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Quantifying the Impact of Energy Traffic on Local Unpaved Roads

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QUANTIFYING THE IMPACT OF ENERGY TRAFFIC ON LOCAL UNPAVED ROADS

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Disclaimer

ABSTRACT

Converse, Goshen, Laramie, and Platte counties were selected in accordance with a legislative directive as part of a project to determine the impact of the oil and gas industry on county infrastructure. This thesis takes into account the impact of county gravel roads and strategies used to help develop methods to assess and mitigate this impact. With a lacking road and bridge budget, these counties are only just keeping up with the current impact. In order to receive additional funding from the state legislature, actual impact needs to be assessed. The different distresses and ride quality of all the county gravel roads showed that, on average, the roads were in good condition no matter the level of impact. However, the cost to keep the impacted roads in this condition came at a much greater price. By modeling the data gathered in this study and comparing the differences between impacted and non-impacted roads, a better understanding of the degradation taking place was attained. A priority ranking for impacted roads was also assessed to determine the severity of the impact. The process developed in this study could be very useful for other local agencies impacted by energy development.

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1. INTRODUCTION

1.1 Background

In 2010, Wyoming ranked 7th in crude oil production and 2nd in natural gas production nationally (Petroleum Association of Wyoming 2010). During the same year, the petroleum industry employed approximately 21,000 people with a payroll of over $1.1 billion. Oil and gas production provided $1.9 billion to state and local governments as taxes and royalties. With advancement in new technologies, these numbers are only expected to increase production, which will in turn increase the associated traffic, the economic benefits, etc. Due to the nature of this growth and the type of traffic associated with the industry, local county roads have seen rapid degradation.

Advancement in oil and gas technologies has led to increased oil and gas production in the Niobrara shale formation throughout Colorado and Wyoming. Horizontal drilling and multistage fracturing are helping the industry turn a formation previously developed only on isolated structures into a promising new resource (Dittrick 2011). This newer technology has extended the life of the oil and gas field in southeast Wyoming due to the possibility of reaching more oil from more accessible locations and fewer rig sites. However, with more drilling and advancement in drilling technologies, an increase in traffic and heavy truck loads are very likely to follow. In 2011, Entek, an oil and gas producing company, set objectives to drill vertical wells to gather information on the best targets for more horizontal and vertical wells in 2012. The oil and gas industry is clearly not declining for any of southeast Wyoming anytime soon. This continuing and increasing production can be better seen from production numbers provided by the Wyoming Oil and Gas Commission (Wyoming Oil and Gas Conservation Commission 2012). These numbers are summarized in Figure 1.1 and Figure 1.2, and actual production numbers for each county can be seen in Appendix A.

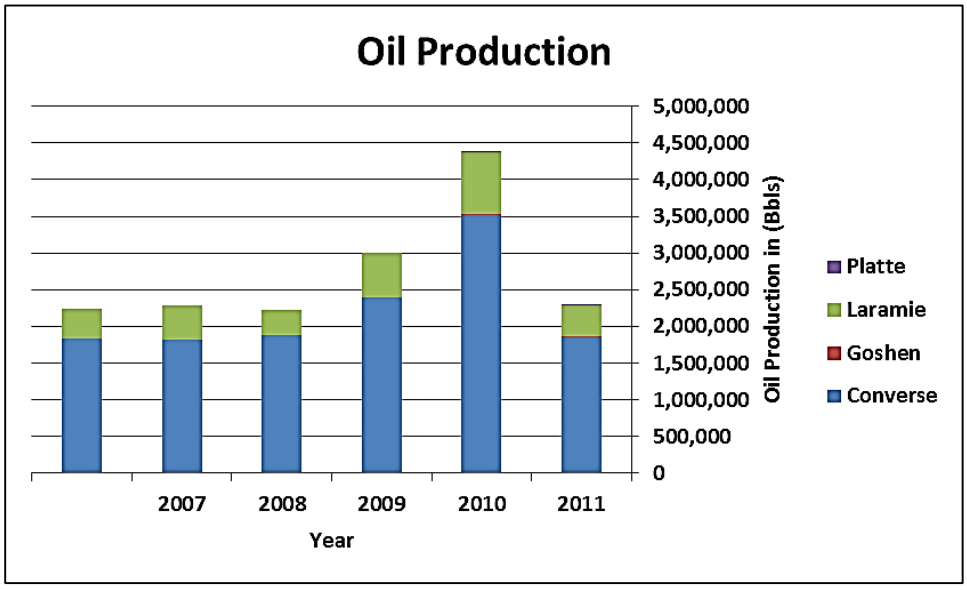


Figure 1.1 Southeast Wyoming Oil Production

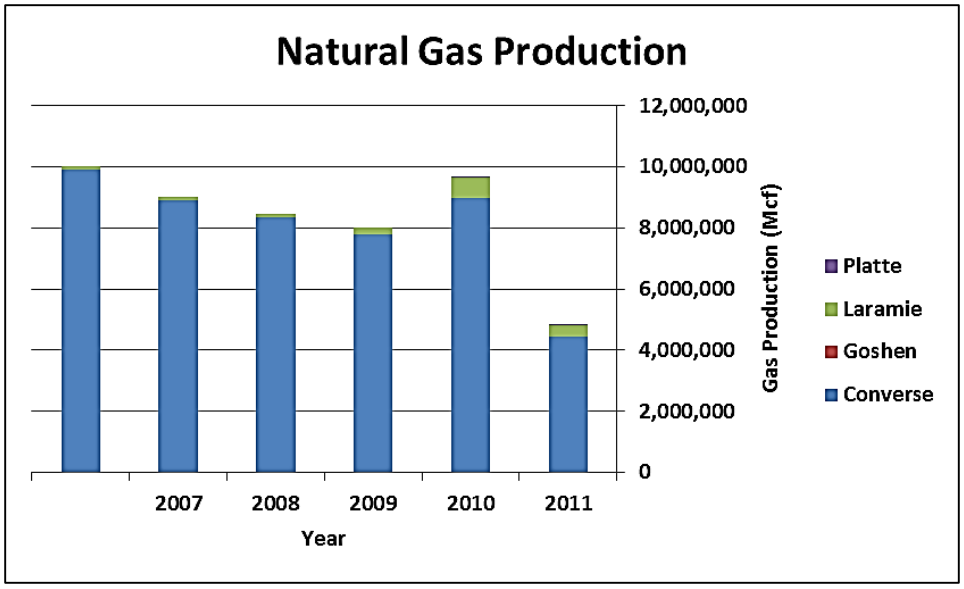


Figure 1.2 Southeast Wyoming Natural Gas Production

From Figure 1.1 and Figure 1.2, it can be seen that oil production across Converse and Laramie counties has increased almost every year. Goshen and Platte Counties show little to no production, but were still part of this study due to a legislative directive. The natural gas production has remained somewhat constant since 2007.

1.2 Problem Statement

The energy production in southeast Wyoming will likely increase in the near future. An increase in production will likely lead to an increase in heavy truck traffic associated with this increase. Low-volume county roads in low population areas of Wyoming will experience an increase in heavy traffic and loads. The counties throughout Wyoming will most likely be insufficiently funded and will struggle financially to sustain proper maintenance of their roads. For immediate preparation of this possible impact, the WYT^2/LTAP has been funded by the state legislature to help assist in developing a strategy to better determine and asses the current conditions of county road infrastructure in Converse, Goshen, Laramie, and Platte counties. This strategy will also help in determining current impacts of the energy production in the four counties and the necessary permitting approaches needed to provide more funding to the county road and bridge departments. Because of how the increased economy energy companies and their production stimulates local economies, it is important that a balance in needs takes place among these companies and the state and local governments. This cooperation will benefit the Wyoming economy, local communities, and the energy companies. The need to maintain road infrastructure to both support the energy development throughout the county while still maintaining a high level of service to the rest of the local community has to be taken into consideration. Efficiency is vital in this situation due to the understaffed county road and bridge departments and the fast moving pace of the energy companies. When a heavy impact is seen in a county, this component is made that much more valuable and evident. Through this thesis and the strategies developed herein, an increase in efficiency for the counties and their resources will be seen, making for a better use of each party's time, money, and resources.

1.3 Objective of Research

Through a legislative directive, the WYT^2/LTAP was assigned the task of developing methods of determining current impact with consideration that a major increase in energy production, and a substantial increase in impact, will be seen in the near future. Figure 1.3 shows a map of the state of Wyoming and the locations of the four counties considered in this thesis and study.

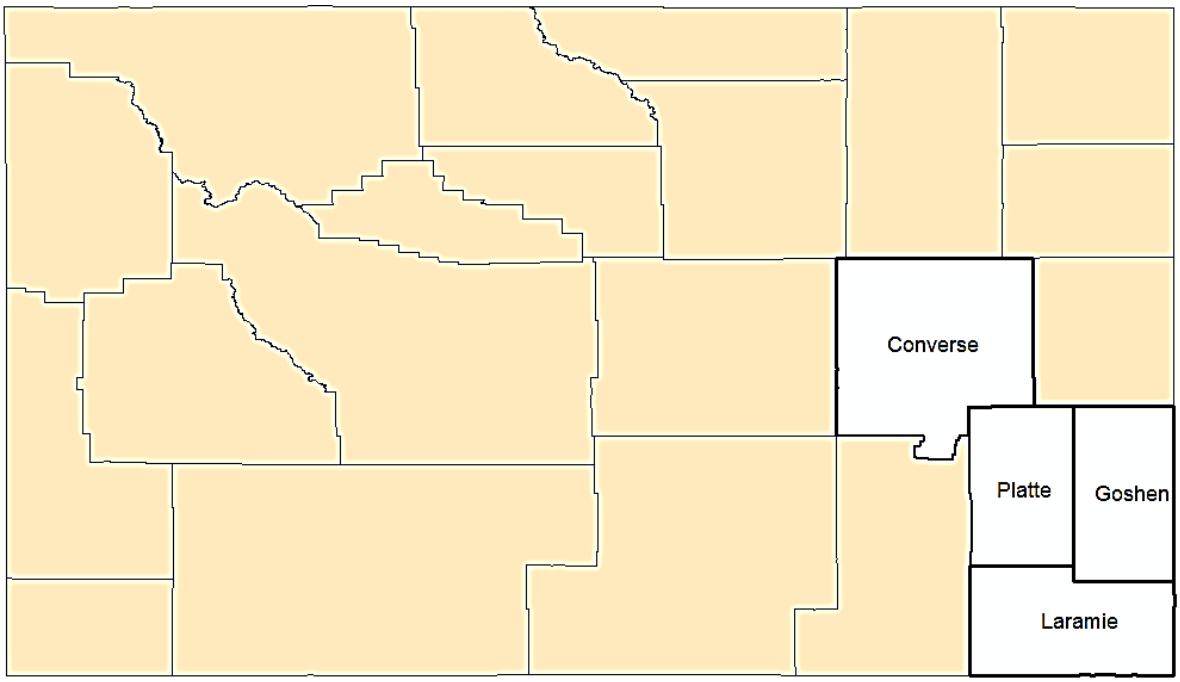


Figure 1.3 Location of Converse, Goshen, Laramie, and Platte Counties

Through the use of the strategies developed throughout this thesis, counties will be able to assess the impact of energy related traffic on their local county roads. By knowing the location and extent of the impact throughout each individual county, proper maintenance recommendations and costs can be determined for each county road. This will, again, provide for a more efficient and effective use of their resources. With data of the impact associated with this type of traffic, additional funding may also be available for each county through the State Legislature.

The primary objective of this research is to develop a strategy to quantify the impact of the energy traffic on local unpaved county roads by examining and assessing the impact throughout Converse, Goshen, Laramie, and Platte counties. The WYT^2/LTAP is working with each county's road and bridge department and the Wyoming Department of Transportation to develop assessment strategies for this impact. This process involved collecting all necessary data for all existing unpaved county roads through the four counties and analyzing the differences between road deemed impacted versus roads deemed non-impacted. After quantifying the impact associated with heavy traffic, more strategies were developed to determine which roads were highly impacted and the methods that could be used maintain and improve these roads.

1.4 Thesis Organization

Chapter 1 provides a brief overview of the topic background of this thesis, the need for addressing the heavy truck traffic associated with the energy related field, and the overall objective of the research.

Chapter 2 of this thesis provides a summary of all applicable literature related to this project of energy related truck traffic on unpaved roads. This chapter details current unpaved road standards and the methods to assess them. There are also brief sections involving cattleguard rating and maintenance strategies and current procedures to permit heavy truck traffic on county roads.

Chapter 3 explains in detail the processes and methodology of this thesis and project. This includes the process of data collection and data analyses as well as determining the impact itself and the means and resources to assess it.

Chapter 4 describes the data collected on all unpaved roads including cattleguards, traffic counts, and unpaved road distress information broken down into each county. This chapter also includes a summary of the data collected and a comparison between each county.

Chapter 5 discusses the various analyses that were performed for the data gathered through this thesis. This includes looking at the difference in impacted versus non-impacted roads, prioritizing roads based on level of impact, and recommending maintenance strategies and costs to the road segments in this study.

Chapter 6 of this thesis looks at the analysis of the cattleguards in the four counties. This includes a brief examination of current conditions and determining the current and replacement costs of the cattleguards in each county.

Chapter 7 describes the permitting processes currently in effect throughout the state of Wyoming. This chapter discusses the permits currently used in every county and how to possibly achieve better results. This chapter also discusses what is currently being done for permitting truck traffic on state roads.

Chapter 8 discusses the conclusions and recommendations based on the analyses performed in chapter 5, 6, and chapter 7. This also includes recommendations for future data collection and further analyses, and how the county agencies can apply the strategies in this thesis toward their efforts.

2. LITERATURE REVIEW

2.1 Advancements in Energy Production Technology

To release the oil and gas from the rock layers, a process known as hydraulic fracturing is used. This process involves pumping sand and highly pressurized fluids into a rock layer causing it to release oil and gas (Halliburton n.d.). Of this pressurized mixture, up to 98%–99.5% of it is made up of sand and water. The force of the water creates tiny fissures in the impermeable rock and helps with the transportation of the sand. The sand then keeps the void open and creates a passageway for the natural gas to flow through. The process itself can take anywhere from three to 10 days to complete. The amount of water needed is dependent on the type and depth of the well and size of the rock layer being fractured. For a typical Chesapeake Energy deep shale natural gas and oil well in the Niobrara formation, approximately 300,000 to 840,000 gallons of water are required for just the drilling operation (Chesapeak Energy 2012). This number is increased to almost five times that amount for fracturing a single Chesapeake Niobrara deep shale horizontal well, which requires an average of 4,000,000 gallons of water. This operation thus creates a great deal of heavy truck traffic for water transportation in addition to that already needed for the oil well equipment. Assuming that most oil and gas companies use a water truck with a capacity of 5,460 gallons of fluid (New York State Department of Environmental Conservation 2011), one well site can produce 780 to 890 water trucks for drilling and fracturing a well. This means the roads that the water trucks are using will experience 1,560 to 1,780 trucks for a drilling process. Due to the excess water from the fracturing process, it is a good possibility that about 75% of these trucks will be fully loaded with water due to half of the return trips being loaded with "dirty" water (New York State Department of Environmental Conservation 2011). At water weighing 8.34 pounds per gallon, the weight of just the water in one of these trucks would be about 45,500 pounds. An average empty truck and trailer used to haul this amount of water weighs about 30,000 pounds, meaning that a full truck and trailer combination would weigh about 75,500 pounds. These heavy loads are obviously not what gravel roads were originally designed for, which causes them to deteriorate at a faster rate and require a great deal of maintenance and time to sustain a warranted level of service.

2.2 Traffic Associated with the Energy Industry

In order to successfully measure the impact of energy related operations on county roads, traffic volumes must be attained. These data provide meaningful information into the type and amount of traffic throughout the counties. However, because of the sporadic nature of most energy companies and their operations, this traffic can be difficult to represent accurately. This is due to route choice by the heavy truck traffic of the energy operations. For example, a road segment in a gridded and developed network may show high traffic volumes, while a road a mile away will show little to no traffic because of the faster route choice to the energy operations. Heavy truck traffic has devastating effects on local low volume roads and causes degradation at an alarming rate. Unfortunately, truck volume estimates on a roadway are very crucial in the design (Federal Highway Administration 1998). A report by the Federal Highway Administration (FHWA) discusses how truck volumes can vary dramatically both over time and site to site by time of the day, day of the week, season of the year, and type of roadway. Along with this, truck classifications have unusual seasonal increases or decreases that relate to specific commodity movements such as harvest hauls, logging, construction, or energy related productions depending on the accessibility of the roads (Federal Highway Administration 1998). The FHWA discusses how this can even vary greatly from month to month depending on some of the same factors.

Oil drilling operations create periods of high truck traffic in a region due to the heavy amounts of equipment needed for the drilling process. Table 2.1 shows information gathered from 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 about truck related traffic in relation to an oil well and its drilling operations.

Table 2.1 Oil Rig Related Movements per Well
(Upper Great Plains Transportation Institute, North Dakota University 2010)

Item	Number of Trucks	Inbound or Outbound
Sand	80	Inbound
Water (Fresh)	400	Inbound
Water (Waste)	200	Outbound
Frac Tanks	100	Both
Rig Equipment	50	Both
Drilling Mud	50	Inbound
Chemical	4	Inbound
Cement	15	Inbound
Pipe	10	Inbound
Scoria/Gravel	80	Inbound
Fuel trucks	7	Inbound
Frac/cement pumper trucks	15	Inbound
Workover rigs	1	Inbound
Total - One Direction	**1,012**	
Total Trucks	**2,024**	

From Table 2.1, it can be seen that there are approximately 2,024 truck movements per well with approximately half of these trip being loaded trips. The North Dakota report also accounts for monthly traffic count adjustments, which show that there is a higher adjustment factor for the summer months, May through September. On major county roads, this report found that there is an average of 61 trucks per day and the average traffic on these roads in oil-producing counties is 145 vehicles per day. Paved roads in this area are generally seeing substantially higher daily traffic as compared with unpaved roads. The paved roads showed mean values of 268 and 99 for the average daily traffic (ADT) and the average daily truck traffic (ADTT), whereas the unpaved roads showed average values of 113 and 52 for ADT and ADTT. From data gathered through this report, benchmark levels were established and traffic numbers on county roads were compared to state highways. The paved roads in this sample showed that the county roads have higher average daily truck traffic than the state collector highways.

2.3 Unpaved Roads

2.3.1 Rating Systems

2.3.1.1 Unsurfaced Road Condition Index

About two-thirds of the highways in the United States and 90% of all roads worldwide are unsurfaced or lightly surfaced low-volume roads (Eaton and Beaucham 1992). In the case of this report, any road not having Portland cement concrete, asphalt concrete, or any other surface treatment will be considered an unsurfaced or unpaved road. To properly maintain this vast majority of roads, certain distresses and problem areas must be examined and appropriate action must be taken in order to halt quick deterioration that will ensue otherwise. Unsurfaced, or unpaved, roads are managed much differently than paved roads and proper maintenance is needed more often on these roads because of the drastic changes in road

conditions due to any changes in weather or traffic (Eaton and Beaucham 1992). In the special report by Eaton, Gerard, and Cate titled, *Rating Unsurfaced Roads: A field manual for measuring maintenance problems,* the authors describe the methods needed for rating these roads. This process is broken down into three distinct steps. The road network is first divided into branches and each branch is then sectioned. A section is simply a part of the branch with consistent characteristics such as the structure, traffic, construction history, unsurfaced road rank, and drainage and shoulders over the length of the section (Eaton and Beaucham 1992). These sections are then divided into sample units of 100 feet, typically, and are then mapped. The next step of this process is to inspect the sections. There are two methods of inspection in this case: a visual "windshield inspection," where the road is driven at 25 mph for the full length noting any problems along the way; the second involves detailed measurements of distresses for the sample sections. The detailed measurements involve recognizing and measuring seven distress types. These distresses are the cross section, drainage, corrugations, dust, potholes, ruts, and loose aggregates. Each distress is measured at low, medium, or high severity and recorded for later analysis. It is suggested through this manual that the visual inspection be conducted four times a year and the detailed measurements be taken once every three years. The third and final step in this process and report is calculating the ratings and determining the Unsurfaced Road Condition Index (URCI). The scale and verbal conditions of the URCI is shown in Figure 2.1.

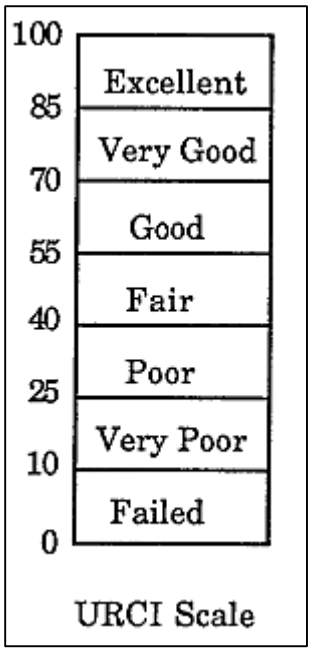


Figure 2.1 URCI Scale (Eaton and Beaucham 1992)

To calculate the URCI, the density of each distress is first determined by calculating the area of the distress as a percentage of the entire sample section area. By knowing the density and the severity of each distress, deduct values can be determined from charts. The total deduct value is then calculated along with a q value, which is simply the number of individual deduct values equal to or greater than 5 (Eaton and Beaucham 1992). By knowing the total deduct value, a line can be drawn from the x-axis up to the q value curve, and a line can then be drawn from this point to the y-axis to determine the URCI value. Figure 2.2 shows the URCI curve and an example of how one would go about finding the URCI from the total deduct value and q value.

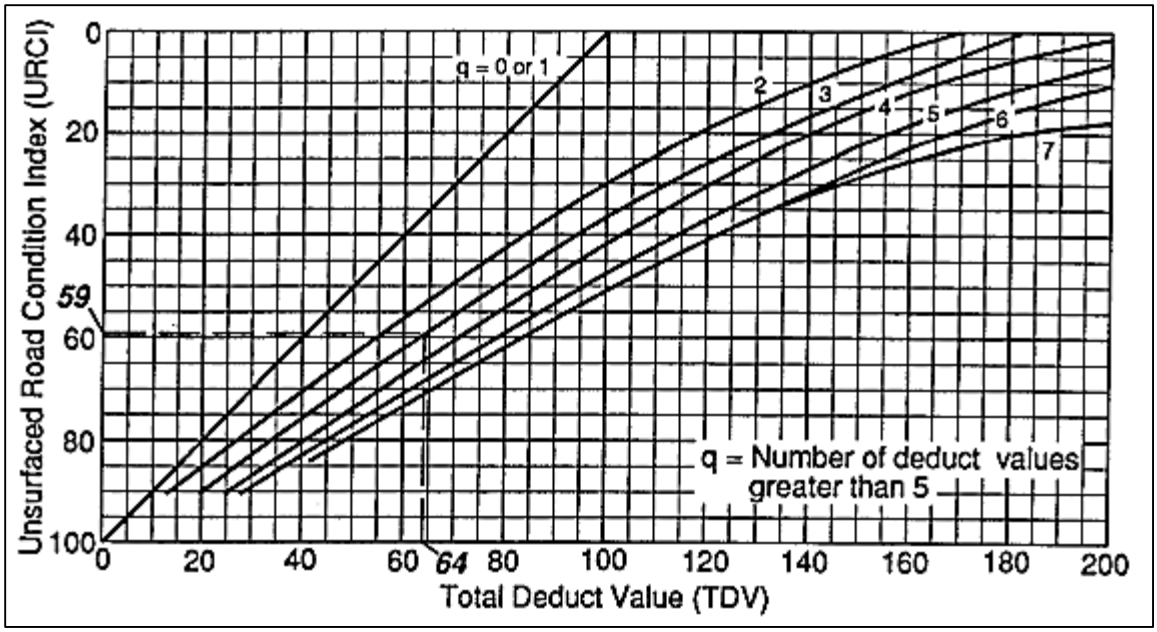


Figure 2.2 URCI Curve (Eaton and Beaucham 1992)

The most valuable information attained from this procedure is to compare the conditions of section in a given road network and use traffic volume, improvement costs, and other information to determine the most cost effective approach for a maintenance budget (Eaton and Beaucham 1992). Although the rating system seems very effective due to the nature of this project this procedure was unusable. This is because of the tedious process involved with measuring the distresses to calculate the URCI and due to the amount of miles needed to be assessed. With short time period in regards to this study this method was simply unfeasible.

2.3.1.2 Gravel PASER

The gravel Pavement Surface Evaluation and Rating manual provided the underlying system used for rating and evaluating the gravel roads in this study and is yet another approach to examining unpaved roads. Due to the nature of gravel roads, the evaluation and rating requires a different perspective than that of asphalt or concrete (Walker, Entine and Kummer 2002). 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 improve the surface conditions significantly. The most important factors in a gravel road are the cross section, drainage and gravel layer (Walker, Entine and Kummer 2002). In order to evaluate and rate the condition of gravel roads, however, the manual describes five road conditions to consider: the crown of the roadway, including the height and condition of the crown and the slope; the drainage of the roadway and the ability of water to be carried away from the road; the gravel layer, which considers adequate thickness and quality of the gravel; the surface conditions, taking into account washboarding, potholes and ruts; and the surface defects of dust and loose aggregate. The rating of each gravel roadway takes into account the different combinations and presence of these five conditions. The 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 or the cross section, drainage, and gravel layer. The actual rating system from this manual is a simple 1 to 5 scale with 5 being excellent and 1 being failed. Table 2.2 shows the rating standards used to rate a road using the Gravel PASER as well as the treatment measures used for each surface rating.

Table 2.2 Gravel PASER Rating Standards (Walker, Entine and Kummer 2002)

Surface Rating	Visible Distress	General Condition/treatment measures
5 (excellent)	No distress. Dust controlled. Excellent surface condition and ride	New construction—or total reconstruction. Excellent drainage. Little or no maintenance needed.
4 (good)	Dust under dry conditions. Moderate loose aggregate. Slight washboarding.	Recently regraded. Good crown and drainage throughout. Adequate gravel for traffic. Routine grading and dust control may be needed.
3 (fair)	Good crown (3”-6”), adequate ditches on more than 50% of roadway. Gravel layer mostly adequate but additional aggregate may be needed in some locations to correct washboarding or isolated potholes and ruts. Some culvert cleaning needed. Moderate washboarding (1”-2” deep) over 10%-25% of the 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)	Shows traffic effects. Regrading (reworking) necessary to maintain. Needs some ditch improvement and culvert maintenance. Some areas may need additional gravel.
2 (poor)	Little or no roadway crown (less than 3”). Adequate ditches on less than 50% of roadway. Portions of the ditches may be filled, over-grown and/or show erosion. Some areas (25%) with little or no aggre-gate. Culverts partially full of debris. Moderate to severe washboard-ing (over 3” deep) over 25% of area. Moderate rutting (1”-3”), over 10%-25% of area. Moderate potholes (2”-4”) over 10%-25% of area. Severe loose aggregate (over 4”).	Travel at slow speeds (less than 25 mph) is required. Needs additional new aggregate. Major ditch construction and culvert maintenance also required.
1 (failed)	No roadway crown or road is bowl shaped with extensive ponding. Little if any ditching. Filled or damaged culverts. Severe rutting (over 3” deep), over 25% of the area. Severe potholes (over 4” deep), over 25% of area. Many areas (over 25%) with little or no aggregate.	Travel is difficult and road may be closed at times. Needs complete rebuilding and/or new culverts.

The roads are segmented according to similar construction and conditions and the averages of each segment will be taken for the final rating. From the 1 to 5 scale, the visible distresses are allocated according to the surface rating, and from each surface rating a maintenance strategy is suggested.

2.3.2 Maintenance Strategies and Costs

2.3.2.1 Gravel Roads Maintenance and Design Manual

Good gravel road maintenance or rehabilitation depends on two basic principles: proper use of a motor grader, or some grading device, and use of good surface gravel (Skorseth and Selim 2000). This is due to the importance of the cross section and drainage characteristics and the quality of gravel materials used in gravel road construction. As vehicle size and weight increase, the effect of degradation on unpaved roads will increase as well. Thus, it is extremely important to properly maintain these roads and provide adequate materials for strength. In order to achieve this, operators must first understand that a crowned driving surface and ditch are needed items (Skorseth and Selim 2000).

Through improper maintenance, the deterioration of unpaved roads occurs quickly. Any increase in traffic numbers, traffic weight, or wet weather conditions only adds to this problem. When weather worsens and adds moisture to the road surface, these needs become much more apparent due to the severity at which unpaved roads deteriorate with wet conditions. Standing water in a road section is one of the major reasons for distress and failure of unpaved roads, so it is extremely important for the cross section to be in proper condition (Skorseth and Selim 2000). However, there are scenarios when water on an unpaved road is needed. The proper amount of water can reduce dust conditions and help reduce washboarding as

well. Thus, the crown of a road is an extremely important aspect when considering maintenance. Too much crown makes for an unsafe roadway while too little creates ponding of water, which then leads to distresses and road deterioration. This same scenario is seen with road shoulders. The shoulders provide drainage as well as a safety area for motorists, and a balance must yet again be reached. When it is impossible to produce effective crown and shoulder drain areas, the subgrade material becomes extremely important. Weak subgrades will not support heavy loads and cause almost immediate deterioration of the road (Skorseth and Selim 2000). This problem is unfortunately not easily fixed through routine maintenance. The most common solution is to both excavate and remove the weak and wet soil, or to add material and reshape the current road if there are no width restrictions (Skorseth and Selim 2000).

Almost every gravel road will gradually begin to show distress that requires more than routine maintenance to correct at some point (Skorseth and Selim 2000). When roads fall into such severe distress, or are in need of maintenance on a more than regular basis, major work needs to be accomplished to provide for more strength or to solve the problem that exists. A combination of any two of severe rutting, loss of crown, gravel loss, and deep secondary ditches will require a major reshaping effort to maintain the given road, and this is usually due to heavy traffic situations (Skorseth and Selim 2000). To maximize cost benefits, it is recommended from this manual that the addition of any gravel layer only be done after the proper reshaping of a given road. In the case of adding gravel to a road, the gradation of the material must be considered for every situation. There must be enough fines to bind everything together and enough coarse materials to increase strength. When proper shape is established and good surface gravel is placed, many gravel road maintenance problems simply go away and road users are provided the best service possible from gravel roads (Skorseth and Selim 2000).

2.3.2.2 Maintenance Costs

A study conducted in Latin America looked at the optimum conditions and costs in which to maintain unpaved roads with varying traffic levels. Although the conditions of these roads may be very different from roads seen in this study, general costs and conclusions can be attained from this data because of the assumption that maintenance costs are directly associated to user costs (Archondo-Callao 2007). Table 2.3Table 2.3 shows the annual vehicle user costs and Table 2.4 shows the annual maintenance costs to maintain a road to a given quality level as provided from the World Bank software program.

Table 2.3 Example of Annual Road User Costs for a Given Road Quality (Archondo-Callao 2007)

Road Condition	Road User Costs, $/vehicle-mile
Very Good	$0.53
Good	$0.61
Fair	$0.78
Poor	$0.91
Very Poor	$1.03

Table 2.4 Example of Annual Maintenance Costs to Maintain a Road Quality Level (Archondo-Callao 2007)

Road Condition	Annual Maint. Costs, $/mile
Very Good	$6,437
Good	$4,828
Fair	$2,414
Poor	$1,609
Very Poor	$805

Although Table 2.3and Table 2.4 show a representation of how costs vary across different road conditions for unpaved roads, it is hard to determine how applicable this would be for more developed road network in more developed regions. Costs associated with improving a road from its current condition to a better condition were determined from this particular study. Improvement examples of this would be re-graveling a road to upgrade its condition to a good standard from a fair standard, rehabilitating a road to upgrade its condition from poor to very good, and widening and improving drainage to upgrade a road from a good condition to a very good condition. Table 2.5, from Archondo-Callao, shows the costs per mile needed to improve a road from one service level to the next.

Table 2.5 Example Investment Costs per Mile Needed to Improve a Road Quality Level

	To Road Quality Level			
From Road Quality Level	Poor	Fair	Good	Very Good
Very Poor	$8,047	$16,093	$64,374	$144,841
Poor		$8,047	$32,187	$80,467
Fair			$16,093	$48,280
Good				$16,093

This study indicates that unpaved roads with 20 or fewer vehicles per day should be maintained to very poor condition, roads with 30 to 90 vehicles per day should be maintained to fair condition, and roads with 100 or more vehicles per day should be maintained to a good condition (Archondo-Callao 2007). Table 2.5 reflects the costs associated with maintaining a road with a lower level of service to lower road conditions. This is purely based off the sample data, but it gives a good illustration of the general principle of gravel road management that low traffic roads should not have a lot of money spent on them (Huntington and Ksaibati, Gravel Roads Management 2010).

2.4 Cattleguards

Cattleguards are a common part of the high plains and the mountainous west and are used to restrict cattle to certain lands while allowing thru traffic without having to open or close gates (Skorseth and Selim 2000). Cattleguards are a special maintenance challenge when installed on gravel roads due to the approach to the cattleguards. The crown has to be eliminated before the cattleguard is reached and must be shaped to match each individual cattleguard while, preferably, not spilling any excess material into the cavity below the grate (Skorseth and Selim 2000). If enough material is spilled into this cavity, the purpose of the cattleguard will be defeated and the cattle will be free to cross into other lands. Because of this, the last few feet before the cattleguard is reached are usually hand-worked to the edge of the cattleguard.

Very little has been done historically for the analysis of cattleguards, and there seem to be only guidelines of maximum load ratings for cattleguards. These ratings and guidelines are produced by The American Association of State Highway Transportation Officials (AASHTO) and provide ratings suitable for all types of applications from passenger cars to logging roads (cattleguards.com 2012). The AASHTO design specifications are as follows:

- H-15 (12 tons per axle)
- H-20 (15 tons per axle)
- U-54 (25 tons per axle)
- U-80 (30 tons per axle)

In order to handle traffic loads, in particular heavier loads, cattleguards are required to be made of certified structural steel and it is generally instructed to use a concrete base for more long-term base support. The concrete base simply keeps the earth from caving into the guard. Due to safety reasons, cattleguards should never be in failing conditions.

2.5 Permitting Energy Related Traffic

2.5.1 Texas Approach

To regulate truck traffic and help stimulate budgets for state and local governments, energy companies, and more in particular, the associated heavy traffic, are required to complete certain permits in relation to their operations. Current energy operations in Texas have led to the development of three different strategies to combat the impact of these operations (Miller and Sassin 2012). The first is a proactive, performance-based approach in which the roads are strengthened before the energy development and fees are associated with facility damage during drilling operations. If funds are spent upfront to preserve the roads, spending will be reduced by 700% compared with situations in which the road is left to be damaged and rebuilt continuously in order to handle the impact (Miller and Sassin 2012). The second is a reactive, performance-based approach. This approach, as the name suggests, looks at the aftermath of the impact and then assesses the fees associated with it. This is also known as a Road Use Agreement, a binding agreement holding the companies damaging the roads responsible for the repair. This damage is assessed from examining the road before and after company use. The third approach is a reactive, non-performance based approach. This approach is much less proactive and has no relation to the actual deterioration of a roadway, but is a simple road damage fee to each well. Through these three methods, a dramatic increase has been seen in regards to the funding of road maintenance in local governments that have adopted these strategies.

2.6 Summary

Through the information gathered in the literature review of this thesis, the analysis of the unpaved roads, cattleguards, permitting, and traffic counts of southeast Wyoming will be achievable. By understanding past processes in these different areas, valuable knowledge can be used to present and analyze the data for this study. Combining and analyzing all this information through uniform and proven procedures will be possible, and the impact of the energy related operations can be determined at a significant level with higher quality control.

3. METHODOLOGY

3.1 Determining Impact

During an initial meeting in the fall of 2011 with the county road and bridge departments, a general framework analysis of the county roads and energy related impact was established. During this meeting, each county road and bridge department representative discussed the location of energy related, and more in particular, oil and gas, companies and operations throughout their county. The roads used to service these locations were then determined. Because of the vast knowledge and experience of the counties about the county road networks, the county road and bridge departments were put in charge of the task of determining the impacted roads in their counties. Because of the faster route choices that energy companies take however, other roads were identified by the county road and bridge departments that were clearly impacted regardless of the proximity of operations. To verify the level of impact on each of these roads, additional strategies were developed later in this thesis. Figure 3.1 shows a basic flowchart of this process to determine the impacted road segments in each county.

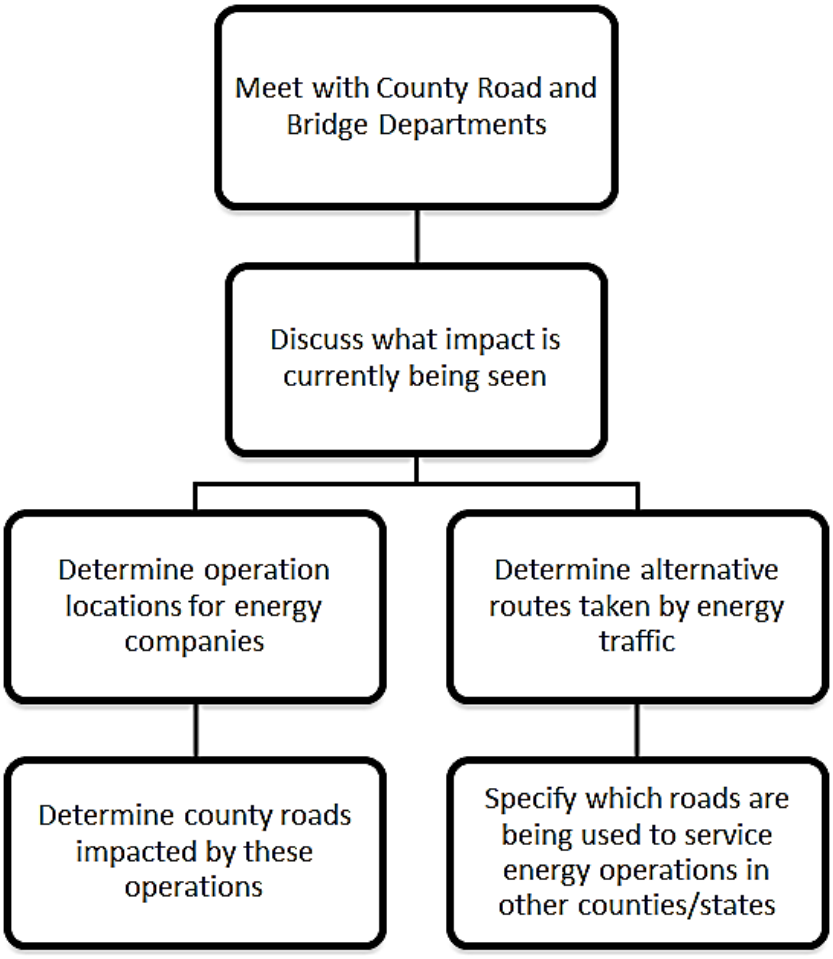


Figure 3.1 Flowchart to Determine Impact in Each County

Because of the more developed networks in Goshen, Laramie, and Platte counties, it was more difficult to determine exactly what routes the energy traffic would utilize to reach their operation locations. However, in Converse County there is a slightly less developed road network, and there is a higher degree of certainty of which roads will be utilized to service an energy company's operation. From this determination of impacted roads within each county, total mileages could be calculated for both the impacted roads and non-impacted roads. Through visually examining the impacted segments in each county, a better understanding of where this impact is and how it could be affecting county roads might be established. This impact can be better seen from
Figure **3.2**, which shows a map of the impacted roads throughout the four counties.

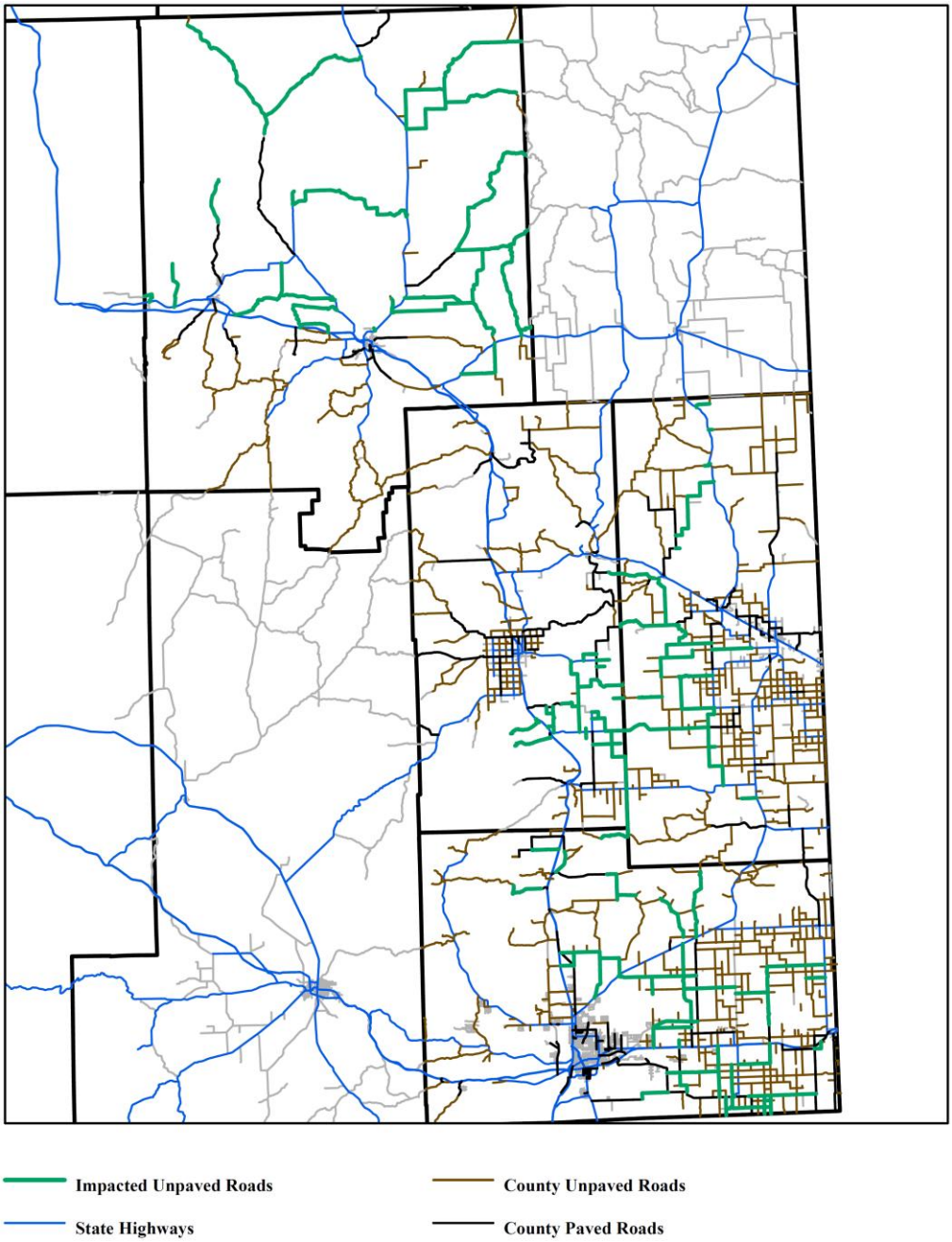


Figure 3.2 Southeast Wyoming Unpaved Impacted Map

Because of the more developed road networks through Goshen, Laramie, and Platte counties, many of the impacted segments were within close proximity of each other, whereas the impacted segments in Converse County are more dispersed through the county. Converse County has higher impacted mileages due to fewer roads, which creates fewer options for traveling to certain locations. However, this does not necessarily mean higher impact and lower road qualities will be seen in this county, and other factors must be considered in determining this.

3.2 Unpaved Roads

The methods used in this thesis to rate and assess unpaved roads were developed by the WYT^2/LTAP. The first step of the process, after determining which roads were impacted according to county road and bridge departments, was to segment both the impacted and non-impacted roads. After segmenting all the impacted roads, data were collected for each segment on current road conditions including distresses and ride quality. These data were then analyzed according to impacted versus non-impacted roads so that priority ranking lists, maintenance recommendations, and costs could be determined. Figure 3.3 shows this general breakdown of the unpaved roads methodology, and the following chapter sections go into more detail about the methodology of the road segmentation, data collection, and data analysis.

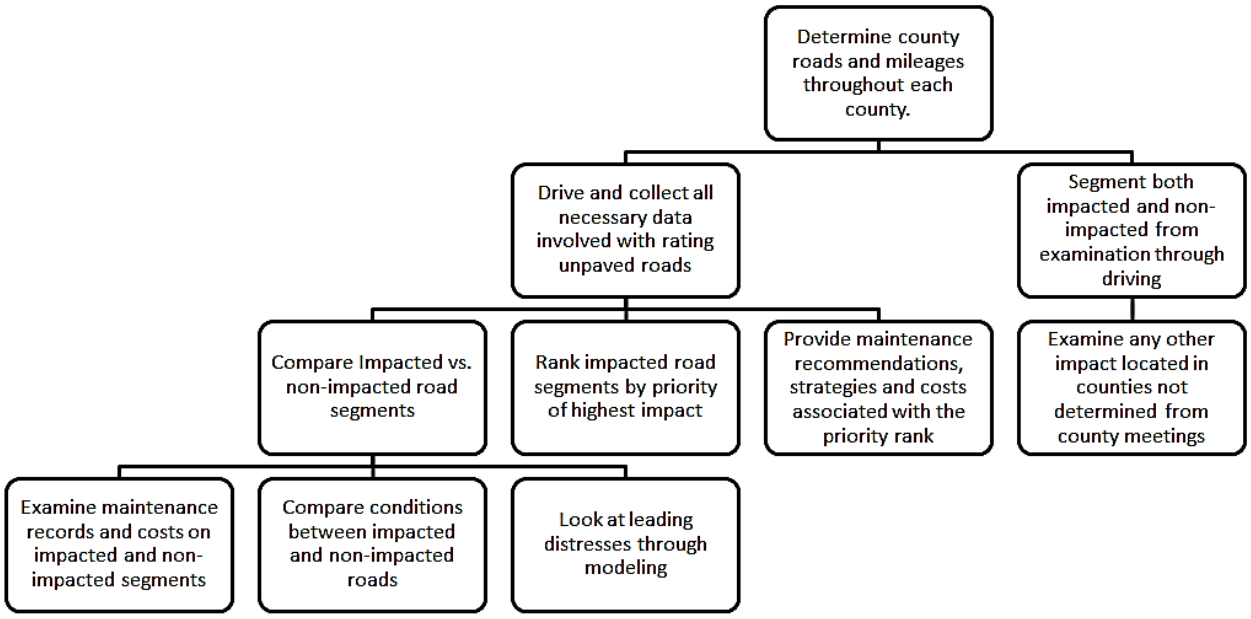


Figure 3.3 General Unpaved Roads Methodology Flowchart

3.2.1 Segmentation

For consistency and quality control purposes, all the unpaved county roads in the four counties needed to be segmented. The segmentation of the roads was based on level of impact, change in surface type, and any major intersections where traffic either diverts or converges with a segment. This was done to create homogenous sections within a road segment for similar distress and ride quality ratings. Most of this segmentation was accomplished during the rating process based on knowledge of the roadway characteristics attained during the driving and rating portion of this study. Once at the beginning of a road segment, the rater would place a pushpin in Microsoft Streets and Trips marking the beginning of a segment. The rater would then drive the road segment until there was an obvious major merge or diverge in traffic. Here, the previous segment would be ended and the next begun. Impacted segments were generally shorter in length because the majority of these roads were in a more developed portion of the

county and the changing conditions through each road due to the randomness of the heavy truck traffic. Non-impacted roads were the opposite of this, being mostly longer in length and located in undeveloped areas. Each segment was rated individually through a visual "windshield" evaluation. The segments were driven at normal traffic speeds and the different distresses and ride quality were analyzed and recorded. For every distress and ride quality of every segment, a single value is recorded based on the guidelines described in the Wyoming modified PASER gravel roads rating standards. Because many of the non-impacted roads showed more uniformity of conditions, longer segments, on average, were produced.

3.2.2 Data Collection

Data collected for the unpaved roads were gathered by driving each road segment. While driving the unpaved roads, any pertinent road information and characteristics were collected before driving and rating each segment. Each segment could then be rated based on distress and ride quality averages. After driving the entire length of the segment, a pushpin would be placed at the end of the segment to determine location. All this information was then compiled into databases and ArcGIS with a common format for future analysis and quality control.

To assess the damage to these roads from the oil and gas impact, they were all driven and rated based on the Wyoming modified PASER system developed by the Wyoming Technology Transfer Center (Huntington, Gravel Roads Rating Standards 2012). Table 3.1 summarizes the standards used for the gravel road evaluation and the Wyoming modified PASER ratings.

Table 3.1 Wyoming Modified PASER Gravel Roads Rating System Standards

Rating	Descriptor	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 (2"-4" deep) over 25% of area; Many areas (over 25%) with little or no aggregate
1	Failed	0-8	

Both the 717 miles of impacted roads and the 2,076 miles of non-impacted roads in all four counties were driven and rated during May 2012 according to this rating system. This was accomplished to gain a better understanding of the conditions of the county gravel roads and how the energy impact is affecting these roads. The Wyoming modified PASER system, unlike the PASER, rates roads on a scale from 1 to 10, with 10 being excellent and 1 being failed. This larger scale is the major difference between the two systems. The Wyoming modified rating system is driven primarily by assessing the damage to the gravel road based on certain types of distresses. The system uses seven different distresses to standardize the gravel roads ratings into one ride quality rating. By examining these ratings, the quality of road conditions can be examined, and a comparison between impacted road conditions and non-impacted road conditions can be assessed. These seven different distresses are numerical ratings and are as follows with the numerical rating in brackets:

- Potholes [1- 9]
- Rutting [1- 9]
- Washboards (Rhythmic Corrugations) [1- 9]
- Loose Aggregate [1- 9]
- Dust [0- 3]
- Cross Section (Crown) [1- 3]
- Roadside Drainage [1 – 3]

These ratings require the driver to be subjective through the segment and use an overall average for each distress. This subjectiveness was reduced by having one person rate every road in every county during the actual rating process, and by receiving training in the Wyoming modified PASER rating system before any rating took place. The standards used to apply the ratings to each road segment can be found in the appendix under Appendix B. Distress Rating Standards. The distresses are designed to be used in conjunction with the Ride Quality Rating Guide, also developed by the WYT^2/LTAP (Huntington, Gravel Roads Ride Quality Rating Guide 2012). The ride quality rating is based on the same numerical ratings from a one to nine (1-9) scale.

Once all the county roads were rated, all this information and any important road characteristic information could be compiled into a database. This database contained all the distress and ride quality ratings, road width, speed (if posted), the location information from Microsoft Streets and Trips, to and from address, road name, segment number, segment length, etc. All this information was then inserted into ArcGIS as shape files for each road segment so that maps could be created from any of the road characteristics or distress and ride quality ratings to easily examine the condition of each road segment throughout each county. The overall process of this data collection has been compiled into a flowchart shown in Figure 3.4.

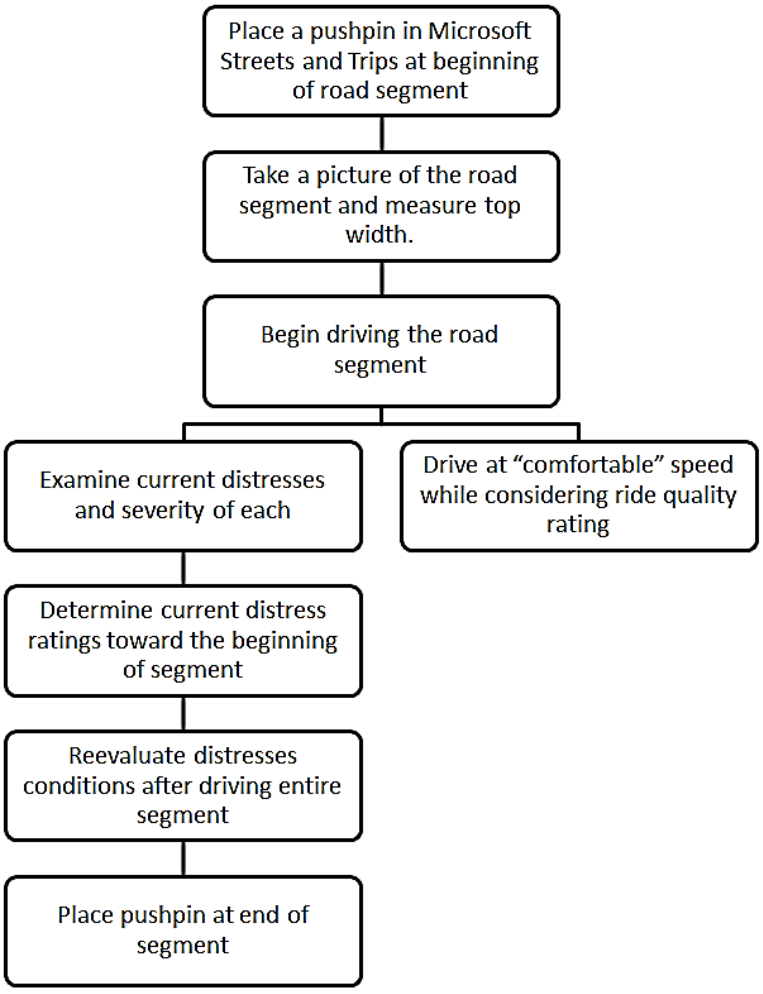


Figure 3.4 Unpaved Roads Data Collection Methodology Flowchart

3.2.3 Data Analysis

The general methodology of the data analysis began with a basic overview and comparison of impacted roads versus non-impacted roads. The distress and ride quality ratings were first examined for each county and were broken down into overall averages of both impacted and non-impacted roads. These averages were then compared to see how the impacted segments differed from non-impacted segments throughout each county. The maintenance records were then examined for Laramie and Goshen counties. Unfortunately, Converse and Platte counties were in the process of developing software to track maintenance records and could not be included in this study. The yearly maintenance costs for each road segment were then calculated for both impacted and non-impacted segments. The total costs for each level of impact and for every segment were then calculated for each year. Total cost per mile per year was then calculated based on the level of impact. These numbers were analyzed to determine the differences in budget spent for impacted roads versus non-impacted roads.

The next step in the data analysis of unpaved roads was to create a priority ranking system. This system produced a list of only impacted roads rated from a 1 to 6 scale based on impact severity. The impact ranks were determined from certain impact characteristics and was produced because there was an obvious difference between many of the impacted segments. These characteristics and the priority ranking process is described in more detail in section 3.2.3.3 of this thesis. The impacted roads then needed to be

divided into high, moderate, and low levels of impact so that maintenance recommendations and costs could be assigned appropriately.

With a priority ranking list now produced, maintenance recommendations and costs could be assigned. In order to accomplish this, the service level for each road segment and road distresses had to be taken into account. From these conditions and the service levels, the maintenance recommendations could be assessed and a price per square yard and cost per mile could be determined from the road width and length. Figure 3.5 shows the basic steps performed for the data analysis of the unpaved roads.

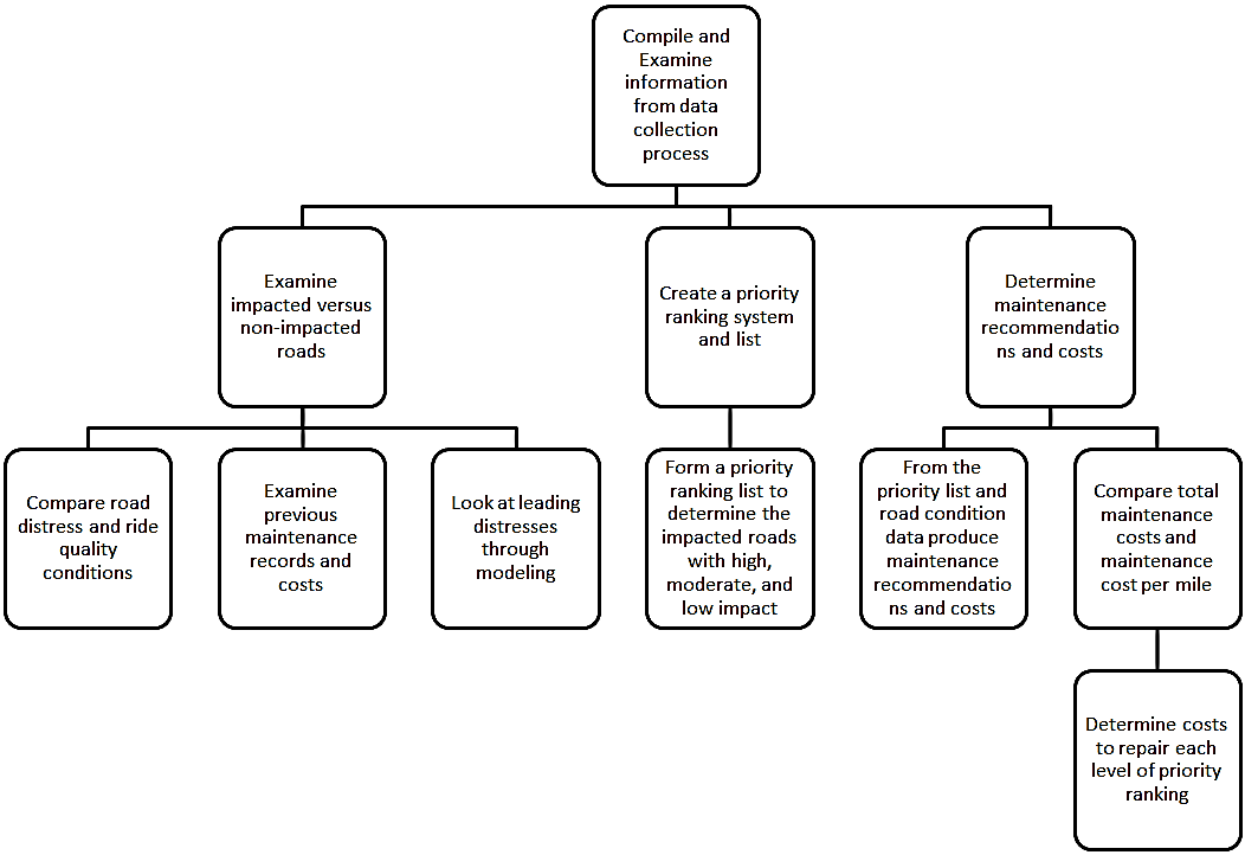


Figure 3.5 Unpaved Roads Data Analysis Methodology Flowchart

3.2.3.1 Impacted Versus Non-Impacted

The condition data (distress and ride quality ratings) were the first things analyzed to gain a better understanding of the difference between impacted and non-impacted segments. These data were expected to show that the distresses and ride quality would be much lower on the impacted road segments due to the higher truck traffic and more degradation. The average distresses and ride qualities through each county were calculated for both impacted and non-impacted segments and the difference between the two could then be determined. From this difference, it could be determined whether or not the impact level has any effect on the distresses or ride quality ratings, and valuable comparisons could be made from this data.

Total maintenance cost and total average cost per mile for both impacted and non-impacted road segments were then determined. This was done through summing the total maintenance costs per year and then dividing this cost by the total impacted or non-impacted mileage of each county. Values would then

be yielded for total cost per year spent on maintenance for impacted and non-impacted roads. These data, again, give a very valuable comparison and understanding in the difference between impacted and non-impacted county unpaved roads. For example, if the cost per mile was lower for non-impacted roads, then there would be a clear indication that the impact level is less.

Each of the four counties uses a computer-based maintenance and cost tracking software to collect information about road maintenance. Unfortunately, the programs used by Platte and Converse counties segment their roads very differently and they assign their work to different types of task. This information thus could not be correlated with the road segmentation used for the unpaved road and therefore could not be used. Laramie and Goshen Counties showed more consistent segmentation in correlation to the segmentation methods used in this thesis. Because of this and the quality of their records, their maintenance records could be used to determine the costs associated with each road segment.

3.2.3.2 Modeling the Data

The program SAS was used for modeling purposes and the statistical analysis portion of this study. Models were created by examining the distresses and impact as independent variables and using the ride quality as the dependent variable. Using the program's stepwise function, variables explaining the most variation in ride quality were produced and selected.

There were two models created using this approach: a full model with all the roads regardless of impact, and a reduced model with only the impacted roads. This was done to determine how the leading distresses differed with impact. With the full model, the variables consisted simply of the distresses and whether the road was impacted or not. The impact portion of these data had to be simplified to a numerical entry and was simply a 0 for no impact or a 1 for impact. The reduced model did not consider the impact because it consisted of only impacted roads and considered the distress along with the ADT, ADTT, and the serviceable rigs within the buffer zone. Both of these models were then statistically analyzed to determine how effective they were in producing models to determine ride quality.

3.2.3.3 Priority Ranking

After analyzing all these data and comparing impacted to non-impacted sections, a final, prioritized, list of highly impacted roads was created and examined. This list was created through a decision tree analyzing the ADT, ADTT, and oil wells and/or water haul sites within a certain proximity of each segment. The oil well proximity was created through using a buffer zone in ArcGIS for each road segment that counted the number of oil wells within the buffer zone. The oil well proximity had to be increased for Converse County due to the sparse road network seen through the county. Each segment was then assigned an impact priority number from 1-6 with the lower number correlating with the higher impact and thus a higher priority. The maintenance records were not part of this decision tree due to the county maintenance segmentation not corresponding to the segmentation process conducted in this study.

3.2.3.4 Maintenance Recommendations

A method previously used by the WYT^2/LTAP has been adapted for this study in maintenance recommendations and associated costs (Huntington and Ksaibati, Annualized Road Works Cost Estimates for Unpaved Roads 2009). The first step of this process was to determine service levels for each road, determined from ADT and the road top width, for quality control purposes. For example, an unpaved county road having a top width of 28 feet and an ADT of 250+ would be expected to have a high service level. This service level would then be taken into account for maintenance recommendations because of the importance of higher quality levels of roads needed for higher traffic levels, and thus more improved maintenance strategies would be used. The road distress conditions, dust, and ride quality ratings were

then evaluated to target a more effective use of maintenance strategies for each road segment. This was done through the use of a decision matrix through the distresses and ride quality to select the most appropriate maintenance strategy. By selecting the most effective and efficient maintenance strategy for each unpaved road segment, the counties will be able to create a more cost effective use of their time and money.

3.3 Cattleguards

The cattleguards in the four counties of southeast Wyoming were also evaluated as part of this study. This was a simple and effective process in which the driver rating the unpaved roads would rate the cattleguards as he/she encountered them. Once a cattleguard was crossed, the driver would place a pushpin in Microsoft Streets and Trips to mark the location, exit the vehicle to document the cattleguard, visually assess the conditions of the base, grates, wings, and approach, and take necessary measurements. After these data were collected and tabulated, overall averages of each condition for each county were assessed. These data were then used to determine replacement costs for the base, grate, wings, and approach in each county. Figure 3.6 shows a basic flowchart of the methodology used for cattleguard evaluation in this context.

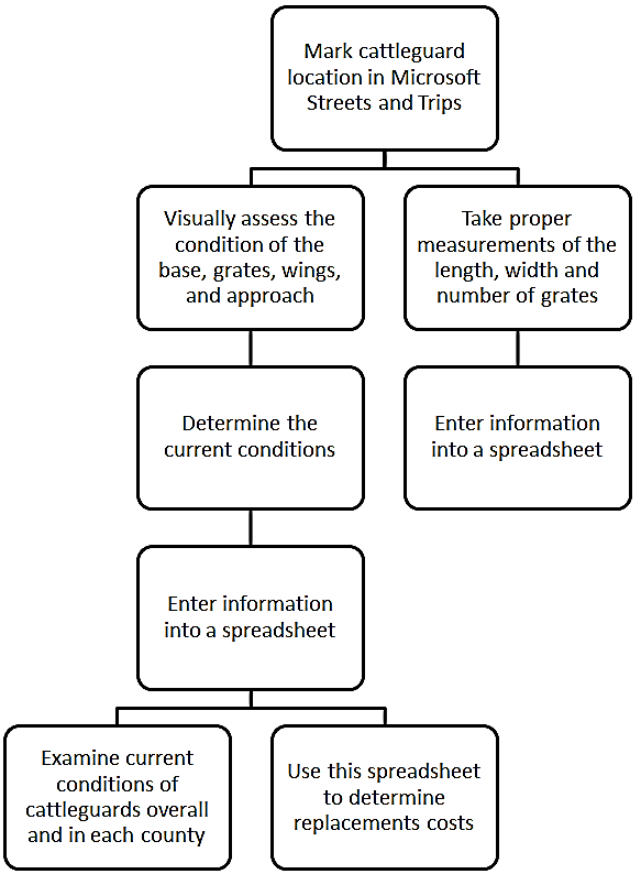


Figure 3.6 General Cattleguard Methodology

For this study, a rating system was developed by the WYT^2/LTAP. This rating system took into account the approach, base, wings, and grate conditions. Each of these is then broken down into five different conditions, with the exception of the wings condition, which takes into account if the cattleguard has wings or not. The other five standards are broken into whether the condition of the different

characteristics is excellent, good, fair, poor, or very poor. Again, this requires the rater to be somewhat subjective in his/her ratings. The verbal standards for these ratings and conditions are as follows:

- Approach
  - Excellent
    - Smooth transition from roadway to structure, no need to reduce speed, and negligible risk of driver losing control of vehicle at typical roadway speeds
  - Good
    - Minor bump, slight reduction in speed is advisable, negligible risk of vehicle or tire damage at typical roadway speeds, and minor risk of driver losing control of vehicle at typical roadway speeds
  - Fair
    - Significant bump, significant reduction in speed is advisable, minor risk of vehicle or tire damage at typical roadway speeds, and moderate risk of driver losing control of vehicle at typical roadway speeds
  - Poor
    - Major bump, significant reduction in speed is necessary, high risk of vehicle or tire damage at typical roadway speeds, and high risk of driver losing control of vehicle at typical roadway speeds
  - Very Poor
    - Large hole at approach, passenger car at risk of bottoming out at any speed, all vehicles must greatly reduce speed, and driver unable to control vehicle at typical roadway speeds
- Base
  - Excellent
    - New or like new and well-constructed
  - Good
    - No significant flaws, minor wear and tear, negligible risk of grate or base movement, and negligible risk of vehicle or tire damage from base
  - Fair
    - Significant wear and tear but no major problems, very minor risk of grate or base movement, and minor risk of vehicle or tire damage from base
  - Poor
    - Moderate risk of vehicle or tire damage from base and minor risk of grate movement or collapse due to base movement or failure
  - Very Poor
    - Significant risk of vehicle or tire damage from base, significant risk of base movement causing grate to shift, and significant risk of base collapse
- Grate
  - Excellent
    - New or like new and well-constructed
  - Good
    - No significant flaws, minor wear and tear, negligible risk of grate bar or brace breakage, and negligible risk of vehicle or tire damage from grate
  - Fair
    - Significant wear and tear but no major problems, very minor risk of grate bar or breakage, and minor risk of vehicle or tire damage from grate
  - Poor
    - Moderate risk of vehicle or tire damage from grate and minor risk of grate bar or brace failure

    - Very Poor
        - Significant risk of vehicle or tire damage from grate and significant risk of bar or brace failure
- Wings
    - Excellent
        - New or like new, well-constructed, negligible risk of wing breakage or failure, negligible risk of vehicle striking wings, and negligible risk of vehicle being stopped abruptly or flipped by wings
    - Good
        - No significant flaws, minor wear and tear, negligible risk of wing breakage or failure, negligible risk of vehicle striking wings, and negligible risk of vehicle being stopped abruptly or flipped by wings
    - Fair
        - Significant wear and tear but no major problems, minor risk of wing breakage or failure, minor risk of vehicle striking wings, and minor risk of vehicle being stopped abruptly or flipped by wings
    - Poor
        - Moderate risk of wing breakage or failure, moderate risk of vehicle striking wings, and moderate risk of vehicle being stopped abruptly or flipped by wings
    - Very Poor
        - Significant risk of wing breakage or failure, significant risk of vehicle striking wings, and significant risk of vehicle being stopped abruptly or flipped by wings
    - None

3.3.1 Data Collection

During the driving and rating of the unpaved roads in May 2012, the cattleguards for each county were visually assessed and marked in Streets and Trips for location purposes. Every cattleguard was rated according to the WYT^2/LTAP Cattleguards Rating Standards. For every cattleguard crossed during the rating of the unpaved and paved roads, the rater would examine and photograph each cattleguard as well as mark the location on Microsoft Streets and Trips for use in ArcGIS. Once examined, the condition ratings were determined and entered into a spreadsheet with the pertinent information such as dimensions, location, date, and raters. These condition ratings were then broken down into each county and the overall average conditions of cattleguards in each county were analyzed. Unfortunately, due to the nature of the data collection and the random nature of replacing cattleguards, there was no comparison between impacted and non-impacted cattleguards for this case.

