wyoming modified version of the gravel PASER ratings, the RQRG.

6.1.3 GRRS – Gravel Roads Rating Standards

The rating of individual distresses on unpaved road segments in this study was based on another Wyoming modification of the PASER system *(Walker 1989)*. It was developed by the WY T^2/LTAP Center. It is referred to as the 'Gravel Roads Rating Standards' (GRRS) and it is shown in Appendix *H.1. Gravel Roads Rating Standards*.

The GRRS is a guide to assessing the condition of unpaved roads by ascribing a numerical value to seven distresses. Due to software constraints, ratings of 9-Very Good and 10-Excellent are both assigned a 9 on this project. This does not significantly affect the results of this project since neither distress level prompts any actions and 10-Excellent unpaved road segments are rare to non-existent. These seven different distresses are as follows with the numerical rating scale in brackets:

- Potholes [1- 9]
- Rutting [1- 9]

- Washboards (Rhythmic Corrugations) [1- 9]
- Loose Aggregate [1- 9]
- Dust [1- 4]
- Cross Section (Crown) [1- 3]
- Roadside Drainage [1 – 3]

Higher numbers indicate superior performance. To arrive at these ratings, the evaluator drives each segment and subjectively assigns a numerical value for each distress. In general terms, the standards in the GRRS mirror those of the gravel PASER manual and the RQRG.

Table 6.1 'Ride Quality Rating Guide' ratings, speeds and brief verbal descriptions *(WTTC 2010a)* **as adapted from the Wisonsin Gravel PASER Manual** *(Walker 1989)***.**

Rating		Speed, mph*	Distresses** Adapted from the Gravel - PASER manual
10	Excellent	60+	
9	Very Good	50 - 60	
8	Good	45 - 50	Dust under dry conditions; Moderate loose aggregate; Slight washboarding
7	Good	40 - 45	
6	Fair	32 - 40	Moderate washboarding (1" - 2" deep) over 10% - 25% of area; Moderate dust, partial obstruction of vision; None or slight rutting (less than 1" deep); An occasional small pothole (less than 2" deep); Some loose aggregate (2" deep)
5	Fair	25 - 32	
4	Poor	20 - 25	Moderate to severe washboarding (over 3" deep) over 25% of area; Moderate rutting (1" - 3") over 10% - 25% of area; Moderate potholes (2" - 4" deep) over 10% - 25% of area; Severe loose aggregate (over 4")
3	Poor	15 - 20	
2	Very Poor	8 - 15	Severe rutting (over 3" deep) over 25% of area; Severe potholes (over 4" deep) over 25% of area; Many areas (over 25%) with little or no aggregate
1	Failed	0 - 8	

** Passenger car speeds based on surface condition allowing for rider comfort and minimal vehicle wear and tear, assuming no safety or geometric constraints force slower travel.* Doesn't spill your coffee!

*** Individual roadways may not have all of the types of distress listed for any particular rating. They may have only one or two types.*

6.2 Methodology

6.2.1 Segmentation

Before rating could take place, all 2,723 miles of gravel roads in the four counties had to be divided into segments. Most of this segmentation was accomplished during the rating process since the roads' characteristics were observed during the initial driving and rating portion of this study. Segmentation was based on perceived usage levels, changes in surface type, and major intersections where traffic either diverts or converges with a road. This was done to create relatively homogeneous sections with similar distresses and ride quality. For a more detailed description of segmentation methods, see *(Eaton and Beaucham 1992)*. Table 6.2 shows the unpaved road mileages for the four counties, with total miles and miles identified by the counties as being impacted by oil and gas activities. Individual segments are shown in Appendices *D.3. Converse County: Unpaved County Road Segments, D.13. Laramie County: Unpaved County Road Segments, D.29 Goshen County: Unpaved County Road Segments,* and *D.39 Platte County: Unpaved County Road Segments*. The impacted roads are shown in Figure 2.1.

Table 6.2 Unpaved Roads Mileage and Segments Evaluated in May 2012.

	Impacted		**Non-Impacted**		**TOTAL**	
County	**Miles**	**Segments**	**Miles**	**Segments**	**Miles**	**Segments**
Converse	287.6	73	232.8	58	520.5	131
Goshen	188.4	57	616.2	207	804.6	264
Laramie	357.2	145	642.5	225	999.7	370
Platte	84.5	35	313.3	100	397.8	135
TOTAL	917.8	310	1,804.8	590	2,722.6	900

6.2.1.1 Oil and Gas Impacts Estimation

During initial discussions with each county's road and bridge department, an analysis of the county roads and of oil and gas impacts was conducted. Since the degree of oil and gas impacts varies widely from county to county, the standards used by each county's representative to assign roads to the impacted status also varied widely. As more information became available, revisions to the mileages thought to be impacted were made. Occasionally, roads were classified as impacted or non-impacted based on field observations of a road's current traffic. Ultimately the process of identifying impacted roads can never be entirely correct since the traffic generators, oil and gas operations, are constantly changing locations, so the impacts on many roads change very quickly. On a percentage basis, these changes are most pronounced on lower volume roads, so unpaved roads see greater percentage changes in drilling traffic than paved roads, and county roads see greater percent changes in oil and gas traffic than higher volume state roads. Figure 6.1 shows the mileage of impacted segments as identified by the counties and rated in October 2011, June 2012 and August 2012.

6.2.2 Surface Condition Evaluation and Top Width Measurement

Each segment was rated individually through a visual "windshield" evaluation. The segments were driven at normal traffic speeds and the various distresses and ride quality were evaluated and recorded.

Unpaved roadway surface and drainage conditions were rated by two evaluators using the 'Ride Quality Rating Guide' (RQRG) *(Wyoming Technology Transfer Center 2010)* and the 'Gravel

Roads Rating System' (GRRS), which are available in Appendices *H.1. Gravel Roads Rating Standards* and *H.2. Ride Quality Rating Guide*.

Road surface widths were measured as described in Figure 1 of the 'Gravel Roads Maintenance and Design Manual' *(Skorseth and Selim 2000).*

The first evaluation was performed on unpaved roads identified as being impacted in Goshen, Laramie and Platte Counties. Initially, the two evaluators worked together, discussing the evaluation process. This evaluation was performed during October 2011. The next two evaluations were performed at nearly the same time: One evaluator rated all the unpaved roads in all four counties during May and early June 2012, while the other evaluator rated the impacted segments in late May and June 2012. The fourth data collection event was performed on the impacted segments in August 2012.

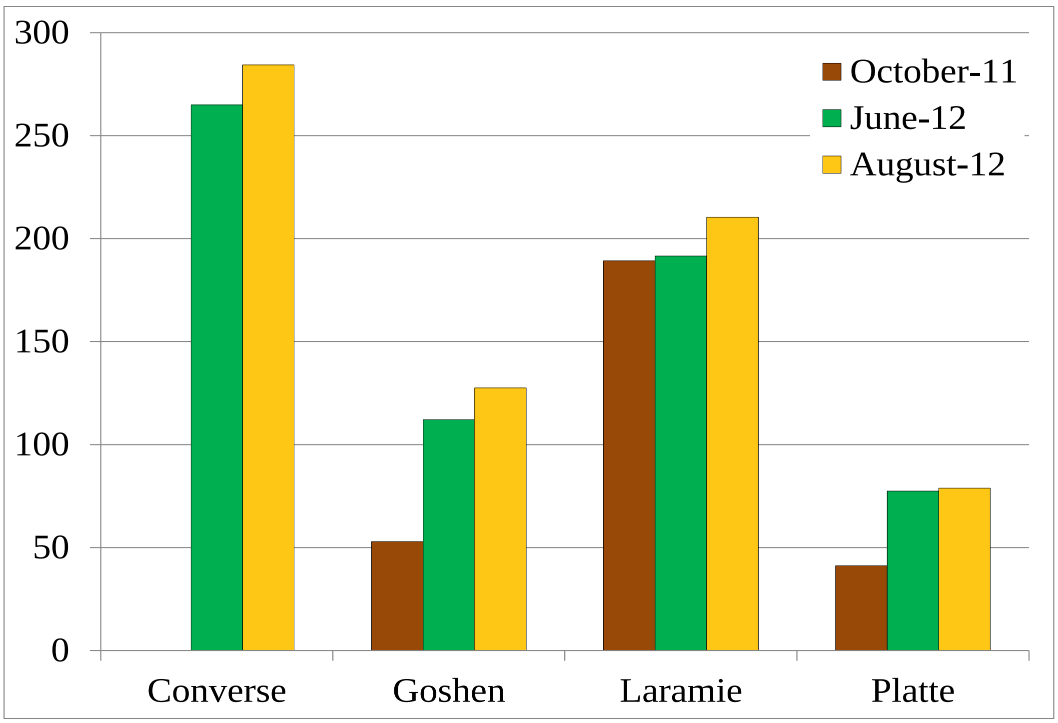


Figure 6.1 Impacted unpaved roads mileages as identified by the counties.

During May 2012 both the 918 miles of impacted roads and the 1,805 miles of non-impacted roads in each of the four counties were rated based on the Wyoming modified PASER rating system, the GRRS and the RQRG.

6.2.3 Maintenance Records

Maintenance records for the unpaved county roads were obtained from the Converse, Goshen and Laramie County Road and Bridge departments and were tabulated and analyzed.

Comparisons of maintenance costs on the impacted and non-impacted unpaved road segments were made.

6.2.4 Prioritization

A prioritized list of highly impacted roads was created and examined. This prioritization was performed with a decision tree that uses the average daily traffic (ADT), the average daily truck traffic (ADTT), and the proximity of oil and gas wells and water haul sites to each segment. This process resulted in each segment being assigned an impact priority from 1 to 6 with the lower number correlated with higher impacts, and thus a higher priority.

6.3 Top Widths, Surface and Drainage Conditions

Unpaved roads change their conditions frequently and quickly, both due to maintenance and to environmental factors, mainly weather and traffic. Temporal comparisons are made for the segments identified by the counties as being impacted, one for road segments that were rated in all three rounds (see Table 6.3) and a second for roads that were rated during both data collection events in 2012 (see Table 6.4).

Table 6.3 Unpaved Impacted Roads Average Condition Ratings During October 2011, June 2012 and August 2012.

County	Ride Quality October 2011	Ride Quality June 2012	Ride Quality August 2012	Potholes October 2011	Potholes June 2012	Potholes August 2012
Goshen	6.10	7.10	5.47	7.12	8.05	6.86
Laramie	7.10	6.85	6.73	7.70	7.88	7.75
Platte	6.77	6.80	5.90	7.49	7.63	7.15
Average	6.66	6.92	6.03	7.44	7.85	7.25
	Washboards / Corrugations			**Rutting**		
Goshen	6.98	7.66	6.20	6.47	8.23	6.92
Laramie	7.35	7.06	6.58	7.82	8.35	8.17
Platte	8.09	7.87	6.95	7.10	7.60	6.95
Average	7.47	7.53	6.58	7.13	8.06	7.35
	Loose Aggregate			**Dust**		
Goshen	6.91	6.79	5.30	3.05	3.04	1.63
Laramie	7.15	6.92	7.25	2.65	2.48	2.65
Platte	6.99	6.89	6.04	2.91	2.85	1.94
Average	7.01	6.87	6.20	2.87	2.79	2.07
	Roadside Drainage			**Cross Section (Crown)**		
Goshen	2.83	2.83	2.73	2.75	2.82	2.64
Laramie	2.95	2.94	2.90	2.98	2.97	2.94
Platte	2.60	2.60	2.59	2.62	2.66	2.70
Average	2.79	2.79	2.74	2.78	2.82	2.76

NOTE: Higher numbers indicate superior performance.
Crown and Drainage are on a scale from 1 to 3.
Dust is on a scale from 1 to 4.
All other distresses are on a scale from 1 to 9.

Table 6.4 Unpaved Impacted Roads Average Condition Ratings During June 2012 and August 2012.

County	June 2012	August 2012	(August) - (June)	June 2012	August 2012	(August) - (June)
	Ride Quality			**Potholes**		
Converse	6.76	5.87	-0.90	7.62	7.23	-0.39
Goshen	7.05	5.60	-1.45	7.96	6.71	-1.25
Laramie	6.69	6.59	-0.10	7.74	7.62	-0.12
Platte	6.34	5.65	-0.69	7.19	6.74	-0.46
Average	6.71	5.93	-0.78	7.63	7.08	-0.56
	Washboards / Corrugations			**Rutting**		
Converse	7.13	6.04	-1.09	7.76	7.47	-0.29
Goshen	7.59	6.35	-1.24	7.86	6.95	-0.91
Laramie	7.08	6.58	-0.50	8.20	7.98	-0.21
Platte	7.55	6.73	-0.82	7.17	6.59	-0.58
Average	7.34	6.43	-0.91	7.75	7.25	-0.50
	Loose Aggregate			**Dust**		
Converse	7.01	6.75	-0.26	2.76	2.18	-0.58
Goshen	7.01	5.44	-1.58	3.12	1.88	-1.24
Laramie	6.84	7.24	0.40	2.38	2.55	0.17
Platte	6.81	6.24	-0.57	3.00	2.23	-0.77
Average	6.92	6.42	-0.50	2.81	2.21	-0.61
	Roadside Drainage			**Cross Section (Crown)**		
Converse	2.89	2.87	-0.02	2.88	2.80	-0.08
Goshen	2.79	2.63	-0.16	2.79	2.56	-0.23
Laramie	2.88	2.85	-0.03	2.92	2.87	-0.05
Platte	2.50	2.40	-0.10	2.53	2.49	-0.04
Average	2.77	2.69	-0.08	2.78	2.68	-0.10

NOTE: Crown and Drainage are on a scale from 1 to 3.
Dust is on a scale from 1 to 4.
All other distresses are on a scale from 1 to 9.
Higher numbers indicate superior performance.

6.3.1 Top Widths

The values from county to county should not be directly compared since some counties have more very low service roads, including double tracks, in this data set. Table 6.5 contains the road surface top widths for the impacted and non-impacted segments in all four counties, demonstrating this situation. Most of the roads are fairly evenly distributed by width between 18 feet and 32 feet.

Table 6.5 Top Width Mileages of Unpaved Roads in May 2012 by County and Impact Status

	Impacted Unpaved County Roads						
County	**6-8½ ft**	**9-12½ ft**	**13-17½ ft**	**18-22½ ft**	**23-27½ ft**	**28-32½ ft**	**Total**
Converse	0.0	0.0	0.0	32.3	157.4	97.9	287.6
Goshen	0.0	0.0	11.5	65.1	84.1	27.7	188.4
Laramie	2.3	14.0	51.4	131.3	111.6	46.5	357.2
Platte	12.1	0.3	13.1	28.2	20.4	10.5	84.5
Total	14.5	14.3	76.1	256.8	373.4	182.6	917.8
	Non-Impacted Unpaved County Roads						
County	**6-8½ ft**	**9-12½ ft**	**13-17½ ft**	**18-22½ ft**	**23-27½ ft**	**28-32½ ft**	**Total**
Converse	0.0	7.0	42.2	80.0	90.3	13.3	232.8
Goshen	0.0	2.0	12.8	169.4	371.8	60.2	616.2
Laramie	0.0	21.6	62.5	245.9	202.9	109.6	642.5
Platte	1.0	5.6	0.6	124.7	174.9	6.5	313.3
Total	1.0	36.2	118.2	620.0	839.9	189.6	1,804.8
	All County Unpaved Roads						
County	**6-8½ ft**	**9-12½ ft**	**13-17½ ft**	**18-22½ ft**	**23-27½ ft**	**28-32½ ft**	**Total**
Converse	0.0	7.0	42.2	112.3	247.7	111.3	520.5
Goshen	0.0	2.0	24.3	234.4	455.9	87.9	804.6
Laramie	2.3	35.6	114.0	377.2	314.5	156.1	999.7
Platte	13.1	5.9	13.7	152.9	195.2	16.9	397.8
Total	15.5	50.6	194.3	876.8	1,213.3	372.2	2,722.6

6.3.2 Surface and Drainage Conditions

6.3.2.1 May 2012 Conditions

Figures 6.2 through 6.6 show conditions for the four counties on their entire unpaved networks in May 2012. As one would expect, wider roads are generally in better condition and have better drainage. Since most roads are maintained after the spring thaw, it is not surprising that the four counties' unpaved roads are generally in good condition at this time.

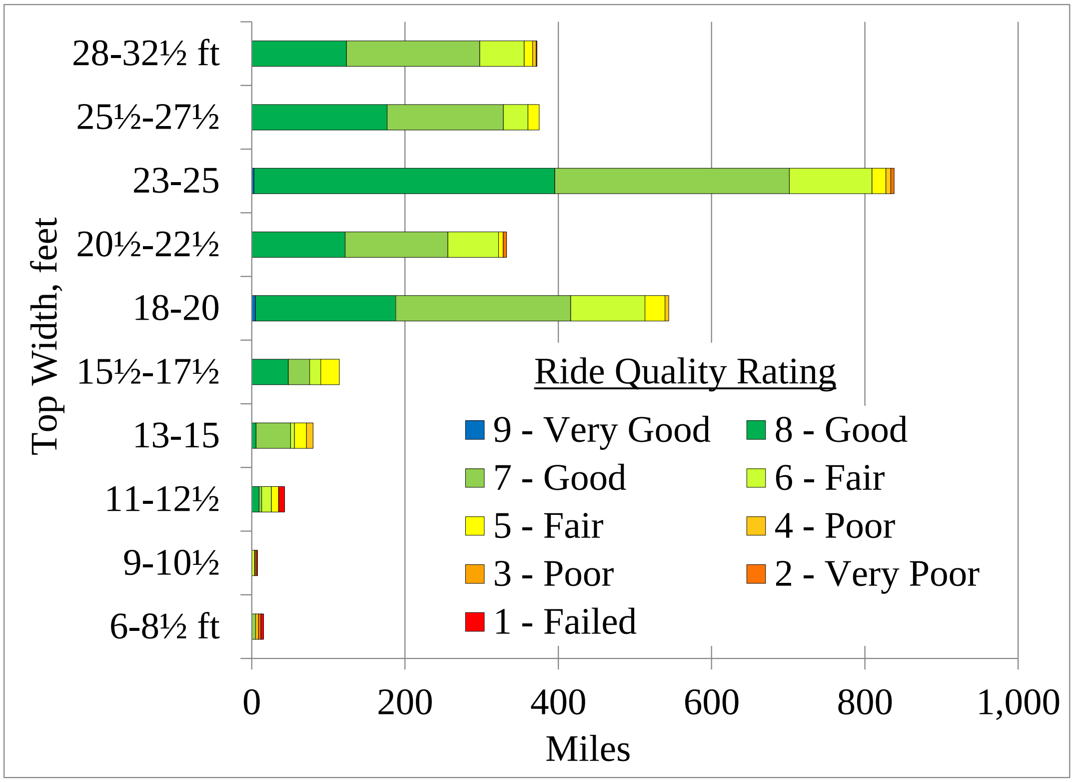


Figure 6.2 Unpaved roads May 2012 ride quality ratings mileages by top width.

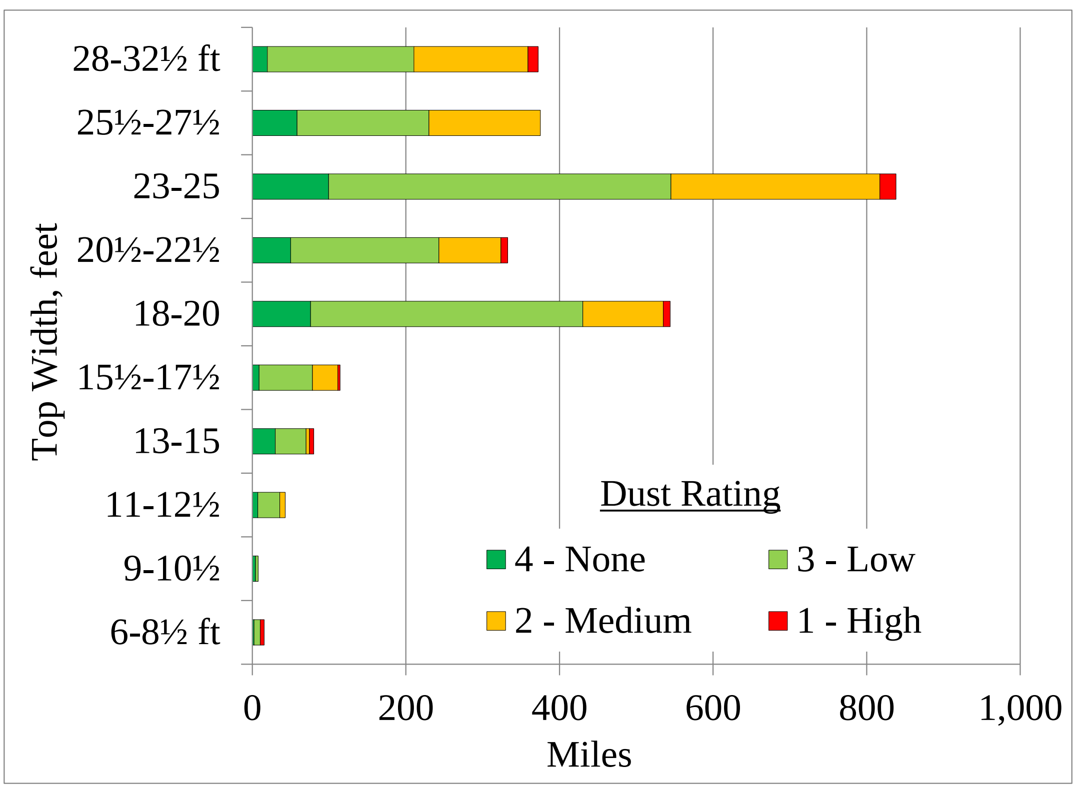


Figure 6.3 Unpaved roads May 2012 dust ratings mileages by top width.

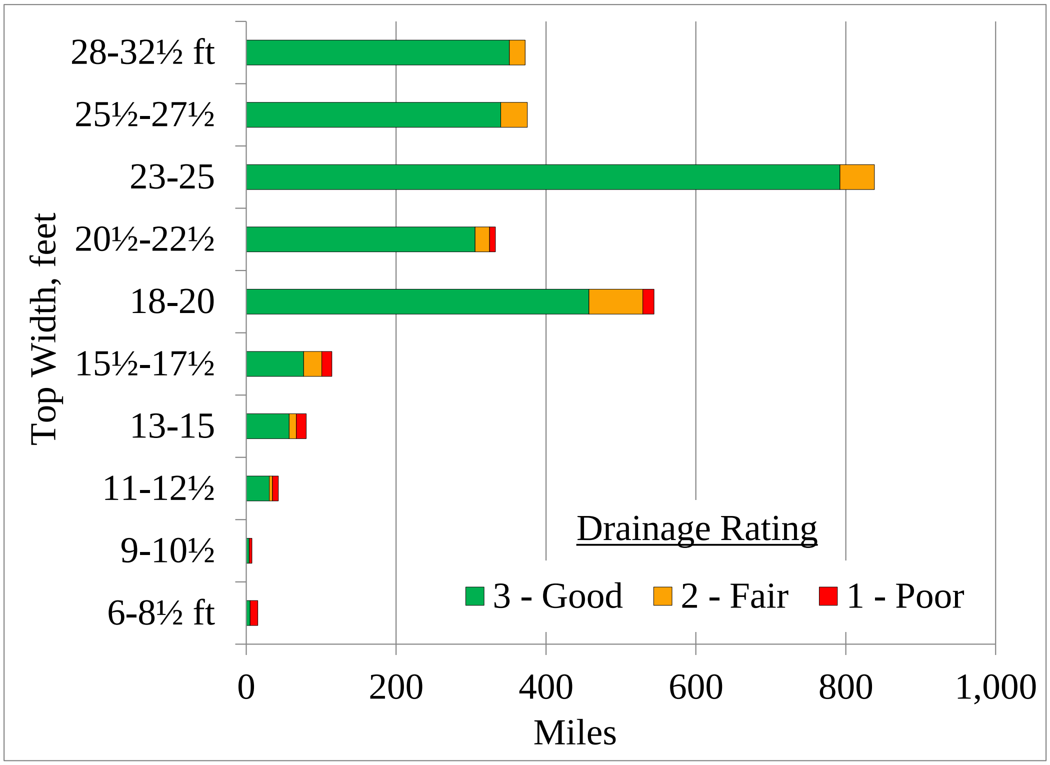


Figure 6.4 Unpaved roads May 2012 drainage ratings mileages by top width.

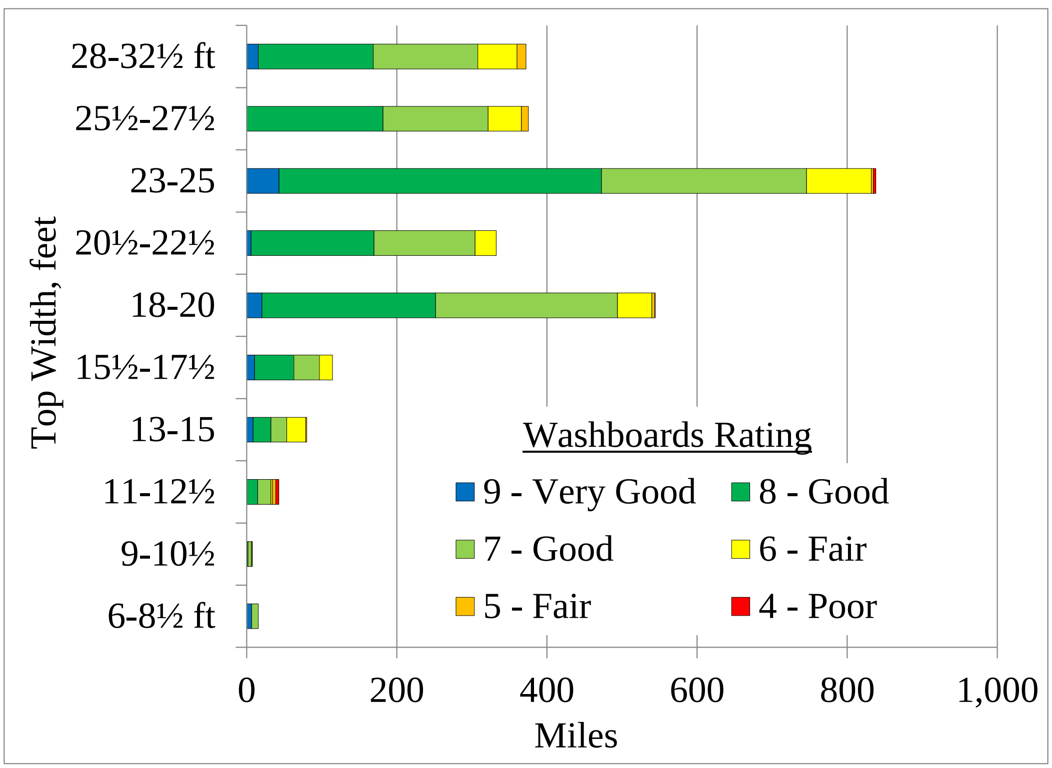


Figure 6.5 Unpaved roads May 2012 washboard ratings mileages by top width.

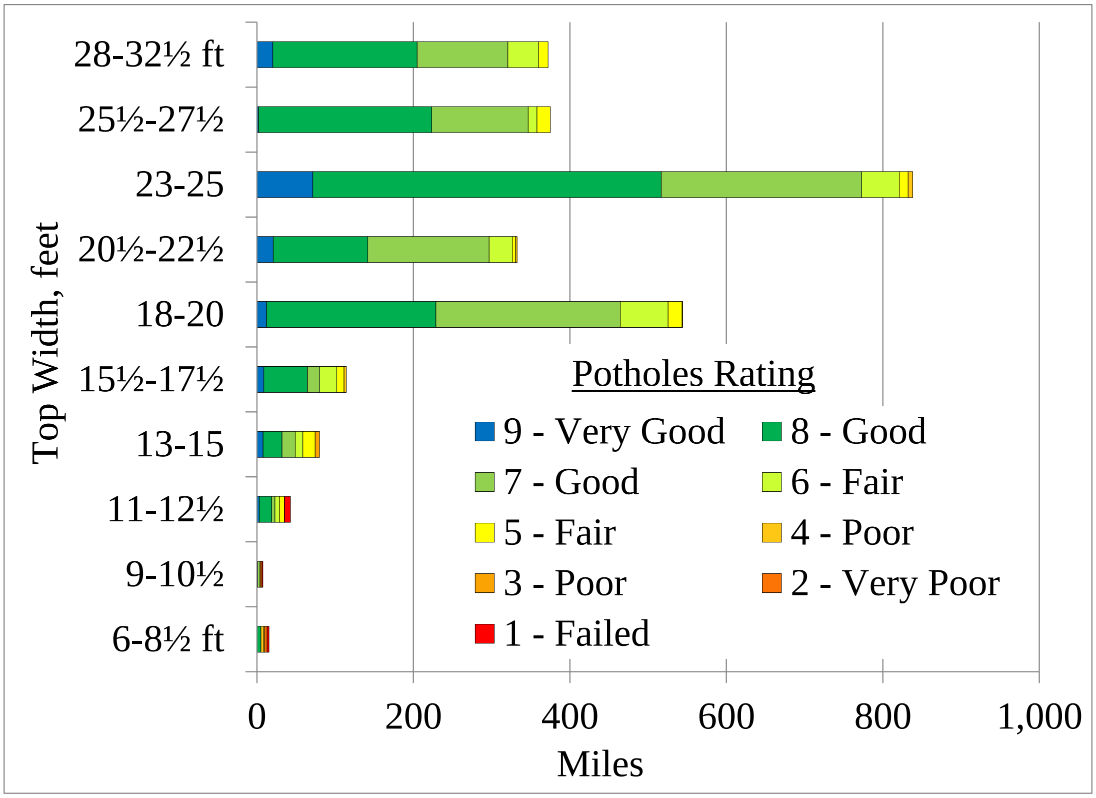


Figure 6.6 Unpaved roads May 2012 pothole ratings mileages by top width.

6.3.2.2 Impacted Roads Changing Conditions

The relative changes with time provide a realistic comparison of how each county's roads fared during this very dry summer.

The rating that mostly closely parallels the general public's perception of the road is 'ride quality' which is a subjective rating of the surface condition and roughness. Figures 6.7 through 6.10 show the ride quality ratings of the impacted roads during each of the three rating events for the impacted segments. During the course of the hot, dry summer of 2012, roads in all four counties suffered as their crust broke up due to moisture loss. This resulted in worsening washboards, dust, loose aggregate, and even dry-weather rutting over the course of the summer.

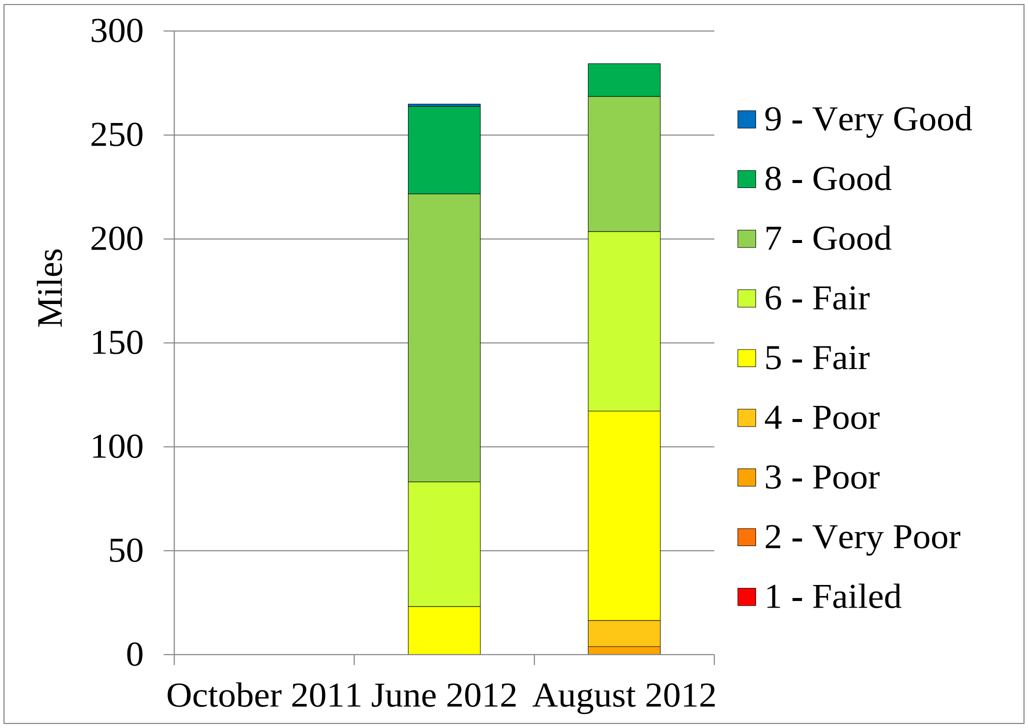


Figure 6.7 Converse County unpaved impacted roads ride quality ratings mileages in June 2012 and August 2012.

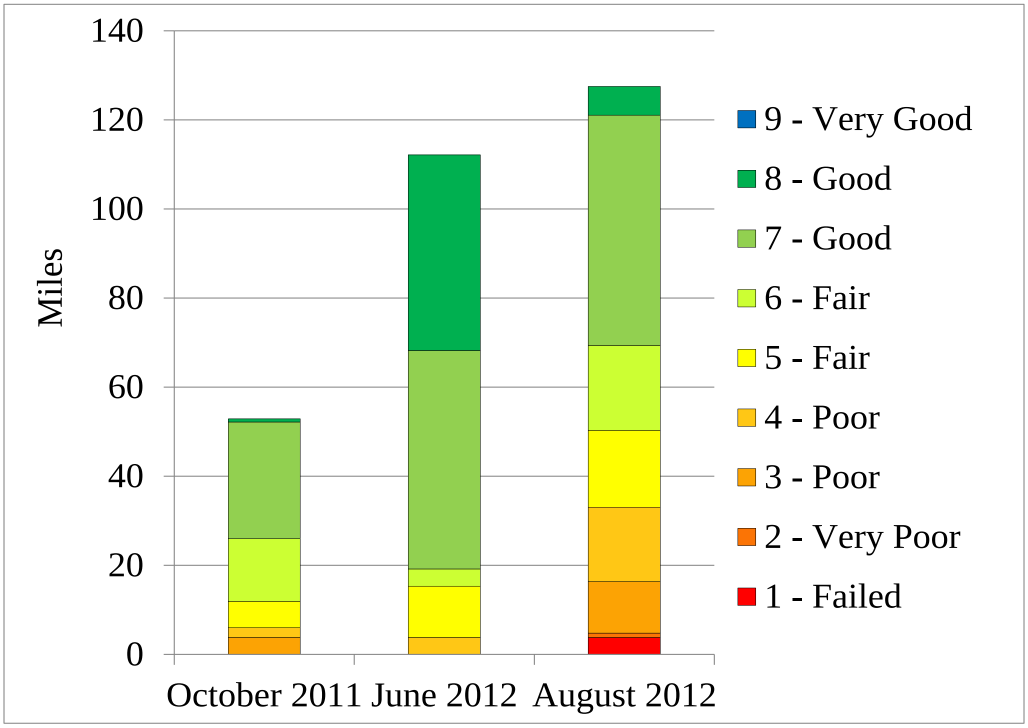


Figure 6.8 Goshen County unpaved impacted roads ride quality ratings mileages in October 2011, June 2012 and August 2012.

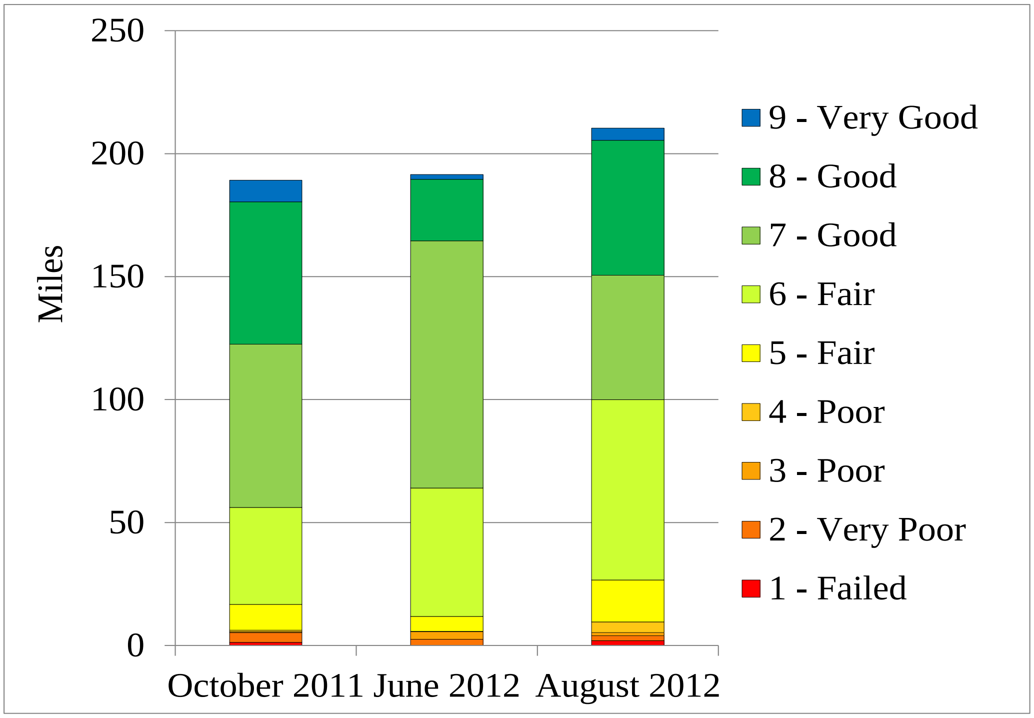


Figure 6.9 Laramie County unpaved impacted roads ride quality ratings mileages in October 2011, June 2012 and August 2012.

