WRRSP
Wyoming Rural Road Safety Program

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October 2009

# ABSTRACT

SAFETEA-LU contains language indicating that state department of transportation (DOTs) will be required to address safety on local and rural roads. It is important for state, county, and city officials to cooperate in producing a comprehensive safety plan to improve their statewide safety. This legislation provides an opportunity to implement a more cohesive and comprehensive approach to local road safety in Wyoming. The Wyoming Local Technical Assistant Program (LTAP) coordinated an effort in cooperation with the Wyoming Department of Transportation (WYDOT) as well as Wyoming counties and cities to identify low cost safety improvements on high risk rural roads in Wyoming. In this project, safety techniques and methodologies were developed to identify and then rank high risk locations on rural roadways in Wyoming. What makes this project unique is the high percentage of gravel roads at the local level in Wyoming. The evaluation procedure developed is based on historical crash records and field evaluations. The main objective of this research was to develop and evaluate transportation safety techniques that can help Wyoming agencies in reducing crashes and fatalities on rural roads statewide. Three Wyoming counties were included in the pilot study. The statewide implementation began in 2009. This report describes the findings and recommendations of this research study, which would be very beneficial not only in Wyoming but also to those states interested in implementing a High Risk Rural Road (HRRR) Program.

## Acknowledgements

Funding for this study was provided by the Wyoming DOT and the Mountain-Plains Consortium (MPC). The authors would like to thank Matt Carlson, WYDOT's Safety Office, Martin Kidner, WYDOT's Planning Office, Paul Harker, FHWA, and Carbon, Laramie, and Johnson Counties' Road and Bridge Departments for their support and assistance. Also, thanks to Alex Literati who helped with some of the tasks described in this report.

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# 1. INTRODUCTION

## 1.1 Background

Rural roads make up a significant portion of the nation's transportation system. Of the 8.4 million lane-miles of roads in the United States, over 6 million lane-miles are rural (U.S. DOT 2008). They range from heavily traveled intercity routes to sparsely traveled links to isolated areas. Rural roads provide a vast network connecting the fringes of urban areas, farm land, resource development areas, and remote outposts (The Road Information Program 2005).

Compared with urban roads, rural roads are not as safe. They carry less than half of America's traffic but account for over half of the nation's vehicular deaths (U.S. DOT 2008). Approximately 60% of the total fatalities nationwide occur in rural areas, and the traffic fatality rate on non-interstate rural roads in 2003 was 2.72 deaths for every 100 million vehicle miles of travel (MVMT), compared with a traffic fatality rate on all other roads in 2003 of 0.99 deaths per 100 MVMT. Between 2000 and 2003, the fatality rate on rural, non-interstate routes had actually increased from 2.65 fatalities per 100 MVMT to 2.72 in 2003. In Wyoming between 2002 and 2006, the average fatality rate per 100 MVMT was 2.23. This rate was ranked 26$^{th}$ place nationwide (Florida has the highest rate at 3.54) (U.S. DOT 2008).

Rural roads face many unique safety challenges that result in higher crash rates. First, inadequate roadway safety design. Second, the presence of roadside hazards such as utility poles, sharp-edged pavement drops-offs, and trees close to roadways. Third, compared with urban crashes, rural crashes are more likely to be at higher speeds. Fourth, it often takes longer for emergency vehicles to respond to the scene of a rural crash (The Road Information Program 2005).

## 1.2 Project Objectives

The main objective of this research was to develop and evaluate a transportation safety program that can help Wyoming local agencies reduce crashes and fatalities on rural roads statewide. Such a system can be also used by other local agencies interested in implementing a rural road safety program.
In order to achieve this main objective, the following subtasks were performed in this study:

1. Identify roadway classification systems used by counties in Wyoming.
2. Develop a methodology of using available data (crash records, traffic volume, speed, etc.) for crash prediction on rural roads.
3. Establish a five-step methodology to identify specific safety countermeasures on high risk local rural roads.
4. Develop a procedure to perform economic analysis for safety countermeasures.

## 1.3 Report Organization

The report is divided into the seven sections. Section 2 presents summaries of the comprehensive literature reviews for each of the three research objectives. Section 3 introduces the detailed procedure of the Wyoming Rural Road Safety Program (WRRSP). Section 4 focuses on the roadway classification survey and its results. Section 5 presents the regression model methodology to predict crashes on rural roads. Section 6 introduces the procedure for performing economic analysis for safety improvements. Finally, Section 7 summarizes the conclusions and provides recommendations for future studies.