3.3.2 Data Analysis

These ratings were then incorporated into a maintenance strategy developed by the WYT^2/LTAP. The general costs for a new cattleguard, thus the replacement costs, were determined from estimates from WYDOT for the weighted average bid prices of medium duty 18- and 24-foot cattleguards. From these costs and maintenance strategies, overall costs of current and replacement values were determined. Replacement cost percentages were determined for each condition rating for the base, grate, wings, and approach. From these percentages, the overall cost of a replacement cattleguard was broken down into each of these categories. Replacement and current values could be determined for each cattleguard and each characteristic in each county, and overall total cost of replacement and current values for each county could be calculated. The difference between replacement and current values is that the replacement values are determined from assuming everything is in excellent condition and thus 100% of its original value. As the conditions of each characteristic lessen, the percentage of original value

decreases thus decreasing the current value and increasing the cost to upgrade all cattleguards to a new, or replaced, condition. Unfortunately there was no appropriate measure of maintenance records or costs for the cattleguards in Southeast Wyoming.

3.4 Traffic Counts

To assist in this comparison and evaluation, traffic counts were also collected on both impacted and non-impacted roads throughout the counties. With the help of the WYT^2/LTAP, traffic counts were placed on 173 different road segments throughout the counties between September 2011 and July 2012. These counters included both impacted and non-impacted roads as well as paved and unpaved roads. However, most of these counters were placed on impacted roads to quantify the amount of heavy truck traffic, and the counters placed on non-impacted roads were used for comparison purposes and to evaluate the distribution of traffic across the counties.

The traffic counters were placed during the week at no less than 24 hours per location. This was done to target the greater amount of oil and gas traffic being on the week days established from the long-term counters placed in Goshen County. The Centurion CC program was used to produce automated output files for the traffic counts with a summary of traffic volumes and speeds. Because it was impossible to obtain traffic counts on every road segment in every county, counts for segments without any traffic information were established from other segments of the same road.

3.5 Methodology Summary

The methodologies developed in this thesis will provide a means to collect and analyze pertinent data in regards to the energy related truck traffic and its impact on county unpaved infrastructure. By incorporating standardized methods to examine unpaved roads, cattleguards, and traffic counts, and to determine the impact in a county, more precise data will be produced and a higher level of quality control will be reached. By ensuring higher quality control through this methodology, the comparisons and analyses conducted later in this study will be significant and at a level useable to the counties, state legislature, and energy companies for future use.

4. DATA COLLECTION

The data collection was a key factor in this study due to the development of strategies to determine energy related truck traffic impact. The quality control throughout all the driving and rating of roads was a top priority because of this. All aspects of every road segment and cattleguard needed to be examined thoroughly to collect valuable data and produce a high quality data set. To help with this quality control, two raters would drive the road segments together to better determine the values for each distress and ride quality rating. These raters would then switch halfway through the day so that the person entering data into the spreadsheet would then be the driver and vice versa. By having two raters discussing the condition ratings and justifying the ratings, a small portion of the subjective aspect of the process could be removed.

4.1 Unpaved Roads

The conditions of gravel roads are very dependent on road characteristics, maintenance levels, and traffic data. Maintenance costs will increase with the increase in traffic in almost every application. However, the addition of new gravel to an unpaved road will have a much higher cost than simple maintenance strategies. Thus, as traffic increases, the addition of gravel layers will increase as well. When traffic on county gravel roads grows to a certain extent, the county is faced with the question of whether or not to pave due to the high cost of maintenance. However, the conditions of the roads must be assessed first. To gain a better understanding of the current conditions of the county unpaved roads, all these roads were driven and rated accordingly. These data will show the level that each county maintains their unpaved roads to and will later show how this differs across each county and impact.

Table 4.1 shows the mileages and number of segments of impacted and non-impacted roads in each county along with the totals.

Table 4.1 Unpaved County Road Mileages and Segment Counts

County	Impacted		Non-Impacted		*Total*	
	Mileage	***# of Segments***	***Mileage***	***# of Segments***	***Mileage***	***# of Segments***
Converse	285.3	73	239.8	59	525.1	132
Goshen	130.0	53	778.0	225	908.0	278
Laramie	222.3	150	786.1	232	1008.4	382
Platte	80.0	35	272.8	104	352.8	139
TOTAL	**717.6**	**311**	**2076.6**	**620**	**2794.2**	**931**

More than 717 miles of gravel roads were deemed impacted by energy related traffic. This represents over 25% of the total unpaved road mileage in the four counties. It can be seen that Converse County is the only county having more mileage of impacted roads than non-impacted. This most likely is due to the nature of the impact in the county and the underdeveloped road network.

4.1.1 Converse County

From Table 4.1, it can be seen that there is approximately 285 miles of impacted roads and 240 miles of non-impacted roads in Converse County. The overall averages, impacted averages, and non-impacted averages for the distress and ride quality ratings of unpaved roads in this county can be seen in Table 4.2.

Table 4.2 Converse County Average Distress and Ride Quality Ratings

County	X-Section [1-3]	Roadside Drainage [1-3]	Dust [0-3]	Rutting [1-9]	Potholes [1-9]	Loose Aggregate [1-9]	Corrugations [1-9]	Ride Quality [1-9]
Overall Averages								
Converse	2.8	2.8	1.6	7.2	7.4	7.1	7.3	7.1
Impacted Averages								
Converse	2.9	2.9	1.5	7.3	7.6	7.1	7.3	7.2
Non-Impacted Averages								
Converse	2.7	2.7	1.8	7.0	7.2	7.1	7.3	7.0

The averages in Table 4.2 show very little variation across each distress and ride quality rating. Again, the higher ratings correlate to the better road conditions. The largest difference of a distress of impacted versus non-impacted segments was the dust rating. The ride quality rating of the impacted segments was only 0.2 higher than that of the non-impacted segments average. A map of the ride quality ratings of all road segments in Converse County are shown in Figure 4.1 while the dust ratings for these same segments are shown in Figure 4.2. The dust ratings used for mapping purposes are scaled from 1-4 as to not show ratings of zero. Therefore, a dust rating of zero would correlate with a rating of 1 on the maps, while a rating of 1 would correlate with 2 on the map, and so on. These were the only maps made of distresses and ride quality due to the importance of ride quality in terms of overall road condition and the importance of dust for county road and bridge departments.

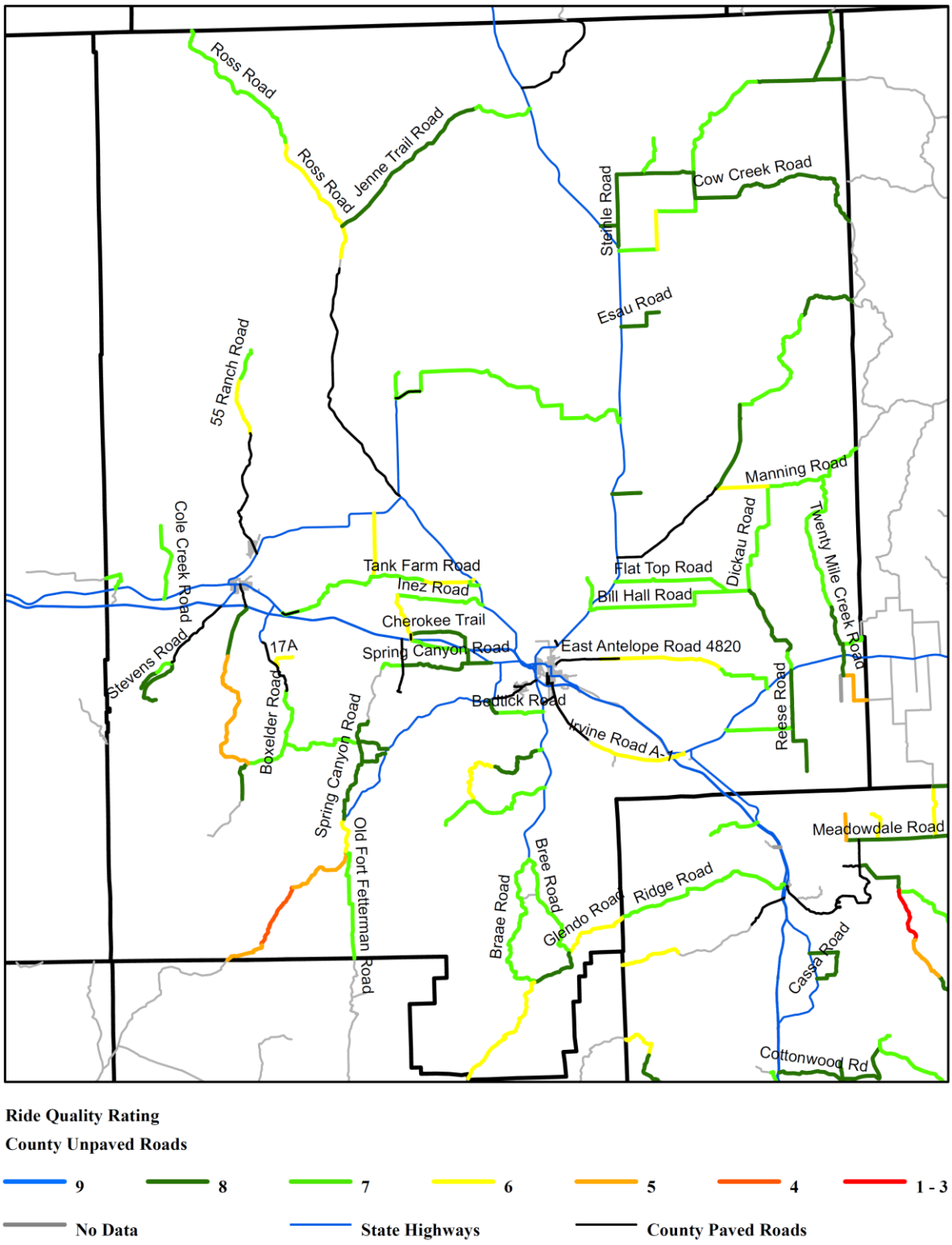


Figure 4.1 Converse County Ride Quality Rating of Unpaved Road Segments

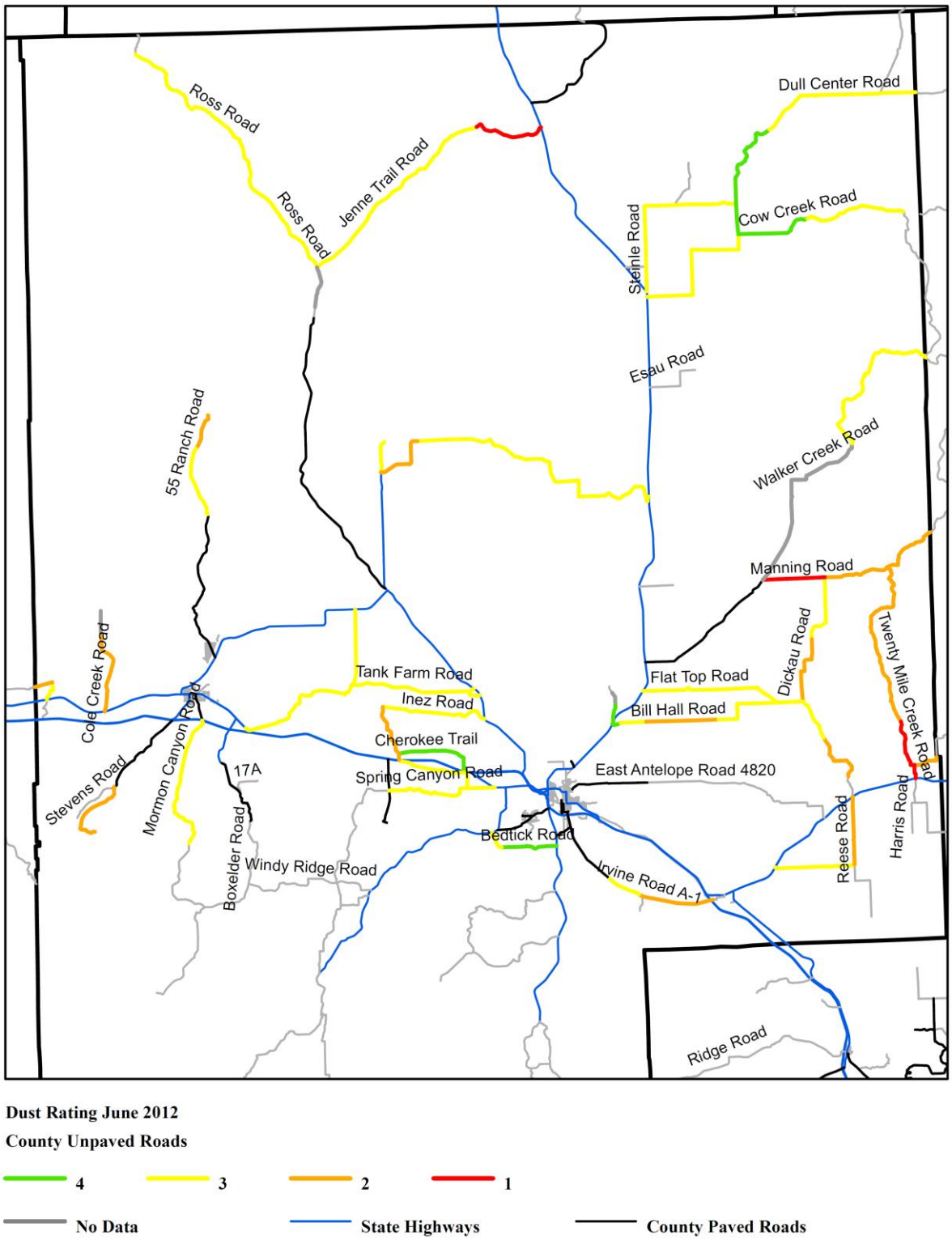


Figure 4.2 Converse County Dust Rating of Unpaved Road Segments

The ride quality ratings in Converse County seem to be spread sporadically throughout the county with only some consistency. The lower ratings, on average, seem to stem from unpaved county roads south of Interstate 25, which happen to be where a majority of the non-impacted roads are located.

4.1.2 Goshen County

Goshen County had only 130 miles of impacted roads of its total 908 miles of unpaved roads in the county. The overall averages, impacted averages, and non-impacted averages for the distress and ride quality ratings of unpaved roads in this county can be seen in Table 4.3

Table 4.3 Goshen County Average Distress and Ride Quality Ratings

County	X-Section [1-3]	Roadside Drainage [1-3]	Dust [0-3]	Rutting [1-9]	Potholes [1-9]	Loose Aggregate [1-9]	Corrugations [1-9]	Ride Quality [1-9]
Overall Averages								
Goshen	2.8	2.8	1.8	6.9	7.3	7.4	7.7	7.0
Impacted Averages								
Goshen	2.7	2.7	1.9	6.7	7.2	7.3	7.8	6.8
Non-Impacted Averages								
Goshen	2.9	2.8	1.6	7.1	7.4	7.4	7.5	7.1

The averages in Table 4.3 show slightly more variation across each distress and ride quality rating in this case. The largest difference of a distress of impacted versus non-impacted segments was the rutting rating, with the impacted segments having approximately a 0.4 lower rating on average. The ride quality rating of the impacted segments was only 0.3 lower than that of the non-impacted segments average. Maps of the ride quality and dust ratings of each road segment in Goshen County are shown in Appendix C. Ride Quality and Dust Maps. There seems to be fewer road segments with lower ride quality ratings throughout Goshen County. The gridded, and more developed, portions of road networks in Goshen County seem to show higher ride quality ratings while the road sections in underdeveloped portions seem to show slightly lower ride quality ratings. The majority of the impacted roads are on the western half of the county and seem to show the most variation in ride quality ratings.

4.1.3 Laramie County

Laramie County had the highest mileage of unpaved county roads with 1,008 miles. Of this, 222 miles were deemed impacted by the County Road and Bridge Department. The overall averages, impacted averages, and non-impacted averages for the distress and ride quality ratings of unpaved roads in Laramie County can be seen in Table 4.4.

Table 4.4 Laramie County Average Distress and Ride Quality Ratings

County	X-Section [1-3]	Roadside Drainage [1-3]	Dust [0-3]	Rutting [1-9]	Potholes [1-9]	Loose Aggregate [1-9]	Corrugations [1-9]	Ride Quality [1-9]
Overall Averages								
Laramie	2.9	2.9	2.0	7.2	7.4	7.3	7.4	7.0
Impacted Averages								
Laramie	2.9	2.8	1.9	7.5	7.1	7.3	7.4	6.9
Non-Impacted Averages								
Laramie	2.9	2.9	2.0	7.2	7.4	7.4	7.4	7.1

The averages in Table 4.4 of the unpaved road segments in Laramie County, show very little variation in distress and ride quality ratings. Again, rutting was the distress with the highest variation between impacted and non-impacted with the impacted being 0.3 higher than the non-impacted, on average. The ride quality of the impacted segments was only 0.2 lower, on average, than the non-impacted roads. Maps of the ride quality and dust ratings of each road segment in Laramie County are shown in the appendix under Appendix C. Ride Quality and Dust Maps. The ride quality ratings are spread sporadically throughout Laramie County. In this case there is no consistency in the higher ride quality ratings being in the more developed road networks and lower ratings being in the less developed areas. With the impacted road segments in Laramie County being more spread out through the county, there are no justifiable conclusions that can made from the ride quality dispersion through this county from only examining the ride quality map.

4.1.4 Platte County

Platte County had the lowest total and impacted mileages between the four counties considered in this study. It only had 80 miles of roads deemed impacted and only about 353 total miles of unpaved county roads in the county. The overall averages, impacted averages, and non-impacted averages for the distress and ride quality ratings of unpaved roads in Platte County can be seen in Table 4.5.

Table 4.5 Platte County Average Distress and Ride Quality Ratings

County	X-Section [1-3]	Roadside Drainage [1-3]	Dust [0-3]	Rutting [1-9]	Potholes [1-9]	Loose Aggregate [1-9]	Corrugations [1-9]	Ride Quality [1-9]
Overall Averages								
Platte	2.7	2.7	2.2	6.9	7.0	7.2	7.7	6.6
Impacted Averages								
Platte	2.5	2.5	2.1	6.7	6.9	7.2	8.0	6.4
Non-Impacted Averages								
Platte	2.9	2.8	2.2	7.0	7.1	7.2	7.3	6.8

In this case, there seems to be slightly more variation across impacted, non-impacted, and overall averages for the distress and ride quality ratings. The corrugations ratings showed almost a full point difference between impacted roads versus non-impacted roads with the impacted roads having a 0.7 higher rating for this distress. However, the other distresses, and the ride quality, showed lower average ratings for the impacted segments compared with the non-impacted segments. The ride quality for impacted roads in Platte County showed, on average, a 0.4 lower rating than the non-impacted roads. Maps of the ride quality and dust ratings of each road segment in Platte County are shown in Appendix C. Ride Quality and Dust Maps. The ride quality ratings throughout Platte County seem to show lower values county-wide. The ratings for ride quality are randomly spread throughout the county, even though the impacted road segments are found only in the southeast corner of the county. The more developed and gridded portions of the county seem to show some consistency in these ratings, unlike the undeveloped portions.

4.1.5 Comparison and Summary

The overall average ride quality (both impacted and non-impacted roads) throughout the four counties is approximately 7, with Platte County being the only exception having a ride quality of 6.6. A ride quality of 7 coincides with a road in good condition having dust in dry conditions, moderate loose aggregate, and

slight wash boarding. The average ratings for all the unpaved roads in all four counties are shown in Table 4.6.

Table 4.6 Road Distress and Ride Quality Conditions

County	X-Section	Roadside Drainage	Dust	Rutting	Potholes	Loose Aggregate	Corrugations	Ride Quality
Overall Averages								
Converse	2.8	2.8	1.6	7.2	7.4	7.1	7.3	7.1
Goshen	2.8	2.8	1.8	6.9	7.3	7.4	7.7	7.0
Laramie	2.9	2.9	2.0	7.2	7.4	7.3	7.4	7.0
Platte	2.7	2.7	2.2	6.9	7.0	7.2	7.7	6.6
Averages	**2.8**	**2.8**	**1.9**	**7.0**	**7.3**	**7.2**	**7.5**	**6.9**
Impacted Averages								
Converse	2.9	2.9	1.5	7.3	7.6	7.1	7.3	7.2
Goshen	2.7	2.7	1.9	6.7	7.2	7.3	7.8	6.8
Laramie	2.9	2.8	1.9	7.5	7.1	7.3	7.4	6.9
Platte	2.5	2.5	2.1	6.7	6.9	7.2	8.0	6.4
Averages	**2.7**	**2.7**	**1.8**	**7.0**	**7.2**	**7.2**	**7.6**	**6.8**
Non-Impacted Averages								
Converse	2.7	2.7	1.8	7.0	7.2	7.1	7.3	7.0
Goshen	2.9	2.8	1.6	7.1	7.4	7.4	7.5	7.1
Laramie	2.9	2.9	2.0	7.2	7.4	7.4	7.4	7.1
Platte	2.9	2.8	2.2	7.0	7.1	7.2	7.3	6.8
Averages	**2.9**	**2.8**	**1.9**	**7.1**	**7.3**	**7.3**	**7.4**	**7.0**
Differences Between Impacted vs. Non-Impacted								
Converse	0.2	0.2	-0.4	0.2	0.3	0.0	0.0	0.2
Goshen	-0.2	-0.1	0.3	-0.4	-0.2	-0.1	0.3	-0.3
Laramie	0.0	-0.1	-0.1	0.3	-0.2	-0.1	0.0	-0.2
Platte	-0.4	-0.3	-0.1	-0.3	-0.2	0.0	0.7	-0.4
Averages	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**0.3**	**-0.2**

From Table 4.6, it can be seen that the unpaved roads in all counties, on average, seem to be in fair to good condition according to the Wyoming modified PASER rating standards. The distresses shown seem to correlate with the ride quality ratings very well, as seen in Table 3.1 of the rating system standards. The overall averages show similar ratings for each county and each distress with the most variation in the rutting and corrugations. The non-impacted averages throughout the four counties show very similar numbers for each distress, and the ride quality with dust being the distress with the highest variation. The drainage and cross section, on average, seem to be in very good condition throughout the counties and the main distresses leading to a lower ride quality seem to be the potholes and rutting. Platte County shows lower ride quality ratings through every average and has the largest difference between impacted and non-impacted ride quality averages. Overall, there were very minimal differences between impacted and non-impacted road segments throughout the four counties in southeast Wyoming, however, and any major variation in the average differences seem to stem from Platte County.

4.2 Cattleguards

The cattleguards in the four counties were spread mostly throughout the underdeveloped portions of the counties. The more developed areas in each county seemed to show less concentration in cattleguard numbers. This is most likely due to the majority of ranches and animals being located in the more underdeveloped areas of each county. Figure 4.3 shows a map of cattleguard locations in Converse,

Goshen, Laramie, and Platte Counties from the data collected on Microsoft Streets and Trips during the driving process.

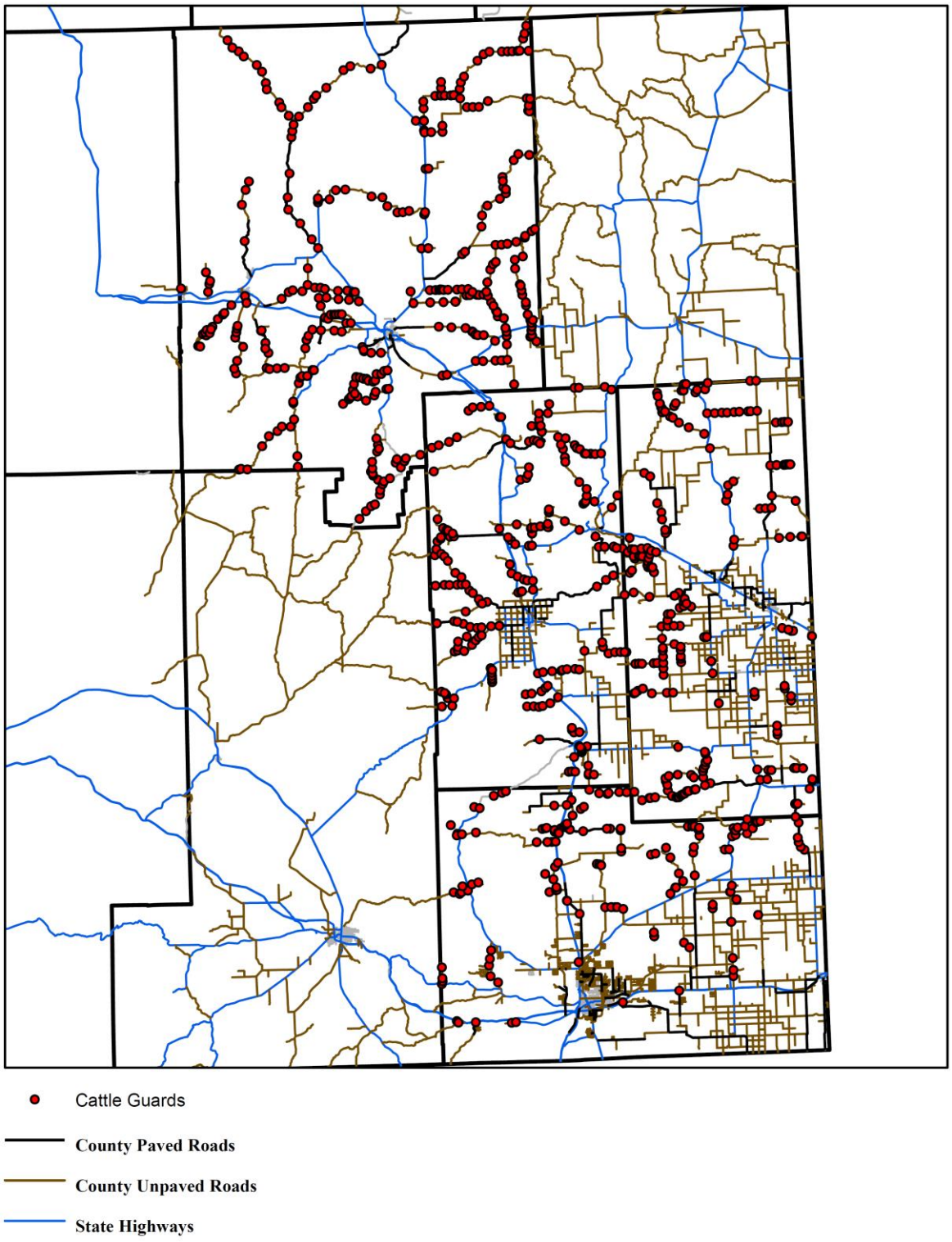


Figure 4.3 Cattleguard Locations in Study Area

The cattleguards in southeast Wyoming were visually assessed during data collection in May 2012. The data collected for this assessment were simply the verbal conditions of the wings, grate, approach, and base of each cattleguard. Table 4.7 shows the numbers and percentages of the approach, base, grate, and wings in excellent, good, fair, poor, or very poor conditions, or whether or not wings were present.

Table 4.7 Overall Cattleguard Conditions

Verbal Condition	Approach Condition	%	Base Condition	%	Grate Condition	%	Wings Condition	%
Excellent	37	4%	50	5%	59	6%	64	7%
Good	471	48%	581	60%	649	67%	300	31%
Fair	381	39%	274	28%	213	22%	153	16%
Poor	80	8%	66	7%	47	5%	121	12%
Very Poor	4	0%	2	0%	5	1%	22	2%
None	**X**	**X**	**X**	**X**	**X**	**X**	313	32%

Table 4.7 shows that the cattleguards in southeast Wyoming are, on average, in good condition. The only exception to this is the condition of the wings. This is because 32% of the cattleguards in southeast Wyoming had no wings on them. For a more comprehensive look at the conditions of the cattleguard, the ratings were broken down into each county.

4.2.1 Converse County

Converse County contained the most cattleguards with 339 throughout the county. The conditions of the cattleguards in the county show the same trend as the overall average conditions, with a majority of the conditions of the approach, base, grate, and wing conditions being in good condition. Table 4.8 shows the breakdown of counts of the conditions of the approach, base, grate, and wings of the cattleguards and shows the percentages of each.

Table 4.8 Converse County Overall Cattleguard Conditions

Verbal Condition	Approach Condition	%	Base Condition	%	Grate Condition	%	Wings Condition	%
Excellent	4	1%	6	2%	9	3%	5	1%
Good	175	52%	206	61%	219	65%	101	30%
Fair	129	38%	92	27%	86	25%	49	14%
Poor	30	9%	35	10%	23	7%	46	14%
Very Poor	1	0%	0	0%	2	1%	3	1%
None	**X**	**X**	**X**	**X**	**X**	**X**	135	40%

A majority of the cattleguards in Converse County have no wings. The other characteristics of the cattleguards in the county are, on average, in good condition. The maps of each characteristic and its condition were mapped in ArcGIS to determine if there were any trends in the conditions of any of the characteristics of the cattleguards in the county with regard to impact. Figure 4.4 shows a map of the conditions of the approach of the cattleguards in Converse County. The remaining maps showing the conditions of the grates, bases, and wings are in Appendix D. Cattleguard Maps and Tables.

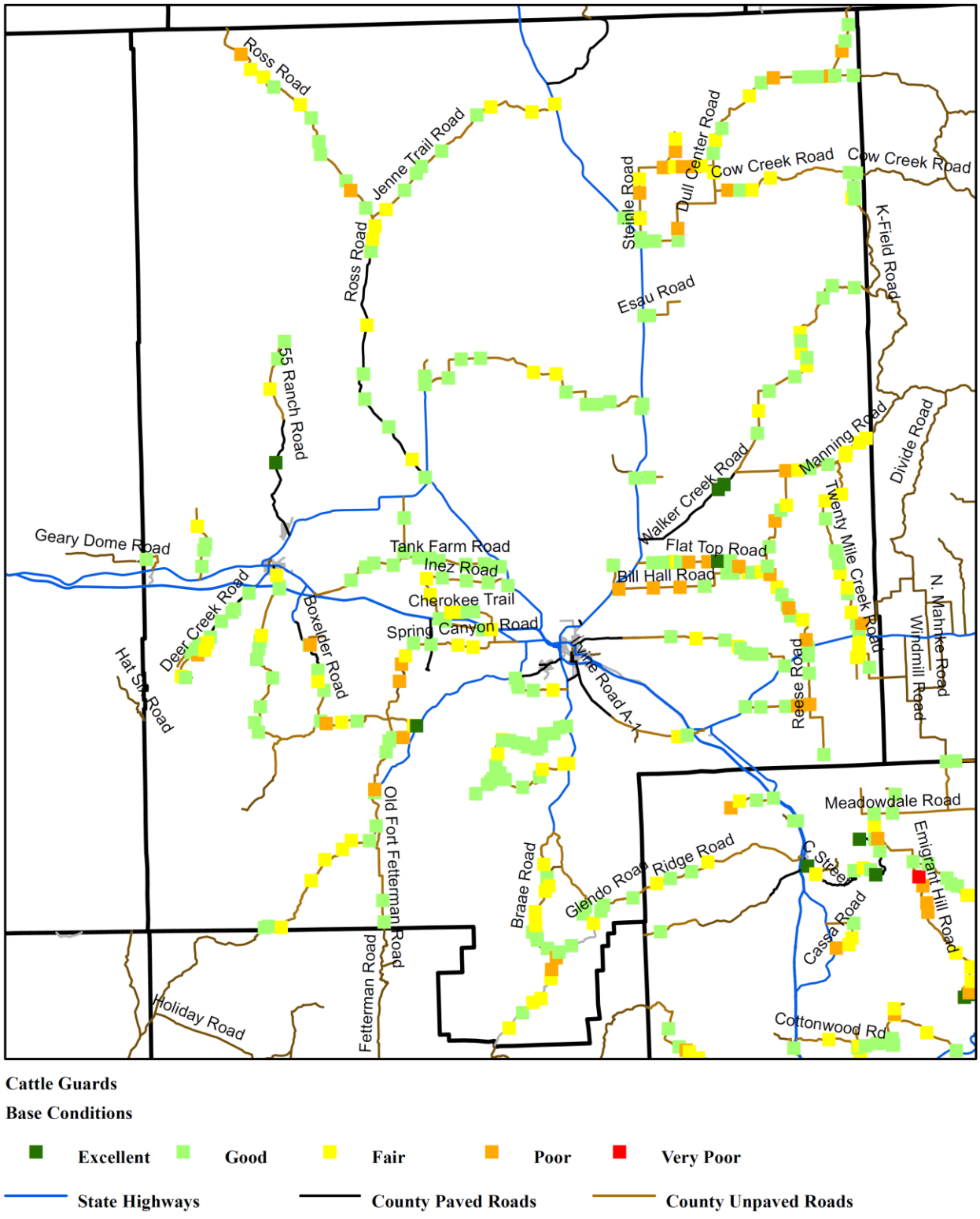


Figure 4.4 Converse County Approach Conditions Map

Because of the randomness of the cattleguard conditions, it is difficult to determine if there are any trends across the county when comparing these conditions with level of impact. From visually inspecting just the maps of the conditions there seems to be no correlation with cattleguard conditions and impact. This problem is only made worse with the undeveloped road network in Converse County.

4.2.2 Goshen County

Goshen County contained a total of 249 cattleguards in the county. The majority of the base and grate conditions of these cattleguards are in good condition and the approach conditions are split almost evenly at about 43% between both fair and good condition. Most of the cattleguards in Goshen County have no wings, as with Converse County. Table 4.9 shows the breakdown of counts of the conditions of the approach, base, grate, and wings of the cattleguards and shows the percentages of each.

Table 4.9 Goshen County Overall Cattleguard Conditions

Verbal Condition	Approach Condition	%	Base Condition	%	Grate Condition	%	Wings Condition	%
Excellent	1	0%	5	2%	6	2%	3	1%
Good	106	43%	167	67%	187	75%	92	37%
Fair	110	44%	68	27%	48	19%	31	12%
Poor	32	13%	8	3%	8	3%	17	7%
Very Poor	0	0%	1	0%	0	0%	2	1%
None	**X**	**X**	**X**	**X**	**X**	**X**	104	42%

Very few of the cattleguards, if any, have excellent or very poor conditions for the approach, base, grate, and wings. Maps of the approach, base, grate, and wing conditions were again created through ArcGIS from the location data gathered from Microsoft Streets and Trips. The maps showing the condition ratings of the approaches, bases, grates, and wings in Goshen County can be found in Appendix D. Cattleguard Maps and Tables.

Again, very few conclusions can be made from the distribution of conditions throughout Goshen County by visually analyzing these maps. There does seem to be a small cluster of cattleguards around county road 90 and 92A with fair to poor base conditions, but this is the only trend that can be seen.

4.2.3 Laramie County

Laramie County had the fewest number of cattleguards with only 154 in the county. In this case, a majority of the approach, base, grate, and wing conditions were in good condition, and only 7% of the cattleguards had no wings. Approximately 69% of the cattleguard grates were in good condition and only 21% had grate condition ratings of fair or worse. Table 4.10 shows the breakdown of counts of the conditions of the approach, base, grate, and wings of the cattleguards and shows the percentages of each.

Table 4.10 Laramie County Overall Cattleguard Conditions

Verbal Condition	Approach Condition	%	Base Condition	%	Grate Condition	%	Wings Condition	%
Excellent	10	6%	9	6%	13	8%	18	12%
Good	89	58%	95	62%	106	69%	62	40%
Fair	49	32%	48	31%	30	19%	42	27%
Poor	5	3%	2	1%	2	1%	20	13%
Very Poor	1	1%	0	0%	2	1%	1	1%
None	**X**	**X**	**X**	**X**	**X**	**X**	11	7%

In the case of Laramie County, there were almost no approach, base, grate, or wing conditions that were in very poor condition, and there was a higher percentage of these in excellent condition. The locations and the conditions for the approaches, grates, bases, and wings for each cattleguard in the county can be seen from the maps in Appendix D. Cattleguard Maps and Tables.

The cattleguards on Kirkbride Road in Laramie County have fair to very poor conditions for the approach, base, and wing conditions. However, this is the only feasible conclusions that could be drawn from examining these maps.

4.2.4 Platte County

Platte County yielded a total of 231 cattleguards. Although the majority of the approach, base, and grate conditions were, yet again, in good condition, this county showed the most variation of conditions. The wing conditions were very evenly distributed in each verbal condition rating, but there were still 27% of the cattleguards in this county that had no wings. Table 4.11 shows a more detailed breakdown of counts of the conditions of the approach, base, grate, and wings of the cattleguards and shows the percentages of each.

Table 4.11 Platte County Overall Cattleguard Conditions

Verbal Condition	Approach Condition	%	Base Condition	%	Grate Condition	%	Wings Condition	%
Excellent	22	10%	30	13%	31	13%	38	16%
Good	101	44%	112	48%	134	58%	45	19%
Fair	93	40%	67	29%	49	21%	31	13%
Poor	13	6%	21	9%	13	6%	38	16%
Very Poor	2	1%	1	0%	1	0%	16	7%
None	**X**	**X**	**X**	**X**	**X**	**X**	63	27%

Although there was more variation in the condition ratings for the cattleguards in Platte County, there were still very few cattleguards with very poor ratings for the approach, base, and grate conditions, and there were more excellent condition ratings in every category. The locations and the conditions for the approaches, grates, bases, and wings for each cattleguard in the county can be seen from the maps in Appendix D. Cattleguard Maps and Tables. Through examining these maps, there is an obvious need for replacing five cattleguards on Emigrant Hill Road in the Northern part of the county. These five cattleguards have no wings or wings in poor condition and the approach, grate, and base conditions are in fair or worse conditions.

4.2.5 Comparison and Summary

The number of cattleguards with each condition rating in each county for the approach, base, grate, and wings is shown in Table 4.12.

Table 4.12 Condition Rating Counts for Approach, Base, Grate, and Wings in Each County

Approach

County	Excellent	Good	Fair	Poor	Very Poor	Total
Converse	4	175	129	30	1	339
Goshen	1	106	110	32	0	249
Laramie	10	89	49	5	1	154
Platte	22	101	93	13	2	231
Total	37	471	381	80	4	973
Percent	4%	48%	39%	8%	0%	100%

Base

County	Excellent	Good	Fair	Poor	Very Poor	Total
Converse	6	206	92	35	0	339
Goshen	5	167	68	8	1	249
Laramie	9	96	47	2	0	154
Platte	30	112	67	21	1	231
Total	50	581	274	66	2	973
Percent	5%	60%	28%	7%	0%	100%

Grate

County	Excellent	Good	Fair	Poor	Very Poor	Total
Converse	9	219	86	23	2	339
Goshen	6	187	48	8	0	249
Laramie	13	107	30	2	2	154
Platte	31	136	49	14	1	231
Total	59	649	213	47	5	973
Percent	6%	67%	22%	5%	1%	100%

Wings

County	Excellent	Good	Fair	Poor	Very Poor	None	Total
Converse	5	101	49	46	3	135	339
Goshen	3	92	31	17	2	104	249
Laramie	18	62	42	20	1	11	154
Platte	38	45	31	38	16	63	231
Total	64	300	153	121	22	313	973
Percent	7%	31%	16%	12%	2%	32%	100%

There are very few condition ratings that show that any of the approach, base, grate, or wings are in very poor condition. Platte County shows the most variation of conditions as well as the greatest amount of cattleguards with excellent conditions across each characteristic. Laramie County is very consistent with a majority of the condition ratings for every characteristic being in good condition. Converse and Goshen counties show that the majority of condition ratings for the approach, base, grate, and wing conditions are in either fair or good condition.

4.3 Traffic Counts

To better determine the impact and extent of the impact in each county, a total of 173 traffic counts were collected on county unpaved and paved roads in southeast Wyoming. Long-term counters were placed through Goshen County as well for insight into the traffic variation during different days of the week and different times of the year. These long-term counters showed that the ADT and ADTT was very consistent through the days of the week and dropped slightly during the weekend. The long-term counters from Goshen County also showed that the ADT and ADTT increased during the summer months starting with May. Therefore, the WYT^2/LTAP determined that it would be most beneficial to place the counters during the day of the week and during the summer months. The locations were determined strictly from gathering the most information about the impacted roads, and the non-impacted roads were collected on roads with similar road characteristics to analyze how traffic volumes changed between impact levels. Through analysis of data supplied from these counters, valuable information was attained about the energy related truck traffic on the roads deemed impacted in each county. Table 4.13 shows the breakdown of traffic counters placed in each county.

Table 4.13 Traffic Counters Placed in Each County

Converse	Goshen	Laramie	Platte
32	33	86	22

Of the 173 counters placed, 123 were placed on county unpaved roads. A majority of these counters by the WYT^2/LTAP were placed on impacted roads, but for comparison reasons, there were some counters placed on non-impacted roads as well. The long-term traffic counters in Goshen County were placed between October 2010 and August 2011 on 12 designated roads. Each of these counters gave information about the average daily traffic (ADT), average daily truck traffic (ADTT), percent of trucks, and 85th percentile speed. By designating where the majority of truck traffic was directed, the impact locations, or impacted roads, could be better established. A map showing the distribution of traffic counters in the four counties can be seen in Figure 4.5. Because of the more developed road networks in Goshen, Laramie, and Platte counties, more traffic counters were placed in these counties.

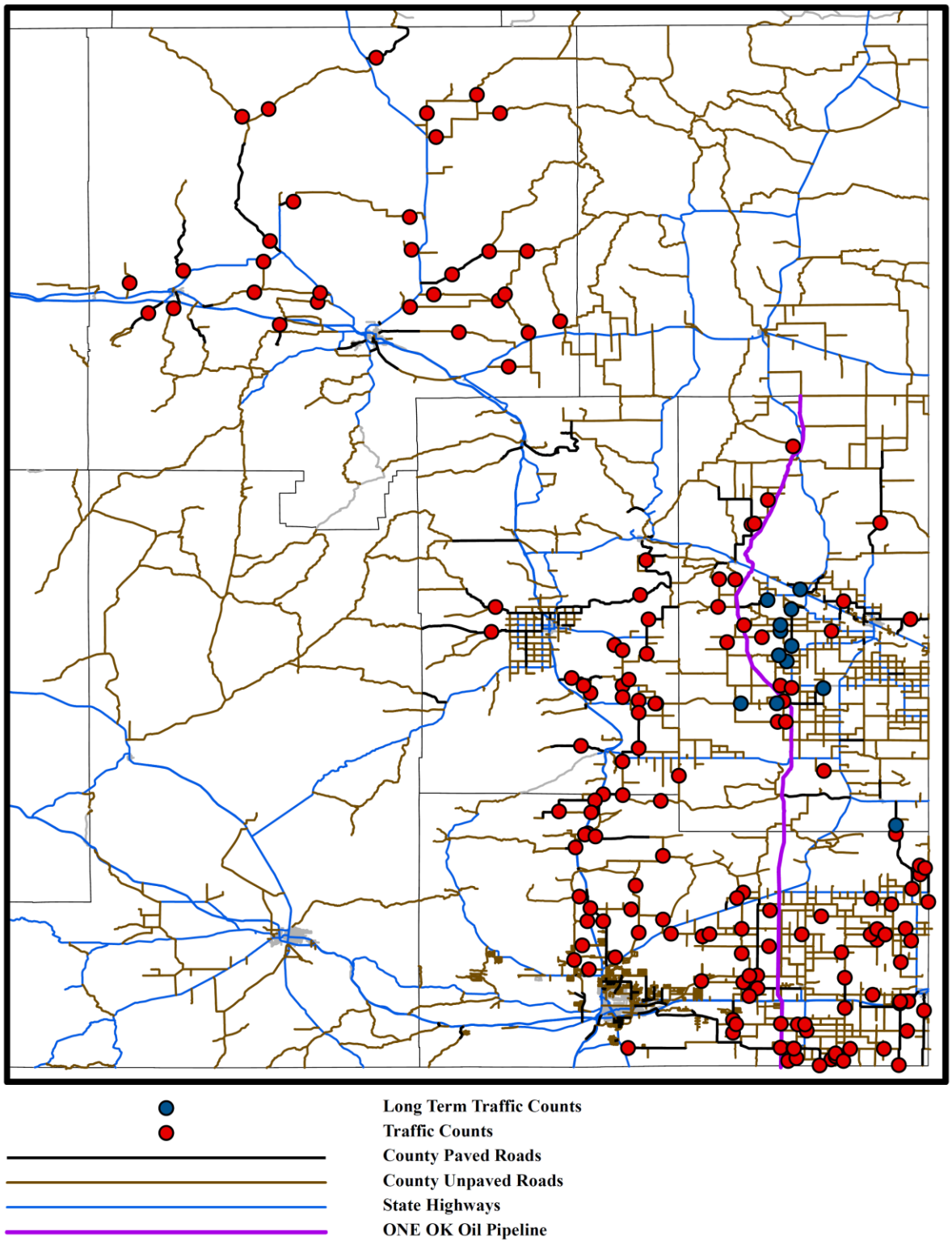


Figure 4.5 Traffic Count Locations in the Study Area

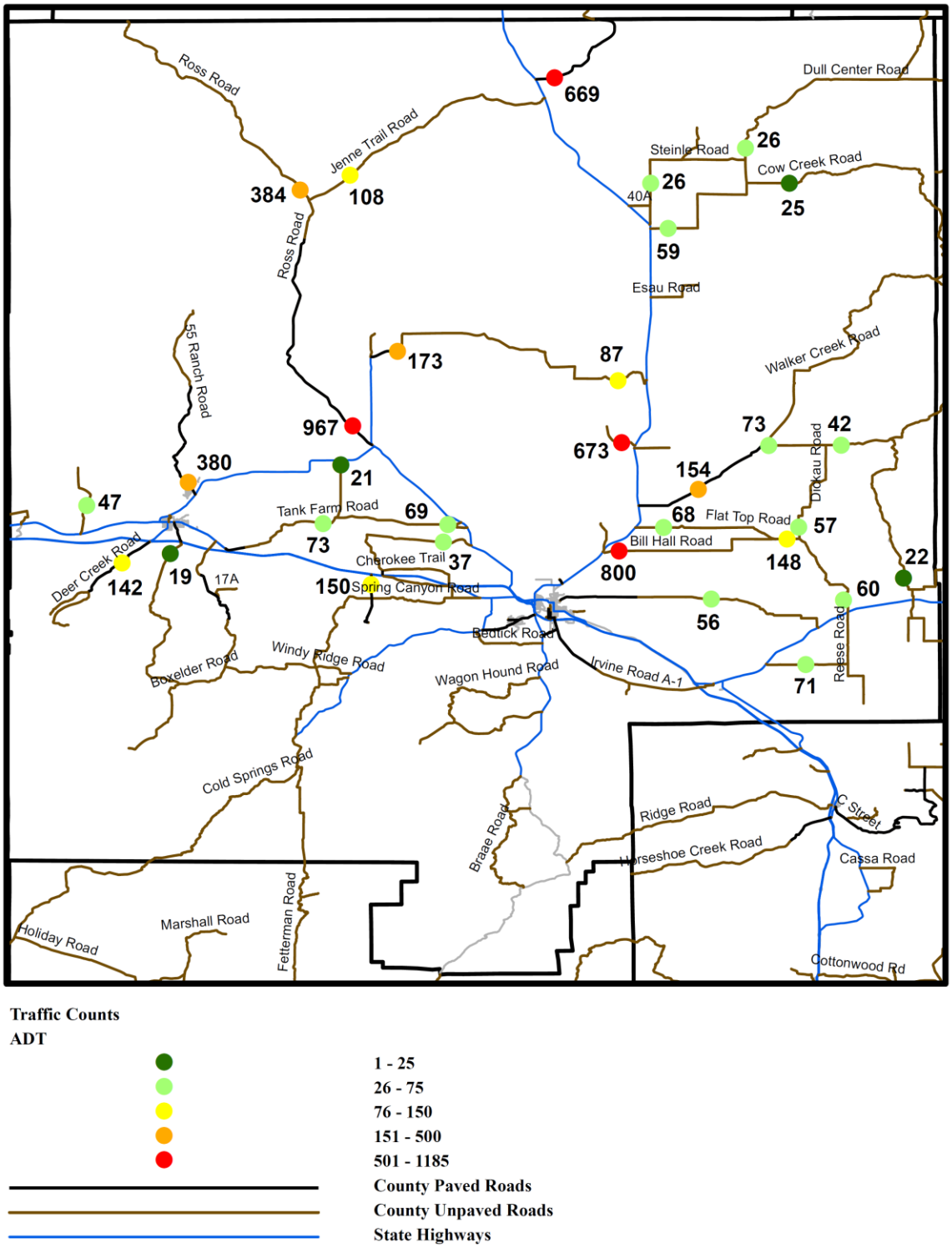
4.3.1 Converse County Traffic Counts

Traffic counters were placed in Converse County from May 2012 to July 2012 to collect valuable information about the traffic characteristics through the county. This information will help to conclude the actual level of impact in the county and where this impact is located. The traffic characteristics determined from the traffic counters placed in Converse County can be seen in detail in Table 4.14.

Table 4.14 Converse County Traffic Count Characteristics

Road Name	ADT	ADTT	% Trucks	85th % Speed	Date from	Date to	Surface Type	Impacted
Ross Road	967	295	30.5	64.5	6/25/2012	6/28/2012	Paved	Yes
Antelope Coal Mine Rd	669	118	17.6	73.7	6/25/2012	6/28/2012	Paved	Yes
55 Ranch	380	21	5.5	55.3	5/22/2012	5/25/2012	Paved	Yes
Highland Loop Road	173	31	17.9	53.0	7/17/2012	7/20/2012	Paved	Yes
Walker Creek	154	27	18.2	60.6	5/21/2012	5/24/2012	Paved	Yes
Natural Bridge	150	7	4.7	57.7	5/22/2012	5/25/2012	Paved	No
Deer Creck	142	10	7.0	58.5	5/22/2012	5/25/2012	Paved	Yes
Bill Hall	800	448	56.0	36.8	5/21/2012	5/24/2012	Unpaved	Yes
Unknown	673	325	48.3	31.1	6/25/2012	6/28/2012	Unpaved	No
Ross Rd	384	180	46.9	42.0	6/25/2012	6/25/2012	Unpaved	Yes
Flat Top	148	84	56.8	43.4	7/16/2012	7/17/2012	Unpaved	Yes
Jenne Trail Rd	108	33	30.6	45.0	6/25/2012	6/28/2012	Unpaved	Yes
Highland Loop Road	87	29	33.3	42.9	7/16/2012	7/19/2012	Unpaved	Yes
Tank Farm Road	73	1	1.4	53.1	7/172012	7/20/2012	Unpaved	Yes
Manning Road	73	14	19.2	48.5	7/16/2012	7/19/2012	Unpaved	Yes
Pickinpaugh	71	14	19.7	48.3	5/21/2012	5/24/2012	Unpaved	Yes
Tank Farm Road	69	11	15.9	55.7	7/17/2012	7/20/2012	Unpaved	Yes
Flat Top	68	12	17.6	42.3	5/21/2012	5/24/2012	Unpaved	Yes
Flat Top	60	24	31.7	29.6	5/21/2012	5/24/2011	Unpaved	No
Dull Center Rd	59	9	15.3	37.2	6/26/2012	6/29/2012	Unpaved	Yes
Dickau Road	57	28	49.1	42.1	7/16/2012	7/19/2012	Unpaved	Yes
East Antelope	56	4	7.1	49.6	5/21/2012	5/24/2012	Unpaved	No
Cole Creek	47	5	10.6	46.5	5/22/2012	5/25/2012	Unpaved	Yes
Manning Road	42	7	16.7	47.7	7/16/2012	7/19/2012	Unpaved	Yes
Inez Road	37	10	27.0	42.9	7/17/2012	7/20/2012	Unpaved	Yes
Dull Center Road	26	3	11.5	48.7	7/9/2012	7/12/2012	Unpaved	Yes
Steinle Road	26	2	7.7	51.8	7/16/2012	7/19/2012	Unpaved	Yes
Cow Creek Rd	25	1	4.0	55.2	6/26/2012	6/29/2012	Unpaved	Yes
Twenty Mile Creek Road	22	1	4.5	50.8	7/16/2012	7/19/2012	Unpaved	Yes
Leuenberger Road	21	0	0.0	43.4	7/17/2012	7/20/2012	Unpaved	Yes
Mormon Canyon	19	0	0.0	55.3	7/9/2012	7/12/2012	Unpaved	Yes
Mormon Canyon	19	2	10.5	48.5	5/22/2012	5/25/2012	Unpaved	No

The data collected from these traffic counters showed information about the ADT, ADTT, percent trucks, and 85th percentile speed for each location. By examining Table 4.14, it is clear that a large degree of variation in traffic characteristics exists for each type of impact level. To show the distribution of traffic characteristics in Converse County, maps were made in ArcGIS of traffic counter locations and data. Figure 4.6 through Figure 4.9 show the maps created and distributions of ADT, ADTT, percent trucks, and 85th percentile speeds.



Traffic Counts
ADT

	1 - 25
	26 - 75
	76 - 150
	151 - 500
	501 - 1185
	County Paved Roads
	County Unpaved Roads
	State Highways

Figure 4.6 Converse County ADT Distribution

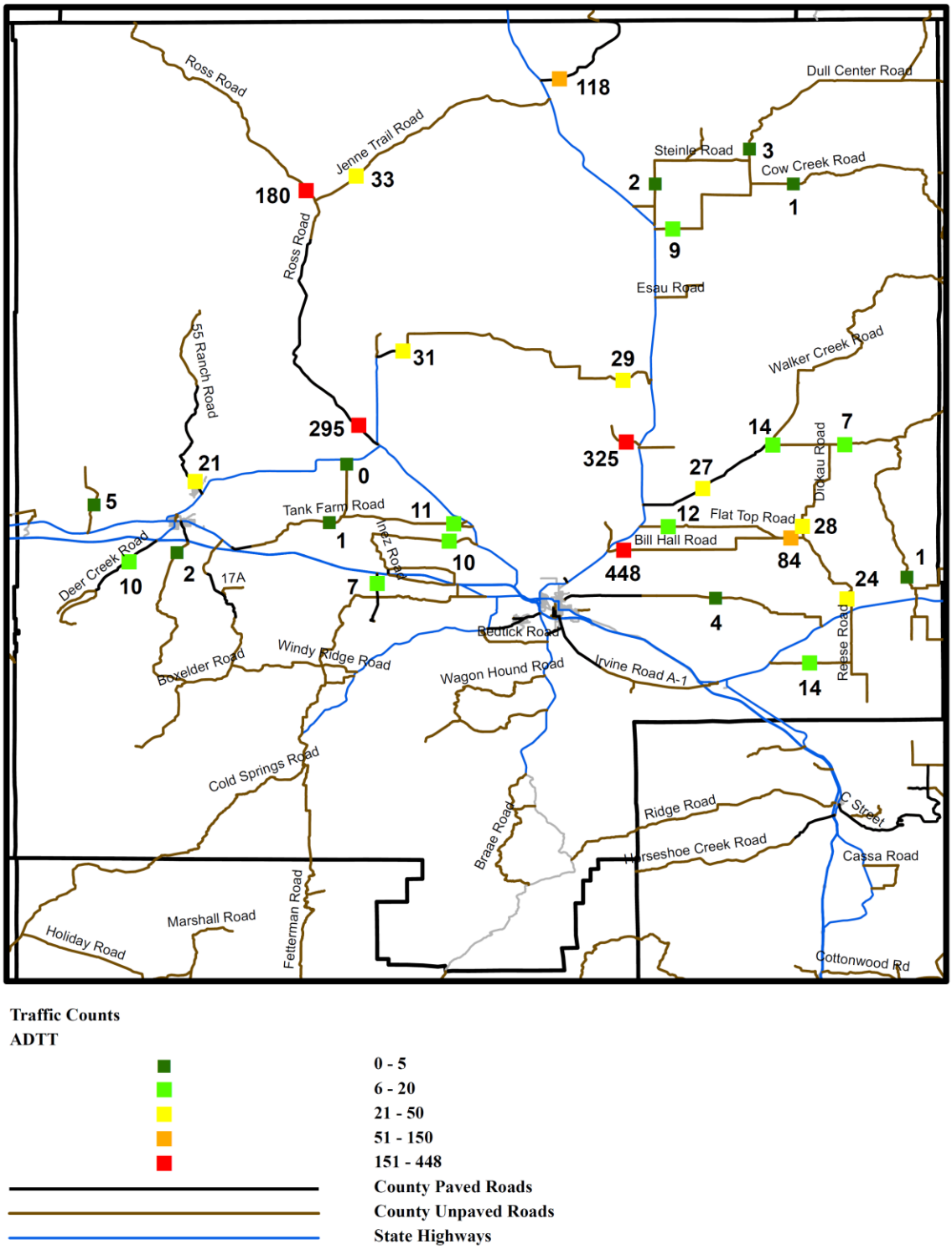


Figure 4.7 Converse County ADTT Distribution

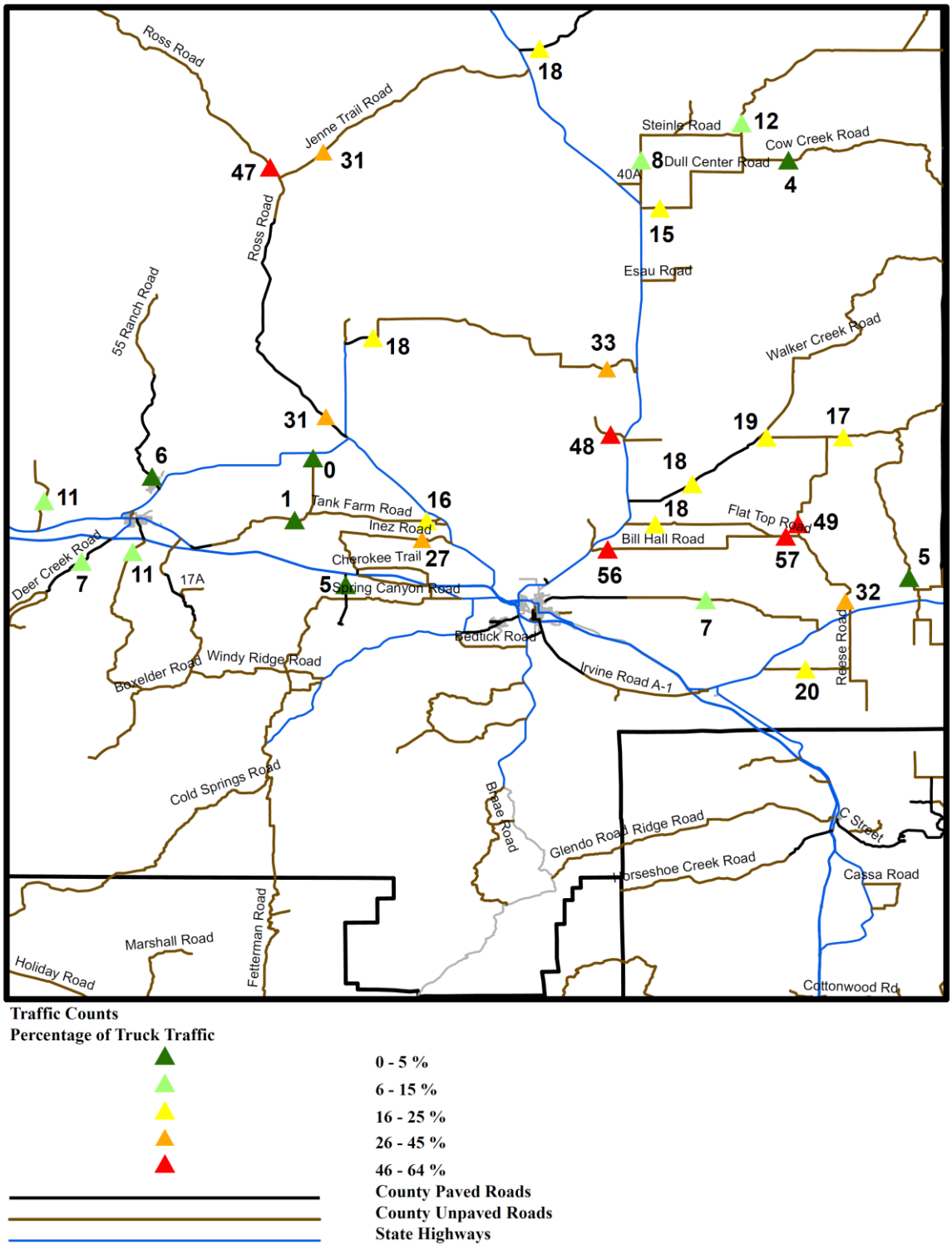
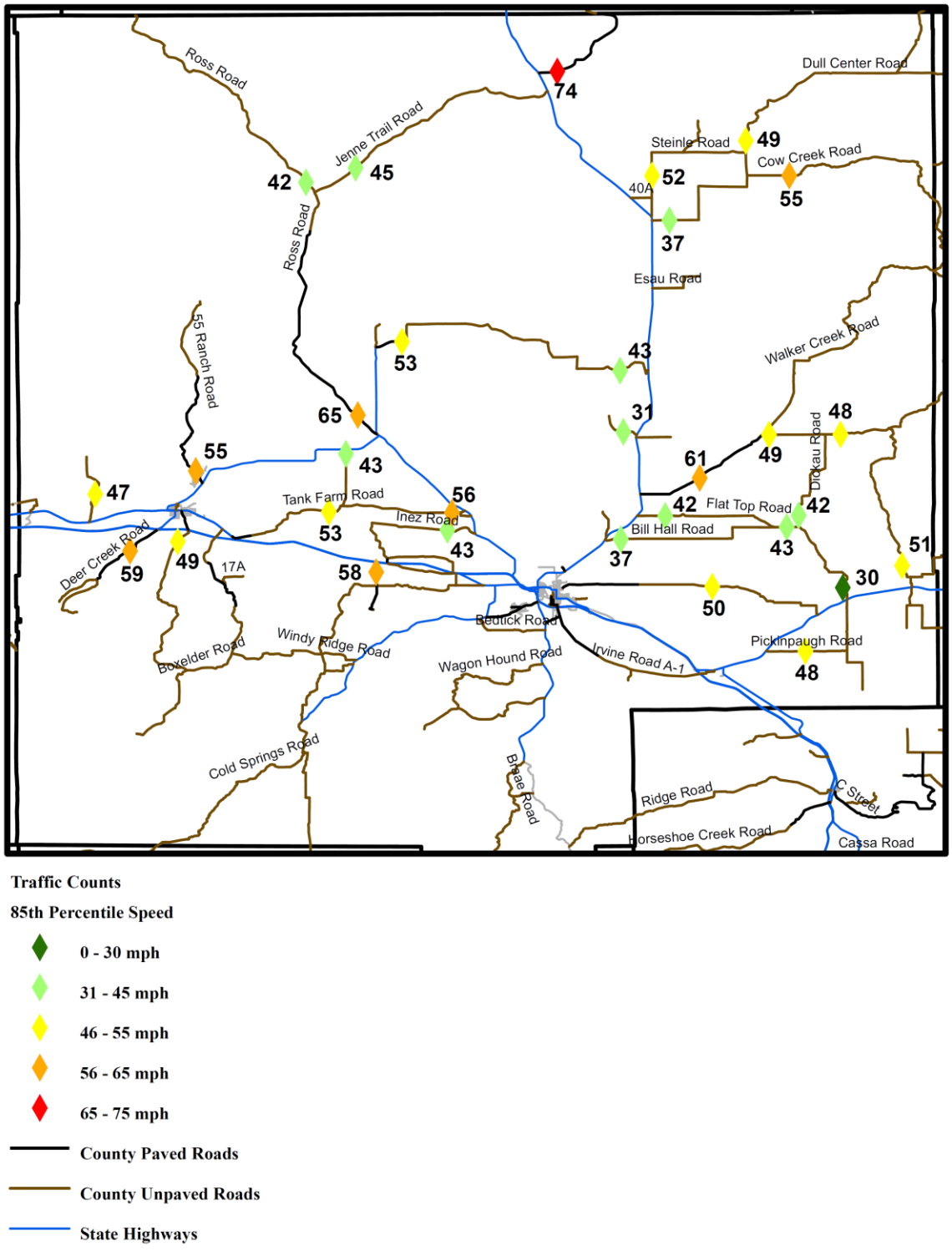


Figure 4.8 Converse County Percent Trucks Distribution



Traffic Counts

85th Percentile Speed

- **0 - 30 mph**
- **31 - 45 mph**
- **46 - 55 mph**
- **56 - 65 mph**
- **65 - 75 mph**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**

Figure 4.9 Converse County 85th Percentile Speed Distribution

By examining the maps of the distribution of the traffic data in Converse County, there seems to be a trend of Bill Hall Road and Ross Road having the highest ADT, ADTT, and percent trucks. Because these are roads deemed impacted by the county, this is to be expected.

4.3.2 Goshen County Traffic Counts

Along with the traffic counters collected by the WYT^2/LTAP, Goshen County also collected traffic count data for long term periods. The data collected from these counters are analyzed in section 4.3.2.1. This analysis was done to determine the appropriate days of the week for the WYT^2/LTAP to place counters. This information will help to conclude the actual level of impact in the county and where this impact is located. The traffic characteristics determined from the traffic counters placed in Goshen County can be seen in detail in Appendix E. Traffic Count Tables and Maps. By examining the data collected from these traffic counters, important traffic characteristics and trends could be mapped. There is, again, variation through every level of impact and the traffic characteristics. To show the distribution of traffic characteristics in Goshen County, maps were made in ArcGIS of traffic counter locations and data. Appendix E. Traffic Count Tables and Maps shows the maps created and distributions of ADT, ADTT, percent trucks, and 85th percentile speeds. The majority of the high truck traffic and percent trucks can be found in the central part of the county between Road 50 and Road 70. The high ADT, however, was observed on the county paved roads with the exception of Road 60A.

4.3.2.1 Goshen Long Term Traffic Counts

Long-term counters (counters placed on county roads for three months or more) were placed on several different roads throughout Goshen County. By analyzing these data, the WYT^2/LTAP can determine if the counters placed in the fall of 2011 and the summer of 2012 are placed during the correct time of season and a representative time of the week. The variation of the oil and gas truck can be determined from these long-term counters as well.

The graphs in Appendix F. Goshen Long Term Counter Figures summarize the average ADT and ADTT broken down into the day of the week and each road. Looking at these graphs of ADT and ADTT versus day of the week, there seems to be very little variation in traffic during the weekdays. On a majority of the counters, however, traffic seemed to have a slight decrease during the weekend. With this in mind, the WYT^2/LTAP collected traffic data this summer during only the weekdays. This was done in hopes that the highest truck traffic, and therefore, the highest impact, would be best represented.

4.3.3 Laramie County Traffic Counts

Traffic counts were collected on county roads in Laramie County during the fall of 2011 and from April 2012 to May 2012. The traffic characteristics determined from the traffic counters placed in Laramie County can be seen in detail in Appendix E. Traffic Count Tables and Maps. By examining the data collected from these traffic counters, important traffic characteristics could be determined and trends could be mapped. There is, again, variation through every level of impact and the traffic characteristics. To show the distribution of traffic characteristics in Laramie County, maps were made in ArcGIS of traffic counter locations and data. Because Laramie County had the highest number of traffic counters, the county had to be split into the west and east side for mapping purposes. The maps created and distributions of ADT, ADTT, percent trucks, and 85th percentile speeds for Laramie County can be found in Appendix E. Traffic Count Tables and Maps. The majority of the heavy traffic and truck traffic seems to be located either on the East side of the county or south of Interstate 80. The 85th percentile speeds show much higher values than the other counties as well.

4.3.4 Platte County Traffic Counts

The traffic counters placed in Platte County showed the least amount of traffic, more in particular, truck traffic, in the four counties. These traffic counts were collected on county roads during the fall of 2011 and April 2012. The traffic characteristics determined from the traffic counters placed in Platte County can be seen in detail in Appendix E. Traffic Count Tables and Maps. Although there is a great deal of variation, especially with ADTT and percent trucks, trends can still be established. To show the distribution of traffic characteristics in Platte County, maps were made in ArcGIS of traffic counter locations and data. Appendix E Traffic Count Tables and Maps shows the maps created and distributions of ADT, ADTT, percent trucks, and 85th percentile speeds. There seems to be significantly less traffic in Platte County, and the roads with the heaviest traffic are on the paved portions of the county roads other than South Gap and Slater Roads. There were no locations in Platte County with an ADT exceeding 150 and ADTT exceeding 21. The 85th percentile speeds on unpaved county roads never exceeded 56 mph, and the highest percentage of trucks in the county was only 30%.