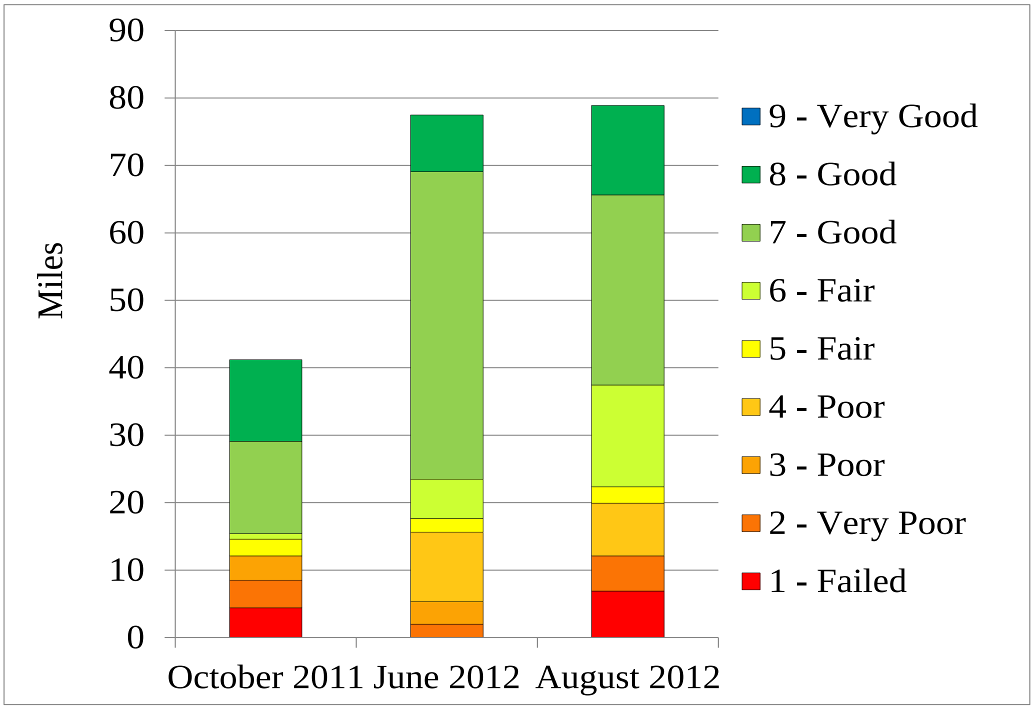


Figure 6.10 Platte County unpaved impacted roads ride quality ratings mileages in October 2011, June 2012 and August 2012.

Table 6.4 shows the average changes in the ride quality and the various distresses over the very hot, dry summer of 2012. On the whole, Goshen County's roads fared the worst, while Laramie County's roads held up best. Laramie County's June ratings were somewhat low for loose aggregate and dust, largely because many of the ratings were performed shortly after surface blade maintenance and before the crust had reformed, a process that probably takes longer because of the relative lack of finer materials used on Laramie County's roads. Laramie County's roads generally have more consistent surfacing aggregate with generally good, if sometimes rather coarse, gradation. Goshen County's aggregate generally has more sand-sized materials than one would want, reflecting the locally available aggregate. Many roads in Goshen County fell apart due to the very dry weather. The crust that made for good roads when some moisture was present fell apart since the surfacing material has too much sand and not enough finer binding material. However, during this dry summer, as the surface crust fell apart, there were many roads, particularly in Goshen County, that turned into unconsolidated sand. Ruts formed in this very dry, unconsolidated material. There is little question that had the summer of 2012 received normal or more than normal precipitation, all four counties' unpaved roads would have performed differently.

The impacted and non-impacted road ratings from the May 2012 data collection event were compared. Table 6.6 shows the average impacted and non-impacted distress ratings, average ride qualities, and the differences between the impacted and non-impacted distress ratings and ride qualities. It shows that there are not any particularly large differences in the performance of the impacted and non-impacted roads. The bottom line shows that rutting and potholes are worse on the non-impacted sections. Crown and drainage are nearly identical. Loose aggregate, dust, washboards, and ride quality are worse on the impacted segments. It would be reasonable to expect that this overall trend reflects more recent maintenance on the impacted segments – ruts and potholes had not yet been removed on all the non-impacted segments since they have gone longer since they were maintained. More dust, loose aggregate and washboards on the impacted roads may be due to more recent maintenance, to more raveling induced by heavy traffic, or to a combination of these factors. County-specific factors in Table 6.6 reveal that each county shows somewhat different overall trends, probably reflecting different maintenance practices and materials.

For example, in Converse County the ride quality is better on the impacted segments, as are rutting and potholes which, along with washboards, play major roles in controlling ride quality. Crown and drainage are worse on the non-impacted segments. This may in large part account for the better performance of the impacted roads in Converse County. Their impacted roads are built to a higher standard as reflected in the better roadside drainage ratings, an element of the road that is not likely to be substantially affected by heavy traffic. This better drainage may account for their better performance in spite of heavier traffic.

Table 6.6 Unpaved Roads May 2012 Average Distress Conditions and Ride Qualities

County	Crown	Drainage	Rutting	Potholes	Loose Aggregate	Dust	Washboards/ Corrugations	Ride Quality
				Impacted				
Converse	2.90	2.87	7.14	7.48	6.99	2.52	7.21	7.09
Goshen	2.75	2.77	7.07	7.17	7.40	2.61	7.38	7.06
Laramie	2.90	2.90	7.52	7.32	7.36	2.79	7.38	7.02
Platte	2.65	2.66	6.96	7.00	7.26	2.82	7.61	6.81
Average	2.85	2.84	7.24	7.31	7.23	2.67	7.35	7.03
				Non-Impacted				
Converse	2.62	2.53	6.94	7.06	7.05	2.80	7.28	6.77
Goshen	2.86	2.86	7.14	7.39	7.36	2.59	7.57	7.20
Laramie	2.90	2.91	7.23	7.33	7.35	2.92	7.36	7.13
Platte	2.91	2.88	7.09	7.10	7.11	3.25	7.23	6.88
Average	2.86	2.85	7.14	7.28	7.28	2.85	7.40	7.08
				(Non-Impacted) - (Impacted)				
Converse	-0.28	-0.35	-0.20	-0.42	0.06	0.28	0.07	-0.33
Goshen	0.10	0.08	0.07	0.23	-0.04	-0.02	0.19	0.14
Laramie	0.00	0.02	-0.29	0.00	-0.01	0.13	-0.02	0.10
Platte	0.26	0.22	0.13	0.11	-0.15	0.43	-0.38	0.08
Average	0.01	0.01	-0.09	-0.02	0.05	0.18	0.06	0.04

6.3.3 Surfacing Material Evaluations

As part of the August 2012 evaluation of the impacted segments, the quality of the surfacing material was evaluated, as was its type. The following features were described:

- Plasticity
  - HP – High Plasticity
    - This rating was never assigned. This is due in part to the lack of very highly plastic soils, such as those containing significant amounts of bentonite, in the four counties, and in part to the very dry conditions which made it nearly impossible to estimate the soil's plasticity with a visual evaluation.
  - LP – Low Plasticity
    - This rating indicates that the surfacing material appeared to set up and bind together, with shrinkage cracks appearing in the tightly bound areas when dry. To assign this rating, there had to be fairly extensive areas fulfilling these criteria.
  - NP – Non-Plastic

    - This rating indicted that there was inadequate binding of the surface material to assign a rating of LP as described above.
- Angularity
  The predominant angularity of the surfacing material was evaluated.
  - A – Angular
    - Either crushed rock or naturally occurring angular materials such as the limestone fragments often observed near the Goshen-Platte County Line.
  - SA – Sub-Angular
    - Far and away the most prevalent rating, describing largely decomposed granite and other hard rocks from the Laramie Range.
  - SR – Sub-Rounded
    - Rocks with the sharper edges worn away, probably by alluvial action.
  - R – Round
    - Rocks well-rounded, probably by alluvial action. No materials fitting this description were observed.
- Gradation
  The overall gradation of the surfacing material was assessed, particularly the amount of fine materials – sands, silts and clays - using those standards as described in the 'Gravel Roads Maintenance and Design Manual' *(Skorseth and Selim 2000)* and below.
  - WTC – Way Too Coarse
    - No or negligible binder is present.
  - TC – Too Coarse
    - Not enough binder to form a good crust on most of the segment. This material will be overly prone to washboards and dust, though it may provide better structural support, particularly for heavy trucks, than those materials rated 'About Right.'
  - AR – About Right
    - Normally able to form a good crust through most of the segment due to the presence of adequate binder, but still having enough coarse material to carry heavy loads under moist conditions. This assessment was difficult to make due to the very dry conditions during the August 2012 data collection period.
  - TF – Too Fine
    - Not enough coarse materials present to provide good strength properties. Due to the dry conditions, this generally did not result in a lot of distress since the materials were very dry, reducing or eliminating the short-term need for coarse materials. However, in the rater's estimation, these materials would be vulnerable to rutting under wet conditions.
  - WTF – Way Too Fine
    - Nearly complete lack of coarse material. Very vulnerable to rutting under wet conditions.
- Type

The predominant surfacing material type was recorded. In some cases, more than one type was listed when more than one surfacing material type covered more than about 15% or 20% of the segment's surface. This does not include the many instances where small amounts of imported material – often gravel or reclaimed asphalt pavement – were placed on occasional soft spots or other areas of unusual distress, such as dust near residences.

- NE – Native Earth
  - The road's surface is composed primarily of material from the surrounding terrain.
- GR – Gravel
  - Imported rock, occasionally crushed, but usually just screened, with gradation usually coarser than the surrounding, native material.
- TG – Treated Gravel
  - Surfacing material that appears to have been treated with a dust control or soil stabilizing agent, as evidenced by a tight binder surface with a dark sheen typical of chloride dust suppressants.
- RAP – Reclaimed Asphalt Pavement
  - Presence of significant amounts of asphalt millings.

- Material Quality
  - VG – Very Good
    - A well-graded blend of crushed or angular rock and binder with low plasticity. Forms a tight surface with good coarse aggregate structure.
  - G – Good
    - A good blend that has a reasonable amount of coarse materials and binder that forms a crust in most areas, and that has adequate coarse material to carry loads even when wet.
  - F – Fair
    - Aggregate that performs reasonably well, but has some significant problems that under some conditions will lead to significant distresses such as washboards and dust or potholes and ruts. Usually imported material, but occasionally native earth will perform as a fair surfacing material.
  - P – Poor
    - Material with major problems that cannot perform well under any conditions and that may lead to failure, particularly under wet conditions. Usually native materials that are not well suited to making a road surface.
  - VP – Very Poor
    - Native earth that has major shortcomings and that cannot perform well regardless of the amount or type of maintenance or drainage. The surface may be prone to emitting extreme and dangerous amounts of dust. Underlying bedrock may make a rough surface. Ruts may be extreme, making travel with low clearance vehicles impossible.

These ratings are highly subjective. Ideally, all materials would be tested for at least gradation and plastic limits, but this would be prohibitively expensive, especially considering the variability in materials even within a single road segment. A quick, visual rating is thought to be better than nothing, particularly as a way of separating the damaging effects of oil and gas traffic from those effects that are the inevitable consequence of the lower quality materials that the counties are often forced to use due to budgetary constraints.

Figures 6.11 through 6.15 show the subjective materials ratings for the four counties' impacted roads in August 2012.

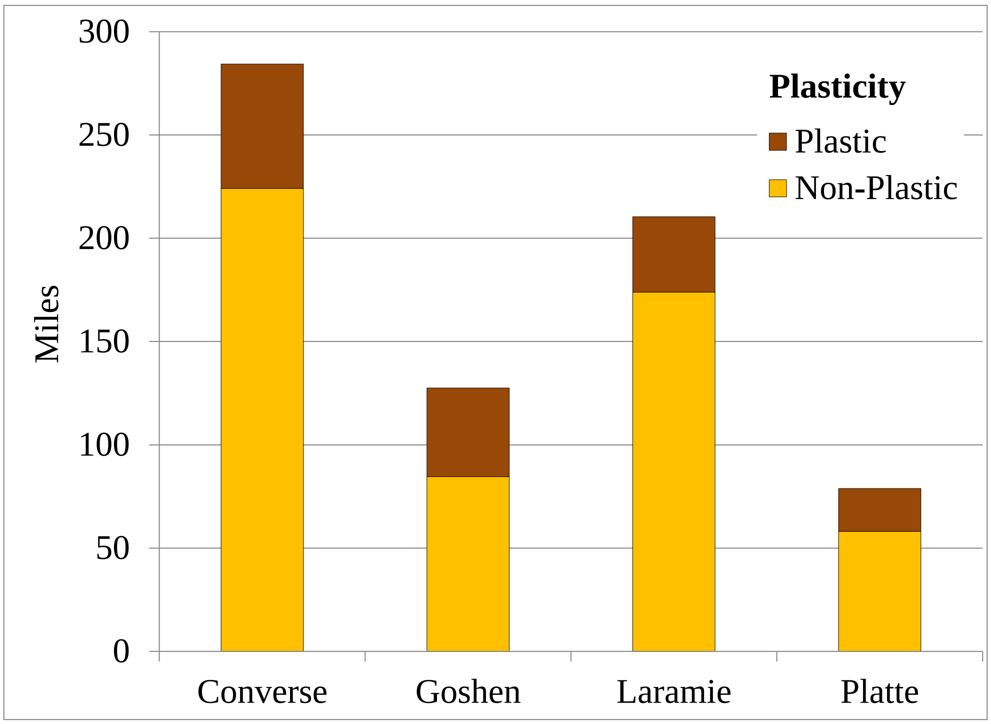


Figure 6.11 Plasticity of unpaved impacted roads surfacing materials in August 2012.

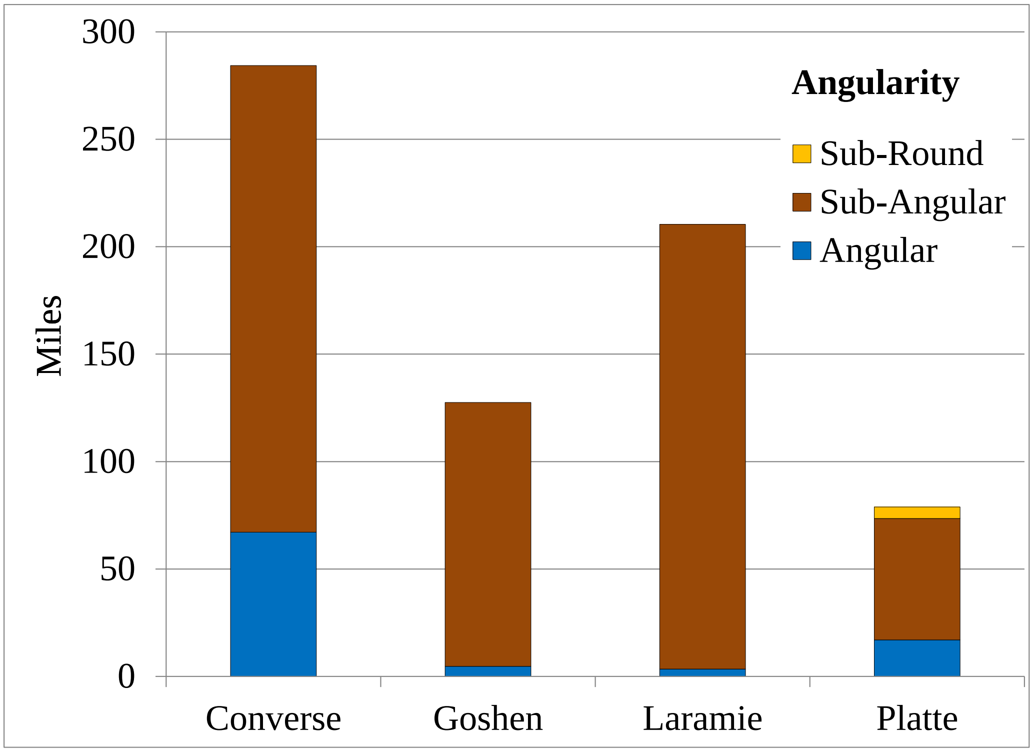


Figure 6.12 Angularity of unpaved impacted roads surfacing materials in August 2012.

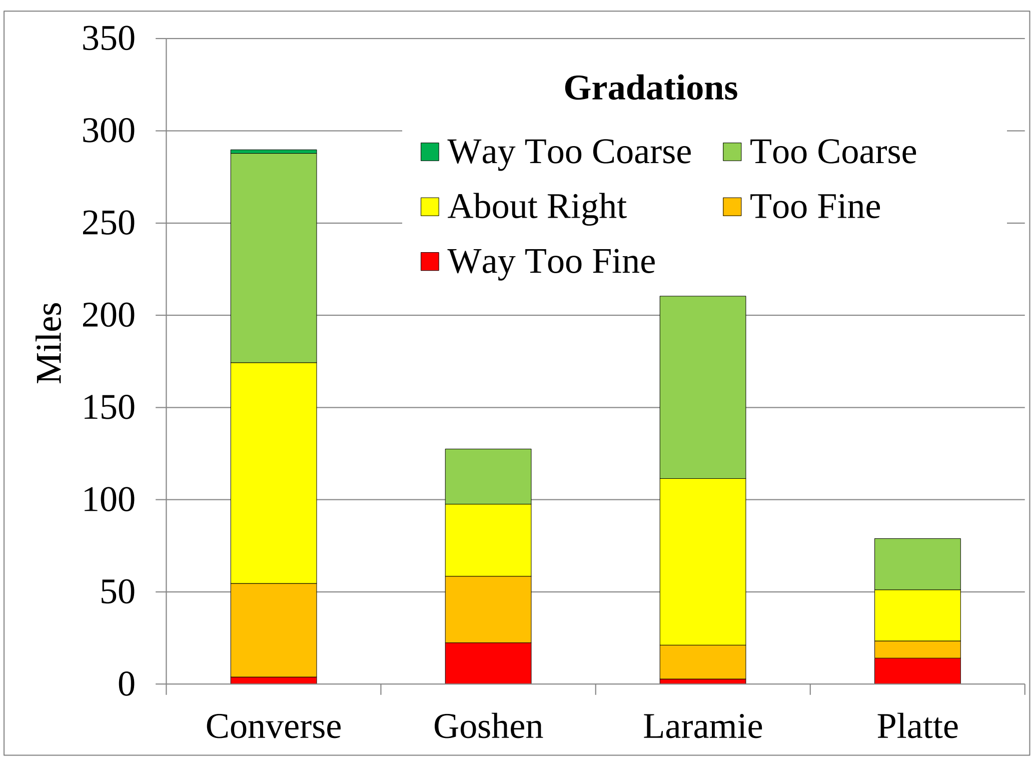


Figure 6.13 Gradations of unpaved impacted roads surfacing materials in August 2012.

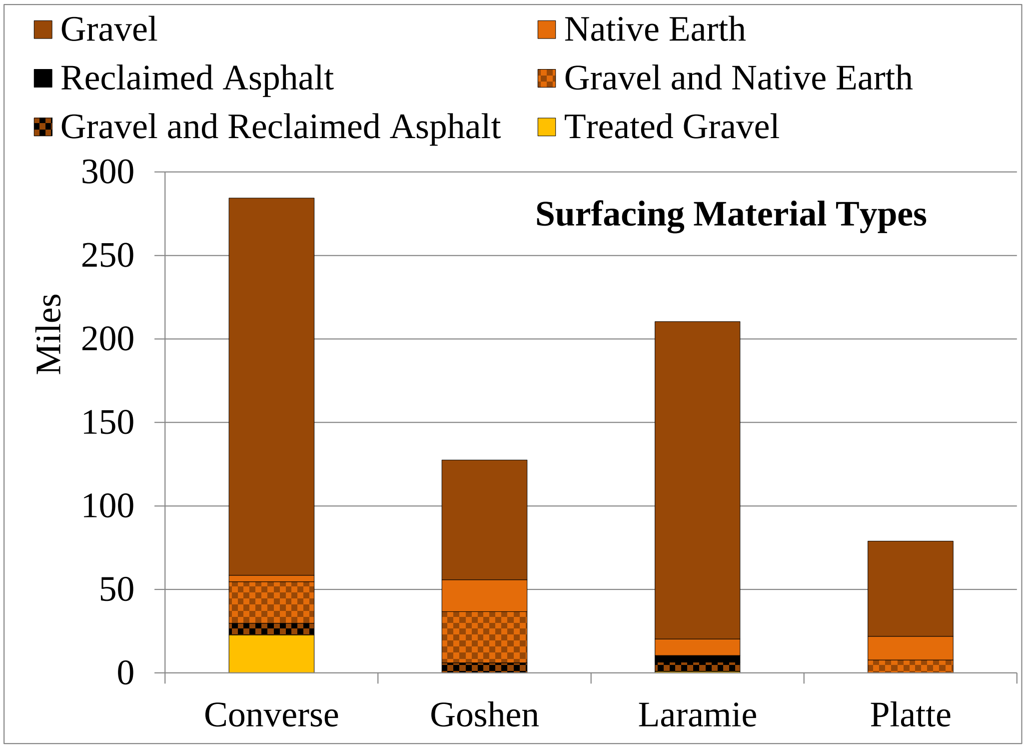


Figure 6.14 Unpaved impacted roads surfacing material types in August 2012.

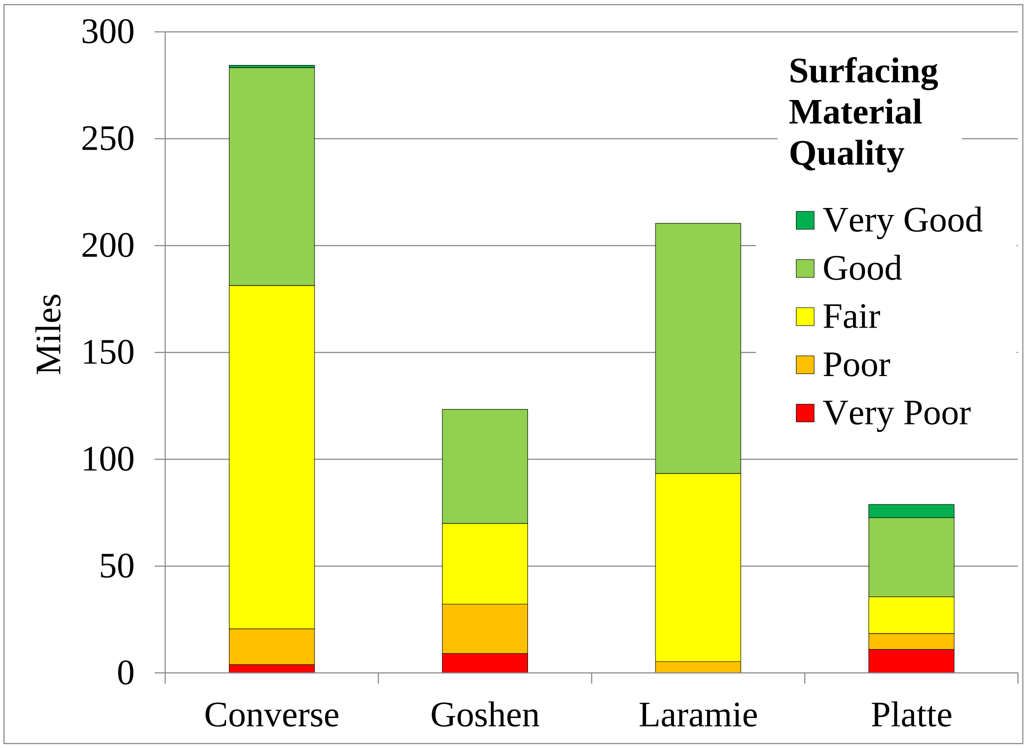


Figure 6.15 Unpaved impacted roads surfacing material quality in August 2012.

6.4 Maintenance Records

Unpaved roads' conditions vary greatly with the roads' characteristics, maintenance levels, and traffic loads. Maintenance costs will increase with increasing traffic in almost every application. The addition of new gravel to an unpaved road will cost more than simpler maintenance practices. Thus, as traffic increases, gravel addition will also increase. The underlying question of how to maintain and construct these roads, and of how oil and gas activities affect them, should not be forgotten when addressing maintenance issues on unpaved roads.

Maintenance records from Laramie and Goshen Counties were received and analyzed according to each segment and level of impact. Platte County was in the process of recording their maintenance costs on gravel roads and simply did not have enough data to make conclusive comparisons. Converse County had maintenance records but they were not broken into the proper segments, so they were also not conclusive enough to use in this study. The maintenance records from Goshen County were segmented into each road and the average maintenance cost per mile on each road was assessed. For the most part, this method coincided with the segmentation from this report. However, when an impacted road segment from this study didn't overlap exactly with their maintenance segmentation, the average maintenance cost per mile was used. With the information from Goshen and Laramie Counties, a comparison between maintenance costs for impacted and non-impacted road segments was made.

6.4.1 Converse County Maintenance Records

Converse County's maintenance records from July 1, 2005 through June 30, 2011 were evaluated to provide an overall assessment of the county's maintenance expenses on its unpaved roads. Since electronic records were not available, WY T^2/LTAP transcribed the county's hard copy records into the county's software, then to a popular spreadsheet. The county assigned employees' hours to a project and task. Though the software also provides for inputting equipment and material costs, these functions have not been consistently entered by the county so they are not used in this analysis. Labor costs were assigned to each project and task and compiled. Since this analysis attempts to evaluate impacts due to increased traffic, costs related to traffic are established as described in the next section.

Converse County's labor costs were assigned by the WY T^2/LTAP to one of these four general categories:

- Overhead
- Bridges, Culverts and Others
- Routine Blade Maintenance
- Regraveling and Building Up Road

Using this approach, costs were tracked by road, year and category. Many costs were not assigned to a particular road. Only 4% of the overhead was assigned to a particular road; 56% of regraveling costs were assigned to a road; 89% of bridge, culvert and other costs were assigned to a road; and 96% of routine blade maintenance costs were assigned to a road. The bridge, culvert and other costs were probably not greatly influenced by heavy truck impacts, at least in the short run, so they are not analyzed further here. The regravel costs were evaluated, though these analyses should be viewed with a degree of skepticism since 44% of the costs associated with regraveling are not attributed to any particular road. The routine blade maintenance costs may be influenced by heavy truck traffic and 96% of them are assigned to a particular road, so these costs are analyzed further to assess the impacts of oil and gas activities on Converse County's unpaved roads. Table 6.7 shows the annual labor costs for bridges, culverts and others; for routine blade maintenance; and for regraveling and building up roads. Table 6.8 shows a cumulative summary of these costs.

Table 6.7 Converse County Unpaved Roads Maintenance Annual Labor Costs

*Work Type**	2005¤	2006	2007	2008	2009	2010	2011¤
				Impacted			
BC	$6,572	$13,715	$29,711	$20,713	$32,735	$29,001	$13,085
RM	$43,080	$90,290	$150,454	$149,854	$125,885	$170,697	$108,136
GR	$7,699	$19,830	$32,221	$26,391	$19,558	$23,400	$14,229
TOTAL	$57,351	$123,836	$212,385	$196,958	$178,177	$223,099	$135,449
				Non-Impacted			
BC	$14,574	$24,030	$32,003	$54,679	$57,879	$30,893	$15,936
RM	$35,720	$59,252	$153,324	$124,450	$158,441	$80,046	$49,678
GR	$32,385	$37,194	$42,622	$14,295	$57,029	$65,090	$5,112
TOTAL	$82,679	$120,476	$227,949	$193,424	$273,348	$176,028	$70,725
				Not Assigned to Any Road			
BC	$0	$8,685	$1,865	$17,404	$9,933	$7,351	$2,994
RM	$2,039	$4,637	$1,892	$3,957	$13,071	$19,865	$19,654
GR	$23,578	$38,882	$42,456	$49,876	$46,817	$64,560	$40,153
TOTAL	$25,617	$52,203	$46,212	$71,237	$69,821	$91,776	$62,801
				All Unpaved Roads			
BC	$21,146	$46,429	$63,578	$92,797	$100,546	$67,245	$32,014
RM	$80,839	$154,179	$305,670	$278,261	$297,396	$270,608	$177,467
GR	$63,662	$95,907	$117,299	$90,562	$123,404	$153,050	$59,494
TOTAL	$165,647	$296,515	$486,547	$461,620	$521,347	$490,903	$268,974

**BC = Bridges, culverts and others*
**RM = Routine blade maintenance*
**GR = Regravel and build up road*
¤Six-month totals

Table 6.8 Converse County Unpaved Road Maintenance 6-Year Labor Costs

	6-Year Total	Annual Average	Annual Cost per Mile
Work Type	**Impacted**		
Bridges, Culverts and Others	$145,531	$24,255	$99
Routine Blade Maintenance	$838,395	$139,733	$571
Regravel and Build Up Road	$143,328	$23,888	$98
TOTAL	$1,127,255	$187,876	$768
	Non-Impacted		
Bridges, Culverts and Others	$229,994	$38,332	$151
Routine Blade Maintenance	$660,911	$110,152	$435
Regravel and Build Up Road	$253,726	$42,288	$167
TOTAL	$1,144,631	$190,772	$754
	Not Assigned to Any Road		
Bridges, Culverts and Others	$48,231	$8,039	--
Routine Blade Maintenance	$65,114	$10,852	--
Regravel and Build Up Road	$306,322	$51,054	--
TOTAL	$419,668	$69,945	--
	All Unpaved Roads		
Bridges, Culverts and Others	$423,757	$70,626	$142
Routine Blade Maintenance	$1,564,420	$260,737	$524
Regravel and Build Up Road	$703,376	$117,229	$236
TOTAL	$2,691,553	$448,592	$901

Converse County's routine blade maintenance costs were determined as described in the previous section. The county identified 288 miles of unpaved roads as being impacted by oil and gas activities. For many of the impacted roads, the oil and gas impacts vary substantially throughout the length of the road, but the maintenance records do not identify which part of the road was worked on. Some trends towards higher blade maintenance labor costs are seen in Table 6.7 which shows an increase in routine blade maintenance (RM) labor cost from 2009 to 2010 of about $45,000 and a corresponding decrease on non-impacted roads of about $78,000. This indicates that maintenance was taken off non-impacted roads and put onto the more heavily trafficked, impacted roads.

There are several possible explanations for the lack of a clear trend towards higher routine blade maintenance costs on roads with more oil and gas traffic. The most obvious is that maintainers did not significantly alter their routes in response to heavier traffic. If this is the case, one would expect worse conditions on the impacted roads, rather than higher maintenance costs. Another obvious source of error is the inability to accurately assess where oil and gas operations are impacting county roads at any given time. Finally, oil and gas companies sometimes maintain county roads themselves; any such road maintenance costs are not included in this analysis. All these factors may combine to prevent the emergence of any clear trend towards higher routine blade maintenance costs due to oil and gas impacts on Converse County's unpaved roads.

Though only 56% of the county-wide regravel costs could be assigned to a particular road, the regravel costs were evaluated to determine whether there are any trends relating regravel costs to oil and gas impacts. As with the routine blade maintenance costs, there are no clear trends towards higher regravel costs on the impacted roads. Reasons for this are probably similar to those described in the previous section for routine blade maintenance costs and to the fact that regraveling costs are incurred over several years as gravel is slowly lost due to heavy traffic, thereby masking the increased costs due to adding additional gravel to the heavily impacted roads.

6.4.2 Goshen County Maintenance Records

Table 6.9 shows the total maintenance costs and maintenance costs per mile for the impacted and non-impacted road segments, and Figure 6.16 shows the maintenance costs per mile for each year.

Table 6.9 Goshen County Annual Unpaved Road Maintenance Costs

	Total Maintenance Costs				
	2008	**2009**	**2010**	**2011**	**Total**
Impacted	$387,094	$142,431	$427,456	$420,847	$1,377,828
Non-Impacted	$837,758	$570,346	$1,153,755	$1,349,408	$3,911,267
(Impacted) - (Non-Impacted)	-$450,664	-$427,915	-$726,299	-$928,561	-$2,533,439
	Maintenance Costs per Mile				
	2008	**2009**	**2010**	**2011**	**Total**
Impacted	$2,977	$1,095	$3,288	$3,237	$10,597
Non-Impacted	$1,077	$733	$1,483	$1,735	$5,028
(Impacted) - (Non-Impacted)	$1,900	$362	$1,805	$1,502	$5,569

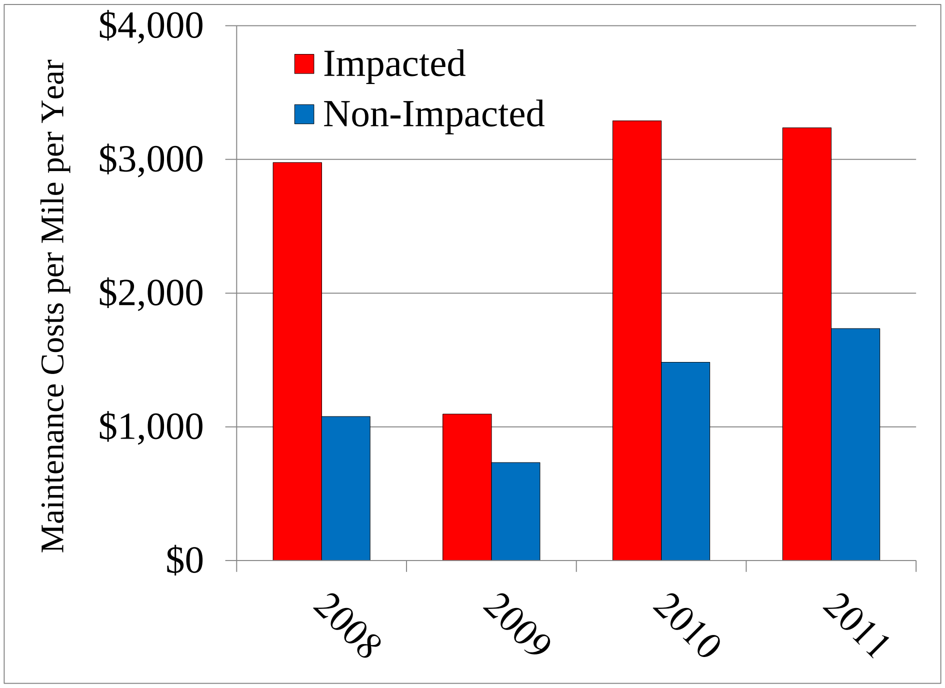


Figure 6.16 Goshen County unpaved road maintenance costs per fiscal year.

Table 6.9 shows that there was much more money spent on the non-impacted roads from 2008 to 2011 in Goshen County. During this time period over $2.5 million more was spent on non-impacted roads than on those identified as being impacted. However, the cost per mile on impacted roads was significantly greater than the non-impacted roads showing that there was more effort and money spent on maintaining these roads. During this four year time period, $10,597 per mile was spent on the maintenance of impacted roads while only $5,028 per mile was spent on the non-impacted roads, a difference of $5,569 per mile over four years, or $1,392 per mile per year.

The Goshen County Road and Bridge Department has been entering their maintenance records into a commercial software package since July 2007. The costs for the ten tasks unique to gravel roads were compiled for the calendar years 2008 through 2011. Table 6.10 shows these costs. The average annual routine blade maintenance cost is $607 per mile per year, while other surface maintenance costs average $273 per mile per year.

Table 6.10 Goshen County Unpaved Road Surface Maintenance Costs

	Total Costs				
County Task	**2008**	**2009**	**2010**	**2011**	**TOTAL**
Blade - Routine	$760,926	$583,746	$856,165	$748,216	$2,949,052
Hauling Gravel	$119,526	$154,593	$157,508	$265,033	$696,660
Repair With Gravel	$6,928	$17,007	$27,604	$31,566	$83,105
Hauling Rap	$71,181	$3,812	$3,663	$2,531	$81,187
Repair With Rap	$2,129	$0	$11,500	$1,648	$15,278
Clean Or Reshape Row	$20,514	$2,465	$14,987	$16,595	$54,561
Hauling Water	$17,632	$24,568	$21,302	$17,954	$81,456
Construct Or Reconstruct Road	$55,181	$76,662	$72,692	$93,846	$298,381
Hauling Dirt	$370	$1,626	$908	$8,618	$11,522
TOTAL	$1,054,388	$864,478	$1,166,331	$1,186,006	$4,271,204

	Costs per Mile				**Annual**
County Task	**2008**	**2009**	**2010**	**2011**	**Average**
Blade - Routine	$627	$481	$705	$616	$607
Hauling Gravel	$98	$127	$130	$218	$143
Repair With Gravel	$6	$14	$23	$26	$17
Hauling Rap	$59	$3	$3	$2	$17
Repair With Rap	$2	$0	$9	$1	$3
Clean Or Reshape Row	$17	$2	$12	$14	$11
Hauling Water	$15	$20	$18	$15	$17
Construct Or Reconstruct Road	$45	$63	$60	$77	$61
Hauling Dirt	$0	$1	$1	$7	$2
TOTAL	$869	$712	$961	$977	$880

6.4.3 Laramie County Maintenance Costs

Table 6.11 shows the total maintenance costs and maintenance costs per mile for Laramie County's impacted and non-impacted road segments, while Figure 6.17 graphs these annual costs. More details on Laramie County's 'grade and pull shoulders' maintenance costs from 2007 through 2011 are shown in Appendices *D.23* through *D.28*. The impacted roads show a much greater cost per mile than the non-impacted roads. Laramie County spent a total of $25,499,371 on gravel road maintenance between 2006 and 2011. Of this, over 55% was spent on the roads deemed impacted by the Laramie County Road and Bridge Department. There was a significant increase in expenditures on unpaved roads maintenance for impacted roads in 2006, 2009 and 2010. Between 2006 and 2011, Laramie County spent $14,260,315 on unpaved road maintenance for impacted roads and $11,239,056 for non-impacted roads. Laramie County spent $64,149 per mile maintaining the impacted roads and only $14,298 per mile maintaining the non-impacted roads, which yields annual average costs of $10,691 per mile on the impacted roads and $2,383 on the non-impacted roads.