# 2. LITERATURE REVIEW

## 2.1 Rural Road Safety

Rural roads are a critical link in the nation's transportation system, providing access from urban areas to the heartland. These roads also provide farm-to-market transportation and are the primary routes of travel and commerce for the approximately 60 million people living in rural America. But rural roads in the nation's heartland, which are carrying growing levels of traffic and commerce, often lack many desirable safety features and experience serious traffic accidents at a rate far higher than all other roads and highways (The Road Information Program). Nationally, about 60% of traffic fatalities are rural, the majority of which occur on two-lane roads. The overall number of U.S. traffic fatalities has remained steady at more than 42,000 annually. According to a National Highway Traffic Safety Administration (NHTSA) study in 2002, health costs each year due to motor vehicle crashes have been estimated at $230 billion, or 2.3% of the U.S. gross domestic product (CERS 2007). Rural America has a significant highway safety problem. Close to 80% of the nation's roadway miles are in rural areas, over 58% of the total fatalities occur in rural areas, and the fatality rate for rural areas (per 100 million vehicles miles of travel) is more than twice that of urban areas. Crashes in rural areas are more likely to result in fatalities due to a combination of factors, including extreme terrain, faster speeds, alcohol involvement, and longer time intervals from the advent of a crash to medical treatment due to delays in locating crash victims and the distance to medical treatment centers.

The U.S. Department of Transportation's highway safety goals are to achieve a 50% reduction in truck crash-related fatalities by 2010, and a 20% reduction in crash-related fatalities and serious injuries by 2008. Among the priority safety areas for the Department of Transportation are reducing single vehicle run-off-road fatal crashes, two-thirds of which occur in rural areas. Many of these fatal crashes take place on two-lane rural roads and involve vehicles striking fixed objects or going down an embankment or into a ditch. Speeding is another factor in many run-off-the road rural crashes (The Community Investment Network).

Although traffic and road congestion are minimal in rural communities, data from the National Highway Traffic Safety Administration show that the fatality rate per million vehicle miles traveled for rural crashes is more than twice the fatality rate of urban crashes. One factor contributing to this risk is the significantly higher number of vehicle miles traveled by people who live in rural communities. The relative scarcity of public transportation and the greater distances between destinations both contribute to this risk factor. Two other factors affecting crash risk are: (1) the greater likelihood that rural residents will be traveling on a roadway that has a speed limit of 55 mph or higher, and (2) that they will be traveling on a roadway that is not straight (rural communities have more curved roads than urban communities).

In addition, straight roads usually provide less of a challenge to a driver than ones that bend and curve. This is particularly true when a driver is going fast, is distracted, is drowsy, or is impaired by alcohol or drugs. When combined with speed limits 55 mph and higher, it is not surprising to find that 28% of rural fatal crashes occurred on curved roads in 2004, as compared with 18% of urban fatal crashes (National Highway Traffic Safety Administration).

Traffic fatality rates on rural roads are higher than on urban roads, partly because rural roads are less likely to have adequate safety features and are more likely than urban roads to have only two lanes. Seventy percent of the nation's non-freeway, urban roads have two lanes, but 94% of rural, non-freeway roads are two-lane routes. Rural routes have often been constructed over a period of years and as a result, often have inconsistent design features for such things as lane widths, curves, shoulders, and clearance zones along roadways. Many rural roads have been built with narrow lanes, limited shoulders, excessive curves, and steep slopes alongside roadways. Significant rural roads are less likely than significant urban roads to have adequate lane widths. A desirable lane width for collector and arterial roadways is at least 11 feet. But 26% of rural collector and arterial roads have lane widths of 10 feet or less, while 19% of urban collector and arterial roads have lane widths of 10 feet or less. With passenger vehicle, heavy truck, and commercial farming traffic increasing, the safety inadequacies of these rural roads are contributing to the higher rate of fatal accidents on rural roads.

More than half (54%) of traffic fatalities on non-interstate rural roads from 1999 to 2003 occurred in single-vehicle accidents, with the remaining fatalities occurring in multiple-vehicle accidents (59,805 out of 110,636 fatalities). This rate is similar to all other routes, where 54% of traffic fatalities during the same period occurred in single vehicle crashes (55,268 out of 100,870). Vehicles driving on rural roads were much more likely than vehicles on all other roads to be involved in a fatal traffic accident while attempting to negotiate curves. From 1999 to 2003, 23% of all vehicle occupants killed in rural, non-interstate accidents, died in crashes that involved a vehicle attempting to negotiate a curve, while only 11% of vehicle occupants killed in all other accidents died in crashes that involved a vehicle attempting to negotiate a curve. Motorists are approximately six-and-a-half times more likely to be killed while attempting to negotiate a curve on rural, non-interstate routes than on all other roads. From 1999 to 2003, the rate of fatalities per 100 million miles of travel from accidents involving negotiating curves on rural, non-interstate routes was 0.58, compared with 0.09 on all other routes (The Road Information Program).

The damage to vehicles involved in rural fatal crashes is more severe than the damage to vehicles involved in urban fatal crashes as measured by the percentage of disabling deformation. Almost 80% of vehicles involved in rural fatal crashes are disabled, whereas 65% of vehicles involved in urban fatal crashes are disabled (USDOT 2001).

Vehicle occupants involved in rural fatal crashes are ejected 16% of the time, while 7% of urban vehicle occupants are ejected. Of all persons involved in fatal rural crashes, 25% are transported to a hospital compared with 16% in fatal urban crashes. Rural areas have a larger portion of fatally injured individuals, 43% compared with 39% in urban fatal crashes. Vehicle occupant fatalities occurring in rural fatal crashes are more likely to have been ejected (27%) compared to occupant fatalities occurring in fatal urban crashes (15%) (USDOT 2001).