4.4 Data Collection Summary

All the data collected for this thesis are valuable for quantifying and mitigating the impact of energy related traffic on county infrastructure. The traffic counters will determine where the truck traffic is and how severe the impact is through the county. The unpaved road distress data will provide a means to examine the difference in condition between an impacted road and a non-impacted road. The cattleguard ratings will establish a baseline for examining how heavy truck traffic damages the different characteristics of cattleguards. With all this information combined, a precise analysis is established for the impact in the southeast.

5. DATA ANALYSIS OF UNPAVED ROADS

The data analysis of unpaved roads in Converse, Goshen, Laramie, and Platte Counties provided insights into the level and type of impact in southeast Wyoming from energy related operations. The analysis of this study and this thesis focuses on three general areas to demonstrate this examination of energy impact and are as follows: Examine the difference between impacted and non-impacted road conditions, identify leading impact factors and maintenance costs, creating a priority list that ranks impacted road based on the severity of the impact, and, from this priority list, determining the costs needed to sustain the roads to a good condition.

5.1 Impacted versus Non-Impacted

To determine the level of impact in southeast Wyoming, the impacted roads and non-impacted roads were compared. This comparison analyzed the distress and ride quality ratings and overall road conditions for both impacted and non-impacted roads. Maintenance records were also examined for Laramie and Goshen counties to determine the cost differences in maintenance for impacted roads versus non-impacted roads. The data collected for the distresses and ride quality ratings were then modeled to determine what distress explained the most variation in impact.

5.1.1 Road Conditions

By analyzing the difference between impacted and non-impacted road conditions, valuable comparisons can be made. Table 4.6 shows that, on average, the county unpaved roads seem to be in good condition with good ride qualities. For further examination, the impacted and non-impacted roads were separated and analyzed. Table 4.6 also shows the average impacted and average non-impacted distresses, average ride quality, and the differences between the impacted versus non-impacted conditions. Table 5.1 shows the overall averages and the differences in impacted and non-impacted average ratings of the distresses and ride quality condition ratings.

Table 5.1 Overall Averages and Average Differences between Impacted and Non Impacted Road Conditions

County	X-Section	Roadside Drainage	Dust	Rutting	Potholes	Loose Aggregate	Corrugations	Ride Quality
Overall Averages								
Converse	2.8	2.8	1.6	7.2	7.4	7.1	7.3	7.1
Goshen	2.8	2.8	1.8	6.9	7.3	7.4	7.7	7.0
Laramie	2.9	2.9	2.0	7.2	7.4	7.3	7.4	7.0
Platte	2.7	2.7	2.2	6.9	7.0	7.2	7.7	6.6
Averages	**2.8**	**2.8**	**1.9**	**7.0**	**7.3**	**7.2**	**7.5**	**6.9**
Differences Between Impacted vs. Non-Impacted								
Converse	0.2	0.2	-0.4	0.2	0.3	0.0	0.0	0.2
Goshen	-0.2	-0.1	0.3	-0.4	-0.2	-0.1	0.3	-0.3
Laramie	0.0	-0.1	-0.1	0.3	-0.2	-0.1	0.0	-0.2
Platte	-0.4	-0.3	-0.1	-0.3	-0.2	0.0	0.7	-0.4
Averages	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**0.3**	**-0.2**

There is very little variation between the impacted roads versus the non-impacted roads on average. The highest variation is 0.2 for ride quality and 0.3 for the corrugations distress, while the rest of the average distress ratings only differ by 0.1. These data show that the counties have been keeping up with the impact on unpaved county roads at the county level. Pie charts of each distress in each county can be

found in Appendix G. Distress Pie Charts. By having similar ratings for distress and ride quality ratings, the four counties have been maintaining the impacted roads to the same condition as the non-impacted. However, if the impacted road segments would have showed higher ratings and thus a better road quality, then the counties would have showed that they were possibly neglecting the maintenance and conditions of the non-impacted roads. In the opposite case, this would have showed that the counties were unable to sustain their roads due to higher impact levels leading to faster road deterioration. In the case of this study however, the counties are keeping up with the impact and sustaining all their roads to the same good conditions. The impact of energy companies located in southeast Wyoming seems to be at a rate sustainable for the counties, at least for the unpaved roads. For further examination, the unpaved roads maintenance records of the impacted sections versus the non-impacted sections need to be assessed and are addressed later in this report.

5.1.2 Maintenance Records

Maintenance records from Laramie and Goshen counties were received and analyzed according to each road segment and level of impact. Platte County was in the process of recording its 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 in the proper segments and were therefore also not conclusive enough to use them 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 did not overlap with the Goshen County 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 could be made.

5.1.2.1 Laramie County

Maintenance records gathered from the Laramie County Road and Bridge Department were tabularized and analyzed according to the segments created in this study. Table 5.2 shows the total maintenance costs and maintenance costs per mile broken down into impacted and non-impacted road segments. Figure 5.1 is a bar graph of the same maintenance costs per mile over each fiscal year.

Table 5.2 Laramie County Impacted Versus Non-Impacted Maintenance Costs

MAINTENANCE COSTS							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
Impacted	$2,858,632	$1,197,432	$1,552,368	$4,264,127	$3,240,983	$1,146,773	$14,260,315
Non Impacted	$1,917,245	$1,775,860	$1,559,766	$2,466,768	$1,946,214	$1,573,204	$11,239,056
Difference	**$941,387**	**-$578,427**	**-$7,398**	**$1,797,358**	**$1,294,769**	**-$426,430**	**$3,021,259**
MAINTENANCE COSTS PER MILE							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
Impacted	$12,859	$5,387	$6,983	$19,182	$14,579	$5,159	$64,149
Non Impacted	$2,439	$2,259	$1,984	$3,138	$2,476	$2,001	$14,298
Difference	**$10,420**	**$3,127**	**$4,999**	**$16,044**	**$12,103**	**$3,157**	**$49,851**

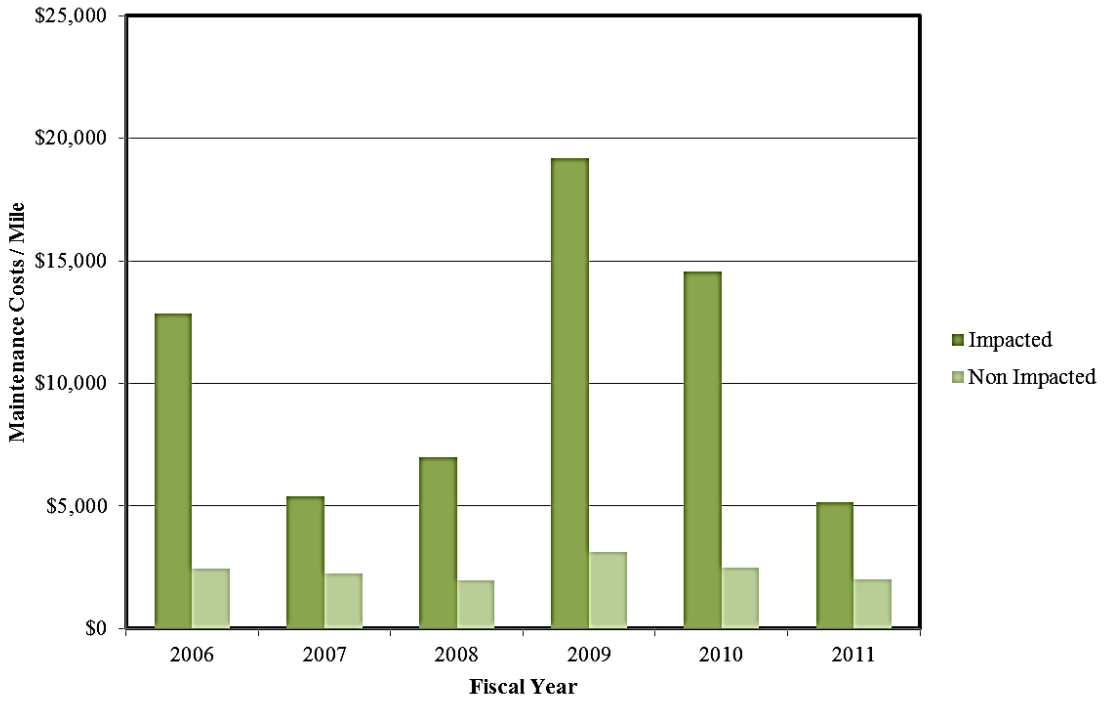


Figure 5.1 Laramie County Gravel Road Maintenance Cost per Mile per Fiscal Year

It can be seen from Table 5.2 that even though there is more total money spent each year on non-impacted roads, the cost per mile is much higher for the impacted roads. From Figure 5.1, it can again be seen that 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 money spent on gravel road maintenance for impacted roads in 2006, 2009, and 2010. Between 2006 and 2011, Laramie County spent $14,260,315 on gravel road maintenance for impacted roads and $11,239,056 for non-impacted roads. This is a difference of $3,021,259 over this five-year span. Laramie County spent $64,149 per mile maintaining the impacted roads and only $14,298 per mile maintaining the non-impacted roads. That's $49,851 more per mile in maintenance costs for impacted roads and, on average, $8,309 more per mile per year.

5.1.2.2 Goshen County

Table 5.3 shows the total maintenance costs and maintenance costs per mile broken down into impacted and non-impacted road segments. Figure 5.2 is a bar graph of the same maintenance costs per mile over each fiscal year.

Table 5.3 Goshen County Impacted Versus Non-Impacted Maintenance Costs

MAINTENANCE COSTS						
	2007	**2008**	**2009**	**2010**	**2011**	**Total**
Impacted	$75,329	$387,094	$142,431	$427,456	$420,847	$1,453,156
Non-Impacted	$110,761	$837,758	$570,346	$1,153,755	$1,349,408	$4,022,028
Difference	**-$35,432**	**-$450,664**	**-$427,916**	**-$726,298**	**-$928,561**	**-$2,568,871**
MAINTENANCE COSTS PER MILE						
	2007	**2008**	**2009**	**2010**	**2011**	**Total**
Impacted	$579	$2,977	$1,095	$3,288	$3,237	$11,176
Non-Impacted	$142	$1,077	$733	$1,483	$1,735	$5,170
Difference	**$437**	**$1,900**	**$362**	**$1,805**	**$1,502**	**$6,006**

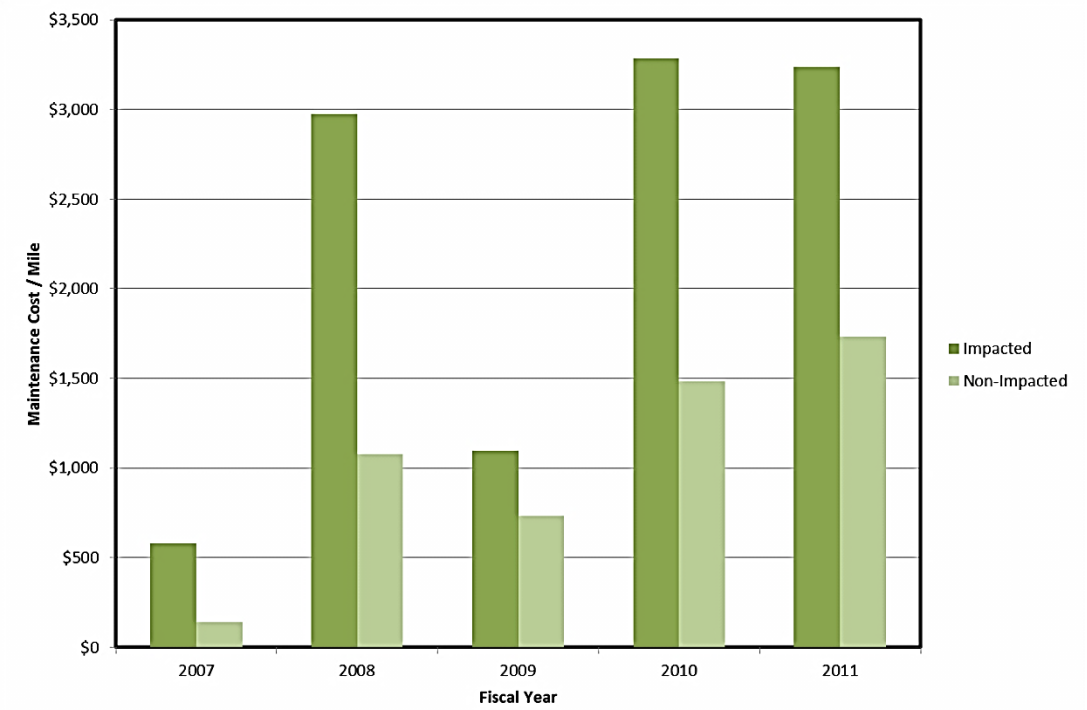


Figure 5.2 Goshen County Gravel Road Maintenance Cost per Mile per Fiscal Year

Table 5.3 shows that there was much more total money spent on the non-impacted roads from 2007 to 2011 in Goshen County. During this period, over $2.5 million more was spent on non-impacted roads. However, the cost per mile of impacted roads was significantly greater than the non-impacted roads, showing that there was more effort and money spent on maintaining these roads. Figure 5.2 gives a graphical representation of the maintenance cost per mile between impacted roads and non-impacted roads since 2007. During this five-year period, $11,176 per mile was spent on the maintenance of impacted roads, whereas only $5,960 per mile was spent on non-impacted roads, a difference of $5,170 per mile.

5.1.3 Modeling

This was a separate analysis from the impact priority list and has no correlation to that portion of this thesis and study. This analysis will simply provide some information of what variables explain the most variation in the ride quality. Unfortunately, the impact seen in southeast Wyoming is not to the level as the impact characteristics in the modeling as seen below. With a better data set containing higher levels of

impact characteristics, maintenance records, serviceable rigs for every road segment, and any other pertinent information regarding impact, the modeling will be a more valuable tool in determining how ride quality is affected. Through this procedure and analysis, modeling of ride quality can be achieved for future impacts in any county, especially those experiencing higher levels of impact.

5.1.3.1 Ride Quality versus Distresses and Impact

In order to better understand how the different distresses collected during the rating process and the level of impact affects ride quality, regression models were developed from the entire data set. By using ride quality as the independent variable and analyzing all the condition data (regardless of county or impact), this was achievable. In order to quantify the impact in the model, this variable was simply a 1 for impacted or a 0 for non-impacted. The first step of this process was examining a correlation matrix of all the variables to determine how each variable linearly relates to the others. The correlation values give a brief examination into the relationship of each variable with the others. Therefore, the higher the value of correlation between two variables, regardless of the sign, the larger the effect those variables will have on each other. Table 5.4 shows this correlation matrix from the program SAS and the associated correlation values.

Table 5.4 Correlation Matrix for Model of Ride Quality through Distresses and Impact

Variable	Cross Section	Drainage	Dust	Rutting	Potholes	Loose Aggregate	Corrugations	Impact	Ride Quality
Cross Section	1.00	0.82	-0.17	0.53	0.70	-0.22	-0.13	-0.09	0.56
Drainage	0.82	1.00	-0.12	0.47	0.65	-0.23	-0.09	-0.10	0.53
Dust	-0.17	-0.12	1.00	-0.11	-0.24	0.12	0.01	-0.05	-0.15
Rutting	0.53	0.47	-0.11	1.00	0.53	-0.20	-0.10	0.02	0.70
Potholes	0.70	0.65	-0.24	0.53	1.00	-0.26	0.07	-0.03	0.64
Loose Aggregate	-0.22	-0.23	0.12	-0.20	-0.26	1.00	0.21	-0.02	-0.13
Corrugations	-0.13	-0.09	0.01	-0.10	0.07	0.21	1.00	0.08	0.15
Impact	-0.09	-0.10	-0.05	0.02	-0.03	-0.02	0.08	1.00	-0.09
Ride Quality	0.56	0.53	-0.15	0.70	0.64	-0.13	0.15	-0.09	1.00

The impact variable has no strong correlation with any of the other distresses or the ride quality in this case. The ride quality has stronger correlation values with the cross section, drainage, rutting, and potholes than the rest of the variables. Many of the distresses themselves were highly correlated as well. For example, the cross section showed the strongest correlations throughout each other variable and the highest correlation with drainage, potholes, rutting, and ride quality. These correlations were expected to be strong, however, due to the nature of unpaved roads and distresses. For example, poor cross section could result in poor drainage, and this would leave standing water in the road and create potholes. Because of this, it is expected that the variance of inflation will be high for these data and variables. Correlations explain relationships among pairs of the variables, but there is still the possibility of the presence of more complex factors affecting the ride quality and overall model.

This full data set was then entered into SAS and put through a stepwise procedure using the forward selection process. This process starts with no variables in the model and tests the addition of each variable by comparing chosen model criteria. In this case, the chosen model criteria was simply a p-value of 0.15 to be entered into the model, and with the addition of more variables, a p-value of 0.05 had to be achieved for that variable to stay in the model. These were the standard p-values for this test and correlate to having a 95% confidence interval with a p-value of 0.05. This process will only add variables that explain the variation of the ride quality of the model the most and will continue until the model cannot be improved any more or the remaining variables do not meet the initial criterion. The initial stepwise process and model contained each independent variable as a first order model.

After the process was complete, the variables with a p-value less than the 0.05 level were drainage, rutting, potholes, corrugations, and impact. The other variables, including the cross section, which had high correlation values among the other variables, did not meet the requirement at the 0.15 level for entry into the model. The impact level entered into the model as a regressor determined by the counties. The R-squared value for the model with these variables was 0.641, meaning that 64.1% of the variation in ride quality is accounted for by these variables. Table 5.5 shows a table with the final variables of the stepwise function along with their parameter estimates and p-values. Table 5.6 shows the partial R-squared values for each of these final variables.

Table 5.5 Results and statistics of Variables from the Stepwise Process

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-1.852	0.282	25.951	43.140	<.0001
Drainage	0.283	0.066	10.965	18.230	<.0001
Rutting	0.560	0.025	306.950	510.210	<.0001
Potholes	0.268	0.026	61.818	102.750	<.0001
Corrugations	0.290	0.028	62.335	103.610	<.0001
Impact	-0.260	0.051	15.628	25.980	<.0001

Table 5.6 R-Squared Values for Variables from the Stepwise Process

Variable Entered	Partial R-Square	Model R-Square	F Value	P-Value	Variance of Inflation
Rut	0.4885	0.4885	941.57	<.0001	1.5190
Potholes	0.1029	0.5913	247.93	<.0001	2.4342
Corrugations	0.0312	0.6226	81.4	<.0001	1.1393
Impact	0.0114	0.6339	30.49	<.0001	1.0290
Drainage	0.0067	0.6406	18.23	<.0001	3.2204

It can be seen from the parameter estimates in Table 5.5 that the impact variable has a negative impact on the ride quality. This is to be expected because the higher the impact and truck traffic on an unpaved road, the more degradation it will see and thus the lower ride quality. The rest of the parameter estimates of the distresses have positive values. Again, this is to be expected since having a higher rating for any of the distresses should result in a higher ride quality rating. The variance of the inflation factor quantifies how much the variance of an estimated variable is increased due to collinearity. When this factor exceeds a value of 10 for a variable, it is suggested that there is a problem with multicollinearity due to the high correlation of variables. This means that the coefficient estimates may change erratically in response to small changes in the model or data. Table 5.6 shows that the rutting variable explains the most about the

ride quality with an R-squared value of 0.489 and the potholes variable explains the most of the remaining variation in the model with an R-squared value of 0.103.

5.1.3.2 Ride Quality versus Distresses and Traffic Data

The next model analyzed dealt with the data set containing only the impacted roads throughout the four counties. In this case, ADT, ADTT, and the number of oil wells within the buffer zone were considered. This was because a majority of the impacted segments have the traffic count information, and every impacted road segment contained the data about number of serviceable rigs. By analyzing this further information, it was possible to determine if these factors had contributable explanation into the ride quality. Information from this data set and statistical analysis will help provide information pertaining to the effect of ride quality on impacted roads from road distresses, traffic counts, and oil wells within a close proximity of the road segments. A log transformation was used for the ADT and ADTT data for scaling purposes with the rest of the data and variables. The first step of this process was examining a correlation matrix of all the variables to determine how each variable interacts with the others. Table 5.7 shows the correlation matrix of the variables from the impacted only data.

Table 5.7 Correlation Matrix for the Impacted Only Data Set Variables

Variable	Cross Section	Drainage	Dust	Rutting	Potholes	Loose Aggregate	Corrugations	Log(ADT)	Log(ADTT)	Rigs in Buffer Zone	Ride
Cross Section	1.00	0.82	-0.17	0.54	0.64	-0.15	-0.08	0.17	0.12	0.07	0.53
Drainage	0.82	1.00	-0.12	0.46	0.60	-0.11	-0.03	0.18	0.11	0.07	0.52
Dust	-0.17	-0.12	1.00	-0.08	-0.18	0.21	0.04	0.02	0.02	-0.19	-0.11
Rutting	0.54	0.46	-0.08	1.00	0.51	-0.12	-0.04	0.14	0.05	0.07	0.61
Potholes	0.64	0.60	-0.18	0.51	1.00	-0.13	0.19	0.03	0.01	-0.07	0.65
Loose Aggregate	-0.15	-0.11	0.21	-0.12	-0.13	1.00	0.16	0.04	0.08	0.00	0.02
Corrugations	-0.08	-0.03	0.04	-0.04	0.19	0.16	1.00	-0.20	-0.09	-0.06	0.25
Log(ADT)	0.17	0.18	0.02	0.14	0.03	0.04	-0.20	1.00	0.77	0.38	0.02
Log(ADTT)	0.12	0.11	0.02	0.05	0.01	0.08	-0.09	0.77	1.00	0.41	0.02
Rigs in Buffer Zone	0.07	0.07	-0.19	0.07	-0.07	0.00	-0.06	0.38	0.41	1.00	-0.01
Ride	0.53	0.52	-0.11	0.61	0.65	0.02	0.25	0.02	0.02	-0.01	1.00

The correlations between the different distresses show very similar numbers from the previous full data set and the only addition is the correlations for the ADT, ADTT, and oil rigs within the buffer zone. It can be seen from Table 5.7 that the strongest correlations that these new variables have are with each other. This reduced data set was then entered into SAS and put through a stepwise procedure using the forward selection process as with the full data set before. The results of this process are shown in Table 5.8 with the variables and their partial R-squared values.

Table 5.8 Results of the Stepwise Process for the Reduced Data Set

Variable Entered	Partial R-Square	Model R-Square	F Value	Pr > F	Variance of Inflation
Potholes	0.4278	0.4278	181.65	<.0001	2.1889
Rutting	0.1059	0.5336	54.93	<.0001	1.5579
Corrugations	0.0353	0.569	19.75	<.0001	1.2072
Drainage	0.0132	0.5822	7.61	0.0063	3.2402
Loose	0.0091	0.5913	5.32	0.0219	1.1069

This new model now explains about 59% of the variation in ride quality, with a cumulative R-squared value of 0.591. Of the variables entered into the model, potholes and rutting explain most of the variation in the model. With the addition of ADT, ADTT, and oil rigs within the buffer zone, and the deletion of the impact into the reduced model, the stepwise process included loose aggregate. The full data set disregarded loose aggregate, however, and showed that the impact variable had more significance in the model. This indicates that the counties are maintaining the roads to a significant enough standard that the level of impact, based on the ride quality, is not being shown through the ADT, ADTT, and oil wells within the buffer zone. Instead, the level of impact is being shown more through the distresses in the case of impacted roads.

For more understanding of these variables and how they affect ride quality, interaction terms were considered in conjunction with the individual variables. One would expect interaction terms to be present in the model after looking at the correlation matrices. Interaction terms between only the variables of the stepwise process and the other variables were considered due to their presence in the stepwise model and explained variation. In other words, interaction terms between two of the variables not included from the stepwise process were not considered. This process was not as straightforward as the stepwise selection. Every interaction term was entered into the model, and the term with the highest p-value above the 0.05 level was dropped from the model. Because the p-values will change after a term is dropped, the model had to be run again and the same process continued until the interaction terms met the 0.05 p-value level. This process yielded a model with the following interaction terms in combination with the terms from the stepwise process:

- Cross section * corrugations
- Cross section * loose aggregate
- Rutting * corrugations
- Dust * rutting
- Dust * loose aggregate

Interaction terms account for joint effects of the individual variables. These effects in the interactions cannot be assessed for the ride quality separately. For example, with the rutting and corrugation terms, the effect of rutting on the ride quality depends upon the amount of corrugations and the effect of corrugations on the ride quality depends upon the amount of rutting. This model was then run through SAS to provide the statistical analysis and relevancy of all the terms. Table 5.9 shows the final model with the interaction terms being considered.

Table 5.9 Reduced Data Set Model with Interaction Terms

Variable	Parameter Estimate	P-Value	Partial R-Square	Cumulative R-Square	Variance of Inflation
Intercept	7.20	0.00	.	0.00	0.00
Drainage	0.29	0.06	0.32	0.32	3.14
Rutting	-1.16	0.00	0.18	0.50	87.59
Potholes	0.25	<.0001	0.08	0.58	2.27
Loose Aggregate	0.90	<.0001	0.01	0.60	23.55
Corrugations	-1.30	<.0001	0.04	0.63	56.75
X-Section * Corrugations	0.16	0.02	0.01	0.64	51.88
X-Section * Loose Aggregate	-0.14	0.03	0.01	0.65	48.91
Rutting * Corrugations	0.16	0.00	0.03	0.68	133.69
Dust * Rutting	0.16	<.0001	0.00	0.68	24.01
Dust * Loose Aggregate	-0.17	<.0001	0.02	0.70	28.20

The sign of some of the parameters from the stepwise procedure are now negative. This is most likely due to the interaction terms accounting for more of the variables than the individual terms. There is a significant amount of variance of inflation through the variables due to the interaction terms. This will not affect the reliability of the model itself and only affects the individual predictors with respect to each other. The addition of the interaction terms into the model now explains nearly 70% of the variation in ride quality.

5.2 Priority List

A priority ranking system was next developed to determine the level of severity of impact in each county and overall. This analysis was separate from the modeling and takes into account the most beneficial sources of degradation to unpaved roads, according to the counties, which are discussed below. One of the most significant tasks through this thesis and study was to identify the level of impact in each county and for each road segment deemed impacted by the county road and bridge department. By determining which roads had the highest impact levels, the counties will be able to distribute their resources more efficiently.

A sensitivity analysis of paved roads from the North Dakota report demonstrated that at a traffic level of 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 (Upper Great Plains Transportation Institute, North Dakota University 2010). The baseline traffic, and the lowest tier for the ADT, is 15 to 50 respectively based on classifications and counts of unpaved roads from the North Dakota State University (NDSU) report. The ADT and ADTT numbers used for the priority ranking and decision tree were determined from analysis of these data from the NDSU report. Due to the lower quality and quicker degradation of unpaved roads, slightly lower numbers were used to define each tier of ADT and ADTT in the decision tree. The numbers of the third tier of serviceable oil rigs and water haul sites were determined from examining the differences of the priority list with changing this variable. The numbers for all three tiers were then approved by the counties.

To determine the level of impact for each road in each county, a priority list was created. This prioritization takes into account the ADT, ADTT, and oil wells/water haul sites within a buffer zone. A decision tree was made with ADT being the first criteria, ADTT being the second and oil wells and water haul sites within the buffer zone being third. This tree then produced an impact priority rank from 1 to 6 with 1 being the highest priority and 6 being the lowest. These ranks were generated from the format of the decision process and through examination of how each criterion affected the overall impact priority rank. Table 5.10 gives better descriptions of which of these impact priorities ranks mean.

Table 5.10 Impact Priority Number Descriptions

Impact Priority Number	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

Of the three criterions taken into account in the priority ranking, the first and highest of this criterion of the impact priority decision process was the ADT of each road. The first tier only considered roads with an ADT of more than 100, the second tier examined only roads with an ADT between 50 and 100, and the third tier contained only road segments with an ADT less than 50. These numbers were concluded based on the sensitivity study from NDSU.

The second criterion considered in this decision process was the ADTT. The first tier in this criterion only considered road segments with ADTT counts higher than 20, the second tier contained counts within 10 and 20 trucks per day, and the third and lowest tier only considered roads with less than 10 trucks per day.

The NDSU study showed that in their analysis, a medium maintenance road is defined as one with at least 20 trucks per day for a paved road. 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 unpaved roads.

The third criterion of the decision process considered the number of oil wells and water hauls within the buffer zone. For Goshen, Laramie, and Platte counties this was created through expanding the zone two miles from each side and each end of a given road segment. This distance was determined from 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 had more developed road networks, the two-mile zone was sufficient enough to show every possible oil well and water haul site affecting the road segment. Converse County, on the other hand, had a much less developed road network. In this case, the buffer zone had to be expanded to four miles. The energy companies would also make their own roads to operation sites, which led to the two-mile zone not showing all the wells and water haul sites affecting the county roads.

After these three criteria were determined, the road segments were entered through the decision process to create the priority list. Unfortunately, any road segment with missing traffic information could not be assessed through this process. Figure 5.3 shows this decision process and how each criterion affects the overall priority rank.

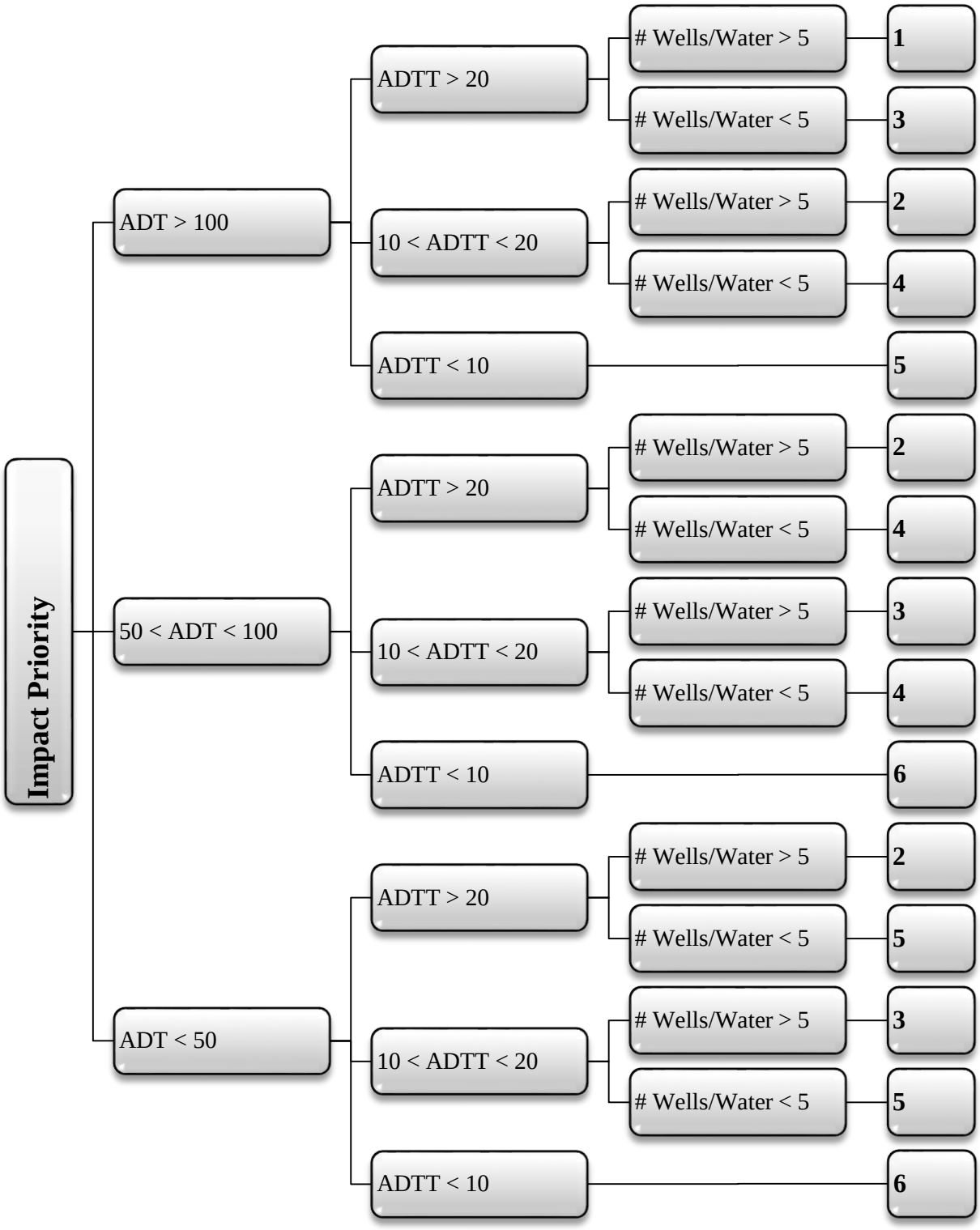


Figure 5.3 Unpaved Impact Priority Decision Process

From the decision process, it can be seen that 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 on a highly used road. The first iteration of the priority ranking, with the ADTT criterion being the first criterion, showed some road segments that were not representative of their impact priority rank. Thus the ADT and ADTT were switched in the decision process, creating much more justifiable results. For example, when having ADTT as the first tier, roads that were known to be less impacted would have higher priority ranks than roads that were highly impacted by energy operations. Table 5.11 shows the results of the impact priority decision process throughout the four counties along with total counts. Figure 5.4 shows the map of the priority ranking in Converse County with the other county priority ranking maps in Appendix H. Priority Ranking Maps and Tables.

Table 5.11 Impact Priority Decision Process Overall Results

County	**Impact Priority Number**					
	1	**2**	**3**	**4**	**5**	**6**
Converse	17	2	11	11	0	26
Goshen	0	0	6	3	8	24
Platte	0	0	0	4	0	11
Laramie	7	30	32	5	1	73
Total	**24**	**32**	**49**	**23**	**9**	**134**
Percentages	**8.9%**	**11.8%**	**18.1%**	**8.5%**	**3.3%**	**49.4%**

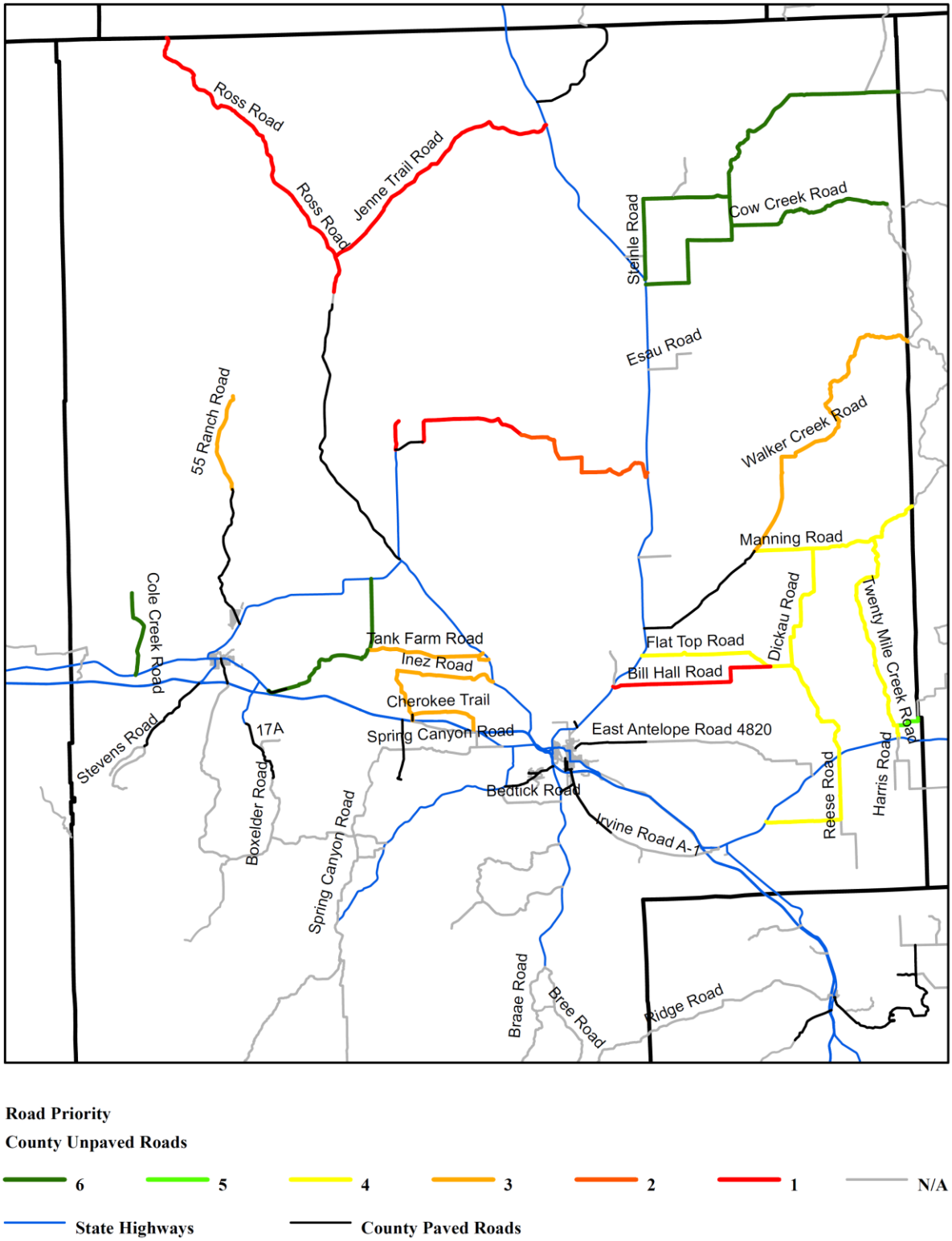


Figure 5.4 Converse County Road Priority Ranking Map

Table 5.11 shows that almost half the impacted segments have the lowest impact priority rank. This means that almost half the impacted roads in the four counties have extremely low energy related impact 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. Because the majority of the roads in the four counties fall within an impact priority rank of 4 or less, it can be said that the impact seen in southeast Wyoming is not at a severe level. Table 5.12 further analyzes how the ADT, ADTT, and serviceable rigs differ for each priority level.

Table 5.12 Averages for Impact Priority Numbers

Impact Priority Number	Averages		
	ADT	ADTT	Serviceable Rigs
1	329	155	16
2	162	20	11
3	126	28	4
4	68	16	2
5	41	23	1
6	34	3	2

It can be seen from Table 5.12 that the roads ranked 1 in the priority list have a significant separation in average ADT, ADTT, and serviceable rigs from all the other priority ranks. Therefore, the roads that do show the highest level of impact with a priority rank of 1 are at very high levels. Although the priority ranking of 3 has a higher ADTT average, it has seven fewer serviceable rigs from that road segment as compared with the priority rank of 2. From this priority list, maintenance costs and recommendations will then be created.

5.3 Maintenance Recommendations

Service levels developed by the WYT^2/LTAP were assigned for each of the unpaved, impacted road segments rated during May 2012 (Huntington and Ksaibati, Annualized Road Works Cost Estimates for Unpaved Roads 2009). This was done to determine appropriate maintenance strategies for each section. The maintenance strategies for unpaved county roads consisted of reconstruction/rehabilitation, re-graveling or building roads up, minor drainage repair, treat gravel/dust control, heavy blading, and light blading (Huntington and Ksaibati, Annualized Road Works Cost Estimates for Unpaved Roads 2009). These maintenance strategies contained options for every type of unpaved road and were developed by the WYT^2/LTAP (Huntington and Ksaibati, Improvement Recommendations for Unsealed Gravel Roads 2011). For example, the same maintenance strategies for a high volume, high width road would not have the same maintenance recommendations as a two-track road seeing very little traffic. The two considerations when determining the service level for each road segment were the road top width and the vehicles per day or ADT. When there were conflicts between the ADT and top width, the service level was averaged toward the ADT. This is because the ADT will have a greater effect on the condition of an unpaved road than the top width of the road. However, when no traffic information was available for a given road segment, the top width alone was the deciding factor for the service level assignment. Table 5.13 shows the breakdown of the top widths and ADTs used for service level determination.

Table 5.13 Unpaved Road Service Level Standards

Service Level	Traffic, ADT	Top Width, ft
Very High	> 400	≥ 28'
High	151 - 400	23' - 27.5'
Medium	51 - 150	18' - 22.5'
Low	16 - 50	13' - 17.5'
Very Low	5 - 15	9' - 12.5'
None	< 5	≤ 8.5'

The maps for the service levels and top widths throughout each county can be seen in Appendix J. Service Level and Top Width Maps. After selecting the service level for each road segment, the necessary maintenance strategies and recommendations can be established. This was done through a decision matrix developed by the WYT[2]/LTAP, which first addresses the service level, followed by taking into account the ride quality and dust conditions, and then considers the rest of the distress conditions. These conditions and service levels apply a cost per square yard for the given maintenance recommendation from which the total cost can be calculated with segment length and road width. The decision matrix used to determine the appropriate maintenance strategy is shown in Figure 5.5.

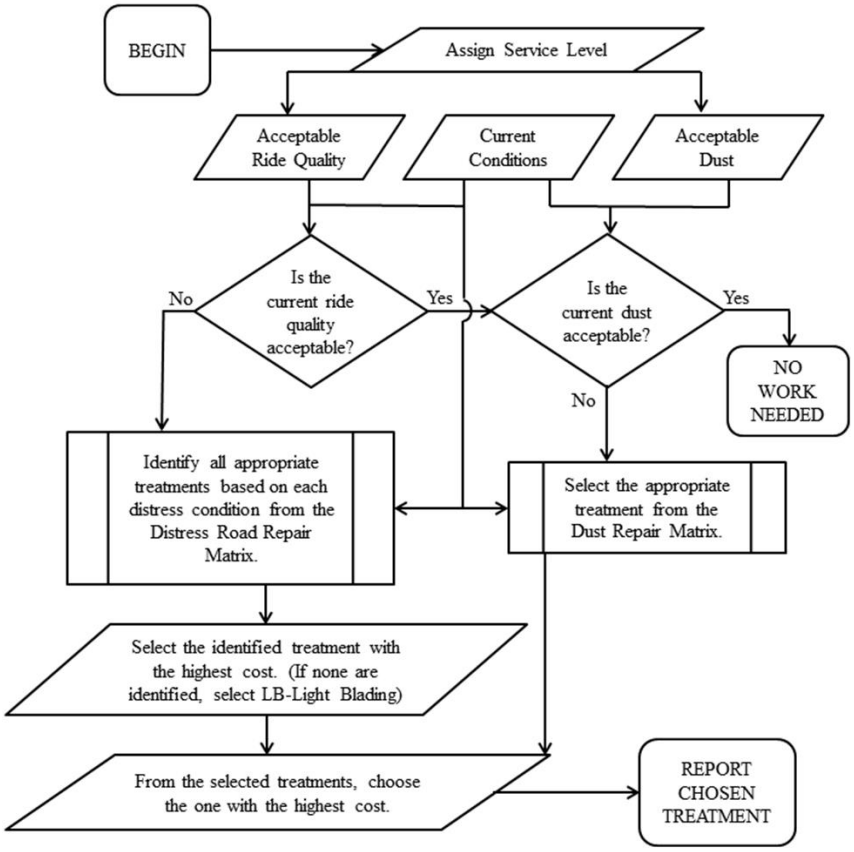


Figure 5.5 Unpaved Road Maintenance Selection Matrix

The maintenance treatment matrices developed by the WYT[2]/LTAP be found in Appendix I. Maintenance Decision Matrix. To determine appropriate costs of the different maintenance strategies, a meeting with the four counties was held and cost per mile was determined for each maintenance strategy. Because every county would have differences in costs, a feasible cost for each maintenance strategy had to be agreed upon. The cost per mile determined for each maintenance strategy assumed a 24-foot top width for each road. The cost per mile was also broken down into cost per square yard so that the actual cost of every road segment with known top width and length could be determined. Table 5.14 shows the cost per mile, assuming a 24-foot top width, and the cost per square yard for each maintenance strategy.

Table 5.14 Unpaved Road Maintenance Strategies and Costs

Treatment	Cost/yard^2	Cost/mile*
Reconstruction/Rehabilitation	$10.65	$150,000
Regravel/Build Up Road	$2.13	$30,000
Major 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
None	$0.000	$0

* Based on 24 foot top width

From these maintenance strategies and costs, maintenance treatment costs could be determined. Now that costs were assigned to each treatment strategy, the conditions of each road were considered from the selection matrix in Figure 5.5. Through the leading distresses, maintenance costs and strategies were determined for every road in the priority ranking list. Table 5.15 shows the recommended improvement costs per county and per priority level from the decision matrix and improvement costs developed by the WYT[2]/LTAP.

Table 5.15 Unpaved Road Maintenance Recommended Treatment Costs For the Priority List

Recommended Improvement Total Costs								
	Priority Level							
County	**1**	**2**	**3**	**4**	**5**	**6**	**None**	**Total**
CO	$164,834	$117,254	$0	$0	$0	$77,136	$69,274	$428,498
GO	$0	$0	$0	$0	$0	$130,625	$1,152,167	$1,282,792
LA	$0	$21,903	$3,120	$0	$0	$30,288	$902,723	$958,035
PL	$0	$0	$0	$22,064	$0	$0	$3,496	$25,559
Total	$164,834	$139,158	$3,120	$22,064	$0	$238,049	$2,127,659	$2,694,883
Recommended Improvement Costs per Prioritized Mile								
	Priority Level							
County	**1**	**2**	**3**	**4**	**5**	**6**	**None**	**Average**
CO	$2,389	$9,334	$0	$0	$0	$1,050	$387	$823
GO	$0	$0	$0	$0	$0	$1,694	$1,941	$1,617
LA	$0	$302	$49	$0	$0	$170	$1,394	$954
PL	$0	$0	$0	$1,817	$0	$0	$12	$63
Total	$2,389	$9,636	$49	$1,817	$0	$2,914	$3,734	$990

A total of almost $2.7 million has been recommended to improve the unpaved county roads in the four counties that are impacted by energy related operations. Of this, over $2 million is recommended for non-impacted roads. This is most likely caused from the much higher mileage of the non-impacted roads and the counties maintaining all their roads, impacted or not, to the same level. Converse County showed total treatment costs to maintain their roads at about $430,000. Dust and washboarding were the leading distresses causing these costs. Goshen County showed the greatest amount of improvement costs with almost $1.3 million. The improvement costs for Goshen County were due to not only dust and washboards, but drainage, potholes, rutting, and loose aggregate as well. Because of these different leading distresses, costs to improve them were increased because of higher costs of repairing worse distresses. Laramie County saw the second highest total treatment costs with almost $960,000. The treatment costs in this county showed every distress, except for loose aggregate and the ride quality as being the causes for maintenance recommendations. Platte County showed almost no treatment costs compared with the other three counties and it only had a total cost of treatments of about $25,000. This lower cost was due to the low mileage of impacted roads in the county and the lower amount of impact being seen in the county. The treatment costs were due to dust, drainage, rutting, and potholes. The total treatment cost per mile showed the same trends as the total costs. Goshen County had the highest costs per mile with $1,617; Laramie County had the next highest cost per mile with $954; Converse County was very similar to this cost per mile with $823; and Platte County showed an extremely low cost per mile at $63. The costs per mile per priority ranking number varied greatly. Because the most severe levels of impact are seen with roads with a priority rank of 1, it would be expected that these roads would see quicker degradation and worse road conditions, which would lead to higher maintenance costs. The treatment cost per mile of roads with a priority rank of 2 was $6,000 per mile more than any other priority rank. This could mean that the counties are neglecting these roads in order to sustain the maintenance of the unpaved roads with a priority rank of 1. A treatment cost of $9,334 per mile for Converse County unpaved roads ranked at a priority level 2 shows a significant maintenance effort to sustain an unpaved road. The roads with priority ranking of 3, however, only showed a treatment cost of only $49 per mile and roads with a priority rank of 5 had no treatment costs associated with them. The maps of the maintenance recommendations can be seen in Appendix K. Recommended Treatment Maps.

5.4 Data Analysis Summary

The analysis of the conditions of unpaved roads based on the level of impact showed that the impact level is not to the point at which the counties are struggling to keep up with the maintenance. This is shown through the maintenance records and road condition data. Although more money is being spent to maintain the impacted roads, these roads are in the same good condition as the rest of the roads throughout the counties. Although more money, time, and resources are being spent on the impacted roads, there has been no indication that this impact is overwhelming the counties. The modeling shows that the impact does have an effect and is relevant to the ride quality. When examining the impacted roads in the modeling, the ADT, ADTT, and oil wells within the buffer zone showed no relevancy in explaining the ride quality. This is most likely because the roads in the counties are all maintained to a good condition, and therefore these characteristics may be shown more accurately through the distresses in the model.

The impact priority ranking and list show that Laramie and Converse Counties have the most severe impact in the four counties. It is not until priority ranking of 3 that Goshen County shows up, and Platte County does not show up until priority ranking of 4. The priority list and ranking system shows that Converse and Laramie Counties are seeing the most severe impact on their roads and that Platte and Goshen Counties are seeing impact, but not at severe conditions yet. Almost half the unpaved county roads throughout the four counties are at the lowest priority level and show little to no immediate improvement concerns due to the low traffic and, in particular, truck traffic.

Treatment costs show that the roads in the four counties have lower maintenance costs for current conditions with the exception of Converse County roads with an impact rank of 2. These costs show that the counties are maintaining most all their unpaved roads to a standard warranted by the current traffic.

6. DATA ANALYSIS OF CATTLEGUARDS

6.1 Current Conditions

As seen from Table 4.7 the cattleguards throughout the four counties seem to be in relatively good overall condition. This can be better seen from Figure 6.1 through Figure 6.4, which show the total number of cattleguards with a given rating for approach, base, grate, and wing conditions.

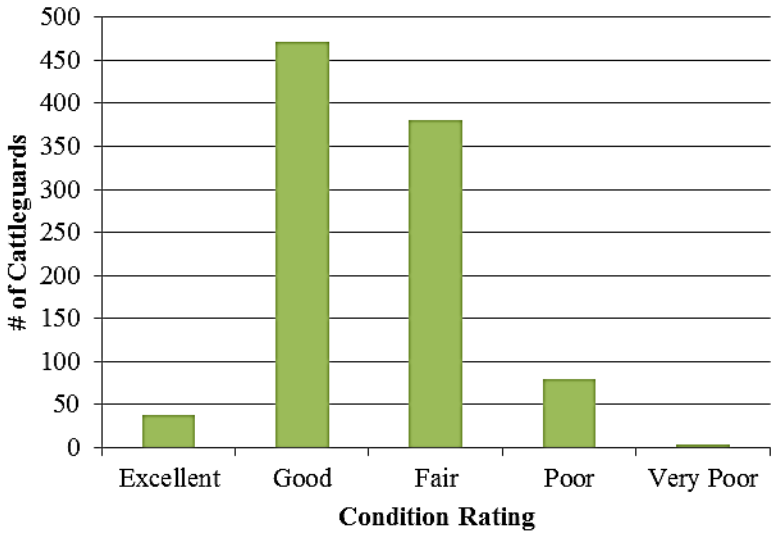


Figure 6.1 Cattleguard Approach Conditions

Figure 6.2 Cattleguard Base Conditions

Figure 6.3 Cattleguard Grate Conditions

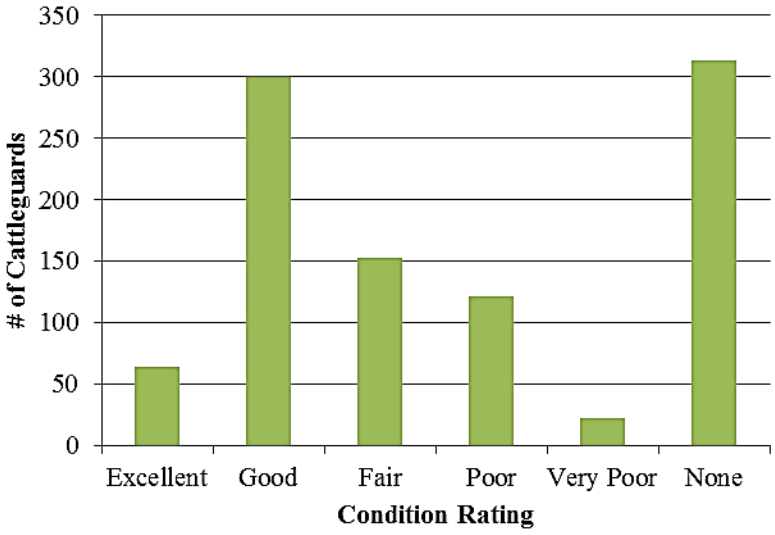


Figure 6.4 Cattleguard Wing Conditions

These graphs show a better representation of the conditions of the cattleguards throughout the four counties. Again, the majority of these condition ratings are between fair and excellent. This is most likely due to counties replacing cattleguards as they become dangerous by being in poor to failing condition. This is important because the maintenance costs for cattleguards are based off of the current conditions of the cattleguard, and therefore, its current value is based off of the base type, length, and whether it is on an unpaved or paved road. To compare the conditions of the approach, base, grate, and wings in each county, pie charts were created for each county and each characteristic. These graphs can be seen in Appendix L. Cattleguard Condition Charts.

6.2 Maintenance Recommendations

Unfortunately, there were no maintenance records or costs for cattleguards in the four counties. Because of this, it was impossible to create a comparison between impacted and non-impacted roads. Not knowing when and how many cattleguards had been replaced on different roads, strong conclusions could not be made about how the impact has affected the cattleguards. Costs for cattleguard replacement were determined from WYDOT's 2011 average bid prices (Wyoming Department of Transportation 2011). The average price for an 18-foot medium duty cattleguard is $8,519 and $10,914 for a 24-foot medium duty cattleguard. After meeting with the counties, these prices were rounded to $8,500 and $10,900. In order to derive costs from base type, lengths, and surface type, these total costs had to be broken down into base cost, grate cost, wing cost, and approach cost. By assuming some of these values, the WYT^2/LTAP developed Table 6.1, which breaks down the total cost per cattleguard into the four characteristics of each cattleguard.

Table 6.1 Cattleguard Assumed Initial Costs

Length	Base Cost		Grate Cost	Wing Cost	Approach Cost		*Total
	Concrete	Other			Unpaved	Paved	
18'	$5,900	$3,500	$2,300	$200	$100	$300	$8,500
24'	$7,600	$4,500	$3,000	$200	$100	$300	$10,900

*based on a cattleguard with a concrete base on an unpaved road

Because there were cattleguards that did not fall under either of these lengths, costs were assumed to be a linear function of the length of the cattleguard. Initial costs for base, grate, wing, and approach could then be put into equations based off of the length of the cattleguard. Current conditions and values also had to be taken into consideration. For example, a cattleguard having a very poor grate condition would not have the same current value as one with a fair or good condition. Thus, percentages based on current conditions were developed to adjust the initial and total costs. These equations and percentages were generated by the WYT^2/LTAP. Table 6.2 and Table 6.3 show the specifics of these equations and percentages.

Table 6.2 Cattleguard Condition Values as Percentages of Their Replacement Costs

	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%

Table 6.3 Cattleguard Initial Cost Equations Based on Length

Cost Equations Based on Length	
Concrete Base Cost, $	= 283 1/3 (Length) + 800
Other Base Cost, $	= 166 2/3 (length) + 500
Grate Cost, $	= 116 2/3 (Length) + 200
Wing Cost, $	= 200
Approach Cost, $	IF Unpaved = $100; IF Paved = $300

From these costs and percentages, the total replacement cost and current value could be calculated for each cattleguard in each county. This is a simple process of multiplying the calculated cost for the base, grate, wings, and approach by the appropriate percentage for its current condition. For example, a concrete base on a 24-foot cattleguard in fair condition would have a replacement and current value cost of:

$$Replacement\ Value\ of\ Base = 283\ \frac{1}{3} * (24\ feet) + 800 = \$7600.00$$

$$Current\ Value\ of\ Base = \$7600.00 * 50\% = \$3800.00$$

By calculating each replacement value and current value for every cattleguard, an assessment can be made about the condition of cattleguards in each county compared with their replacement, or new, value. To better understand how these costs break down for each characteristic of a cattleguard, the total replacement and current values were calculated for each, and the total costs were then determined. From these values, the percentages of replacement values could be determined from the current conditions and costs. Table 6.4 shows the breakdown of these values.

Table 6.4 Cattleguard Replacement Costs and Current Values

Replacement Value							
County	**# Cattleguards**	**Approach**	**Base**	**Grate**	**Wings**	**Total Replacement Value**	**Average Replacement Value**
Converse	339	$ 36,700	$ 2,254,149	$ 907,095	$ 40,800	$ 3,238,744	$ 9,554
Goshen	249	$ 20,000	$ 1,042,600	$ 415,331	$ 28,600	$ 1,506,531	$ 6,050
Laramie	154	$ 26,100	$ 1,442,633	$ 568,497	$ 29,000	$ 2,066,230	$ 13,417
Platte	231	$ 35,900	$ 1,345,783	$ 543,430	$ 33,600	$ 1,958,713	$ 8,479
Total	**973**	**$118,700**	**$6,085,165**	**$2,434,353**	**$132,000**	**$ 8,770,218**	**$ 9,014**
Current Value							
County	**# Cattleguards**	**Approach**	**Base**	**Grate**	**Wings**	**Total Current Value**	**Average Current Value**
Converse	339	$ 22,525	$ 1,434,400	$ 595,093	$ 23,350	$ 2,075,368	$ 6,122
Goshen	249	$ 13,800	$ 712,767	$ 294,715	$ 18,100	$ 1,039,382	$ 4,174
Laramie	154	$ 15,050	$ 967,325	$ 395,560	$ 18,350	$ 1,396,285	$ 9,067
Platte	231	$ 24,300	$ 916,883	$ 384,440	$ 19,350	$ 1,344,973	$ 5,822
Total	**973**	**$ 75,675**	**$4,031,375**	**$1,669,808**	**$ 79,150**	**$ 5,856,008**	**$ 6,019**
Current Percent of Replacement Values							
County	**# Cattleguards**	**Approach**	**Base**	**Grate**	**Wings**	**Total Value Percentages**	
Converse	339	61%	64%	66%	57%	64%	
Goshen	249	69%	68%	71%	63%	69%	
Laramie	154	58%	67%	70%	63%	68%	
Platte	231	68%	68%	71%	58%	69%	
Average		**64%**	**67%**	**69%**	**60%**	**67%**	

From Table 6.4, it can be seen that the total replacement value for the cattleguards in the four counties is $8.77 million and the total current value of these cattleguards is $5.86 million. This total current value represents 67% of the total replacement, or new, value. This means, on average, two-thirds of the cattleguards in each county are at the replacement, or new, value. The replacement cost would then be the

total replacement value minus the total current value, which is $2.91 million, which corresponds to about $3,000 per cattleguard. This, however, is simply an averaged value and may be much higher. This is because if the cattleguard has a very poor, or failing, grate or base condition, then the whole cattleguard would be replaced even if the other characteristics are in excellent condition. Table 6.4 reflects the importance of the base and grate with much higher costs than both the wings and approach.

6.3 Summary

Although there was no method to address the comparison between impacted and non-impacted roads for cattleguards, this analysis will help determine future impact. This will be done by establishing a baseline for future ratings and replacement costs. These future ratings can then be compared to these previous ratings and a comparison can be made between impacted roads versus non-impacted roads. By having the current conditions, replaced cattleguards will be able to be identified. This will be valuable in showing whether or not heavy truck traffic from energy related operations causes quick deterioration, and thus failure, of cattleguards on impacted roads.

7. PERMITTING

7.1 Background

The permitting process for much of the oil and gas truck traffic, as well as the rig and well sites themselves, is a complicated process. Oversize/overweight, road use agreement, and access permits have been the main focus and most involved of the permitting process. The most difficult of these, and the one with the least amount of success, is the oversize/overweight permit. This is largely due to the high amount of truck traffic and the counties' lack of manpower to be able to permit every load. Standardizing these permits and the processes involved with them will make for an easier and more efficient use of the counties' time. This would also regulate the oil and gas industry, and more importantly, the truck traffic on the county roads. In the long run, this could create safer roads to travel on and help reduce the cost to the county to maintain these roads. This could also possibly require the oil and gas companies themselves to help pay for this maintenance while saving time and money for the county. Currently, the counties in Wyoming are permitting energy related truck traffic through the use of access permits, road use agreements, and oversize/overweight permits.

7.1.1 Oil and Gas Permits

The permitting process for the energy related industries in southeast Wyoming is currently a growing process due to the majority of the impact occurring more recently. Permits for not only land use but for road infrastructure are currently being used to regulate this industry and compensate for damages. For a better understanding of this impact and the permits associated with it, accepted oil and gas permits were examined and summarized. Figure 7.1 shows the approved oil and gas permits from the Wyoming Oil and Gas Commission broken down into county and year (Wyoming Oil and Gas Conservation Commission 2012).

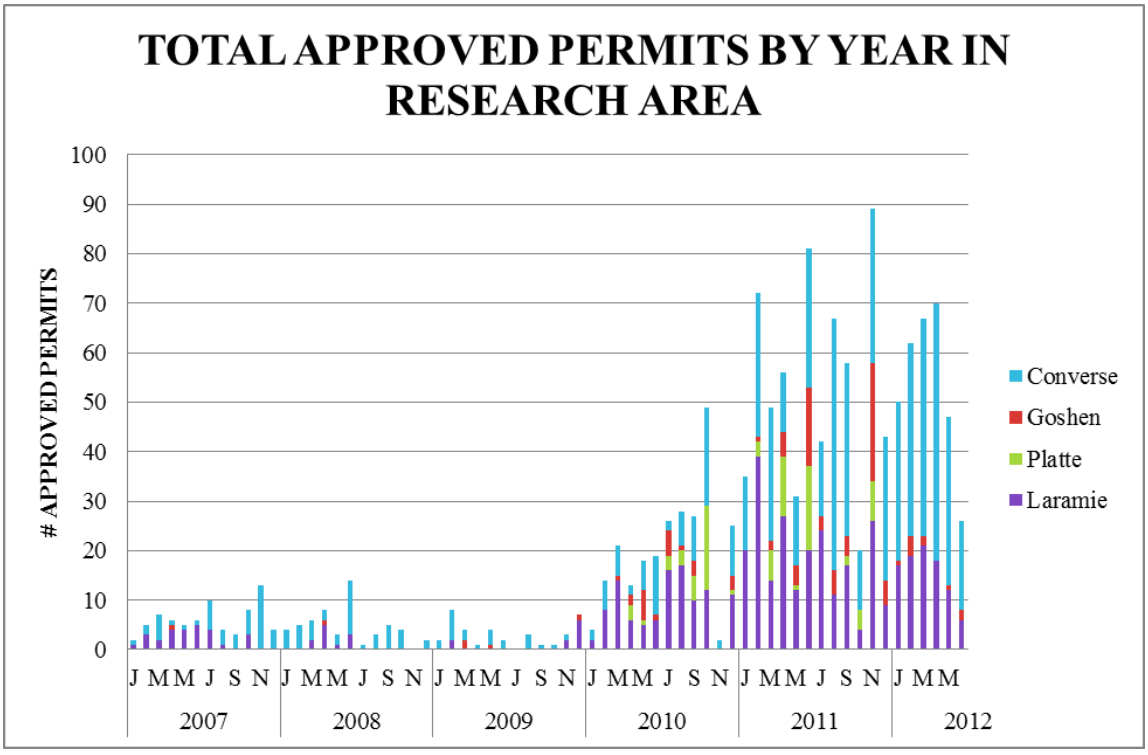


Figure 7.1 Approved Oil and Gas Permits from WOGCC Website

A dramatic increase in the approved oil and gas permits can be seen starting in 2010 and continuing into 2012. It can be seen that Converse County and Laramie County have had more permits accepted during this time period. With the heavy amount of traffic associated with this industry, permitting is a necessity at this point. Unfortunately, of the four counties in this study, only Laramie County and Goshen County have permits associated with this heavy traffic.

7.2 Standardizing County Permits

In the fall of 2011 and spring of 2012, a separate study was conducted to determine the county resources and permits for the trucking industry. This was done with the intention to develop a standardized set of permits and a common permitting process across Wyoming with the hope that compliance with permits and fees would be implemented. Through research of each county website throughout Wyoming, information about the permits associated with the trucking industry was gathered, as well as the permits themselves. Pertinent information such as fee scheduling, rules, regulations, and specifications was tabularized under each permit type in each county to compare the current methods being used in Wyoming. Through this process, it was found that the most common permits used for addressing the trucking industry are the access permit, road use agreement, and oversize/overweight permit. To confirm that nothing was missed during this initial data collection, a survey was made with a common set of questions. Through these questions it was determined if any permits were missed in any of the counties and were used to verify the information already gathered, as well as determine if any other permit or process were being used to mitigate energy related truck traffic. This survey can be found under Appendix N.

With the information gathered from the survey, the original data were updated. At this point a standardized permit was ready to be formed by using all the information gathered. The similarities of each permit were then examined and included in the standard permit. Each county permit was then individually inspected and the portions that were deemed too important to leave out were incorporated into the standard permit. This was the most difficult task because there was an obvious reason for every item being in each individual permit, however, having an overly lengthy permit did not seem to be the best option.

7.3 WYDOT and the WHP

For comparison purposes, on March 7, 2012, a meeting with WYDOT and the Wyoming Highway Patrol (Smith 2012) was held to gain a better understanding of what their procedures and permits were in regard to the trucking industry. Questions regarding the permitting of heavy truck traffic and what is currently being accomplished by the WHP were inquired, and the detailed answers to these questions can be found in Appendix N. Questions from the WHP. Through this meeting and these questions, it was discovered that the Wyoming Highway Patrol currently has only the oversize/overweight permit. Table 7.1 shows the approved WHP oversize/overweight permits per year.

Table 7.1 WHP Oversize/Overweight Permits Issued per Year

	Number of Permits Issued/year				
	2007	2008	2009	2010	2011
Oversize-Overweight Permits	120,663	126,970	106,340	101,915	114,405

To handle the massive amount of oversize/overweight permits seen on state highways, the WHP has more than 100 people in their permitting department. For its oversize 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. Overweight permits are charged $0.03 for each foot in excess of the legal limit with a base fee of $25.00. It was also their opinion that the counties would struggle in the enforcement area of these permits. This is because the counties lack the scales needed to weigh the trucks and determine their appropriate permit for their given load.

7.4 Survey Results

Data collected from each county's website gave detailed specifications and fee scheduling for the permits they had in regard to the energy industry. These permits regulating this industry include access permits, road use agreements, and oversize/overweight permits. After analyzing the websites for each county, the survey in Appendix M was distributed through each county to verify the initial information. Table 7.2 shows the results of the survey and the permits that each county has in regard to the energy related traffic.

Table 7.2 County Permits and Types

County	Permit Type		
	Oversize/Overweight	Road Use Agreement	Access
Albany	N	Y	Y
Big Horn	N	N	Y
Campbell	N	N	N
Carbon	N	N	Y
Converse	N	N	Y
Crook	Y	N	Y
Fremont	N	N	Y
Goshen	Y	Y	Y
Hot Springs	N	N	Y
Johnson	N	Y	Y
Laramie	Y	Y	Y
Lincoln	N	N	Y
Natrona	N	N	Y
Niobrara	N	N	N
Park	N	N	Y
Platte	N	N	Y
Sheridan	N	N	Y
Sublette	N	N	Y
Sweetwater	N	N	Y
Teton	N	N	Y
Uinta	N	N	Y
Washakie	N	N	N
Weston	N	N	N

The results of the survey were close to what was expected. A majority of information from the initial research was correct and most of the county permits were found on their websites. It was apparent in the initial research however that not all of the permits would be found on the websites, and that some of this information would possibly be outdated. Although it seemed that many of the counties were in the process of updating their permits, there was only one county that was creating new permits during the course of this survey and project. Therefore there was only one county that was really affected by any outdated information.

Currently, Laramie and Goshen counties have the most up-to-date permitting and have all three permits associated with trucking. Unfortunately, Platte and Converse counties do not have either of the permits that help regulate energy traffic and compensate for road damage. For the oversize/overweight permit in Laramie County, the fee scheduling is the same as the fees for the WHP. Goshen County, however, 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 from within the county or not. The rig movement option from outside the county is a one-time $1,000 charge, whereas the rig movement option within the county is only $250. Weight and lengths must be specified in both counties' oversize/overweight permit however.

7.5 Permitting Cost Analysis

Data gathered from Laramie County showed little to no income generated from the oversize/overweight permits. Table 7.3 shows the revenue from the oversize/overweight permits filed each year since 2007.

Table 7.3 Laramie County Oversize/Overweight Permit Revenue

	Number of Permits Issued/year				
Oversize-Overweight Permits	2007	2008	2009	2010	2011
	0	81	45	343	805
	Dues Collected in $/year				
Oversize-Overweight Permits	2007	2008	2009	2010	2011
	$0.00	$3,240.00	$1,800.00	$13,720.00	$49,939.79

Considering the amount of truck traffic seen from oversize/overweight permits, there does not seem to be a great deal of compensation to Laramie County when considering the cost of road damage and repair. However, if Laramie County, and all the 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 7.3 shows the significance of this revenue.