Table 6.11 Laramie County Unpaved Road Maintenance Costs

	Total Maintenance Costs							
	2006	2007	2008	2009	2010	2011	Total	Annual Average
Impacted	$2,858,632	$1,197,432	$1,552,368	$4,264,127	$3,240,983	$1,146,773	$14,260,315	$2,376,719
Non-Impacted	$1,917,245	$1,775,860	$1,559,766	$2,466,768	$1,946,214	$1,573,204	$11,239,057	$1,873,176
(Impacted) - (Non-Impacted)	$941,387	-$578,428	-$7,398	$1,797,359	$1,294,769	-$426,431	$3,021,258	$503,543
	Maintenance Costs per Mile							
	2006	2007	2008	2009	2010	2011	Total	Annual Average
Impacted	$12,859	$5,387	$6,983	$19,182	$14,579	$5,159	$64,149	$10,692
Non-Impacted	$2,439	$2,259	$1,984	$3,138	$2,476	$2,001	$14,298	$2,383
(Impacted) - (Non-Impacted)	$10,420	$3,127	$4,999	$16,044	$12,103	$3,157	$49,851	$8,309

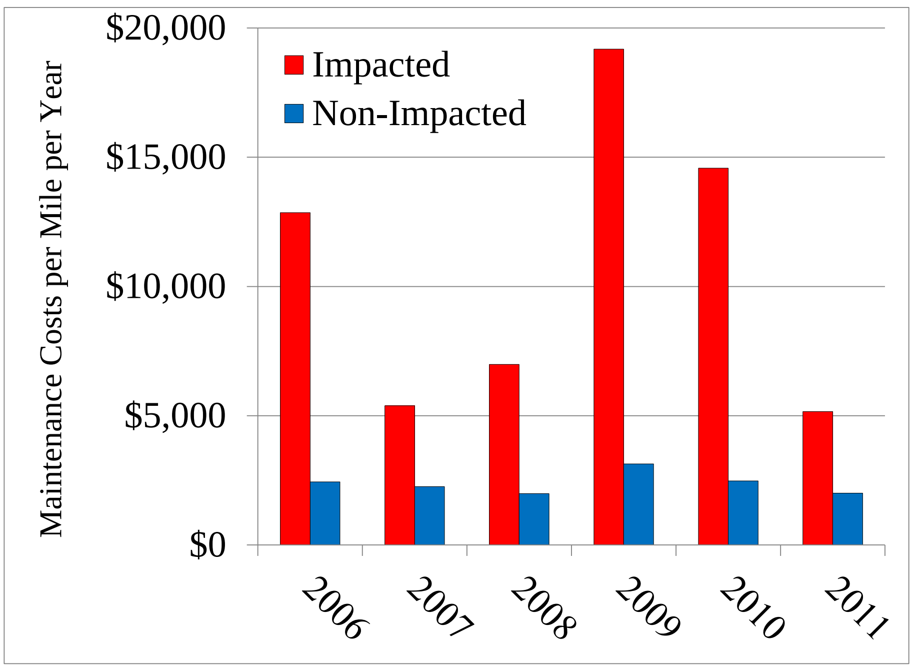


Figure 6.17 Laramie County unpaved roads maintenance costs per mile per year.

6.4.4 Platte County Maintenance Records

Platte County has only recently begun storing their road and bridge maintenance costs in a computer. The data presented in this section covers Platte County's maintenance costs from October 3, 2011 through September 13, 2012. Table 6.12 summarizes the county's costs by surface type on a per mile and per square yard basis. It shows higher per mile-year costs on gravel surfaced than on paved roads. Table 6.13 shows the maintenance costs for nine general categories of work. Those task costs included in the Regravel category are 'Laying New Gravel,' 'Building/Improving Road,' 'Haul Material,' and 'Load Trucks.'

Table 6.12 Platte County Nearly One-Year System Mileages and Maintenance Costs by Surface Type

Surface	Miles	SY	Total Costs	Average Costs per Mile	Average Costs per SY
Dirt	3.5	26,330	$1,188	$337	$0.045
Gravel	466.9	5,628,880	$890,738	$1,908	$0.158
Paved	150.6	1,967,668	$189,663	$1,259	$0.096
Subtotal	621.0	7,622,878	$1,081,588	$1,742	$0.142
Other	--	--	$333,180	--	--
TOTAL	1,242.1	15,245,756	$1,414,768	--	--

Table 6.13 Platte County Nearly One-Year Maintenance Costs by Surface Type and General Category

	Surface Type	**Grading**	**Regravel**	**Other Road Maintenance**	**Admistrative**	**Bridge Maintenance**	**Shop**	**Emergency**	**In the Field**	**Personal**	**TOTAL**
Total Costs	*Dirt*	$1,188	$0	$0	$0	$0	$0	$0	$0	$0	$1,188
	Gravel	$413,818	$310,017	$137,135	$925	$9,960	$840	$488	$17,556	$0	$890,738
	Paved	$38,844	$17,373	$123,084	$148	$500	$838	$3,113	$5,765	$0	$189,663
	Other	$9,875	$19,729	$145,701	$16,618	$520	$82,758	$16,253	$22,178	$19,550	$333,180
Costs per Mile	*Dirt*	$337	$0	$0	$0	$0	$0	$0	$0	$0	$337
	Gravel	$886	$664	$294	$2	$21	$2	$1	$38	$0	$1,908
	Paved	$258	$115	$817	$1	$3	$6	$21	$38	$0	$1,259
Costs per SY	*Dirt*	$0.045	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.045
	Gravel	$0.074	$0.055	$0.024	$0.000	$0.002	$0.000	$0.000	$0.003	$0.000	$0.158
	Paved	$0.020	$0.009	$0.063	$0.000	$0.000	$0.000	$0.002	$0.003	$0.000	$0.096

6.5 Prioritization

To determine the level of impact for each road in each county, a priority list was created consisting of roads identified by the counties as being impacted by oil and gas traffic. This prioritization takes into account the average daily traffic (ADT), the average daily truck traffic (ADTT), and oil wells and water haul sites within a buffer zone. Table 6.14 provides verbal descriptions of these impact priority ranks. More detailed results for the four counties are shown in Appendix *D. Unpaved County Roads*. A decision tree produced these impact priority rankings from 1 to 6, with 1 being the highest priority and 6 being the lowest. For example, any road segment having more than 20 trucks per day and more than 5 wells within a close proximity to the road segment yields a higher impact priority of either a 1 or 2. The decision tree has ADTT as the first criteria, ADT as the second, and oil wells and water haul sites within the buffer zone third; it is shown in Figure 6.18.

Table 6.14 Impact Priority Level Descriptions

Impact Priority Level	Description
1	Extremely High energy related impact - immediate improvement concern
2	High energy related impact - high improvement concern
3	Moderately high energy related impact - moderately high improvement concern
4	Moderately low energy related impact - moderately low improvement concern
5	Low energy related impact - low improvement concern
6	Extremely low energy related impact - low to no improvement concern

The first, and highest, criterion in the impact priority decision process is the ADT. The first tier only considers roads with an ADT of more than 100; the second tier examines roads with an ADT between 50 and 100; and the third tier contains road segments with an ADT less than 50. These numbers were selected based on a sensitivity study by North Dakota State University. The sensitivity analysis of paved roads from the North Dakota Report demonstrated that at 150 vehicles per day, a paved surface has life-cycle costs equal to a gravel surface, but due to higher truck percentages on impacted roads, a lower threshold was used *(UGPTI 2010)*.

The second criterion is ADTT. The first tier in this criterion only considers road segments with ADTT counts higher than 20 trucks per day; the second tier contains counts with 10 to 20 ADTT; and the third and lowest tier only considers roads with less than 10 ADTT. The North Dakota State University report showed that in their analysis, a medium maintenance road is defined as one with at least 20 trucks per day for a paved road *(UGPTI 2010)*. Because trucks affect an unpaved road at a much higher rate than a paved road, this medium threshold was used as the high threshold for reconstruction and damage for unpaved roads.

The third criterion of the decision process considers the number of oil wells and water hauls within the buffer zone, which is simply a zone created by the GIS software around each road segment. For Goshen, Laramie, and Platte Counties, this was created through creating the zone two miles from each side and each end around the given road segment. This distance was determined by examining buffer zones of different lengths around each segment and how they affected the count of oil wells and water haul sites within the zone. Because these counties have denser road networks, the two mile zone was sufficient to show most oil well and water haul sites affecting the road segment. Converse County has a much less dense road network. Therefore, the buffer zones in Converse County were expanded to four miles from each side and end of the road segments.

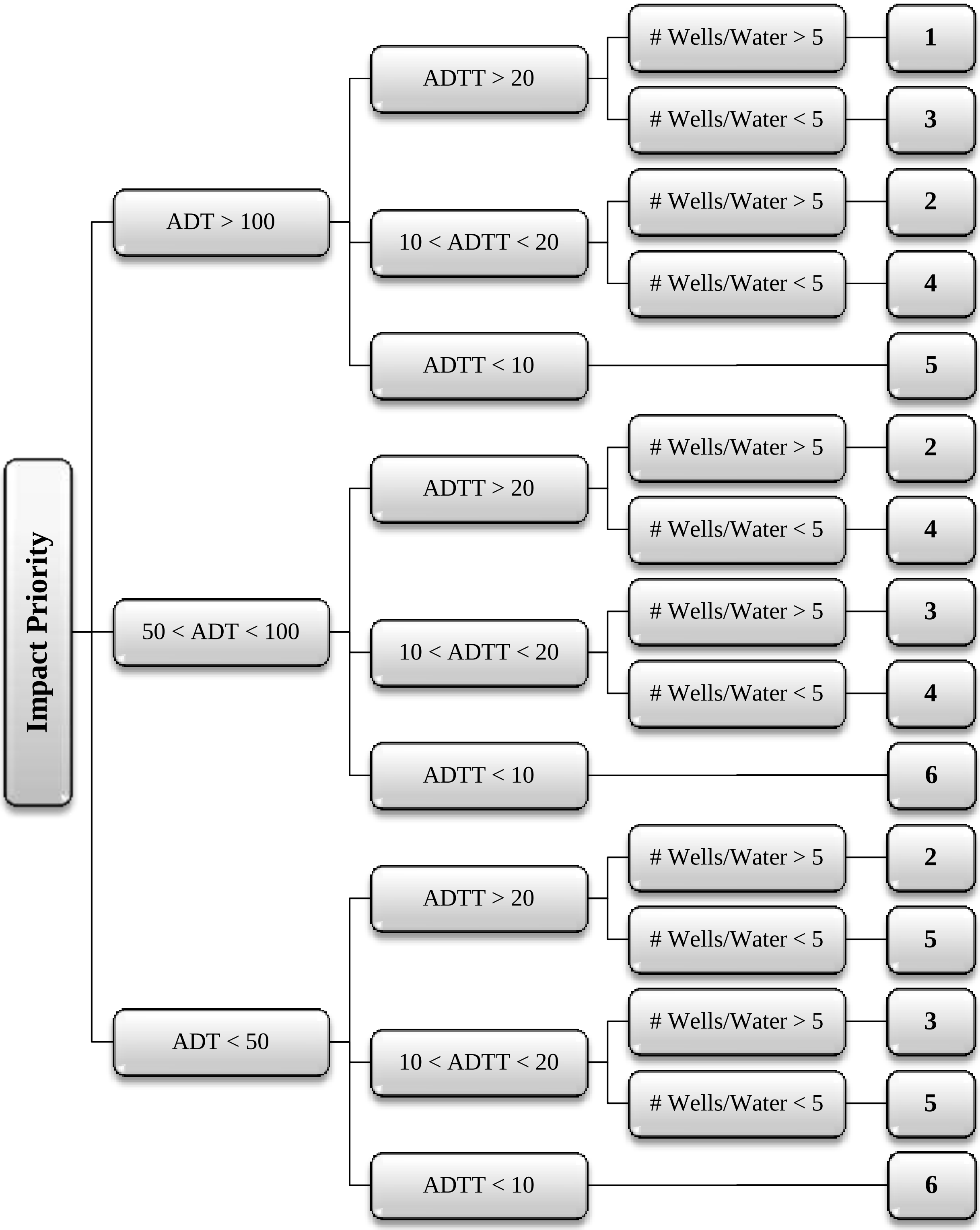


Figure 6.18 Unpaved roads impact priority decision process.

After these three criteria were determined, the road segments were analyzed with the decision process to create the priority list. Unfortunately, any road segment with missing traffic information could not be assessed through this process. Figure 6.18 shows this decision process and how each criterion affects the overall priority rank.

From the decision process, if a road has less than 10 trucks per day, no matter what the ADT is, that segment drops to a priority rank of 5 or lower. This is because if a road experiences less than 10 trucks per day, it is most likely not highly impacted by energy related traffic and the ADT is most likely local traffic. The first iteration of the ADTT criterion generated some road segments that did not accurately represent their impact priority rank, thus the ADT and ADTT were switched in the decision process creating much more reasonable results. Table 6.15 shows the results of the impact priority decision process throughout the four counties with total segment counts and mileages.

Table 6.15 shows that almost half of the impacted segments have the lowest impact priority rank of 6. This means that almost half of the impacted roads in the four counties have extremely low energy related impacts and there is a low to no improvement concern for these roads. However, almost 39% of these roads have a priority rank between 1 and 3 which corresponds to moderately high to immediate improvement concerns. From this priority list, maintenance costs and recommendations were created.

Table 6.15 Impact Priority Decision Process Overall Results

	Mileage						
	Impact Priority						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
CO	69.0	12.6	56.9	68.8	2.0	73.5	282.6
GO	0.0	0.0	17.4	7.0	16.2	77.1	117.7
LA	16.4	72.6	63.1	14.8	4.0	177.7	348.6
PL	0.0	0.0	4.3	12.1	0.0	24.4	40.9
TOTAL	85.4	85.2	141.6	102.7	22.2	352.7	789.8
Percent	10.8%	10.8%	17.9%	13.0%	2.8%	44.7%	100.0%
	Segment Counts						
	Impact Priority						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
CO	18	2	12	17	1	20	70
GO	0	0	6	2	7	21	36
LA	7	29	32	5	1	68	142
PL	0	0	1	4	0	12	17
TOTAL	25	31	51	28	9	121	265
Percent	9.4%	11.7%	19.2%	10.6%	3.4%	45.7%	100.0%

6.5.1 Converse County Prioritization

Table 6.15 shows that a majority of the priority ranks on the road segments in Converse County are above a 4 and over 25% of the road segments are ranked at a priority level 1. However there were also 26 road segments, or about 39%, that were ranked at a priority level of 6. As shown in Table 6.16, there is a significant difference in the magnitude of traffic and serviceable rigs and water haul sites between a segment with a priority rank of 1 and any other priority rank. This suggests that the road segments in Converse County with a level 1 priority rank are seeing a great deal more impact, and thus damage, than any other road segments with a different priority rank. Appendix *D.6. Converse County: Unpaved County Road Impact Priority Rankings* maps detailed results of this prioritization process.

Table 6.16 Converse County Priority Ranking Inputs

	Impact Priority Level					
	1	**2**	**3**	**4**	**5**	**6**
			ADT			
Average	404	87	151	62	NA	42
High	800	87	380	73	NA	73
Low	108	87	37	57	NA	21
			ADTT			
Average	198	29	19	17	NA	4
High	448	29	28	28	NA	9
Low	31	29	10	12	NA	0
			Serviceable Rigs/Water Haul Sites			
Average	20	12	5	2	NA	3
High	34	12	10	5	NA	7
Low	12	12	1	0	NA	1

6.5.2 Goshen County Prioritization

Table 6.15 shows that Goshen County has no road segments that ranked in the highest two priority ranks of 1 or 2. Almost 60% of the county's road segments were priority ranked at a level 6 meaning that 60% of the road segments in Goshen County deemed impacted are at a low to no improvement concern.

Table 6.17 shows the high, low, and average values of the three criteria used to determine each priority number. On average, the traffic characteristics for road segments with a priority rank of 3 show about twice the traffic of the other levels. Of the 6 segments in Goshen County with a priority ranking of 3, there was only one segment that had an ADT of less than 100 and ADTT less than 20. Appendix *D.32. Goshen County: Unpaved County Road Impact Priority Rankings* maps detailed results of this prioritization process.

Table 6.17 Goshen County Priority Ranking Inputs

	Impact Priority Level					
	1	2	3	4	5	6
	ADT					
Average	NA	NA	134	69	31	31
High	NA	NA	186	75	44	64
Low	NA	NA	61	56	24	0
	ADTT					
Average	NA	NA	37	19	25	2
High	NA	NA	52	24	28	7
Low	NA	NA	12	10	24	0
	Serviceable Rigs/Water Haul Sites					
Average	NA	NA	2	2	1	1
High	NA	NA	6	2	1	2
Low	NA	NA	1	2	0	0

6.5.3 Laramie County Prioritization

Table 6.15 shows that Laramie County has the widest priority ranking distribution. This is probably because the county has more segments deemed impacted. Over 46% of the roads are at a priority rank of 3 or higher, only 4% are ranked at a 4 or 5, and 49% are ranked at a priority level 6.

Table 6.18 shows the average, high, and low values for ADT, ADTT, and serviceable rigs and water haul sites within the buffer zone. Unlike the other counties, Laramie County does not show a clear distinction between all the criteria within the different priority levels. In this case, many of the segments ranked as a priority level 2 are not ranked as the highest priority level because of the amount of trucks per day. If there is a clear impact on a designated road segment, the ADTT would be at least 20 and a majority of the time that number will be considerably higher. Appendix *D.16. Laramie County: Unpaved County Road Impact Priority Rankings* maps detailed results of this prioritization process.

6.5.4 Platte County Prioritization

Table 6.15 shows Platte County with the least amount of impact of the four counties and also had the most missing traffic counts information. For this reason, there were only 15 road segments that could be considered in the priority ranking process, and of these 15, 11 of the segments were ranked at a priority level 6. The other 4 segments were rated as priority level 4 which is on the moderate to low level of impact.

Table 6.19 shows the average, low, and high values for the ADT, ADTT, and serviceable rigs and water haul sites within the buffer zone. It also shows that the most serviceable rigs and water haul sites within the buffer zone of a road segment was only 2 and the most truck traffic seen on a road segment was only 18 trucks per day. Although the energy related impact was minimal in Platte County, this report will give them the means to assess the damage when and if it comes. Appendix *D.42. Platte County: Unpaved County Road Impact Priority Rankings* maps detailed results of this prioritization process.

Table 6.18 Laramie County Priority Ranking Inputs

	Impact Priority Level					
	1	**2**	**3**	**4**	**5**	**6**
	ADT					
Average	147	167	116	69	113	29
High	180	438	195	73	113	62
Low	116	42	62	62	113	3
	ADTT					
Average	50	20	30	12	5	3
High	52	53	50	14	5	7
Low	44	11	13	11	5	0
	Serviceable Rigs/Water Haul Sites					
Average	7	11	4	2	1	3
High	10	20	8	4	1	25
Low	6	7	0	0	1	0

Table 6.19 Platte County Priority Ranking Inputs

	Impact Priority Level					
	1	**2**	**3**	**4**	**5**	**6**
	ADT					
Average	NA	NA	NA	83	NA	49
High	NA	NA	NA	103	NA	72
Low	NA	NA	NA	60	NA	16
	ADTT					
Average	NA	NA	NA	15	NA	4
High	NA	NA	NA	18	NA	8
Low	NA	NA	NA	12	NA	2
	Serviceable Rigs/Water Haul Sites					
Average	NA	NA	NA	1	NA	1
High	NA	NA	NA	2	NA	1
Low	NA	NA	NA	0	NA	0

6.6 Unpaved Road Maintenance and Improvement Recommendations

When recommending maintenance on unpaved roads, a method previously used by the WY T^2/LTAP *(Huntington and Ksaibati 2009)* was adapted for this study. The overall process consists of: Establishing a service level for each road segment; evaluating the segment's ride quality, distress conditions, and fugitive dust emissions; and selecting appropriate maintenance practices based on the service levels and road conditions using decision matrices for ride quality and dust emissions. This process is described in more detail in the following sections.

6.6.1 Service Level Standards and Selection

To determine appropriate maintenance for unpaved roads, a necessary first step is to assign service levels to each road segment – one would not apply the same standard to a double-track as to an unpaved road carrying hundreds of vehicles per day and a 30 foot top width. The selection of service levels could include a variety of factors. In this study the criteria used to assign them are traffic volume in vehicles per day (vpd) and road top width in feet (ft) as shown in Table 6.20. These standards are averaged to assign service levels; they are rounded towards the traffic value if the two criteria average out to half way between two service levels. When no traffic counts are available, top width alone is used according to the values in Table 6.20. Table 6.21 shows the miles in each service level for those segments identified by the counties either as impacted or as non-impacted sections. Appendices *D.5. Converse County: Unpaved County Road Levels of Service, D.15. Laramie County: Unpaved County Road Levels of Service, D.31. Goshen County: Unpaved County Road Levels of Service,* and *D.41. Platte County: Unpaved County Road Levels of Service* map the service levels in detail.

Table 6.20 Unpaved Road Service Level Standards

Service Level	Traffic, vpd	Top Width, ft
Very High	> 400	≥ 28'
High	151 - 400	23' - 27½'
Medium	51 - 150	18' - 22½'
Low	16 - 50	13' - 17½'
Very Low	5 - 15	9' - 12½'
None	< 5	≤ 8½'

Once service levels are established, the standards to which these roads should be maintained are also established. In this study, the minimum ride quality and dust ratings which roads of each service level should meet are shown in Table 6.22 along with the seasonal conditions under which it might be acceptable for the segment to be closed or impassable.

6.6.2 Maintenance Selection and Decision Process

The overall process of selecting unpaved road segment maintenance is shown in Figure 6.19. Service levels are assigned as described in the previous segment. Acceptability of the current segments is determined based on ride quality and fugitive dust emissions as shown in Table 6.22. Appropriate maintenance practices are selected using the decision matrixes shown in Tables 6.23 and 6.24. And the maintenance practice with the highest cost is selected using Table 6.25. Once the appropriate maintenance practice has been selected using this process, the cost per mile and the total segment cost can be calculated using the cost per square yard from Table 6.25, the segment length, and the segment top width. (Though maintenance costs will not always be directly proportional to surface area, it is considered the best approximation.) Once these costs, both the total cost for each segment and costs per mile, have been determined, recommended improvement lists are generated.

Table 6.21 Service Level Mileages on Unpaved Impacted and Non-Impacted Sections Identified by the Counties from the May 2012 Data Collection Event

	Impacted						
County	**Very High**	**High**	**Medium**	**Low**	**Very Low**	**None**	**TOTAL**
Converse	51.6	153.2	82.8	0.0	0.0	0.0	287.6
Goshen	27.7	68.6	70.2	18.2	3.6	0.0	188.4
Laramie	16.2	80.1	151.6	82.5	21.5	5.4	357.2
Platte	10.5	11.0	37.5	13.1	0.3	12.1	84.5
TOTAL	106.0	312.9	342.2	113.8	25.5	17.5	917.8
	Non-Impacted						
County	**Very High**	**High**	**Medium**	**Low**	**Very Low**	**None**	**TOTAL**
Converse	9.0	70.6	98.8	47.5	7.0	0.0	232.8
Goshen	60.2	375.2	165.0	13.8	2.0	0.0	616.2
Laramie	37.8	114.8	326.8	124.9	38.2	0.0	642.5
Platte	6.5	174.9	124.7	0.6	5.6	1.0	313.3
TOTAL	113.5	735.5	715.3	186.8	52.8	1.0	1,804.8
	Total						
County	**Very High**	**High**	**Medium**	**Low**	**Very Low**	**None**	**TOTAL**
Converse	60.6	223.8	181.6	47.5	7.0	0.0	520.5
Goshen	87.9	443.8	235.2	32.0	5.7	0.0	804.6
Laramie	54.1	194.9	478.4	207.4	59.7	5.4	999.7
Platte	16.9	185.9	162.3	13.7	5.9	13.1	397.8
TOTAL	219.5	1,048.3	1,057.5	300.5	78.3	18.5	2,722.6

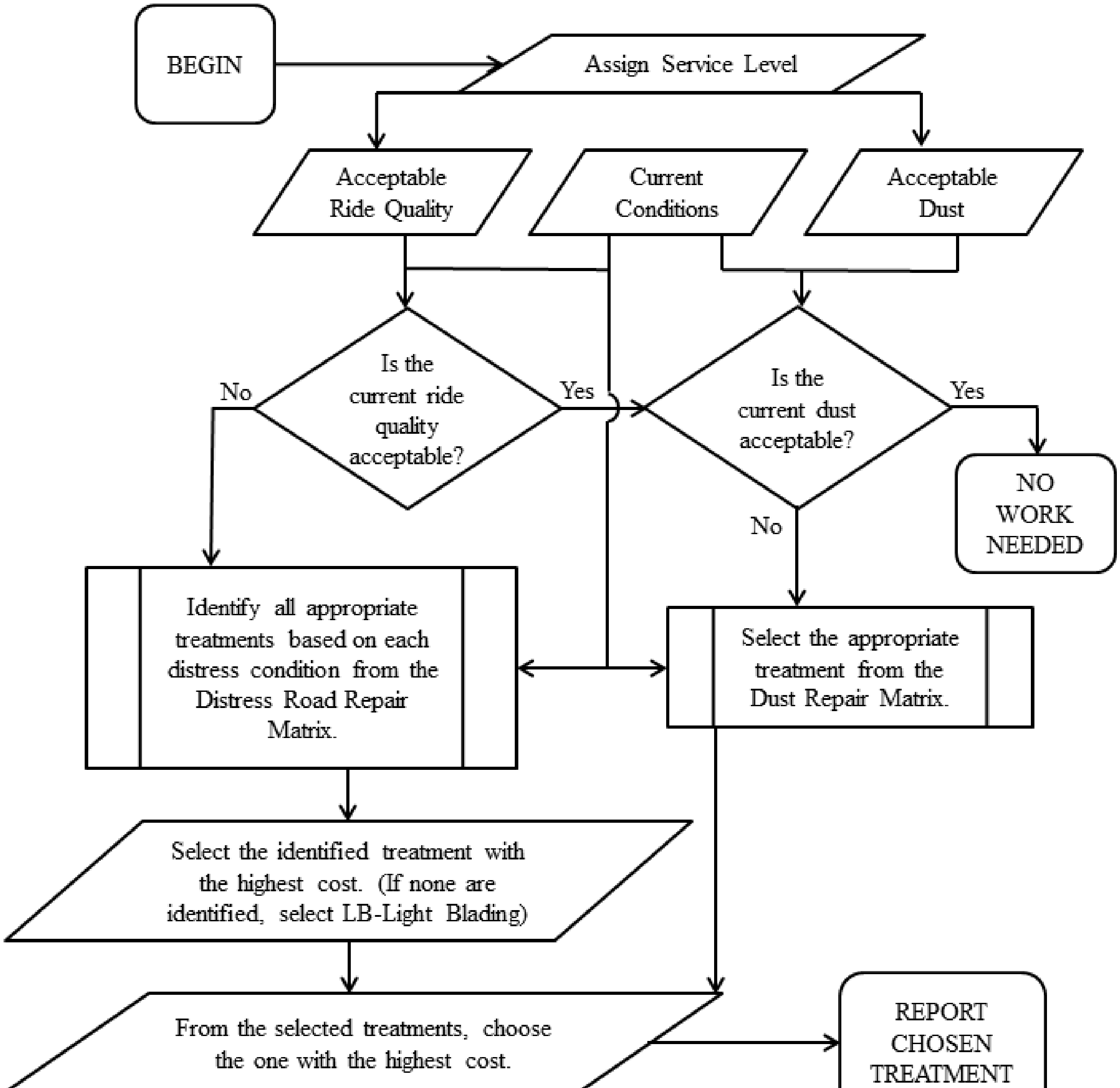


Figure 6.19 Unpaved road maintenance selection process.

6.6.3 Maintenance Cost Estimates

A preliminary version of the maintenance cost estimates was developed by the WY T^2/LTAP Center. It was presented to representatives of the four counties and revised based on their suggestions. For all costs except Regravel/Build Up Road, the county representatives directly addressed costs per mile. The costs agreed upon are shown in Table 6.25. The derivation of the $30,000 per mile for regraveling, $2.13 per square yard, was made based on costs provided by the county representatives as described in the next section.

Table 6.22 Unpaved Road Minimum Maintenance Standards

Service Level	Minimum Acceptable Ride Quality	Worst Acceptable Dust Level	Periods of Impassability
Very High	7 - Good	3 - Low	Blizzard
High	6 - Fair	2 - Medium	Blizzard
Medium	5 - Fair	2 - Medium	Blowing Snow
Low	4 - Poor	1 - High	Snow
Very Low	3 - Poor	1 - High	Winter/Spring
None	1 - Failed	1 - High	Winter/Spring

6.6.3.1 Regravel/Build Up Road Cost Derivation

Based on the following inputs provided to the WY T^2/LTAP Center by the counties, a cost of $2.13 per square yard was derived for regravel/build up road costs:

- Lift thickness: 3 inches
- Typical haul: 20 miles * 2 directions = 40 miles
- Haul cost: $0.23 per ton-mile
- Gravel cost: $7.00 per ton
- Gravel density: 1.35 tons per cubic yard (cy)

The above values are the inputs for the following calculations:

Gravel volume per square yard (sy): 3 inches * (1 yard/36 inches) = 0.08333 cy per sy

Gravel haul cost per ton: 40 miles * $0.23 per ton-mile = $9.20 per ton

Gravel haul cost per cy: $9.20 per ton * 1.35 tons per cy = $12.42 per cy

Gravel cost at the stockpile: $7.00 per ton * 1.35 tons per cy = $9.45 per cy

Gravel cost on the road: $12.42 per cy (haul) + $9.45 per cy (stockpile) = $21.87 per cy

Gravel cost per sy: 0.08333 cy per sy * $21.87 per cy = $1.82 per sy

sy per mile (24 foot width): 5,280 feet per mile * 24 feet / 9 sf per sy = 14,080 sy per mile

Gravel cost per mile (24 foot width): 14,080 sy per mile * $1.82 per sy = $25,661 per mile

This cost of $25,661 per mile was rounded up to $30,000 per mile since these costs are only for the gravel. The rounding up is justified by preparation and placement costs. This yields a final cost per sy of:

In-place Regravel/Build Up Road cost = $30,000 per mile / 14,080 sy per mile = $2.13 per sy

This value of $2.13 per square yard is used in all subsequent calculations and is shown in Table 6.25.

Table 6.23 Unpaved Road Maintenance Decision Matrix – Part 1

	Service Level					
Distress & Condition	**None**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Cross-Section/Crown						
3 - Good	N	N	N	N	N	N
2 - Fair	N	N	LB	LB	LB	LB
1 - Poor	N	LB	HB	HB	HB	HB
Roadside Drainage						
3 - Good	N	N	N	N	N	N
2 - Fair	N	N	HB	HB	DR	DR
1 - Poor	N	HB	DR	DR	RC	RC
Rutting						
9 - Very Good	N	N	N	N	N	N
8 - Good	N	N	N	N	N	N
7 - Good	N	N	N	N	N	N
6 - Fair	N	N	N	N	N	LB
5 - Fair	N	N	N	N	LB	HB
4 - Poor	N	N	LB	LB	HB	RG
3 - Poor	N	LB	HB	HB	RG	RC
2 - Very Poor	N	HB	HB	RG	RC	RC
1 - Failed	N	HB	RG	RC	RC	RC
Potholes						
9 - Very Good	N	N	N	N	N	N
8 - Good	N	N	N	N	N	N
7 - Good	N	N	N	N	N	N
6 - Fair	N	N	N	N	LB	LB
5 - Fair	N	N	N	LB	HB	HB
4 - Poor	N	N	LB	HB	HB	RG
3 - Poor	N	LB	HB	RG	RG	RG
2 - Very Poor	N	HB	HB	RG	RC	RC
1 - Failed	N	HB	RG	RC	RC	RC

* N-None; LB-Light Blading; HB-Heavy Blading; TG-Treat Gravel;
DR-Minor Drainage Repair; RG-Regravel; RC-Reconstruct

Table 6.24 Unpaved Road Maintenance Decision Matrix - Part 2

	Service Level					
Distress & Condition	**None**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Loose Aggregate						
9 - Very Good	N	N	N	N	N	N
8 - Good	N	N	N	N	N	N
7 - Good	N	N	N	N	N	N
6 - Fair	N	N	N	N	N	HB
5 - Fair	N	N	N	HB	HB	TG
4 - Poor	N	N	HB	TG	TG	RG
3 - Poor	N	HB	TG	RG	RG	RG
2 - Very Poor	N	TG	RG	RG	RG	RG
1 - Failed	N	RG	RG	RG	RG	RG
Corrugations						
9 - Very Good	N	N	N	N	N	N
8 - Good	N	N	N	N	N	N
7 - Good	N	N	N	N	N	N
6 - Fair	N	N	N	N	TG	TG
5 - Fair	N	N	N	TG	RG	RG
4 - Poor	N	N	N	RG	RG	RG
3 - Poor	N	N	RG	RG	RG	RG
2 - Very Poor	N	RG	RG	RG	RG	RG
1 - Failed	N	RG	RG	RG	RG	RG
Dust						
3 - None	N	N	N	N	N	N
2 - Low	N	N	N	N	N	N
1 - Medium	N	N	N	N	TG	TG
0 - High	N	N	N	RG	RG	RG

* N-None; LB-Light Blading; HB-Heavy Blading; TG-Treat Gravel;
DR-Minor Drainage Repair; RG-Regravel; RC-Reconstruct

Table 6.25 Unpaved Road Maintenance Treatments and Costs

Treatment	Cost/yard^2	Cost/mile*
Reconstruction/Rehabilitation	$10.65	$150,000
Regravel/Build Up Road	$2.13	$30,000
Minor Drainage Repair	$1.07	$15,000
Treat Gravel/Dust Control	$0.50	$7,000
Heavy Blading/Reshape Ditch/Pull Shoulders	$0.089	$1,250
Light Blading/Routine Maintenance	$0.018	$250

* Based on 24 foot top width

6.6.4 Recommended Unpaved Road Improvement Treatments

The procedures described above were used to generate lists of road segments recommended for improvement. The following sections provide an overall assessment of the maintenance and improvement procedures recommended by these procedures. Separate sections identify treatments recommended for individual roads within each county. Recommendations are based on the data collection events conducted in May 2012. Details of the improvement recommendations are shown in Appendix *D. Unpaved County Roads*.

In May 2012, all unpaved roads in each of the four counties were rated. Table 6.26 shows the treatments recommended and the distresses that necessitated these treatments.

Table 6.26 Unpaved Roads May 2012 Recommended Treatments, Costs and Controlling Distresses

Distress	Recon-struction	Regravel	Drainage Repair	Treat Gravel	Heavy Blading	Light Blading	Total
Crown	$0	$0	$0	$0	$263	$0	$263
Drainage	$0	$0	$241,633	$0	$2,630	$0	$244,264
Rutting	$0	$279,762	$0	$0	$13,393	$277	$293,432
Potholes	$0	$0	$0	$0	$6,812	$767	$7,579
Loose Aggregate	$0	$160,198	$0	$0	$3,255	$0	$163,454
Dust	$0	$375,352	$0	$891,314	$0	$0	$1,266,666
Washboards	$0	$579,566	$0	$137,163	$0	$0	$716,729
Ride Quality	$0	$0	$0	$0	$0	$2,134	$2,134
Total	$0	$1,394,877	$241,633	$1,028,477	$26,354	$3,178	$2,694,520

The treatments with the highest recommended improvement costs are regraveling at $1.39 million and gravel treatment at $1.03 million. Regravel costs were generated by, in order from highest to lowest improvement costs: washboards; dust; rutting; and loose aggregate. Gravel treatment costs were due mostly to dust, with a small amount – 13% – due to washboards.

Table 6.27 shows the costs recommended in each county for each treatment. The only recommended treatment in Converse County is $428,498 of gravel treatment due to dust. Platte County has only $25,559 of recommended treatment, mostly gravel treatment and some heavy blading. Goshen and Laramie Counties have substantially higher recommended treatment costs. Goshen has a total of $1.28 million in recommended treatments, while Laramie County has $0.96 million. Both of these counties have substantial regravel and gravel treatment cost recommendations, while Goshen County also has $0.24 million in recommended minor drainage repairs. There are several reasons for these results.