Table 7.4 County Revenue Generated From Reactive, Non-Performance Based System

	2006		2007		2008	
County	# of Wells	Total Estimated Revenue	# of Wells	Total Estimated Revenue	# of Wells	Total Estimated Revenue
Converse	20	$160,000	9	$72,000	19	$152,000
Goshen	1	$8,000	0	$0	1	$8,000
Laramie	0	$0	11	$88,000	6	$48,000
Platte	0	$0	0	$0	0	$0
	2009		**2010**		**2011**	
County	# of Wells	Total Estimated Revenue	# of Wells	Total Estimated Revenue	# of Wells	Total Estimated Revenue
Converse	6	$48,000	30	$240,000	44	$352,000
Goshen	0	$0	6	$48,000	4	$32,000
Laramie	4	$32,000	31	$248,000	24	$192,000
Platte	0	$0	1	$8,000	0	$0
	Converse Total*		**$1,024,000**	**Goshen Total***		**$96,000**
	Laramie Total*		**$608,000**	**Platte Total***		**$8,000**
*Assuming $8000.00 fee per well						

Using the reactive, non-performance-based approach would generate $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 revenue generated from the oversize/overweight permits between 2007 and 2011, Laramie County would have created almost $540,000 more for those five years. This is a considerable increase in funds to help mitigate the road damage and repair, and in conjunction with the oversize/overweight permits and any other permits pertaining to the energy industry, funds will become more abundant to the counties.

7.6 Standard Permits

Each standard permit was created with the underlying goal that every county would be represented. In other words, this process and project was for the benefit of the counties. In creating these permits, the most common set of fees, rules, regulations, conditions, and specifications was used. After these rules and regulations were determined, the remaining portions were added/removed from the standardized permit. This process 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.

7.6.1 Access Permit

The standardized access permit begins with a first page of general information involving the licensee, the location of the property, and the fee for this permit. The fee for the standardized access permit includes a $75.00 processing fee and an inspection fee of $32.50/hour. The following three pages of the permit describe the rules, regulations, and specifications that are required for this permit, and the fifth page of the permit is for the approval by the county. The last two pages of the permit are drawings associated with the specifications to create a better understanding of what is being asked. The standardized access permit can be found in Appendix O1 Standard Access Permit.

7.6.2 Road Use Agreement

The standardized road use agreement is a straightforward document. The permit contains mostly rules and regulations due to the nature of the permit itself. The first page defines the company's business and its intended use of the road, where its business is taking place, the roads that are going to be used due to its business, the length of time the business expects to use these roads, approximately how many loads of legal limit will be transported on these roads, etc. The next two and half pages go into depth about the many rules and regulations are associated with this permit. The main reasoning behind the rules and regulations being the majority of the permit is to protect the county roads and indemnify the county. The last page of this permit, as with the access permit, is simply the signatures required. The standardized road use agreement can be found in Appendix O2 Standard Road Use Agreement.

7.6.3 Oversize/Overweight Permit

The oversize/overweight permit ended up being the most extensive standardized permit as far as paperwork is considered. The first page of the permit is information about the load and company. The rest of the permit specifies the rules and regulations required when hauling an oversize/overweight load, the specifications for an oversize/overweight load, and the fee schedule and tables to determine an oversize load. The standard oversize, overweight permit can be found in Appendix O3 Standard Oversize/Overweight Permit.

7.7 Summary and Conclusions

WHP personnel were interviewed during the meeting in March to see what their thoughts and opinions were about the permitting of energy related traffic. They believed there was a definite need for regulating this traffic through permitting. They also believed that a denied oversize/overweight load would re-route to move the load, which included 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 to create better efficiency in the energy industry.

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 energy companies to use these standard permits and a uniform process. By integrating the needed permits into each county and having them standardized across the state of Wyoming, it will be possible to impose on these companies some control, which has been highly stressed by the counties.

Had the counties adopted the non-performance-based approach from Texas, they would have been able to help generate more budgets for their road and bridge departments. This would have allowed the counties to mitigate some of the damage incurred from the energy industry and heavy truck traffic on the county road infrastructure. It also would have been very beneficial to the counties due to the lack of manpower to handle the mass amounts of oversize/overweight permits and road use agreements that the energy industry would produce, as well as the issue of enforcing these permits. 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 what they will do about it.

8. CONCLUSION AND RECOMMENDATIONS

8.1 Summary

Through this study, strategies were developed for determining energy related impact on local county road infrastructure. Through the development of these strategies, much was learned about the nature of the impact in Converse, Goshen, Laramie, and Platte counties. The knowledge gained is invaluable and can be used to help other counties by giving them a resource to quantify the impact and acquire more knowledge of the impact in their county. By having the resources and knowledge to quantify this impact, counties will be able to handle energy impact. The knowledge gained through the strategies in this study will also give counties the resources to handle much larger impacts by creating a more effective and efficient use of their time. Although all the strategies in this study are viable to quantify the impact of energy operations, the most valuable tools gained from this study were the analysis of the maintenance records in regard to level of impact, and the priority ranking lists. With these two tools, the counties can determine which county unpaved roads are most affected by the energy industry, which of these roads need immediate attention, and the difference in maintenance efforts for each road segment and level of impact. By analyzing these two criteria, the counties can better determine where any deficiencies in their regions may exist.

The impact of energy related traffic and operations in southeast Wyoming is far from nonexistent, but it is not yet at the level at which it is unsustainable for the counties. The conditions of unpaved roads for both impacted and non-impacted roads show that these roads are all in good condition, meaning that the counties are able to maintain the impact thus far. However, as the impact increases, the counties may not be able to ensure the proper maintenance for the roads at a higher service level, and the road condition may drop. Until the impact reaches this level though, the procedures found in this thesis will provide a standardized method of quantifying and mitigating the current impact.

8.2 Conclusions

The strategies in this thesis consisted of collecting condition and distress ratings on the roads in the four counties as well as traffic counts, cattleguard conditions, and current permitting procedures. In order to evaluate the average conditions of the unpaved roads in these counties, the following conclusions were generated:

- A total of 931 segments were created on unpaved county roads.
    - 311 of these segments and 717 miles were impacted segments, and 620 segments and 2077 miles were non-impacted.
    - Converse County had 525 miles of unpaved roads and 132 total segments.
    - Goshen County had 908 miles of unpaved roads and 278 total segments.
    - Laramie County had 1008 miles of unpaved roads and 382 total segments.
    - Platte County had 353 miles of unpaved roads and a total of 139 segments.
- The distress and ride quality conditions showed that, on average, the unpaved roads in the four counties were in good condition.
    - There was little to no difference between the impacted and non-impacted road conditions on average.
    - The maintenance records gathered from Laramie and Goshen Counties show that, historically, more efforts and money have been spent maintaining impacted roads. Laramie County showed an average difference of $8,309 per mile on impacted roads than non-impacted roads. This shows that there is substantially more time and money being placed into unpaved road maintenance in Laramie County and that the impact seen in this county is at a significant level.

    - The level of impact seen in southeast Wyoming is not to the level at which it is unsustainable to the county road and bridge departments.
- The modeling of the data also showed that the impact had an effect on ride quality and explained only a small amount of the variation of the ride quality model for the full data set in the presence of the other variables found relevant at the 0.05 P-value level.
    - Because of the low levels of impact in these counties, the modeling in this study was not representative of explaining the impact characteristics for the variation in the ride quality.
    - The correlation matrix showed that many of the variables showed strong correlations, due to the nature of gravel roads and the distresses shown in them.
    - The reduced data set of just impacted roads did not show that the ADT, ADTT, and serviceable rigs variables showed significant explanation of the ride quality. This is most likely because the impact seen from these variables is shown more through the distresses than the numbers themselves.
- The impact priority list shows that the impact levels seen in the four counties are not at a severe level yet.
    - A majority of the impacted road segments from the impact priority ranking are at an impact ranking of 6. This is the lowest impact level and shows that little to no impact is seen on roads with this rating. Therefore, the majority of the impact seen in this thesis is at lower levels.
    - Converse and Laramie counties show the highest priority ranking and are therefore the most impacted by energy operations and traffic.
    - Platte County shows little to no impact in the county, and Goshen County shows close to the same.
- The maintenance treatment costs determined from current road distresses shows that the road segments are currently in good conditions.
    - Because the maintenance costs per mile for almost every priority are lower, the current conditions of the roads are in reasonable conditions.
    - Road segments in Converse County with a priority rank of 2 show the highest cost per mile and are therefore currently showing the worst distress conditions.
    - Priority ranking in each county better determines where the impact is and the extent of the current impact.

Funding will also be a vital role in providing resources to the county to help maintain roads. The permitting processes described above need to be seriously considered in order to give the counties another resource to use to maintain their roads. Permitting will also help in controlling some of the heavy truck traffic associated with the intense operations found in this field, and several conclusions can be drawn from this.

- Permitting will be a necessity for the counties to stimulate budget and resources to help sustain county unpaved roads.
    - Very little is currently being done in the counties of Wyoming with permitting heavy truck traffic.
    - Through the use of standardized permits and the reactive non-performance based approach from Texas, budget can be attainable due to greater compliance with counties in regard to energy related permitting.
    - Enforcement is a significant issue in the permitting field and is needed to control the current truck traffic being seen.

The cattleguard analysis in this thesis will provide a baseline for comparisons and valuable analyses in the future. Although no comparison could be made in this study between impacted and non-impacted roads,

the data gathered will help with future determination of how heavy truck traffic affects cattleguards. From these data, however, certain conclusions can be made.

- A vast majority of the cattleguards seen in this study were on county unpaved roads and in underdeveloped regions of the county.
- The cattleguards show various conditions and current values across every county and show no justifiable conclusions.
    - This is most likely due to cattleguards being replaced as they approach failing conditions.
    - No previous maintenance records were established in any of the four counties and it was impossible to determine when cattleguards had been replaced.
- The current conditions of the cattleguards, on average, show that they are in good overall condition.
- The costs and equations derived to determine replacement value of a cattleguard show that the base and grate conditions are the most significant factors addressed.
- The replacement and current values show that, overall, the cattleguards are currently in 67% of replacement condition.

Lastly, the traffic counts showed that the traffic in southeast Wyoming is very sporadic in nature. The nature of the energy impact seen in the four counties from traffic count data shows that the impact is seen in various parts of the county, with few highly impacted roads. Because of this, few conclusions could be made.

- The long-term counters in Goshen County showed that the highest traffic counts were recorded during weekdays.
- Converse County showed consistently high ADT and ADTT numbers for Ross Road and Bill Hall Road.
- Platte County showed very low ADT and ADTT numbers with significantly less traffic than the other counties.
- Although many roads were deemed impacted, the ADTT and percent trucks on these roads were very low and showed otherwise.
- The variation in all the traffic characteristics is extremely high in each county and may show some indication of the randomness of energy related traffic.

8.3 Recommendations

Recommendations provided herein are an attempt to offer guidance and possibly improve the ability to quantify the impact of energy related traffic on county infrastructure. These recommendations are considered only after close evaluation of all data contained within this report and rationally determining the validity of the data gathered and methodologies and analyses used. It is recommended that the strategies developed in this study be used in the future for impact analysis, and that these findings be implemented statewide. This will provide for more understanding of current impact levels and how to efficiently mitigate energy impact. Detailed recommendations are as follows:

- The maintenance records and priority ranking lists are two of the most important items addressed in this thesis and need to be seriously considered for every county. These two criteria, and the strategies developed with them, are the most efficient ways to quantify the impact of energy operations in a county.

    - The counties need to keep appropriate maintenance records with the proper segmenting. Without proper historical maintenance costs, no determination can be made about the costs of maintaining the impact in the county.
    - Maintenance records should be segmented according to procedures in this thesis to determine how impact affects different road segments.
- The strategies in this thesis should be adopted and implemented statewide to better determine the overall levels and locations of impact throughout the state of Wyoming. This may create a more efficient system for mitigating the damage of county roads due to energy operations in the state.
- The modeling in this study should be analyzed for a more representative data set showing higher impacts to determine how impact characteristics affect ride quality. A better data set containing more information including maintenance records, serviceable rigs for every road, etc., should be developed in this case as well.
- The rating system and analysis should be standardized for quantifying the impact on unpaved roads.
    - All roads should have the distresses and ride quality rated according to the methodology and strategies used in this thesis.
    - Information about road segments, including length, width, location, posted speed, road I.D., photo numbers, current impact seen on road segments, and whether or not the road is impacted, should be addressed and tabularized during the rating process.
    - The priority ranking system developed in this thesis should be adopted to address the different levels of impact seen throughout every county and to determine the road segments that are most affected by energy impact.
    - The maintenance recommendations and treatment costs developed in this thesis should also be developed to maintain unpaved county roads more efficiently and provide a better use of county budget.
- The methods used to analyze cattleguard conditions should establish a baseline for future analysis.
    - The condition rating system used in this thesis should be adopted for future ratings for cattleguards in the four counties.
    - The condition ratings from this thesis should be used as a baseline to determine how impact affects cattleguards.
    - The costs and strategies associated with cattleguard replacement should be adopted to determine the decrease in cattleguard value over time by analyzing current values.
- All pertinent traffic count information should be gathered on every county road to determine the traffic characteristics and relation to impact.
    - It is recommended that traffic counts be placed on all county roads to determine traffic fluctuations and characteristics. Roads deemed impacted by energy operations should have counters placed on them periodically through the year to assess the daily and monthly variations.
    - Traffic counts should be placed on both unpaved and paved roads to determine the movements of different traffic types in each county, and any traffic count information available from state agencies should also be attained.
- To help create more county road and bridge budgets for maintaining roads being impacted by energy traffic and its operations, permitting of truck traffic needs to be addressed.
    - The counties can help mitigate truck traffic and increase budgets by adopting a standardized process and standardized permits across the state. Without

permitting, the counties will most likely lack the budget and resources to sustain heavy impact that will likely be seen with developing technologies.

- Standardizing an oversize/overweight permit, a road use agreement, an approach permit, and having a one-time charge to energy companies, as with the non-performance reactive-based approach from Texas, will greatly help regulate some of the truck traffic seen from energy operations. This will also increase county budgets to a greater extent seen than in the past to help with maintenance costs and improvements.

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10. APPENDICES

APPENDIX A. OIL AND GAS PRODUCTION

Southeast Wyoming Oil, Natural Gas, and Water Production

Year	Production of Oil Bbls	Production of Gas Mcf	Production of Water Bbls
Converse			
2012 (thru June)	1,857,306	4,435,165	2,440,712
2011	3,520,122	8,978,489	6,527,576
2010	2,398,869	7,787,984	6,805,954
2009	1,877,259	8,338,563	6,077,471
2008	1,816,819	8,898,883	8,415,811
2007	1,833,350	9,890,098	8,826,895
Goshen			
2012 (thru June)	12,760	11,060	72,977
2011	6,088	12,687	95,541
2010	0	0	0
2009	0	0	0
2008	0	0	0
2007	0	0	0
Laramie			
2012 (thru June)	414,761	351,793	773,043
2011	839,039	637,341	1,733,747
2010	599,920	210,934	1,426,754
2009	345,931	100,918	1,172,618
2008	474,063	97,005	1,197,299
2007	409,525	114,138	1,132,922
Platte			
2012 (thru June)	258	955	3,460
2011	2,868	3,092	7,721
2010	0	0	0
2009	0	0	0
2008	0	0	0
2007	0	0	0

APPENDIX B. DISTRESS RATING STANDARDS

Potholes

Numerical Rating	Verbal Rating	Description
9	Very Good/ Excellent	No or negligible potholes or other isolated depressions in the roadway that cause a rough ride.
8 7	Good	Some small potholes and surface roughness, most less than 1" deep and less than 1' in diameter; Minor impact on ride quality; Negligible impact on safety or vehicle speeds.
6 5	Fair	Considerable potholes; Up to 3" deep though most less than 2" deep; Generally less than 2' in diameter; Significant impact on ride quality and vehicle speeds; Moderate safety risk, both as drivers dodge potholes and as they cause the driver to momentarily lose control of the vehicle; Much of the driver's focus may be on avoiding potholes.
4 3	Poor	Many potholes, some up to 4" deep and 3' in diameter; Major impact on ride quality and vehicle speeds; Safety risks are reduced as drivers are forced to greatly reduce speed to avoid the potholes, though the occasional imprudent driver may endanger other vehicles as they dodge potholes; Avoiding potholes is a constant driver task.
2	Very Poor	Potholes up to 8" deep and over 4' in diameter; Passenger cars must avoid the worst potholes or risk becoming high-centered; Ride quality and vehicle speeds drastically reduced.
1	Failed	Impassable to most passenger cars; Jeep trail.

Rutting

Numerical Rating	Verbal Rating	Description
9	Very Good/ Excellent	No or negligible ruts, though it may appear that there are ruts when berms of loose aggregate form. In this instance, the rater should determine whether or not the underlying, consolidated material has ruts. If so, a lower 'Rutting' rating should be assigned.
8 7	Good	Ruts less than 1" deep; Ruts over less than 5% of the roadway; Minor impact on ride quality.
6 5	Fair	Ruts 1" to 3" deep; Ruts over 5% to 15% of the roadway; Moderate impact on ride quality.
4 3	Poor	Ruts 3" to 6" deep; Ruts over 10% to 40% of the roadway; Major impact on ride quality; Drivers are tempted to drive between the ruts, not through them.
2	Very Poor	Ruts 6" to 12" deep; Any instance of this depth rutting implies a 'Very Poor' rating; Passenger cars will high-center unless they straddle the ruts; Severe impact on ride quality.
1	Failed	Ruts over 12" deep; Passenger cars generally cannot pass; Jeep trail.

Washboards (Rhythmic Corrugations)

Numerical Rating	Verbal Rating	Description
9	Very Good/ Excellent	No or negligible rhythmic corrugations.
8 7	Good	Corrugations generally less than 1" deep; Less than 10% of the roadway has significant corrugations; Minor influence on ride quality; Very little loss of vehicle control; Little impact on safety.
6 5	Fair	Corrugations generally 1" to 2" deep; 10% to 25% of the roadway has corrugations; Ride quality significantly reduced; Some areas where safety is significantly compromised as vehicle control is lost; Major safety issue as drivers are tempted to drive faster, skimming over the top of the corrugations.
4 3	Poor	Corrugations generally 2" to 3" deep; Corrugations over 25% or more of the roadway; Severe decline in ride quality; Major safety issue as drivers are tempted to drive faster, skimming over the top of the corrugations.
2	Very Poor	Similar to Poor, but deeper and more extensive corrugations.
1	Failed	Similar to Very Poor, but deeper and more extensive corrugations.

Loose Aggregate

Numerical Rating	Verbal Rating	Description
9	Very Good/ Excellent	Only occasional loose material on the road surface; No berms on the traveled way; Only very small berms on the shoulders; Negligible risk of chipped windshields.
8 7	Good	Some loose material in berms less than 1" deep; Berms have only a very minor influence on vehicles' trajectory; Loose material spread over the entire roadway is generally only a few particles thick, and usually ¾" thick or less; Minor risk of chipped windshields.
6 5	Fair	Some loose material in berms less than 2" deep; Some influence on vehicles' trajectory, posing a minor safety hazard; Loose material spread over the entire roadway is generally less than 1½" thick; Significant risk of chipped windshields.
4 3	Poor	Berms between 2" and 4" thick on the shoulders and between the wheelpaths; Vehicle trajectory is significantly affected, posing a substantial safety hazard; Major risk of chipped windshields.
2	Very Poor	Berms over 4" deep; Vehicle speeds are greatly reduced; Major safety issues if driver does not greatly reduce speeds; Risk of chipped windshields reduced only by substantially lowered speeds.
1	Failed	Sand dunes, for example; Road surface completely unconsolidated; May be difficult for some vehicles to pass.

Dust

Numerical Rating	Verbal Rating	Description
3	None	No dust visible from raters' or others' vehicles.
2	Low	Minor dust emissions; Hard to see dust from the raters' vehicle; *Normal traffic produces a thin dust that does not obstruct visibility*; Dust loss is a minor concern from a materials loss point of view.
1	Medium	Significant dust emissions; Easy to see dust from the raters' vehicles; *Normal traffic produces a moderately thick cloud that partially obstructs visibility and causes traffic to slow down*; Dust loss is a major concern from a materials loss standpoint.
0	High	Heavy dust obscures vision and is a major traffic hazard; *Normal traffic produces a very thick cloud that severly obstructs visibility and causes traffic to slow down significantly or stop*; Dust loss is a major concern from a materials loss point of view, but this loss is overshadowed by safety concerns.
U	Not Rated	Due to moisture in the top road surface material, dust was not assessed.

NOTE: Descriptions in *italics* are quoted from the USACE URCI method

Cross Section (Crown)

Numerical Rating	Verbal Rating	Description
3	Good	*No restriction to water flow from centerline to ditch;* Little or no ponding on the road surface; Cross slope 3% or more; Superelevations as needed; good 'rooftop' shape.
2	Fair	Occasional restriction of water flow from centerline to ditches; Occasional ponding, particularly near the centerline; Cross slope 1% to 3%; Some instances of inadequate superelevations; Occasional longitudinal erosion due to inadequate crown; Some flattening of the crown, especially at the centerline.
1	Poor	Water does not flow from the road surface to the shoulders; Cross slope less than 1% or inverted; Generally inadequate superelevations; Longitudinal erosion due to lack of crown; Frequent ponding on the road surface.

NOTE: Description in *italics* is from the PASER Gravel manual

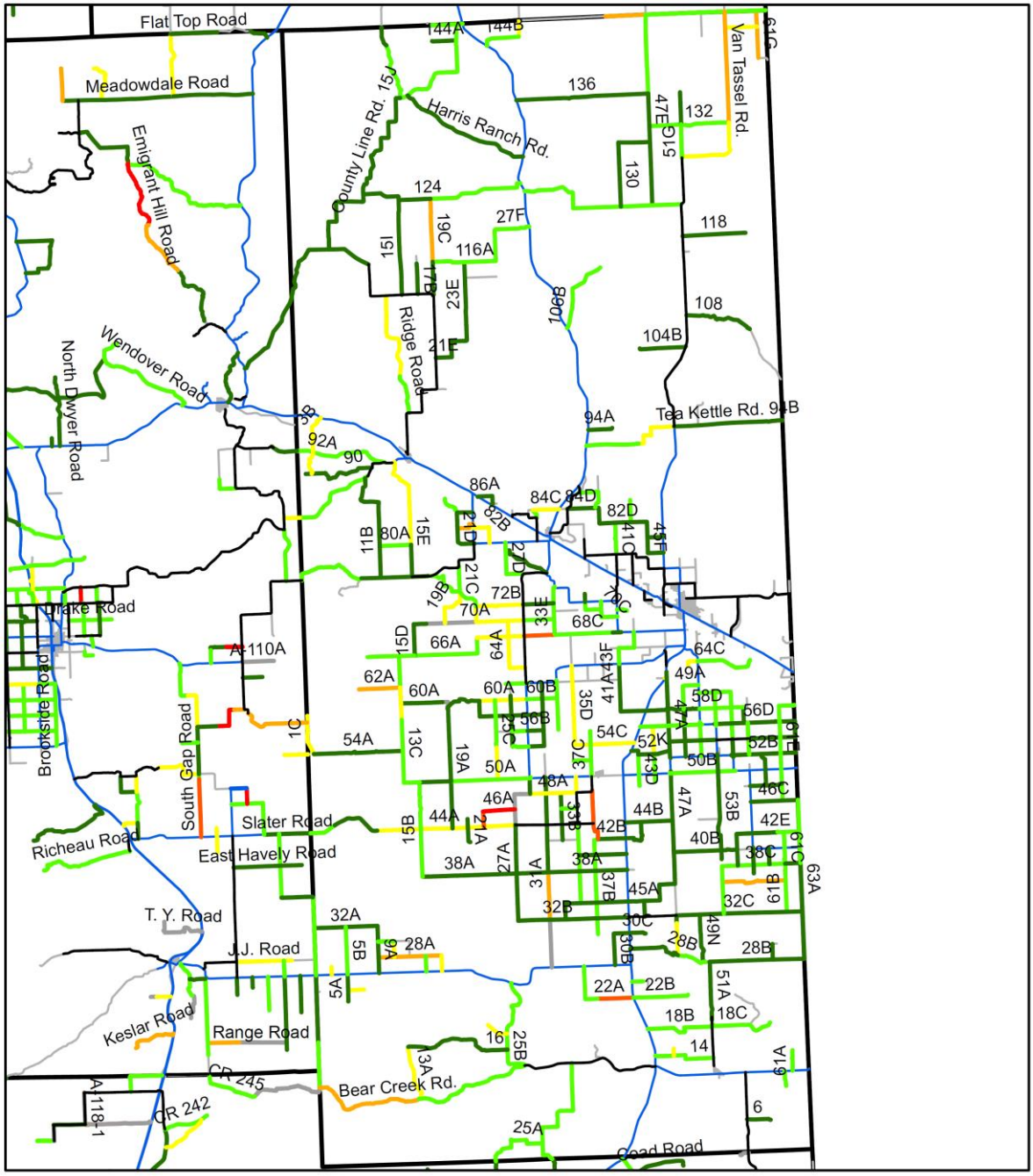
Roadside Drainage

Numerical Rating	Verbal Rating	Description
3	Good	Roadway above the surrounding terrain; Good foreslopes, ditches and culverts that quickly carry water away from the road surface.
2	Fair	Roadway near the grade of the surrounding terrain; Marginal foreslopes, ditches and culverts; Secondary ditches; Occasional transverse erosion due to roadside drainage not carrying water away from the road surface.
1	Poor	Roadway at or below the grade of the surrounding terrain; Few or no ditches; Runoff is forced onto the road surface, causing transverse and longitudinal erosion.

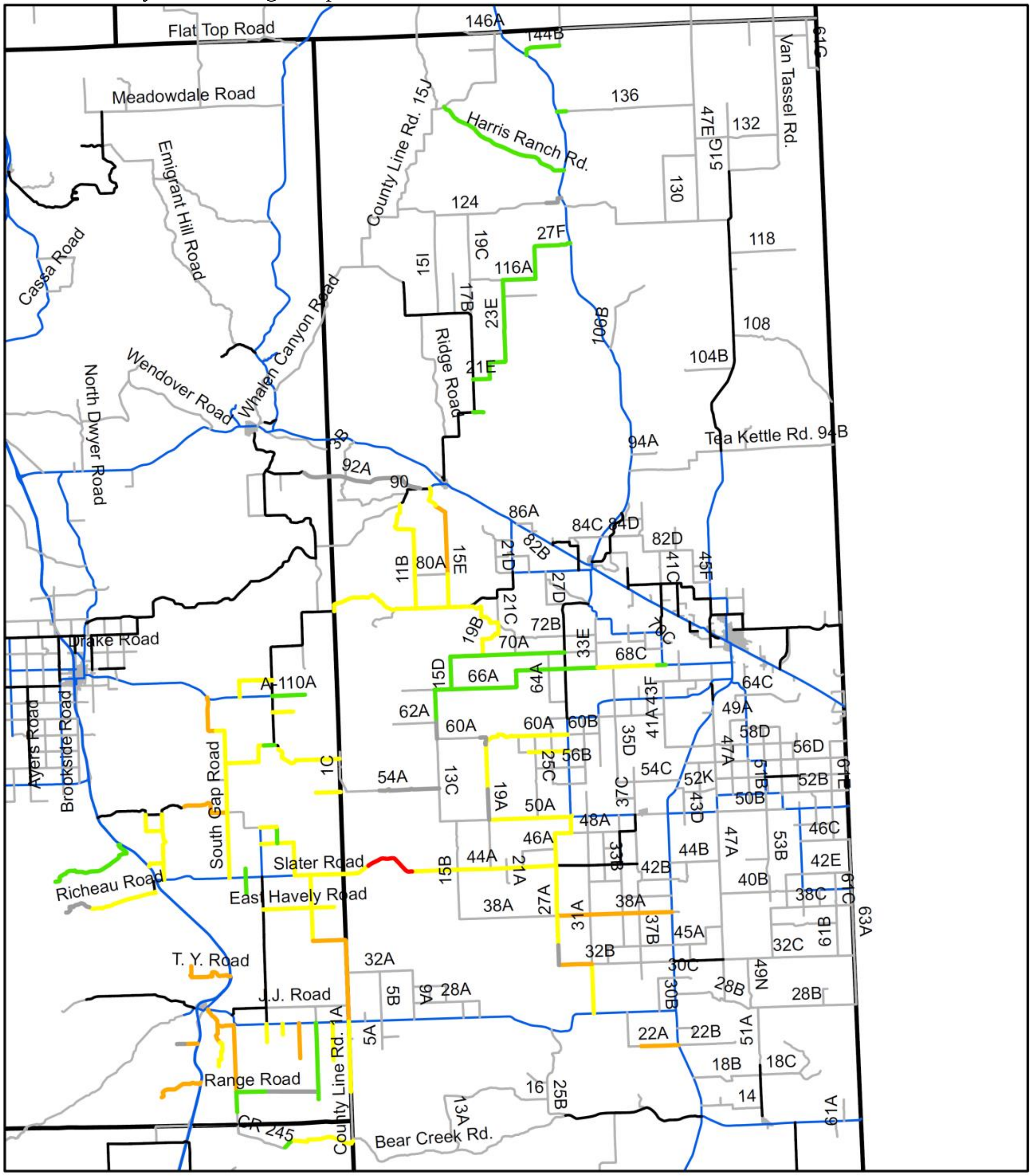
NOTE: The descriptions above typify roads with this quality drainage. Not all flaws will be apparent in every road in each category.

APPENDIX C. RIDE QUALITY AND DUST MAPS

Goshen County Ride Quality Map



Goshen County Dust Ratings Map



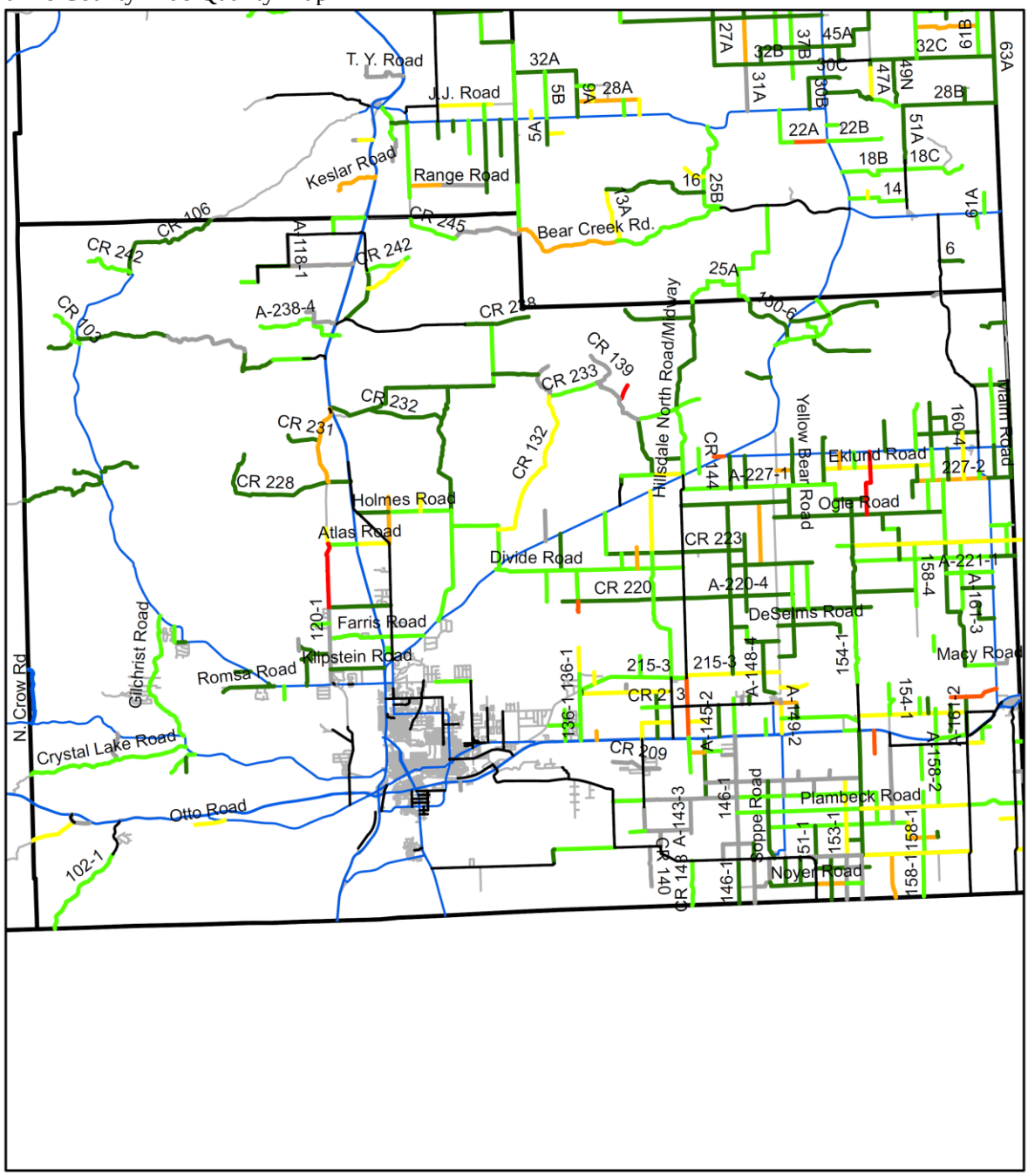
Dust Rating June 2012

County Unpaved Roads

4 **3** **2** **1**

No Data **State Highways** **County Paved Roads**

Laramie County Ride Quality Map



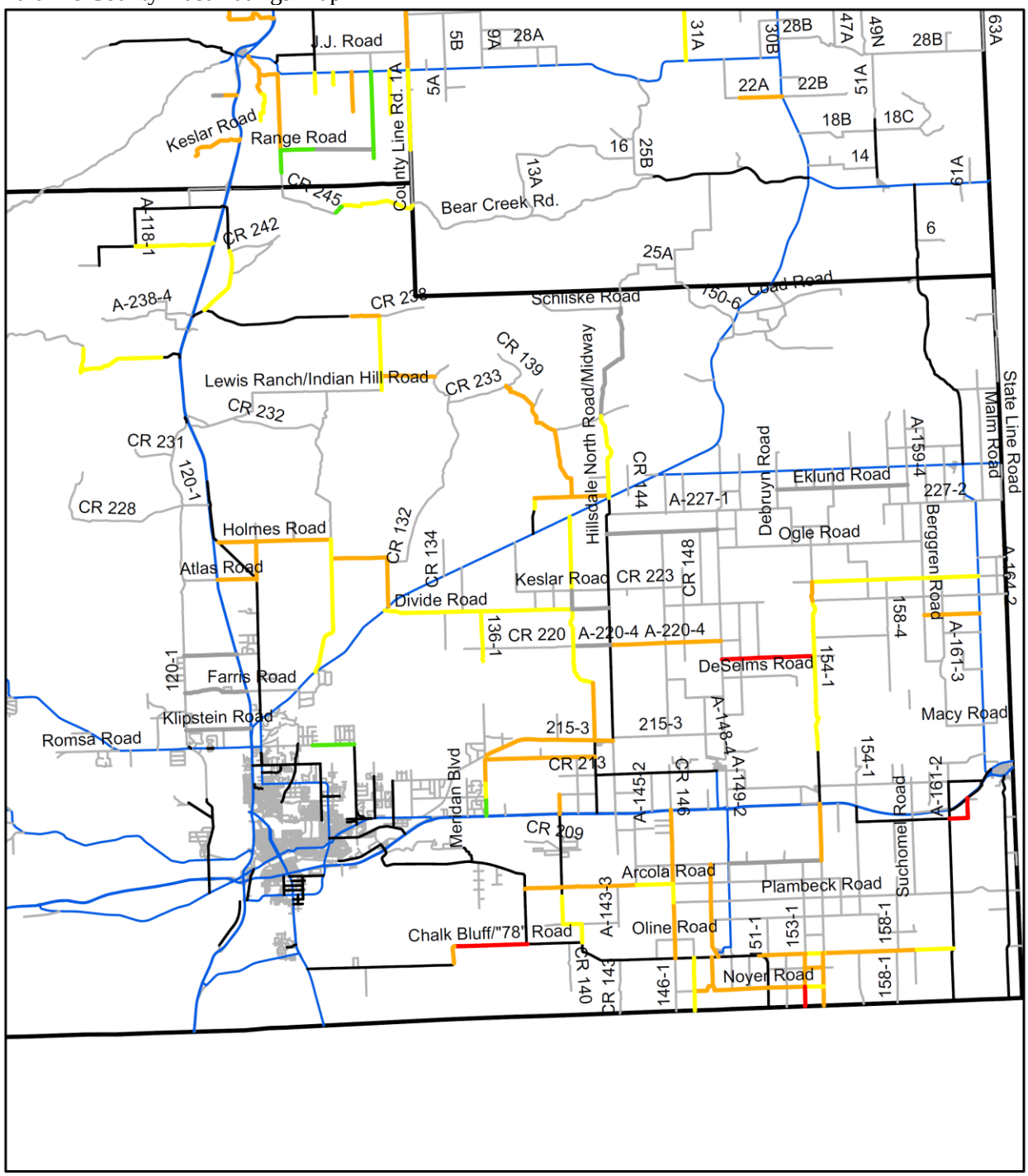
Ride Quality Rating

County Unpaved Roads

9 **8** **7** **6** **5** **4** **1 - 3**

No Data **State Highways** **County Paved Roads**

Laramie County Dust Ratings Map



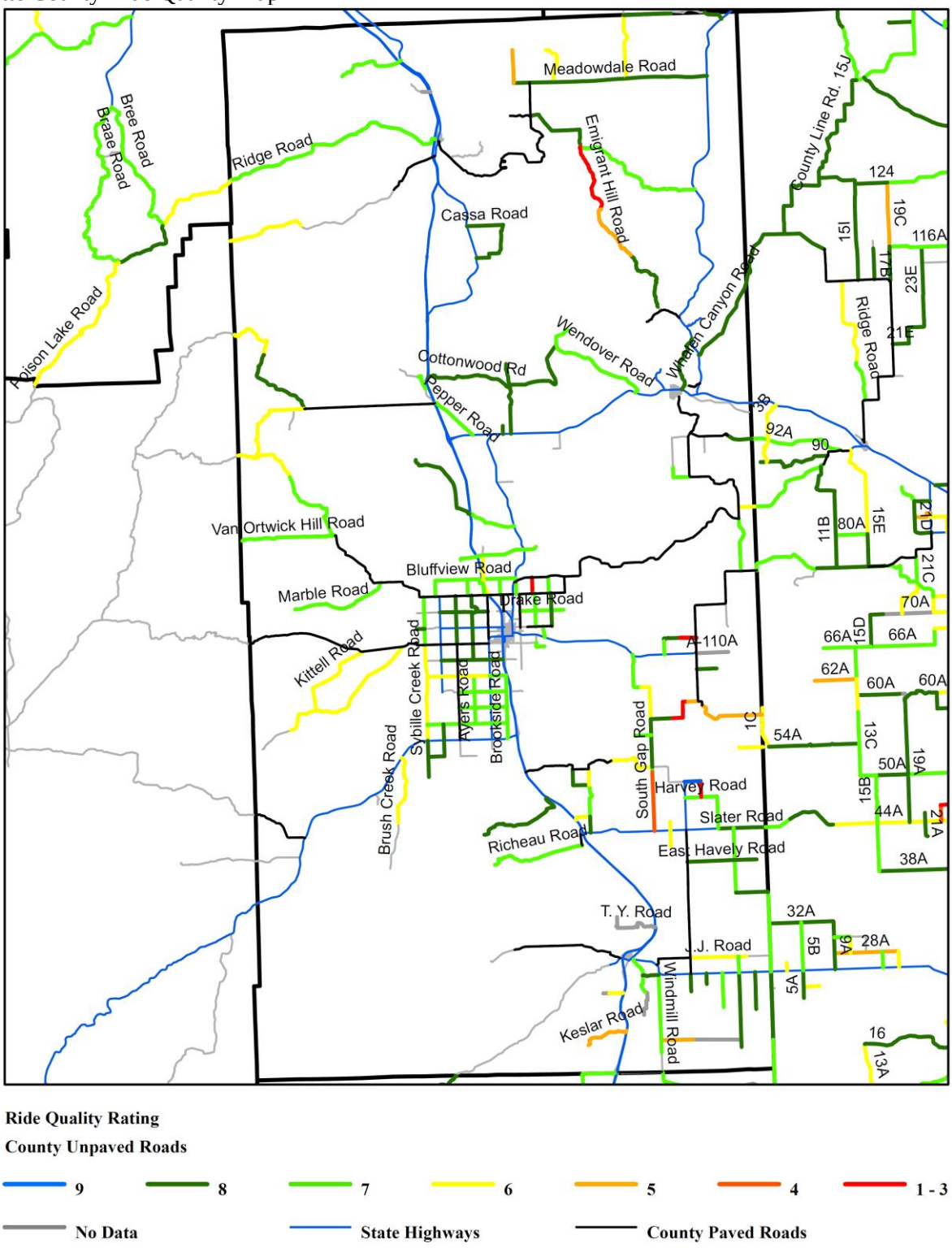
Dust Rating June 2012

County Unpaved Roads

4 **3** **2** **1**

No Data **State Highways** **County Paved Roads**

Platte County Ride Quality Map



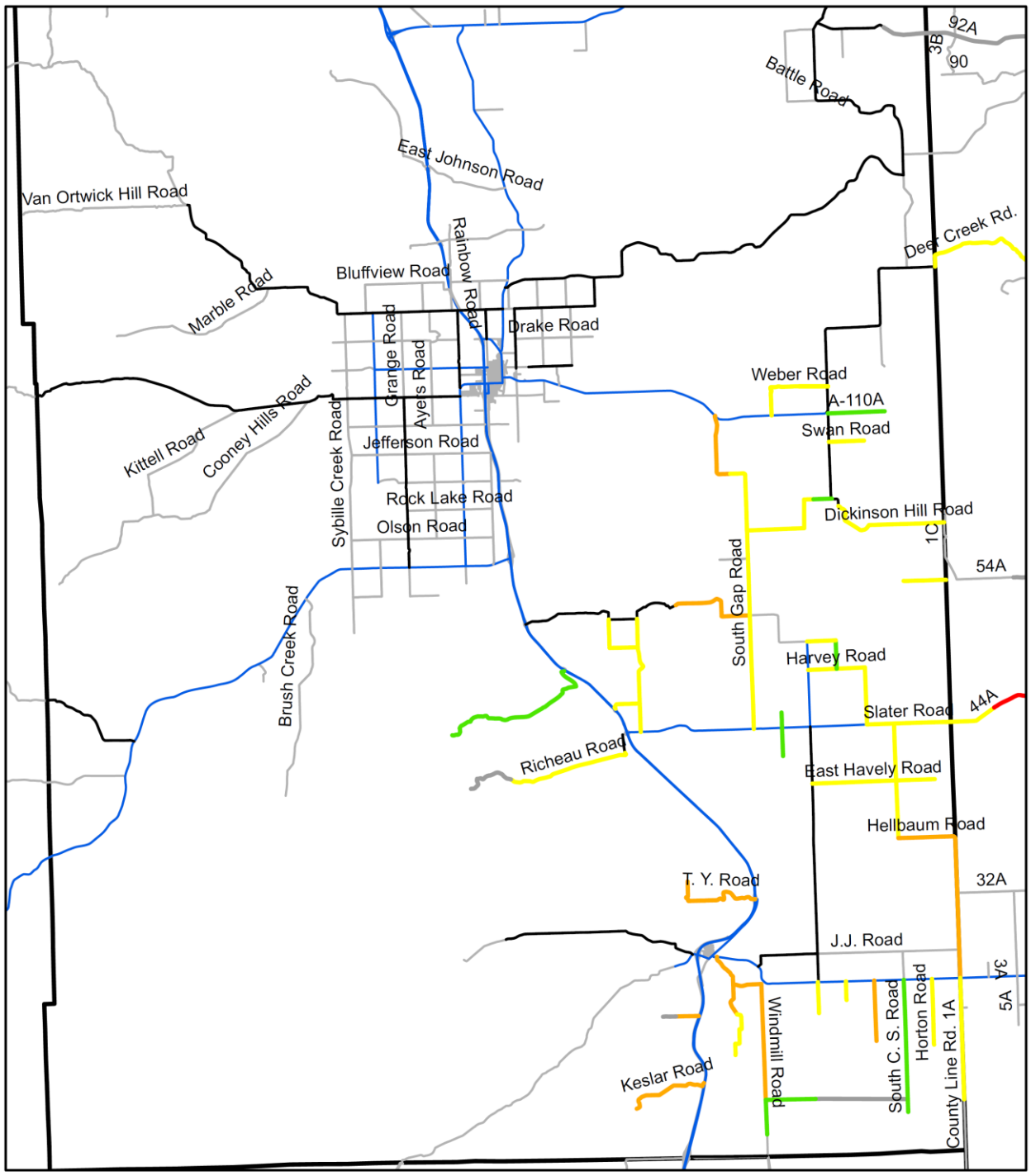
Ride Quality Rating

County Unpaved Roads

9 **8** **7** **6** **5** **4** **1 - 3**

No Data **State Highways** **County Paved Roads**

Platte County Dust Ratings Map



Dust Rating June 2012

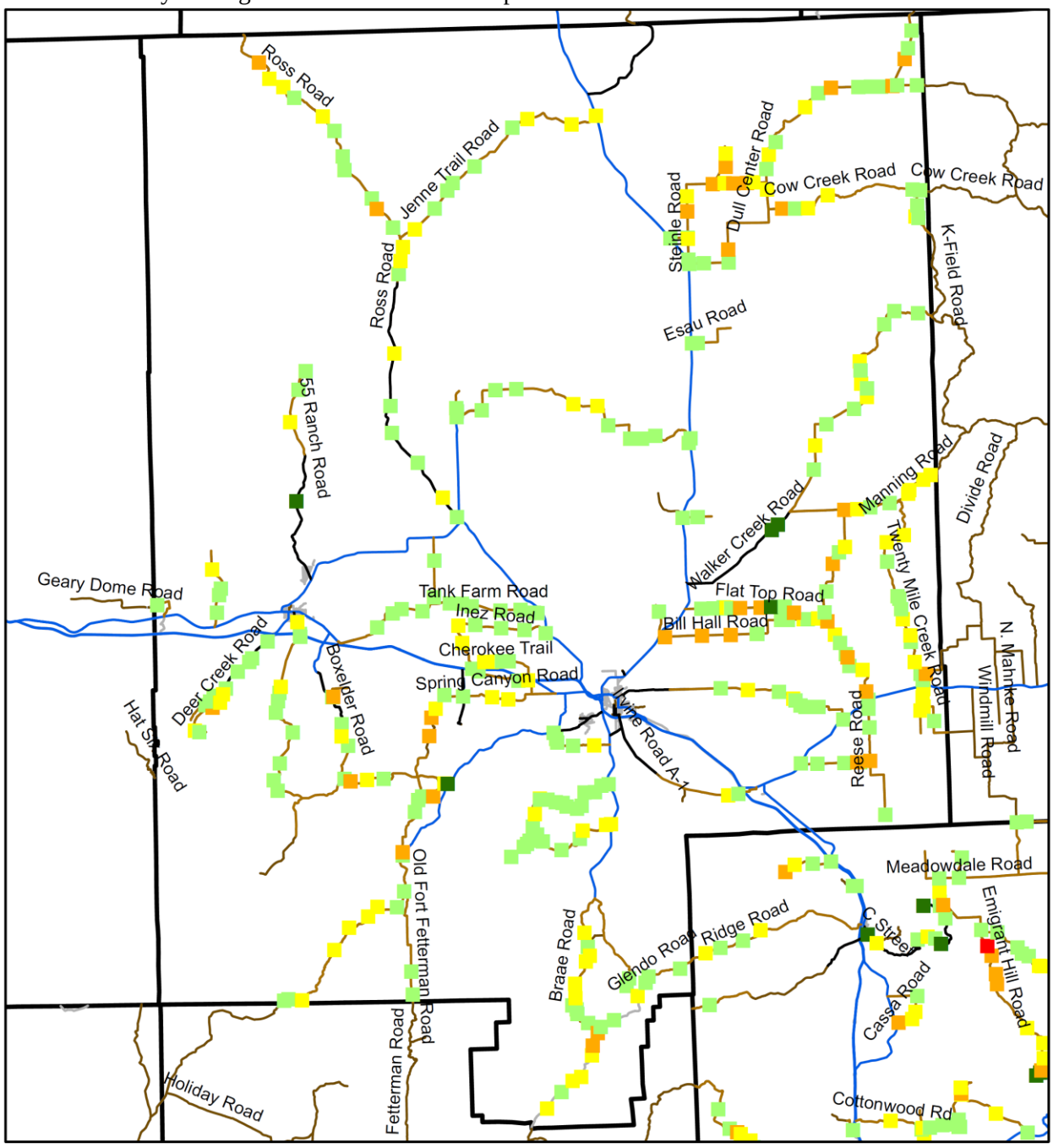
County Unpaved Roads

4 **3** **2** **1**

No Data **State Highways** **County Paved Roads**

APPENDIX D. CATTLEGUARD MAPS AND TABLES

Converse County Cattleguard Base Conditions Map



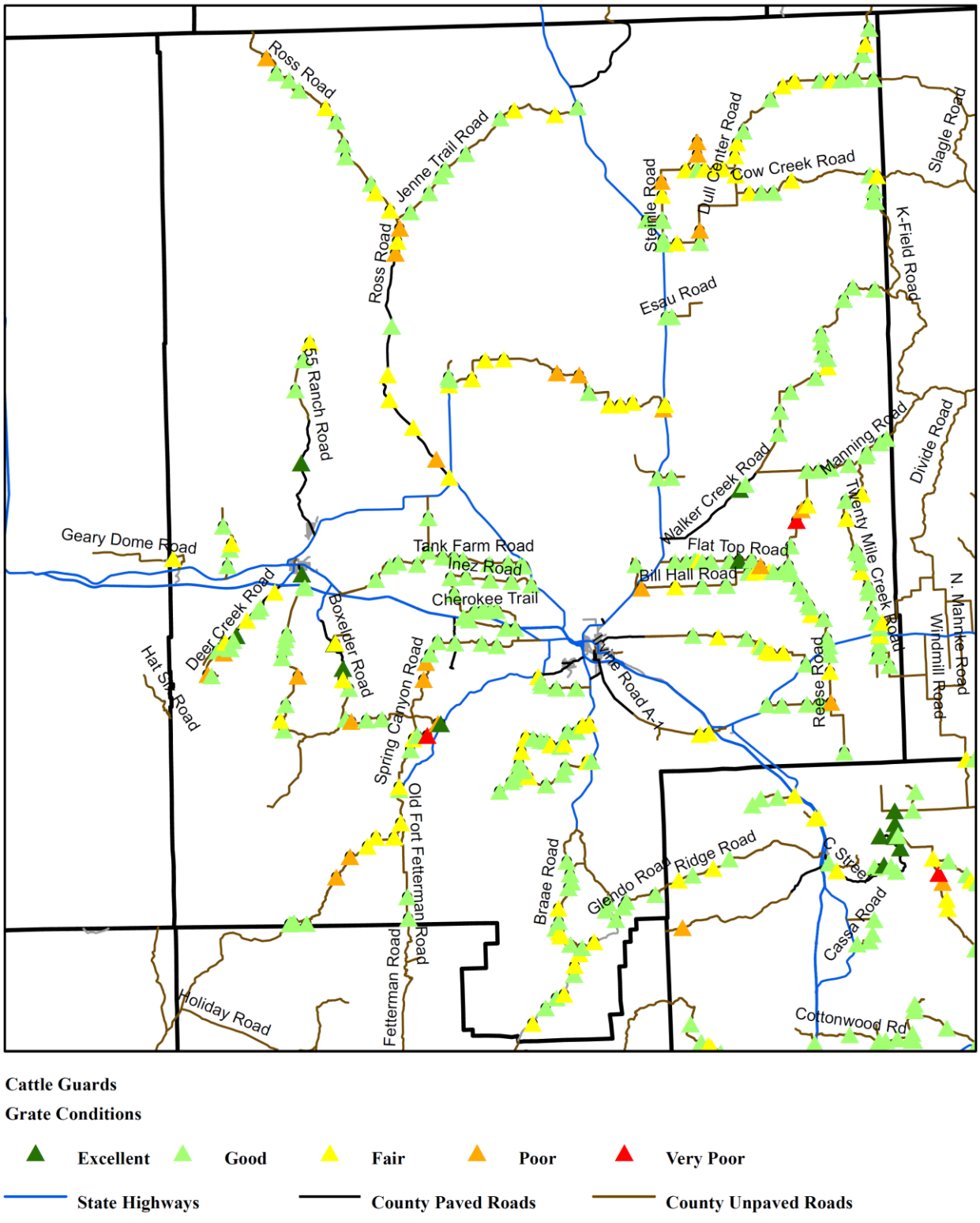
Cattle Guards

Base Conditions

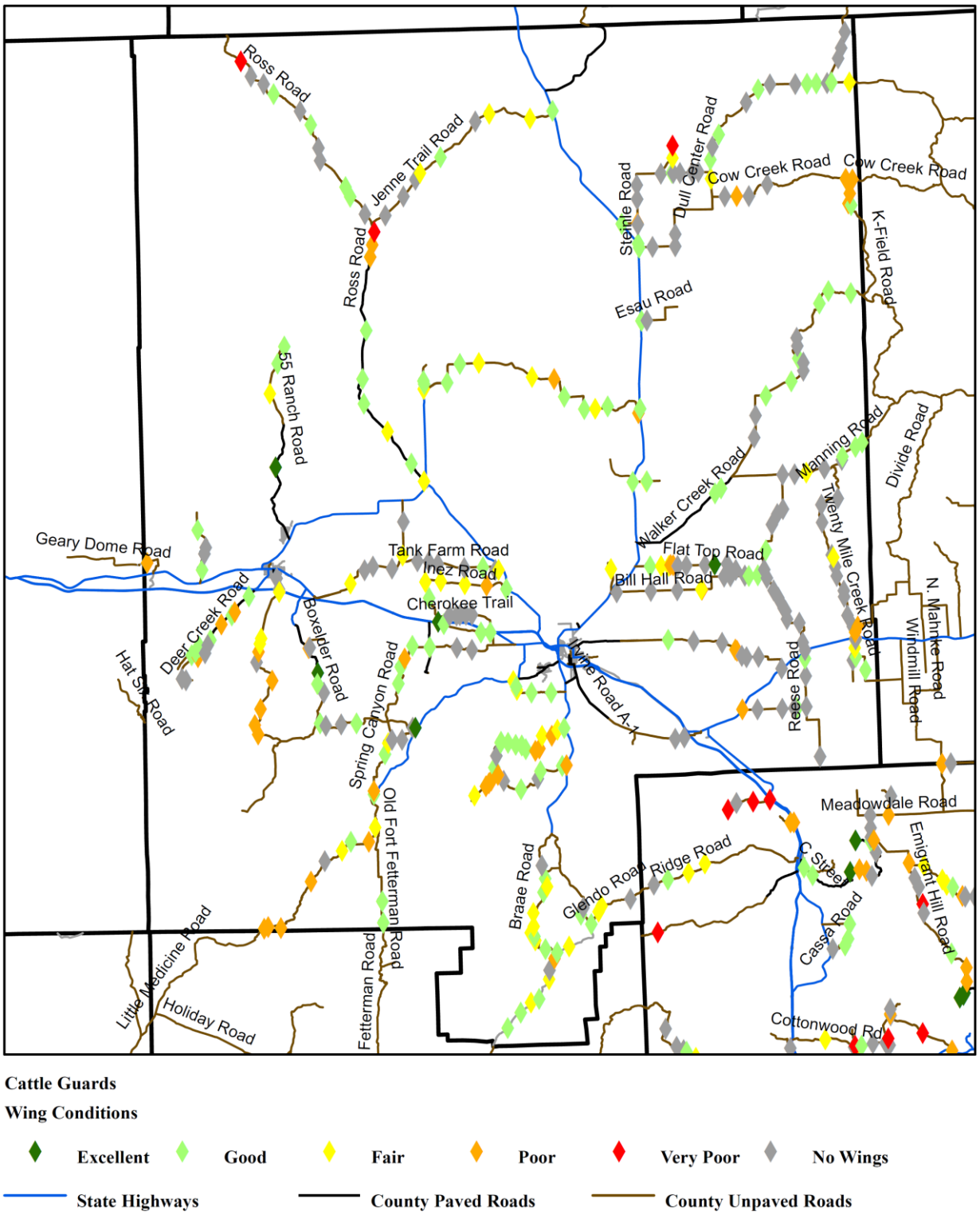
Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

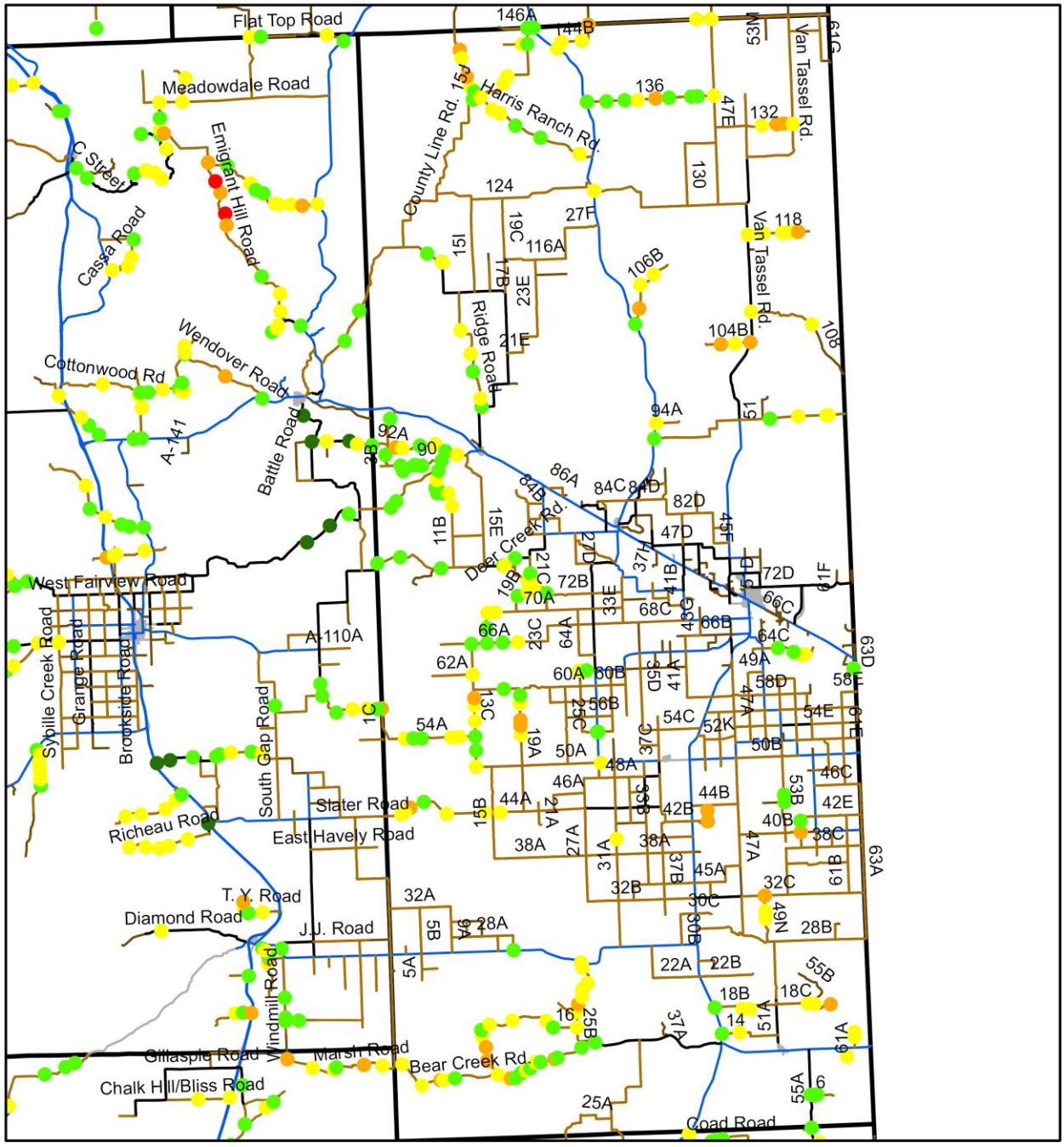
Converse County Cattleguard Grate Conditions Map



Converse County Cattleguard Wing Conditions Map



Goshen County Cattleguard Approach Conditions Map



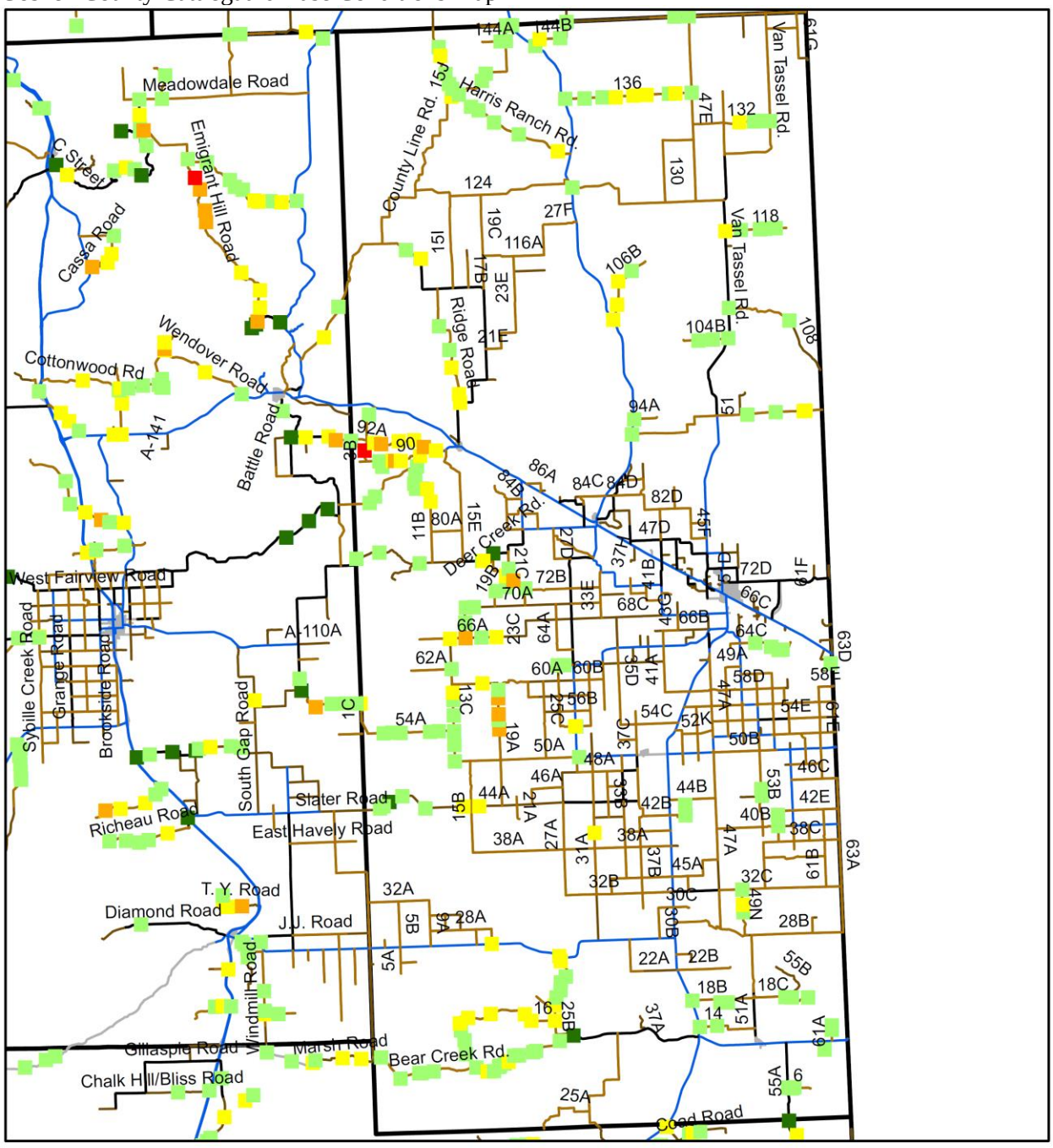
Cattle Guards

Approach Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways County Paved Roads County Unpaved Roads