Table 6.27 Unpaved Roads May 2012 Recommended Treatments and Costs by County for Impacted and Non-Impacted Segments

County	Recon-struction	Regravel	Drainage Repair	Treat Gravel	Heavy Blading	Light Blading	Total	Cost per System-Mile
				Impacted				
Converse	$0	$0	$0	$359,224	$0	$0	$359,224	$1,249
Goshen	$0	$98,137	$48,964	$140,415	$0	$0	$287,516	$1,526
Laramie	$0	$0	$0	$49,004	$5,177	$767	$54,948	$154
Platte	$0	$0	$0	$22,064	$0	$0	$22,064	$261
Subtotal	$0	$98,137	$48,964	$570,706	$5,177	$767	$723,751	$789
Cost per Impacted Mile	--	$107	$53	$622	$6	$1	$789	--
				Non-Impacted				
Converse	$0	$0	$0	$69,274	$0	$0	$69,274	$298
Goshen	$0	$641,627	$192,670	$156,433	$4,547	$0	$995,276	$1,615
Laramie	$0	$655,114	$0	$232,064	$13,135	$2,411	$902,723	$1,405
Platte	$0	$0	$0	$0	$3,496	$0	$3,496	$11
Subtotal	$0	$1,296,740	$192,670	$457,771	$21,177	$2,411	$1,970,768	$1,092
Cost per Non-Imp. Mile	--	$718	$107	$254	$12	$1	$1,092	--
				All Unpaved Roads				
Converse	$0	$0	$0	$428,498	$0	$0	$428,498	$823
Goshen	$0	$739,764	$241,633	$296,848	$4,547	$0	$1,282,792	$1,594
Laramie	$0	$655,114	$0	$281,068	$18,312	$3,178	$957,671	$958
Platte	$0	$0	$0	$22,064	$3,496	$0	$25,559	$64
Subtotal	$0	$1,394,877	$241,633	$1,028,477	$26,354	$3,178	$2,694,520	$990
Cost per Unpaved Mile	--	$512	$89	$378	$10	$1	$990	--

Table 6.27 also compares the costs per mile of recommended treatments for each county. Only Converse County shows substantially higher costs per mile on impacted segments – Converse

has average treatment costs of $1,249 per mile on impacted segments but only $298 per mile on the non-impacted segments. In Goshen and Laramie Counties, recommended treatment costs are higher on the non-impacted segments, averaging $89 per mile per year more in Goshen County and $1,251 more per mile per year in Laramie County. This implies that less work is needed on these two counties' impacted roads, but these two counties keep their impacted roads in good condition at a price. Based on Table 6.9, Goshen County has spent $1,392 more per mile per year on their unpaved, impacted roads than on their non-impacted, unpaved roads. Table 6.11 shows that Laramie County spends $8,309 more per mile per year on its unpaved, impacted roads. In Platte County the recommended treatment cost per mile is only $192 for the 'impacted' segments compared to $12 per mile for the non-impacted sections, though these costs are very low relative to the other counties. This reflects Platte County's ability to keep up with the currently very minor oil and gas impacts to their county roads. Aside from Converse County, this indicates that the counties are not experiencing increased damage to their roads due to oil and gas activities. However, one should keep in mind that these values reflect the roads' conditions but not their maintenance costs. Where maintenance costs are higher on the impacted roads, particularly in Goshen and Laramie Counties, this indicates that damage is taking place but maintenance activities have prevented substantial deterioration.

Tables 6.28 through 6.31 show the recommended improvements for all unpaved roads in the four counties.

6.6.4.1 Converse County Improvement Recommendations

Table 6.28 shows that all the recommended improvements are for gravel treatment due to excessive dust and washboards. These improvements are mapped in Appendix *D.7. Converse County: Unpaved County Road Recommended Improvements*. About two-thirds of the improvement recommendation costs for Converse County's unpaved roads are on those roads identified as being impact priority 1 or 2 indicating that in spite of only slightly higher maintenance costs as shown in Table 6.8, most of the recommended improvement costs are on the impacted roads.

Table 6.28 Converse County May 2012 Unpaved Road Improvement Recommendations and Costs

Impacts	Road Name	Treatment Cost per SY	Treatment Cost per Mile	Treatment Cost	Treatment	Controlling Distress(es)	Service Level	Priority	Miles
Yes	Highland Loop Road	$0.50	$9,334	$117,254	Treat Gravel	Dust, Washboards	VH	2	12.56
Yes	Highland Loop Road	$0.50	$9,334	$102,023	Treat Gravel	Dust	VH	1	10.93
Yes	Tank Farm Road	$0.50	$8,751	$47,837	Treat Gravel	Dust, Washboards	VH	6	5.47
Yes	Tank Farm Road	$0.50	$8,751	$29,298	Treat Gravel	Dust	VH	6	3.35
No	Braae Road	$0.50	$8,167	$69,274	Treat Gravel	Dust	VH	--	8.48
Yes	Bill Hall Road	$0.50	$8,167	$62,811	Treat Gravel	Dust	VH	1	7.69
			TOTAL	$428,498	--	--	--	--	48.48

6.6.4.2 Goshen County Improvement Recommendations

Table 6.29 shows that, as of May 2012, oil and gas impacts are not having a great impact on Goshen County's unpaved roads, as indicated by the recommended improvements being mainly on non-impacted roads. These improvements are mapped in Appendix *D.33. Goshen County: Unpaved County Road Recommended Improvements*. However, as the maintenance records summary in Table 6.9 shows, in the longer term, the roads identified as being impacted are demanding substantially more maintenance resources. Goshen County has prevented the relatively minor oil and gas impacts on their roads from leading to deteriorated conditions by increasing their maintenance efforts on these roads.

Table 6.29 Goshen County May 2012 Unpaved Road Improvement Recommendations and Costs

Impacts	Road Name	Treatment Cost per SY	Treatment Cost per Mile	Treatment Cost	Treatment	Controlling Distress(es)	Service Level	Priority	Miles
No	Van Tassell Rd	$2.13	$40,000	$481,428	Regravel	Washboards	VH		12.04
No	CR 28A	$2.13	$40,000	$160,198	Regravel	Loose Aggregate	VH		4.00
Yes	CR 37B	$2.13	$30,000	$98,137	Regravel	Washboards	H		3.27
No	CR 64A	$1.07	$18,749	$74,951	Drainage	Drainage	VH		4.00
No	Bear Creek Rd	$1.07	$16,249	$117,719	Drainage	Drainage	H		7.24
Yes	CR 31A	$1.07	$16,249	$48,964	Drainage	Drainage	H	6	3.01
No	CR 59B	$0.50	$8,751	$8,769	Treat Gravel	Dust	VH		1.00
No	CR 63A	$0.50	$8,751	$17,500	Treat Gravel	Dust	VH		2.00
Yes	CR 136	$0.50	$8,751	$44,075	Treat Gravel	Dust	VH		5.04
No	CR 38C	$0.50	$8,167	$40,793	Treat Gravel	Dust	VH		4.99
No	CR 37C	$0.50	$8,167	$23,360	Treat Gravel	Dust	VH		2.86
Yes	CR 38A	$0.50	$8,167	$51,892	Treat Gravel	Dust	VH	6	6.35
No	CR 38A	$0.50	$8,167	$57,417	Treat Gravel	Dust	VH		7.03
Yes	CR 76A Deer Creek Rd	$0.50	$7,001	$29,770	Treat Gravel	Dust	M	6	4.25
No	CR 82A	$0.50	$7,001	$8,593	Treat Gravel	Washboards	H		1.23
Yes	CR 19B/72/21	$0.50	$5,250	$14,678	Treat Gravel	Dust	M		2.80
No	CR 62A	$0.089	$1,250	$3,277	Heavy Blading	Potholes	H		2.62
No	CR 46A	$0.089	$625	$1,270	Heavy Blading	Drainage, Ruts, Potholes	VL		2.03
			TOTAL	$1,282,792	--	--	--	--	75.77

6.6.4.3 Laramie County Improvement Recommendations

Table 6.30 shows that in Laramie County only 2.6% of the recommended improvement costs are on impacted roads with impact priorities of 2 or 3 while the other 97.4% of the improvement costs are on either non-impacted roads or roads with an impact priority of 6, showing that as of May 2012, Laramie County was able to keep its impacted roads in adequate conditions. These improvements are mapped in Appendix *D.17. Laramie County: Unpaved County Road Recommended Improvements*. Regraveling accounted for 68% of the recommended improvements, while gravel treatment accounted for 29% of the recommended improvements, with blading maintenance accounting for about 2%. The true impacts of oil and gas drilling are shown in Table 6.11 which shows that unpaved road maintenance costs on the impacted roads are $8,309 per mile per year higher than on the non-impacted roads.

Table 6.30 Laramie County May 2012 Unpaved Road Improvement Recommendations and Costs

Impacts	Road Name	Treatment Cost per SY	Treatment Cost per Mile	Treatment Cost	Treatment	Controlling Distress(es)	Service Level	Priority	Miles
No	CR 109	$2.13	$40,000	$375,352	Regravel	Dust	VH		9.38
No	CR 143	$2.13	$40,000	$153,130	Regravel	Ruts	H		3.83
No	CR 120	$2.13	$30,000	$126,632	Regravel	Ruts	M		4.22
No	CR 159	$0.50	$8,751	$34,937	Treat Gravel	Dust	VH		3.99
Yes	CR 215 Railroad Rd	$0.50	$7,584	$7,199	Treat Gravel	Washboards	VH	2	0.95
No	Harriman Rd	$0.50	$7,001	$45,789	Treat Gravel	Dust	H		6.54
No	CR 213	$0.50	$7,001	$32,109	Treat Gravel	Washboards	H		4.59
Yes	CR 142	$0.50	$7,001	$27,867	Treat Gravel	Dust	M	6	3.98
No	CR 143 Breeden Rd	$0.50	$7,001	$20,673	Treat Gravel	Dust	H		2.95
No	CR 143	$0.50	$7,001	$15,823	Treat Gravel	Dust	H		2.26
Yes	CR 215 Railroad Rd	$0.50	$7,001	$13,938	Treat Gravel	Dust	VH	2	1.99
No	CR 210	$0.50	$7,001	$6,717	Treat Gravel	Washboards	H		0.96
No	CR 110A	$0.50	$7,001	$6,486	Treat Gravel	Dust	H		0.93
No	CR 106 Horse Creek Rd	$0.50	$6,417	$49,860	Treat Gravel	Dust	M		7.77
No	CR 110	$0.50	$6,417	$6,590	Treat Gravel	Dust	M		1.03
No	CR 110	$0.50	$5,834	$12,036	Treat Gravel	Dust	M		2.06
No	CR 116	$0.50	$5,834	$1,046	Treat Gravel	Dust	M		0.18
Yes	CR 136	$0.089	$1,667	$1,146	Heavy Blading	Ruts	H	3	0.69
No	CR 140	$0.089	$1,563	$1,672	Heavy Blading	Ruts	H		1.07
Yes	CR 210	$0.089	$1,459	$1,447	Heavy Blading	Potholes	VH	3	0.99
No	CR 120 True Rd	$0.089	$1,250	$6,511	Heavy Blading	Ruts, Loose Aggregate	H		5.21
No	CR 155	$0.089	$1,146	$4,953	Heavy Blading	Ruts	M		4.32
Yes	CR 136	$0.089	$781	$527	Heavy Blading	Crown, Drainage	M	3	0.67
Yes	CR 242 Chalk Hill Rd	$0.089	$469	$1,500	Heavy Blading	Drainage, Ruts, Potholes	VL	6	3.20
Yes	CR 237 Bristol Ridge Rd	$0.089	$417	$557	Heavy Blading	Drainage, Ruts	VL	6	1.34
Yes	CR 201	$0.089	$365	$364	Heavy Blading	Drainage, Potholes	VL	6	1.00
No	CR 215	$0.018	$334	$2,015	Light Blading	Ride Quality	VH		6.03
Yes	CR 215 Railroad Rd	$0.018	$251	$767	Light Blading	Potholes	VH	2	3.06
No	CR 155	$0.018	$188	$277	Light Blading	Ruts	M		1.47
No	CR 229	$0.018	$188	$119	Light Blading	Ride Quality	M		0.63
			TOTAL	$958,035	--	--	--	--	87.29

6.6.4.4 Platte County Improvement Recommendations

Table 6.31 shows only very minor recommended improvements on Platte County's unpaved roads. This indicates that no negative effects of oil and gas traffic were reflected as deteriorated conditions. This is almost certainly due to the almost non-existent oil and gas traffic on Platte County's roads as of May 2012. The improvements recommended for all of Platte County's unpaved roads are mapped in Appendix *D.43. Platte County: Unpaved County Road Recommended Improvements*.

Table 6.31 Platte County May 2012 Unpaved Road Improvement Recommendations and Costs

Impacts	Road Name	Treatment Cost per SY	Treatment Cost per Mile	Treatment Cost	Treatment	Controlling Distress(es)	Service Level	Priority	Miles
Yes	Bordeaux Rd	$0.50	$5,250	$22,064	Treat Gravel	Dust	M	4	4.20
No	Emigrant Rd	$0.089	$625	$2,861	Heavy Blading	Drainage, Ruts, Potholes	VL		4.58
No	North Bellis Rd	$0.089	$625	$634	Heavy Blading	Drainage, Ruts, Potholes	VL		1.01
			TOTAL	$25,559	--	--	--	--	9.79

6.6.5 Improvement Costs and Prioritization Summary

Most of the data upon which this report is based was collected during late spring and summer of 2012, a period that experienced some of the driest conditions in memory. When examining the data generated by this study and presented in this report, these anomalous conditions should be kept in mind at all times.

Using the recommended improvements shown in Section *6.6.4 Recommended Unpaved Road Improvement Treatments*, costs by county and priority level are shown in Table 6.32. Those costs not assigned to any priority level, Non-Prioritized in Table 6.32, were not prioritized since they were not on roads identified as being impacted or other crucial data were not available.

Table 6.32 shows that the improvement costs per system mile average $990 per mile for all unpaved roads in the four counties. Non-prioritized roads average $1,101 per mile for all four counties, indicating that on average, the prioritized roads have less unmet maintenance needs than the prioritized roads. However, roads with Priority Levels 1 and 2 have higher average, system-wide improvement costs of $1,930 and $1,633 per mile, respectively. This indicates that, on average, only those roads with Priority Levels of 1 and 2 are truly being negatively impacted by oil and gas impacts.

Using the information in Table 6.32 to compare the four counties, it is apparent that only Converse County's roads have significantly more improvements recommended on their impacted roads than on the rest of their road network. Platte County also has higher costs on the impacted, prioritized roads, but their overall recommended improvements amount to only $64 per system mile; the other four counties all average over $800 of improvement recommendations per system mile. The overall implication of these observations is that only Converse County's unpaved roads are being damaged by oil and gas traffic in a demonstrable way.

Table 6.32 Recommended Improvement Costs by Priority Level and County

Priority		Converse	Goshen	Laramie	Platte	TOTAL
1	*Cost*	$164,834	$0	$0	$0	$164,834
	Miles Improved	18.6	0.0	0.0	0.0	18.6
	Cost per Improved Mile	$8,852	--	--	--	$8,852
	Cost per Priority 1 Mile	$2,389	--	--	--	$1,930
2	*Cost*	$117,254	$0	$21,903	$0	$139,158
	Miles Improved	12.6	0.0	6.0	0.0	18.6
	Cost per Improved Mile	$9,334	--	$3,651	--	$7,497
	Cost per Priority 2 Mile	$9,334	--	$302	--	$1,633
3	*Cost*	$0	$0	$3,120	$0	$3,120
	Miles Improved	0.0	0.0	2.4	0.0	2.4
	Cost per Improved Mile	--	--	$1,326	--	$1,326
	Cost per Priority 3 Mile	--	--	$49	--	$22
4	*Cost*	$0	$0	$0	$22,064	$22,064
	Miles Improved	0.0	0.0	0.0	4.2	4.2
	Cost per Improved Mile	--	--	--	$5,250	$5,250
	Cost per Priority 4 Mile	--	--	--	$1,817	$215
5	*Cost*	$0	$0	$0	$0	$0
	Miles Improved	0.0	0.0	0.0	0.0	0.0
	Cost per Improved Mile	--	--	--	--	--
	Cost per Priority 5 Mile	--	--	--	--	--
6	*Cost*	$77,136	$130,625	$29,925	$0	$237,685
	Miles Improved	8.8	13.6	8.5	0.0	31.0
	Cost per Improved Mile	$8,751	$9,591	$3,513	--	$7,679
	Cost per Priority 6 Mile	$1,050	$1,694	$168	--	$674
Non-Prioritized Impacted	*Cost*	$0	$156,891	$0	$0	$156,891
	Miles Improved	0.0	11.1	0.0	0.0	11.1
	Cost per Improved Mile	--	$14,130	--	--	$14,130
	Cost per Non-Prioritized Impacted Mile	--	$2,019	--	--	$3,592
Non-Impacted	*Cost*	$69,274	$995,276	$902,723	$3,496	$1,970,768
	Miles Improved	8.5	47.0	69.4	5.6	130.5
	Cost per Improved Mile	$8,167	$21,156	$13,003	$625	$15,097
	Cost per Non-Impacted Mile	$298	$1,615	$1,405	$11	$1,092
System Total	*Cost*	$428,498	$1,282,792	$957,671	$25,559	$2,694,520
	Miles Improved	48.5	60.7	86.3	9.8	216.3
	Cost per Improved Mile	$8,839	$21,146	$11,098	$2,610	$12,455
	Cost per System Mile	$823	$1,594	$958	$64	$990

Table 6.33 shows the recommended improvement costs by the type of improvement. For the four counties as a whole, regraveling at $1.39 million and dust control and gravel treatment at $1.03 million are the two main recommended treatment types, with only minor drainage repairs

at $0.24 million making any other financially significant contribution to the recommended improvement costs. Comparing the prioritized to non-prioritized road segments' recommended improvements, regravel costs are predominant on the non-prioritized roads, while gravel treatment and dust control are much more frequently recommended on the prioritized roads. However, about two-thirds of the gravel treatment costs on the prioritized roads are on those roads with a priority level of 6, indicating that much of the oil and gas impacts are compensated for by the counties' flexible, ongoing maintenance practices.

Table 6.33 Recommended Improvement Costs by Priority Level and Improvement Type

Priority Level		**Reconstruction/ Rehabilitation**	**Regravel/Build Up Road**	**Minor Drainage Repair**	**Treat Gravel/ Dust Control**	**Heavy Blading/ Reshape Ditch/ Pull Shoulders**	**Light Blading/ Routine Maintenance**	**Total**
1	*Cost*	$0	$0	$0	$164,834	$0	$0	$164,834
	Miles	0.0	0.0	0.0	18.6	0.0	0.0	18.6
Cost per Priority 1 Mile		--	--	--	$1,930	--	--	$1,930
2	*Cost*	$0	$0	$0	$138,391	$0	$767	$139,158
	Miles	0.0	0.0	0.0	15.5	0.0	3.1	18.6
Cost per Priority 2 Mile		--	--	--	$1,624	--	$9	$1,633
3	*Cost*	$0	$0	$0	$0	$3,120	$0	$3,120
	Miles	0.0	0.0	0.0	0.0	2.4	0.0	2.4
Cost per Priority 3 Mile		--	--	--	--	$22	--	$22
4	*Cost*	$0	$0	$0	$22,064	$0	$0	$22,064
	Miles	0.0	0.0	0.0	4.2	0.0	0.0	4.2
Cost per Priority 4 Mile		--	--	--	$215	--	--	$215
5	*Cost*	$0	$0	$0	$0	$0	$0	$0
	Miles	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost per Priority 5 Mile		--	--	--	--	--	--	--
6	*Cost*	$0	$0	$48,964	$186,664	$2,057	$0	$237,685
	Miles	0.0	0.0	3.0	23.4	4.5	0.0	31.0
Cost per Priority 6 Mile		--	--	$139	$529	$6	--	$674
Non-Prioritized	*Cost*	$0	$98,137	$0	$58,753	$0	$0	$156,891
Impacted	*Miles*	0.0	3.3	0.0	7.8	0.0	0.0	11.1
Cost per N-PI Mile		--	$767	--	$459	--	--	$1,225
Non-Impacted	*Cost*	$0	$1,296,740	$192,670	$457,771	$21,177	$2,411	$1,970,768
	Miles	0.0	33.5	11.2	60.9	20.8	8.1	134.5
Cost per Non-Imp. Mile		--	$718	$107	$254	$12	$1	$1,092
Total	*Cost*	$0	$1,394,877	$241,633	$1,028,477	$26,354	$3,178	$2,694,520
	Miles	0.0	33.5	14.3	122.6	27.7	11.2	209.2
Cost per System Mile		--	$512	$89	$378	$10	$1	$990

6.7 Summary

Data about the four counties' unpaved roads were collected from a number of sources. The unpaved roads in the four counties were rated on four occasions. Information on the oil and gas impacts to roads segments were obtained in two ways. First, the counties were asked which roads were impacted, and, second, information on the locations of oil and gas wells and water haul sites were also used to estimate impacts from oil and gas traffic. Traffic counts were performed on many of the counties' unpaved roads. Traffic data and information about oil and gas impacts were combined to establish impact priorities of the road segments the counties identified as being impacted. Maintenance records from the four counties were obtained, compiled and analyzed. Based on the traffic data and top widths, service levels were established for all the counties' unpaved roads. Then, based on the service levels and current conditions, recommended improvements were generated for all the counties' unpaved roads. The impact priorities and improvement recommendations were used to generate a prioritized list of recommended improvements. These data about the counties' unpaved roads were combined to provide an overall picture of the status and condition of these roads. Further details on the unpaved county roads data collection and analysis are shown in Appendix *D. Unpaved County Roads*.

There were $2.7 million of improvements recommended for the four counties on 221 miles of unpaved roads as shown in Tables 6.28 through 6.33. Converse County had $428,498 of recommended gravel treatment on 48 miles due to dust and, on two segments, to washboards. Goshen County had $1.28 million in recommended treatments, mostly regravel, minor drainage upgrades, and gravel treatment, on 76 miles. Most of these improvements were recommended based on washboards, drainage and dust. Laramie County had $958,035 of recommended improvements, mostly regravel and gravel treatment due to dust and washboards, on 87 miles of their unpaved roads. Platte County had only $25,559 of improvements on 10 miles of unpaved roads, mostly gravel treatment on Bordeaux Road to mitigate dust.

Conditions and top widths were evaluated on four occasions. In October 2011, Goshen, Laramie and Platte Counties' impacted roads were rated and measured. In May 2012, all the unpaved roads in the four counties were rated and measured. The impacted roads were rated and measured again in June and August of 2012. These evaluations showed that the counties' roads were generally in good condition, though they deteriorated considerably during the unusually dry summer of 2012. This was reflected in worse dust, washboarding and even rutting ratings, with the exception of Laramie Counties' roads which held up somewhat better. Laramie Counties' unpaved roads were somewhat dustier in June, probably due in large part to recent maintenance breaking up the crust leading to higher dust ratings.

Table 6.34 shows the method used to estimate the documentable portion of the financial impacts to each county's unpaved roads. First, the annual maintenance costs were assessed using the counties' maintenance records. They vary in reliability and completeness, as described in

Section *6.4 Maintenance Records*. Also, regraveling needs may not be immediately addressed by the counties. Their costs may be either underestimated or completely ignored in this analytical procedure. Second, the costs of recommended improvements on all the counties' unpaved roads are determined, and average per mile costs are generated as described in Section *6.6 Unpaved Road Maintenance and Improvement Recommendations*. This provides a measure of the cost to improve deficient roads. Thus, for each county's unpaved road network, there is a measure of the cost to maintain those roads, though it may be incomplete, and there is a measure of the improvements needed to the roads, a measure of the cost to bring those roads back to acceptable conditions. Combining these two cost differences provides a preliminary assessment of the cost to the counties of oil and gas traffic on their unpaved roads.

Table 6.34 Unpaved Roads Additional Costs on Impacted Segments from the Average per Mile Maintenance Costs and the Recommended Improvements by County

	Maintenance Costs per Mile-Year		Recommended Improvement Costs per Mile		Additonal Costs on Unpaved Impacted Segments	
County	Impacted	Non-Impacted	Impacted	Non-Impacted	Costs per Mile	Total Annual Costs
Converse [a]	$2,688	$2,639	$1,249	$298	$1,000	$287,733
Goshen [b]	$3,237	$1,735	$1,526	$1,615	$1,413	$266,178
Laramie [b]	$5,159	$2,001	$155	$1,405	$1,908	$681,561
Platte [c]	$1,908		$261	$11	$250	$21,121
Average [d]	$3,248	$2,071	$789	$1,092	*Total*	$1,256,593

a. Converse County maintenance costs are estimated to be the 2010 labor costs times 3½.

b. Goshen and Laramie Counties' maintenance costs are for 2011.

c. Platte County maintenance costs are not split into impacted and non-impacted categories.

d. Average of the four counties' individual values, not of the four-county network as a whole.

The calculation of the 'additional costs' in Table 6.34 is performed by, first, calculating the additional cost per mile of maintenance on each county's unpaved roads (except on Platte County's roads which have very little oil and gas traffic). This difference ranges from about $50 extra per mile – $2,688 minus $2,639 – on Converse County's impacted roads to over $3,000 extra per mile – $5,159 minus $2,071 – on Laramie County's impacted roads. Next, the difference in the cost of needed improvements per mile is determined. This difference ranges from almost $1,000 per mile - $1,249 minus $298 – for Converse County to a negative value of about $1,250 - $155 minus $1,405 – on Laramie County's unpaved, impacted roads. This implies that Laramie County's impacted roads are in better condition than its non-impacted roads. These two values, additional maintenance cost and additional improvements needed, are calculated and added for each county, yielding a net additional cost per mile on their impacted, unpaved roads. Finally, this additional cost per mile is multiplied by the unpaved, impacted mileage to yield a total cost due to oil and gas impacts. For the four counties combined, this yields a total of $1.26 million in additional costs, though it should be kept in mind that the maintenance costs are not complete, so the true value is probably higher.

Comparing the annual maintenance costs and the improvement recommendations in Table 6.34 demonstrates somewhat different adaptations by each county to increased traffic due to oil and gas activities. Converse County, which has the most oil and gas traffic, spent similar amounts on its impacted and non-impacted roads. This led to their impacted roads being in somewhat worse conditions as reflected by higher recommended improvement costs on their impacted roads. Goshen County had similar recommended improvement costs, indicating that they maintained their impacted and non-impacted roads to about the same standard. This was accomplished by spending over twice as much per mile on the impacted roads. Laramie County had lower recommended improvement costs on their impacted roads, indicating that they were kept in good condition, but this came at a cost. They spent over 2½ times as much per mile maintaining their impacted roads. Platte County had negligible oil and gas impacts, and also had the least recommended improvements, indicating that they are currently operating under similar conditions as in past years, without significant oil and gas impacts.

6.8 Recommendations

Providing long-term evaluations of the counties' road networks and of the oil and gas industry's impacts on them demands several basic elements. Of course to evaluate the oil and gas industry's impacts, traffic, particularly from heavy trucks, must be quantified on a road segment-by-road segment basis. Expenses on each segment should be tracked throughout the counties' road networks. Finally, there must be some measure of the unpaved roads' conditions. More detailed descriptions of these issues and processes are available elsewhere *(WTTC 2010b).*

6.8.1 Inventory and Segmentation

A fundamental aspect of any road analysis or management system is the development of an inventory. A primary element of this process is dividing roads into segments, the smallest unit analyzed by a road management and analysis system. Segmentation has been performed by the WY T^2/LTAP Center. All additional condition data and maintenance tracking should be assigned to an individual unpaved road segment.

6.8.2 Traffic Assessments

In this project, two methods have been used to assess oil and gas impacts on county roads. First, a subjective assessment was made by the county road and bridge supervisors, identifying some of their county's roads as being impacted by oil and gas activities. Second, traffic counts and proximities to oil and gas wells or water haul sites were used to assign a priority to each road identified as impacted. Traffic should continue to be monitored using a combination of these or similar methods.

6.8.3 Maintenance Records

The two most basic needs of a useful maintenance tracking system are an inventory and a list of work that the agency performs. A good inventory allows costs to be assigned to a road segment, the basic unit of any road management system. Too often maintenance costs and activities are assigned to a road by name or number, but not to a specific segment. For some tasks, such as plowing snow or fence repair, this is a minor problem. However, for other actions such as routine blade maintenance, pulling shoulders, or adding gravel, the work done must be tracked to properly manage a road or to establish the costs that are attributable to oil and gas activities.

To achieve this, first the counties must assign their maintenance activities and costs to a specific road segment. The segments established by the WY T^2/LTAP Center could be used, perhaps as modified by the counties as necessary. Second, common tasks should be selected and time, cost and segment locations should be associated with necessary costs.

In general terms, maintenance tasks that are unique to unpaved roads should be defined and tracked, both for effective maintenance planning and to assess the impacts of oil and gas traffic. Clear distinctions should be made to establish appropriate levels of data collection. Effort should not be wasted on tracking activities or costs that are not to be used for future decision making. Conversely, planning and assessment should not be hampered because the necessary information is not available.

Exactly how costs are tracked should be established and all counties should assign costs in the same way. All costs – labor, equipment, fuel, materials and overhead – should be tracked to accurately plan maintenance and determine the true financial impacts of oil and gas activities on unpaved roads.

6.8.4 Performance Assessments

Ideally roads would be maintained when maintenance is needed, when the condition of the road surface falls below acceptable levels. Practically, other factors greatly influence the timing and type of unpaved roads maintenance. The road surface should be damp – not too wet and not too dry – when surface blading is performed. Personnel, equipment and funds must be available to perform the work. Still, some measures of the roads' conditions are needed.

6.8.5 Overall Unpaved Roads Recommendations

Impacts on unpaved roads from any type of traffic appear in two ways: Costs may increase or conditions may worsen. To adequately assess the effects of oil and gas traffic, both maintenance costs and road conditions should be monitored. Costs are inherently expressed in terms of dollars; conditions must be converted into quantified costs to provide an overall assessment of the financial impacts on county roads from increased traffic. While calculating the increased user costs for deteriorated conditions is possible, a much easier, simpler approach is to determine the costs of repairing any damage done. The method presented in this section provides reasonable costs for repairing this damage. Thus, with good maintenance data and roadway condition evaluations, a reasonable, comprehensive overall financial assessment of oil and gas activities' impacts can be generated. To accomplish this, the counties must collect maintenance cost data in a consistent, useful way, and roadway conditions must be evaluated periodically.

7. CATTLE GUARDS

Cattle guards frequently cross county roads as they go from pasture to pasture. With time and loads, they deteriorate or are damaged, eventually needing maintenance, repairs or replacement. As part of this study, the current condition of the four counties' cattle guards is documented. Current conditions are assessed and both the current and replacement values of the counties' cattle guards are estimated as of late spring and early summer of 2012.

7.1 Data Collection

Cattle guards were rated with a visual inspection following the standards developed by the WY T^2/LTAP Center and shown in Appendix *H.3. Cattle Guards Rating Standards*. This guide has verbal condition descriptions accompanied by photographs. Four elements of cattle guards – the base, the grate, the wings, and the approach – were rated as Excellent, Good, Fair, Poor, or Very Poor. Grate dimensions and base types were recorded. The cattle guards were also photographed. Locations of the cattle guards rated in the four counties are shown in Figure 7.1. Maps of the ratings are in Appendix *E. Cattle Guards*.

7.2 Data Analysis

The data analysis is relatively simple. The replacement costs of cattle guards are estimated based on the base type, length, and road surface type. Costs were estimated based on WYDOT's 2011 Weighted Average Bid Prices *(WYDOT 2012)*. WYDOT's costs for Medium Duty 18 foot cattle guards averaged $8,518 while Medium Duty 24 foot cattle guards averaged $10,914. Based on discussions with representatives of the four counties, replacement values for the counties' cattle guards were estimated. These values are $8,500 for 18 feet and $10,900 for 24 feet. Table 7.1 shows the assumed replacement costs to the counties for cattle guards. These values are used to derive costs based on length, base type, and road surface type.

Table 7.1 Cattle Guard Replacement Costs

	Base Cost				Approach Cost		TOTAL (Concrete Base, Unpaved Road Surface)
Length, ft	Concrete Base	Other Base Type	Grate Cost	Wing Cost	Unpaved Road Surface	Paved Road Surface	
18	$5,900	$3,500	$2,300	$200	$100	$300	$8,500
24	$7,600	$4,500	$3,000	$200	$100	$300	$10,900

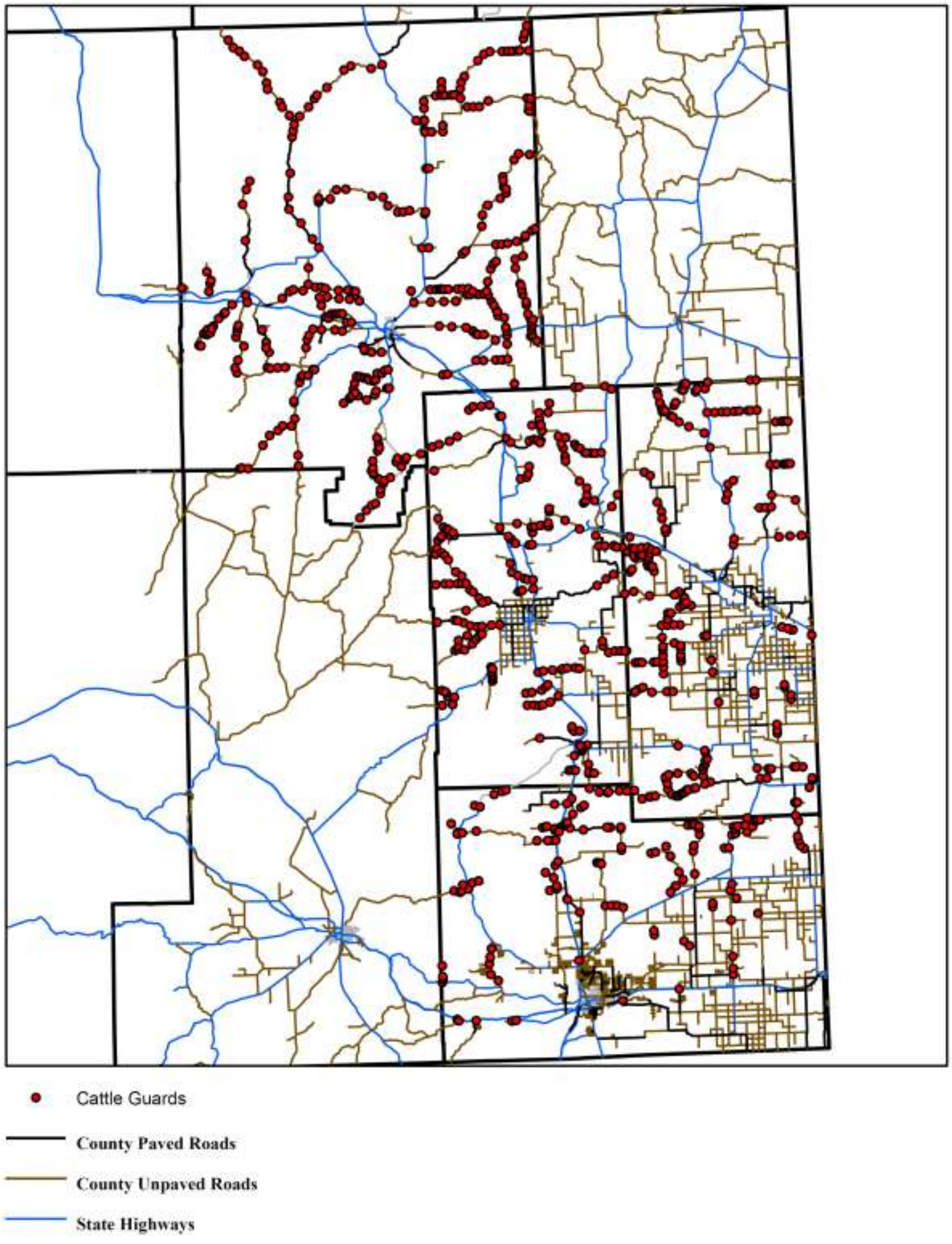


Figure 7.1 Cattle guard locations in southeastern Wyoming.

Equations and algorithms were derived from the values in Table 7.1, assuming costs are a linear function of length. These were used to generate replacement costs for the various types and sizes of cattle guards. These formulas are shown in Table 7.2. The costs are adjusted based on current conditions using the percentages of their replacement costs shown in Table 7.3. They are assumed to have their full value if they are in excellent condition; they are assumed to have no value if they are in very poor condition.

Table 7.2 Cattle Guard Replacement Cost Equations and Algorithms

Concrete Base Cost, $	= 283⅓(Length, ft) + 800
Other Base Cost, $	= 166⅔(Length, ft) + 500
Grate Cost, $	= 116⅔(Length, ft) + 200
Wing Cost, $	= 200
Approach Cost, $	IF Unpaved = $100; IF Paved = $300

Table 7.3 Cattle Guard Current Values as Percentages of Their Replacement Costs Based on Their Current Conditions

	Base	**Grate**	**Wings**	**Approaches**
Excellent	100%	100%	100%	100%
Good	75%	75%	75%	75%
Fair	50%	50%	50%	50%
Poor	25%	25%	25%	25%
Very Poor	0%	0%	0%	0%

7.3 Results

Tables 7.4, 7.5, 7.6 and 7.7 show the current conditions for each county's cattle guards.

Table 7.4 Cattle Guard Base Conditions

County	**Excellent**	**Good**	**Fair**	**Poor**	**Very Poor**	**TOTAL**
CO	6	206	92	35	0	339
GO	5	163	67	8	1	244
LA	13	105	50	2	0	170
PL	26	106	66	21	1	220
TOTAL	50	580	275	66	2	973
Percent	5%	60%	28%	7%	0%	100%

Table 7.5 Cattle Guard Grate Conditions

County	Excellent	Good	Fair	Poor	Very Poor	TOTAL
CO	9	219	86	23	2	339
GO	5	183	48	8	0	244
LA	17	116	31	4	2	170
PL	28	129	48	14	1	220
TOTAL	59	647	213	49	5	973
Percent	6%	66%	22%	5%	1%	100%

Table 7.6 Cattle Guard Approach Conditions

County	Excellent	Good	Fair	Poor	Very Poor	TOTAL
CO	4	175	129	30	1	339
GO	1	102	109	32	0	244
LA	18	95	51	5	1	170
PL	14	99	92	13	2	220
TOTAL	37	471	381	80	4	973
Percent	4%	48%	39%	8%	0%	100%

Table 7.7 Cattle Guard Wing Conditions

County	Excellent	Good	Fair	Poor	Very Poor	NA/None	TOTAL
CO	5	101	49	46	3	135	339
GO	3	87	31	17	2	104	244
LA	28	68	42	20	1	11	170
PL	28	44	31	38	16	63	220
TOTAL	64	300	153	121	22	313	973
Percent	7%	31%	16%	12%	2%	32%	100%

As these tables show, most – 87% or 88% – of the cattleguards' bases, grates, and approaches in the four counties are in good or fair condition. Since most of the costs associated with cattle guards are for the bases and grates, their conditions are shown in Figures 7.2 and 7.3. As these figures show, the cattle guards in all four counties are in similar condition with most in good or fair condition. Converse County has the most cattle guards while Laramie County has the fewest.