Goshen County Cattleguard Base Conditions Map



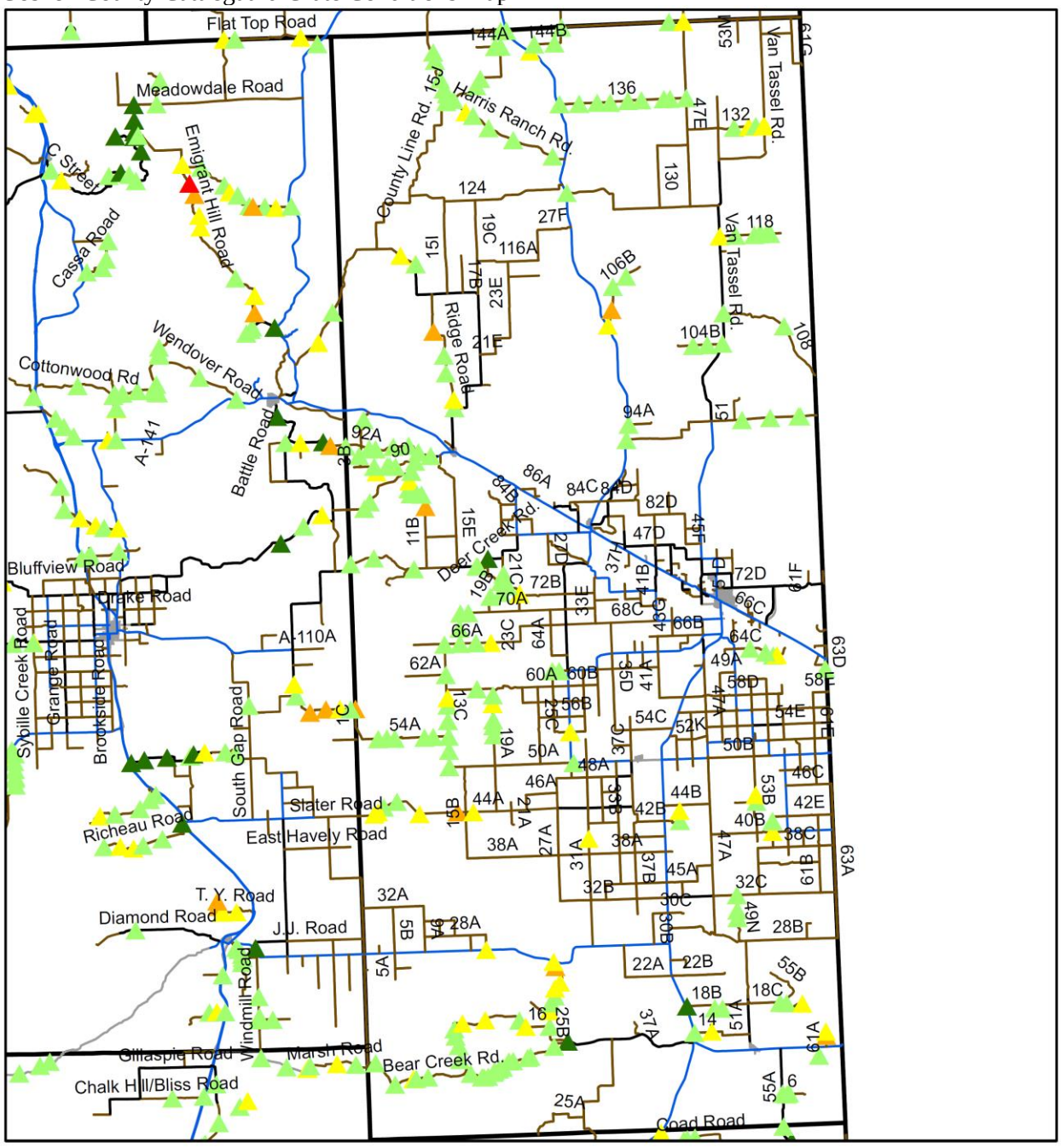
Cattle Guards

Base Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

Goshen County Cattleguard Grate Conditions Map



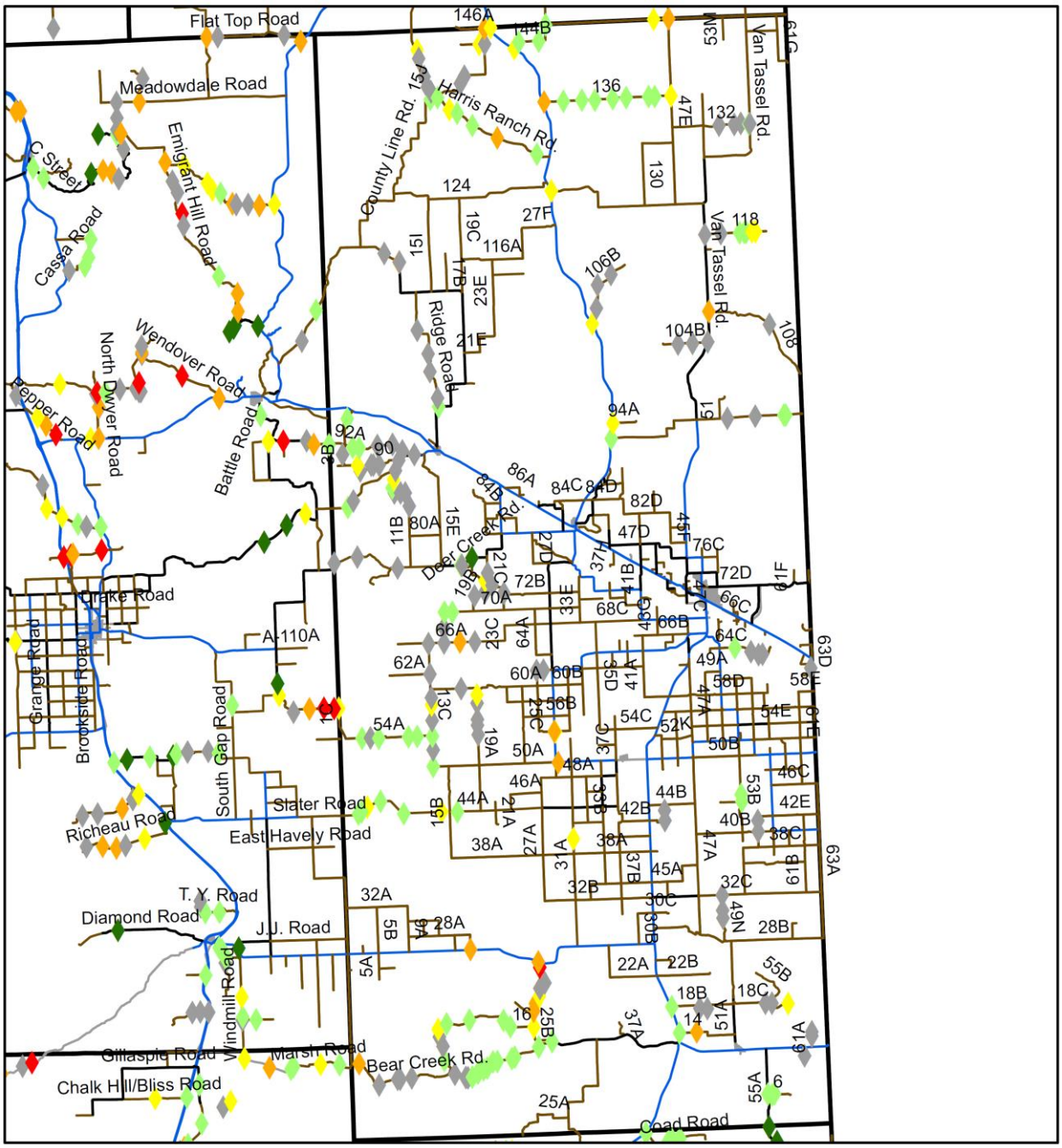
Cattle Guards

Grate Conditions

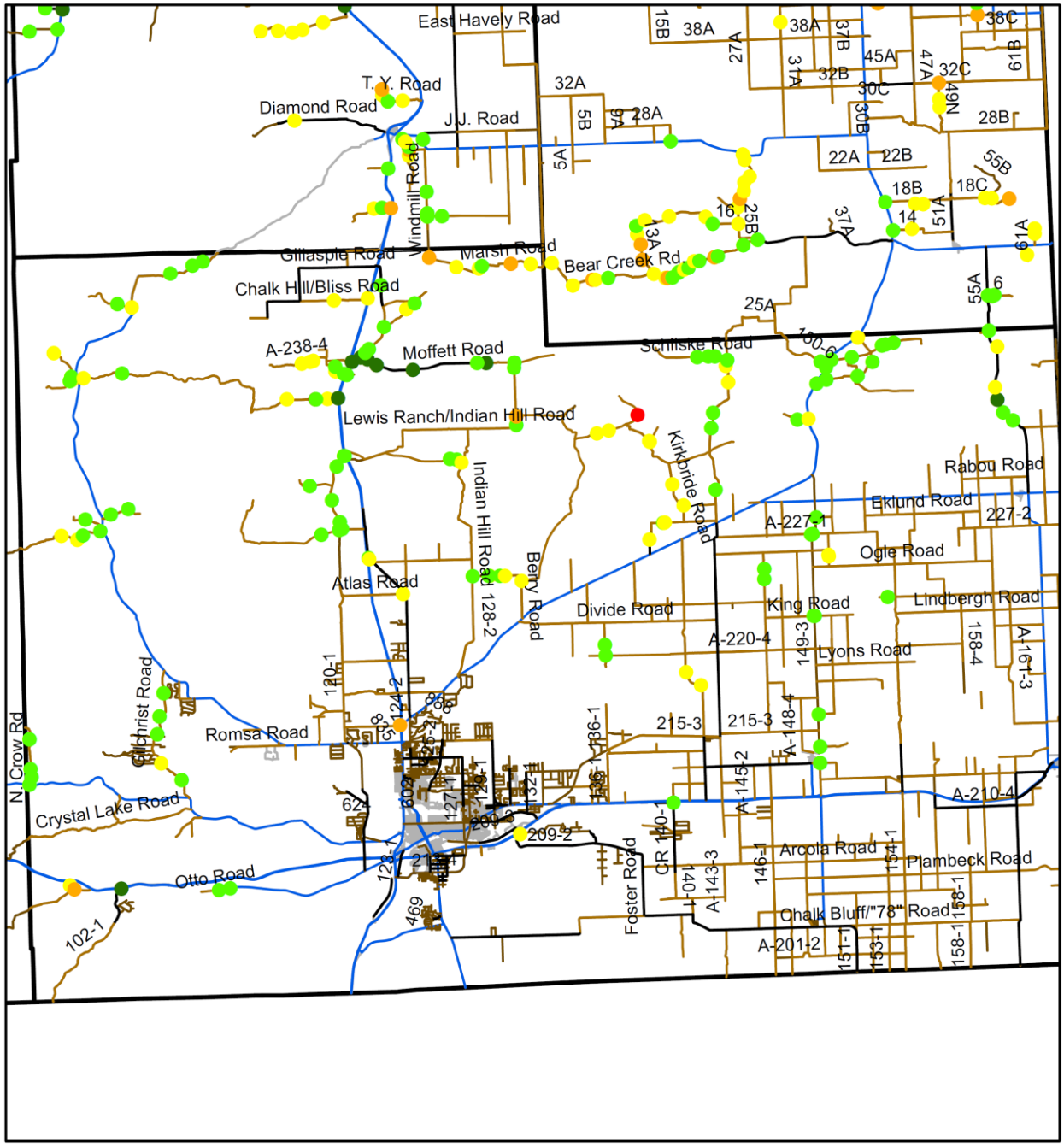
Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

Goshen County Cattleguard Wing Conditions Map



Laramie County Cattleguard Approach Conditions Map



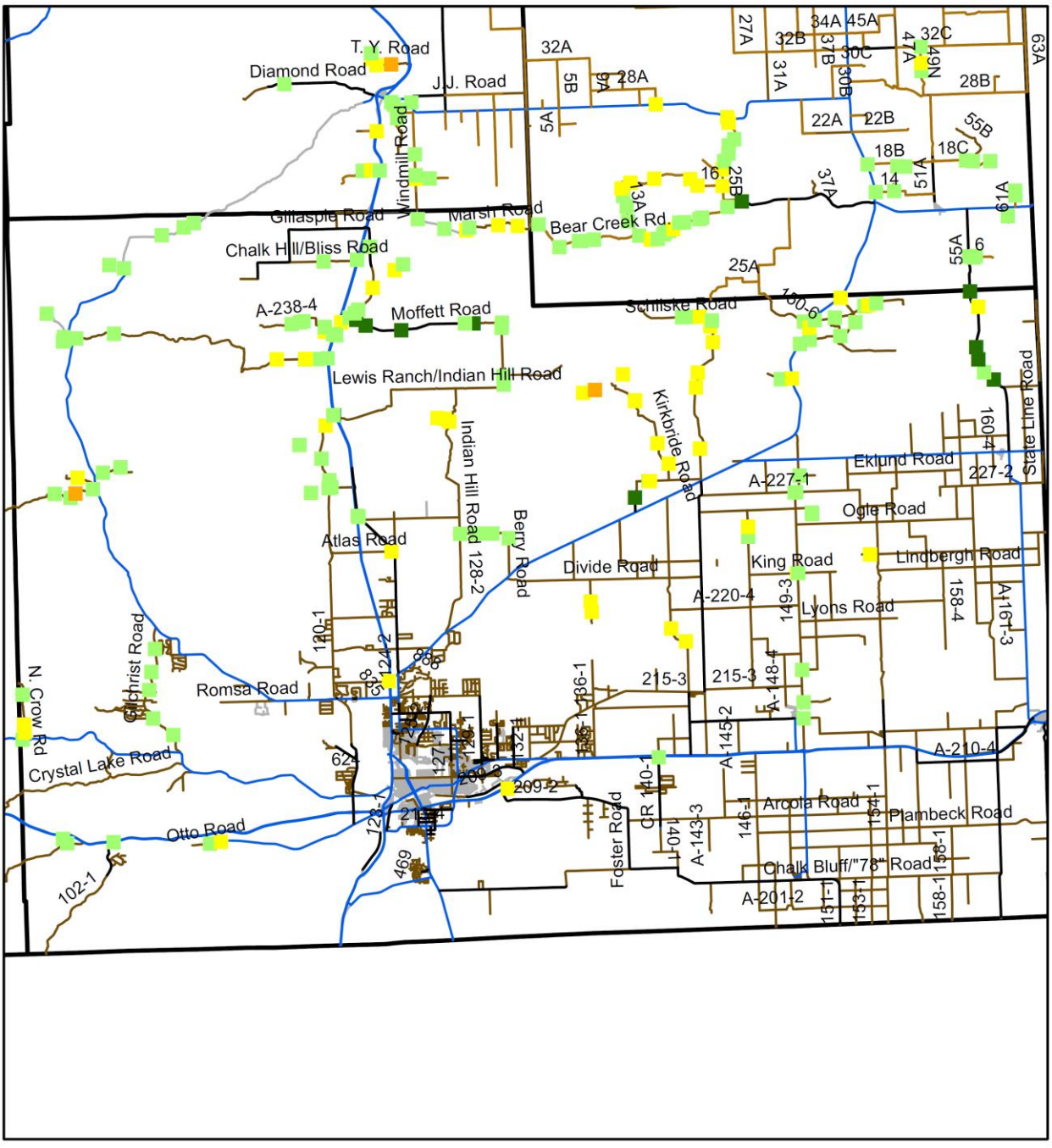
Cattle Guards

Approach Conditions

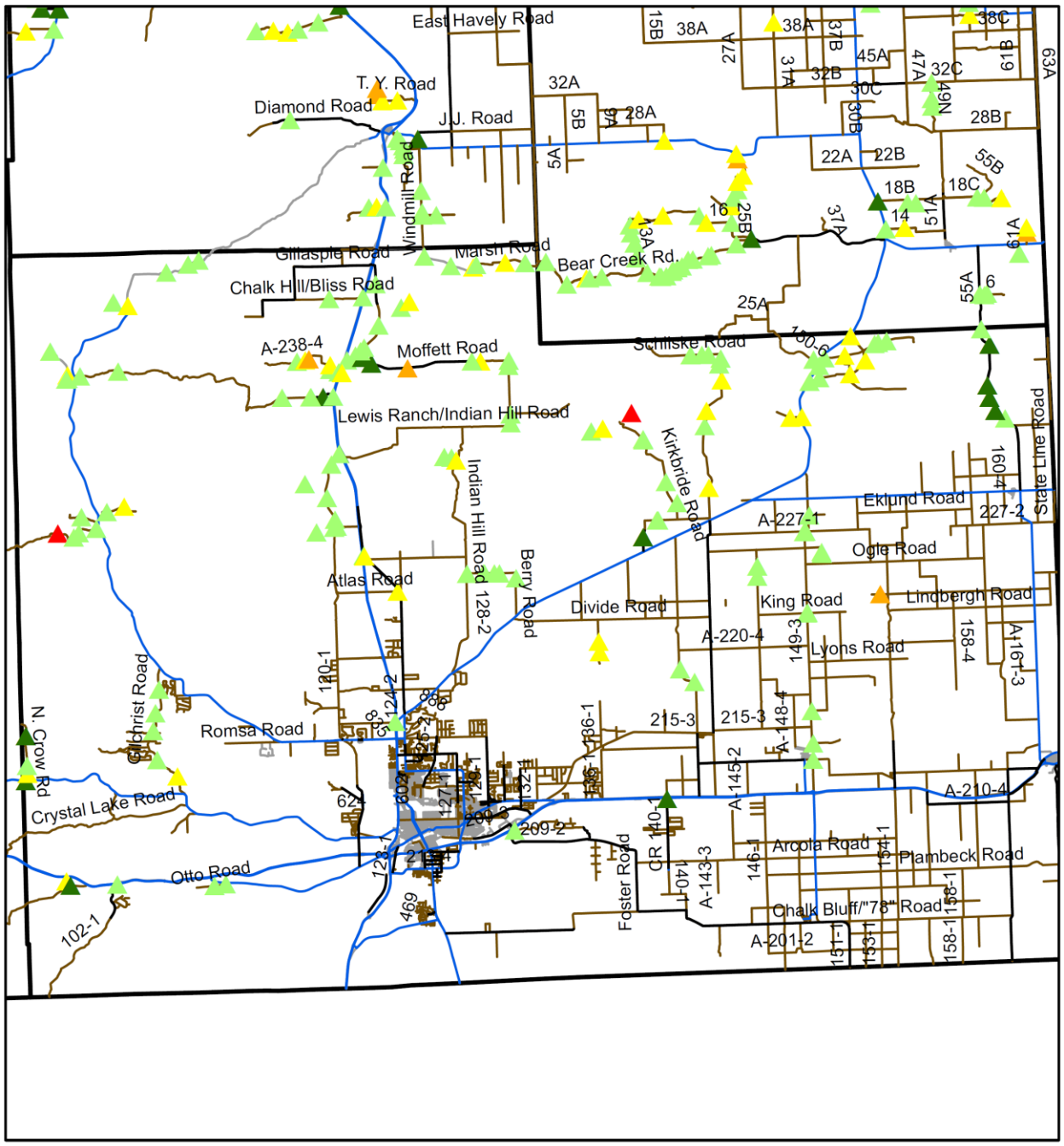
Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways County Paved Roads County Unpaved Roads

Laramie County Cattleguard Base Conditions Map



Laramie County Cattleguard Grate Conditions Map



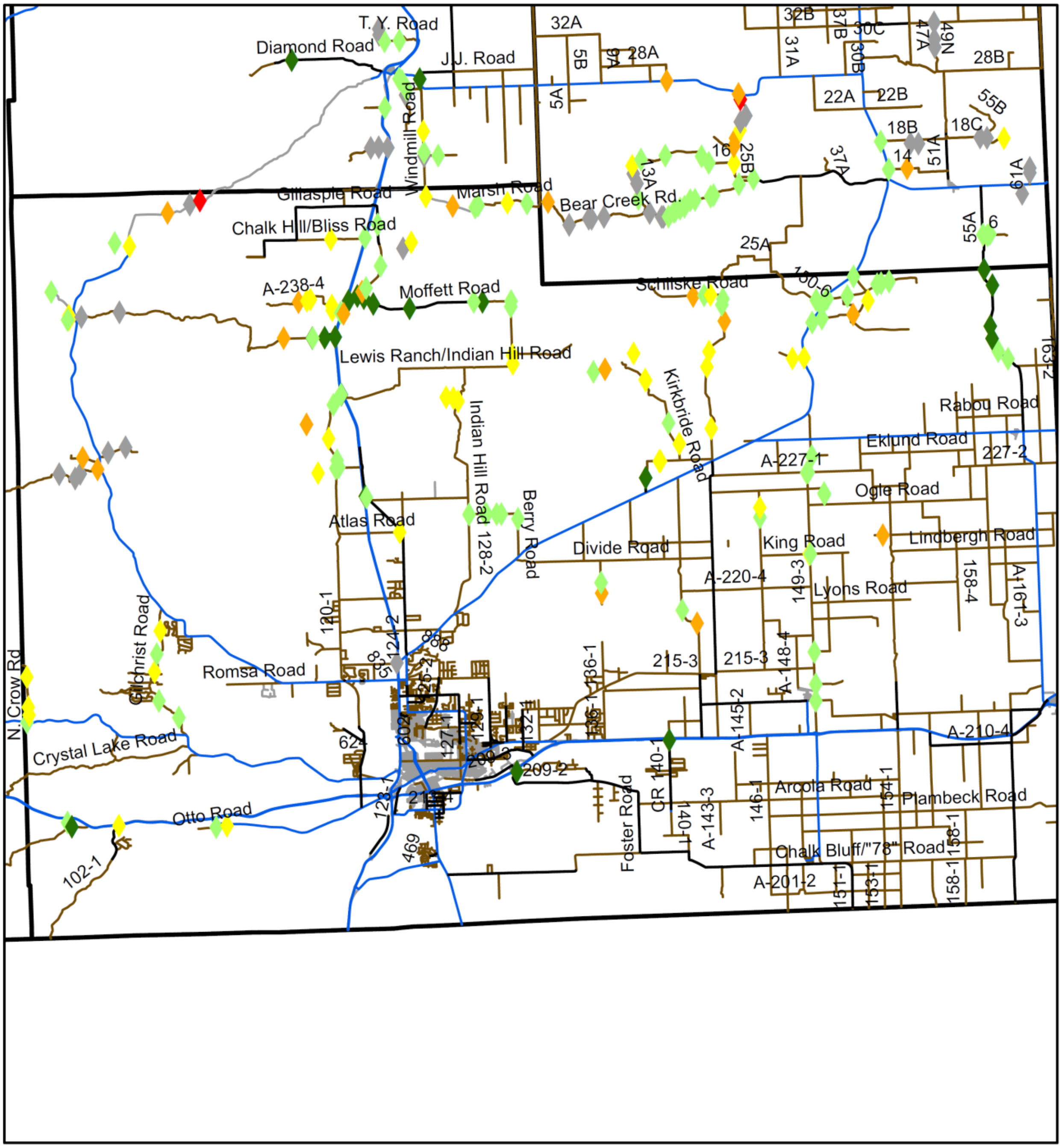
Cattle Guards

Grate Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

Laramie County Cattleguard Wing Conditions Map



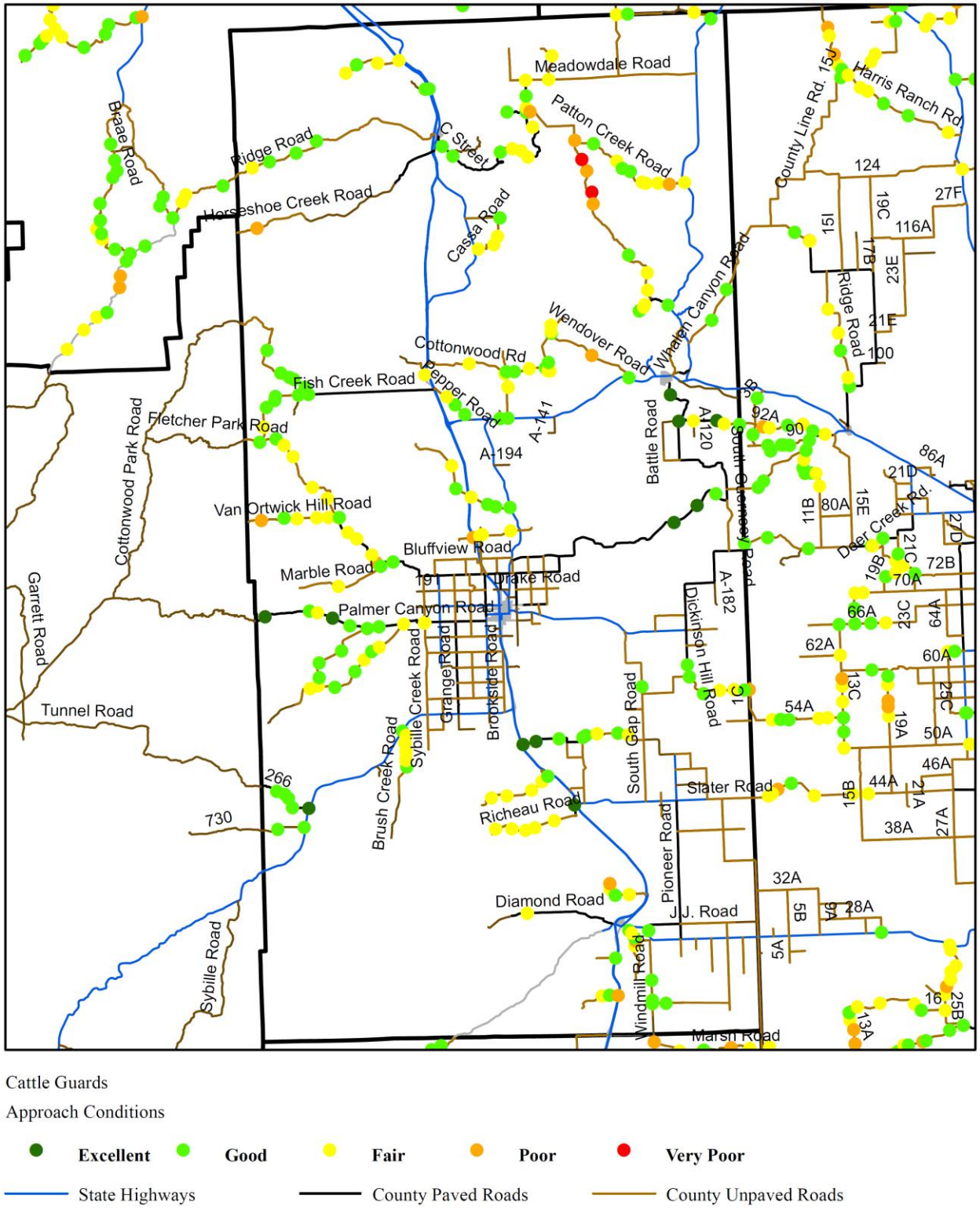
Cattle Guards

Wing Conditions

Excellent **Good** **Fair** **Poor** **Very Poor** **No Wings**

State Highways **County Paved Roads** **County Unpaved Roads**

Platte County Cattleguard Approach Conditions Map



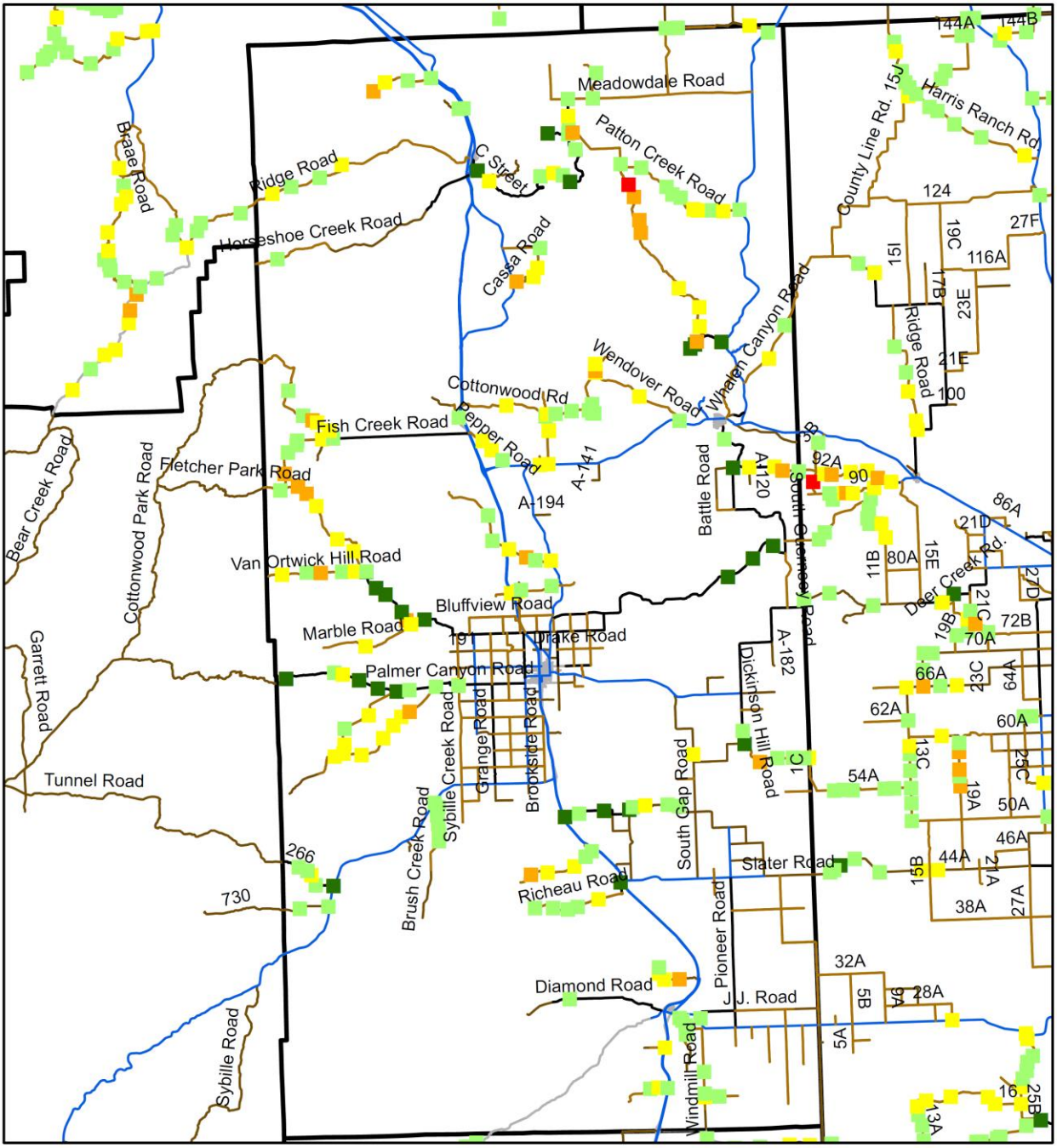
Cattle Guards

Approach Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways — County Paved Roads — County Unpaved Roads

Platte County Cattleguard Base Conditions Map



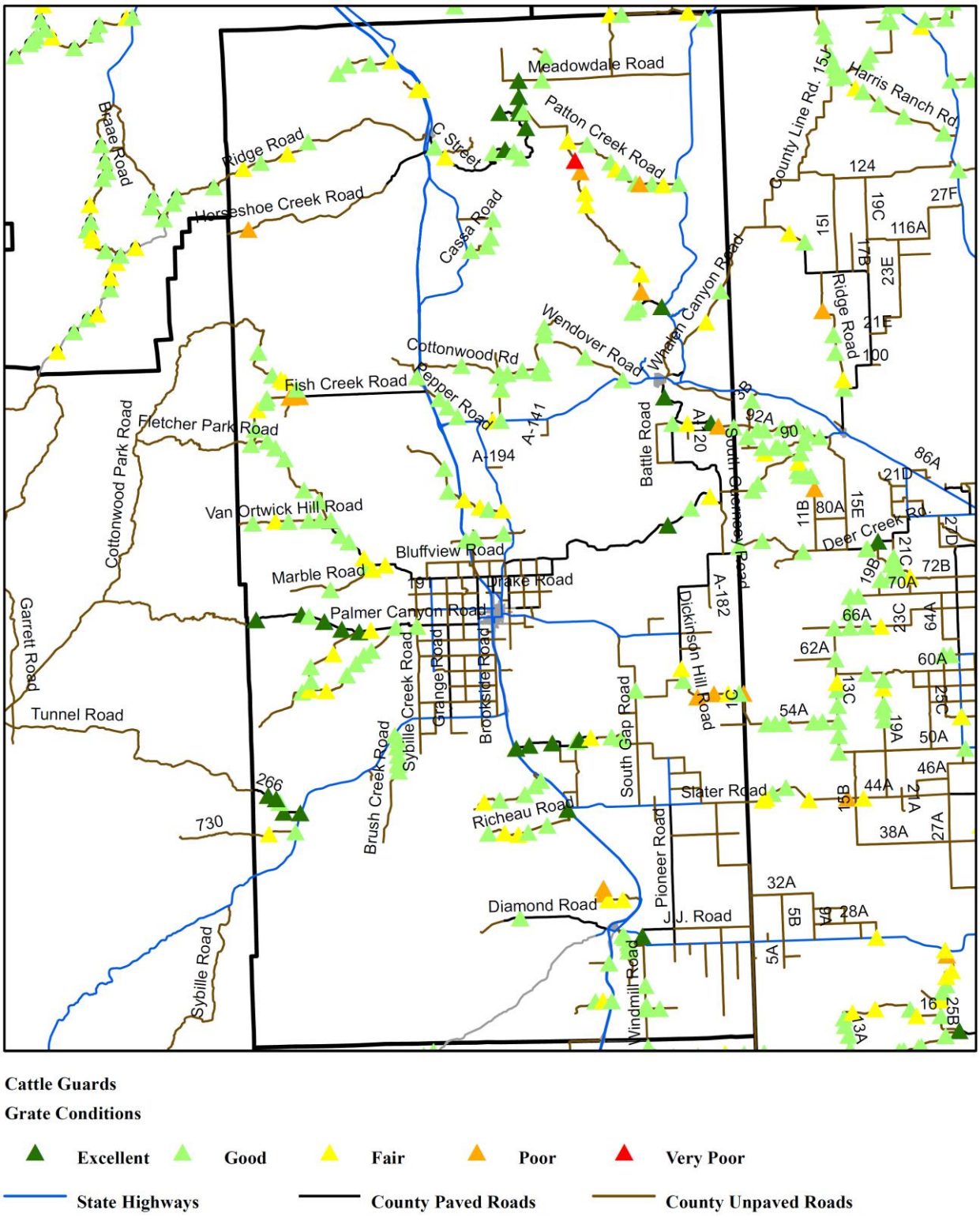
Cattle Guards

Base Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

Platte County Cattleguard Grate Conditions Map



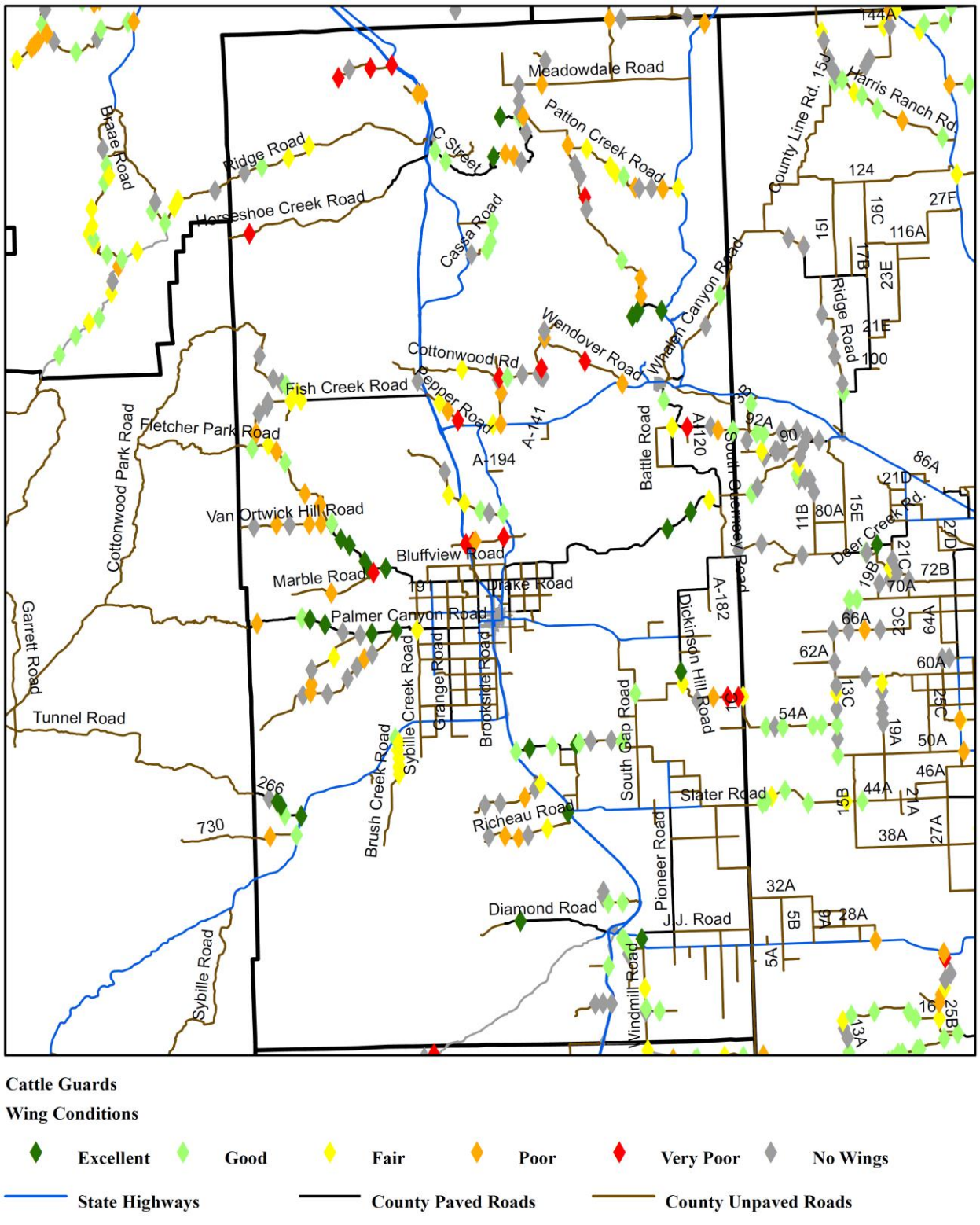
Cattle Guards

Grate Conditions

Excellent **Good** **Fair** **Poor** **Very Poor**

State Highways **County Paved Roads** **County Unpaved Roads**

Platte County Cattleguard Wing Conditions Map

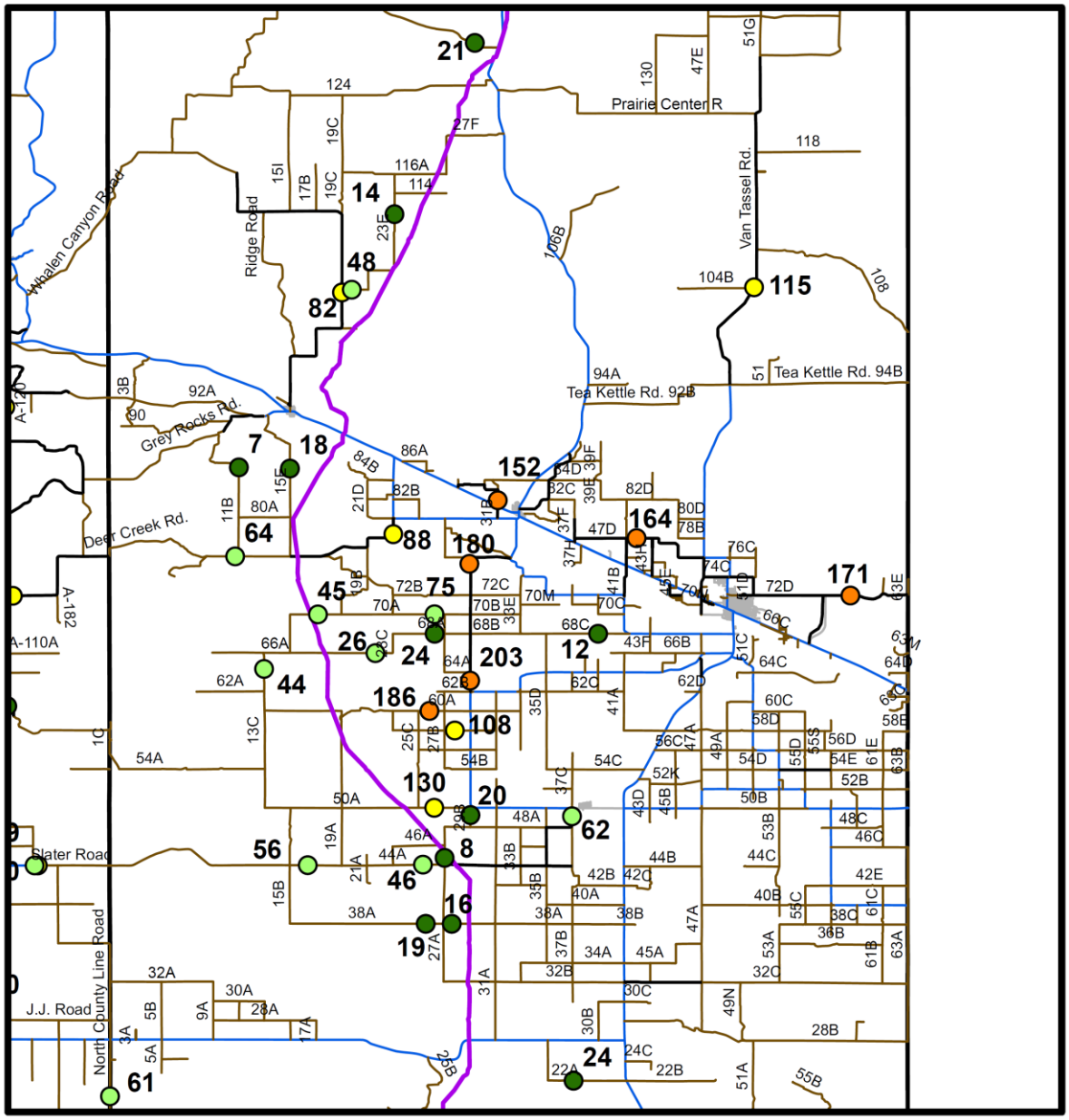


APPENDIX E. TRAFFIC COUNT TABLES AND MAPS

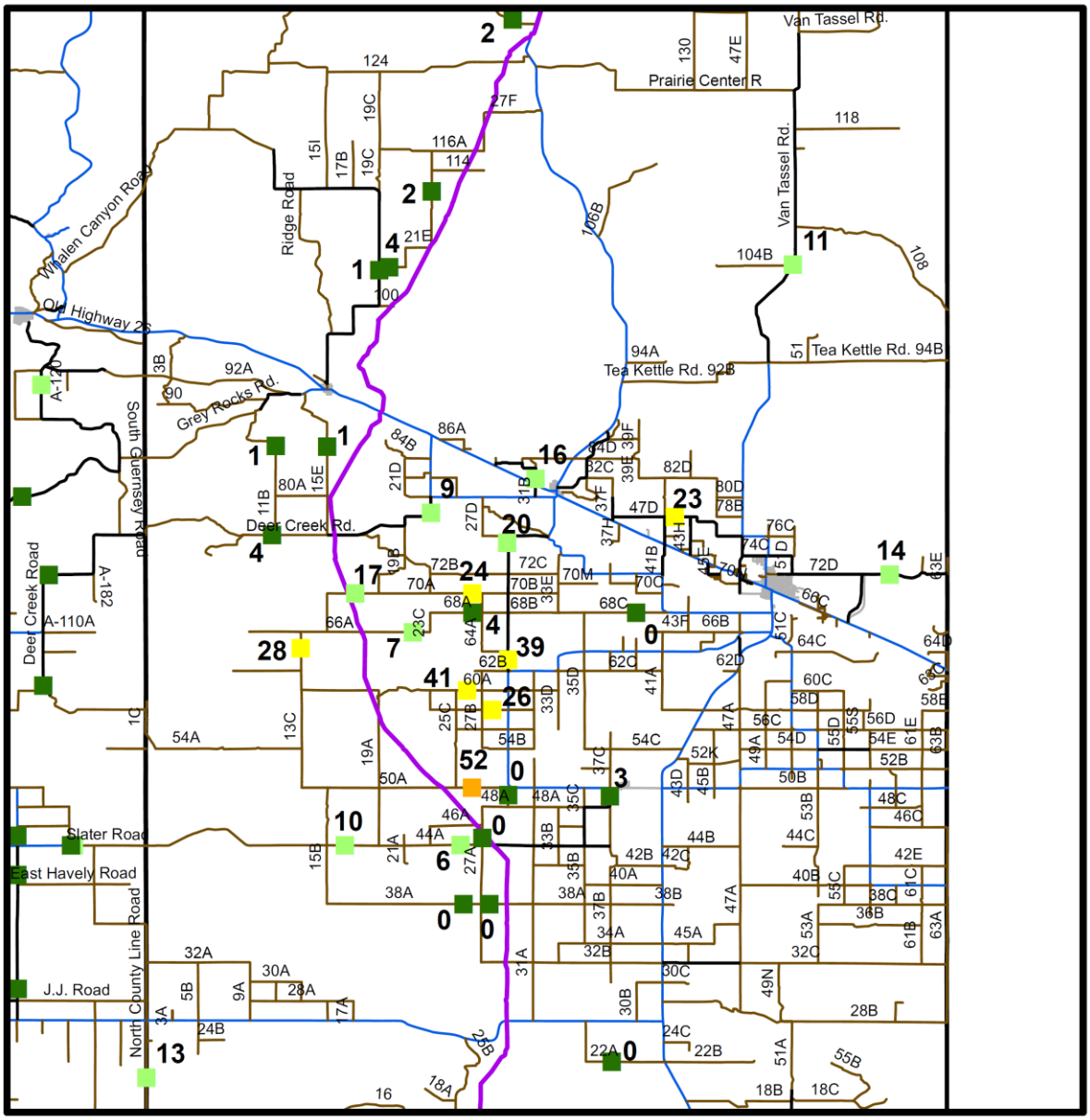
Goshen County Traffic Count Characteristics

Road Name	ADT	ADTT	% Trucks	85th % Speed	Date from	Date to	Surface Type	Impacted
L-V HWY S RD76	203	39	19.2	62.8	2/17/2011	9/21/2011	Paved	Yes
L-V HWY N WS154	180	20	11.1	60.9	2/17/2011	8/18/2011	Paved	Yes
Sheep Creek	171	14	8.2	55.2	5/1/2012	5/4/2012	Paved	No
Buttermilk	164	23	14.0	54.2	5/1/2012	5/4/2012	Paved	No
WYNCOTE E/S R31	152	16	10.5	52.6	6/21/2011	8/18/2011	Paved	Yes
V Tassell	115	11	9.6	66.7	5/1/2012	5/4/2012	Paved	No
RD 55 S RD 6	115	16	13.9	68.3	3/2/2011	6/16/2011	Paved	Yes
DEER CRK S RD80	88	9	10.2	57.2	5/6/2011	8/14/2011	Paved	Yes
Kaspier/Fort Laramie	82	1	1.2	63.7	5/7/2012	5/10/2012	Paved	No
WS152 S WS 154	62	3	4.8	63.1	3/3/2011	8/18/2011	Paved	No
RD60 W OF RD25	186	41	22.0	45.1	2/10/2011	3/3/2011	Unpaved	Yes
50 A	130	52	40.0	53.6	7/9/2012	7/12/2012	Unpaved	Yes
RD58 W OF WS154	108	26	24.1	41.4	10/11/2010	2/10/2011	Unpaved	No
RD70 W OF RD 27	75	24	32.0	52.4	10/11/2010	8/18/2011	Unpaved	Yes
Deer Cr./Harmony Heights	64	4	3.1	56.8	5/7/2012	5/10/2012	Unpaved	Yes
South County Line	61	13	19.7	59.1	5/7/2012	5/10/2012	Unpaved	Yes
RD 44 W OF RD15	56	10	17.9	53.6	10/11/2010	8/18/2011	Unpaved	Yes
21 E	48	4	8.3	40.0	7/10/2012	7/13/2012	Unpaved	Yes
RD 44 W OF RD 27	46	6	13.0	53.5	3/3/2011	8/18/2011	Unpaved	Yes
70 A	45	17	37.8	50.1	7/9/2012	7/12/2012	Unpaved	Yes
13 C	44	28	63.6	54.7	7/9/2012	7/12/2012	Unpaved	Yes
66 A	26	7	26.9	47.8	7/9/2012	7/12/2012	Unpaved	Yes
CR 22A	24	0	0.0	0.0	5/1/2012	5/4/2012	Unpaved	Yes
RD 68 W OF RD 27	24	4	16.7	56.4	10/11/2010	8/18/2011	Unpaved	No
Harris Ranch Rd	21	2	9.5	46.2	7/10/2012	7/13/2012	Unpaved	No
29 A	20	0	0.0	52.9	7/23/2012	7/27/2012	Unpaved	Yes
38 A	19	0	0.0	55.3	7/9/2012	7/12/2012	Unpaved	No
15 E	18	1	5.6	40.5	7/9/2012	7/12/2012	Unpaved	Yes
38 A	16	0	0.0	51.7	7/23/2012	7/27/2012	Unpaved	Yes
23 E	14	2	14.3	40.1	7/10./2012	7/13/2012	Unpaved	Yes
Highland	12	0	0.0	53.0	5/1/2012	5/4/2012	Unpaved	Yes
27 A	8	0	0.0	44.9	7/23/2012	7/27/2012	Unpaved	Yes
11 B	7	1	14.3	32.1	7/9/2012	7/12/2012	Unpaved	No

Goshen County ADT Distribution



Goshen County ADTT Distribution

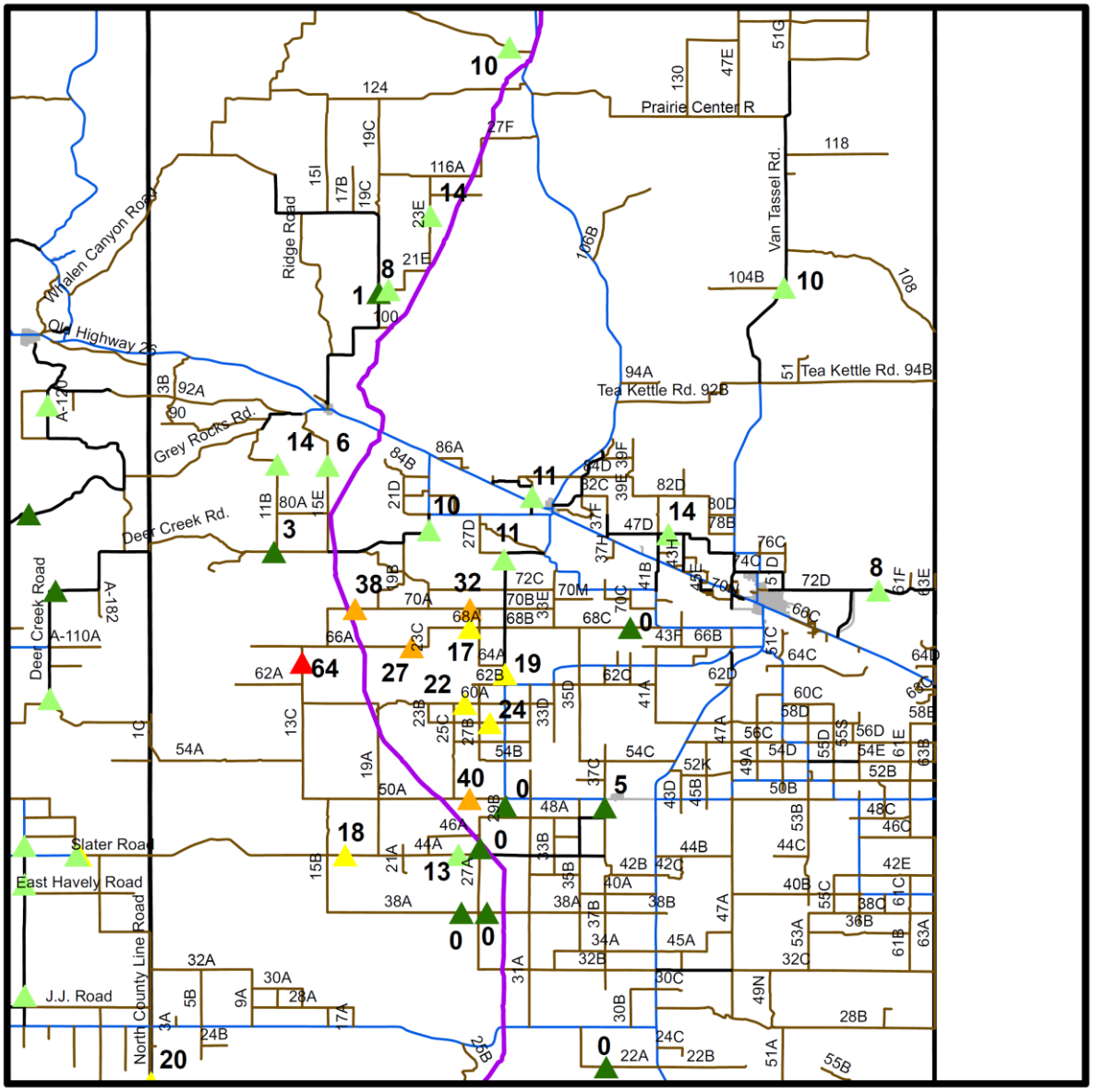


Traffic Counts

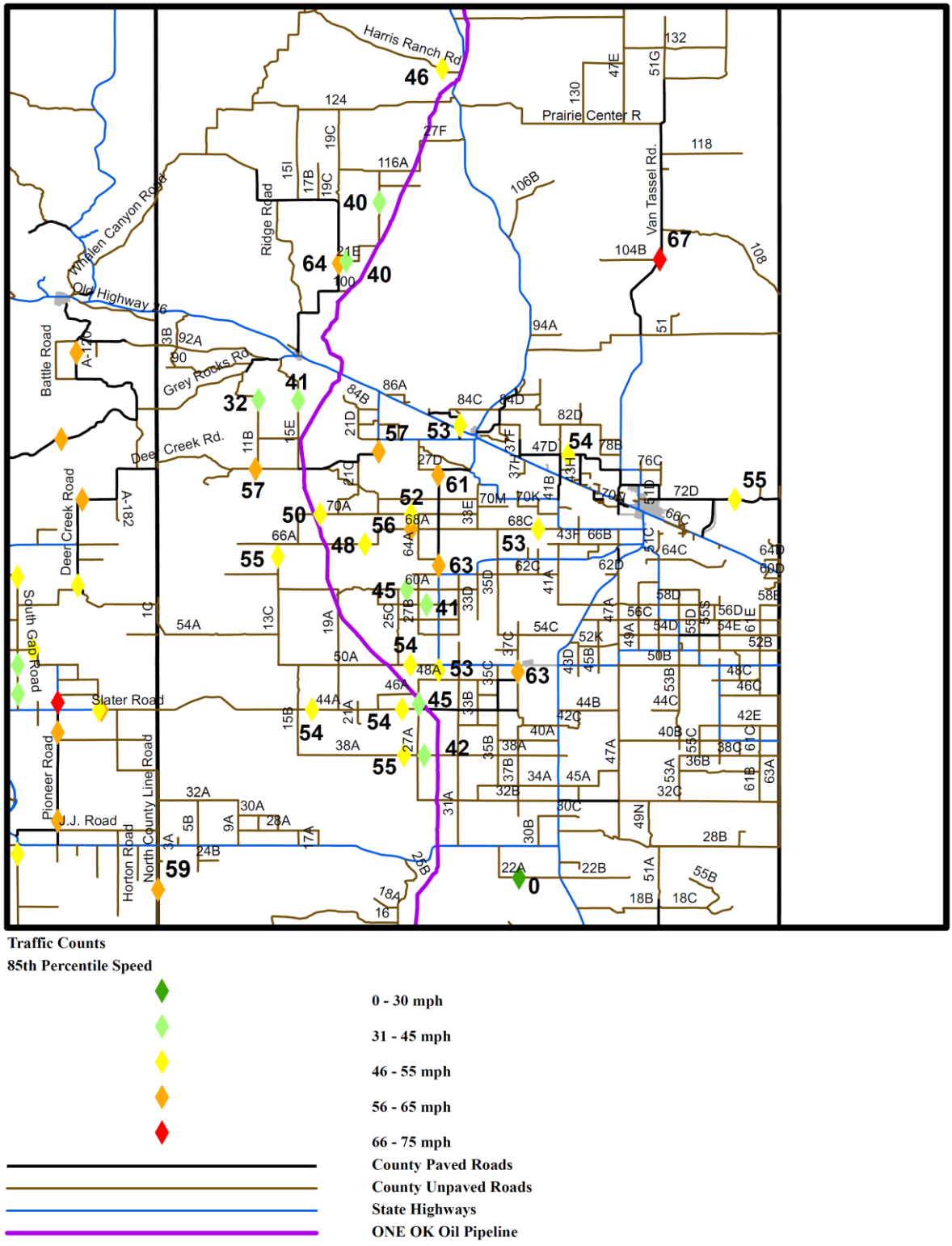
ADTT

- **0 - 5**
- **6 - 20**
- **21 - 50**
- **51 - 150**
- **151 - 448**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**
- **ONE OK Oil Pipeline**

Goshen County Percent Trucks Distribution



Goshen County 85th Percentile Speed Distribution



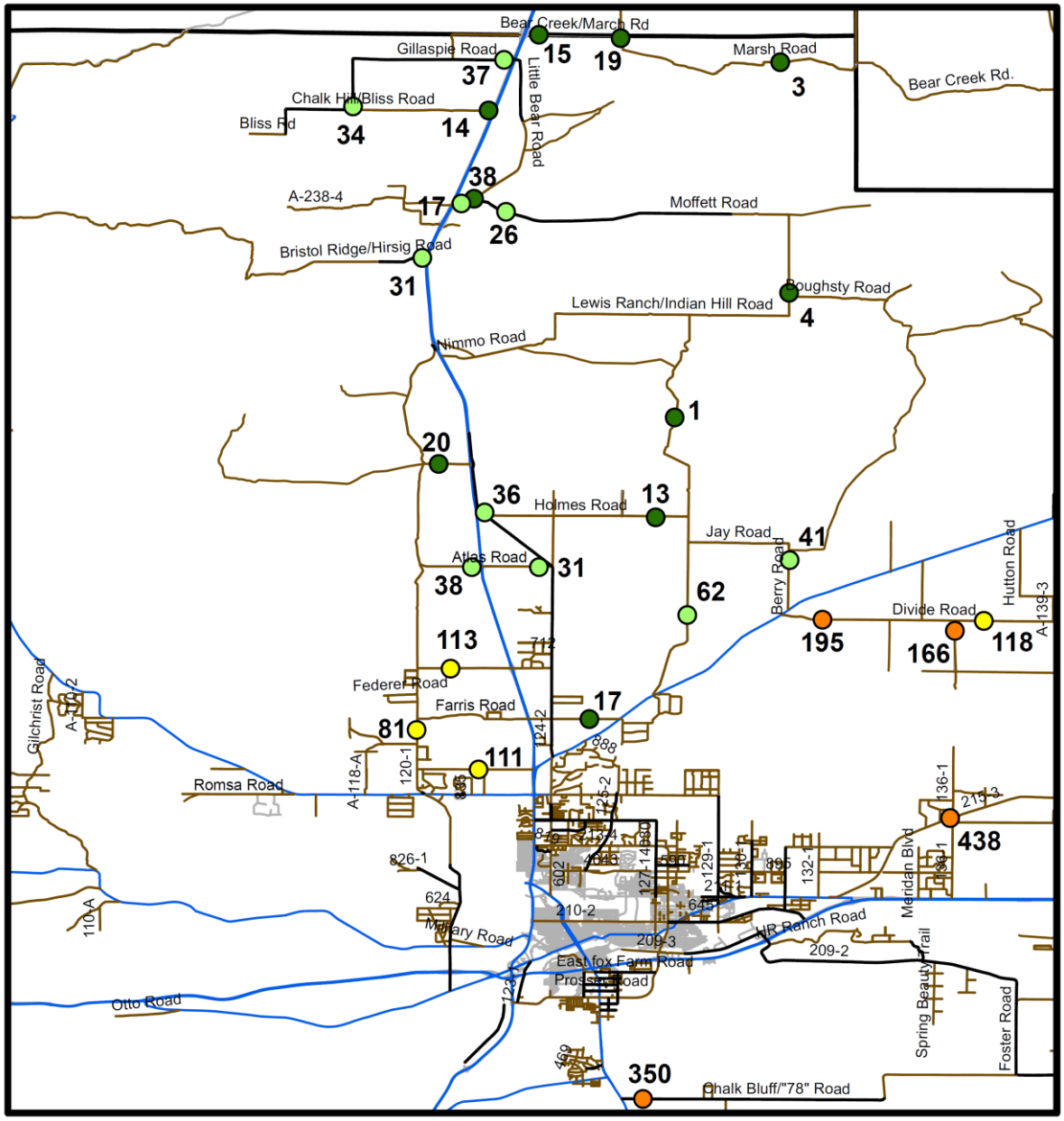
Laramie County Traffic Count Characteristics

Road Name	ADT	ADTT	% Trucks	85th % Speed	Date from	Date to	Surface Type	Impacted
HWY 214	1185	416	35.1	74.3	4/17/2012	4/18/2012	Paved	Yes
Hillsdale Road West	603	59	9.8	61.8	10/4/2011	10/6/2011	Paved	Yes
Carpenter Road/ Berger Road	518	243	46.9	70.2	10/3/2011	10/5/2011	Paved	Yes
Hillsdale North Road/Midway Road	372	62	16.7	63.9	10/4/2011	10/6/2011	Paved	Yes
Chalk Bluff Road	350	40	11.4	70.2	9/28/2011	9/30/2011	Paved	Yes
Stuckey Road	328	40	12.2	71.5	9/28/2011	9/30/2011	Paved	Yes
Old Highway Burns West	198	26	13.1	63.4	10/4/2011	10/6/2011	Paved	Yes
Cemetery/Pine Bluff South Road	170	14	8.8	71.3	4/17/2012	4/19/2012	Paved	No
Chalk Bluff Road	168	72	42.9	68.5	9/28/2011	9/30/2011	Paved	Yes
A-161-2	155	23	14.8	53.1	10/3/2011	10/5/2011	Paved	No
Black Hills Road	114	36	31.6	64.5	10/3/2011	10/5/2011	Paved	Yes
Albin/La Grange Road	108	22	20.4	60.8	10/24/2011	10/27/2011	Paved	Yes
Albin/La Grange Road	91	15	16.5	67.0	10/24/2011	10/27/2011	Paved	Yes
Chalk Bluff Road	49	7	14.3	60.8	10/3/2011	10/5/2011	Paved	Yes
Little Bear Road	38	0	0.0	62.7	10/17/2011	10/20/2011	Paved	Yes
Gillaspie Road/RD 244	37	7	18.9	64.2	10/18/2011	10/21/2011	Paved	Yes
Old Yellowstone Road	36	6	16.7	58.8	11/8/2011	11/10/2011	Paved	Yes
A-118-1	34	7	20.6	48.6	10/18/2011	10/21/2011	Paved	Yes
Bristol Ridge Road	31	0	0.0	49.0	10/18/2011	10/21/2011	Paved	Yes
Moffett Road	26	1	3.8	66.2	10/17/2011	10/20/2011	Paved	Yes
E Bear Creek Road	15	0	0.0	45.8	10/18/2011	10/21/2011	Paved	Yes
Railroad Road	438	16	3.7	56.4	10/4/2011	10/6/2011	Unpaved	No
Divide Road	195	37	19.0	52.0	5/8/2012	5/11/2012	Unpaved	Yes
Chalk Bluff Road	181	52	28.9	62.1	10/3/2011	10/5/2011	Unpaved	Yes
Durham Road	166	55	33.1	50.0	11/14/2011	11/18/2011	Unpaved	Yes
Arcola Road	161	15	9.3	49.3	9/28/2011	9/30/2011	Unpaved	Yes
A-147-1	143	44	30.8	50.4	10/3/2011	10/5/2011	Unpaved	Yes
Noyer Road	116	50	43.1	28.9	10/3/2011	10/5/2011	Unpaved	Yes
Arcola Road	114	42	36.8	49.6	4/23/2012	4/26/2012	Unpaved	No
Ridley Rd	113	5	4.4	57.2	4/10/2012	4/13/2012	Unpaved	No
Klipstein Rd	111	3	2.7	46.0	4/10/2012	4/13/2012	Unpaved	No
CR 154-1	110	13	12.7	60.5	4/17/2012	4/19/2012	Unpaved	Yes
Arcola Road	102	52	51.0	22.5	4/23/2012	4/26/2012	Unpaved	No
Thunder Basin Road/ Road	101	11	10.9	54.3	9/28/2011	9/30/2011	Unpaved	Yes
CR 154-1	89	52	59.6	59.4	4/16/2012	4/19/2012	Unpaved	Yes
Potato Plant Road West	86	32	37.2	37.0	10/3/2011	10/5/2011	Unpaved	No
Telephone Rd	81	7	8.6	54.9	4/10/2012	4/13/2012	Unpaved	No
CR 227-2	81	13	16.0	54.4	4/24/2012	4/27/2012	Unpaved	No
A-162-1	76	11	14.5	45.4	10/3/2011	10/7/2011	Unpaved	Yes
Old Highway(durham east)	73	11	15.1	57.0	10/4/2011	10/6/2011	Unpaved	Yes
Old Highway Pine Bluffs West	72	12	16.7	60.0	4/17/2012	4/19/2012	Unpaved	No
Hillsdale Road West	65	13	20.0	52.1	5/8/2012	5/11/2012	Unpaved	Yes
Chalk Bluff Road	62	14	22.6	65.1	4/16/2012	4/19/2012	Unpaved	Yes

Laramie County Traffic Count Characteristics (continued)

Road Name	ADT	ADTT	% Trucks	85th % Speed	Date from	Date to	Surface Type	Impacted
Indian Hill Road	62	1	1.6	52.8	5/1/2012	5/4/2012	Unpaved	Yes
Reeder Road	61	8	13.1	55.2	9/28/2011	9/30/2011	Unpaved	Yes
Hermann Road	60	12	16.7	60.3	4/16/2012	4/19/2012	Unpaved	Yes
State Line	53	6	11.3	59.0	4/24/2012	4/27/2012	Unpaved	No
A-161-3	51	2	3.9	45.5	5/8/2012	5/11/2012	Unpaved	No
Eggbert Road North	45	11	24.4	58.3	10/24/2011	10/27/2011	Unpaved	Yes
Plambeck Road	44	15	34.1	56.0	4/17/2012	4/19/2012	Unpaved	No
Hillsdale Road West	43	7	16.3	47.0	10/4/2011	10/6/2011	Unpaved	Yes
Lindbergh Road North	42	22	52.4	60.3	10/24/2011	10/27/2011	Unpaved	Yes
Berry Road	41	2	4.9	47.9	11/8/2011	11/10/2011	Unpaved	Yes
Atlas Road	38	5	10.5	58.7	11/8/2011	11/10/2011	Unpaved	No
Ogle Road	36	12	33.3	65.2	4/24/2012	4/27/2012	Unpaved	No
CR 153-1	33	4	12.1	57.4	4/16/2012	4/19/2012	Unpaved	Yes
Linbergh	32	4	15.6	59.7	5/8/2012	5/11/2012	Unpaved	No
Atlas Road	31	1	3.2	50.1	11/8/2011	11/10/2011	Unpaved	Yes
A-221-1	28	3	10.7	39.3	10/24/2011	10/27/2011	Unpaved	Yes
Linbergh Road	25	3	12.0	55.7	5/8/2012	5/11/2012	Unpaved	No
Holgerson	25	2	8.0	53.7	4/24/2012	4/27/2012	Unpaved	No
Sandberg road	24	4	16.7	51.0	11/14/2011	11/18/2011	Unpaved	No
CR 158-4	24	4	16.7	62.1	5/8/2012	5/11/2012	Unpaved	No
Lyons Road	23	5	20.8	58.0	10/24/2011	10/27/2011	Unpaved	Yes
Anderson Road	21	3	14.3	60.3	11/14/2011	11/17/2011	Unpaved	Yes
Noyer Road	21	1	4.8	52.1	4/16/2012	4/19/2012	Unpaved	Yes
Malm Road	21	5	23.8	57.7	4/24/2012	4/27/2012	Unpaved	No
Eklund Road	21	5	23.8	57.6	4/24/2012	4/27/2012	Unpaved	No
Whitaker Rd	20	3	15.0	56.9	4/10/2012	4/13/2012	Unpaved	No
CR 163-2	20	7	35.0	52.6	4/24/2012	4/27/2012	Unpaved	No
Windmill Road	19	0	0.0	52.5	10/18/2011	10/21/2011	Unpaved	No
Thunder Basin Road/ Road	18	3	16.7	52.4	9/28/2011	9/30/2011	Unpaved	Yes
Kirkbride Road	18	2	11.1	44.6	11/14/2011	11/18/2011	Unpaved	Yes
King RD	18	5	27.8	59.1	4/23/2012	4/26/2012	Unpaved	No
Little Bear Road	17	0	0.0	52.3	10/17/2011	10/20/2011	Unpaved	Yes
Farris Road	17	0	0.0	52.3	4/10/2012	4/13/2012	Unpaved	No
Plambeck Road	16	1	6.3	59.5	4/17/2012	4/19/2012	Unpaved	No
Chalk Hill Road	14	5	35.7	27.5	10/18/2011	10/21/2011	Unpaved	Yes
Holmes Road	13	1	7.7	53.7	11/8/2011	11/10/2011	Unpaved	Yes
Hillsdale Road	12	0	0.0	51.0	11/14/2011	11/18/2011	Unpaved	Yes
Golden Praire	8	0	0.0	60.2	4/23/2012	4/26/2012	Unpaved	No
Indian Hill Road	4	0	0.0	35.2	10/17/2011	10/20/2011	Unpaved	Yes
CR 158-4	4	0	0.0	18.4	5/8/2012	5/11/2012	Unpaved	No
Marsh Road	3	0	0.0	63.6	5/7/2012	5/10/2012	Unpaved	Yes
Indian Hill Rd	1	0	0.0	34.5	4/23/2012	4/26/2012	Unpaved	No
Divide Road	118	31	26.3	51.0	11/14/2011	11/17/2011	Unpaved	Yes

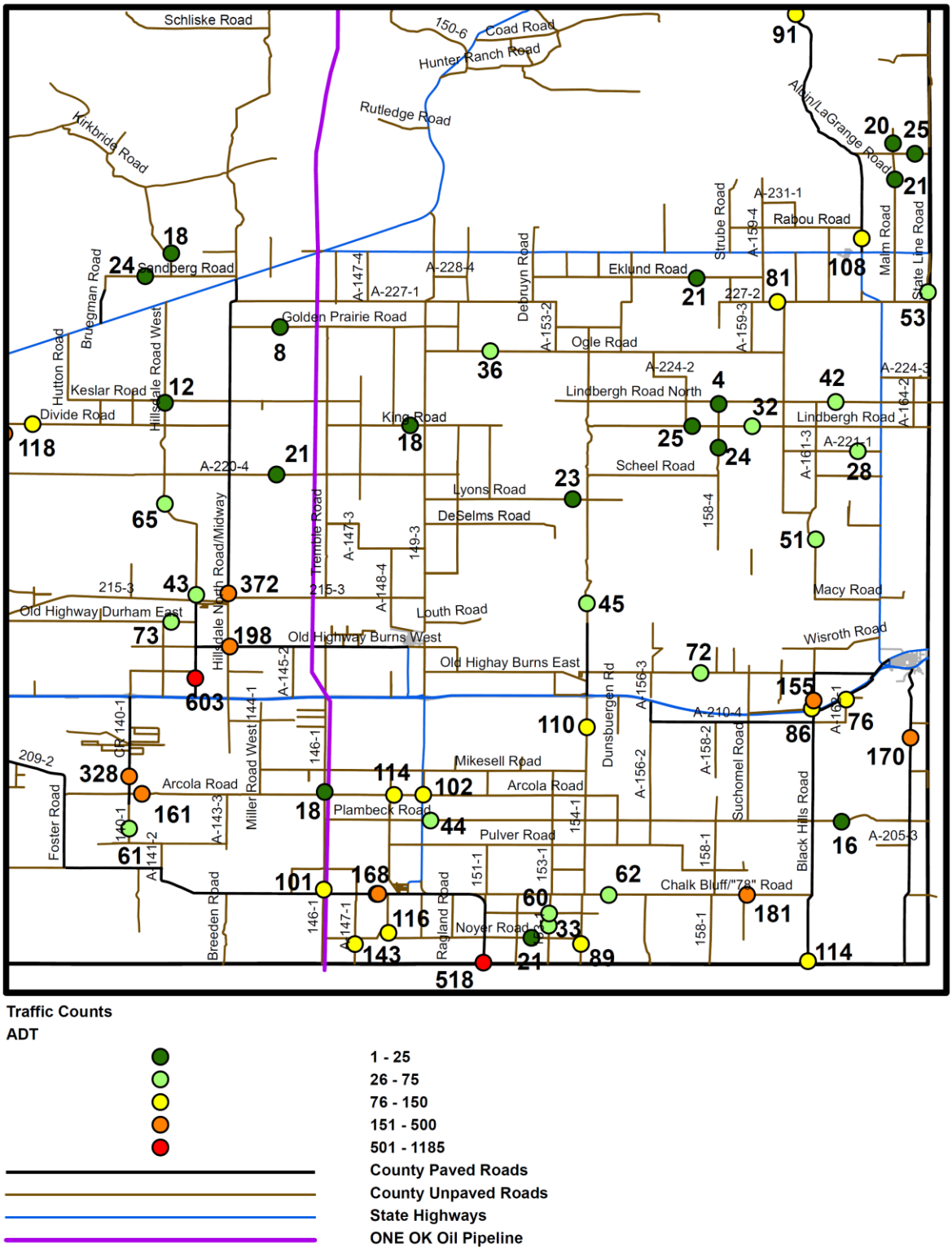
West Laramie County ADT Distribution



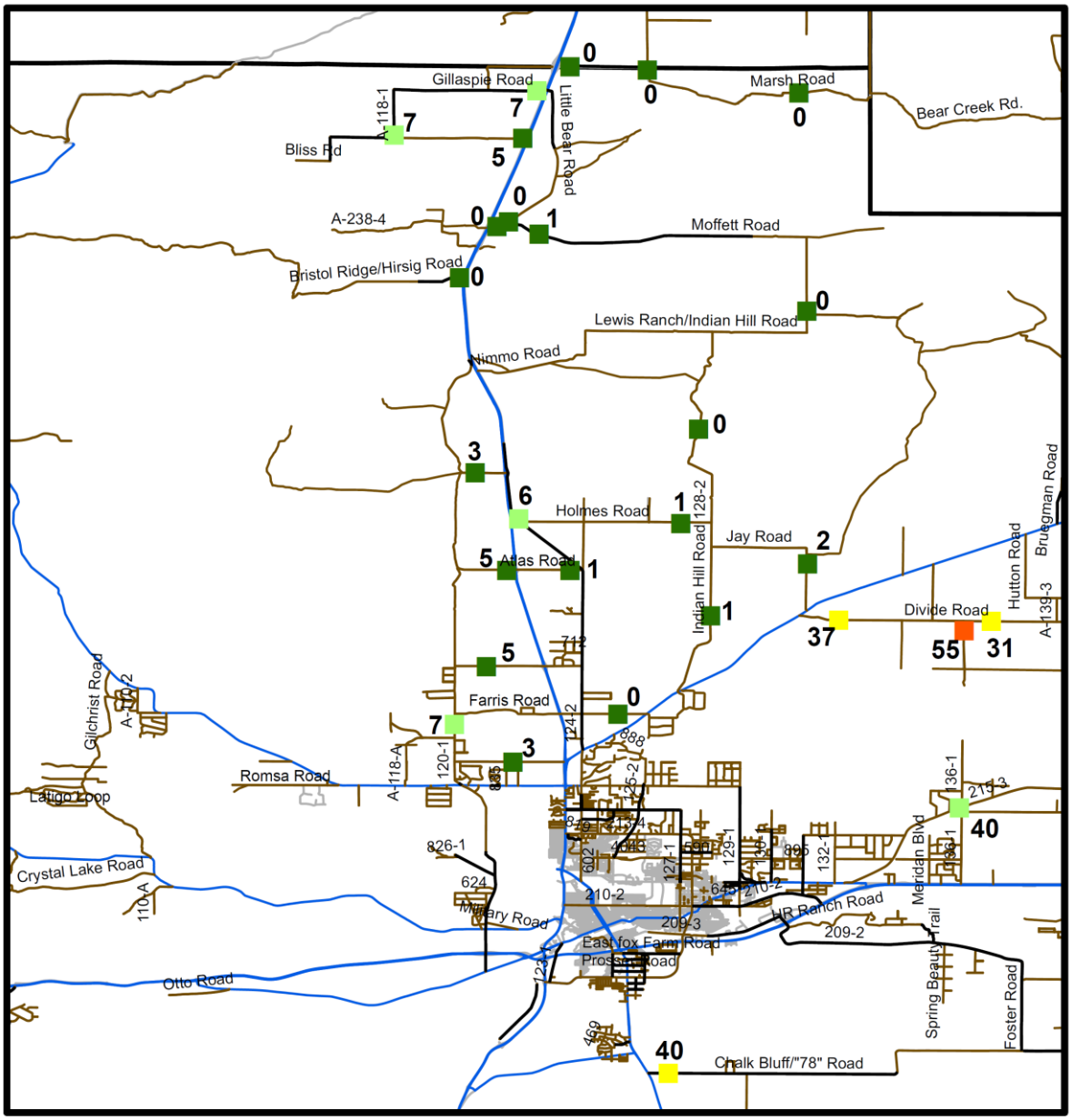
Traffic Counts
ADT

	1 - 25
	26 - 75
	76 - 150
	151 - 500
	501 - 1185
	County Paved Roads
	County Unpaved Roads
	State Highways

East Laramie County ADT Distribution



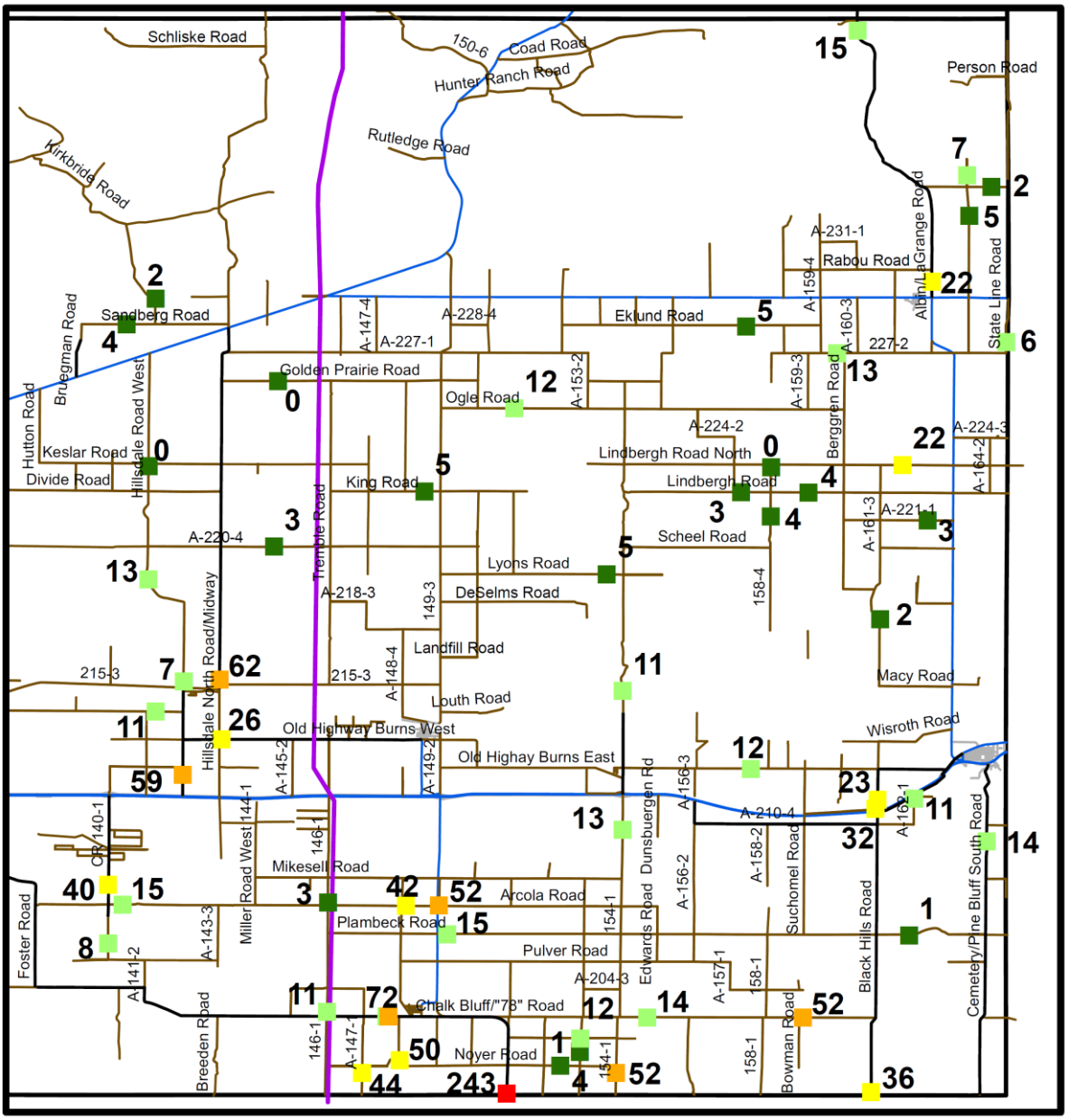
West Laramie County ADTT Distribution



Traffic Counts
ADTT

	0 - 5
	6 - 20
	21 - 50
	51 - 150
	151 - 448
	County Paved Roads
	County Unpaved Roads
	State Highways

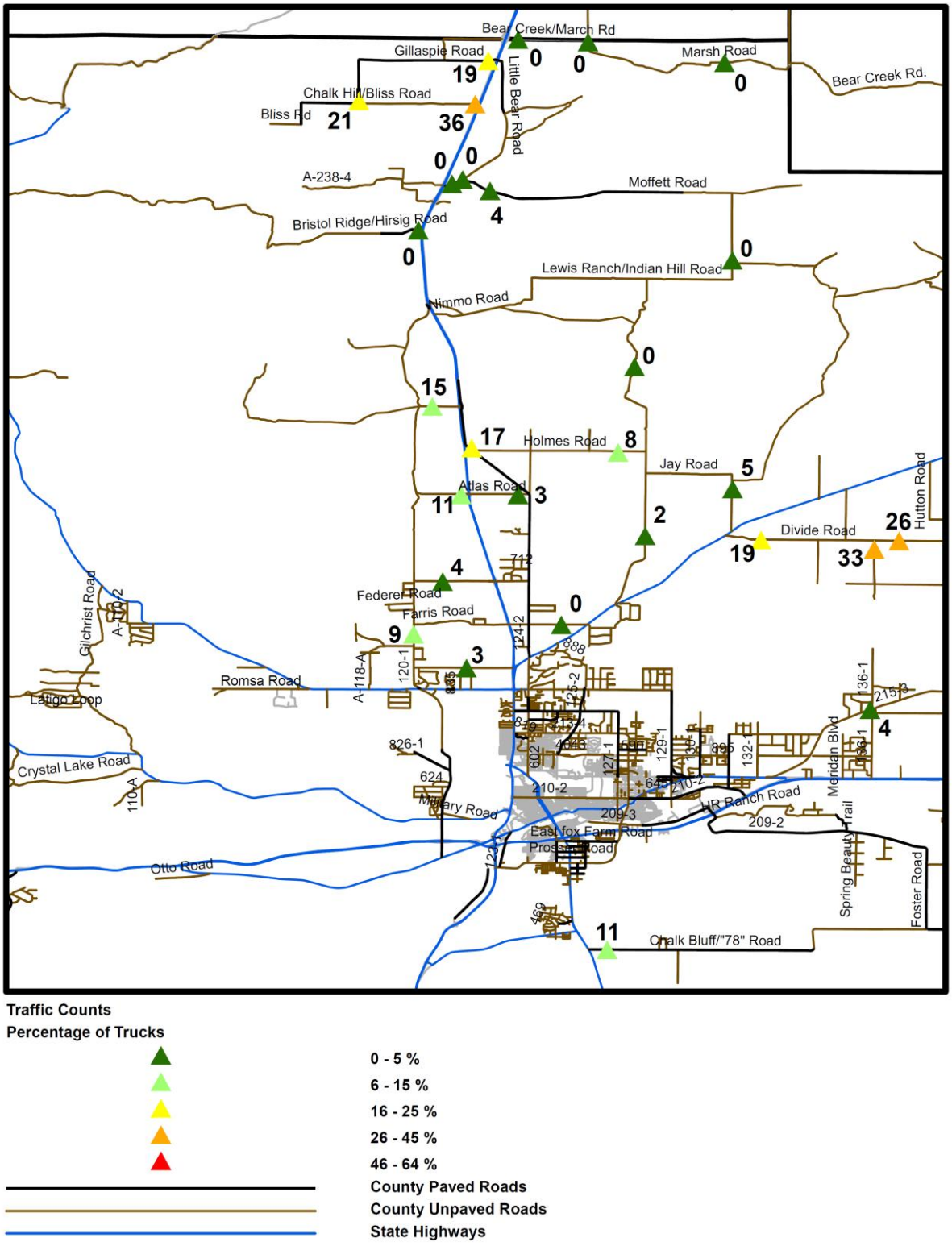
East Laramie County ADTT Distribution



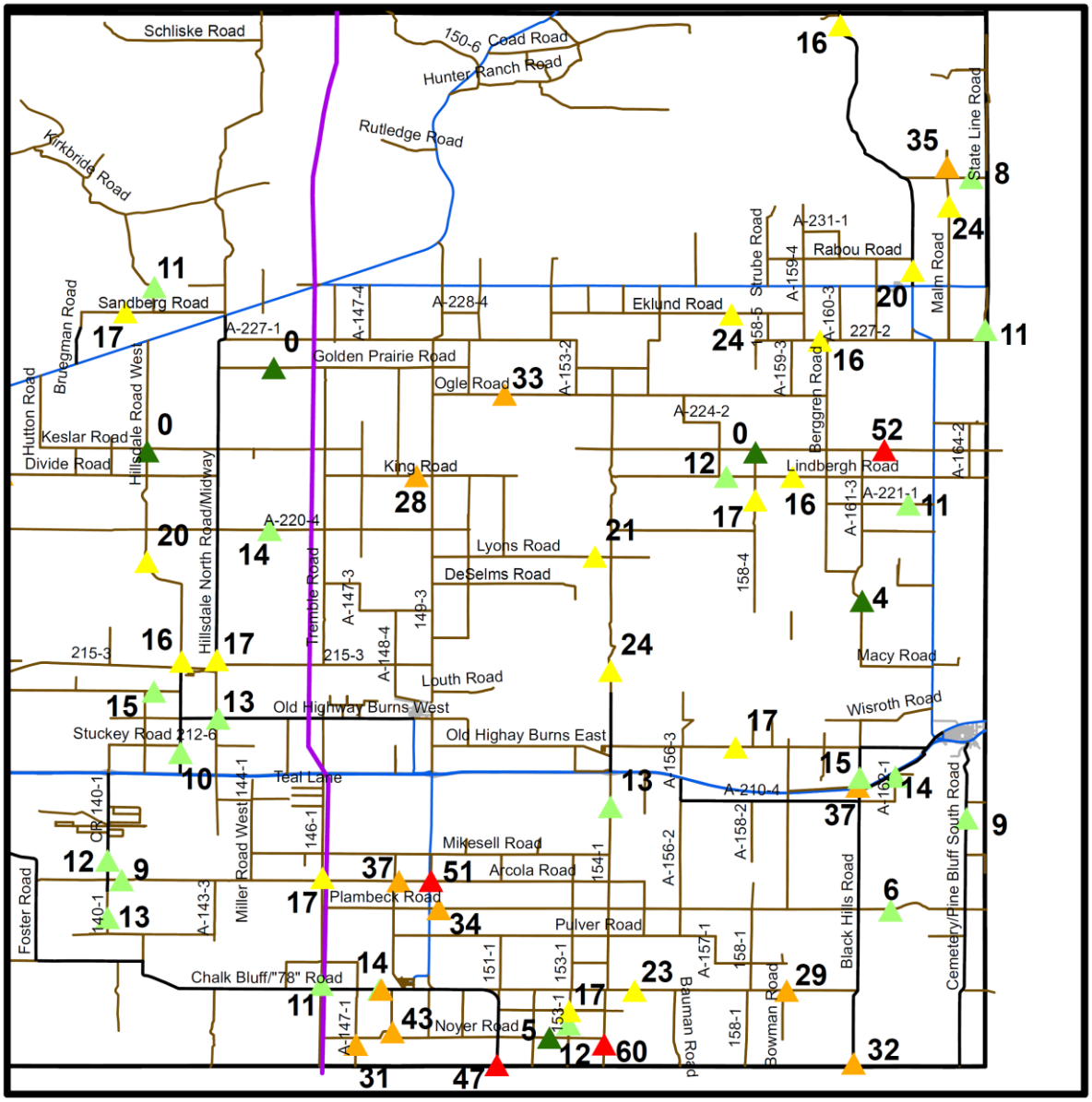
Traffic Counts
ADTT

- **0 - 5**
- **6 - 20**
- **21 - 50**
- **51 - 150**
- **151 - 448**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**
- **ONE OK Oil Pipeline**

West Laramie County Percent Trucks Distribution



East Laramie County Percent Trucks Distribution

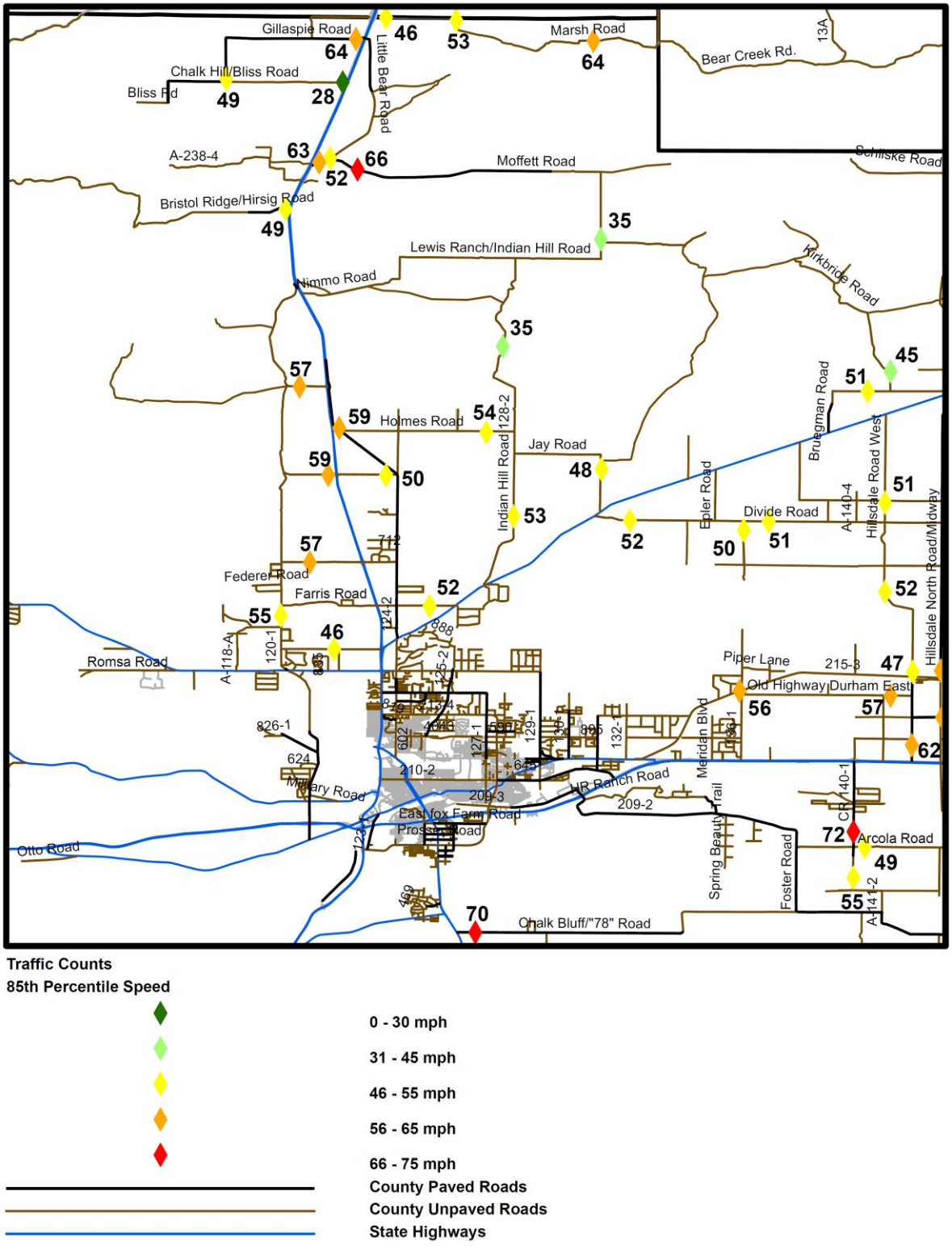


Traffic Counts

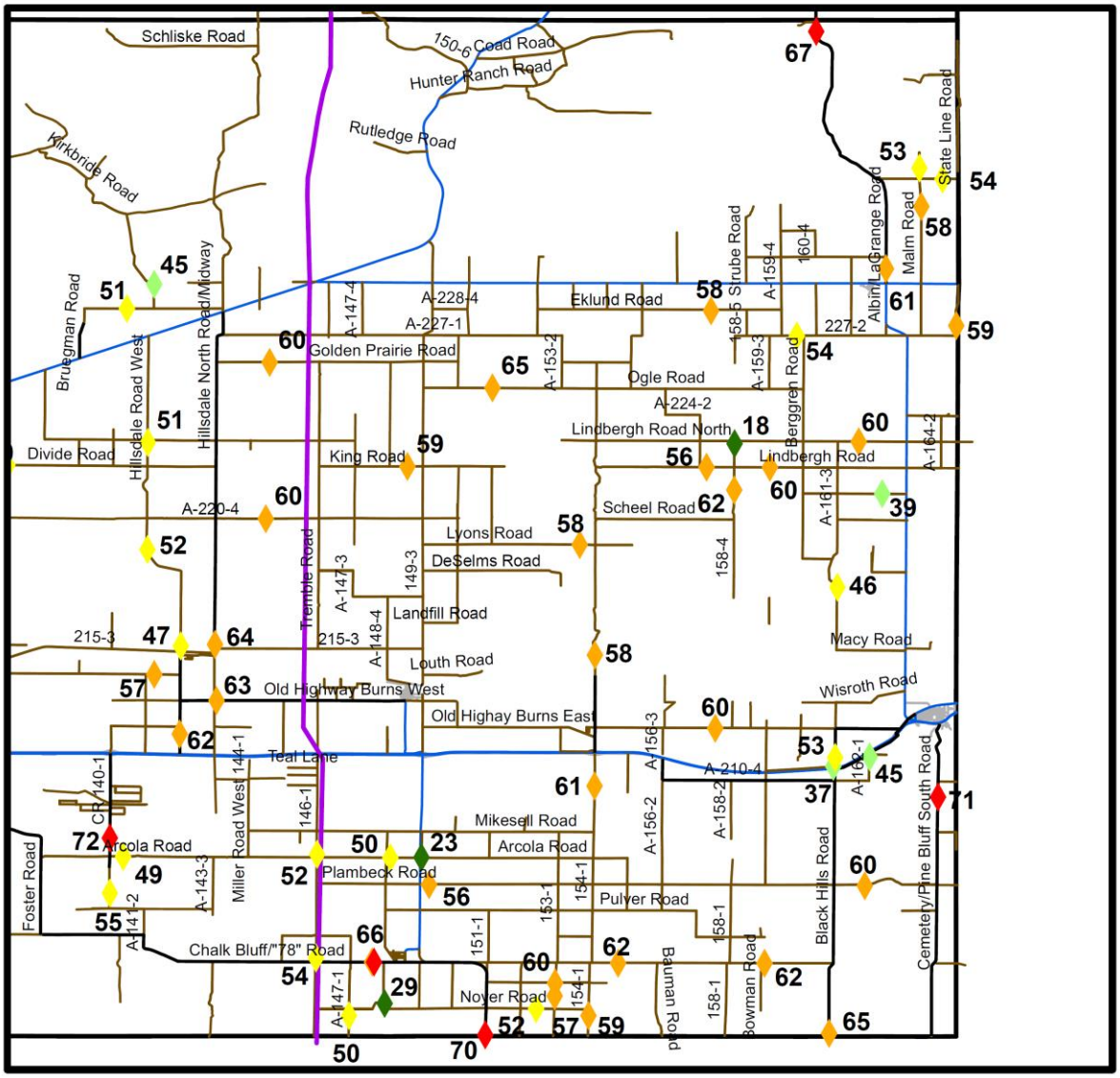
Percentage of Truck Traffic

- **0 - 5 %**
- **6 - 15 %**
- **16 - 25 %**
- **26 - 45 %**
- **46 - 64 %**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**
- **ONE OK Oil Pipeline**

West Laramie County 85th Percentile Speed Distribution



East Laramie County 85th Percentile Speed Distribution



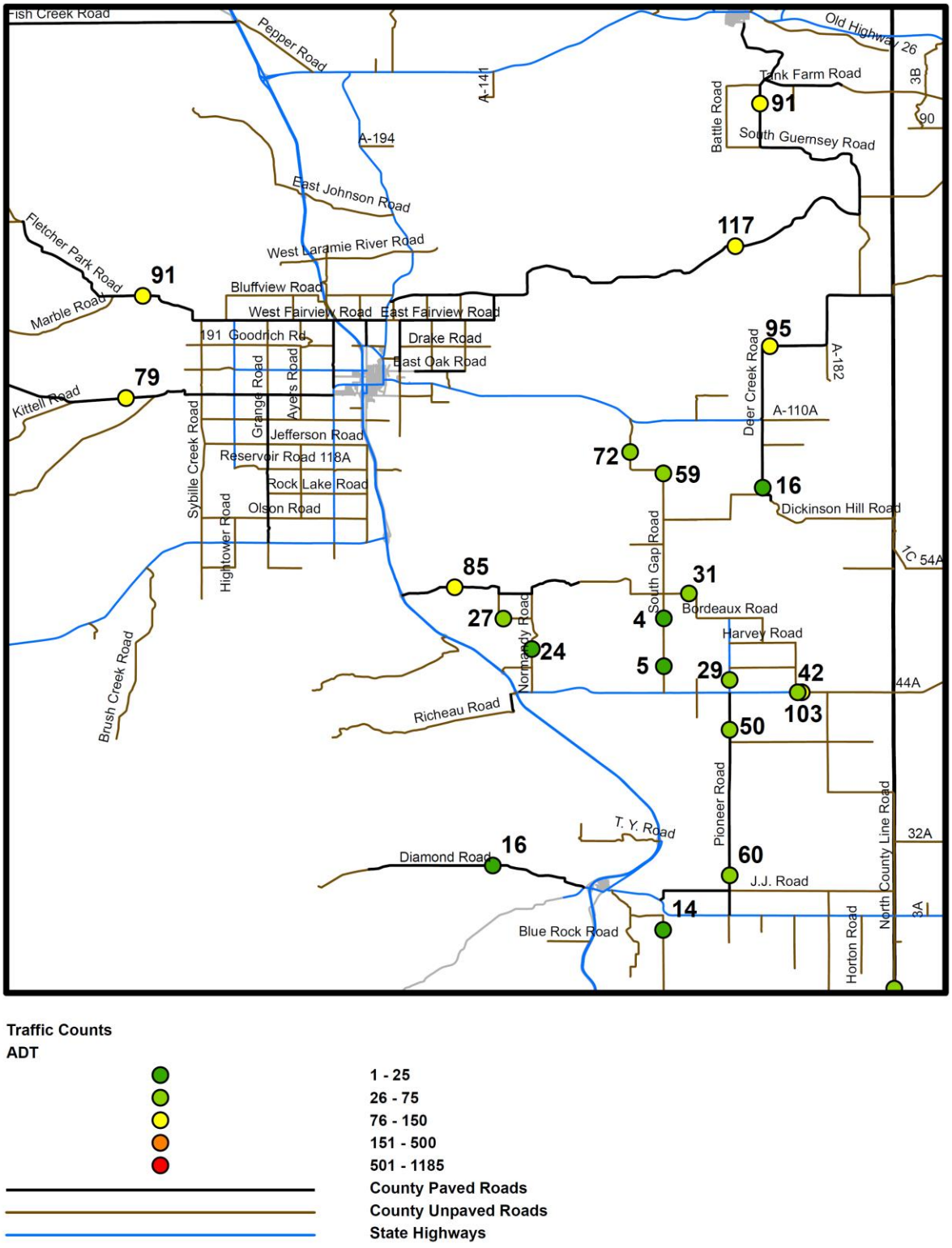
Traffic Counts
85th Percentile Speed

- **0 - 30 mph**
- **31 - 45 mph**
- **46 - 55 mph**
- **56 - 65 mph**
- **66 - 75 mph**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**
- **ONE OK Oil Pipeline**

Platte County Traffic Count Characteristics

Road Name	ADT	ADTT	% Trucks	85th % Speed	Date from	Date to	Surface Type	Impacted
Anelope Gap Road	242	32	13.2	74.9	10/10/2011	10/12/2011	Paved	No
Grey Rocks	117	2	1.7	56.7	4/30/2012	5/3/2012	Paved	No
Deer Creek Road	95	2	2.1	62.1	10/10/2011	10/12/2011	Paved	No
South Guernsey	91	6	6.6	64.5	4/30/2012	5/3/2012	Paved	No
Fletcher Park	91	1	1.1	59.5	4/30/2012	5/3/2012	Paved	No
Bordeaux Road	85	15	17.6	58.0	10/11/2011	10/13/2011	Paved	Yes
Palmer Canyon	79	12	15.2	58.4	4/30/2012	5/3/2012	Paved	No
Pioneer Road	60	4	6.7	64.8	10/11/2011	10/13/2011	Paved	Yes
Pioneer Road	50	3	6.0	63.1	11/4/2011	11/11/2011	Paved	Yes
North Pioneer Road	29	2	6.9	67.5	10/11/2011	10/13/2011	Paved	No
Dickenson Hill Road	16	2	12.5	53.4	10/10/2011	10/12/2011	Paved	Yes
Diamond	16	0	0.0	65.3	4/30/2012	5/3/2012	Paved	No
Slater Road	103	18	17.5	61.1	10/4/2011	11/11/2011	Unpaved	Yes
South Gap Road	72	3	4.2	53.3	10/10/2011	10/12/2011	Unpaved	Yes
South Gap Road	59	4	5.1	48.8	10/10/2011	10/12/2011	Unpaved	Yes
Slater Road	42	3	7.1	52.6	10/11/2011	10/13/2011	Unpaved	Yes
Bordeaux Road	31	1	3.2	52.7	10/10/2011	10/12/2011	Unpaved	No
Brittany Road	27	8	29.6	38.8	10/11/2011	10/13/2011	Unpaved	Yes
Normandy Road	24	6	25.0	47.7	10/11/2011	10/13/2011	Unpaved	Yes
Windmil Rd	14	0	0.0	50.2	7/23/2012	7/27/2012	Unpaved	No
South Gap Road	5	0	0.0	34.2	7/23/2012	7/27/2012	Unpaved	Yes
South Gap	4	0	0.0	32.8	4/30/2012	5/3/2012	Unpaved	Yes

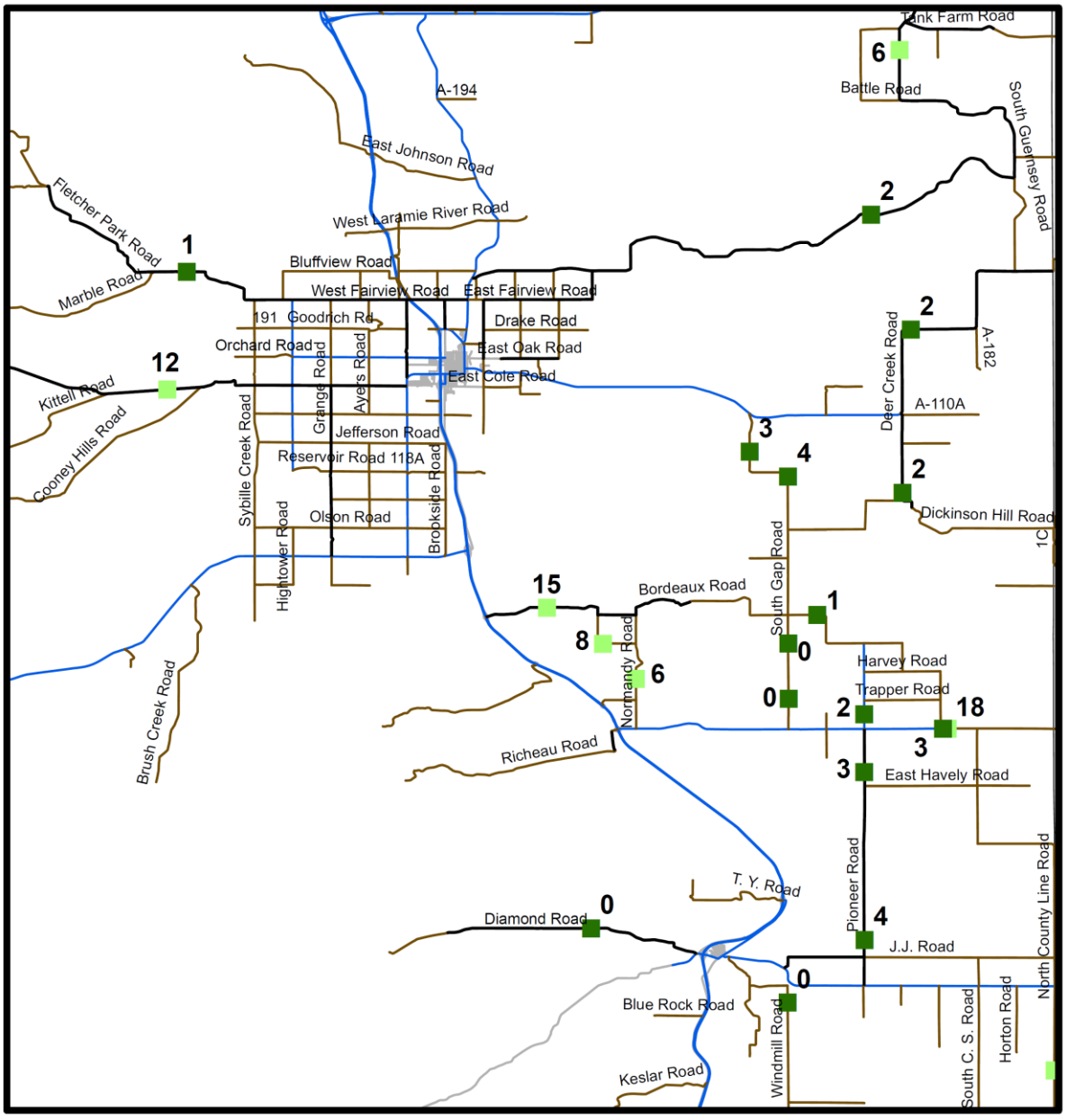
Platte County ADT Distribution



Traffic Counts
ADT

	1 - 25
	26 - 75
	76 - 150
	151 - 500
	501 - 1185
	County Paved Roads
	County Unpaved Roads
	State Highways

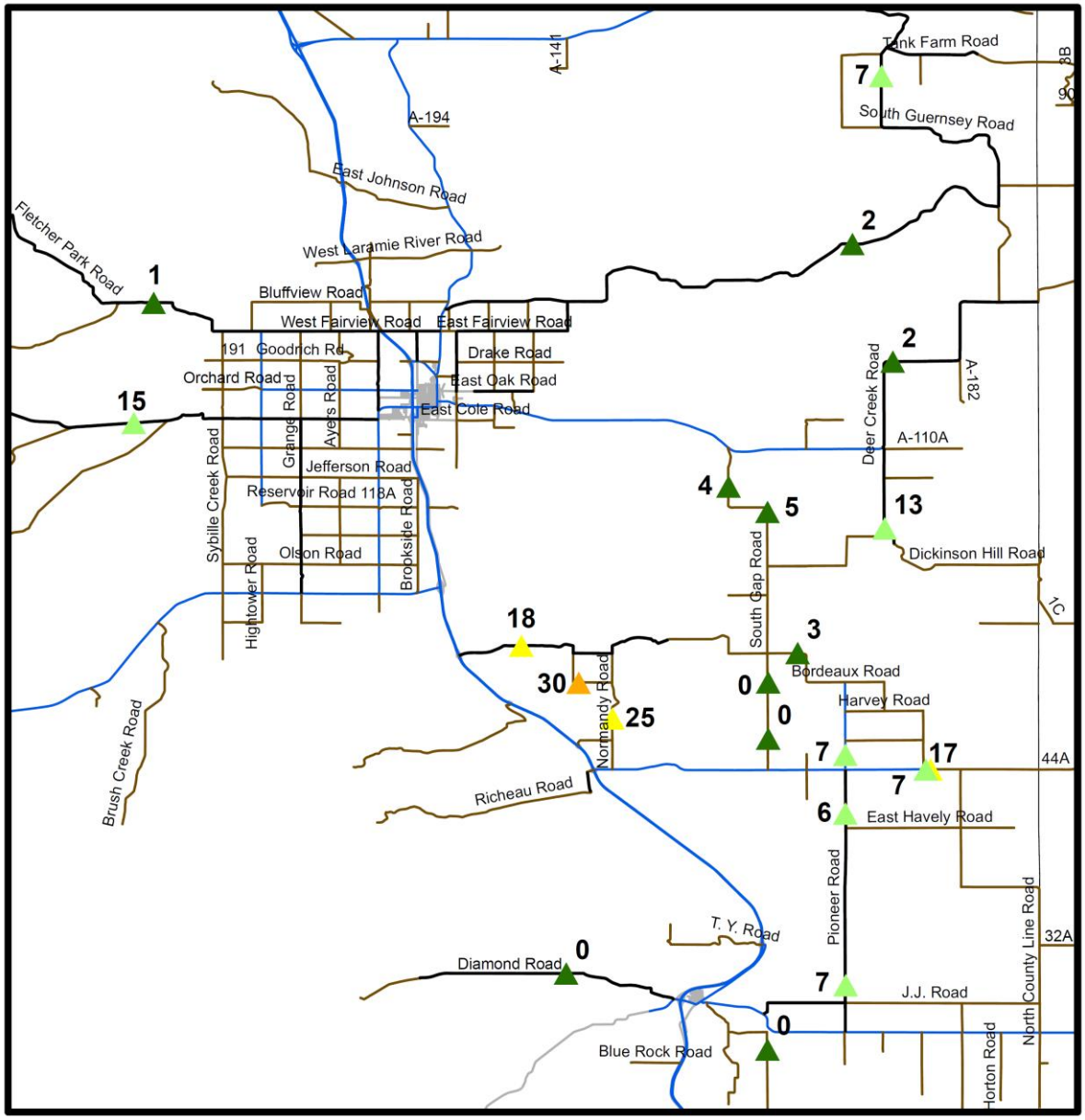
Platte County ADTT Distribution



Traffic Counts
ADTT

	0 - 5
	6 - 20
	21 - 50
	51 - 150
	151 - 448
	County Paved Roads
	County Unpaved Roads
	State Highways

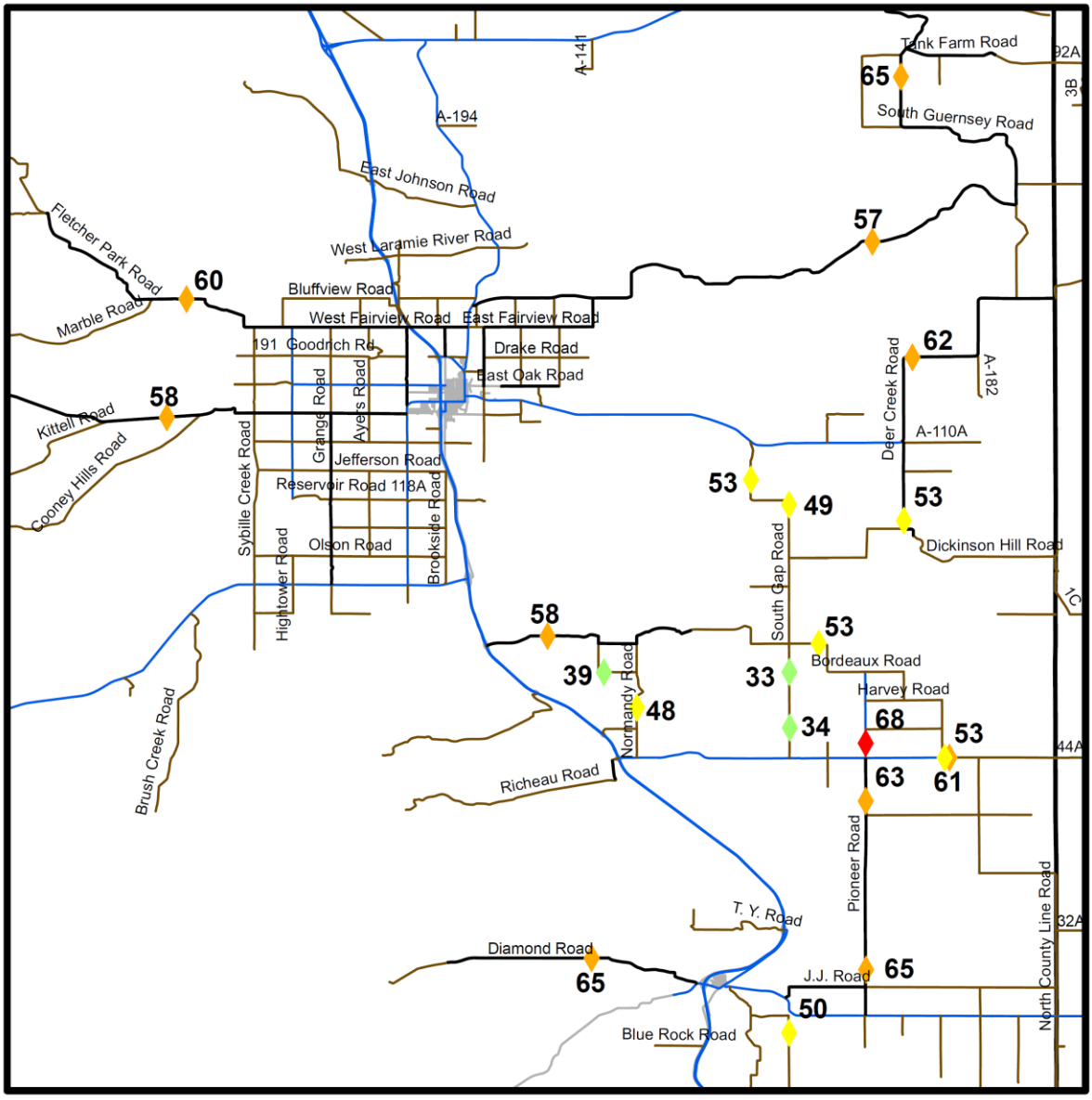
Platte County Percent Trucks Distribution



Traffic Counts
Percentage of Truck Traffic

- **0 - 5 %**
- **6 - 15 %**
- **16 - 25 %**
- **26 - 45 %**
- **46 - 64 %**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**

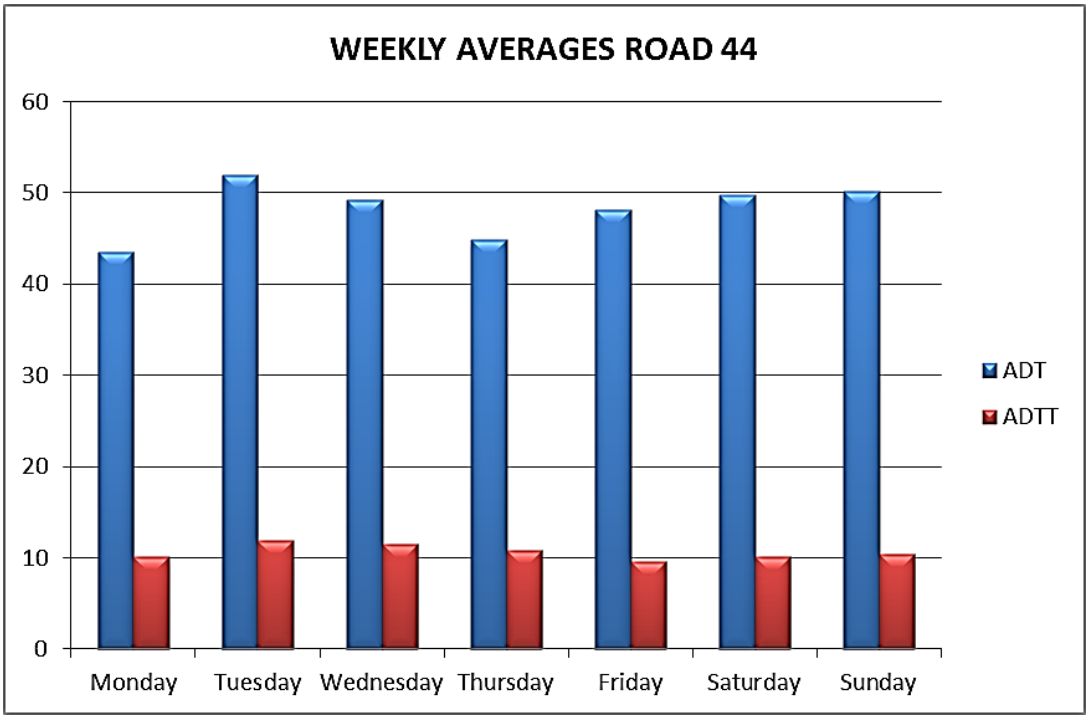
Platte County 85th Percentile Speed Distribution

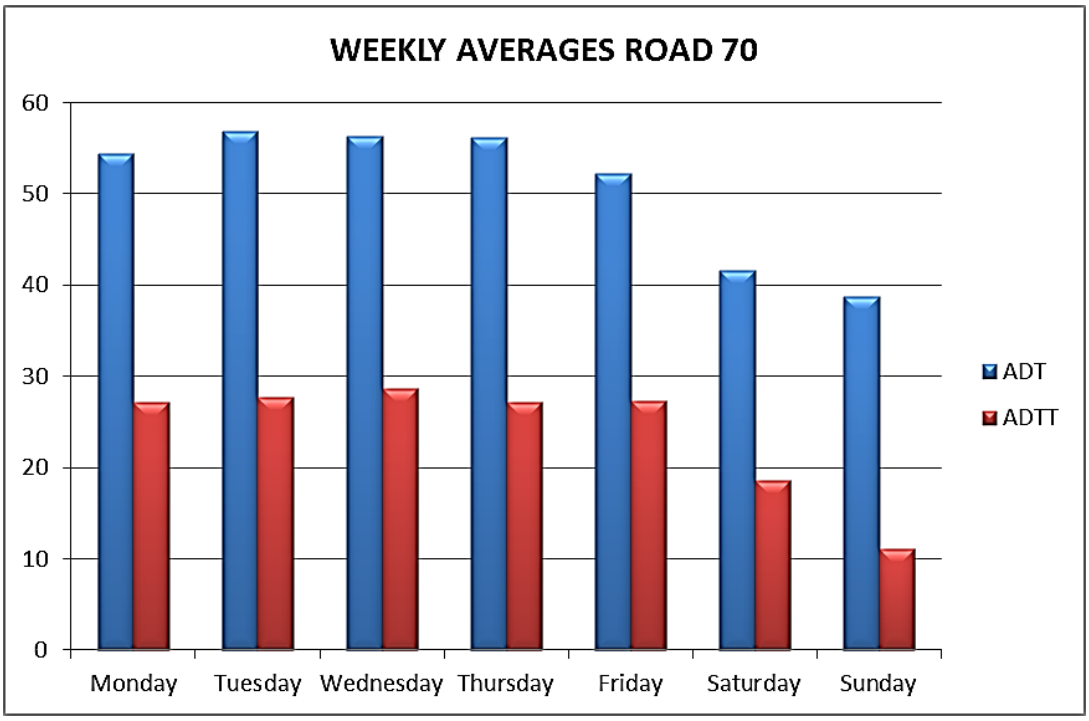


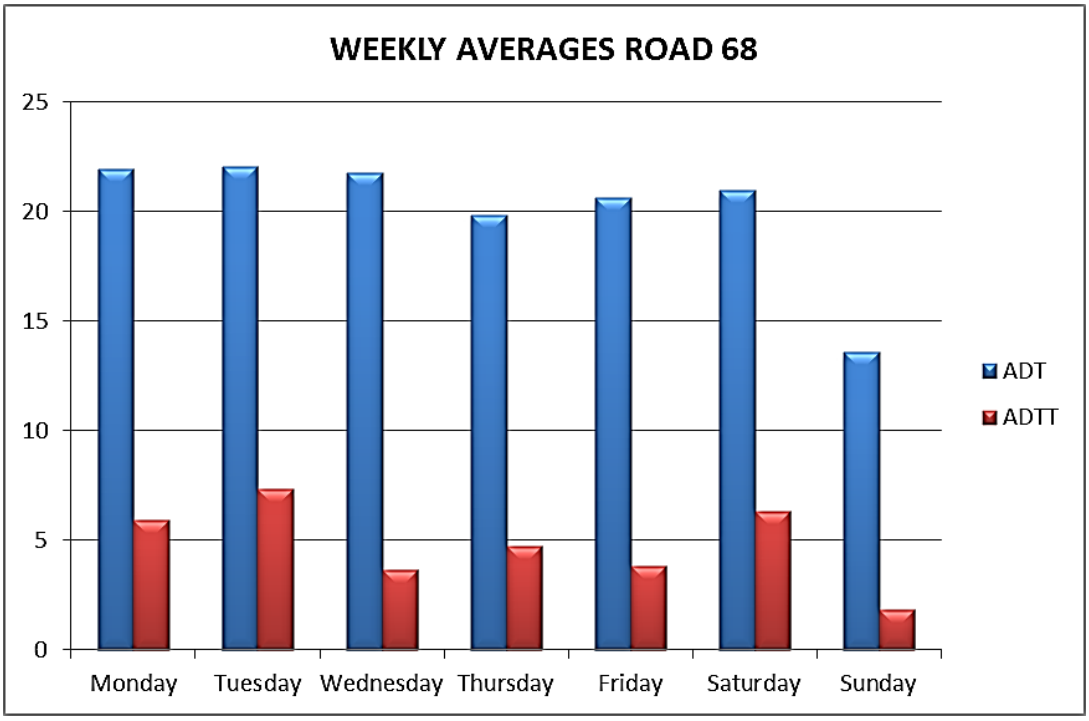
Traffic Counts
85th Percentile Speed

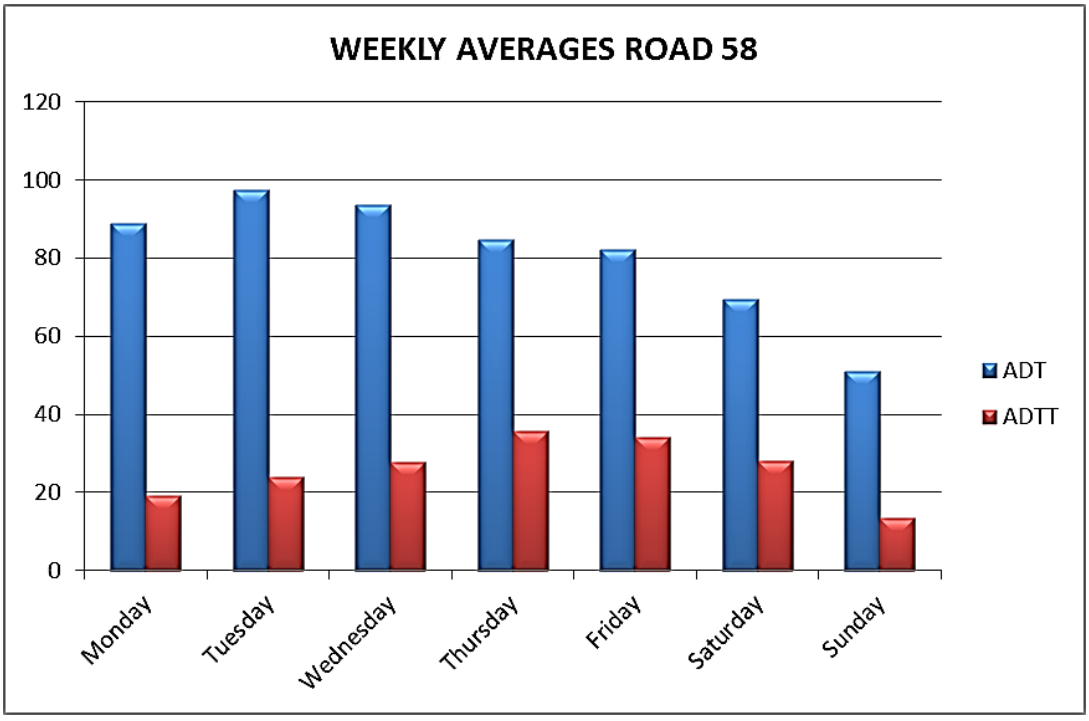
- **0 - 30 mph**
- **31 - 45 mph**
- **46 - 55 mph**
- **56 - 65 mph**
- **66 - 75 mph**
- **County Paved Roads**
- **County Unpaved Roads**
- **State Highways**

APPENDIX F. GOSHEN LONG TERM COUNTER FIGURES






WEEKLY AVERAGES ROAD 68
25
20
15
10
5
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
ADT
ADTT


WEEKLY AVERAGES ROAD 58
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100
80
60
40
20
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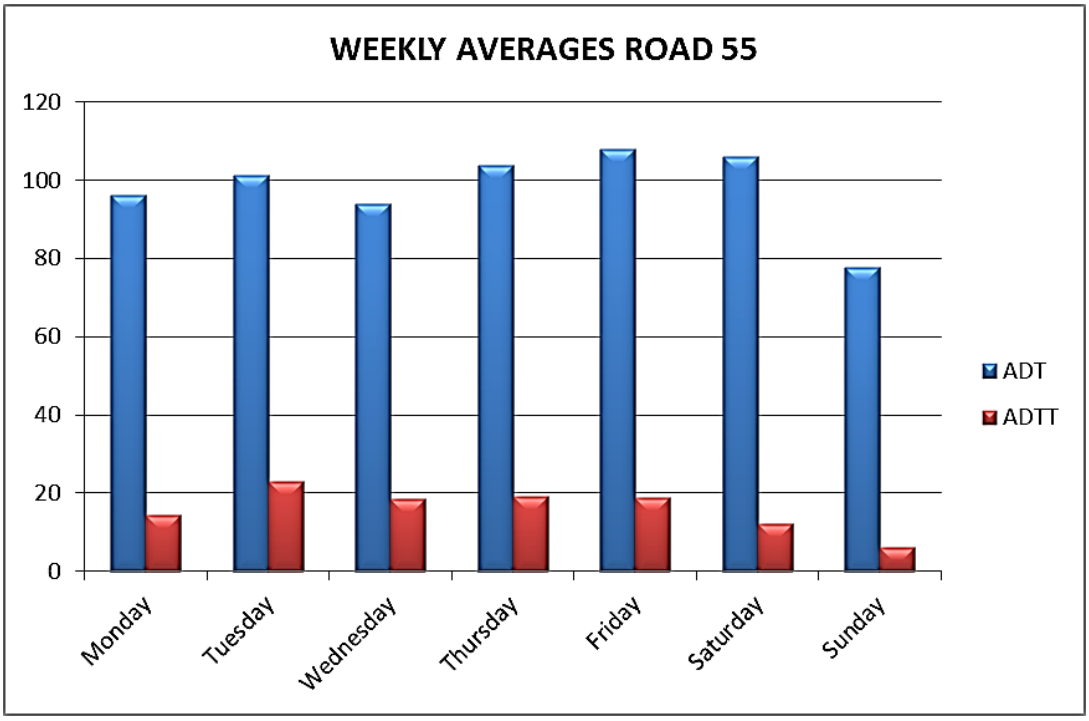
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
ADT
ADTT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80
60
40
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Tuesday
Wednesday
Thursday
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Saturday
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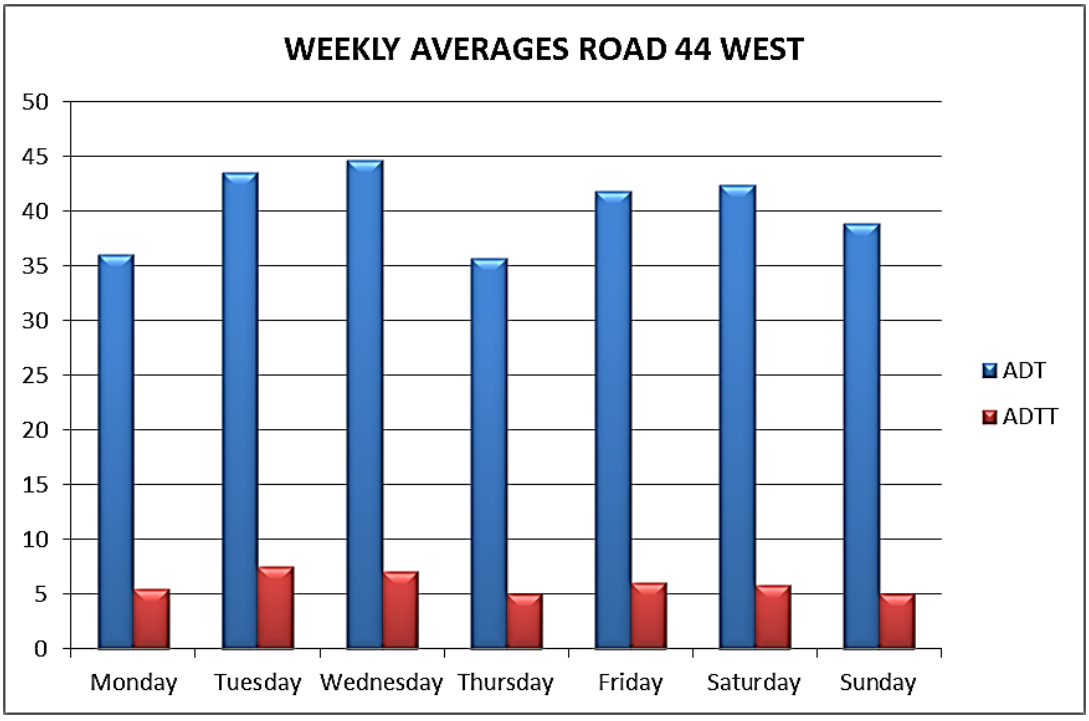
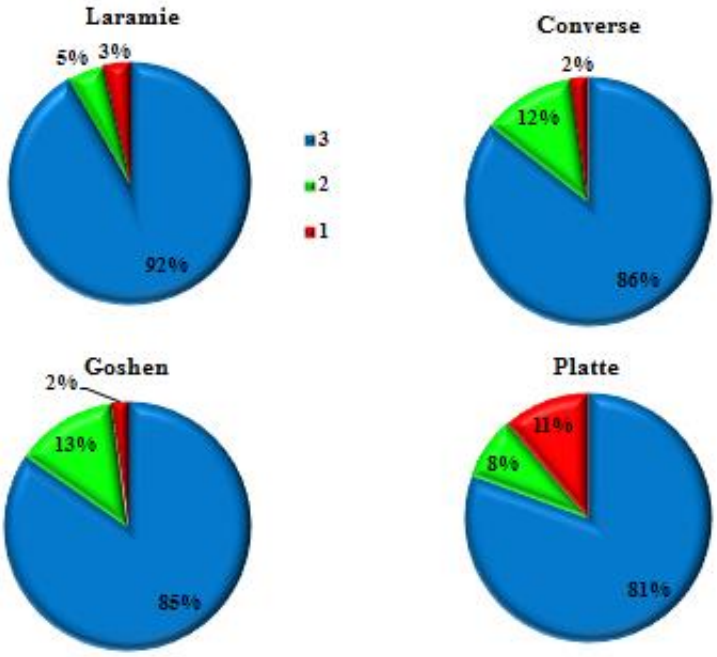
ADT
ADTT

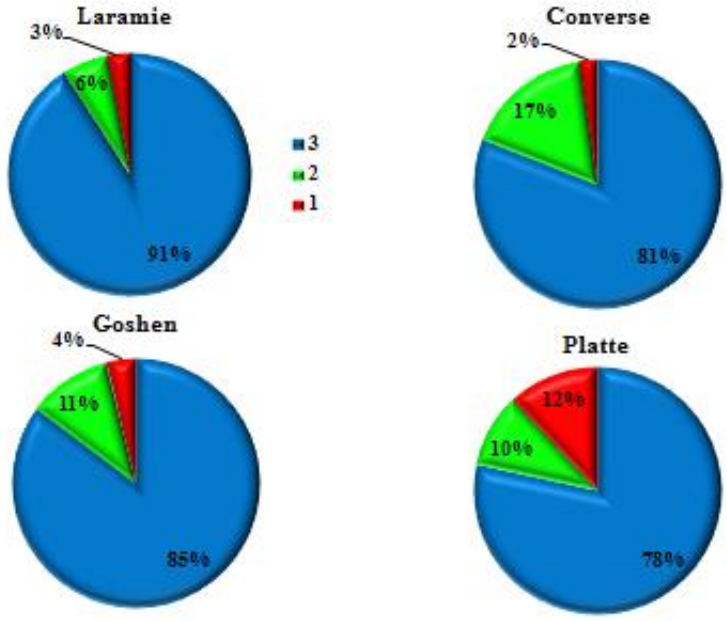

WEEKLY AVERAGES ROAD 44 WEST
50
45
40
35
30
25
20
15
10
5
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
ADT
ADTT