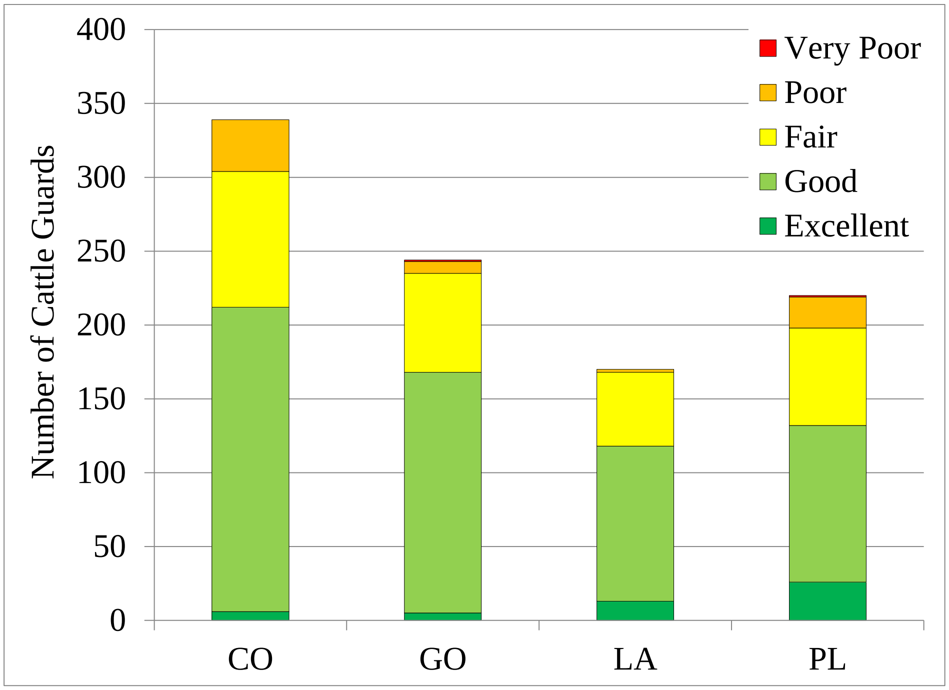


Figure 7.2 Cattle guard base conditions in May 2012.

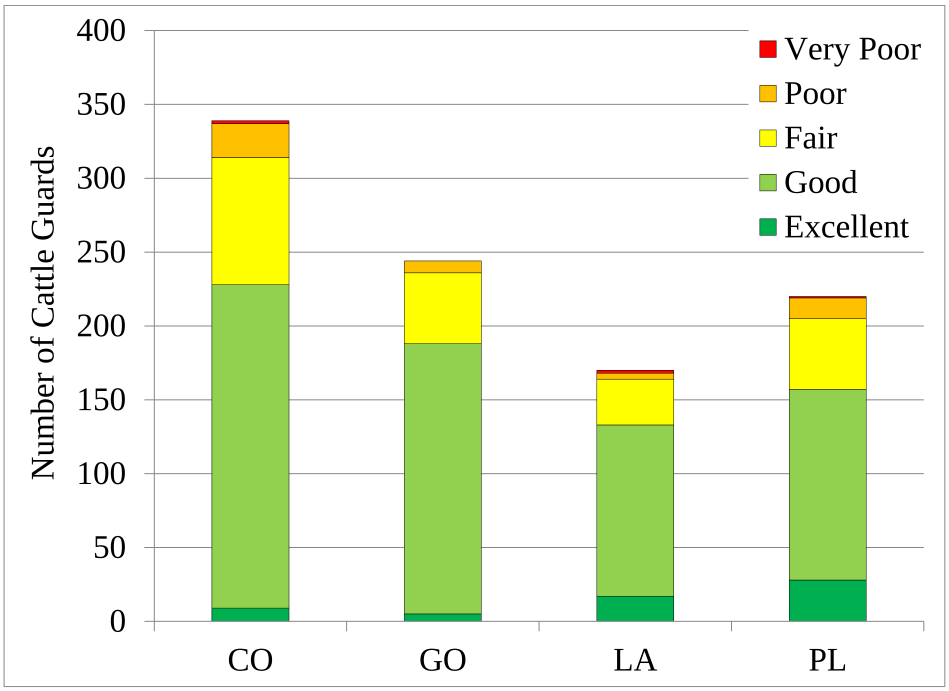


Figure 7.3 Cattle guard grate conditions in May 2012.

7.4 Summary

The current value and replacement costs of all the cattle guards in each of the four counties are shown in Table 7.8. In all four counties, the current value of the cattle guards countywide is around two-thirds of their replacement cost, reflecting an average value between good – rated at 75% of initial value – and fair – rated at 50% of initial value.

Table 7.8 Cattle Guard Replacement Costs and Current Values

County	Number of Cattleguards	Total Replacement Value	Total Current Value	Average Replacement Value	Average Current Value	Current Percentage of Replacement
CO	339	$3,229,550	$2,075,371	$9,527	$6,122	64%
GO	244	$2,015,200	$1,359,487	$8,259	$5,572	67%
LA	170	$1,698,333	$1,192,508	$9,990	$7,015	70%
PL	220	$1,813,017	$1,231,500	$8,241	$5,598	68%
TOTAL	973	$8,756,100	$5,858,867	$8,999	$6,021	67%

7.5 Recommendations

This report provides baseline data upon which further analyses can be based. These simple data collection and analytical methods can easily be repeated periodically to provide an assessment of the damage done by oil and gas traffic.

To assess the damage to the four counties' cattle guards due to oil and gas impacts, each counties' cattle guards should be rated periodically, perhaps every two or three years. This report documents the current conditions of the four counties' cattle guards, providing baseline data upon which further assessments should be based. Condition ratings that provide the necessary inputs for current value assessments should be performed in subsequent years. The loss in current value for cattle guards on impacted roads should be compared to the cattle guards on the counties' other, non-impacted roads. For such an analysis to be meaningful, the counties would have to track their maintenance, repair, and replacement costs for each individual cattle guard. They would also need to separate their costs by whether or not they are primarily related to heavy truck traffic. A cost not directly related to traffic is cleaning earth and gravel out of the cattle guards' bases. Additionally, one would need a reasonable evaluation of traffic, particularly the heavy trucks that are most likely to damage cattle guards. With future ratings using the same standards, accurate recording of costs incurred for maintenance, repairs and replacement, and the amount and type of heavy traffic traversing the cattle guards, one could generate a reasonable estimate of the damage to cattle guards done by oil and gas related traffic.

8. BRIDGES

Bridges are a critical and expensive element of each county's infrastructure. Concerns about the oil and gas industry's impacts on the four counties' bridges include the preliminary bridge assessment in this report. WYDOT is responsible for inventorying and analyzing all of Wyoming's bridges over 20 feet long as part of a national bridge inventory compiled by the Federal Highway Administration (FHWA).

WYDOT provided the Wyoming T^2/LTAP Center with a log of all local bridges in the four counties. The National Bridge Inventory (NBI) released a rating guide called "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (*FHWA 1996*) to help state, federal and other agencies record bridge information and create uniformity in the database. This preliminary assessment of the four counties local bridges does not include bridges less than 20 feet long. The database is also used for the FHWA and the Military Traffic Management Command to identify and classify the Strategic Highway Corridor Network and it's connectors for defense. The bridge information includes the geometrics, identification information, operational conditions, bridge type and specifications. This information is shown in numerous maps in Appendix *F. Bridges*.

8.1 Background

In 2010 the NBI database contained just over than 600,000 bridges located on public roads, highways, state and county roads, 3,068 of which are in Wyoming. The number of bridges on urban roadways is increasing, while the number of bridges on rural roadways is decreasing as shown in Table 8.1. Urban bridges tend to have more traffic, therefore they are better taken care of and more are being built. Conversely, there are over 100,000 rural bridges that are either structurally deficient or functionally obsolete.

Table 8.1 National Public Bridges by Condition and Year *(FHWA 2011)*

	2005	2006	2007	2008	2009	2010
	Structurally Deficient Bridges					
Urban	12,600	12,585	12,951	12,896	12,828	12,443
Rural	63,323	61,199	59,569	58,565	58,349	56,777
TOTAL	75,923	73,784	72,520	71,461	71,177	69,220
	Functionally Obsolete Bridges					
Urban	31,391	32,292	33,139	33,691	33,743	33,714
Rural	49,021	48,025	46,665	46,242	44,734	43,698
TOTAL	80,412	80,317	79,804	79,933	78,477	77,412
	All Bridges					
Urban	137,598	146,041	151,171	153,407	156,305	157,571
Rural	452,955	451,299	448,595	447,989	446,954	446,889
TOTAL	590,553	597,340	599,766	601,396	603,259	604,460

Slightly more than 50 percent of the nation's bridges are owned by local agencies, with state agencies owning about 48 percent and the remaining 2 percent owned by the federal government. Rural local roads have around 35 percent of the bridges but carry less than 2 percent of the traffic (*FHWA 2006*). Figure 8.1 shows the number of bridges on each roadway classification and the difference between the bridges on rural and urban roads. Rural roads show significantly more bridges on collector and local roads than in urban environments.

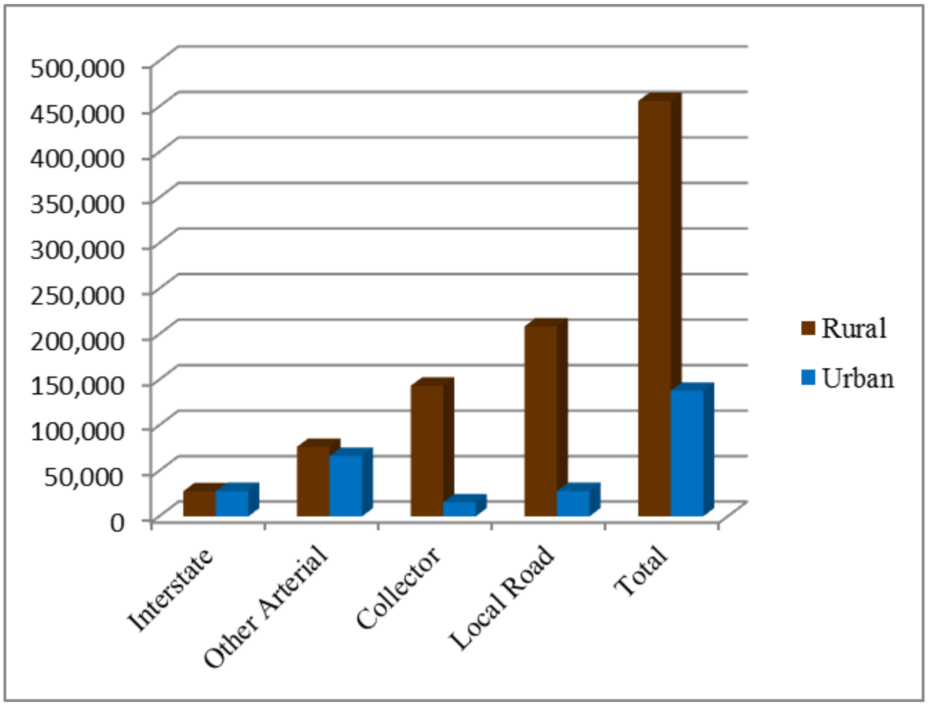


Figure 8.1 Bridges nationally by roadway classification *(FHWA 2006)***.**

A bridge may be described as inadequate either because it is structurally deficient or it is functionally obsolete. Structural deficiency is when the bridge's significant load-carrying elements are found to be in poor or worse condition due to deterioration or damage. A deficient bridge does not mean that the bridge is likely to collapse immediately or is unsafe, but it may require significant repairs. To remain open, deficient bridges may have posted weight limits. Functional obsolete bridges' geometry doesn't meet the design standards for the road (*FHWA 2006).* For example, bridges that were built in the 1930s didn't have to meet the same design standards as those built in the 2000s. Around 27% of the bridges were built between 1957 and 1971, reflecting increased bridge construction during the interstate construction era. Older bridges are more likely to be structurally deficient than newer bridges. Bridges both structurally deficient and functionally obsolete comprise 20% of the bridges 35 to 39 years old, 40% of those 55 to 59 years old, and over 50% of the bridges 80 to 84 years old.

8.2 Bridge Conditions

The NBI rating guide discusses the data that needs to be recorded as part of each state's final bridge reports. It discusses inspection procedures and the process for recording the information in detailed reports about the bridges' components. For some of the bridge features highlighted in this section the following rating guide was used by WYDOT to record bridge deck, bridge superstructure, and bridge substructure ratings (*FHWA 1996*).

0 FAILED CONDITION – out of service – beyond corrective action

1 IMMINENT FAILURE CONDITION – major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but with corrective action, may be put back in light service.
2 CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
3 SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
4 POOR CONDITION - advanced section loss, deterioration, spalling or scour.
5 FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
6 SATISFACTORY CONDITION - structural elements show some minor deterioration.
7 GOOD CONDITION - some minor problems.
8 VERY GOOD CONDITION - no problems noted.
9 EXCELLENT CONDITION.
N/A Not Applicable or unknown.

8.3 Bridge Data Analysis

For the preliminary assessment of the county bridges, seven different categories were examined: Year Bridge Built; Design Load; Bridge Width; Bridge Deck Rating; Bridge Superstructure Rating; Bridge Substructure Rating; and General Bridge Condition. Each category was then broken into five groups: Overall; Impacted; Non-impacted; Paved; and Unpaved. An overall analysis of each county's bridges was also included for each category. Detailed maps of these bridge condition s are shown in Appendix *F. Bridges*.

8.3.1 Year of Construction

Bridges are built to last a long time, but every bridge has a finite service life. Bridges are typically designed to provide 50 years of service, but this period can be extended with rehabilitation and favorable conditions. Table 8.2 provides a list of when the four counties' bridges were built. Over 60% of the bridges in the four counties were built more than 30 years ago, with the majority of these older bridges built in the 1970s.

Table 8.2 Wyoming Study Bridges Year of Construction

Year	1924 - 1949	1950 - 1959	1960 - 1969	1970 - 1979	1980 - 1989	1990 - 1999	2000 - 2010	Total
Impacted	6	5	3	11	4	10	6	45
Non-Impacted	7	6	10	52	11	19	13	118
Paved	4	8	5	7	6	4	8	42
Unpaved	9	3	8	56	9	25	11	121
Total	13	11	13	63	15	29	19	163

Figure 8.2 shows five categories of the percentage of bridges by year that they were built. For example in the overall category, 39% of the bridges were built in the 1970s. Two points that stand out are the high percentage of bridges built between 1924 and 1949 on impacted roads, and the high percentage of bridges built in the 1950s on paved roads.

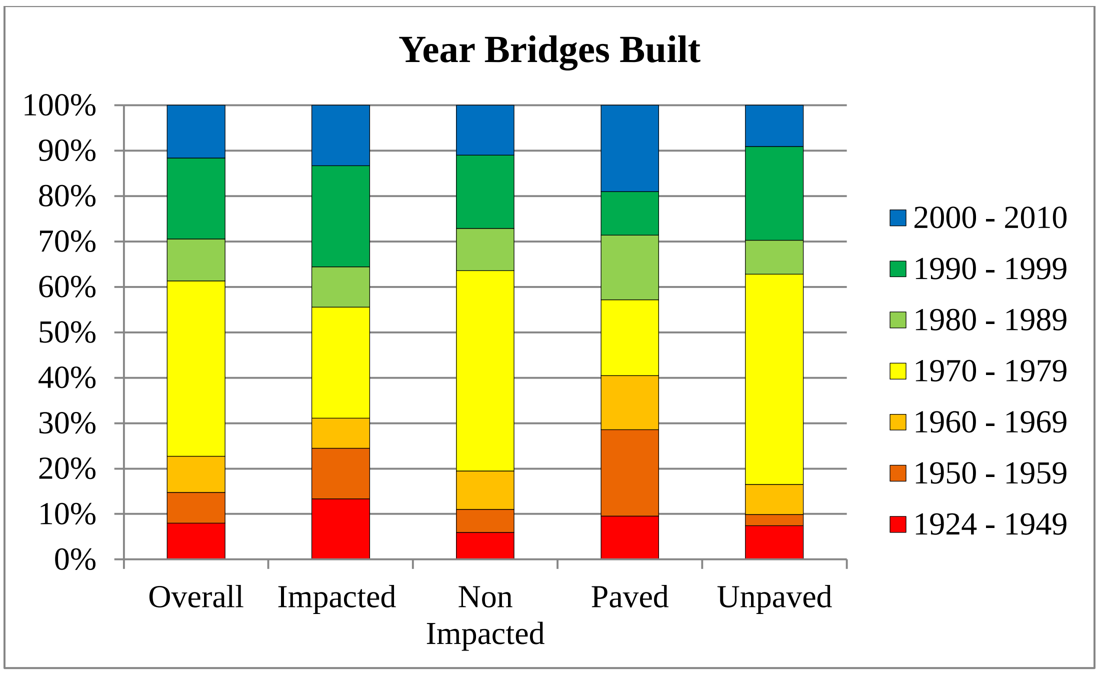


Figure 8.2 Wyoming study bridges years of construction by category.

Table 8.3 shows the year bridges were built for each county. Goshen County has the most bridges at 61, with 31 of them built in the 1970s. Converse County has five bridges built before 1950, while Laramie County has four.

Figure 8.3 shows a map of Laramie County bridges by the year they were built. Maps of all four counties showing the years their bridges were built are in Appendices *F.2. Converse County: County Bridge Years of Construction, F.8. Laramie County: County Bridge Years of*

Construction, F.14. Goshen County: County Bridge Years of Construction, and *F.20. Platte County: County Bridge Years of Construction*.

Table 8.3 Bridges Year of Construction by County

Year Built	1924 - 1949	1950 - 1959	1960 - 1969	1970 - 1979	1980 - 1989	1990 - 1999	2000 - 2010	Total
Converse	5	2	5	7	5	10	6	40
Goshen	3	5	3	31	5	12	2	61
Laramie	4	2	4	15	1	4	9	39
Platte	1	2	1	10	4	3	2	23

8.3.2 Design Load Ratings

The bridge design load indicates the live load for which the structure was designed. There are five design load designations for the four counties bridges: H 15; H 20; HS 20; HS + 20 MOD; and HS 25. An H 15 loading is represented by a two-axle single unit truck weighing 30,000 pounds (15 tons) with 6,000 pounds on its steering axle and 24,000 pounds on its drive axle. The 20 in the H 20 loading stands for 20 tons, with 4 tons on the steering axle and 16 tons on the drive axle as shown in Figure 8.4. The additional S in the HS designates that a semi-trailer is added to the design load as shown in Figure 8.5. The HS + 20 MOD indicates that the bridge is designed for military loading (*Munkelt 2010*).

Table 8.4 shows the design loads for the county bridges. Two bridges have an H 15 designation and one of them is on an impacted road. Thirty-six percent (36%) of the bridges have an HS 20 designation and 10 have an HS 25 designation. Over half of the bridges had an unknown design load. The bridges' design loads are mapped in Appendices *F.3. Converse County: County Bridge Design Loads, F.9. Laramie County: County Bridge Design Loads, F.15. Goshen County: County Bridge Design Loads,* and *F.21. Platte County: County Bridge Design Loads*.

Table 8.4 County Bridge Design Loads by Category

	N/A	H 15	H 20	HS 20	HS 20+Mod	HS 25	Total
Impacted	19	1	0	23	1	1	45
Non-Impacted	71	1	1	36	0	9	118
Paved	22	2	0	16	1	1	42
Unpaved	68	0	1	43	0	9	121
TOTAL	90	2	1	59	1	10	163

Table 8.5 shows the bridge design load for each county. Converse and Laramie Counties each have one bridge with the H 15 design load.

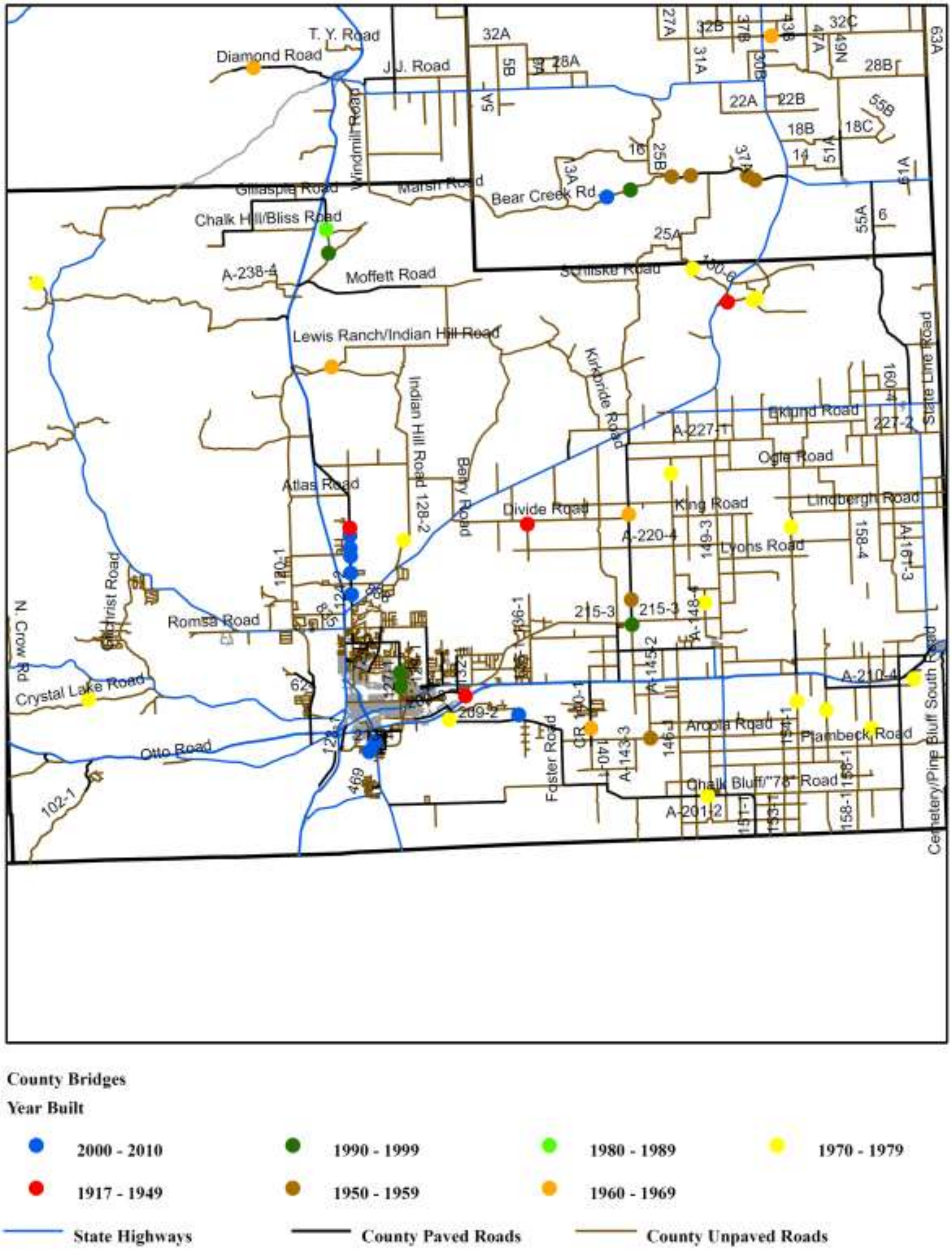


Figure 8.3 Laramie County bridges years of construction.

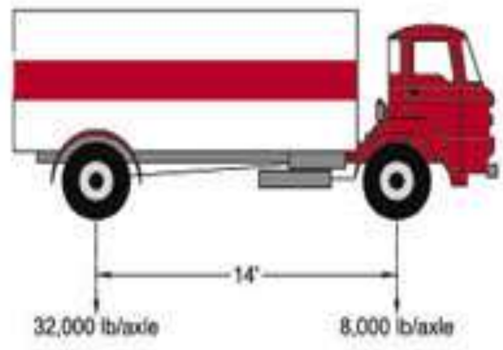


Figure 8.4 H 20 design load *(Munkelt 2010)***.**

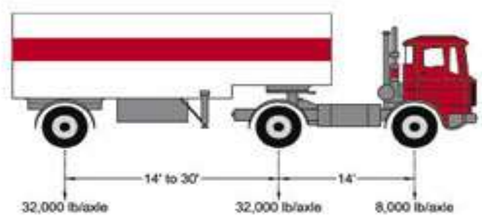


Figure 8.5 HS 20 design load *(Munkelt 2010)***.**

Table 8.5 Bridge Design Loads by County

	N/A	H 15	H 20	HS 20	HS 20+Mod	HS 25	Total
Converse	22	1	1	11	1	4	40
Goshen	42	0	0	17	0	2	61
Laramie	14	1	0	22	0	2	39
Platte	12	0	0	9	0	2	23

8.3.3 Deck Widths

The bridge deck width is the distance in feet between the bridge railings. It is important to identify any bridges on the county network that might restrict wider trucks. Table 8.6 shows the county bridge deck widths. Bridges 10 to 15 feet wide may allow only one vehicle to pass at a time, especially if it's a truck. Bridges 16 to 20 feet wide may also have difficulty allowing two trucks on the bridge at the same time. Overall, 11% of county bridges are less than 16 feet wide and 40% are less than 21 feet wide. No bridges less than 16 feet are on paved roads.

Table 8.6 Bridge Widths by Category, Feet

	N/A	10 to 15	16 to 20	21 to 25	26 to 30	31 to 35	Total
Impacted	9	5	6	14	10	1	45
Non Impacted	17	13	41	35	9	3	118
Paved	16	0	5	12	8	1	42
Unpaved	10	18	42	37	11	3	121
TOTAL	26	18	47	49	19	4	163

Table 8.7 shows the bridge width for each county. Converse County has 11 bridges less than 16 feet, which is more than the other three counties combined. Over 45 percent of Goshen County bridges are less than 21 feet wide; visual inspection showed that many of these bridges are canal crossings.

Table 8.7 Bridge Widths by County, Feet

County	N/A	10 to 15	16 to 20	21 to 25	26 to 30	31 to 35	Total
Converse	0	11	12	10	6	1	40
Goshen	7	3	25	20	4	2	61
Laramie	16	2	5	11	5	0	39
Platte	3	2	5	8	4	1	23

Figure 8.6 is a map of Goshen County bridge widths, showing most of them in the 16 to 20 foot range. Maps of all four counties showing their bridges' widths are in Appendices *F.4. Converse County: County Bridge Widths (feet), F.10. Laramie County: County Bridge Widths (feet), F.16. Goshen County: County Bridge Widths (feet),* and *F.22. Platte County: County Bridge Widths (feet).*

8.3.4 Deck Ratings

Bridge deck condition ratings consider different aspects depending on whether they are concrete, steel grid, or timber decks. For concrete decks the rater inspects cracking, scaling, spalling, leaching, chloride contamination, potholing, delamination, and full or partial depth failures. Steel grid decks are inspected for broken welds, broken grids, section loss, and growth of filled grids from corrosion. Timber decks are inspected for splitting, crushing, fastener failure, and deterioration from rot. Items not included in the bridge deck inspection are the wearing surface/protective system, joints, expansion devices, curbs, sidewalks, parapets, fascia's, bridge rails, and scuppers (*FHWA, 1996*).

Table 8.8 shows the bridge deck ratings for the four counties. Only two bridge decks were rated in critical condition but both are located on impacted roads. Almost 80% of the bridges were rated in fair condition and better.

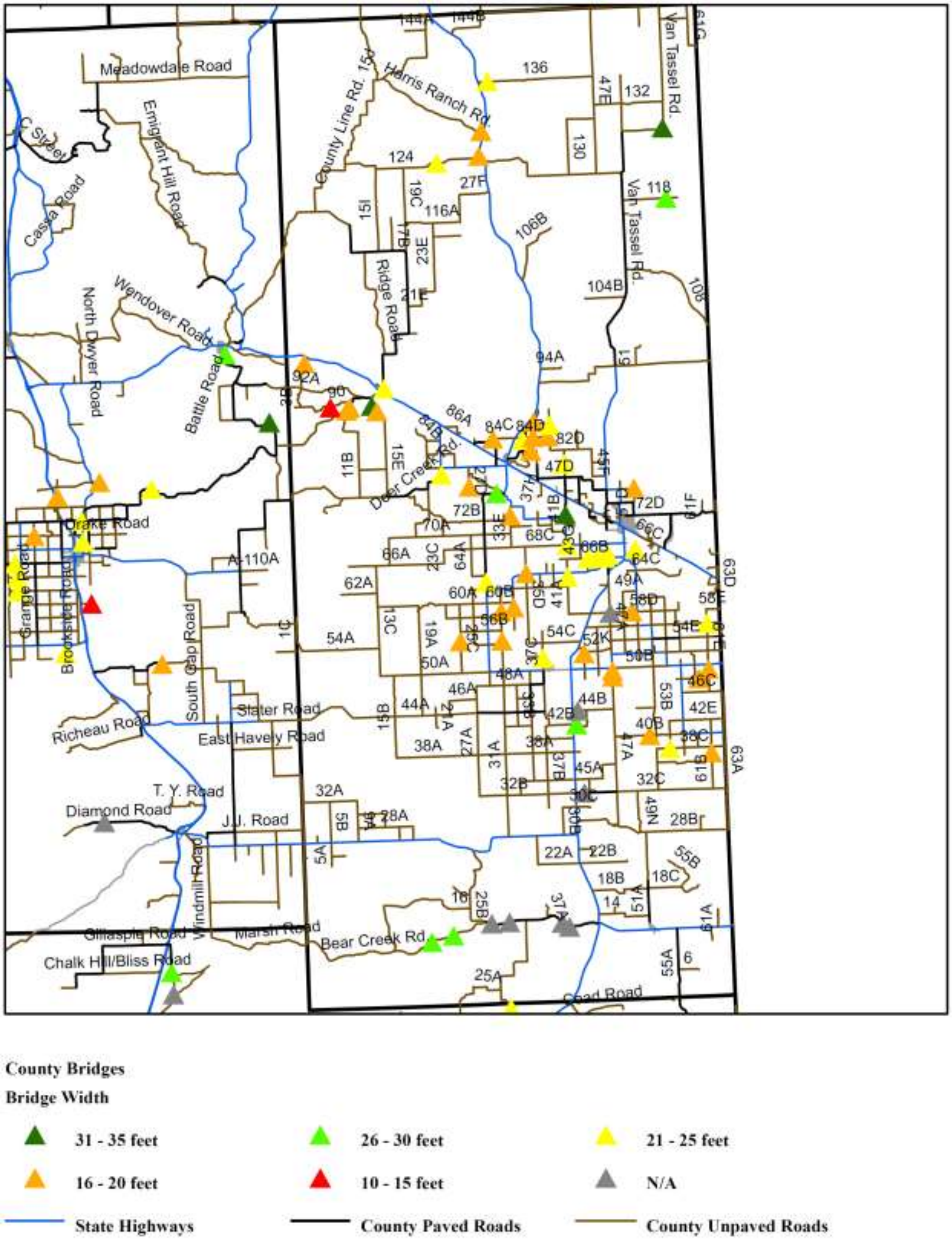


Figure 8.6 Goshen County bridge widths, feet.

Table 8.8 Bridge Deck Ratings by Category

	N/A	Critical	Serious	Poor	Fair	Satisfactory	Good	Total
Impacted	9	2	0	2	7	17	8	45
Non Impacted	18	0	1	2	33	34	30	118
Paved	16	0	0	1	10	10	5	42
Unpaved	11	2	1	3	30	41	33	121
TOTAL	27	2	1	4	40	51	38	163

Table 8.9 shows the bridge deck rating by county. Laramie County has three bridges with a rating of poor or worse. The bridge deck ratings are mapped in Appendices *F.5. Converse County: County Bridge Deck Ratings, F.11. Laramie County: County Bridge Deck Ratings, F.17. Goshen County: County Bridge Deck Ratings* and *F.23. Platte County: County Bridge Deck Ratings*.

Table 8.9 Bridge Deck Ratings by County

	N/A	Critical	Serious	Poor	Fair	Satisfactory	Good	Total
Converse	0	1	0	0	7	21	11	40
Goshen	7	0	0	2	19	16	17	61
Laramie	17	1	0	2	6	10	3	39
Platte	3	0	1	0	8	4	7	23

8.3.5 Superstructure Ratings

The bridge superstructure ratings are the physical condition of all structural members. This includes cracking, deterioration, section loss, and malfunction and misalignment of bearings. Fracture critical components receive careful attention because failure could lead to collapse of a span or of the bridge (*FHWA 1996*).

Table 8.10 shows the type of structure for the main bridge span(s) by county. Converse County has 9 of the 13 wood or timber main spans.

Table 8.10 Bridge Structure Material by County

County	Concrete	Concrete Continuous	Steel	Steel Continuous	Prestressed Concrete	Wood or Timber	Total
Converse	3	1	18	4	5	9	40
Goshen	7	8	7	6	31	2	61
Laramie	11	6	6	0	15	1	39
Platte	3	0	10	3	6	1	23

Table 8.11 shows the bridge superstructure ratings for all the counties. Seven (7) of the 163 bridges were in poor condition or worse. Satisfactory ratings were assigned to 36% of the bridges.

Table 8.11 Bridge Superstructure Ratings by Category

	N/A	**Serious**	**Poor**	**Fair**	**Satisfactory**	**Good**	**Very Good**	**Total**
Impacted	9	0	1	9	21	3	2	45
Non Impacted	18	1	5	19	38	29	8	118
Paved	16	0	2	3	11	6	4	42
Unpaved	11	1	4	25	48	26	6	121
TOTAL	27	1	6	28	59	32	10	163

Table 8.12 shows the bridge superstructure rating for each county. Converse County had three bridges in poor condition or worse. Laramie and Platte Counties had two bridges each with a Poor rating for the bridge superstructure. The bridge superstructure ratings are mapped in Appendices *F.6. Converse County: County Bridge Superstructure Ratings, F.12. Laramie County: County Bridge Superstructure Ratings, F.18. Goshen County: County Bridge Superstructure Ratings* and *F.24. Platte County: County Bridge Superstructure Ratings*.

Table 8.12 Bridge Superstructure Ratings by County

County	**N/A**	**Serious**	**Poor**	**Fair**	**Satisfactory**	**Good**	**Very Good**	**Total**
Converse	0	1	2	12	17	3	5	40
Goshen	7	0	0	5	26	21	2	61
Laramie	17	0	2	6	9	4	1	39
Platte	3	0	2	5	7	4	2	23

8.3.6 Substructure Ratings

The bridge substructure rating refers to the physical condition of piers, abutments, piles, fenders, footings, and other components. The substructure is considered to be the portion below the bearings for non-integral bridges, and for integral bridge structures the substructure is considered to be the portion below the superstructure (*FHWA 1996*).

Table 8.13 shows the bridge substructure ratings for all the bridges in the four counties. One bridge was considered to be in imminent failure condition and is located on an impacted road. Seven bridges have a poor substructure condition or worse.

Table 8.13 Bridge Substructure Ratings by Category

	N/A	Imminent Failure	Critical	Serious	Poor	Fair	Satisfactory	Good	Total
Impacted	9	1	0	1	1	4	21	8	45
Non Impacted	18	0	0	1	5	19	44	31	118
Paved	16	0	0	0	0	6	12	8	42
Unpaved	11	1	0	2	6	17	53	31	121
TOTAL	27	1	0	2	6	23	65	39	163

Table 8.14 shows the bridge substructure rating for each county. Converse County has the imminent failure condition bridge on an impacted road. Converse County also has two serious condition bridges with one on an impacted road. The bridge substructure ratings are mapped in Appendices *F.7. Converse County: County Bridge Substructure Ratings, F.13. Laramie County: County Bridge Substructure Ratings, F.19. Goshen County: County Bridge Substructure Ratings and F.25. Platte County: County Bridge Substructure Ratings*.

Table 8.14 Bridge Substructure Ratings by County

County	N/A	Imminent Failure	Critical	Serious	Poor	Fair	Satisfactory	Good	Total
Converse	0	1	0	2	3	4	17	13	40
Goshen	7	0	0	0	2	6	30	16	61
Laramie	17	0	0	0	0	7	13	2	39
Platte	3	0	0	0	1	6	5	8	23

8.4 Summary and Recommendations

The four counties requested a preliminary assessment of the oil and gas traffic impacts on their bridges. The county bridges weren't originally part of this study but were added to establish current conditions. Only general attributes were analyzed during this analysis, but in future studies a methodology for identifying rehabilitation strategies and associated costs for the counties' bridges may be developed. As part of such a methodology, routes will be identified for oil and gas companies to use that will minimize damage and risks on older, narrower bridges. Also bridges less than 20 feet long were not included in the preliminary assessment but may be added to the analysis in future studies.

For the current conditions of the four county bridges, six attributes were analyzed: Year Bridge Built; Bridge Design Load; Bridge Width; Bridge Deck Rating; Bridge Superstructure Rating; and Bridge Substructure Rating.

Analysis of when bridges were built shows that 24 of the 163 bridges were built over 50 years ago. These bridges may have outlived their service life, though most of their useful lives can be extended with rehabilitation. Over 60% of the counties' bridges were built over 30 years ago, so in another 10 to 20 years most of them will have reached the end of their anticipated design life. The impacted roads have a higher percentage of bridges over 50 years old than the counties' bridges on non-impacted roads. The design load for the county bridges was examined to determine if they are capable of carrying the heavy loads associated with the oil and gas industry. Only two of the 163 bridges had an H15 design load. However, 40% of the bridges are less than 21 feet wide. The narrower bridges need appropriate signage so that only one direction of traffic will cross them at a time.