APPENDIX G. DISTRESS PIE CHARTS

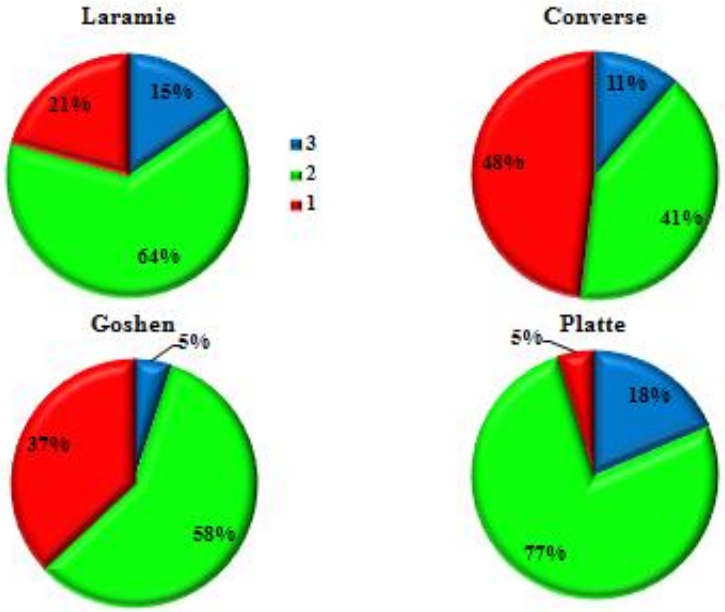
Cross Section



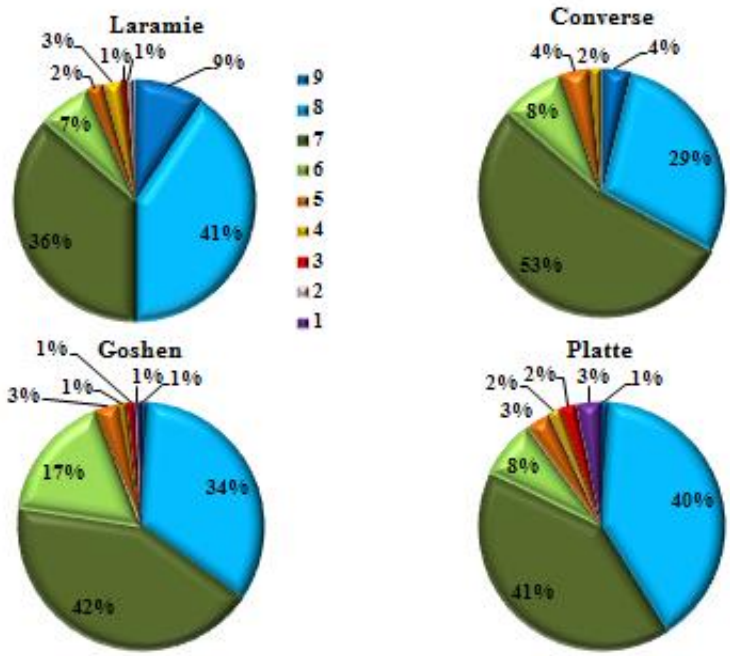
Drainage



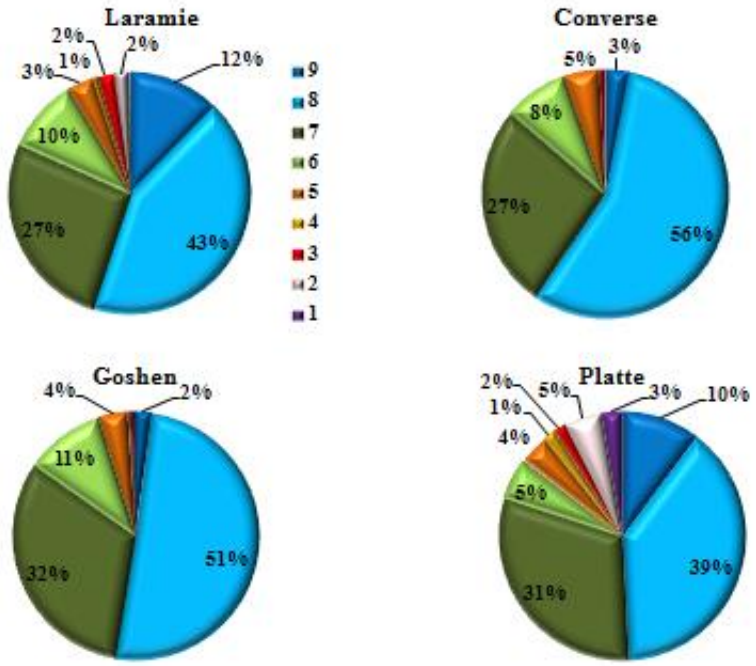
Dust



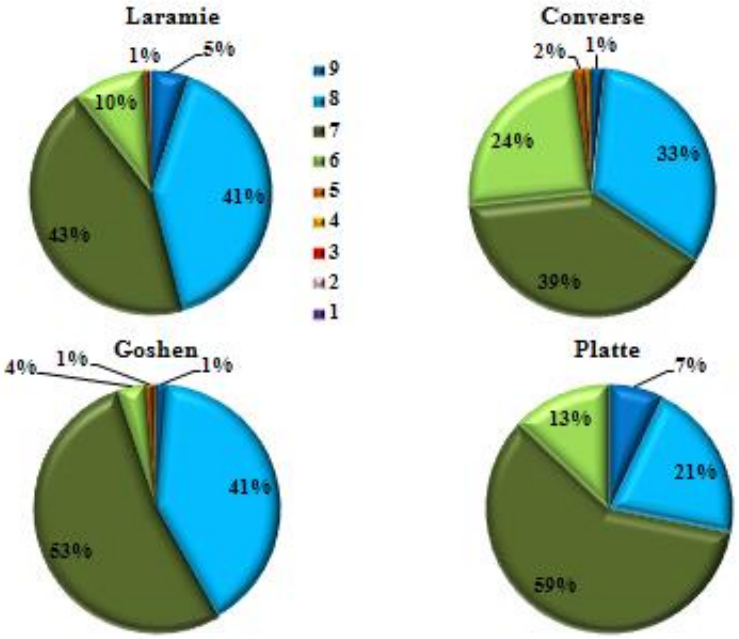
Rutting



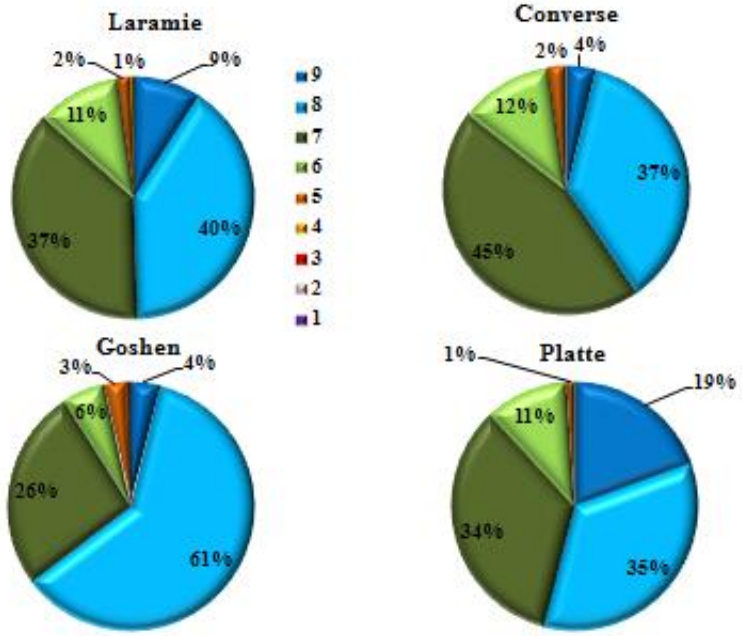
Potholes



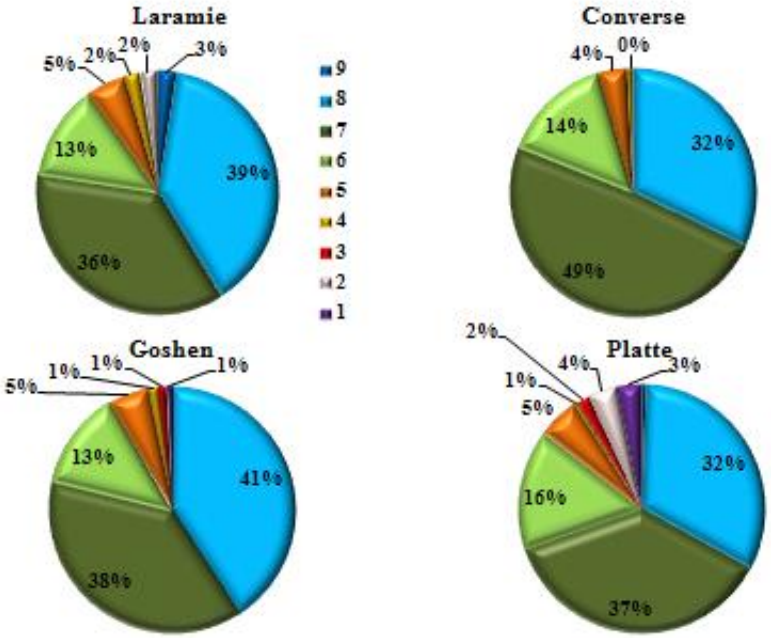
Loose Aggregate



Corrugations

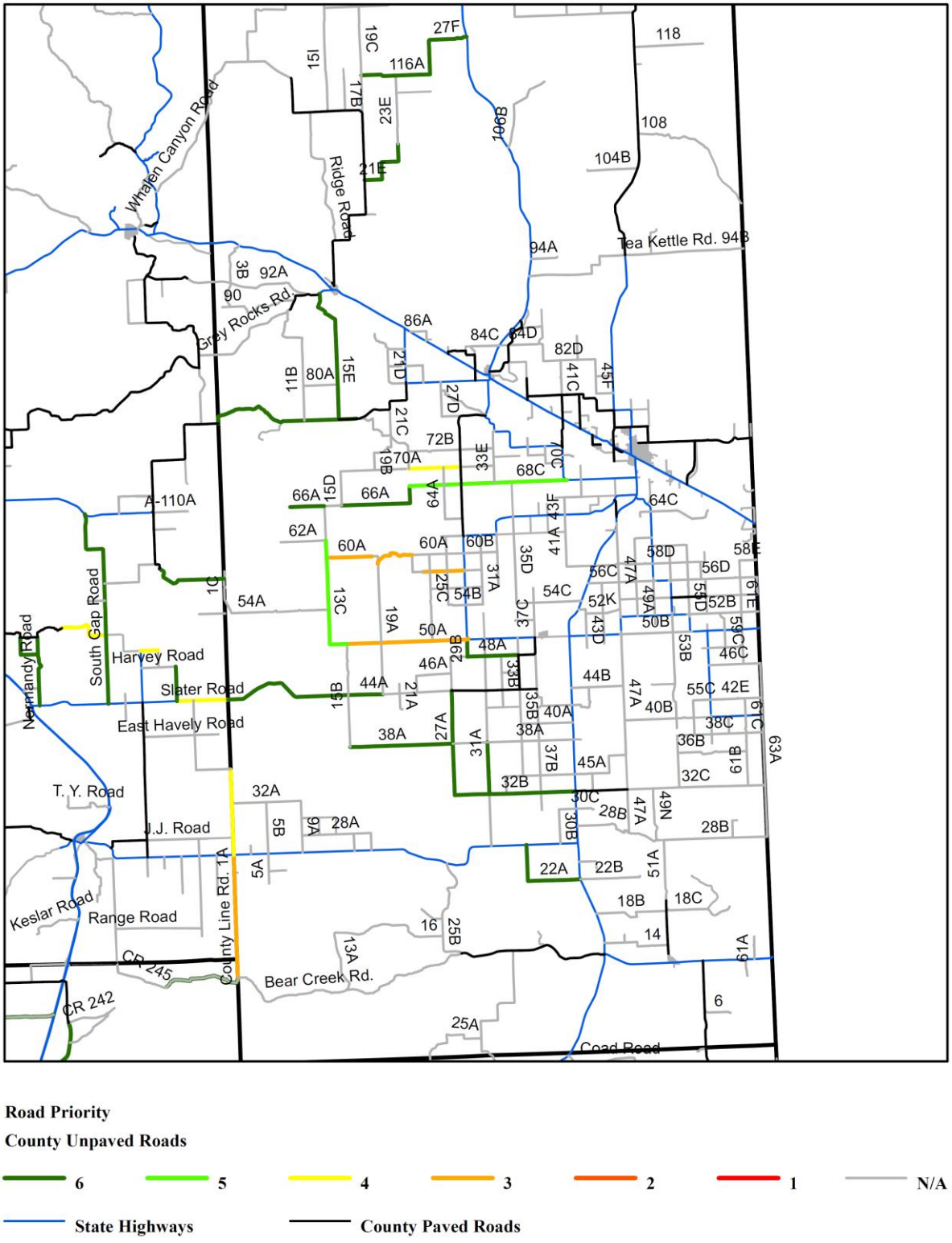


Ride Quality

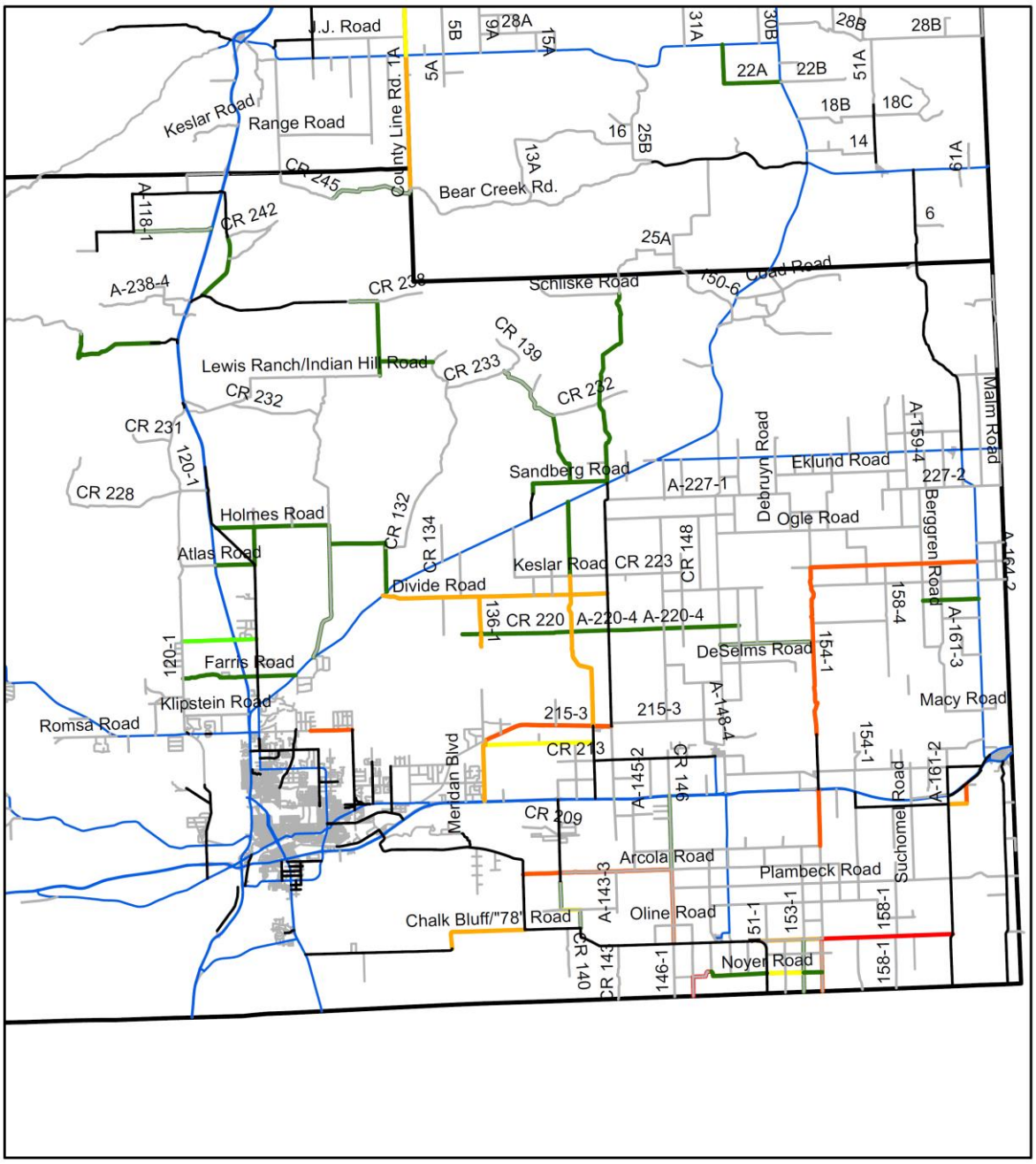


APPENDIX H. PRIORITY RANKING MAPS AND TABLES

Goshen County Priority Ranking Map



Laramie County Priority Ranking Map



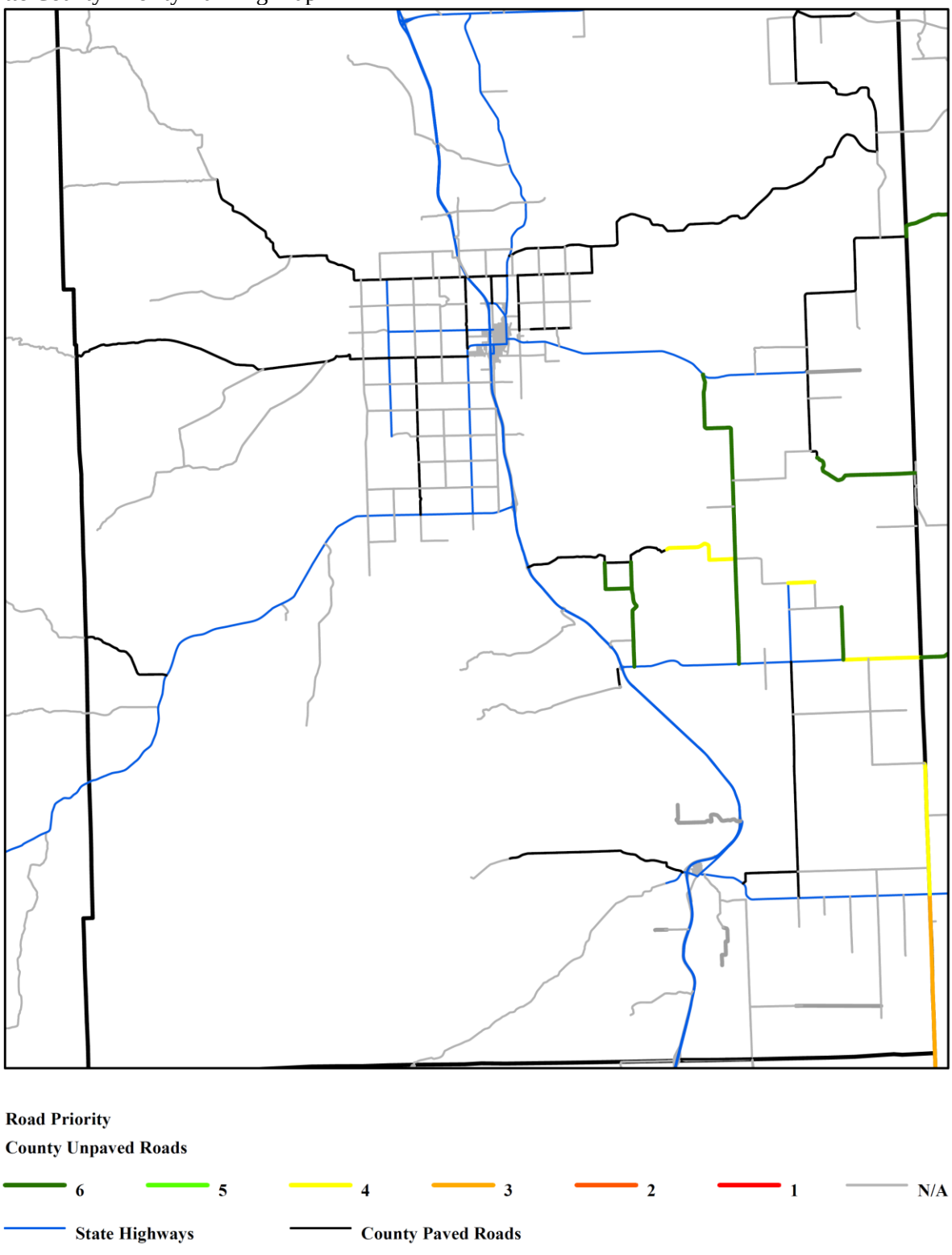
Road Priority

County Unpaved Roads

6 **5** **4** **3** **2** **1** **N/A**

State Highways **County Paved Roads**

Platte County Priority Ranking Map



Priority Ranking Tables

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Converse	3062	Ross Road	6	384	180	34	**1**	Very High
Converse	3112	Bill Hall Road	7	800	448	12	**1**	Very High
Converse	3113	Bill Hall Road	7	800	448	12	**1**	Very High
Converse	3114	Bill Hall Road	7	800	448	12	**1**	Very High
Converse	3115	Bill Hall Road	7	800	448	12	**1**	Very High
Converse	3116	Bill Hall Road	7	800	448	12	**1**	Very High
Converse	3063	Ross Road	6	384	180	34	**1**	Very High
Converse	3064	Ross Road	7	384	180	34	**1**	Very High
Converse	3065	Ross Road	7	384	180	34	**1**	Very High
Converse	3066	Ross Road	7	384	180	34	**1**	Very High
Laramie	145	CR 203	8	180	52	6	**1**	High
Laramie	146	CR 203	8	180	52	6	**1**	High
Laramie	878	CR 203	6	180	52	6	**1**	High
Laramie	158	CR 201	8	116	50	8	**1**	Medium
Laramie	159	CR 201	7	116	50	8	**1**	Medium
Laramie	161	CR 201	6	116	50	8	**1**	Medium
Laramie	555	CR 147	5	142	44	10	**1**	Medium
Converse	3067	Jenne Trail Road	7	108	33	17	**1**	Medium
Converse	3068	Jenne Trail Road	8	108	33	17	**1**	Medium
Converse	3069	Jenne Trail Road	8	108	33	17	**1**	Medium
Converse	3070	Jenne Trail Road	7	108	33	17	**1**	Medium
Converse	3098	Highland Loop Road	7	173	31	12	**1**	High
Converse	3099	Highland Loop Road	7	173	31	12	**1**	High
Converse	3100	Highland Loop Road	7	173	31	12	**1**	High
Laramie	148	CR 154	7	89	53	10	**2**	Medium
Laramie	434	CR 154	7	89	53	10	**2**	Medium
Laramie	848	CR 154	8	89	53	10	**2**	Medium
Converse	3096	Highland Loop Road	7	87	29	12	**2**	High
Converse	3097	Highland Loop Road	7	87	29	12	**2**	High
Laramie	120	CR 223	8	42	22	20	**2**	Medium
Laramie	121	CR 223	8	42	22	20	**2**	Low
Laramie	126	CR 223	9	42	22	20	**2**	Medium
Laramie	950	CR 223	6	42	22	20	**2**	Medium
Laramie	951	CR 223	6	42	22	20	**2**	Medium
Laramie	952	CR 223/ Lindbergh R	6	42	22	20	**2**	Low
Laramie	132	CR 215	7	438	16	8	**2**	High
Laramie	133	CR 215 Railroad Rd	7	438	16	8	**2**	Very High
Laramie	134	CR 215 Railroad Rd	6	438	16	8	**2**	Very High
Laramie	138	CR 215 Railroad Rd	6	438	16	8	**2**	Very High
Laramie	142	CR 215 IronMountai	7	438	16	8	**2**	Very High
Laramie	916	CR 215	7	438	16	8	**2**	Very High

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Laramie	167	CR 207	7	161	15	8	**2**	High
Laramie	168	CR 207	7	161	15	8	**2**	High
Laramie	169	CR 207	6	161	15	8	**2**	Medium
Laramie	170	CR 207	8	161	15	8	**2**	High
Laramie	870	CR 207	8	161	15	8	**2**	High
Laramie	127	CR 154 Egbert North	8	110	14	10	**2**	Medium
Laramie	128	CR 154 Egbert North	8	110	14	10	**2**	Medium
Laramie	129	CR 154 Egbert North	7	110	14	10	**2**	Medium
Laramie	130	CR 154 Egbert North	8	110	14	10	**2**	Medium
Laramie	825	CR 154	8	110	14	10	**2**	Medium
Laramie	826	CR 154/Egberdt Rd	7	110	14	10	**2**	Medium
Laramie	827	CR 154 Egbert North	8	110	14	10	**2**	Medium
Laramie	164	CR 146	7	101	11	7	**2**	Medium
Laramie	165	CR 146	8	101	11	7	**2**	Medium
Laramie	864	CR 146	7	101	11	7	**2**	Medium
Goshen	1192	CR 50A	8	130	52	1	**3**	Medium
Goshen	1217	CR 50A	7	130	52	1	**3**	Medium
Laramie	95	CR 136	6	166	50	2	**3**	High
Laramie	137	CR 136	6	166	50	2	**3**	High
Laramie	139	CR 136	7	166	50	2	**3**	High
Laramie	140	CR 136	7	166	50	2	**3**	High
Laramie	141	CR 136	7	166	50	2	**3**	High
Laramie	602	CR 136	4	166	50	2	**3**	Medium
Laramie	737	CR 136	7	166	50	2	**3**	High
Laramie	738	CR 136	7	166	50	2	**3**	High
Laramie	739	CR 136	8	166	50	2	**3**	High
Laramie	742	CR 136	4	166	50	2	**3**	High
Laramie	743	CR 136	7	166	50	2	**3**	High
Goshen	1195	CR 60A	8	186	41	2	**3**	High
Goshen	1196	CR 60A	8	186	41	2	**3**	High
Laramie	96	CR 222	6	195	37	3	**3**	High
Laramie	941	CR 222	7	195	37	3	**3**	High
Laramie	601	CR 222	6	118	30	3	**3**	Medium
Laramie	942	CR 222	7	118	30	3	**3**	High
Laramie	943	CR 222	7	118	30	3	**3**	Medium
Converse	3090	Walker Creek Road	8	154	28	1	**3**	High
Converse	3091	Walker Creek Road	7	154	28	1	**3**	High
Converse	3092	Walker Creek Road	7	154	28	1	**3**	High
Converse	3093	Walker Creek Road	8	154	28	1	**3**	High
Goshen	1015	CR 58A	8	108	26	2	**3**	Medium
Laramie	143	CR 210	9	108	22	0	**3**	Medium

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Laramie	144	CR 162	9	108	22	0	**3**	Medium
Laramie	899	CR 210	6	108	22	0	**3**	High
Converse	3060	55 Ranch Road	6	380	21	3	**3**	Very High
Converse	3061	55 Ranch Road	7	380	21	3	**3**	Very High
Laramie	147	CR 203	8	62	14	6	**3**	High
Laramie	150	CR 203	8	62	14	6	**3**	Medium
Laramie	155	CR 203	8	62	14	6	**3**	Medium
Laramie	174	CR 203	7	62	14	6	**3**	Medium
Laramie	175	CR 203	8	62	14	6	**3**	Medium
Laramie	875	CR 203	8	62	14	6	**3**	Medium
Laramie	92	CR 142	8	65	13	8	**3**	Medium
Laramie	110	CR 142	7	65	13	8	**3**	Medium
Laramie	111	CR 142	7	65	13	8	**3**	Medium
Laramie	112	CR 142	7	65	13	8	**3**	Medium
Laramie	113	CR 142	7	65	13	8	**3**	Medium
Laramie	762	CR 142	7	65	13	8	**3**	Medium
Laramie	763	CR 142	7	65	13	8	**3**	Medium
Goshen	1020	CR 1A/South County	7	61	12	6	**3**	Medium
Converse	3054	Orpha Road CR 28	7	69	11	7	**3**	Medium
Converse	3055	Tank Farm Road	6	69	11	8	**3**	Medium
Converse	3056	Tank Farm Road	7	69	11	8	**3**	Medium
Converse	3052	Inez Road	6	37	10	10	**3**	Medium
Converse	3053	Inez Road	7	37	10	10	**3**	Medium
Converse	3120	Dickau Road	7	57	28	0	**4**	Medium
Converse	3121	Dickau Road	7	57	28	0	**4**	Medium
Goshen	32	CR 70A	8	75	24	2	**4**	Medium
Goshen	1004	CR 70A/RD 98W	3	75	24	2	**4**	Medium
Converse	3108	Flat Top Road	7	60	19	1	**4**	High
Converse	3109	Flat Top Road	8	60	19	1	**4**	High
Converse	3110	Flat Top Road	8	60	19	1	**4**	High
Platte	2001	Slater Road	8	103	18	0	**4**	Medium
Platte	2020	Bordeaux Rd	7	85	15	1	**4**	Medium
Platte	2021	Bordeaux Rd	8	85	15	1	**4**	Medium
Converse	3105	Reese Road	8	71	14	2	**4**	Medium
Converse	3107	Pickinpaugh Road	7	71	14	4	**4**	Medium
Converse	3122	Manning Road	6	73	14	5	**4**	Medium
Laramie	172	CR 205	8	62	14	0	**4**	Medium
Laramie	872	CR 205	5	62	14	0	**4**	Medium
Converse	3111	Flat Top Road	7	58	12	1	**4**	High
Converse	3118	Flat Top Road	7	58	12	1	**4**	High
Converse	3119	Flat Top Road	7	58	12	1	**4**	High

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Platte	2121	N COUNTY LINE R	7	61	12	2	**4**	Medium
Laramie	135	CR 214 Durham Rd	8	73	11	4	**4**	Medium
Laramie	136	CR 214 Durham Rd	6	73	11	4	**4**	Medium
Laramie	914	CR 214	6	73	11	4	**4**	Medium
Goshen	750	CR 44A	7	56	10	2	**4**	Medium
Goshen	1007	CR 13C	6	44	28	1	**5**	Low
Goshen	1187	CR 13C	6	44	28	1	**5**	Low
Goshen	1188	CR 13C	7	44	28	1	**5**	Low
Goshen	1009	CR 68B	6	24	24	1	**5**	Low
Goshen	1010	CR 68B	7	24	24	1	**5**	Low
Goshen	1011	CR 68C	7	24	24	0	**5**	Low
Goshen	1012	CR 68C	8	24	24	0	**5**	Low
Goshen	1013	CR 68C	8	24	24	0	**5**	Low
Laramie	935	CR 220	8	113	5	1	**5**	Medium
Converse	3077	Dull Center Road	7	59	9	1	**6**	Medium
Converse	3078	Dull Center Road	7	59	9	1	**6**	Medium
Converse	3079	Dull Center Road	8	59	9	1	**6**	Medium
Converse	3081	Dull Center Road	8	59	9	1	**6**	Medium
Converse	3082	Dull Center Road	8	59	9	1	**6**	Medium
Converse	3083	Dull Center Road	7	59	9	1	**6**	Medium
Converse	3084	Dull Center Road	6	59	9	1	**6**	Medium
Converse	3085	Dull Center Road	7	59	9	1	**6**	Medium
Platte	2019	Brittany Rd	7	17	8	0	**6**	Low
Converse	3123	Manning Road	7	42	7	5	**6**	Medium
Converse	3124	Manning Road	7	42	7	5	**6**	Medium
Goshen	1185	CR 66A	7	26	7	2	**6**	Low
Goshen	734	CR 66A	7	26	7	2	**6**	Medium
Laramie	70	CR 143	7	43	7	0	**6**	Medium
Laramie	91	CR 142	7	43	7	8	**6**	Low
Laramie	171	CR 140	7	61	7	7	**6**	Medium
Laramie	173	CR 141	7	61	7	0	**6**	Medium
Laramie	764	CR 142	6	43	7	8	**6**	Medium
Laramie	770	CR 143	7	43	7	0	**6**	Medium
Laramie	771	CR 143	8	43	7	0	**6**	Low
Laramie	871	CR 140	8	61	7	7	**6**	Medium
Laramie	873	CR 141	7	61	7	0	**6**	Medium
Goshen	751	CR 44A	1	46	6	2	**6**	Medium
Goshen	752	CR 44A	8	46	6	2	**6**	Low
Goshen	757	CR 44A	7	46	6	2	**6**	Low
Platte	2015	Normandy Rd	8	24	6	0	**6**	Low
Platte	2017	Normandy Rd	7	24	6	0	**6**	Low

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Platte	2018	Normandy Rd	8	24	6	0	**6**	Low
Converse	3038	Cole Creek Road	7	47	5	4	**6**	Medium
Converse	3039	Cole Creek Road	7	47	5	4	**6**	Medium
Laramie	44	CR 242 Chalk Hill Rc	5	14	5	2	**6**	Very Low
Laramie	45	CR 242 Chalk Hill Rc	1	14	5	2	**6**	Very Low
Laramie	47	CR 242 Chalk Hill Rc	2	14	5	2	**6**	Very Low
Laramie	48	CR 242 Chalk Hill Rc	4	14	5	2	**6**	Very Low
Laramie	117	CR 219	7	24	5	3	**6**	Medium
Laramie	118	CR 219	7	24	5	3	**6**	Low
Goshen	1143	CR 116/120	7	48	4	1	**6**	Low
Goshen	1144	CR 116/120	7	48	4	1	**6**	Low
Goshen	1141	CR 21E	8	48	4	0	**6**	Medium
Goshen	1142	CR 23E	8	48	4	0	**6**	Medium
Laramie	88	CR 228	8	24	4	1	**6**	Medium
Laramie	89	CR 228	8	24	4	1	**6**	Medium
Laramie	107	CR 124 Pry Rd	5	38	4	2	**6**	Low
Laramie	152	CR 153	7	33	4	4	**6**	Low
Laramie	153	CR 153	6	33	4	4	**6**	Low
Laramie	154	CR 153	8	33	4	4	**6**	Low
Laramie	722	CR 124A	5	38	4	2	**6**	Low
Laramie	973	CR 228	8	24	4	1	**6**	Low
Laramie	974	CR 228	6	24	4	1	**6**	Low
Platte	2009	Gap Rd	7	72	3	1	**6**	Medium
Platte	2010	Gap Rd	6	72	3	1	**6**	Medium
Platte	2011	Gap Rd	8	72	3	1	**6**	Medium
Platte	2012	Gap Rd	8	72	3	1	**6**	Medium
Platte	2013	Gap Rd	7	72	3	1	**6**	Low
Platte	2014	Gap Rd	3	72	3	1	**6**	Low
Laramie	115	CR 220	7	21	3	1	**6**	Low
Laramie	116	CR 220	8	21	3	1	**6**	Low
Laramie	119	CR 221	8	28	3	25	**6**	Low
Laramie	936	CR 220	8	21	3	1	**6**	Medium
Laramie	937	CR 220	8	21	3	1	**6**	Low
Laramie	940	CR 221	7	28	3	25	**6**	Low
Converse	3072	Steinle Road	8	26	2	1	**6**	Medium
Converse	3073	Steinle Road	8	26	2	1	**6**	Medium
Converse	3074	Steinle Road	8	26	2	1	**6**	Medium
Converse	3076	Steinle Road	8	26	2	1	**6**	Medium
Goshen	1126	CR 31E / HARRIS RA	8	21	2	0	**6**	Low
Goshen	1127	CR 31E / HARRIS RA	8	21	2	0	**6**	Medium
Goshen	1002	CR 76A/ Deer Creek	7	64	2	0	**6**	Medium

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Goshen	1003	CR 76A/ Deer Creek	7	64	2	0	**6**	Medium
Goshen	2005	CR 76A/ Deer Creek	7	64	2	0	**6**	Medium
Platte	2112	DICKENSON HILL I	5	16	2	0	**6**	Medium
Laramie	87	CR 139	8	18	2	1	**6**	Medium
Laramie	97	CR 131 Berry Road	5	41	2	2	**6**	Low
Laramie	98	CR 225 Jay Rd	6	41	2	4	**6**	Low
Laramie	99	CR 225 Jay Rd	7	41	2	4	**6**	Low
Laramie	166	CR 146	8	18	2	7	**6**	Low
Laramie	420	CR 139	7	18	2	1	**6**	Low
Laramie	605	CR 139	8	18	2	1	**6**	Low
Laramie	606	CR 139	7	18	2	1	**6**	Low
Laramie	728	CR 131	6	41	2	2	**6**	Low
Laramie	748	CR 139	8	18	2	1	**6**	Low
Laramie	749	CR 139	8	18	2	1	**6**	Medium
Laramie	958	CR 225	7	41	2	4	**6**	Low
Converse	3058	Tank Farm Road	7	73	1	8	**6**	High
Converse	3059	Tank Farm Road	7	73	1	8	**6**	High
Converse	3086	Cow Creek Road	8	24	1	7	**6**	Medium
Converse	3087	Cow Creek Road	8	24	1	7	**6**	Medium
Converse	3088	Cow Creek Road	8	24	1	7	**6**	Medium
Converse	3125	Twenty Mile Creek F	7	22	1	4	**6**	Medium
Converse	3126	Twenty Mile Creek F	7	22	1	4	**6**	Medium
Converse	3127	Twenty Mile Creek F	7	22	1	4	**6**	Medium
Converse	3128	Twenty Mile Creek F	8	22	1	4	**6**	Medium
Goshen	1176	CR 15E	8	18	1	0	**6**	Low
Goshen	1177	CR 15E	6	18	1	0	**6**	Low
Laramie	80	CR 238 Moffet Rd	6	25	1	0	**6**	Low
Laramie	100	CR 128 Indian Hill R	7	62	1	4	**6**	Medium
Laramie	101	CR 128 Indian Hill R	7	62	1	4	**6**	Medium
Laramie	102	CR 128 Indian Hill R	5	62	1	4	**6**	Medium
Laramie	103	CR 128 Indian Hill R	7	62	1	4	**6**	Medium
Laramie	104	CR 128 Indian Hill R	6	62	1	4	**6**	Medium
Laramie	105	CR 226 Holmes Roac	7	13	1	2	**6**	Very Low
Laramie	105	CR 226 Holmes Roac	8	13	1	2	**6**	Very Low
Laramie	106	CR 226 Holmes Roac	7	13	1	2	**6**	Very Low
Laramie	108	CR 224 ATLAS ROA	6	31	1	2	**6**	Medium
Laramie	156	CR 201	8	21	1	8	**6**	Low
Laramie	157	CR 201	7	21	1	8	**6**	Low
Laramie	179	CR 201	2	21	1	8	**6**	Very Low
Laramie	955	CR 224	6	31	1	2	**6**	Medium
Laramie	961	CR 226	8	13	1	2	**6**	Very Low

County Impact Priority - Unpaved Roads								
County	**Segment ID**	**Road Name**	**Ride Quality**	**ADT**	**ADTT**	**Serviceable Rigs/Water Haul Sites**	**Impact Priority**	**Service Level**
Laramie	962	CR 226	7	13	1	2	**6**	Very Low
Converse	3057	Leuenberger Road	6	21	0	3	**6**	Medium
Goshen	1001	CR 22A	4	24	0	0	**6**	Low
Goshen	1263	CR 22A	7	24	0	0	**6**	Low
Goshen	1248	CR 27A	8	8	0	0	**6**	Low
Goshen	1241	CR 29B	8	20	0	1	**6**	Medium
Goshen	1250	CR 31A	5	8	0	0	**6**	Low
Goshen	1249	CR 32B	8	8	0	0	**6**	Low
Goshen	1247	CR 38A	8	16	0	0	**6**	Medium
Goshen	1238	CR 48A	6	20	0	1	**6**	Medium
Laramie	14	CR 245 Marsh Road	7	3	0	0	**6**	None
Laramie	15	CR 245 Marsh Road	3	3	0	0	**6**	None
Laramie	16	CR 123	7	37	0	1	**6**	Low
Laramie	56	CR 237 BRISTOL RI	7	31	0	0	**6**	Low
Laramie	78	CR 237 BRISTOL RI	2	31	0	0	**6**	Very Low
Laramie	79	CR 237 BRISTOL RI	6	31	0	0	**6**	Low
Laramie	82	CR 131	6	4	0	2	**6**	None
Laramie	451	CR 235	8	4	0	0	**6**	None
Laramie	721	CR 123 LITTLE BE	8	37	0	1	**6**	Medium
Laramie	729	CR 131	7	4	0	2	**6**	None
Laramie	928	CR 218	7	17	0	0	**6**	Low
Laramie	990	CR 235	8	4	0	0	**6**	None
Laramie	997	CR 237 BRISTOL RI	8	31	0	0	**6**	Low
Laramie	998	CR 237 BRISTOL RI	7	31	0	0	**6**	Medium
Laramie	4018	CR 245 BEAR CREE	7	3	0	0	**6**	None

APPENDIX I. MAINTENANCE DECISION MATRIX

	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

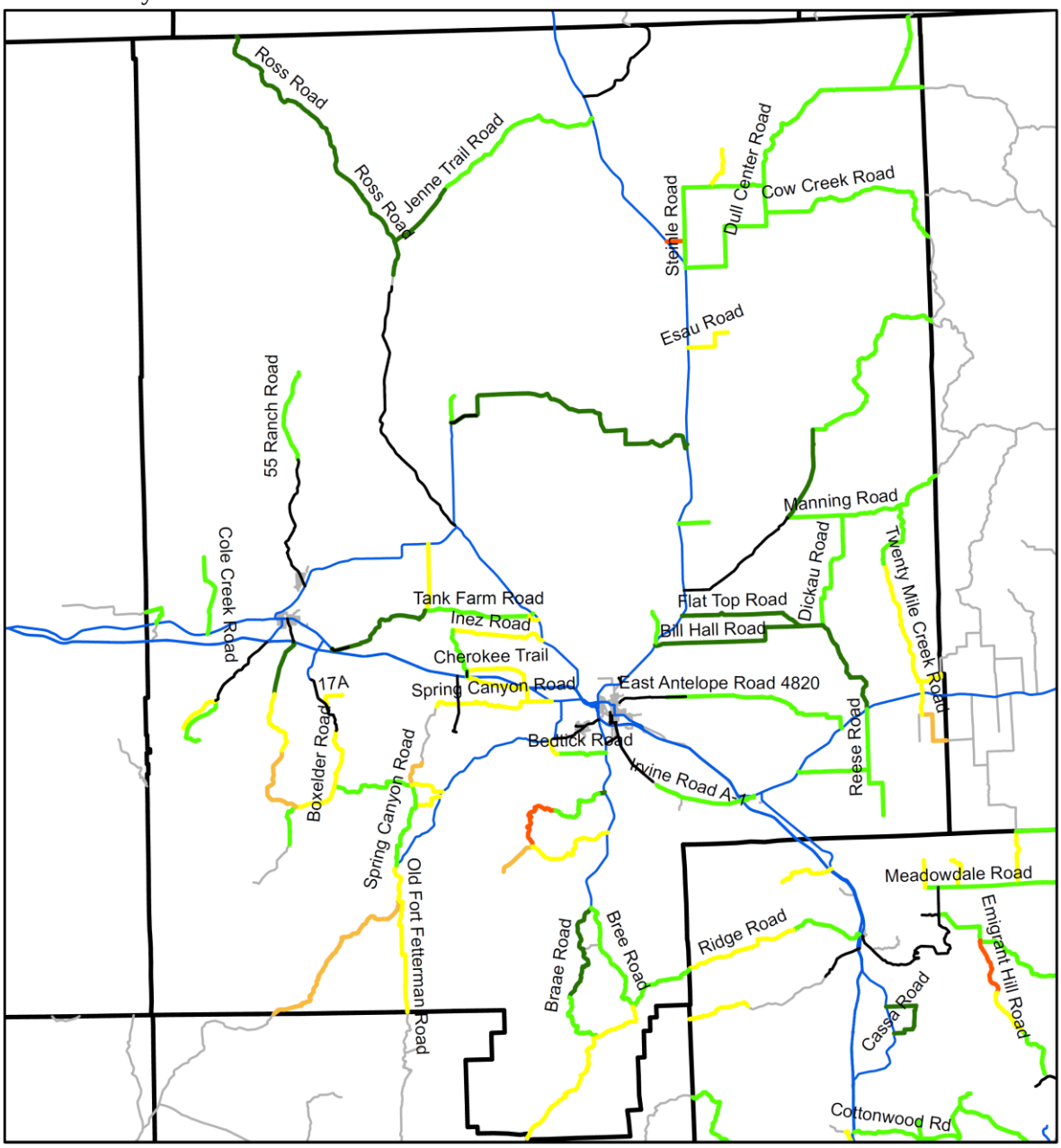
* N-None; LB-Light Blading; HB-Heavy Blading; TG-Treat Gravel; DR-Minor Drainage Repair; RG-Regravel; RC-Reconstruct

	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

APPENDIX J. SERVICE LEVEL AND TOP WIDTH MAPS

Converse County Road Widths

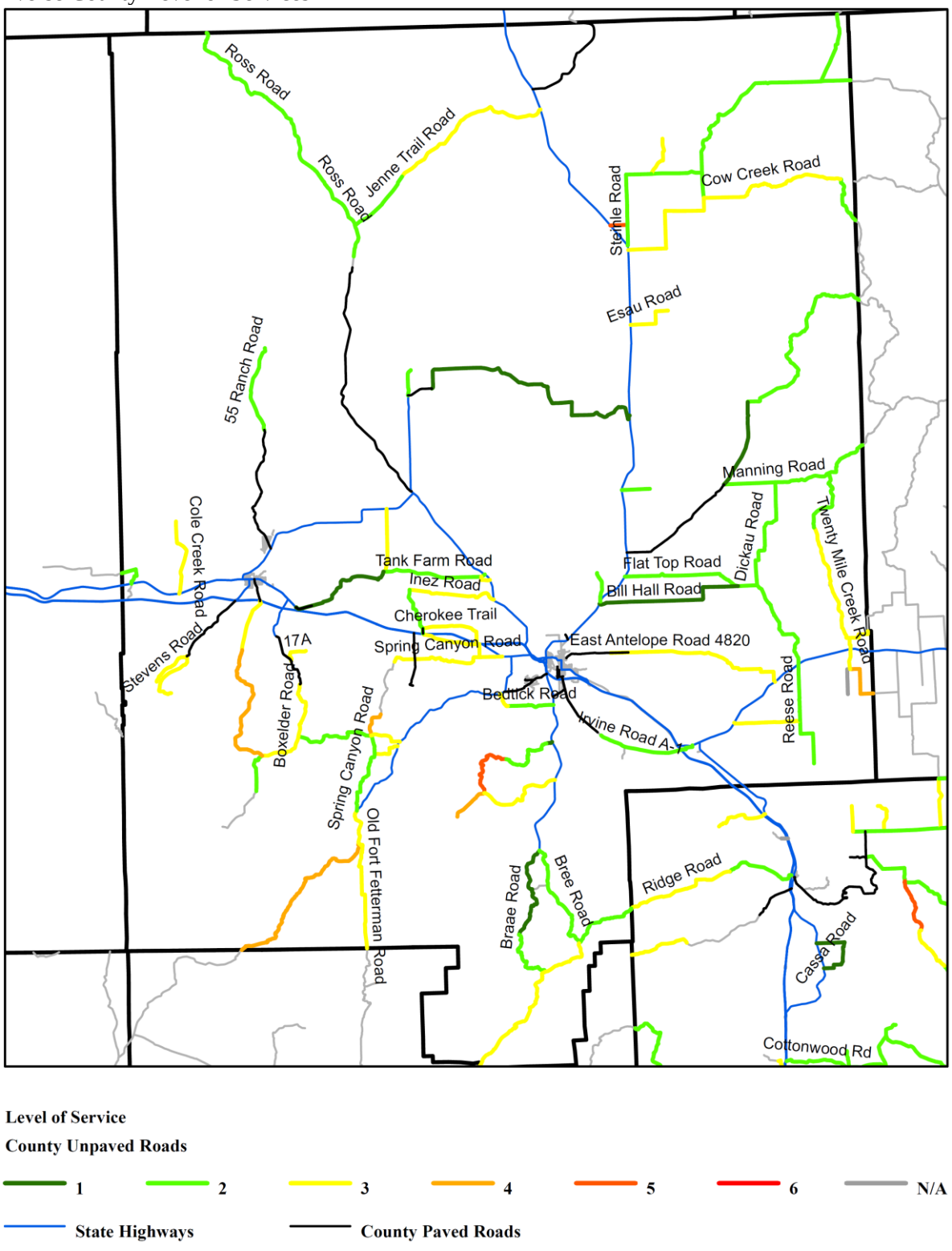


Road Width

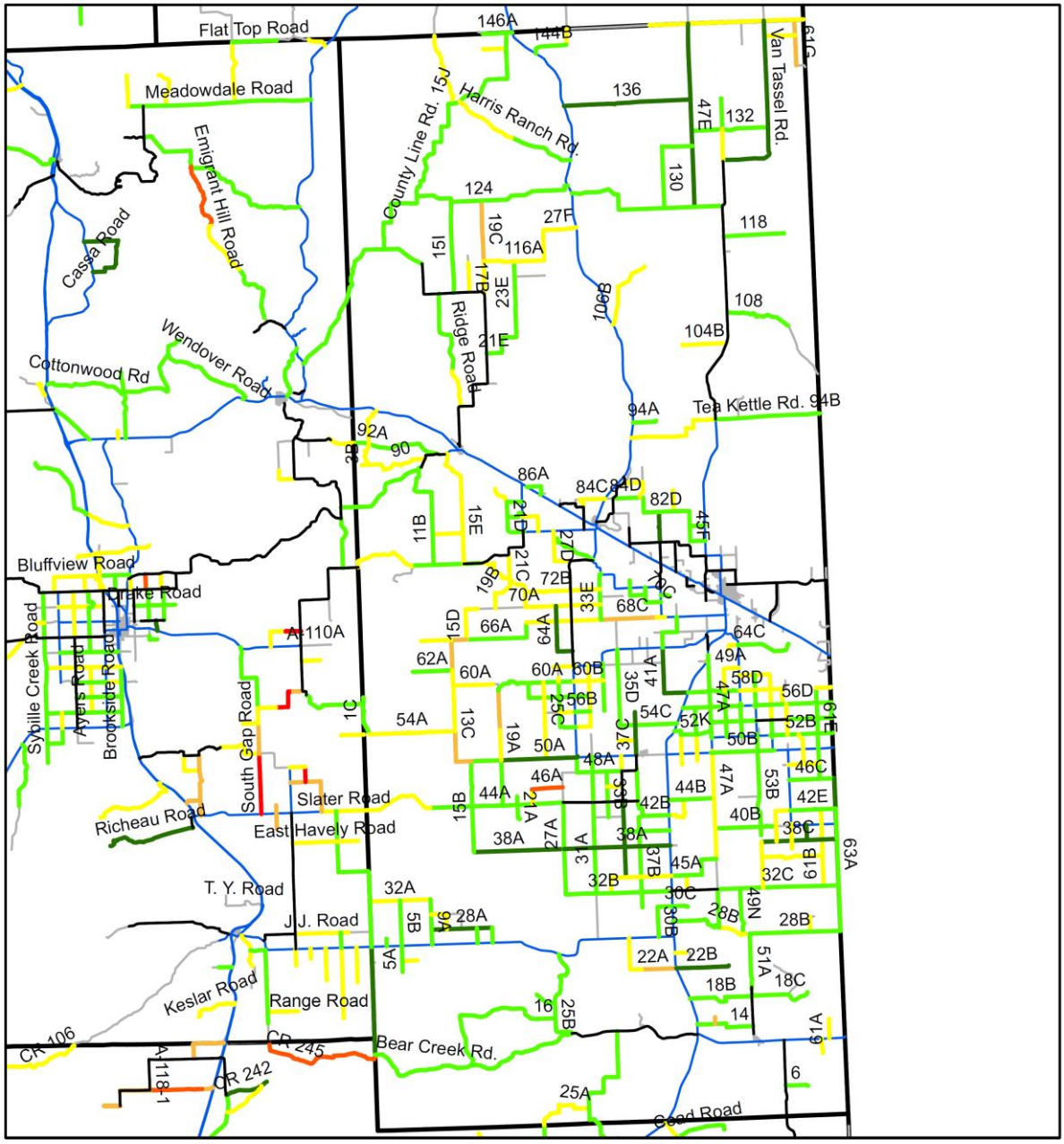
County Unpaved Roads

- **More than 28 feet**
- **23 - 27.5 feet**
- **18 - 22.5 feet**
- **13 - 17.5 feet**
- **9 - 12.5 feet**
- **Less than 8.5 feet**
- **State Highways**
- **County Paved Roads**

Converse County Level of Services



Goshen County Road Widths



Road Width

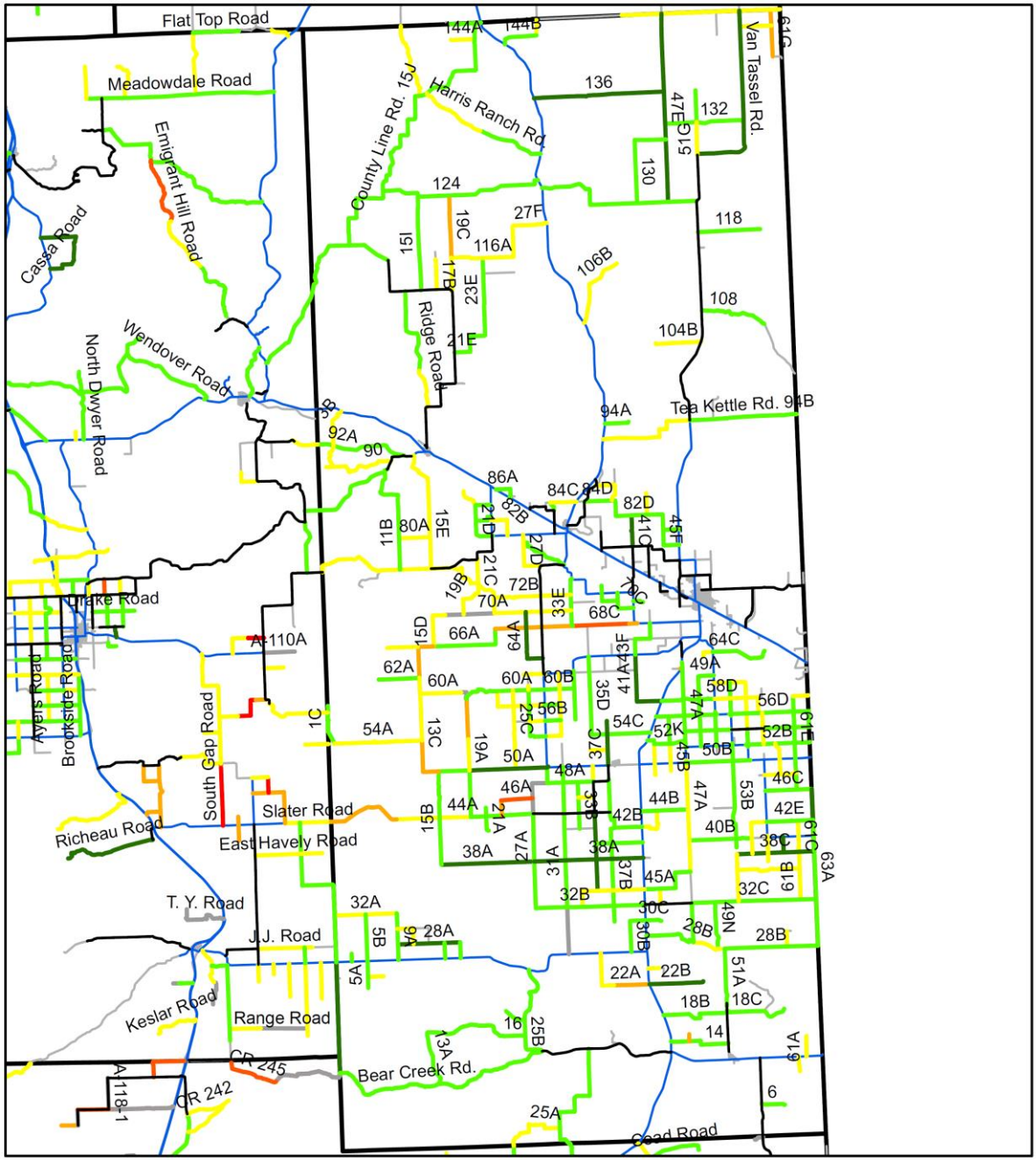
County Unpaved Roads

More than 28 feet | **23 - 27.5 feet** | **18 - 22.5 feet**

13 - 17.5 feet | **9 - 12.5 feet** | **Less than 8.5 feet**

State Highways | **County Paved Roads**

Goshen County Level of Services



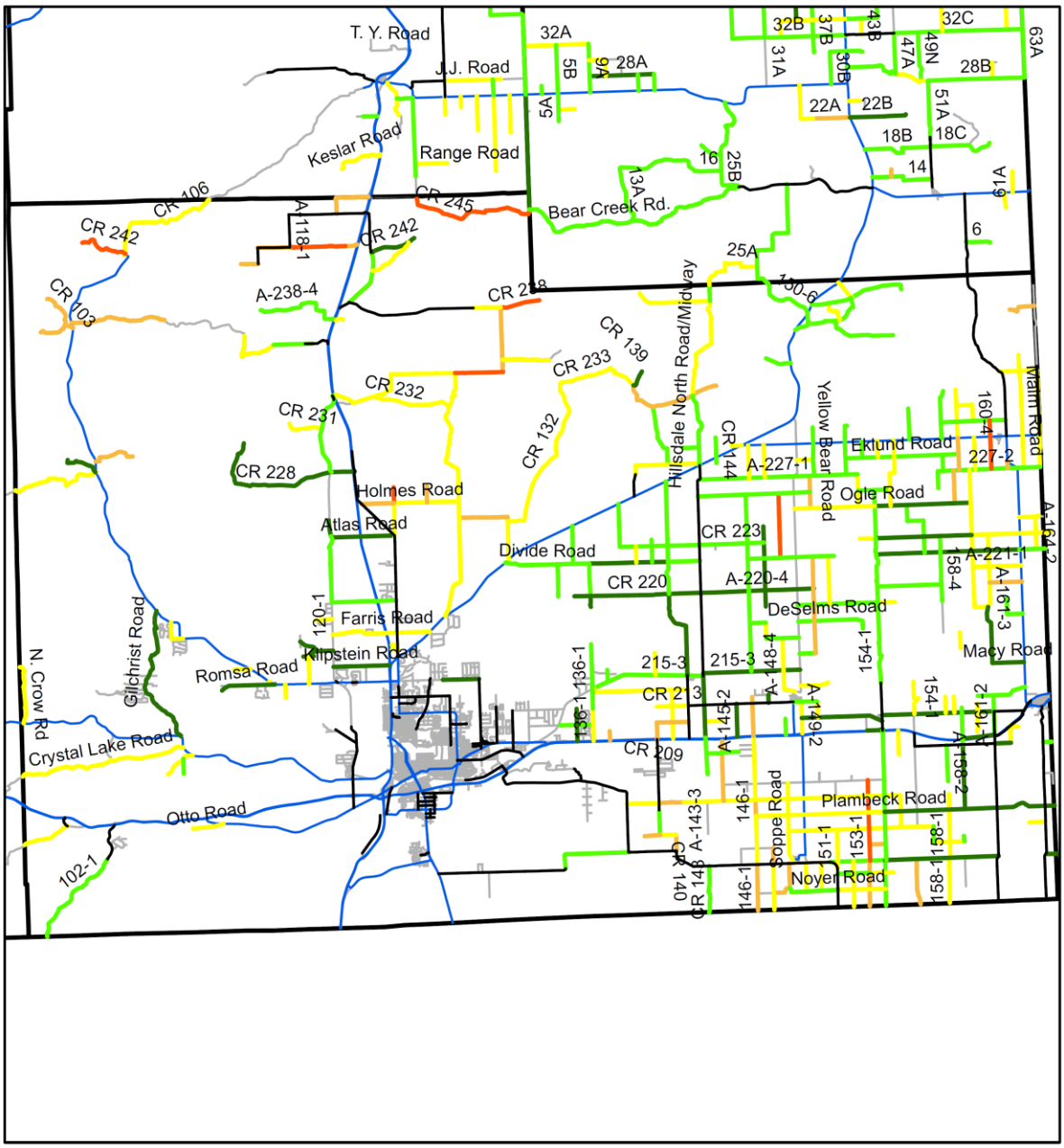
Level of Service

County Unpaved Roads

1 2 3 4 5 6 N/A

State Highways **County Paved Roads**

Laramie County Road Widths

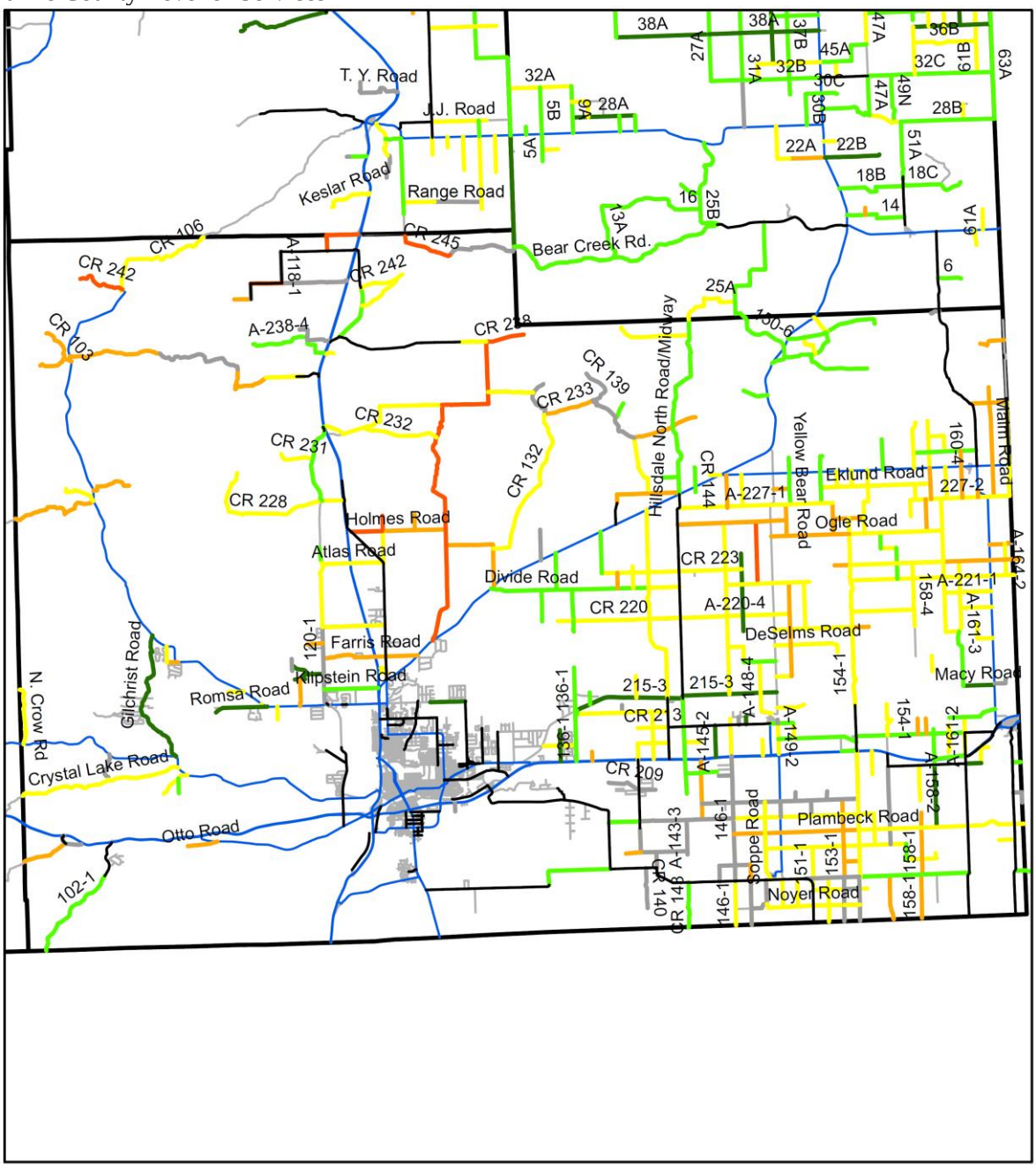


Road Width

County Unpaved Roads

- **More than 28 feet**
- **23 - 27.5 feet**
- **18 - 22.5 feet**
- **13 - 17.5 feet**
- **9 - 12.5 feet**
- **Less than 8.5 feet**
- **State Highways**
- **County Paved Roads**

Laramie County Level of Services



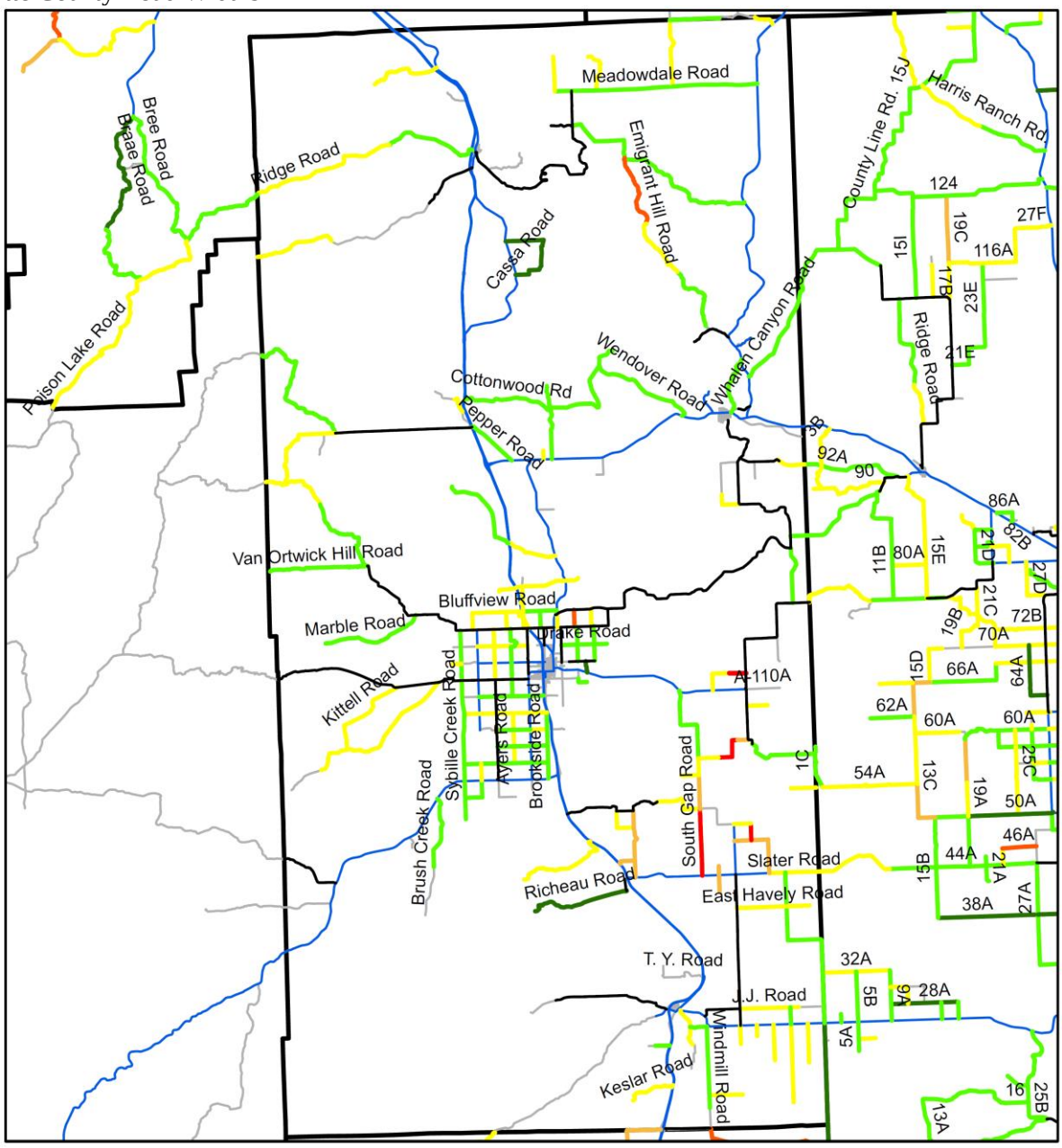
Level of Service

County Unpaved Roads

1 **2** **3** **4** **5** **6** **N/A**

State Highways **County Paved Roads**

Platte County Road Widths

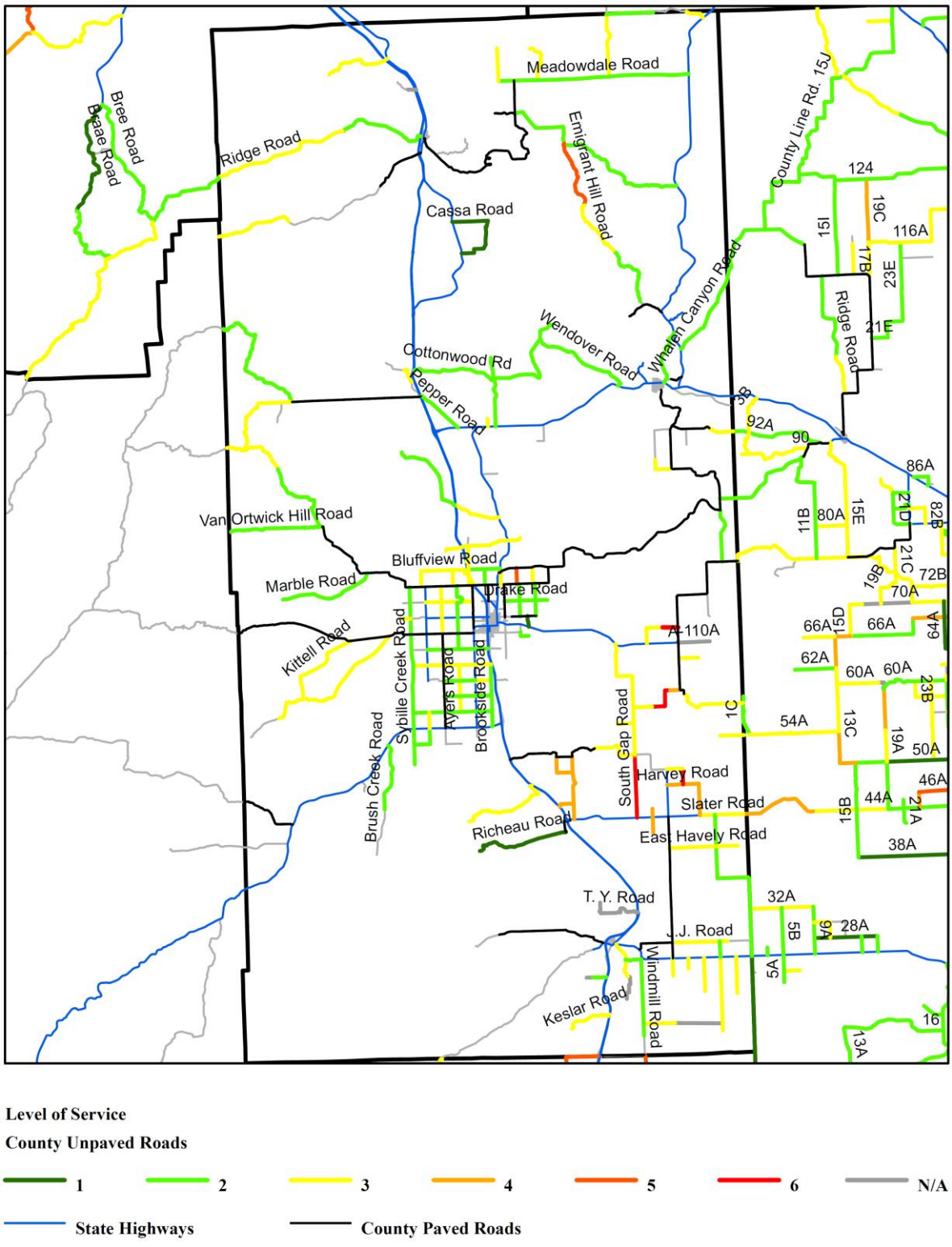


Road Width

County Unpaved Roads

- **More than 28 feet**
- **23 - 27.5 feet**
- **18 - 22.5 feet**
- **13 - 17.5 feet**
- **9 - 12.5 feet**
- **Less than 8.5 feet**
- **State Highways**
- **County Paved Roads**