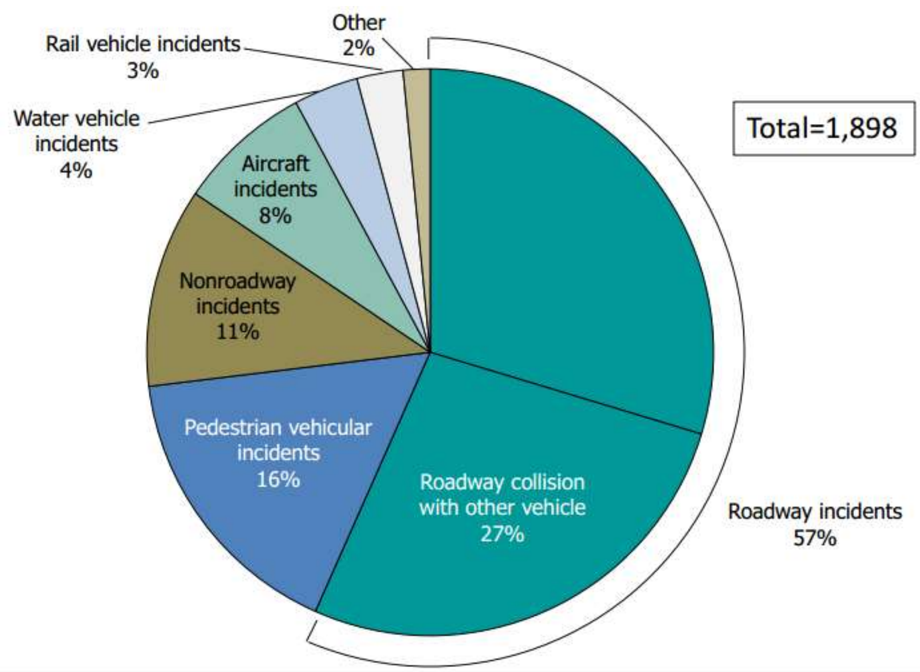
The bridge deck rating was examined next. Two bridge decks, both of which are on impacted roads, were in critical condition. Almost 80% of the bridge decks were in fair condition or better, though as many of the bridges built in the 1970's approach the end of their design life, many of the fair and satisfactory decks may soon fall into poor or worse condition. The structure type for the main bridge span(s) was also examined. Wood or timber bridges may wear faster and need different rehabilitation than the other span types. Wood or timber span bridges comprise 13 of the 163 bridges; 9 of them are in Converse County.

The bridge superstructure ratings show that 7 of the 163 bridges are in poor condition or worse, while 36% of the bridges have a satisfactory rating. One bridge substructure on an impacted road was rated as being in imminent failure condition. Seven bridges have a poor substructure or worse.

9. SAFETY

Oil and gas extraction is a growing industry in many parts of the United States. This is leading to substantial increases in heavy truck traffic on many local roads. The National Institute for Occupational Health and Safety (NIOHS) performs an annual study called the Census of Fatal Occupational Injuries (CFOI) examining the number of fatalities afflicting field workers *(Conway and Mode 2008)*. Following a 15% increase in fatalities for field workers from 2003 to 2004 *(USDOL 2006)*, a full investigation was performed which revealed that from 2003 through 2006, 404 fatalities happened among extraction workers. Of these fatalities, 110 were highway-related incidents, classified as non-collision, collision between vehicles, or other events.

The results of the CFOIs conducted over the past 10 years show that highway crashes were consistently one of the leading causes of worker fatalities. The 2011 CFOI data indicates that the mining industry had the second highest worker fatality rate, the majority of which occurred in the oil and gas extraction industries with roadway incidents accounting for 23% of all the field worker fatalities. As shown in Figure 9.1, the majority of the transportation-related fatalities were the result of a roadway incident, and over a quarter of all incidents involved a collision with another vehicle *(USDOL 2012)*.



Roadway incidents accounted for the greatest number of work-related transportation fatalities. Of these, 512 deaths resulted from a roadway collision with another vehicle. Pedestrian vehicular incidents constituted the second greatest number transportation-related fatal injuries.

Figure 9.1 Fatal transportation incidents by type *(USDOL 2012)*.

A safety survey was conducted in Western North Dakota examining the public view of the impacts of increased oil drilling *(NDDOT 2008)*. Their research shows a significant increase in both truck traffic and crashes within the counties which have seen the largest increases in oil drilling. The survey revealed that 89% of the drivers in the affected counties felt less safe driving on the roads than they did five years ago, which is approximately when much of the drilling started increasing. In an attempt to reduce the number of crashes, researchers asked if the public would be in favor of paying for an incident messaging system or for more visible traffic enforcement. The response was more positive toward the increased enforcement. The survey also found that drivers would be willing to drive for longer periods of time if it meant better driving road conditions and fewer trucks *(Kubas and Vachal 2012)*.

As part of a comprehensive strategy to mitigate the effect the oil and gas industry has on county roads, a preliminary safety assessment was performed. This preliminary safety assessment was not originally part of the overall study but was added to demonstrate the need for a more in-depth safety evaluation. This section considers the number of crashes on county roads as well as the severity of each crash. Also, crashes were identified as occurring either on an unpaved or paved road to get a better understanding of how the crashes are distributed on each of the counties roads. All of the crashes were mapped in ArcGIS and are shown in Appendix G. Crashes. This helped verify the locations of the crashes and to visualize trends on a network-wide map.

9.1 Data Collection

The Critical Analysis Reporting Environment (CARE) software package was used to identify and compile crash data for the four counties. Quality checks were performed at multiple stages of the analysis. The database with a total of 10 years and 3 months, included only the crashes in Converse, Goshen, Laramie, and Platte Counties. Crashes were also limited to those on county roads, excluding roadways owned and maintained by the state, such as interstates and major highways.

Once the applicable crash data was extracted from the CARE software, the results were exported into a Microsoft Excel file and also displayed as an ArcGIS map for further evaluation and quality checks. Crashes were identified as either fatal, injury, property damage only (PDO), or unknown. Crashes of interest, those on the local road network, were mapped along with the roads' classifications. In order to be analyzed as a paved or unpaved road crash, the crash points needed a verified ML road identification number and a latitude-longitude location. Upon further inspection, some points were found to be listed without an ML number or a GPS coordinate. If a route number or location for these points could not be confirmed, they were removed from the final analyzed data set. This difference in the total number of crashes analyzed accounts for differentiation between "All Crashes" and "Crashes with Confirmed Locations" in Table 9.1. During further analysis, only the crashes with confirmed locations were used due to the necessity of knowing whether their location lies on a paved or unpaved road.

The road surface type was determined using the map generated by ArcGIS. Each crash point with a verified location was classified as being on a paved or unpaved road. Individual crash data points were compiled into a Microsoft Excel file along with all of their crash data including:

- County
- Latitude and Longitude
- Route ID
- ML Number
- Time Frame and Date
- Number Killed
- Crash Severity
- First Harmful Event
- Manner of Collision
- Roadway Surface

Table 9.1 All County Crashes from January 2002 to April 2012

		All Crashes		Crashes with Confirmed Locations	
County	**Length, miles**	**Total Crashes**	**All Injury & Fatal Crashes**	**Crashes with Confirmed Locations**	**Injury & Fatal Crashes with Confirmed Locations**
Converse	610.7	330	112	329	104
Goshen	916.5	287	99	284	99
Laramie	1229.9	514	220	473	203
Platte	559.2	355	127	319	108
Total	3316.3	1486	558	1405	514

9.2 Data Analysis and Results

9.2.1 Crash Rates per Mile

Analysis of the crashes are shown in Table 9.2 for Converse, Goshen, Laramie, and Platte Counties' roads. The total number of crashes for all four counties are shown as well as the average for each column. Platte and Converse Counties had the highest total crashes per mile per year with Laramie County next and Goshen County with the lowest crash rate.

This table shows that the highest crash rates per paved mile are on Converse County's roads with 0.065 injury or fatal crashes per mile per year. The other three counties' paved roads had rates less than the average rate of 0.038 injury or fatal crashes per mile per year. This observation reflects the substantially higher traffic volumes and truck traffic (see Chapter 3. Traffic Counts) on Converse County's roads.

On unpaved roads, Converse and Laramie Counties have similar rates of 0.034 and 0.035 crashes per mile per year, respectively, while Goshen County has a much lower rate of 0.024. The highest crash rate on unpaved roads occurred in Platte County with 0.043 crashes per mile per year.

Table 9.2 Number of Crashes with Confirmed Locations on County Roads

All County Roads					
County	**Length, miles**	**Total Crashes**	**Total Crashes per Mile per Year**	**Injury & Fatal Crashes**	**Injury & Fatal Crashes per Mile per Year**
Converse	610.7	329	0.053	113	0.018
Goshen	916.5	284	0.030	99	0.011
Laramie	1229.9	473	0.038	203	0.016
Platte	559.2	319	0.056	115	0.020
Total	3316.3	1405		530	
Average	829.1	351.25	0.044	132.5	0.016
Paved					
County	**Length, miles**	**Total Crashes**	**Total Crashes per Mile per Year**	**Injury & Fatal Crashes**	**Injury & Fatal Crashes per Mile per Year**
Converse	90.2	147	0.159	60	0.065
Goshen	123	92	0.073	38	0.030
Laramie	225.2	112	0.049	52	0.023
Platte	156.5	143	0.089	52	0.032
Total	594.9	494		202	
Average	148.7	123.5	0.092	50.5	0.038
Unpaved					
County	**Length, miles**	**Total Crashes**	**Total Crashes per Mile per Year**	**Injury & Fatal Crashes**	**Injury & Fatal Crashes per Mile per Year**
Converse	520.5	182	0.034	53	0.010
Goshen	793.5	192	0.024	61	0.008
Laramie	1004.7	361	0.035	151	0.015
Platte	402.7	176	0.043	63	0.015
Total	2721.4	911		328	
Average	680.4	227.8	0.034	82	0.012

Figures 9.2 to 9.7 show crash rate trends observed for each county for all roads with confirmed locations. The average crash rate for each analysis is displayed horizontally across each graph. Each group includes trends for total crashes and injury and fatal crashes per mile per year.

Figures 9.2 and 9.3 show that Converse and Platte Counties are above the average crash rate for total crashes per mile per year. Laramie and Goshen Counties' total crash rates are both under the average. Platte County had the highest injury and fatal crash rate for all roads while Laramie and Converse Counties had injury and fatal crash rates closer to the average.

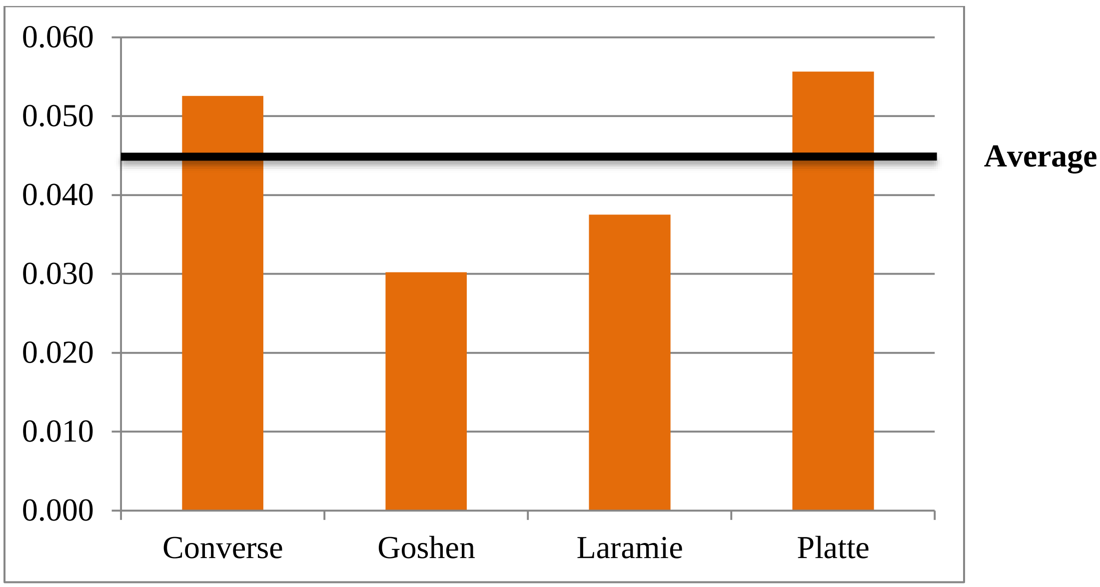


Figure 9.2 Total crashes per mile per year.

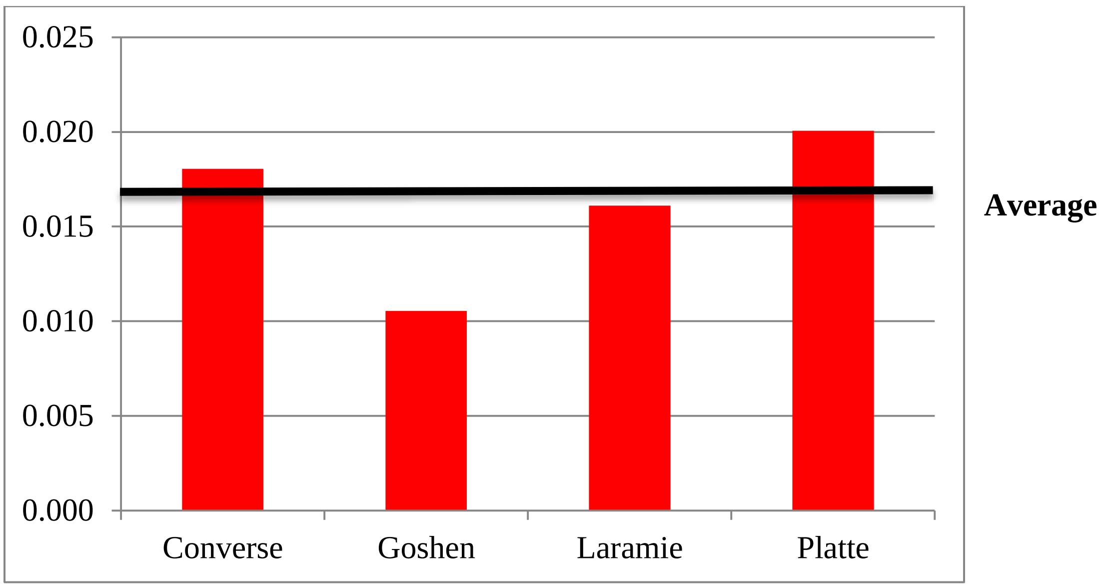


Figure 9.3 Injury & fatal crashes per mile per year.

The data for paved county roads is displayed in Figure 9.4 and Figure 9.5. Converse County has a significantly higher than average crash rate for total crashes and the injury & fatal crashes on paved roads. Converse County has a total crash rate of 0.159 crashes per mile per year, while the average is approximately half of that at 0.092 crashes per mile per year. The average injury and fatal rate is 0.038 crashes per mile per year, while Converse County's is 0.065, which is more than double Platte County's rate of 0.32.

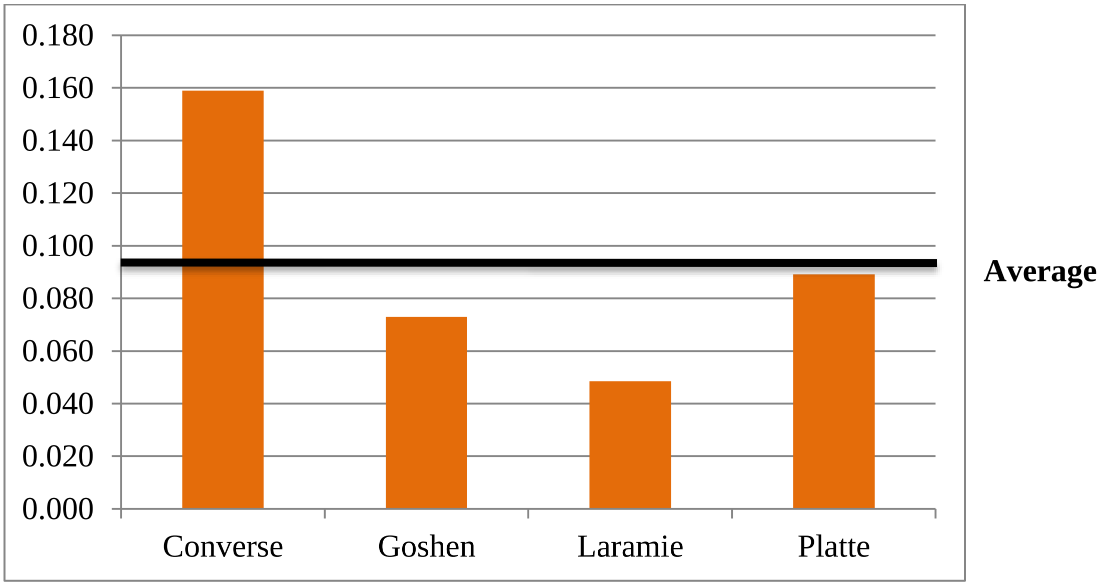


Figure 9.4 Total crashes per mile per year on paved roads.

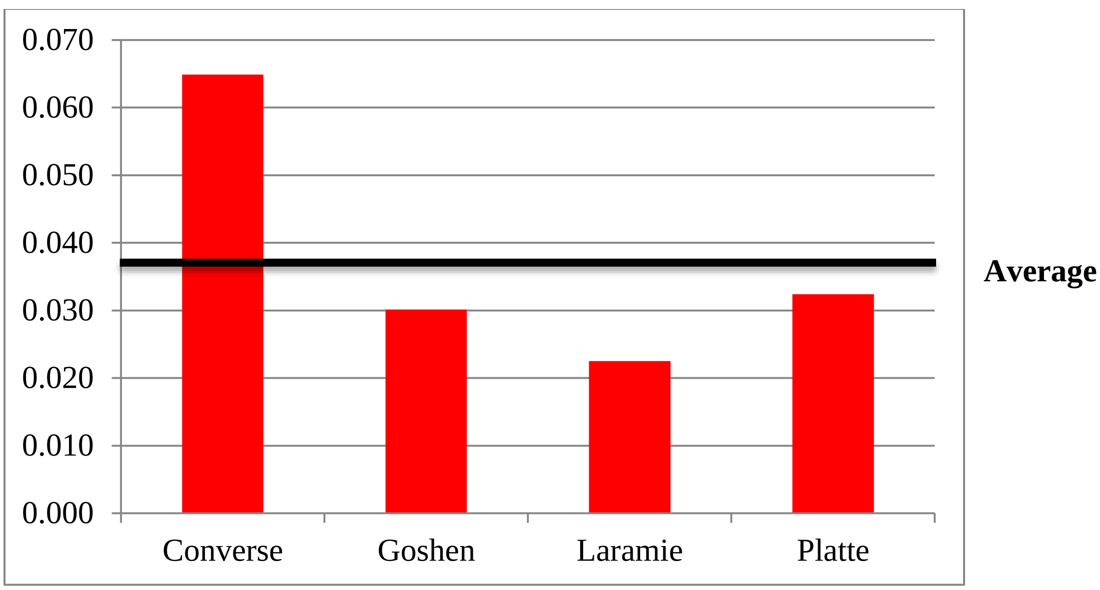


Figure 9.5 Injury & fatal crashes per mile per year on paved roads.

The crash rates per mile per year for unpaved roads are displayed in Figures 9.6 and 9.7. Laramie and Converse Counties are close to the average crash rates while Laramie County is above the average for injury and fatal crashes. Platte County has higher than average rate for both total crashes and injury and fatal crashes.

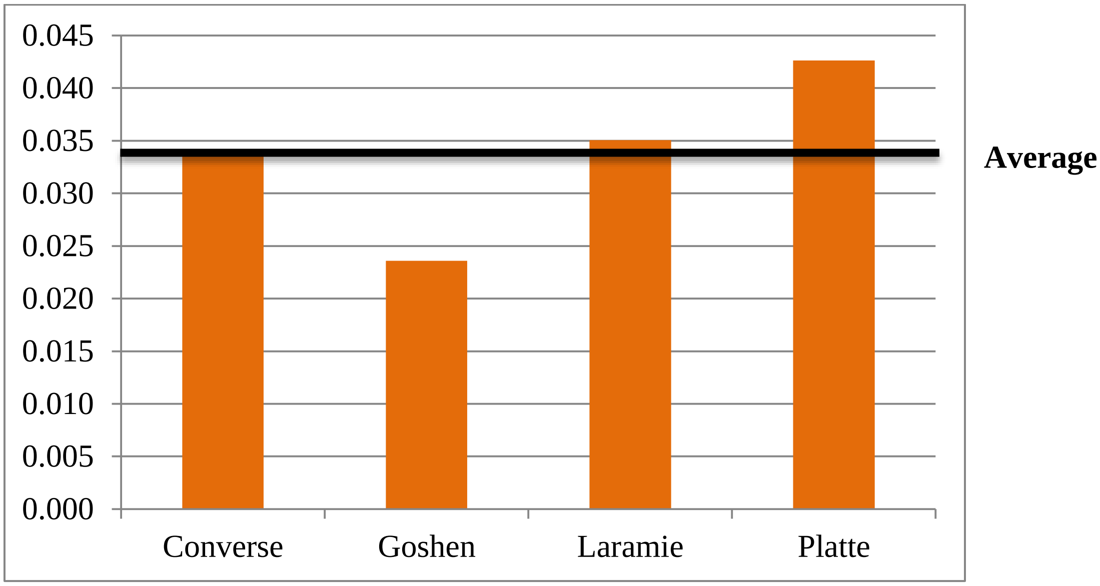


Figure 9.6 Total crashes per mile per year on unpaved roads.

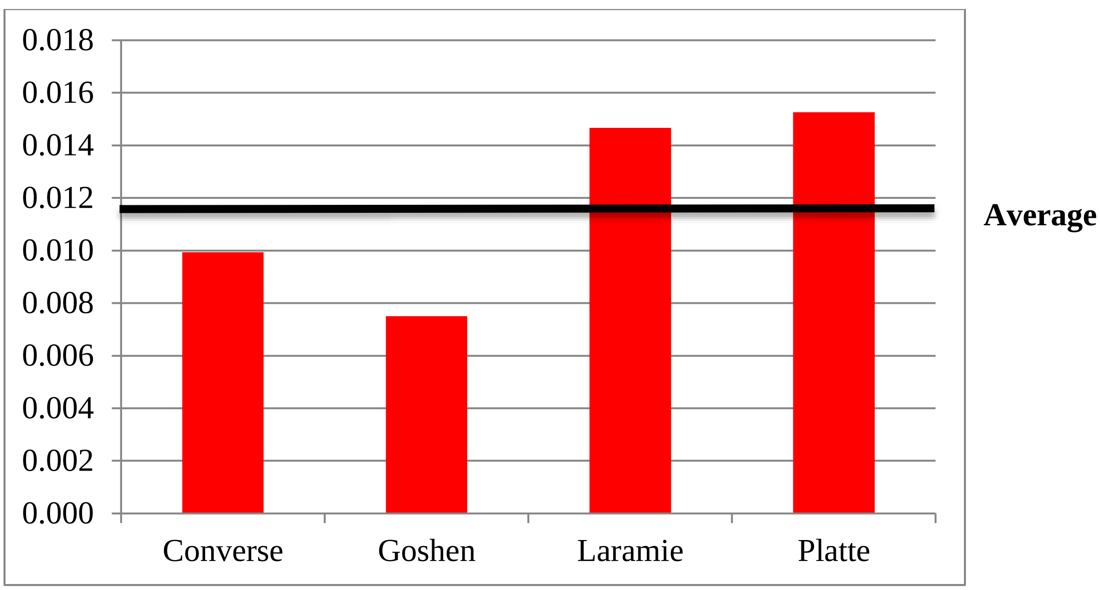


Figure 9.7 Injury & fatal crashes per mile per year on unpaved roads.

9.3 Conclusions and Recommendations

A preliminary safety assessment was performed for the four counties in the study. The safety assessment was added to the study to get a network-wide view of the crashes in each county. A total of 1,486 crashes were obtained from the CARE program with 1,405 locations verified in ArcGIS and through the route identification number. The county crashes were analyzed on a county by county basis and by roadway surface type. The crash numbers and trends showed that Converse County has more than double the total crash rate on paved roads than the other three counties. Converse County has a smaller network which concentrates traffic on those roads. Most of their paved roads north of the Platte River are used as connectors to be used in the oil and gas industry. This has increased the traffic volumes which has in turn increased the number of crashes on those roads. It is recommended that a detailed crash analysis be performed on Converse County's paved roads to improve the safety for the whole network. Laramie and Platte Counties experienced a higher than average rate of injury and fatal crashes on their unpaved roads. The injury and fatal crashes should be analyzed in more detail to find any trends for the serious crashes on their unpaved roads.

Roadway crashes are one the most dangerous aspects for field workers in the oil and gas industry. Putting heavier vehicles on the roadway also creates additional hazards for the traveling public. It is recommended that the safety of local roads be fully investigated in future studies in order to ensure the safety of the users of county roads.

10. PERMITTING

10.1 Background

Permits for the use of state and county roads in Wyoming take several forms. Oversize and overweight, road use agreement, and access permits are the main focus of this effort to describe the current status of road permitting in Wyoming. Address request applications are another form of permitting; these are not addressed in this report. The permitting process is not consistent from county to county. The permitting process may be complicated and tedious, particularly for the oil and gas industry.

Oversize and overweight permits have met with the least success, largely due to the amount of heavy truck traffic and the counties' lack of manpower to issue permits for every load. Standardizing the permitting processes could reduce the effort put forth by the counties' and also regulate the oil and gas industry, particularly truck traffic on county roads. In the long run, this could help improve roadway safety and reduce the costs to the counties of maintaining their roads. Oil and gas companies could help pay for this maintenance while saving the counties time and money.

10.1.1 Texas Permitting Processes

Attempts in Texas to regulate truck traffic, largely generated by energy development, consist of requirements that users complete certain permits related to their operations. Current energy operations in Texas have led to the development of three different strategies to compensate state and local governments for the impact of these operations *(Miller and Sassin 2012).* Through these three methods described in the following paragraphs, a dramatic increase has been seen in local government funding by those agencies which have adopted these strategies.

A proactive, performance-based approach consists of strengthening roads in anticipation of energy development, then assessing fees to compensate state and local agencies for facility damage during drilling operations. If funds are spent upfront to preserve the roads, spending will be reduced by 700% compared to situations in which the road is left to be damaged and rebuilt continuously in order to handle the impact *(Miller and Sassin 2012).*

A reactive, performance-based approach looks at the aftermath of energy development impacts and then assesses fees associated with resulting damages. This is also known as a Road Use Agreement, a binding agreement holding energy companies responsible for any road damage they cause. This damage is assessed by examining the road before and after the company's use of it.

A reactive, non-performance based approach has no relation to the actual deterioration of a roadway, but is a simple road damage fee assessed on each well.

10.1.2 Wyoming Oil and Gas Permits

The number of permits issued in southeast Wyoming has increased substantially over the past several years, largely due to oil and gas drilling. Permits for land use and road infrastructure are currently being used to regulate the oil and gas industry and compensate for road damage. For a better understanding of this impact and the permits associated with it, accepted oil and gas permits were examined and summarized. Figure 10.1 shows the approved oil and gas permits from the Wyoming Oil and Gas Commission in the four counties by year *(WOGCC 2012)*.

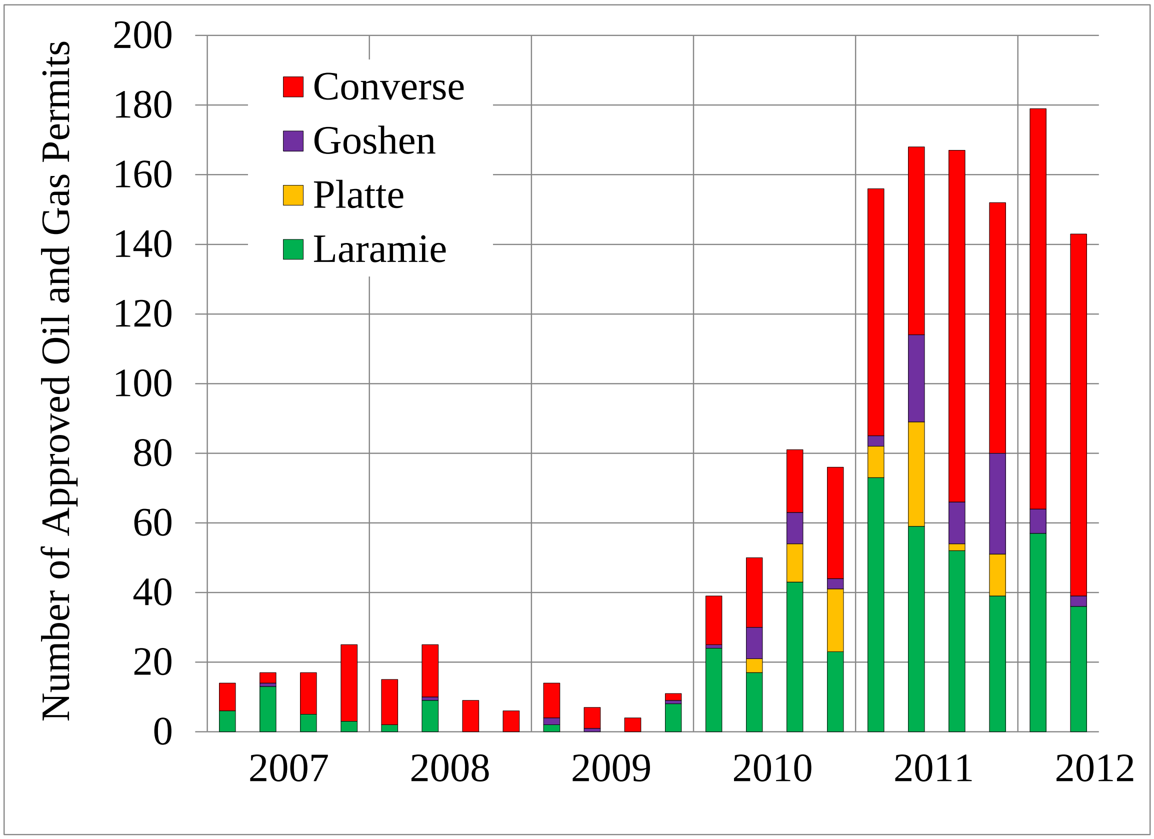


Figure 10.1 Approved oil and gas permits by county and quarter *(WOGCC 2012)***.**

A dramatic increase in the approved oil and gas permits began in 2010 and continues into 2012. Converse and Laramie Counties have had a larger number of accepted permits during this time period. With the heavy amount of traffic associated with this industry, permitting should be a necessity at this point. Unfortunately, of the four counties in this study, only Laramie and Goshen Counties have permits associated with this heavy traffic.

10.1.3 WYDOT and the WHP

A meeting with the Wyoming Highway Patrol (WHP) and others with WYDOT *(Smith 2012)* was held March 7, 2012 to gain a better understanding of their procedures and what the permitting processes were for the trucking industry. Appendix *I.1. WYDOT and WHP Permitting Meeting: March 7, 2012* contains a summary of this meeting. Questions were asked regarding heavy truck permits and what is currently being accomplished by the WHP. These questions are presented in Appendix *I.2. Permitting Survey Questions Asked of Counties*. Through this meeting and these questions, it became apparent that the WHP currently has only the oversize/overweight permit. Table 10.1 shows the approved WHP oversize/overweight permits issued per year.

Table 10.1 Number of Oversize/Overweight Permits Issued by the WHP per Year

2007	2008	2009	2010	2011
120,663	126,970	106,340	101,915	114,405

To handle the massive amount of oversize/overweight permit applications on the state's highways, the WHP has over 100 people in their permitting department. For their overweight permits, the WHP charges $0.06 for each ton in excess of the legal weight and each mile traveled along with a base fee of $40.00. Oversize permits are charged $0.03 for each foot in excess of the legal limit with a base fee of $25.00. WHP representatives thought that the counties would encounter difficulties enforcing these permits since the counties lack the scales needed to weigh the trucks and determine the appropriate permit for a load.

10.2 Standardizing County Permits

An evaluation of Wyoming counties' truck permitting processes was conducted in the fall of 2011 and spring of 2012. The intent of this evaluation was to develop a standardized set of permits and a common permitting process across Wyoming so that compliance with permits and fees would be encouraged. Through research of each Wyoming county's website, information about trucking industry permits was gathered along with the permits themselves. Pertinent information, such as fee schedules, rules, regulations, and specifications, was tabularized under each permit type in each county to compile, compare, and assess the current permitting processes being used by Wyoming counties. Through this process, it was found that the most common truck permits are access permits, road use agreements, and oversize/overweight permits. To confirm that nothing was missed during this initial data collection, a survey of all Wyoming counties was conducted with a common set of questions. Through these questions it was determined whether any permits were missed in any of the counties, and the information gathered from the websites was verified. It was also determined whether any other permits or processes were being used to mitigate energy-related truck traffic.

With the information gathered from the survey, the original data from the websites was updated. At this point a standardized permit was developed using all the information gathered. The similarities of each permit were examined and included in the standard permit. Each county permit was individually inspected, and portions that were deemed too important to leave out were incorporated into the standard permit. This was a difficult task since there was an obvious reason for each item in every individual permit, but an overly lengthy permit is undesirable.

10.2.1 Survey Results

Data collected from each county's website gave detailed specifications and fee schedules for their trucking permits. These permits included access permits, road use agreements, and oversize/overweight permits. After analyzing the websites for each county, the survey shown in Appendix *I.2. Permitting Survey Questions Asked of Counties* was distributed to each county to verify the initial information. Table 10.2 shows the trucking permits in use by each county.

Table 10.2 Trucking Permits by Type and Wyoming County

	Permit Type		
County	**Oversize/ Overweight**	**Road Use Agreement**	**Access**
Albany	--	√	√
Big Horn	--	--	√
Campbell	--	--	--
Carbon	--	--	√
Converse	--	--	√
Crook	√	--	√
Fremont	--	--	√
Goshen	√	√	√
Hot Springs	--	--	√
Johnson	--	√	√
Laramie	√	√	√
Lincoln	--	--	√
Natrona	--	--	√
Niobrara	--	--	--
Park	--	--	√
Platte	--	--	√
Sheridan	--	--	√
Sublette	--	--	√
Sweetwater	--	--	√
Teton	--	--	√
Uinta	--	--	√
Washakie	--	--	--
Weston	--	--	--
TOTAL	3	4	19

Most of the information from the initial examination of the counties' websites was correct, and most counties' permits were found on their websites. However, not all of the permits were found on the websites, and some of the information on the websites may have been outdated. Although it appears that many of the counties were in the process of updating their permits, there was only one county that was creating new permits during this survey and project. Therefore, there was only one county that had outdated information.

Currently, Laramie and Goshen Counties have the most up-to-date permitting and have all three trucking permits. Unfortunately, Platte and Converse Counties do not have either oversize/overweight permits or road use agreements which help regulate energy traffic and provide financial compensation for road damage. For the oversize/overweight permit in Laramie County, the fee schedule is the same as the fees charged by the WHP. However, Goshen County charges $0.03 per foot in excess of legal size limits per mile with a base fee of $15.00 for oversize loads, and $0.04 per ton in excess of legal weight limits per mile with a base fee of $25.00 for overweight loads. Goshen County's oversize/overweight permit contains a rig movement option that requires the energy company to pay a "one-time oil drilling rig move option" that varies by whether or not the movement originates within the county. The rig movement option from outside the county is a one-time, $1000 charge, while the rig movement option within the county is $250. Weight and lengths must still be specified in both counties' oversize/overweight permits.

10.3 Permitting Cost Analysis

Laramie County data shows that little income is generated from the oversize/overweight permits. Table 10.3 shows the revenue from the oversize/overweight permits filed each year since 2007.

Table 10.3 Laramie County Oversize/Overweight Permits Issued and Revenue

Number of Permits Issued Annually				
2007	**2008**	**2009**	**2010**	**2011**
0	81	45	343	805
Fees Collected Annually				
2007	**2008**	**2009**	**2010**	**2011**
$0	$3,240	$1,800	$13,720	$49,940

Considering the truck traffic volume from oversize/overweight permits, there does not seem to be a great deal of compensation to Laramie County for the cost of road damage and repair. However, if Laramie County, and other counties for that matter, were to adopt the reactive, non-performance base system from Texas, revenue generated from energy companies would see a significant increase. Table 10.4 projects the revenues that would have been collected with a flat $8,000 fee per well.

Using the reactive, non-performance based approach would have generated $1,024,000 for Converse County, $96,000 for Goshen County, $608,000 for Laramie County, and $8,000 for Platte County. Comparing these numbers to Laramie County's revenue generated from the oversize/overweight permits between 2007 and 2011, the county would have generated about

$558,000 in additional revenue during those 5 years. This sum, along with the oversize or overweight permits and any other permits required of the energy industry, would have gone a long way towards mitigating the additional road repair costs necessitated by oil and gas-related traffic.

Table 10.4 Projected County Revenue Generated from a Reactive, Non-Performance Based Permit Fee System (Assuming $8,000 per Well Fee)

Year	2006	2007	2008	2009	2010	2011	TOTAL
				Converse County			
Wells	20	9	19	6	30	44	128
Projected Revenue	$160,000	$72,000	$152,000	$48,000	$240,000	$352,000	$1,024,000
				Goshen County			
Wells	1	0	1	0	6	4	12
Projected Revenue	$8,000	$0	$8,000	$0	$48,000	$32,000	$96,000
				Laramie County			
Wells	0	11	6	4	31	24	76
Projected Revenue	$0	$88,000	$48,000	$32,000	$248,000	$192,000	$608,000
				Platte County			
Wells	0	0	0	0	1	0	1
Projected Revenue	$0	$0	$0	$0	$8,000	$0	$8,000
				Four-County Totals			
Wells	21	20	26	10	68	72	217
Projected Revenue	$168,000	$160,000	$208,000	$80,000	$544,000	$576,000	$1,736,000

10.4 Standard Permits

Standardized, statewide permits with a common set of fees, rules, regulations, conditions and specifications were developed. This was done by taking into consideration the most important aspects of each rule and regulation and, most importantly, the safety and welfare of the traveling public.

10.4.1 Access Permit

The standardized access permit begins with a first page of general information involving the licensee, the location of the property and the permit fee. The fee for the standardized access permit includes a $75.00 processing fee and an inspection fee of $32.50/hour. The next three pages of the permit describe the rules, regulations and specifications required for this permit. The fifth page of the permit consists of the county's approval. The last two pages of the permit are drawings associated with the specifications to create a better understanding of what is being requested. The standardized access permit is shown in Appendix *I.3. Standard Access Permit*.

10.4.2 Road Use Agreement

The standardized road use agreement contains mostly rules and regulations due to the nature of the permit itself. The first page defines the company's business and their intended use of the road, where their business is taking place, the roads that are going to be used due to their business, the length of time they expect to use these roads, approximately how many loads of legal limit will be transported on these roads, and so on. The next two and half pages describe the rules and regulations associated with this permit. The main purpose of the rules and regulations is to protect the county roads and indemnify the county. The last page of this permit, as with the access permit, consists of the required signatures. The standardized road use agreement is shown in Appendix *I.4. Standard Road Use Agreement*.

10.4.3 Oversize/Overweight Permit

The first page of the oversize/overweight permit contains information about the load and the company applying for the permit. The rest of the permit specifies the rules and regulations required when hauling an oversize/overweight load, the specifications for an oversize/overweight load, the fee schedule, and tables to evaluate an oversize load. The standard oversize, overweight permit can be found in Appendix *I.5. Standard Oversize/Overweight Permit*.

10.5 Summary and Conclusions

The WHP was interviewed during the meeting in March 2012 to see what their thoughts and opinions were about the permitting of energy-related traffic. They believed that there was a definite need for regulating this traffic through permitting. They also believed that a denied oversize/overweight load will go out of their way to move the load, including using county roads. Because of the lack of manpower, resources, and enforcement to handle the permitting in the counties, there is a good chance that these loads are missed. With this in mind, Smith and Mickelson suggested that the counties should adopt the WHP standards for oversize/overweight permits and should set up a statewide website to have a standardized process and permits for the energy industry to improve efficiency.

Standardized permits and a uniform process throughout the state would create a more efficient use of time and money for the counties. One of the most important aspects of permitting is to manage the energy-related companies and their traffic on the county roads. It would be extremely beneficial to both the counties and the energy companies to use these standard permits and a uniform process. By integrating the necessary permits into each county and having them standardized across the State of Wyoming, it will be possible to create some control on these companies, an issue that has been strongly emphasized by the counties.

Although these concepts may be extremely beneficial in the long run, for short-term remediation, or until the oversize/overweight permits and road use agreements become more effective, it is suggested that counties adopt the one-time fee per well using the reactive, non-performance based approach used in Texas. This will allow the counties to mitigate some of the damage incurred from heavy truck traffic on county roads and bridges. This will also help the counties handle the many oversize/overweight permits and road use agreements generated by the energy industry. This strategy would also solve the problem of the counties having to enforce the oversize/overweight permits and their inability to do so. Regardless of the procedure, however, the permitting and costs of the heavy truck traffic will be in the hands of the counties and it will be their final decision as to how they will address this issue.

11. COUNTY RESOURCES

To evaluate the ability of each of the four counties to meet changing and expanding demands for road and bridge maintenance and construction due to oil and gas drilling activities, each county was asked to complete a county resources survey to assess their available funding and personnel. The counties were also asked to provide insight into the distribution of costs between maintenance and construction. The county resource survey responses from each county are shown in Appendices *J.1* through *J.4*.

Each county's responses were analyzed individually to assess the county's ability to provide sustained service with increased oil and gas activity. The counties were analyzed individually instead of together since each has its own, unique situation. Using the information collected with the county resources survey, budget and personnel data were plotted to help understand how each county has been affected by increased oil and gas impacts and how the county responded. Also, it was possible to see whether or not each county had the personnel available to handle increased maintenance efforts made necessary by increasing oil and gas-related traffic. The following sections discuss each county's ability to handle increases in traffic due to oil and gas drilling activities.

11.1 Converse County

Converse County maintains 90 miles of paved and 525 miles of unpaved roads. Based on the results of this study, Converse County has experienced significant increases in oil and as traffic in the past several years. One would expect to see an increased operating budget reflecting this increased impact and the corresponding need for more road maintenance. Figure 11.1 shows the five year trend for the operating budget of Converse County. The budget shows slight increases in recent years reflecting increased oil and gas activity.

County personnel were also evaluated in the survey. Figure 11.2 shows the number of employees and employee expenditures in Converse County over the past five years. Converse County has had a fifteen member team through the past five years and has seen very little in terms of expenditure increases during this time. No additional employees have been added with the increases in oil and gas traffic.

Ideally, increased oil and gas impacts on county roads would be balanced by increased maintenance and construction costs. Based on the county resources survey, maintenance and construction costs were plotted for the past five years. All maintenance costs were divided into four asset types: paved roads, unpaved roads, bridges, and culverts. Figures 11.3 and 11.4 show each asset type's maintenance and construction costs over the past five years. Figure 11.3 shows increases in both paved and unpaved maintenance costs through the five year period.

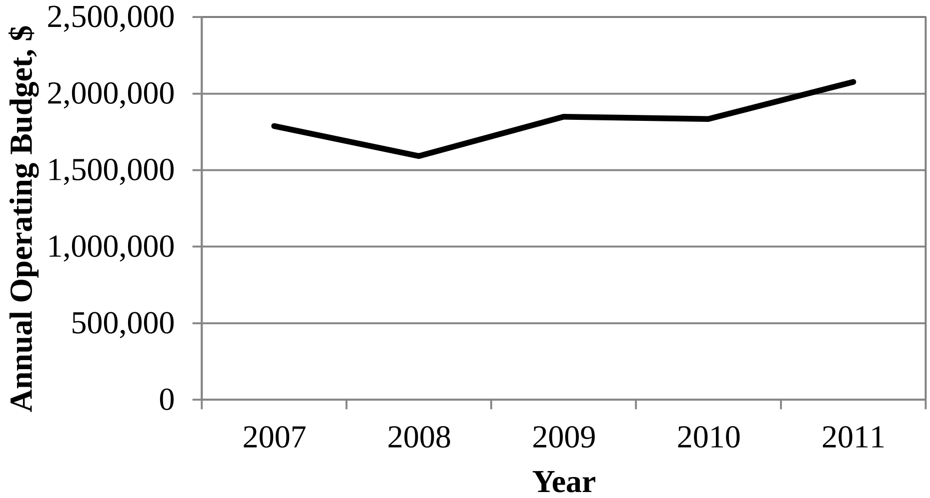


Figure 11.1 Converse County annual operating budget, 2007 - 2011.

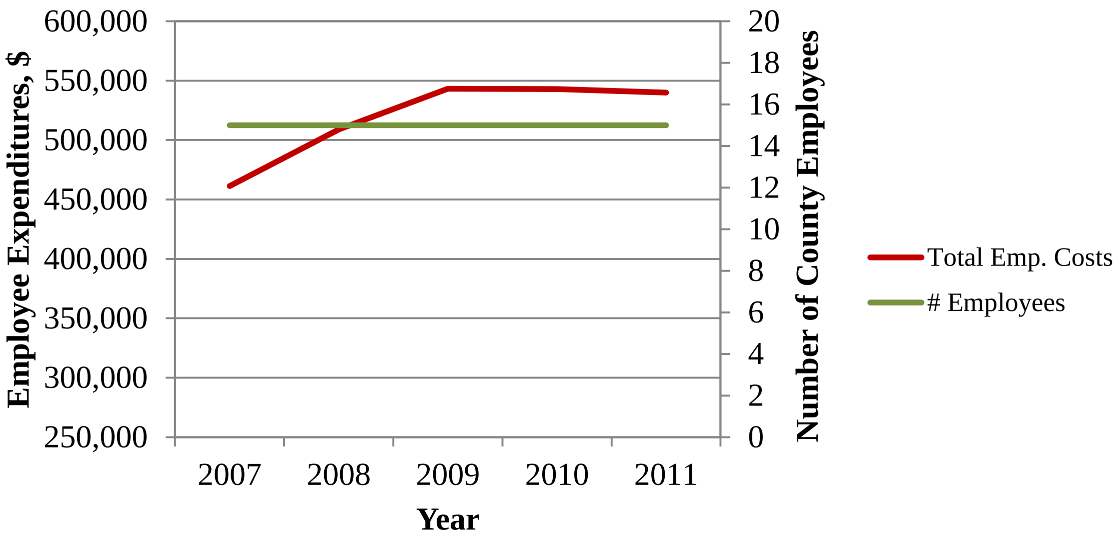


Figure 11.2 Converse County personnel counts and employee expenditures.

Figure 11.4 shows a wide variability in construction costs for unpaved roads while showing no paved road construction investments with the exception of 2011. In 2011, Converse County was granted additional funding to complete road rehabilitation on Ross Road due to its severe deterioration caused mainly by oil and gas traffic. The county repaired 7.7 miles of the road. The decreasing trend in unpaved road construction suggests that funds are necessary in other portions of the county (maintenance), possibly due to increased oil and gas impacts. Based on

Figures 11.3 and 11.4, the county has spent very little on bridge and culvert maintenance and construction.

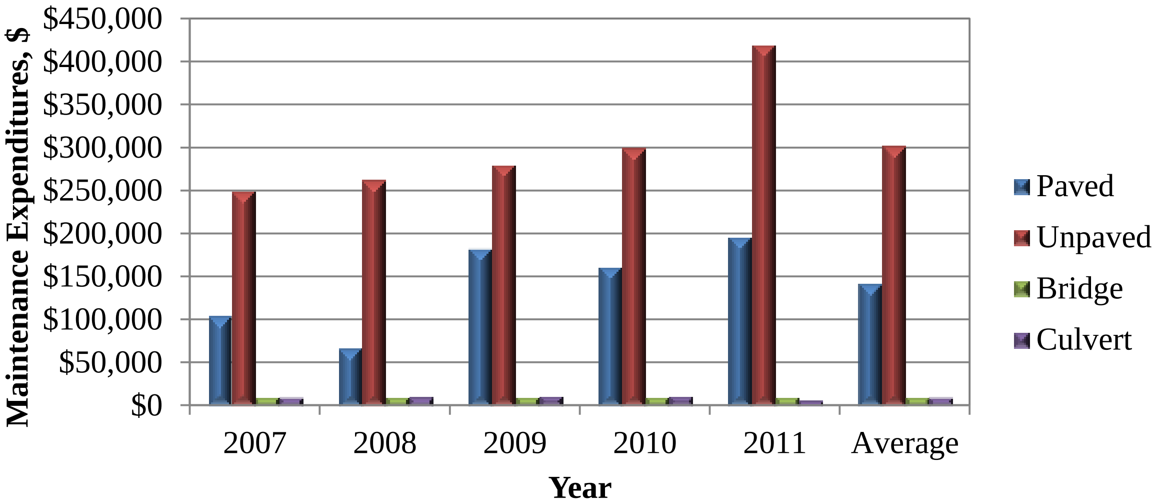


Figure 11.3 Converse County annual maintenance costs by asset type.

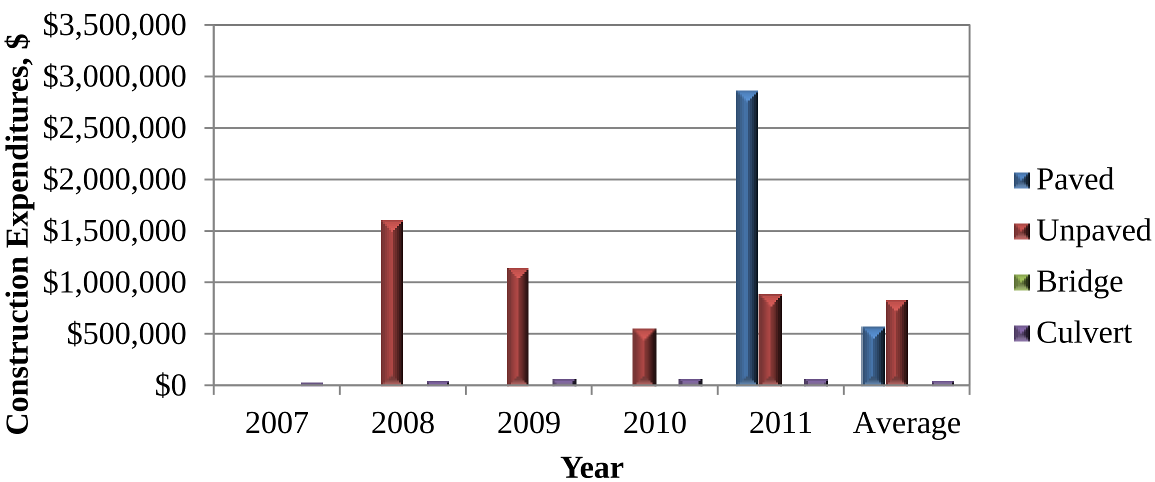


Figure 11.4 Converse County annual construction costs by asset type.

Using the same data, the total paved and unpaved expenditures were combined to create values representing the annual investments per mile on paved and unpaved roads. These values were divided by the total paved and unpaved miles in Converse County's road network. These values, shown in Figure 11.5, represent the annual investments per mile that Converse County dedicates to paved and unpaved roads. The 2011 reconstruction of Ross Road highly skews the average results in terms of paved road investments and is a direct result of the increased oil and gas impact. Ignoring the additional funding received for this project, Converse County annually invests $1,581 per mile on paved roads annually, while investing $2,182 per mile-year on unpaved roads.

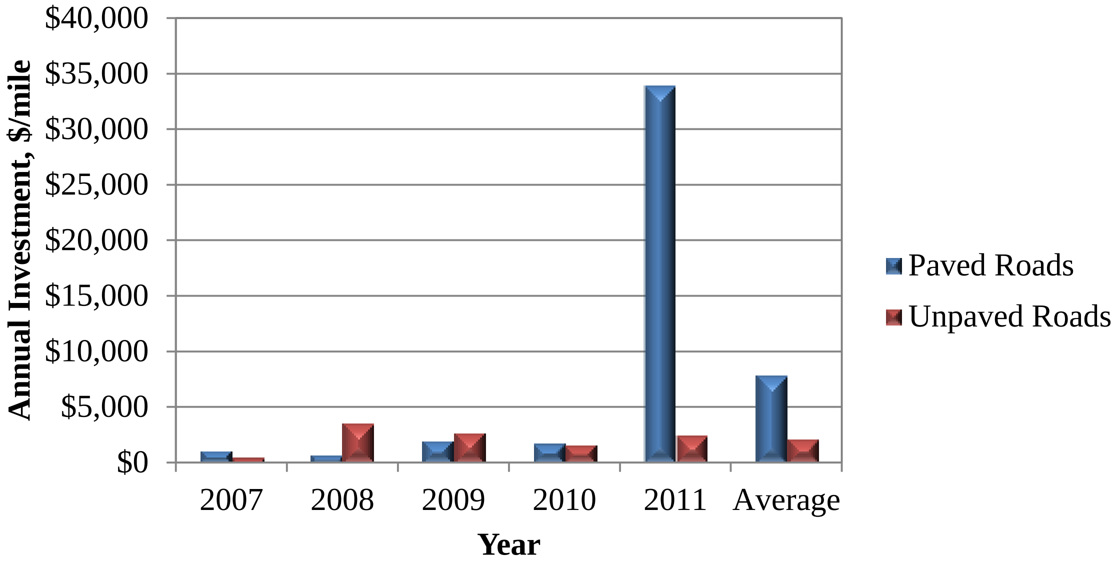


Figure 11.5 Converse County annual road investments.

11.2 Goshen County

Goshen County maintains 123 miles of paved roads and 908 miles of unpaved roads. Based on the results of this study, Goshen County has experienced only limited increases in oil and gas activity. Current impacts from the oil and gas activities are minimal. This industry, however, is very sensitive. With the right results from one oil well, a boom can occur almost overnight. The county's operating budget was analyzed as was done for Converse County, as described above. Figure 11.6 shows the five year operating budget for Goshen County's Road and Bridge Department. This only includes funds allocated by Goshen County. The funding has decreased slightly since 2007 until 2011, when it increased. Goshen County also obtained additional funds through special grants. From 2007 through 2011 they received $376,421; $1,801,115; $1,425,778; $1,332,087; and $4,188,447 in grants per year, respectively. These funds were not included in the annual operating budget.

County personnel were also evaluated in the survey. Figure 11.7 shows the number of employees and employee expenditures in Goshen County over the past five years. Goshen County has had a fourteen member team over the past few years and has seen very little increase in expenses during this time.

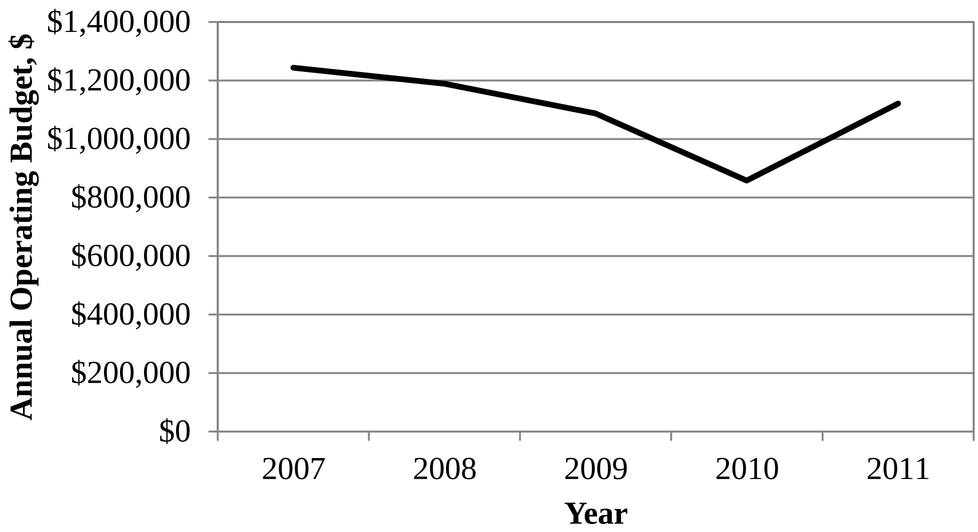


Figure 11.6 Goshen County annual operating budget, 2007 - 2011.

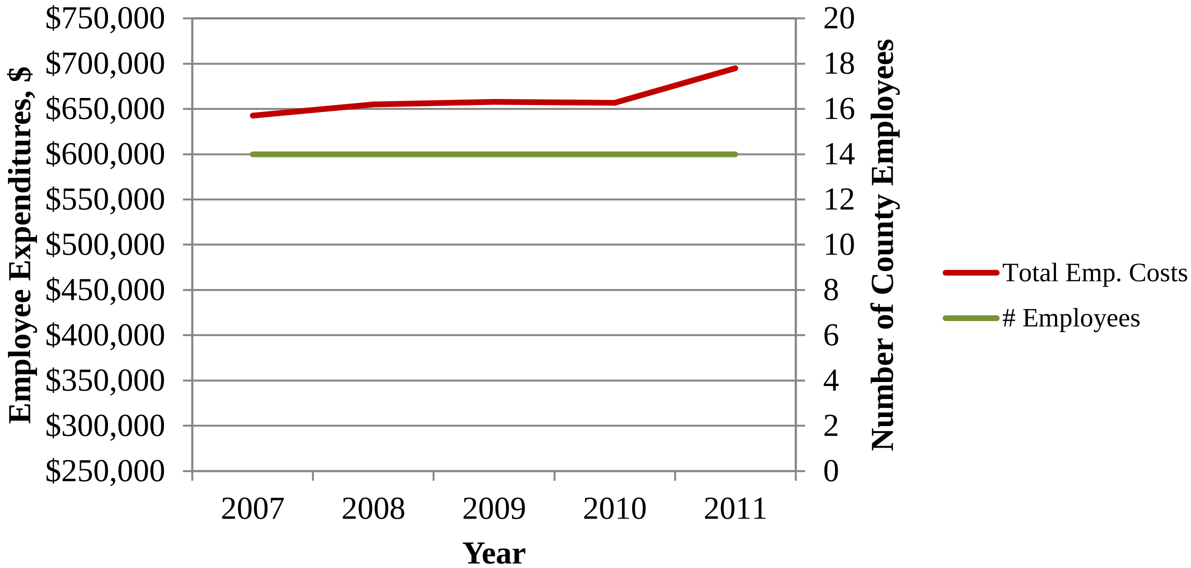


Figure 11.7 Goshen County personnel counts and employee expenditures.

Based on the county resources survey, maintenance and construction costs were plotted for the past five years. All maintenance costs are divided into four asset types: paved roads, unpaved roads, bridges, and culverts. Figures 11.8 and 11.9 show the annual maintenance and construction expenses for each asset type over the past five years, showing consistent maintenance costs over this time. Paved road construction spiked in 2009 when a road construction project consumed those funds. Goshen County dedicates a small portion of their annual budget on the maintenance and construction of bridges and culverts. According to the county resources survey, Goshen County annually invests an average of approximately $120,000 per year to keep their culverts and bridges in good working order.

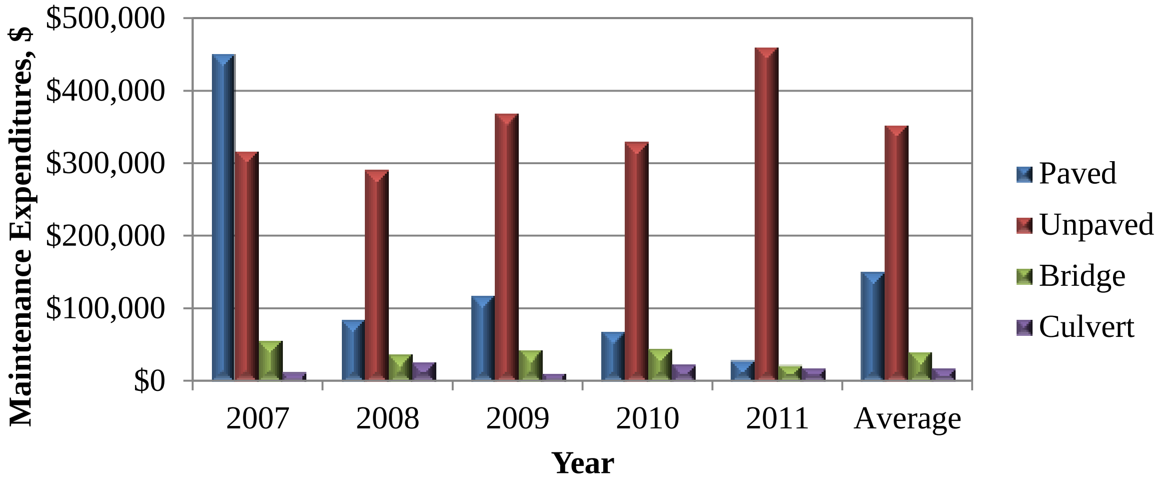


Figure 11.8 Goshen County annual maintenance costs by asset type.

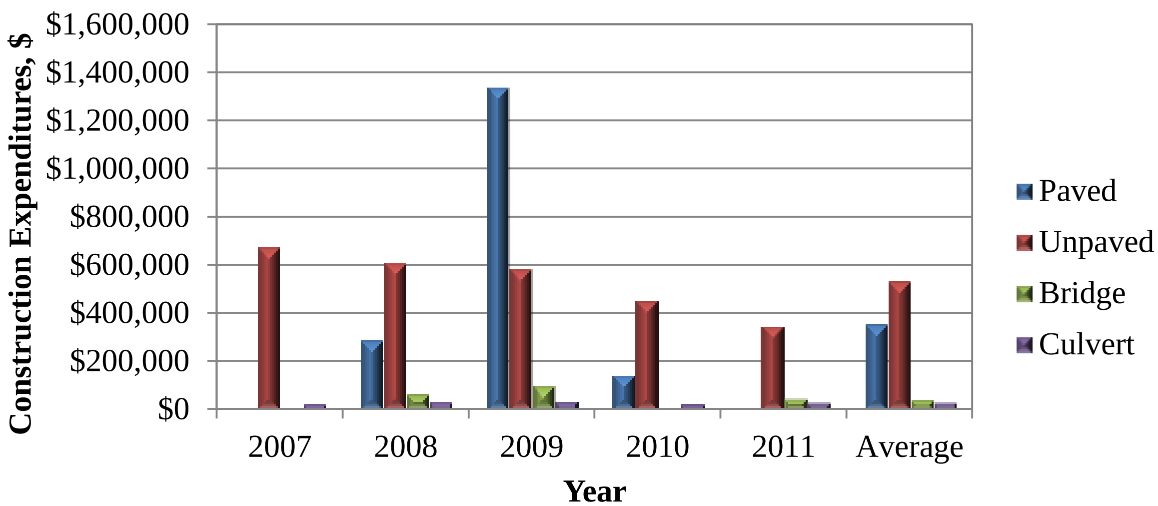


Figure 11.9 Goshen County annual construction cost by asset type.

Using the same data, the total paved and unpaved expenditures were combined to generate a value for the annual investment per mile on paved and unpaved roads. This value was divided by the total number of paved and unpaved miles. This value represents the annual investment per mile that Goshen County dedicates to paved and unpaved roads. Figure 11.10 presents these values. The 2009 paved road reconstruction skews the average results in terms of paved road investments. Regardless Goshen County annually invests $4,114 per mile on paved roads annually and $978 per mile annually on unpaved roads.

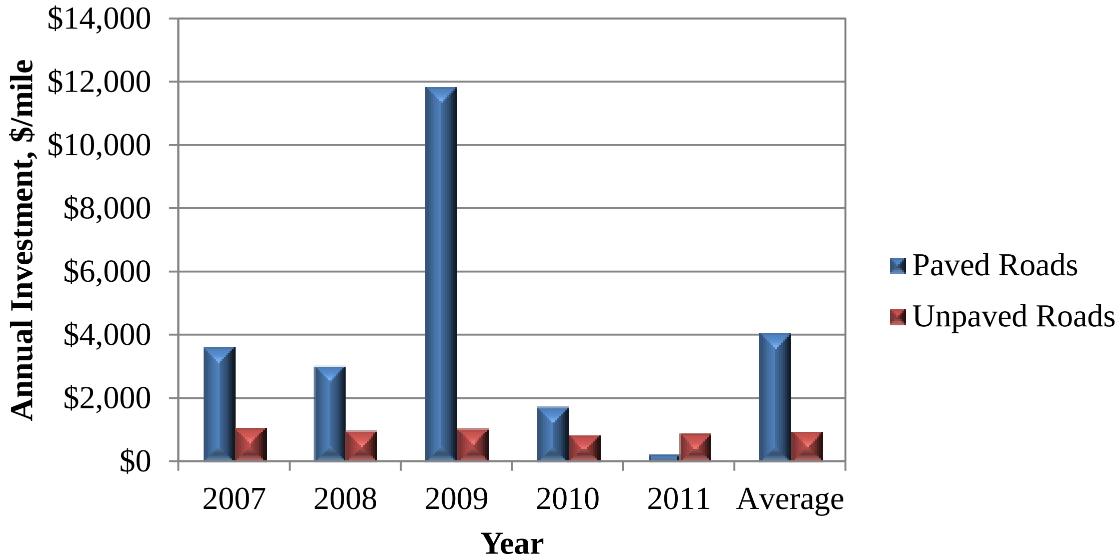


Figure 11.10 Goshen County annual road investments, 2007 - 2011.

Similar to Ross Road in Converse County, the additional construction costs in 2009 were removed and the data re-analyzed. Goshen County annually invests $1,935 per mile per year into paved roads annually while investing $978 per mile per year on unpaved roads.

11.3 Laramie County

Laramie County maintains 225 miles of paved and 1,008 miles of unpaved roads. Based on the results of this study, Laramie County has experienced significant increases in oil and gas-related impact over the past few years. Figure 11.11 shows Laramie County's operating budget for road and bridge over the past five years. The budget shows considerable decreases in recent years in spite of increasing oil and gas impacts.

County personnel were also evaluated in the survey. Figure 11.12 shows employee counts and expenditures for the past five years. Laramie County has seen some variation in employee numbers over the last few years but has recently increased their staff to a team of 58 employees.

Based on the county resources survey, maintenance and construction costs were compiled for the past five years. All maintenance costs were divided into four asset types: paved roads, unpaved roads, bridges, and culverts. Figures 11.13 and 11.14 below show the annual maintenance and construction expenditures for each category over the past five years. Figure 11.13 displays fairly constant maintenance expenditures. No expenditures were reported for bridge maintenance.

Figure 11.14 shows reductions in construction costs over the past few years for paved roads, unpaved roads, and culverts. Based on Figures 11.13 and 11.14, Laramie County is experiencing decreased funding while oil and gas impacts are increasing, which may lead to insufficient funding if additional traffic loads must be carried by the county's roads and bridges.

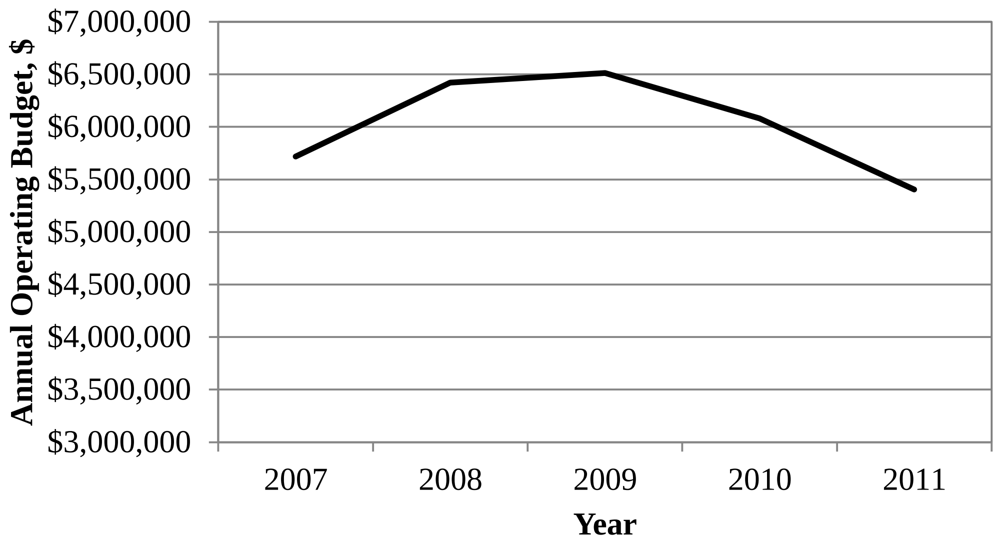


Figure 11.11 Laramie County annual operating budget, 2007 - 2011.

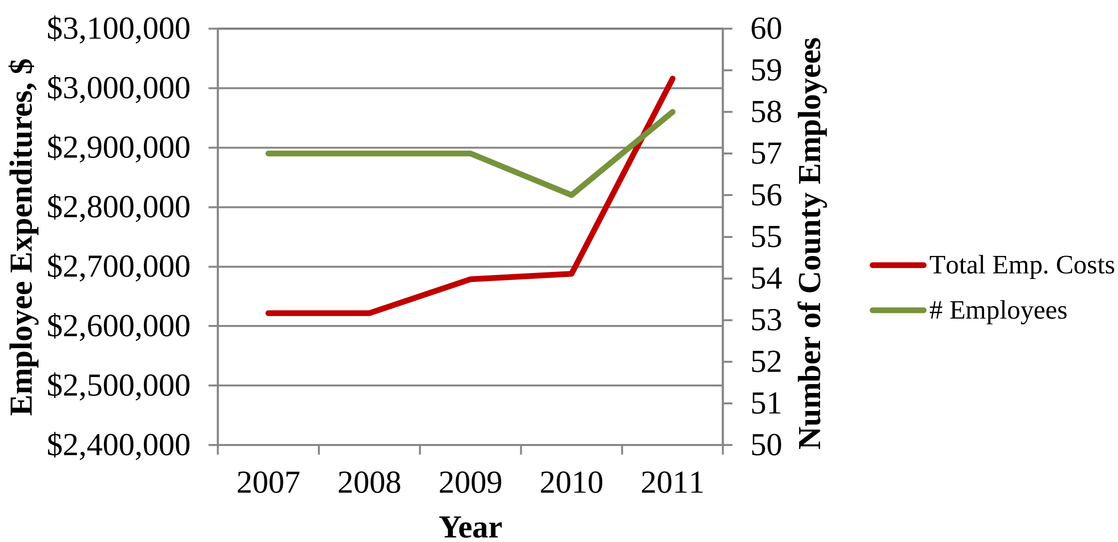


Figure 11.12 Laramie County personnel counts and employee expenditures.

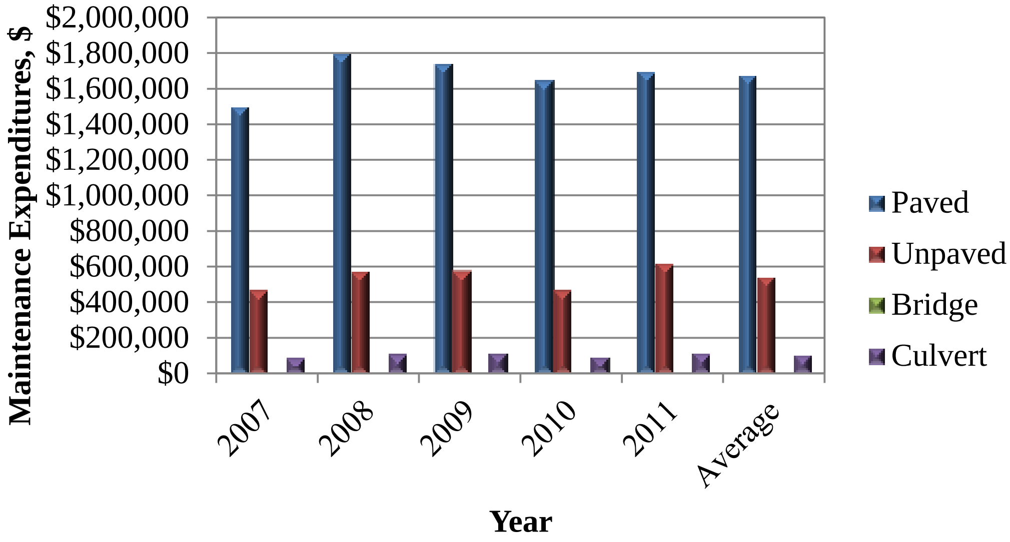


Figure 11.13 Laramie County annual maintenance costs, 2007 - 2011.

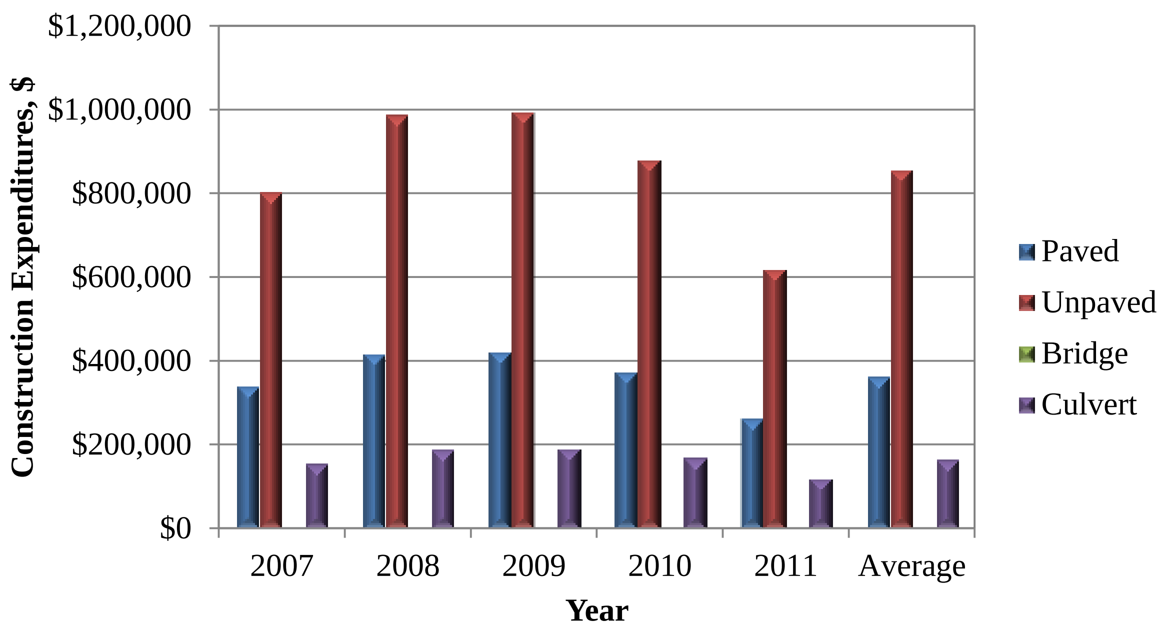


Figure 11.14 Laramie County annual construction costs, 2007 - 2011.

Using the combined maintenance and construction data, the total paved and unpaved expenditures were used to generate a cost for the total annual investment for paved and unpaved roads. This value was then divided by the total number of paved and unpaved miles, yielding the annual investment per mile that Laramie County dedicates to paved and unpaved roads. Figure

11.15 shows these values, showing significantly more money spent on paved roads than unpaved roads per mile. The average annual cost per mile for paved roads is $9,066, while unpaved roads are only receiving $1,389 per mile per year.