Platte County Level of Services



Level of Service

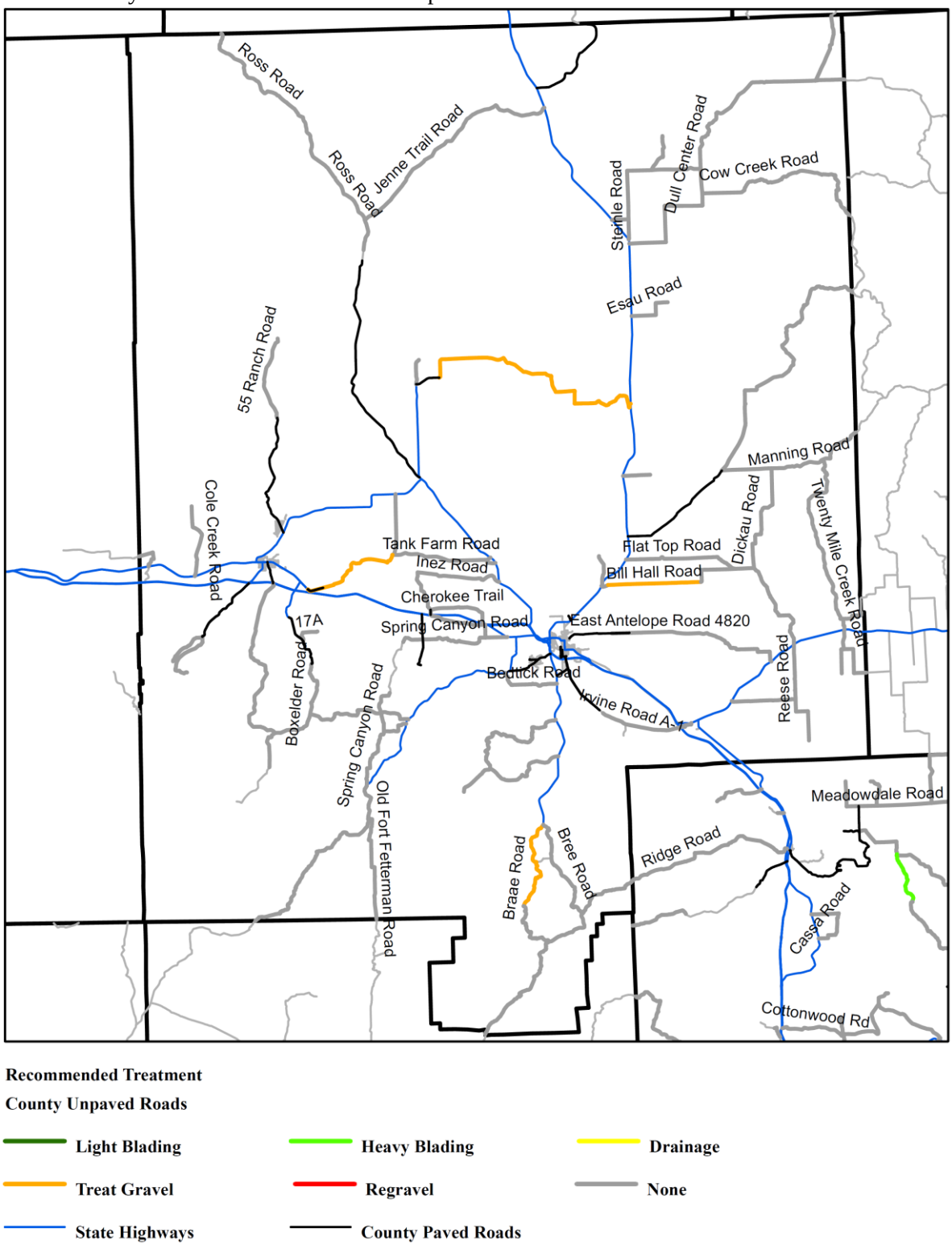
County Unpaved Roads

1 **2** **3** **4** **5** **6** **N/A**

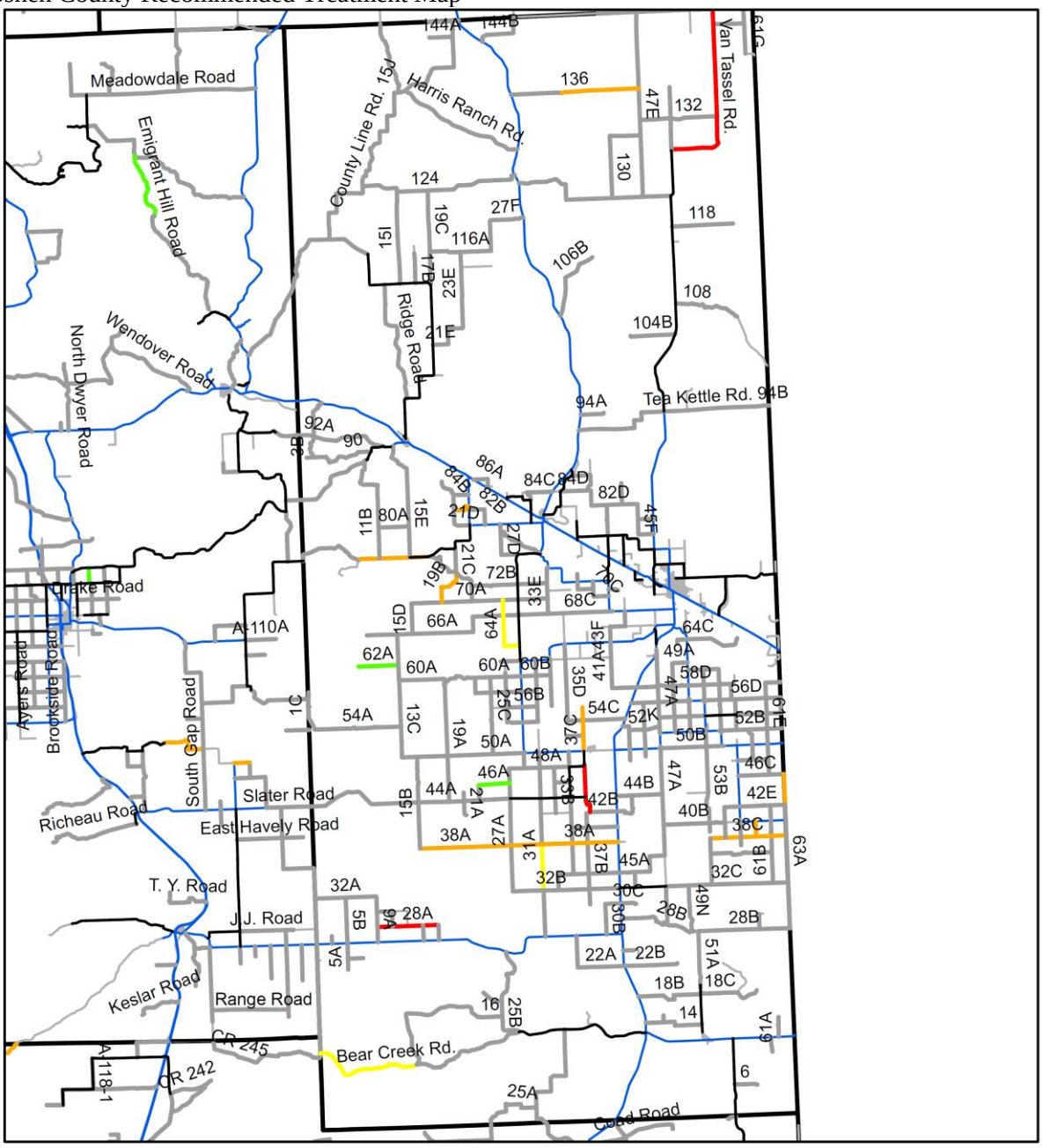
State Highways **County Paved Roads**

APPENDIX K. RECOMMENDED TREATMENT MAPS

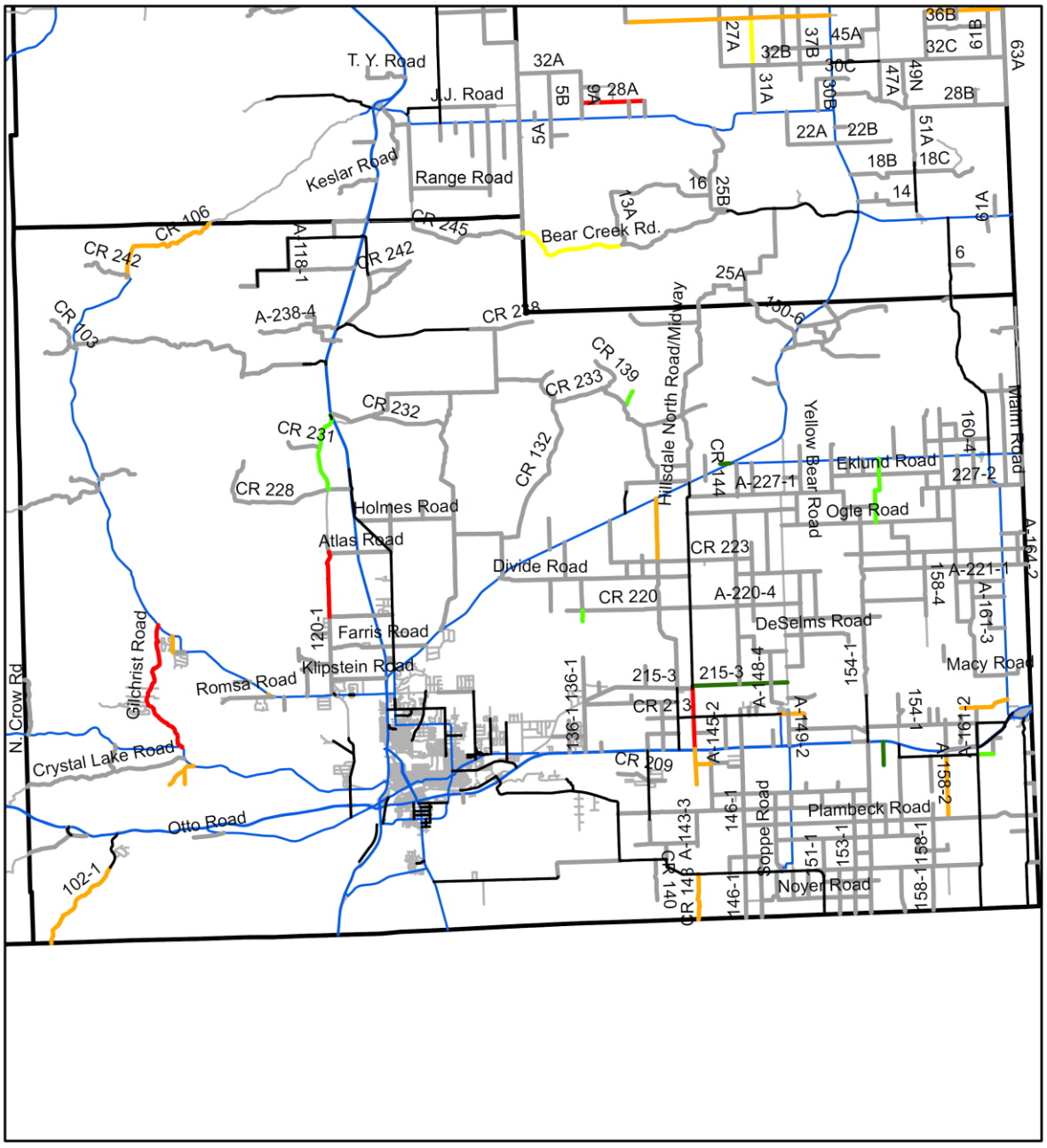
Converse County Recommended Treatment Map



Goshen County Recommended Treatment Map



Laramie County Recommended Treatment Map

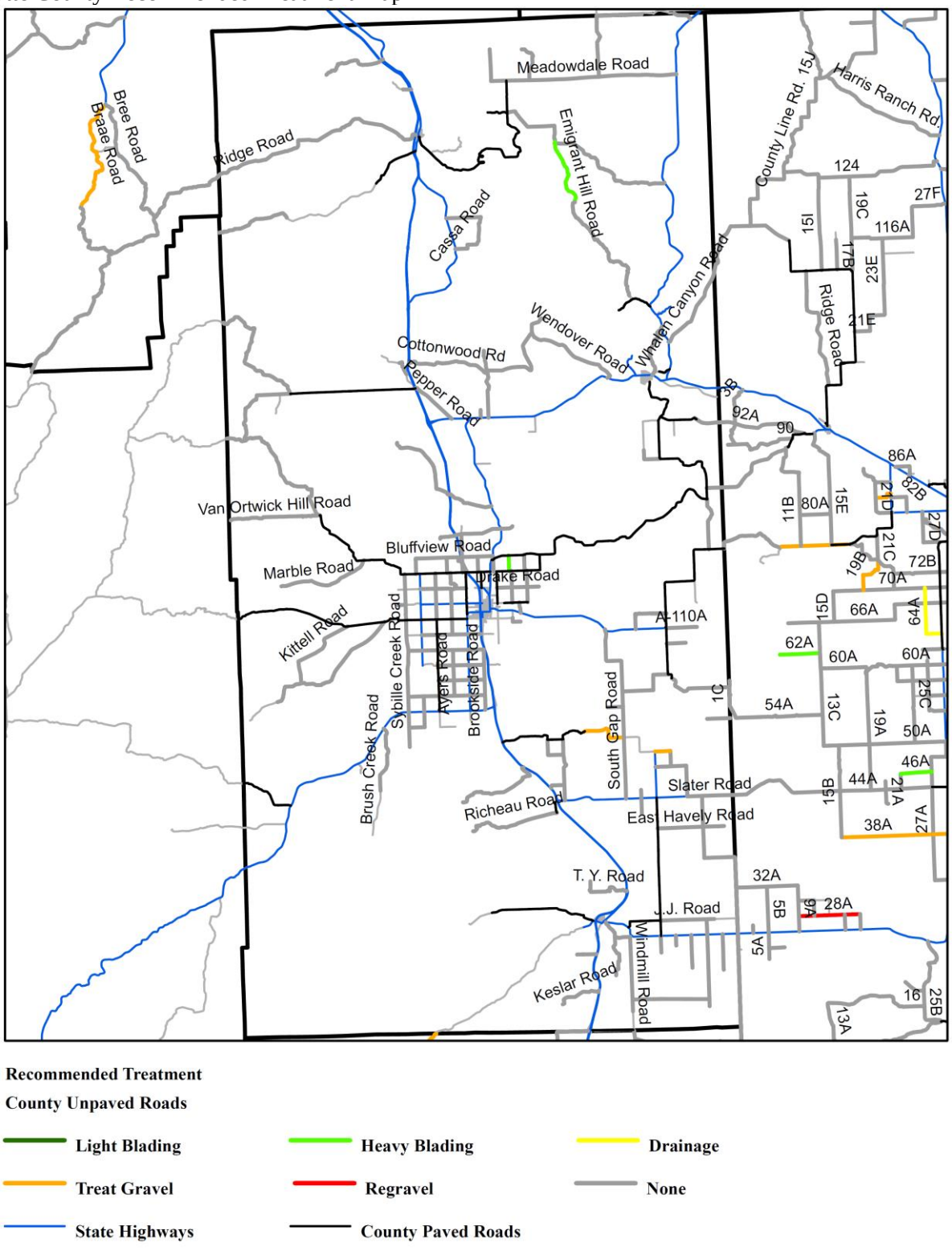


Recommended Treatment

County Unpaved Roads

- **Light Blading**
- **Heavy Blading**
- **Drainage**
- **Treat Gravel**
- **Regravel**
- **None**
- **State Highways**
- **County Paved Roads**

Platte County Recommended Treatment Map



Recommended Treatment

County Unpaved Roads

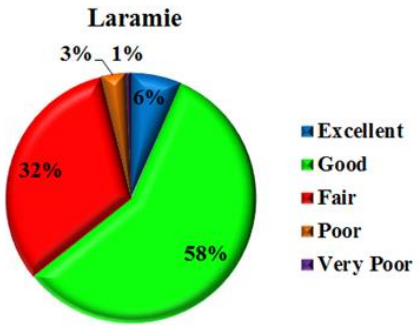
Light Blading **Heavy Blading** **Drainage**

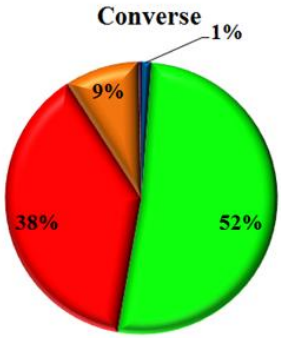
Treat Gravel **Regravel** **None**

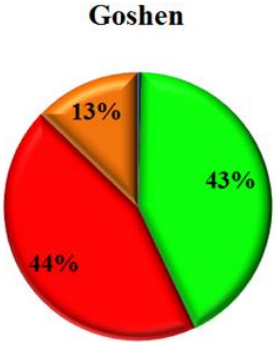
State Highways **County Paved Roads**

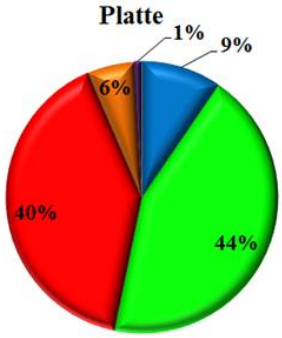
APPENDIX L. CATTLEGUARD CONDITION CHARTS

Approach Condition

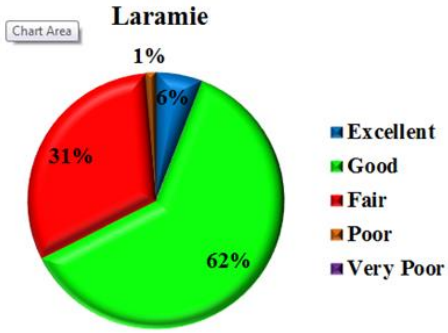


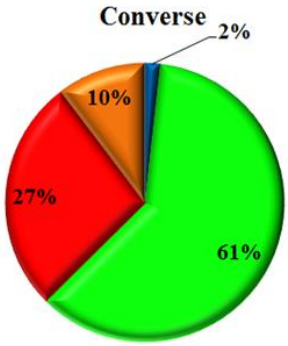


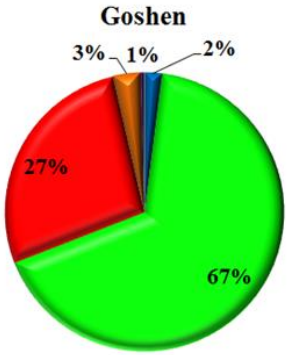


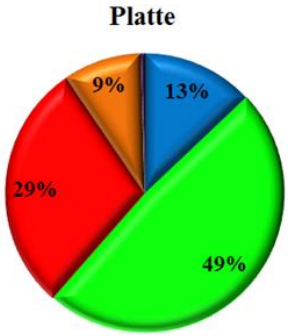


Base Condition

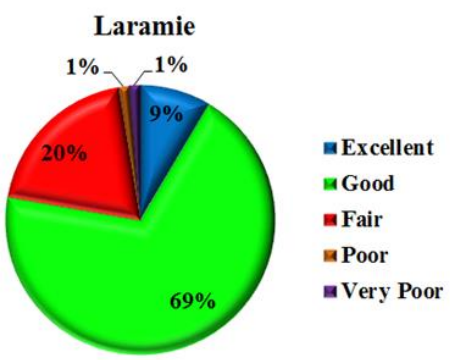


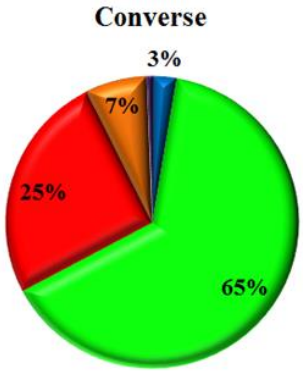


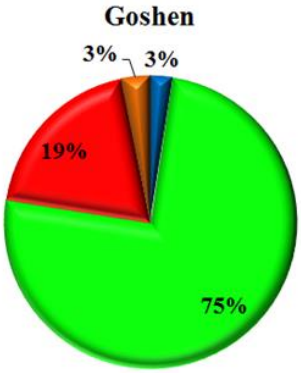


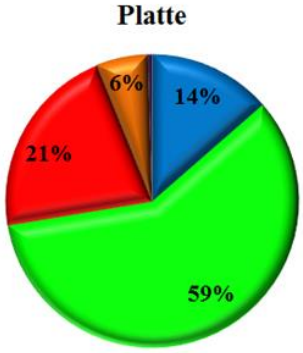


Grate Condition

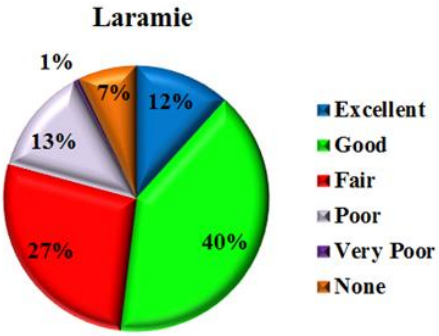


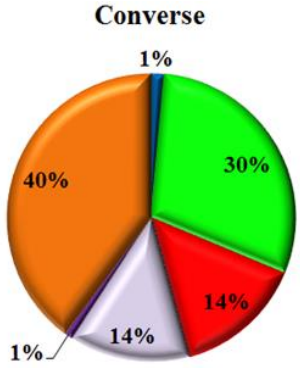


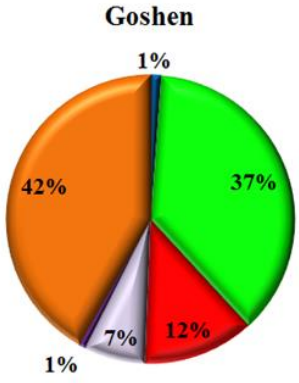


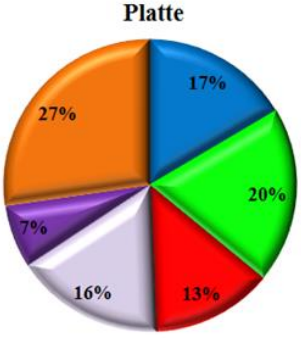


Wing Condition









APPENDIX M. PERMIT QUESTIONNAIRE

County Survey

County: _____ **Conducting Survey:_____**

County Contact: _____

Phone: _____

E-mail: _____

Purpose

Earlier in September the Wyoming Association of County Engineers and Road Supervisors (WACERS) held a meeting in Jackson Hole. At the meeting, present members decided that a uniform permitting process should be developed and implemented across all of Wyoming. This system would ease the implementation process for counties and simplify paper work and compliance for companies doing business in Wyoming. The purpose of this survey is to acquire information regarding each County's current permitting system. A standard system would then be developed and approved by WACERS and the Wyoming County Commissioners Association (WCCA).

General Question

What kind of permits does your county have for the truck traffic associated with the oil and gas industry?

Thoughts and Opinions

Approach/Encroachment/Access Permits

Descriptions of Permits:

Approach: A permit allowing construction or alteration of a private driveway, approach road or other facility that provides ingress to or egress from a Public road.

Access: A permit required for any access on any county maintained or publicly dedicated right-of-way.

Does your county currently have an Access Permitting process?

☐ Yes ☐ No

Would your county be willing to email, mail, or give us access and information to their Access Permit forms, and the associated rules and regulations, fees and processes?

☐ Yes ☐ No

What fees are associated with your county's Access permits?

What are the basic rules, regulations and specifications associated with your county's Access permits?

Does your county keep updated records and data regarding Access Permits?

☐ Yes ☐ No

Additional Notes:

Road Use Agreement (RUA)

Description of Permit:
A permit binding companies to provide repair of any County Roads subjected to damage or degradation caused by frequent or repetitive traversing of heavy vehicles.

Does your county currently have a RUA Permitting process?

☐ Yes ☐ No

Would your county be willing to email, mail, or give us access and information to their C/M Permit forms, and the associated rules and regulations, fees and processes?

☐ Yes ☐ No

What fees are associated with your county's RUA permits?

What are the basic rules, regulations and specifications associated with your county's RUA permits?

How does your county determine the severity and type of damage associated with the RUA permit and how is the cost then determined from this?

Does your county keep updated records and data regarding RUA Permits?

☐ Yes ☐ No

Additional Notes:

Oversize/Overweight Permits

Description of Permit:

A permit for a load that exceeds the standard or ordinary legal size and/or weight limits for a specified portion of road, highway or other transport infrastructure.

Does your county currently have an Oversize/Overweight Permitting process?

☐ Yes ☐ No

Would your county be willing to email, mail, or give us access and information to their Oversize/Overweight Permit forms, and the associated rules and regulations, fees and processes?

☐ Yes ☐ No

What fees are associated with your county's Oversize/Overweight permits?

What are the basic rules, regulations and specifications associated with your county's Oversize/Overweight permits?

What are the size limitations associated with your county's Oversize/Overweight permits?

Does your county keep updated records and data regarding Oversize/Overweight Permits?

☐ Yes ☐ No

Additional Notes:

Haul Route Assessments

Description of Permit:

A permit required to identify the route of the load when commercial hauling activities are identified as likely to cause extraordinary damage or accelerated damage to county roads.

In addition to the oversize/overweight permit, does your county currently have a Haul Route Assessment determining the route the load will take through the county?

☐ Yes ☐ No

Would your county be willing to email, mail, or give us access and information to their Haul Route Assessment forms, and the associated rules and regulations, fees and processes?

☐ Yes ☐ No

What fees are associated with your county's Haul Route Assessments?

What are the basic rules, regulations and specifications associated with your county's Haul Route Assessments?

Does your county keep updated records and data regarding Haul Route Assessments?

☐ Yes ☐ No

Additional Notes:

Additional Questions

Does your county have any other permitting processes not stated above in regards to county roads?

☐ Yes ☐ No

If so, please explain:

Additional Notes:

APPENDIX N. QUESTIONS FROM THE WHP

On March 7, 2012, a meeting with WYDOT and the Wyoming Highway Patrol was held to gain a better understanding of what their procedures and permits were in regard to the trucking industry. Certain questions were asked to better determine what is done with truck permitting. These questions and the responses are as follows:

- What is the process, and what forms do WYDOT use when issuing oversize/overweight permits?

The vast majority of our permits are issued at our Ports of Entry. The carrier must first contact the port and get authorization to come to that location to obtain the permit, this takes approximately 2 minutes. When the driver reaches the location the vehicle is weighted and it is confirmed that the vehicle qualifies for a permit, is a non-divisible. The driver parks and brings in the paper work for the transport vehicle(s) and load. If the carrier and vehicle are properly qualified the information is entered into the Port of Entry Permit System (PEPS) which figures the fees due according to sizes, axle configurations and axle weights, and prints the permit. Providing the load is not restricted by construction or structures, this takes approximately 3 minutes. For loads which must be routed around construction and/or structures this may take up to 30 minutes. Hand written permits on the A-67A form may take up to 30 addition minutes over what it takes to have (PEPS) figure the fees, this is dependent on the sizes and number of calculations that must be performed to determine the amount the vehicle is overweight. If the vehicle will not be going by one of our permit issuing locations or is not able to have a Trooper issue the permit the carrier may fax the required information to one of the ports and we will fax them a permit. Information required for all permits: Carrier information making the move, USDOT #, WY Docket # or company name; Power unit and trailer plate #; Type of configuration; Commodity; Origin and destination; Highways that will be used; number of miles traveled on State highways; class of permit being issued; Date(s) the permit is valid for. Information required for oversize permits: Overall length, single vehicle length, width and height. Information required for overweight permits: Axle weights and axle spacing's. All permits have the basic safety requirements and responsibilities on them, additional requirements are added when required (Smith 2012).

- Approximately how long does it take to complete the paper work for an oversize/overweight permit?

ABOVE, additionally, to determine a route due to the exceptional size and/or if the load requires a bridge analysis, loads which go through the Overweigh Loads Office may take up to 3 days before the carrier receives authorization to obtain a permit (Smith 2012).

- There seems to be a misconception that when the state denies an oversize/overweight permit, the denied load still travels, but on local roads. Do you believe this is avalid statement?

No it is not a misconception, I know that some of the time, if we deny travel to a carrier or they just know we will not allow it, they will go out of their way to make a move which includes using non-State highways (Smith 2012).

- Who approves these permits, and what are the reasons for not approving a permit?

Port of Entry officers, Highway Shop permit issuers and Troopers may issue permits up to specific limits. If these limits are exceeded the load must be approved through the Overweight loads Office. The most common reasons we do not issue a permit are the load is divisible, too heavy or the size is too great (Smith 2012).

- Can you answer the same questions above for Road Use Agreements or any other permits issued by WYDOT?

I have not heard of a Road Use Agreements. Other permits we issue are: Registration, fuel, transporter, private demo, dealer demo, mobile machinery decals and radioactive. The process is primarily the same as the oversize/overweight permits except the carrier does not have to receive authorization to proceed to the location. These permits may be issued in conjunction with an oversize/overweight permit. It takes approximately 2 minutes to issue one of these permits (Smith 2012).

APPENDIX O. STANDARD PERMITS

Appendix O1 Standard Access Permit

County Road Department
Application/Permit to Construct Access Driveway

DATE OF APPLICATION: _____

The UNDERSIGNED hereby makes application for permission to construct an access driveway (s) as described below and as shown on the AITACHED SKETCH OR PLAN "hereby made part of the application".

The UNDERSIGNED also agrees to abide by the terms of the attached permit agreement.

Name: _____ Address: _____
Firm Name: _____ Signature:
_____
Address _____
City _____ State_____ Zip Code_____

Location of Property

Road #/(or name)_____, Approximately_____miles from_____

(City or well defined point)

Township _____North Range_____ West Section_____

This license is granted for and in consideration of the following:

1. A seventy-five dollar ($75.00) processing fee, in hand paid by the Licensee to the Board of County Commissioners on the date of signing of this license; Receipt hereof is hereby acknowledged.

2. Thirty-two and 50/100 dollars ($32.50) per hour inspection fee to be paid by the Licensee to the county on or before the date of completion of the said access. (Number of hours to be determined by the appropriate department of the county.)

This license is granted upon such express terms and conditions as are inserted below, and should the Licensee at any time violate any of the said terms or conditions herein contained or use or attempt to use said facility for any other or different purpose than that above specified, or refuse or fail to comply with any rule or direction of the County Highway Superintendent, under his general supervisory powers of control and supervision of county highways for the use and safety of the general public, then the Board may, at its opinion, immediately revoke this license. The foregoing license is subject to the following conditions and specifications:

- The work on constructing, altering and maintaining of the Facility shall be prosecuted and completed in a good and workmanlike manner, using acceptable materials and at the sole expense of the Licensee and under the supervision of, and to the satisfaction of, the county. Such work of construction, alteration and maintenance of the Facility shall be done in such a manner as to in no way interfere with use, operation and maintenance by the county of a county highway for county highway purposes and in no such manners as to in no way endanger the general public in its use of said county highway right-of-way. Additionally the Licensee agrees to the standards for traffic control as outlined in the “Wyoming State Highway Traffic Control for Roadway Work Operations” manual and the “Wyoming State Highway Department Utility Accommodation Regulation” manual. Standards developed by the Licensee may be substituted for the cited manual provided they have been approved by the County Road and Bridge superintendent. The

Licensee must cease all operations if he does not comply with traffic control standards. Traffic control plans and road closure plans will be submitted to the County Road and Bridge Superintendent for approval prior to starting any work on the highway right-of-way.

- The right-of-way involved in the access permit shall be cleaned and left in a condition equal to or better than the original condition.
- Profile grade of accesses shall be constructed as indicated on an attached sketch or plan and shall in no case be graded or maintained such that water will drain onto the county road.
- This Permit becomes VOID if construction is not completed within 90 days after the approval date, construction or maintenance work authorized is not commenced within 90 days, or if construction or maintenance work is suspended or abandoned for a period of 30 days at any time after work is commenced.
- The property owner shall furnish all materials necessary for the construction of accesses and all materials shall be subject to inspection and approval by the county.
- No access shall be constructed such that there will be parking or servicing of vehicles on the county road right-of-way.
- The said Licensee hereby assumes all liability for and agrees to pay for all loss of property or damage to property or injury to or death of persons, including all costs and expenses incident thereto, arising wholly or in part from or in connection with the existence of, construction, alteration, maintenance, repair, renewal, reconstruction, operation, use or removal of said access, or any defect therein or failure thereof, causing same or contributing in any manner to the loss of or damage to such property or the injury to or death of any person. The said Licensee shall forever indemnify the county against and save them harmless from all liability for any such loss, damage, injury or death, including the costs and expenses incident thereto.
- The said Licensee shall give to the county at least ten days' notice, in writing, before entering upon the county highway right-of-way for the purpose of construction or alteration of the access or to make necessary repairs, except in case of genuine emergency requiring immediate repair, then in that event, Licensee shall notify the county immediately enter upon the highway right-of-way and make the necessary repairs.
- The county shall have the right at any time to revoke this license by giving thirty (30) days' notice in writing to the said licensee and at the expiration of the time limited by said notice, or upon the express revocation of this license for any of the causes enumerated herein, the Licensee shall promptly and in the manner directed by the county remove said access and each and every part thereof, hereby authorized, from the premises of the county highway right-of-way and leave said premises in the same condition as before the granting of this license, and the said Licensee hereby agrees promptly to pay to the county the cost of said removal for the access, and each of every part thereof.
- The county reserves the right to use, occupy and enjoy its right-of-way for a county highway and for county highway purposes in such manner and at such times as it shall desire, the same as if this instrument had not been executed by it. If any such use shall at any time necessitate any change in the location or manner of the location or manner of use of said access, or any part thereof, such change or alteration shall be made by the licensee, upon the demand of the county shall be liable to the said Licensee on account thereof, or on account of any damage growing out of any use which the county may make of its said right-of-way.
- Location of proposed access shall be clearly indicated on both the permit and the actual site with highly visible markings for the field inspection.

- The County and the Board of County Commissioners hereby disclaim any representation or implication that it retains any title in any County Road Right-of-Way, other than a perpetual easement for the use thereof, and the Permittee, by signing this contract, accepts notice and agrees that any expenses or damages incurred by the Permittee, abandonment, removal, reconstruction or alteration of any County Road by the County shall not vest any cause of action in, nor give any right to recovery therefor to the said Permittee through the abandonment, removal, reconstruction or alteration of any County Road, and any and all expenses or damages incurred by said Permittee through the abandonment, removal, reconstruction or alteration of any County Road, shall be borne by the Permittee.
- The County reserves the right to inspect the installation(s) at the time of construction and at all times thereafter; and to require such changes, maintenance and repairs as may at any time be considered necessary to provide protection of life and property on or adjacent to the roadway.
- The Licensee will be fully responsible for furnishing and installing culverts / drainage structures and driveways in accordance with this policy. After acceptance, applicant will maintain culvert and driveway and perform snow removal.
- Unless otherwise approved by the county, the access shall be level with the road shoulder within the County Right-of-way.
- Any structures will be built according to plans and specifications dated, attached, and made part of this application.
- This license is granted upon such express terms and conditions as are inserted below and should the Licensee at any time violate any of the said terms or conditions herein contained or use or attempt to use said facility or any other or different purpose other than that above specified, or refuse or fail to comply with any rule or direction of the County highway Superintendent, under his general supervisory powers of control and supervision of county highways for the use and safety of the general public, then the Board may, at its opinion, immediately revoke this license.
- When disturbed areas are reseeded, a certified noxious weed seed mixture must be used.
- Approved access permits are required prior to any driveway construction.
- The Applicant shall inform the proper department when the access project is completed for final inspection and approval.
- All ROW fences will be maintained and cattle guards installed where the access passes through the ROW fence. Exceptions are only granted where the road passes through open range.
- All debris, rubbish and surplus materials resulting from work under the terms of this permit shall be removed and disposed of off-site as soon as possible, but in no event, no later than at the completion of construction. The work site shall not be used as a storage area for equipment, debris, rubbish or surplus materials.
- Localized excavations shall be backfilled with granular materials in lifts no greater than 12 inches. Continuous excavations may be backfilled to within 24 inches of the pavement surface with select native materials, free of organic materials, lumps, large stone and frozen material in lifts no greater than 8 inches. All backfill materials shall be thoroughly compacted to at least 95% of the maximum dry density by approved methods. The adequacy of the backfill effort shall be determined by the County Engineer, his agents and assigns, at his sole discretion.
- No fixed obstructions shall be placed within 30 feet of the edge of the county road travel way except for approved mailbox assemblies or fencing at the right-of-way line.
- Residential access drive(s) are not to exceed 24 feet in width; all other access drive(s) are not to exceed 40 feet in width, no access shall have a width less than 16 feet and all cattle guards are to be a minimum of 12 feet in width.

- All driveways and turnouts shall be located so there is minimum horizontal and vertical sight distance of 500 feet in both directions along the county roadway.
- All driveways and turnouts shall be located a minimum of 75 feet from the intersecting right-of-way lines of other roadways.
- All parts of any access driveway or turnout, including the radii, shall be a minimum of 25 feet from any other access driveway or turnout to the same roadway.
- The County Engineer will determine the size of culvert or drainage structure and the minimum size of a culvert shall be 18 inches in diameter. Any culvert exceeding 18 inches in diameter will be required to have flared ends.
- All parts of any access driveway or other turnout, including the radii, shall be a minimum of 12.5 feet from the side property lines. Exceptions to this rule may be allowed when physical conditions make it impossible to comply or where such compliance will create a potential safety hazard.
- Embankment slopes shall have a minimum slope of 4 feet horizontal to 1 foot vertical. Slopes will be dressed and compacted. Deviations from these standard dimensions will be approved on an individual basis.
- The minimum radius for any access driveway shall be 12.5 feet.
- The material for any access driveway shall consist of a base material of coarse stone at a minimum of 8 inches in depth and a surface material of crushed gravel at a minimum of 4 inches in depth.
- Cover over a ditch pipe for a ditch will be as follows:
  - 18 to 30 inch pipes = 9 inches minimum of cover
  - 36 to 48 inch pipes = 12 inches minimum of cover
  - 54 inch + pipes = 18 inches minimum of cover

No official or employee of the County, other than the Board of County Commissioners, shall have the authority to waive any term or condition herein contained.

IN WITNESS WHEREOF, the County, acting by and through the Board of County Commissioners has executed this license on the_____day of_____,20_____.

(SEAL)

THE BOARD OF COUNTY COMMISSIONERS

_____
(Chairperson)

ATTEST:

_____
(County Clerk)

The undersigned, the Licensee mentioned in the foregoing License, hereby accepts the same, subject to the terms and conditions contained herein.

_____
Licensee

_____

Title

_____
Work Phone

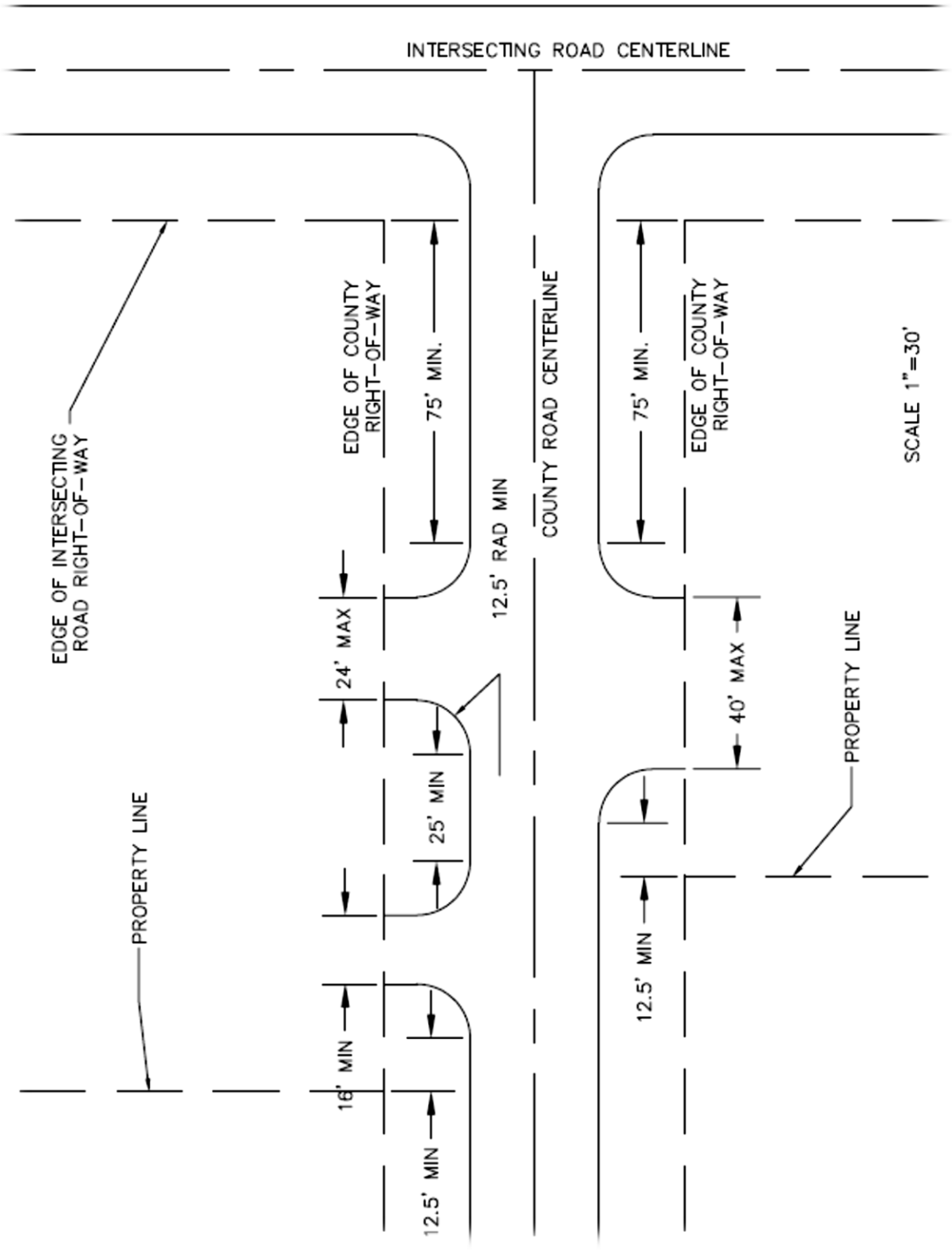
_____
Home Phone

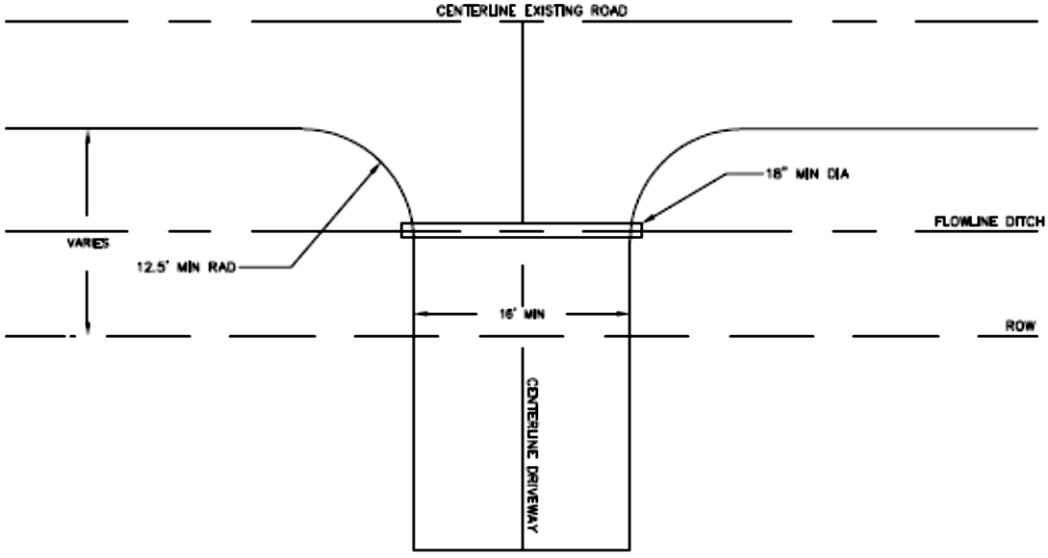
Attest:

_____
Title

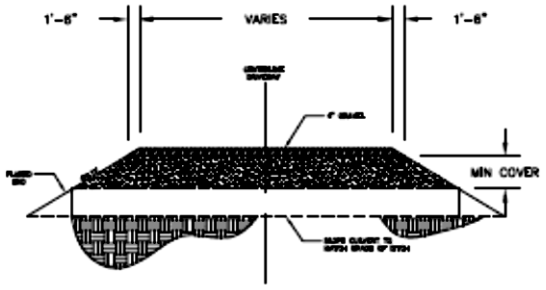
(SEAL)

Typical Approach Minimum and Maximum Approach Standards Dimensions

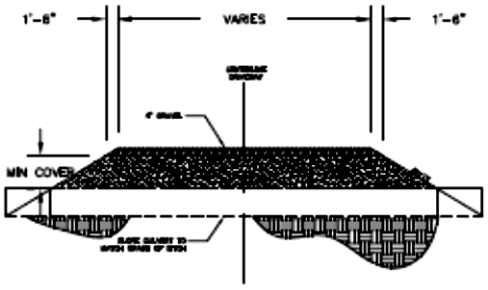

INTERSECTING ROAD CENTERLINE
EDGE OF INTERSECTING ROAD RIGHT-OF-WAY
EDGE OF COUNTY RIGHT-OF-WAY
75' MIN.
24' MAX
12.5' RAD MIN
COUNTY ROAD CENTERLINE
75' MIN.
EDGE OF COUNTY RIGHT-OF-WAY
SCALE 1"=30'
40' MAX
PROPERTY LINE
25' MIN
PROPERTY LINE
16' MIN
12.5' MIN
12.5' MIN



PLAN VIEW



CROSS SECTION VIEW
CULVERTS GRATER THAN 18"
REQUIRE FLARED ENDS



CROSS SECTION VIEW
WITH 18" CULVERT

Appendix O2 Standard Road Use Agreement

Road Use Agreement

WITNESSETH:
WHEREAS, the Operator is engaged generally in_____ and
(Type of Business)
WHEREAS, the Operator is planning to (project description) _____in
Section_____, Township_____North, Range_____West, on Road _____;
and
WHEREAS, said operation and/or project may continue for as long as_____ (weeks, months, or years); and
WHEREAS, the Operator has obtained and filed all of the necessary permits with the respective County, State and Federal agencies; and
WHEREAS. the Licensee has reported that as a result of the above described activities, traffic on Road _____from said site to Road_____ _____could include up to _____total loads or _____loads per day, week, month or year (with said loads being within legal load limits as currently defined by the Wyoming Department of Transportation); and
WHEREAS. the County and the County residents are concerned about damage to the County Roads, culverts, cattle guards, and appurtenances and are also concerned about noise disturbance from trucks, dust creation, the safety of residents driving the road including use by the farmers, ranchers, tourists and sightseers, interference with wildlife, road maintenance and open range protection; and
WHEREAS, it is the desire of the County, the Licensee and the residents of the area to work cooperatively.
NOW, THEREFORE, in and for the mutual promises and consideration as described herein, the parties agree as follows.

- A mandatory meeting with the County Planning Department shall be held two (2) weeks prior to project initiation. The purpose of this meeting is to collect pertinent information related to the project and to complete and submit all required permits. The meeting will address the required Commercial/Industrial Road Use Application and the County Conditions of Road Use as well as any need for Public Works Construction Permits, Oversize and Overweight Load Permits, requirements for emergency services, addressing, etc. Prior to project initiation, transportation routes will be identified as well as the potential need for roadway infrastructure inventories and potential roadway improvements. After project completion, road and roadway infrastructure will be reevaluated within ten (10) working days to document any damages in order to assess repairs needed to return the Roads to their original condition, before operations began.
- To the extent authorized by law, the Licensee agrees to indemnify, save, and hold the county harmless from and against any and all claims, damages, losses and judgments, which may be suffered or incurred by the County as a consequence of any breach by the Licensee of its obligations and duties set forth in this agreement on those portions of the haul route described in this agreement. In the event that any dispute shall arise under this agreement, the prevailing party in such dispute shall be entitled, in addition to any other relief to which such party may be granted, to recover its reasonable attorney's fees and court costs incurred in connection with the resolution of such dispute.
- The Licensee will post a right-of-way bond in the amount of $_____to the benefit of the County in the event that the Licensee terminates their operations without performing road repairs.

- If either party fails to comply with the third party viewer's assessment and estimate, then that party shall be responsible for all fees and attorney's costs in litigation to enforce this agreement.
- The County and the Licensee agree they shall cooperate with each other regarding all matters necessary to carry out the full intent and purpose of this Agreement. If the parties are unable to agree on necessary repairs and maintenance, then the parties agree to binding arbitration by a third party independent viewer. The County Commissioners at the first regular meeting following notice of such disagreement will appoint the third party independent viewer. The third party independent viewer shall be a freeholder within the County. The third party independent viewer shall, within ten (10) days of appointment, make arrangements and provide notice to both the County and the Licensee having date and time for an on-site inspection of the damage in question. Following the on-site inspection, the third party independent viewer shall submit an assessment and damage estimate to the County Commissioners. At the next regular meeting, the County Commissioners shall certify third party independent viewer's assessment and estimate of damage paid. If the third party independent viewer determines that the Licensee is in violation of the agreement, the Licensee shall within ten (to) days of the County Commissioners' certification of third party independent viewer's assessment and estimate, pay to the County the assessed estimate of damage costs.
- All construction and material controls for a project will be in accordance with the current Standard Specifications for Road and Bridge Construction, as supplemented or revised, provided by the Wyoming Department of Transportation. The County shall post speed limits, stop signs and other control signs on County Roads. During construction, the Licensee shall ensure that all temporary traffic control signs are placed as needed and in compliance with "Manual on Uniform Traffic Control Device Standards" guidelines and regulations.
- The Licensee agrees to keep equipment noise as low as possible while using the County Roads and to respect resident housing located in the above described area.
- The Licensee agrees to respect open range and the danger of livestock grazing along the route, both with speed control and stopping as necessary along the route.
- The Licensee agrees to provide dust control measures on this road as dictated and required by Department of Environmental Quality permit and the County. For the purposes of this agreement water applied in sufficient quantity to suppress dust shall be considered to be an adequate dust control measures.
- The County Road and Bridge or appropriate department will inspect the county road from time to time and shall report, in writing, necessary repairs and maintenance to The Licensee. The Licensee hereby agrees to repair said damage and provide such maintenance within five (5) days of notice. If The Licensee fails to make necessary repairs within five (5) days of written notice from the County, the County at its option may elect to make such repairs and The Licensee will be responsible for the cost of such repairs. These costs may include, but are not limited to, materials, use of the County's' equipment, labor, and other related expenses.
- During Licensee's use of the above described County Roads, the Licensee may be subject to imposition of load restrictions by the County should damage occur to said Roads that endangers the public safety as a result of the Licensee's activities on said Roads. Should the County conclude that such damage to said Roads requires immediate repair, the County may make such reasonable repairs and seek reimbursement from the Licensee.

- The Licensee and the County acknowledge that other companies may conduct industrial projects in the area which may require use of the same Roads during the Licensee's planned use of said Roads. Should the County or the Licensee become aware of another company's use of said Roads during the Term of this agreement, the County or the Licensee shall promptly notify the other. In the event one or more of those companies and the Licensee utilize said Roads concurrently during the Term of this Agreement, the County shall bill the Licensee for the Licensee's proportionate share of the costs for damages.
- Licensee shall notify the County one (1) week prior to the start of any mobilization of equipment authorized by the County's Oversize and Overweight Load Permit so that the County may verify the condition of the proposed route on County Roads. The road condition inventory will be conducted by the County's Road and Bridge Department, and/or the County's Engineer's Office, and coordinated with the Licensee. Upon request of the Licensee, the County shall provide the Licensee with copies of the baseline documentation from the road condition inventory.
- The Licensee shall provide training and information to all its employees, contractors and subcontractors emphasizing safety, compliance with speed limits, potential hazards, and awareness of local traffic and wildlife, with respect to the use of County Road(s).
- If any clause or provision of this agreement is illegal, invalid, or unenforceable, then it is the intention of the parties that the remainder of this agreement shall not be affected.
- Failure of either party to perform any of its respective obligations hereunder by reason of acts of God, strike or acts of any governmental agency or authority having jurisdiction over matters set forth herein shall excuse timely performance of such obligations as soon as reasonably practical. The parties may, however, mutually consent to excuse a party from performing any obligation, in whole or in part, upon showing that performance has been rendered impracticable by reason of Force Majeure.
- Should the licensee sell its operation, cease operating, file bankruptcy, or in any way release ownership and responsibility of the permitted property, except as described herein, this agreement, as set forth herein in, shall be terminated. If the aforementioned release should occur, the licensee shall give a minimum notice of ninety (90) days to the county before the date of termination. If the aforementioned release should occur, the county shall have the option of immediately terminating this agreement.
- This agreement may not be assigned in whole or in part by either party hereto without the written consent of the other party. Such consent will not be reasonably withheld, conditioned, or delayed.
- The licensee shall maintain the following insurance:
  - The licensee shall maintain coverage, during the entire term of this agreement, against claims arising out of bodily injury, death, damage to or destruction of the property of others, including loss of use thereof, and including underground, collapse and explosion and products and completed operations, and in an amount of not less than Five Hundred Thousand Dollars ($500,000.00) per occurrence and One Million Dollars ($1,000,000.00) general aggregate.
  - The insurance requirements set forth above apply to all subcontractors. It is the licensee's responsibility to ensure that the subcontractors meet these insurance requirements. The county has the right to review the Certificates of any and all subcontractors used by the licensee.

Signatures

In witness whereof, the parties to this Agreement, through their duly authorized representatives, have executed this agreement on the days and dates set out below, and certify, that they have read understood and agreed to terms and conditions of this Agreement as set forth herein.
The effective date of this Agreement is the date of the signature last affixed to this page.

LICENSEE:	COUNTY:
By:	By:
_____	_____
(Authorized Signature)	(Authorized Signature)
_____	_____
Printed Name	Printed Name
_____	_____
Date	Date

Appendix O3 Standard Oversize/Overweight Permit

Oversize and Overweight Load Permit

Issuing County_____

Address_____City_____State_____Zip Code_____

Phone Number_____Email_____

Oversize/Overweight Permit # _____

Special Permit for Operation of Oversize and Overweight Loads

Name of Company_____Contact Person for Billing_____

Address_____City_____State_____Zip Code_____

Billing Address_____City_____State_____Zip Code_____

Phone Number_____Date of Move_____Date of Permit_____

Load Origin_____Load Destination_____

County Roads in Use_____Total Miles (attach road map)_____

Vehicle Type: ☐ Single Unit Truck ☐ Tractor-Trailer ☐ Semi-Trailer ☐ Non-Registered

Truck/Tractor Number_____

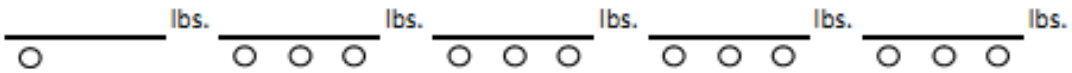
Truck/Tractor License Number_____Trailer License Number_____

Licensing State_____Carrier Authority:

Description of Load_____

_____

Axle configuration: Indicate axle configuration and weight. Indicate other axle groups by adding or crossing out axles



Gross Vehicle Weight_____lbs.

Oversize Total Overall Dimensions: Length_____Width_____Height_____

Length of Single Unit Within Combination_____

Vehicle Size and Weight Determined by: ☐ Scale ☐ Carrier

Scale Location_____

Date of Approval_____Approved By_____

Fee Assessment_____

Company Billing Address_____

Special Permit Regulations

- A permit must be issued 2 business days before the load is moved unless prior approval is given
- All elements of load that can be reasonably removed shall be transported separately to reduce the overweight load.
- Oversize loads may require carrier escort as specified.
- The county public works department shall be notified a reasonable time prior to the movement of any oversize/overweight load
- The movement may be postponed if poor road conditions or maintenance operations dictate
- Any oversize/overweight load found to be moving on any county road may be stopped by the county's sheriff's department for verification of permit. If no permit has been issued, a citation may be issued and in the discretion of the law enforcement officer, the vehicle may be ordered not to be moved until a permit has been approved by the Public Works Department. The carrier and/or operator of the vehicle may be subject to a fine
- In the event that an oversize/overweight load is found to be moving on any county road without a permit, the carrier and/or operator may be cited for the violation. In the discretion of the law enforcement officer the vehicle may have its movement halted or limited until remedial permit has been obtained and an additional fee of $250.00 shall be imposed for issuance such a remedial permit
- Any repeated violations of the terms and conditions expressed herein may result in the county taking action by revoking permit
- A onetime rig move fee of $1,000 may be used for multiple oversize/overweight loads. This fee covers one rig, one site move (to destination and from destination). The licensee must provide anticipated number and size of loads required to move rig to and from destination noted in the Commercial/Industrial Road Use Application. All terms and conditions contained in the County Conditions of Road Use are herein incorporated by reference.
- Payment shall be made by the Licensee within 30 days after billing by the County. Permittee shall have 10 days after receipt of the billing to notify the County in writing of any dispute related to the billing.
- During hauling operations, Licensee may be subject to imposition of load restrictions by the County should damage occur to the Road that endangers the public safety as a result of Licensee' s hauling activities and repairs in such circumstances will be made by the Licensee.
- Movements will only be allowed during daylight hours.
- The Licensee agrees to pay for any and all necessary repairs of damages to the roads which damages (as determined by the County) are caused by any hauling operations or activities of the Licensee.
- The county may reduce the maximum allowable axle loads and gross weight limits for specific county roads or sections thereof or for bridges under the county's jurisdiction if the continued operation of vehicles or combinations of vehicles would create undue damage to the highways or bridges.
- The county allows for the reduction in the maximum allowable axle loads and gross weight limits for specific county roads or sections thereof or for bridges by the county if the operation of vehicles or combination of vehicles would create undue damage to the county road.
- The issuance of a permit shall not be construed to warrant the condition of the roadways and structures and shall not relieve the holder or their assigns acting on the holder's behalf from

responsibility for damages to any roadway structures or other appurtenances. By issuance of this permit the county does not waive its governmental immunity as provided by any applicable law.

- Any repeated violations of the terms and conditions expressed herein may result in the county taking action by revoking the access or driveway permit of the entity or operator engaging in the business activity served by the violating oversize or overweight vehicle(s).
  - Notice of any such intended revocation shall be in writing directed to the address of the driveway or access permit holder on file with the department of public works.
  - Revocation shall take place within seven (7) business days of the service by mail of the notice of intended revocation.
  - Prior to the date of revocation, the recipient may request in writing a hearing before the board of county commissioners in order to contest the intended revocation. Said hearing will be set within ten (10) business days of the written request. Upon the setting of a hearing, the revocation of the permit shall be held in abeyance pending the hearing and decision of the board of commissioners.
  - "Repeated" as used in this subsection, means more than two violations. Said violations may be committed by one operator or separate oversize or overweight vehicle operator's engaged in serving the business to which the access or driveway permit was issued.
  - Use of an access way or driveway after revocation will result in issuance of a criminal citation for a violation of w.s. 18-5-206 and/or the initiation of any other available legal action against the entity or operator whose access or driveway permit has been revoked.
- A pre-trip inspection report regarding equipment, load securement, and a basic overall inspection of the truck and load shall be filled out and approved before the driver begins the trip.
- Hauler is responsible for surveying route beforehand and assessing if it is viable for load being transported.
  - This will also include the inspection of the road geometry of routes that would exclude the load due to:
    - Long grade >10%
    - Narrow lanes
    - Hairpin curves
    - Clearance
- Bridges or roads with posted weight restrictions shall be detoured and posted weight limitations shall not be exceeded. Before crossing bridges or entering underpasses or tunnels, distance for clearance shall be carefully checked so as to ascertain for ample clearance.
- All loads shall be securely fastened so as to prevent shifting of load or falling from transporting vehicle.
- Operations shall be conducted, insofar as it is possible, to permit safe and reasonable free travel whereby all safety provisions for the movement of such traffic shall be provided by the permit holder. Red warning flags, size 24 inches by 24 inches, shall be carried to warn and protect traffic, and as indication of oversize load moving.
- In moving over any narrow section of highway or narrow bridge, where it is impossible to keep free and clear at least one full lane of pavement for passing traffic, each movement over such section shall be accompanied by a flagger, stationed at least 500 feet ahead and 500 feet following such vehicle so as to warn and protect traffic. Clearance shall be checked on bridges, and where there are weak or posted bridges a detour shall be made.
- Overhead wires, cables, signals or traffic lights, limbs of trees, or overhead structures shall not be disturbed without first obtaining permission from the owners thereof. Movements are not to be started until after such consents have been obtained from said owners.

- Proper insurance and proof of insurance shall be established before the permit be issued and shall be in effect through the duration of said permit.
- Vehicle operators are required to keep said permits in their cab at all and must present it to law enforcement when requested.
- Speed limits posted and imposed by the permit issuing authority shall be obeyed by the permitted vehicle as well as any escort vehicles in company.
- Escorts are required on Primary and Secondary highways (unless otherwise required) when movement is 110 ft. long, 14 ft. or greater in width, or will extend to the left of the centerline during movement. Escorts are required on Interstate highways for width of 15 ft. or greater. Escorts for height on all highways, and for length on Interstate highways, are at the discretion of the approving authority. When rear overhang is 25ft or greater must have a rear escort regardless of length.
- The following requirements and minimum equipment are needed when escorting oversize and/or overweight movement upon the highways of the State of Wyoming.
  - Escort vehicles must be a licensed vehicle. Motorcycles will not be allowed to serve as an escort vehicle. May not be a combination vehicle.
  - All escort vehicles must display a revolving flashing amber light, amber strobe light, or two (2) two-way flashing amber lights mounted on the roof of the vehicle. The lights shall be at least four (4) inches in diameter and be clearly visible at least five hundred (500) feet from the front and rear of the vehicle.
  - Escort vehicles must also be equipped with an "OVERSIZE LOAD" sign. The sign must measure five feet wide by ten inches high, and lettering must be eight inches high painted in black with a one inch brush stroke on a yellow background.
  - Escort vehicles shall conspicuously display clean bright red or fluorescent orange flags mounted on a staff at each side of the vehicle sign. Flags shall be a minimum of twelve (12) inches square.
  - Headlights and taillights must be on during the movement.
  - Escort vehicles must be equipped with two-way radio communications with the escorted vehicle.
  - Escort vehicle must be equipped with left outside mirrors.
  - Escort vehicle must be equipped with emergency triangles, extra oversize load signs, extra flags and a fire extinguisher (minimum 5 lb. BC).
  - Escorts shall be provided to the front and the rear of movements on primary and secondary highways and to the rear on Interstate and divided highways. Escorts shall maintain a distance of approximately 1000 feet from the oversize load, unless a shorter distance is necessary to provide control over the movement.
  - Two oversize loads, each requiring escorts, may be authorized by proper permit issuing authority to travel together on a two lane highway maintaining a distance of approximately 1000 feet apart. One escort in front of the first load and one escort behind the second load shall be maintained at a distance of approximately 1000 feet, unless a shorter distance is necessary to provide control over the movement. On Intestate or four-lane highways, one escort to the rear of the second load will be maintained.

- A third oversize load requiring escorts cannot travel with a group of two oversize loads, but must remain at a minimum distance of one-half mile from the group and must also have its own escorts.
- A convoy of four oversize loads requiring escorts may be authorized to travel in two groups separated by a distance of at least one-half mile. Each group must have their own escorts.
- Emergency moves after daylight hours requiring escorts will not be allowed to convoy.
- When movements are confined to four-lane divided highways, and a segment of one lane is closed for repairs and the other lane is being used for two-way traffic, additional escorts may be required if a special hazard exists or the movement cannot be kept to the right of the centerline.
- Movements requiring escorts using the interstate highways and intervening two-lane highways will need one escort for the interstate and two for two-lane highways.
- Oversize/overweight loads approaching narrow bridges or other obstacles that pose potential hazards shall be halted when safety dictates and removed from the traveled way until the escort vehicle proceeds past the obstacle and halts approaching traffic. The load may proceed past the obstacle when safe to do so.
- Drivers of the escort vehicles shall insure that oversize/overweight loads do not park on the main traveled portion or the shoulder of the highway unless it becomes necessary in an emergency, or to properly pass an obstacle. Should it be necessary to park an oversize/overweight load due to an emergency, the load will be adequately protected by flagmen, flares, an escort vehicle, or other suitable warning devices.

- The following sign requirements must be observed on all oversize load movements upon the highways of the State of Wyoming.
  - All oversize loads and vehicles must display yellow warning signs on both front and rear.
  - The legend on the sign must be: "OVERSIZE LOAD". No other combination will be allowed.
  - The sign must be five (5) feet wide by ten (10) inches high with eight (8) inch letters painted in black brush strokes one (1) inch wide on a yellow background.
  - The signs must be displayed so the entire message is legible to oncoming traffic.
  - The signs must be maintained in a clean and legible manner.
  - The signs must not be displayed unless actually transporting an approved, permitted, oversize load.
- Travel shall be conducted with a minimum of impediment to other highway users. Oversize/overweight loads shall move to the highway shoulder whenever vehicular traffic behind the movements becomes congested and shall remain off the main traveled portion of the roadway until the following traffic has cleared.
- Fee Schedule:
  - Oversize vehicles the fee shall be: $25.00 min. For any dimension in excess of 8’6” wide, 14’ high, 60’ single unit length of everything but the power unit. This initial $25.00 fee covers the dimensions up to 15’ wide, 15’ high, and 75’ single unit length. Once these dimensions are exceeded there is an additional $.03 per foot, per mile in excess of these limits.
  - Overweight vehicles the fee shall be: $40.00 minimum and $.06 per ton, per mile in excess of the statutory limits with no maximum fee.
  - Maximum loads for axles and axle groups shall be determined from tables 1 & 2, based on axle spacing, as contained in the Wyoming Department of transportation regulations entitled

"truck sizes, weights and permits", section 1 oversize and overweight limitations of vehicles, pages 1.11-1.13 (attached).

GROSS WEIGHT TABLE I

Distance in feet between the extremes of any group of two (2) or more consecutive axles	Maximum gross weight in pounds carried on any group of two (2) or more consecutive axles							
	2 axles	3 axles	4 axles	5 axles	6 axles	7 axles	8 axles	9 or more axles
4	36,000							
5	36,000							
6	36,000							
7	36,000							
8	36,000	42,000						
9	39,000	42,500						
10	40,000	43,500						
11		44,000						
12		45,000	50,000					
13		45,500	50,500					
14		46,500	51,500					
15		47,000	52,000					
16		48,000	52,500	58,000				
17		48,500	53,500	58,500				
18		49,500	54,000	59,000				
19		50,000	54,500	60,000				
20		51,000	55,500	60,500	66,000			
21		51,500	56,000	61,000	66,500			
22		52,500	56,500	61,500	67,000			
23		53,000	57,500	62,500	68,000			
24		54,000	58,000	63,000	68,500	74,000		
25		54,500	58,500	63,500	69,000	74,500		
26		55,500	59,500	64,000	69,500	75,000		
27		56,000	60,000	65,000	70,000	76,000		
28		57,000	60,500	65,500	71,000	76,500	82,000	
29		57,500	61,500	66,000	71,500	77,000	82,500	
30		58,500	62,000	66,500	72,000	77,500	83,000	
31		59,000	62,500	67,500	72,500	78,000	83,500	
32		60,000	63,500	68,000	73,000	78,500	84,500	90,000
33			64,000	68,500	74,000	79,000	85,000	90,500
34			64,500	69,000	74,500	80,000	85,500	91,000
35			65,500	70,000	75,000	80,500	86,000	91,500
36	Two (2) consecutive sets of tandem axles may carry 36,000 pounds each if the distance is 36 feet or more between the consecutive sets of tandem axles		66,000	70,500	75,500	81,000	86,500	92,000
37			66,500	71,000	76,000	81,500	87,000	93,000
38			67,500	72,000	77,000	82,000	87,500	93,500
39			68,000	72,500	77,500	82,500	88,500	94,000
40			68,500	73,000	78,000	83,500	89,000	94,500
41			69,500	73,500	78,500	84,000	89,500	95,000
42			70,000	74,000	79,000	84,500	90,000	95,500
43			70,500	75,000	80,000	85,000	90,500	96,000
44			71,500	75,500	80,500	85,500	91,000	96,500
45			72,000	76,000	81,000	86,000	91,500	97,500
46			72,500	76,500	81,500	87,000	92,500	98,000
47			73,500	77,500	82,000	87,500	93,000	98,500
48			74,000	78,000	83,000	88,000	93,500	99,000
49			74,500	78,500	83,500	88,500	94,000	99,500
50			75,500	79,000	84,000	89,000	94,500	100,000
51			76,000	80,000	84,500	89,500	95,000	100,500
52			76,500	80,500	85,000	90,500	95,500	101,000
53			77,500	81,000	86,000	91,000	96,500	102,000
54			78,000	81,500	86,500	91,500	97,000	102,500
55			78,500	82,500	87,000	92,000	97,500	103,000
56			79,500	83,000	87,500	92,500	98,000	103,500

Distance in feet between the extremes of any group of two (2) or more consecutive axles	Maximum gross weight in pounds carried on any group of two (2) or more consecutive axles							
	2 axles	3 axles	4 axles	5 axles	6 axles	7 axles	8 axles	9 or more axles
57			80,000	83,500	88,000	93,000	98,500	104,000
58				84,000	89,000	94,000	99,000	104,500
59				85,000	89,500	94,500	99,500	105,000
60				85,500	90,000	95,000	100,500	105,500
61				86,000	90,500	95,500	101,000	106,000
62				87,000	91,000	96,000	101,500	107,000
63				87,500	92,000	97,000	102,000	107,500
64				88,000	92,500	97,500	102,500	108,000
65				88,500	93,000	98,000	103,000	108,500
66				89,000	93,500	98,500	104,000	109,000
67				90,000	94,000	99,000	104,500	110,000
68				90,500	95,000	99,500	105,000	110,500
69				91,000	95,500	100,000	105,500	111,000
70				92,000	96,000	101,000	106,000	111,500
71				92,500	96,500	101,500	106,500	112,000
72				93,000	97,000	102,000	107,000	112,500
73				93,500	98,000	102,500	107,500	113,000
74				94,500	98,500	103,000	108,500	113,500
75				95,000	99,000	104,000	109,000	114,000
76				95,500	99,500	104,500	109,500	115,000
77				96,000	100,000	105,000	110,000	115,500
78				97,000	101,000	105,500	110,500	116,000
79				97,500	101,500	106,000	111,000	116,500
80				98,000	102,000	106,500	111,500	117,000
81				98,500	102,500	107,000	112,000	
82				99,000	103,000	108,000	113,000	
83				100,000	104,000	108,500	113,500	
84					104,500	109,000	114,000	
85					105,000	109,500	114,500	
86					105,500	110,000	115,000	
87					106,000	111,000	115,500	
88					107,000	111,500	116,000	
89					107,500	112,000	117,000	
90					108,000	112,500		
91					108,500	113,000		
92					109,000	113,500		
93					110,000	114,000		
94					110,500	115,000		
95 or more					111,000	115,500		

GROSS WEIGHT TABLE II
PRIMARY AND SECONDARY HIGHWAYS

Distance in feet between the extremes of the first and last axle of any vehicle or combinations of vehicles	Maximum gross weight in pounds
10	43,500
11	45,000
12	48,000
13	50,000
14	52,000
15	54,000
16	54,000
17	54,000
18	56,000
19	58,000
20	62,000
21	64,000
22	65,000
23	66,000
24	66,000
25	66,000
26	66,000
27	66,000
28	66,000
29	66,000
30	67,000
31	68,000
32	69,000
33	70,000
34	71,000
35	72,000
36	73,000
37	74,000
38	75,000
39	76,000
40	76,000
41	76,000
42	76,000
43	76,000
44	76,000
45	77,000
46	77,400
47	78,300
48 or more	80,000