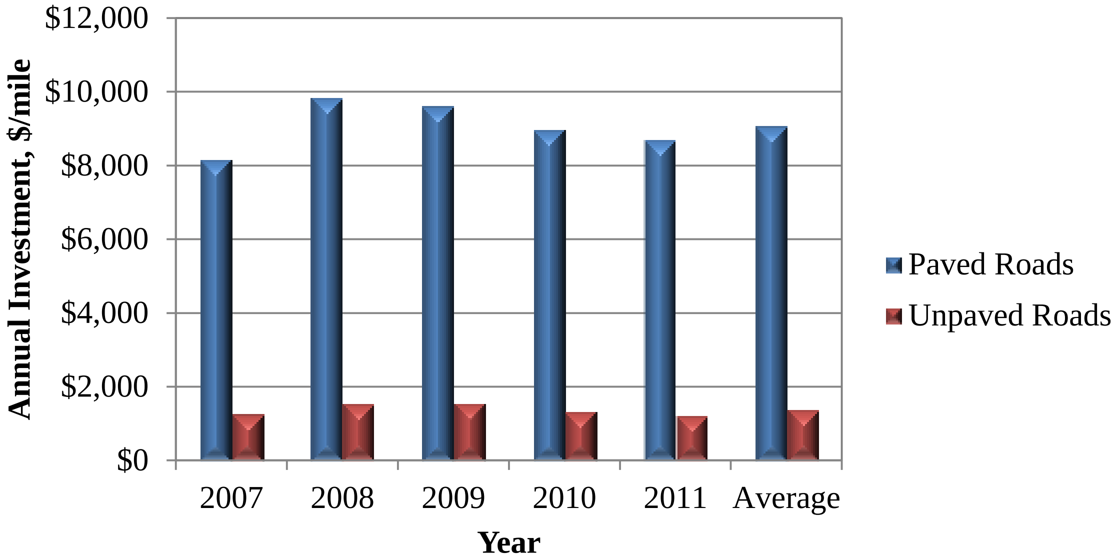


Figure 11.15 Laramie County annual road investments, 2007 - 2011.

11.4 Platte County

Platte County maintains 156 miles of paved and 353 miles of unpaved roads. Based on the results of this study, Platte County has experienced only limited increases in oil and gas activity. The operating budget was analyzed as for the other counties in this report. Figure 11.16 shows the five year road and bridge operating budget. Platte County currently operates with an $840,000 road and bridge budget.

County personnel were evaluated and analyzed as for the other three counties. Figure 11.17 shows employee counts and employee expenditures in Platte County over the past five years. Platte County has held a consistent 10 member team through the past several years and has seen very little expenditure increases during this time.

Based on the county resources survey, maintenance and construction costs were compiled for the past five years. All maintenance costs were divided into four asset types: paved roads, unpaved roads, bridges, and culverts. Figures 11.18 and 11.19 below show the annual maintenance and construction expenditures for each asset type over the past five years. Figure 11.18 shows very consistent maintenance costs over the past five years. Figure 11.19 is very interesting: All new construction investments have been dedicated to culvert construction. No paved or unpaved roads have been constructed in Platte County in the past five years. Overall, Platte County annually invests $85,000 towards bridge and culvert maintenance with $75,000 dedicated to just culverts.

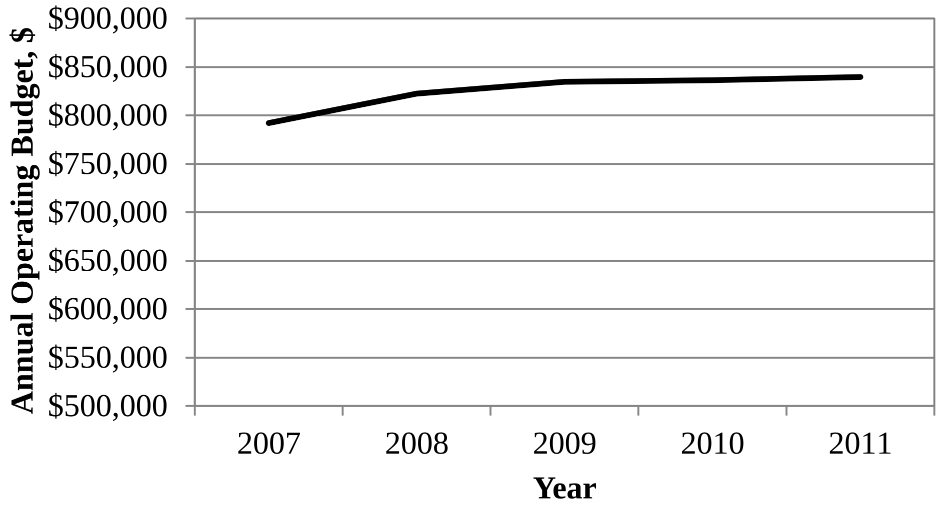


Figure 11.16 Platte County annual operating budget, 2007 - 2011.

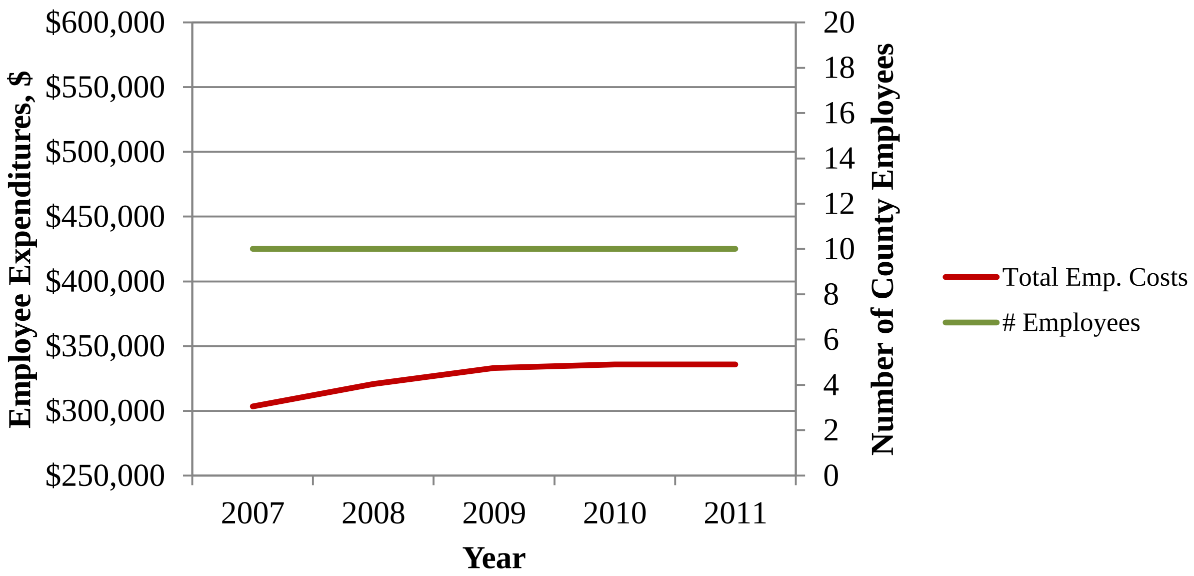


Figure 11.17 Platte County personnel counts and employee expenditures.

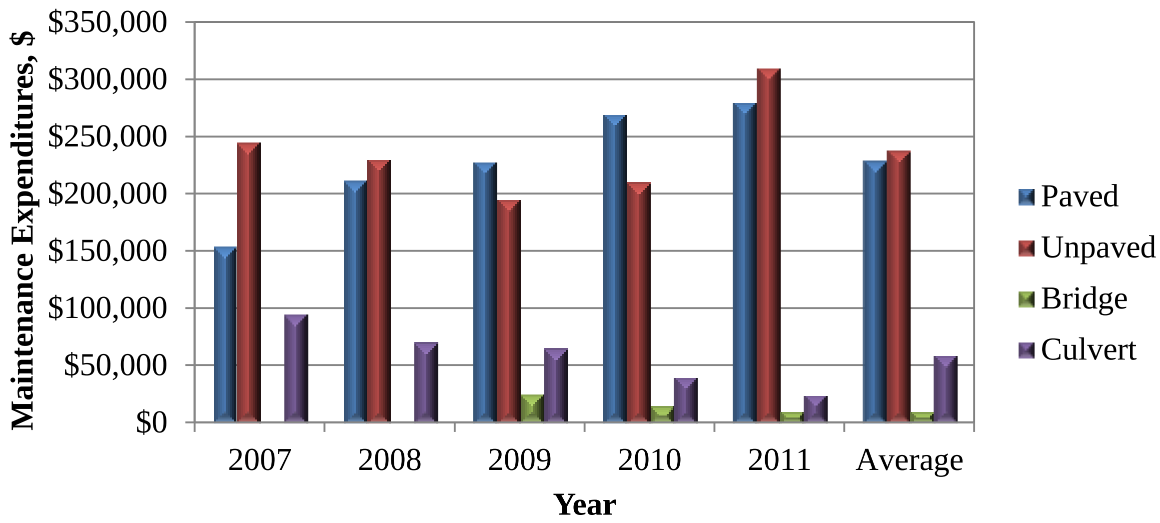


Figure 11.18 Platte County annual maintenance costs, 2007 - 2011.

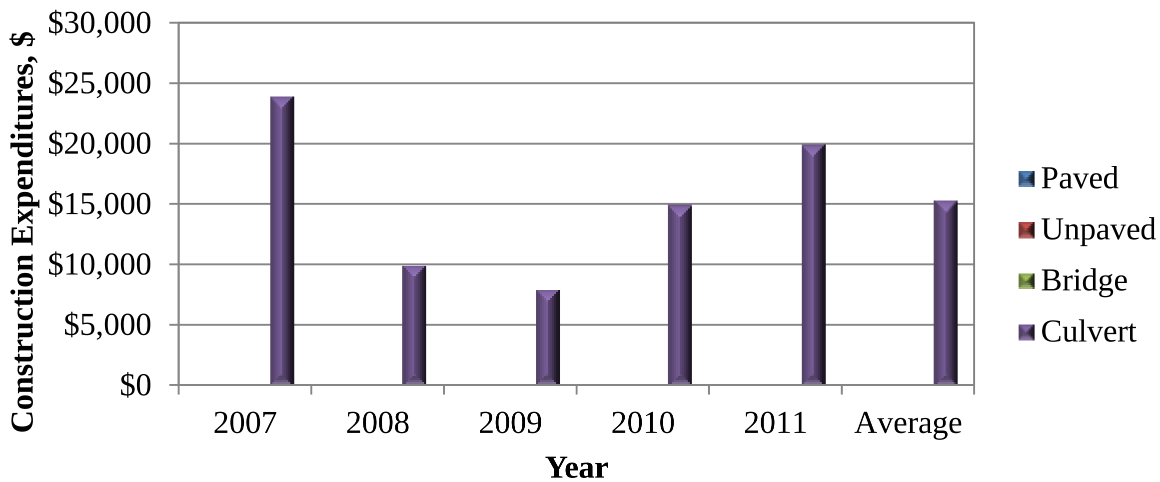


Figure 11.19 Platte County annual construction costs, 2007 - 2011.

Using the same data, the total paved and unpaved expenditures were used to generate a value for the annual investment on paved and unpaved roads. This value was divided by the total number of paved and unpaved miles. The value generated represents the annual investment per mile that Platte County spends on paved and unpaved roads. Figure 11.20 shows these expenditures. Overall, the annual investment on paved roads is on an upward trend. This could be explained by the worsening condition of paved roads in Platte County. These old paved roads need more and more maintenance year after year. Overall, Platte County annually invests $1,463 per mile on paved roads annually, while investing $675 per mile per year on unpaved roads.

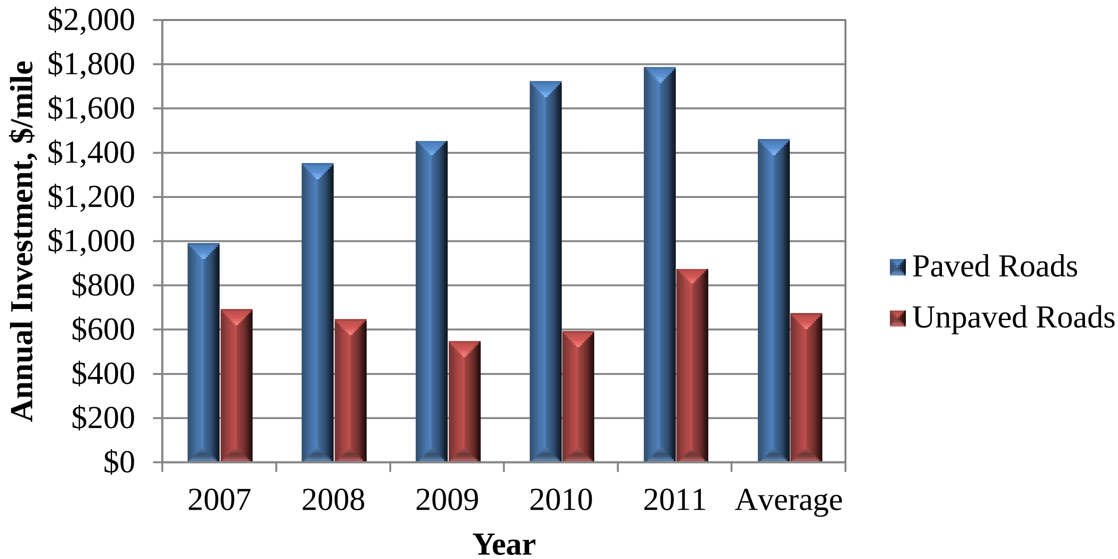


Figure 11.20 Platte County annual road investments, 2007 - 2011.

11.5 Summary

Converse, Goshen, Laramie, and Platte Counties have all maintained fairly constant annual budgets and personnel throughout the past five years in spite of rising impacts from oil and gas activities. This chapter analyzes each county's personnel and expenditures over the past five years. Converse and Laramie Counties are currently being impacted by increased oil and gas activities, while little current impacts are being observed in Platte and Goshen Counties. For this reason, Converse and Laramie County road and bridge departments need to be equipped to handle current impacts. With the unpredictable nature of the oil and gas industry, all four counties need to be prepared to handle the impacts of increased oil and gas traffic. In order to gauge their abilities, each county's budget, maintenance costs, construction costs, and annual investments were analyzed.

Table 11.1 summarizes this information for each county for the past five years. Laramie County shows the greatest level of consistency in annual costs out of all the counties. It also possesses the funds to invest more money per mile of road than any other county. Goshen and Converse County each have one year of very high costs per mile for their paved roads, representing years they obtained additional funding to complete necessary projects. Platte County receives the least annual funding to maintain their county's road and bridge infrastructure. With greater impacts due to substantial increases in oil and gas activities, it is unlikely that any of the four counties would be able to financially support necessary maintenance and improvements without additional funding.

Table 11.1 County Resources Summary

County	Year	Unpaved Roads Cost	Unpaved Roads $/mile	Paved Roads Cost	Paved Roads $/mile	Other Costs
CO	*2007*	$250,000	$476	$105,283	$1,168	$47,684
	2008	$1,880,350	$3,581	$67,524	$749	$70,830
	2009	$1,430,000	$2,723	$182,875	$2,028	$90,457
	2010	$859,000	$1,636	$161,290	$1,789	$92,303
	2011	$1,309,431	$2,494	$3,067,112	$34,019	$85,980
	Average	$1,145,756	$2,182	$716,817	$7,947	$77,451
GO	*2007*	$994,732	$1,096	$451,317	$3,670	$92,344
	2008	$902,724	$994	$376,421	$3,061	$162,962
	2009	$953,915	$1,051	$1,458,977	$11,864	$185,860
	2010	$781,982	$861	$214,257	$1,742	$90,909
	2011	$807,761	$890	$29,366	$239	$115,602
	Average	$888,223	$978	$237,995	$1,935	$129,535
LA	*2007*	$1,275,000	$1,264	$1,841,000	$8,175	$245,000
	2008	$1,563,000	$1,550	$2,218,000	$9,849	$300,000
	2009	$1,574,000	$1,561	$2,164,000	$9,609	$302,000
	2010	$1,349,000	$1,338	$2,023,000	$8,983	$260,000
	2011	$1,241,000	$1,231	$1,963,000	$8,716	$235,000
	Average	$1,400,400	$1,389	$2,041,800	$9,066	$268,400
PL	*2007*	$245,000	$694	$155,000	$991	$119,000
	2008	$230,000	$652	$212,000	$1,355	$80,000
	2009	$195,000	$553	$228,000	$1,457	$98,000
	2010	$210,000	$595	$270,000	$1,726	$70,000
	2011	$310,000	$879	$280,000	$1,790	$55,000
	Average	$238,000	$675	$229,000	$1,463	$84,400

Personnel were also assessed for each county. Converse County Road and Bridge currently has 15 employees; Goshen County has 14; Laramie County has 58; and Platte County has 10. To evaluate the preparedness in terms of staff size, the total mileage of unpaved and paved roads was divided by the number of employees for each county, yielding a value for the miles per employee, as shown in Table 11.2.

Table 11.2 Miles per Employee

County	Unpaved	Paved
CO	35.0	6.0
GO	64.9	8.8
LA	17.4	3.9
PL	35.3	15.7

The values in Table 11.2 indicate that Laramie County has more staff per mile than the other counties, followed by Converse County. Miles per employee do not present the entire situation. Tables 3.2 and 3.3 show that Laramie and Converse Counties also have more traffic on their roads, so they need more staff per mile. Given that Converse County has more traffic than Laramie County, it might be concluded that Laramie County is less efficient. However, this ignores the nature of rural traffic in the two counties. Laramie County has far more residential and crop agricultural traffic than Converse County. Thus, the users of Laramie County roads generally demand roads maintained to a higher standard than the largely industrial and ranching traffic on Converse County's rural roads. At the other end of the employees per mile spectrum, Goshen and Platte Counties have more miles per employee, but they also have less traffic on their roads, so lower maintenance costs are to be anticipated. For historical reasons Goshen and Platte Counties are in very different situations, in spite of similar funding levels per mile. As shown in Table 2.1, Platte County has twice as high a proportion of paved roads compared to Goshen County, reflecting different construction strategies decades ago. Historical construction practice differences between Platte and Goshen Counties, and traffic makeup differences between Laramie and Converse Counties illustrate the county-to-county deviations that make direct comparisons between the four counties irrelevant at best.

The discussions above generally show that Laramie and Converse Counties are better prepared for an influx of oil and gas traffic since they already serve higher traffic volumes; Goshen and Platte Counties are more vulnerable since neither their roads nor their staff are prepared to handle even relatively minor increases in traffic volume. Converse County has far more current impacts, stretching their resources thin, so they are vulnerable to a major increase in oil and gas traffic. As shown in Table 11.2, Converse County is in the middle in terms of miles per employee. However, since they already have adjusted to their current, heavier traffic from oil and gas activities, they may be able to handle modest traffic increases. Laramie County has the fewest miles per employee since they already handle higher traffic from other sources – mainly residential and agricultural. Therefore they are probably best prepared to handle a major influx in oil and gas traffic since it would represent a smaller percentage of their total traffic. Goshen and Platte Counties have not seen major increases in traffic from oil and gas activities, so they are not currently experiencing significant road network damage from oil and gas traffic. However, they currently have the most miles per employee, so they have the least capacity to adjust to substantial increases in traffic, regardless of its source. Ultimately, none of the four counties will be able to sustain their operations at current levels if their roads are forced to carry substantially heavier oil and gas traffic.

12. SUMMARY AND CONCLUSIONS

This report documents the WY T^2/LTAP Center's efforts to evaluate the impact of energy related traffic on the condition of Converse, Goshen, Laramie and Platte Counties' road networks. The primary data collection activities described in this report were performed during the fall of 2011 through the summer of 2012. Additionally, an effort has been made to glean as much useful information as possible from the counties' maintenance records and other sources. The documentation of road networks in the four counties was based on the methodology developed in Phase I *(Ksaibati 2011)*.

12.1 Traffic Counts and Oil and Gas Impacts Estimation

Accurate traffic counts are a fundamental starting point when deciding how to maintain and upgrade a road network. Traffic counts should be performed periodically on county roads, particularly those carrying heavier traffic. Since most road damage is done by heavy trucks, any traffic counts should include a way of classifying vehicles. At a minimum, there should be a way of determining whether a passing vehicle is a car or light truck, or whether it is a heavy truck.

The WY T^2/LTAP Center conducted 160 traffic counts with Goshen County providing another 12 counts from their continuous traffic counts. A total of 115 counts were performed on roads identified by the counties as being impacted by the oil and gas industry, with the remaining 57 counts on non-impacted roads. Each county experiences different levels of truck traffic with Laramie County having the highest average percentage of truck traffic on paved roads and Converse County having the highest average percentage of truck traffic on unpaved roads. Goshen County also had a high average percentage of truck traffic on unpaved roads at 16 percent. Average 85^{th} percentile speeds vary little from county to county, generally about 60 mph on paved roads and about 50 mph on unpaved roads. Overall, Converse County had the highest traffic and truck volumes on both unpaved and paved roads.

The Wyoming Oil and Gas Conservation Commission (WOGCC) provided the WY T^2/LTAP Center with a list of 1,917 oil and gas wells since 1917. Of the four counties in this study, Converse County has had the most wells drilled but the other three counties have seen an increase in the number of wells drilled over the last 20 years. Laramie County had the most temporary water haul sites with 67, while Goshen County had 13. Converse County has only 2 temporary water haul sites since the oil and gas companies get most of their water from the Douglas City water pipeline. Also, there is considerable oil and gas traffic that serves operations outside of Wyoming, particularly in southern Laramie County where many county roads are used to access water haul sites for drilling activities in Colorado. All these activities generate heavy truck traffic on county roads.

12.2 Paved Roads

Paved roads were evaluated with automated data collection, supported by distress evaluation based on video recordings made during the automated data collection. Based on the recorded conditions and top surface widths of each paved road segment, improvements were recommended for all paved road segments as described in section 5.4 Improvement Recommendations. The roads were prioritized as a way of assessing the degree of oil and gas impacts. As described in section 5.4.1.1 Quantifying Oil and Gas Impacts, a priority level for 1 to 6 was assigned to each road identified as being impacted by the counties, except those for which the available data was insufficient to assign a priority level. A priority 1 road indicates high impacts, while a priority 6 indicates the lowest level of impact. Table 12.1 shows the costs and mileages of these roads identified for improvement for each priority level.

Table 12.1 Paved Roads Rehabilitation Costs by Priority Level

Impact Priority Level	Segments	Miles	Estimated Cost
1	3	18.9	$9,454,250
2	2	14.2	$7,260,000
3	5	31.9	$18,448,500
4	4	15.6	$7,732,250
5	5	34.0	$40,788,000
6	25	103.2	$61,616,700
Subtotal	44	217.7	$145,299,700
Completed Projects	2	16.3	$12,018,750
Missing Data	22	28.0	NA
TOTAL	68	261.9	$157,318,450

Paved roads deteriorate fairly slowly and predictably, at least most of the time. An exception to this generality occurs when a road with very limited structural strength is exposed to a sudden increase in heavy traffic loads, particularly when the base, subbase and subgrade materials that support the pavement surface are wet and, therefore, weak. In such conditions, a road that performed well for many years or even decades may be destroyed over a matter of weeks, days, or even hours. To both assess the long-term, predictable deterioration of county paved roads and to track sudden deterioration of paved roads, a program of periodic monitoring of county paved roads should be instituted. Such monitoring should be used both to evaluate the impacts from oil and gas-related traffic and to plan maintenance and repairs on the counties' paved roads.

Since Pathway Services Incorporated already monitors the state highway system, they should also monitor the paved county roads. WYDOT monitors the interstate system annually and the rest of the state system every other year. County paved roads should also be monitored periodically, with a period of two to four years. Provisions should be made to perform condition analyses using the videos as WYDOT does for the state highways.

The rehabilitation strategy recommendation procedure and the prioritization procedure developed through this study should be used to help decide how to allocate funds to county road projects. These methodologies are based on current road conditions, on traffic counts, and on the magnitude and likelihood of future oil and gas impacts. Inputs to these analytical procedures include PSI, PCI, rut depth, ADT, and ADTT which combine to indicate whether a road meets serviceability standards now and to predict whether the roads will do so in the future. The rehabilitation strategy decision tree and priority rankings should be used to help determine which roads have the greatest need of additional maintenance or construction.

The design specifications developed during this study are representative of typical designs that can be used for the various rehabilitation options. It is recommended that these designs be used as possible starting points for project level designs of particular roadways.

Additional resources should be provided to collect pavement condition data on a routine basis. This data would be extremely useful in determining impacts of the oil and gas industry and quantifying impacts of increased traffic loads.

12.3 Unpaved Roads

Most of the unpaved roads in each of the four counties were evaluated in May 2012. Based on their observed distresses and measured top surfacing widths, lists of recommended improvements were generated for each county as shown in Table 12.2.

Table 12.2 Unpaved Roads Improvement Recommendations Summary

	Improvement Costs						
County	**Light Blading**	**Heavy Blading**	**Treat Gravel**	**Drainage Repairs**	**Regravel**	**Reconstruct**	**TOTAL**
CO	$0	$0	$428,498	$0	$0	$0	$428,498
GO	$629	$4,547	$296,848	$241,633	$739,764	$0	$1,283,421
LA	$3,804	$18,676	$281,068	$0	$655,114	$0	$958,661
PL	$0	$3,496	$22,064	$0	$0	$0	$25,559
TOTAL	$4,433	$26,718	$1,028,477	$241,633	$1,394,877	$0	$2,696,139
County	**Improved Mileages**						**TOTAL**
CO	0.0	0.0	48.5	0.0	0.0	0.0	48.5
GO	3.0	4.7	37.6	14.3	19.3	0.0	78.8
LA	14.2	18.5	40.2	0.0	17.4	0.0	90.3
PL	0.0	5.6	4.2	0.0	0.0	0.0	9.8
TOTAL	17.2	28.7	130.4	14.3	36.7	0.0	227.3

Overall, the four counties are currently maintaining their unpaved roads in fair to good conditions. However, this maintenance comes at a cost. The counties frequently spend extra time and money on maintaining impacted roads.

12.4 Cattle Guards

This report provides baseline data upon which further analyses can be based. These data collection and analytical methods can easily be repeated periodically to provide an assessment of the damage done by oil and gas traffic.

To assess the damage to the four counties' cattle guards due to oil and gas impacts, each counties' cattle guards should be rated periodically, perhaps every two or three years. This report documents the current conditions of the four counties' cattle guards, providing baseline data upon which further assessments should be based. Condition ratings that provide the necessary inputs for current value assessments should be performed in subsequent years. The loss in current value for cattle guards on impacted roads should be compared to the cattle guards on the counties' other, non-impacted roads. For such an analysis to be meaningful, the counties would have to track their maintenance, repair, and replacement costs for each individual cattle guard. They would also need to separate their costs by whether or not they are primarily related to heavy truck traffic. A cost not directly related to traffic is cleaning earth and gravel out of the cattle guards' bases. Additionally, one would need a reasonable evaluation of traffic, particularly the heavy trucks that are most likely to damage cattle guards. With future ratings using the same standards, accurate recording of costs incurred for maintenance, repairs and replacement, and the amount and type of heavy traffic traversing the cattle guards, one could generate a reasonable estimate of the damage to cattle guards done by oil and gas related traffic.

12.5 Bridges

Though on the whole, the bridges in the four counties are generally rated as Fair or better in most aspects, this is likely to change in the fairly near future. Since 39% of the bridges in the four counties were built during the 1970s, many of them are approaching the end of their 50-year design life. Additionally, 15% of the bridges in the four counties were built before 1960, so they have already exceeded their design lives. As the bridges age, they will continue to deteriorate. This deterioration may be accelerated by additional heavy truckloads carrying oil and gas-related traffic.

12.6 Safety

Crash rates are proportional to traffic volumes, leading to more crashes of all types on Converse and Laramie Counties' roads. Based on available crash data, Converse County roads have the worst safety record. This is mainly due to the heavier traffic volumes and the increased level of oil and gas impact in that county.

Crash data on the four counties' roads should be monitored. As areas of high crash density are identified, they should be examined to determine whether any mitigation techniques might be undertaken to improve safety in these areas. In addition, the overall types of crashes should be examined to establish the most frequent causes of crashes on both the counties paved and unpaved networks. This might provide insights into how crashes and fatalities might be reduced on a network-wide basis.

12.7 Permits

An examination of current truck permitting by the State of Wyoming and its counties was conducted. Each county's website was examined and the results of this survey were compiled. This website survey was followed up by a survey to individuals with each of Wyoming's counties. This verified, and occasionally corrected, the results of the website survey. Three primary truck permit types were identified – oversize and overweight permits, road use agreements, and access permits.

Based on consultation with WYDOT and the Wyoming Highway Patrol, the desirability of standardized, statewide permitting processes was established. By taking the most important elements of these three permit types from the survey results, three standard permits were developed and presented in appendices I.3. Standard Access Permit, I.4. Standard Road Use Agreement, and I.5. Standard Oversize/Overweight Permit.

The standard permits developed as part of this project should be presented to all Wyoming counties. The counties should be encouraged to adopt the standard permits. The three permit types developed are oversize and overweight permits, road sue agreements, and access permits. Counties might also be also encouraged to take an easier first step of instituting a single, flat rate road use fee such as the system used in Texas. This would consist of charging a single fee for every oil and gas well drilled, thereby generating revenue to partially offset any damage done to the counties' roads by oil and gas drilling.

12.8 County Resources

Converse, Goshen, Laramie, and Platte Counties have all maintained fairly constant annual budgets and personnel throughout the past five years in spite of rising impacts from oil and gas activities. Each county's personnel and expenditures over the past five years are analyzed. Converse and Laramie Counties are currently being impacted by increased by oil and gas activities, while less current impacts are being observed in Platte and Goshen Counties. For this reason, Converse and Laramie County road and bridge departments need to be equipped to handle current impacts. With the unpredictable nature of the oil and gas industry, all four counties need to be prepared to handle the impacts of increased oil and gas traffic. In order to gauge their abilities, each county's budget, maintenance costs, construction costs, and annual investments were analyzed.

Laramie County shows the greatest level of consistency in annual costs out of all the counties. It also possesses the funds to invest more money per mile of road than any other county. Goshen and Converse County each have one year of very high costs per mile for their paved roads, representing years they obtained additional funding to complete necessary projects. Platte County contains the least annual funding to maintain their county's road and bridge infrastructure. With greater impacts due to substantial increases in oil and gas activities, it is unlikely that any of the four counties would be able to financially support necessary maintenance.

13. PHASE III: RECOMMENDATIONS AND PLANS

None of the four counties studied in this investigation, Converse, Goshen, Laramie and Platte, have enough resources allocated to their road and bridge departments to maintain their road and bridge networks if oil and gas development similar to that in North Dakota takes place in Wyoming. The four counties' have aging paved roads and bridges which, even when they were originally constructed, had only enough structural capacity to handle light agricultural and residential traffic. Many of these light duty structures have already provided many years of service, and the application of dramatically higher loads than they have ever experienced will lead to widespread and sometimes severe deterioration. The counties will not be able to repair or replace these paved roads and bridges with their current budgets or manpower. In addition, just as the counties' paved roads and bridges are being damaged and are in need of repair and replacement, substantially higher maintenance efforts and costs will be needed to keep their unpaved roads in barely adequate condition for both the oil and gas industry and for the general public. If oil and gas traffic increases dramatically, none of these counties will be able to maintain an adequate road and bridge network without substantial and timely maintenance, repair and replacement funding. In many cases, the failure to provide timely structural enhancements will cause the existing road and bridge structures to deteriorate to the point where they can only be restored to adequate conditions with very expensive replacement.

The ultimate goal of this project is to evaluate the four counties' road and bridge networks and the impact of oil and gas-related traffic on them. In simplest terms, there are three fundamental inputs needed to perform this evaluation: traffic; construction and maintenance; and performance. The following sections provide recommendations as to how these inputs could and should be obtained.

Traffic on the roads and bridges must be quantified in terms of oil and gas-related traffic and other traffic. It is also important to know the makeup of the traffic in terms of light traffic – cars, pickups and SUVs – and heavy traffic – larger trucks, tractors and trailers. Maintenance costs and activities must be tracked and assigned to specific road segments. The performance of the roads must be quantified by assessing their conditions. There are a number of other variables, weather being foremost, that affect the condition of the road and bridge networks. However, tracking these other variables, most of which are beyond the control of either the counties or the oil and gas companies, would not be a practical or cost-effective effort. Tracking the three primary facets – traffic, maintenance and performance – allows predictions and assessments of the impacts of oil and gas activities on the counties, as well as providing information that will allow the counties' road and bridge networks to be managed more efficiently.

To assess the impacts of oil and gas-related traffic on Converse, Goshen, Laramie and Platte Counties' road networks, assessments of their conditions should be made over an extended period of time. While this report considers historical data, such as oil and gas well permits and county maintenance records, these sources are generally inadequate to provide an accurate assessment of oil and gas activities' impacts on the county roads. If the counties consistently performed maintenance on an as-needed basis and weather were constant, maintenance records could be correlated with past oil and gas drilling to measure the financial impacts on county road and bridge departments originating from oil and gas activities. This, however, is not the case. County maintenance expenditures are driven by many factors. Expenditures on a particular road or bridge are driven by the availability of funds and by competing needs as much as they are by the needs of the road or bridge in question. Therefore, simply evaluating maintenance costs does not necessarily provide a reasonable assessment of the traffic impacts on that road or bridge.

None of the four counties have a systematic method of evaluating, recording and storing the conditions of their roads. While all four counties track their maintenance costs, assessments of each county's current maintenance cost tracking processes should be performed with the specific goal of tracking costs due to traffic. For the three most expensive assets managed by county road and bridge departments – paved roads, unpaved roads, and bridges – appropriate methods of tracking costs and monitoring conditions should be developed and implemented. The following sections describe a few basic recommendations for assessing impacts to these three distinct elements of a county road and bridge network.

13.1 Bridges

WYDOT routinely monitors the condition of all bridges over 20 feet long on every Wyoming County's network. Since the time frame over which bridges generally deteriorate is long, generally decades, and the time frame over which oil and gas impacts takes place is much shorter, generally several years, the long-term data collected by WYDOT should be compared to the short-term oil and gas trip generation data which was compiled as described in Section *12.1 Traffic Counts and Oil and Gas Impacts Estimation*. In the event of a surge in oil and gas traffic, this method would allow the cost of additional damage due to the surge in heavy traffic to be estimated.

A methodology for assessing the conditions of short bridges, those less than 20 feet long, should be developed and implemented. These bridges are normally maintained by the counties and they will be impacted by oil and gas traffic.

Future studies should identify the actual funding levels required to keep bridges in serviceable condition for the driving public as well as the oil and gas traffic in the four counties.

13.2 Paved Roads

Two options are described below that might be used to address the deterioration of paved county roads in Wyoming. One consists of continued monitoring on the four counties analyzed in this study, while the other consists of a rotating monitoring schedule for all paved county roads throughout the state. A few similarities between the two options should be understood. The counties generally do not have accurate enough historical construction history information to accurately track these costs. The cost of maintenance, either reactive or preventive, varies widely due in large part to factors not directly related to traffic impacts, so simply monitoring maintenance and construction costs would not be particularly informative. Like bridges, paved roads normally deteriorate over fairly long time periods – usually years or even decades – though with heavy traffic loads, this can change. Roads that were in adequate condition may be destroyed quickly, especially with lots of heavy truck traffic when the road's base and subgrade are wet and soft. Thus, the most efficient way to evaluate damage to paved roads from oil and gas or other activities is with periodic monitoring evaluated with information on traffic type, volume, and sources.

13.2.1 Option 1: Southeastern Wyoming Annual Monitoring

This option involves continuing with the efforts begun with this phase, Phase II. The four southeastern Wyoming counties, perhaps with other counties added as deemed desirable, would be monitored annually with the automated pavement condition analysis van.

The current study has provided baseline data for the condition of the road and bridge networks in Converse, Goshen, Laramie and Platte Counties. Continued monitoring of these counties' paved roads, perhaps along with other counties identified as being at risk of receiving rapid increases in traffic due to oil and gas activities, could be performed on an annual basis. Such monitoring would parallel the automated data collection methods employed by WYDOT, probably adding monitoring on the county roads to WYDOT's contract with the pavement monitoring firm. The automated data collection van would provide roughness and rutting data automatically. The Wyoming T^2/LTAP analysis would provide more detailed information on the nature of any damage to the counties' roads. This option will provide rapid assessments of the conditions of the counties monitored, generally those likely to be impacted by accelerated development of the Niobrara shale fields.

13.2.2 Option 2: Statewide Rotating Monitoring

This option involves monitoring all paved county roads within the state on a rotating basis every three or four years. Adding a third or a quarter of the paved county roads within the state to WYDOT's annual contracted automated pavement data collection process will provide baseline conditions on all paved county roads throughout the state. This information will provide every county with an assessment of the current conditions of their roads. Ultimately it would provide the information needed by the state and the counties to determine where funding needs are greatest.

This approach should incorporate both traffic estimation and condition components. Funding decisions for roads should be made based on the cost to the funding agencies and the benefit to the public. Current conditions play a large role in controlling costs while traffic volumes play a large role in determining public benefit. These two basic characteristics should be considered when road funding allocations are made.

13.3 Unpaved Roads

The Wyoming T^2/LTAP Center recommends that standardized maintenance cost records be kept by each of the counties. These records should assign costs to road segments, not just to a road name since one end of a road often has very different traffic impacts and maintenance efforts from the other. Additionally, some evaluation of both traffic and performance is desirable. Like for bridges and paved roads, methods should be developed to assess traffic on unpaved roads using a combination of traffic counts and trip generation based on oil and gas well locations, other oil and gas activities, and other traffic generating activities such as wind farms and agriculture. Combining traffic estimates with maintenance costs, including both routine and other blade maintenance and regraveling, will provide an approximate gauge of the impacts of oil and gas traffic on unpaved roads.

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