The Highway Safety Improvement Program (HSIP) was elevated to a core program as a result of the passage of SAFETEA-LU. It includes a new set-aside provision known as the High Risk Rural Roads (HRRR) Program. This program is a component of the HSIP and is a $90 million per year program set-aside after HSIP funds have been apportioned to the states. The purpose of this program is to achieve a significant reduction in traffic fatalities and incapacitating injuries on rural major or minor collectors, and/or rural local roads (Federal Highway Administration).

As a new statutory requirement, it is expected to learn from ongoing implementation practices in the HRRRP. Best practices and implementation techniques associated with the State’s application of this provision will be shared nationally and could include modifications to this guidance (Federal Highway Administration).

## 2.2 Road Safety Audits

Road safety audits (RSAs) had been successfully used in Great Britain, Australia, New Zealand, and other countries for several years. RSAs apply safety principles to design new or modify roads to reduce the likelihood of crashes or decrease severity of crashes (CCMTA-CCATM 1999). A road safety audit is “a formal safety performance examination of an existing or future road or intersection by an independent audit team" (FHWA 2004). RSAs are proven to be effective in identifying and reducing potential crashes. After carefully reviewing the impact of RSAs in other countries, FHWA held a workshop for RSAs and initiated a one-year pilot study in 1998 (FHWA 2007). Unlike the traditional informal safety reviews, RSAs have their unique features. Table 2.1 shows the differences between traditional safety review and RSAs.

**Table 2.1** Road Safety Audits Features

| **Traditional Safety Reviews** | **Road Safety Audits** |
|---|---|
| • A safety review uses a small (1-2 person) team with design expertise. | • A safety audit uses a larger (3-5 person) interdisciplinary team. |
| • Safety review team members are usually involved in the design. | • Safety audit team members are usually independent of the project. |
| • Field reviews are usually not part of safety reviews. | • The field review is a necessary component of the safety audit. |
| • Safety reviews concentrate on evaluating designs based on compliance with standards. | • Safety audits use checklists and field reviews to examine all design features. |
| • Safety reviews do not normally consider human factors issues. This includes driver error, visibility issues, etc. | • Safety audits are comprehensive and attempt to consider all factors that may contribute to a crash. |
| • Safety reviews focus on the needs of roadway users. | • Safety audits consider the needs of pedestrians, cyclists, large trucks as well as automobile drivers. |
| • The safety review is reactive. Hazardous locations are identified through analysis of crash statistics or observations and corrective actions are taken. | • Safety audits are proactive. They look at locations prior to the development of crash patterns to correct hazards before they happen. |

(Source: Road Safety Audits. FHWA 2007)

RSAs have several advantages over the traditional safety reviews. First, RSAs are implemented at several stages of a project, such as initial plan stage, final design stage, pre-opening stage, and existing roadways. The RSAs provide transportation agencies more opportunities to review and correct their future or existing plans. Second, RSAs identify potential safety problems for all road users, including pedestrians, large trucks, etc. Third, the RSAs team is independent of the project to make unbiased evaluation. Fourth, RSAs are comprehensive and they consider all the factors that may affect road safety. Road safety audit is a formal process, therefore, it requires following a step-by-step procedure. The RSAs consist of following ten steps (Owers and Wilson 2001):

1. Select the road safety audit team.
2. Provide background information.
3. Hold a commencement meeting.
4. Assess the documents/review the site.
5. Inspect the site.
6. Write the road safety audit report.
7. Hold a completion meeting.
8. Write a response to the audit report.
9. Implement the agreed changes.

10. Feedback the knowledge gained.

Several transportation agencies have successfully implemented RSAs. For example, South Carolina DOT (SCDOT) completed 50 RSAs for existing roads and 6 for the design projects. On Interstate 585, after the RSAs, eight recommendations were made and four implemented. The result was impressive: a 12.5% decrease in accidents and a $40,000 savings. Also on SC 296, 25 recommendations were implemented, which resulted in a 23.4% reduction in accidents with an economic impact savings of $147,000 (FHWA 2007).

FHWA's executive summary of road safety audits (FHWA 2007) concludes that "RSAs are a powerful tool for state and local agencies to enhance the state of safety practices in the United States. The value of the RSA process in identifying roadway safety issues makes it an important component of any agency's safety strategy."

## 2.3 Roadway Classification System

Roadway classification systems hierarchically stratify roads into different classes. One purpose of establishing a roadway classification system is to insure efficient use of limited funds and resources. The system can be used as a funding tool to identify whether streets and roads are eligible for federal funds. Since the early 1920s, a functional classification system had been used to assign facilities to a Federal-aid Highway System (Ohio DOT 2002). Roadway classification systems can also be used as a management tool to assign jurisdiction responsibility, establish appropriate design standards, and maintenance practices for each class of roadways (Ohio DOT 2002).

Different classification schemes can be applied based on different purposes in different rural and urban regions. As an example, for highway location and design procedures, roadways are classified by design types based on major geometric features. For traffic operations purpose, roadways are classified by route number (AASHTO 2004).

Functional classification is one type of roadway classification system and it has been widely adopted by most state DOTs in the United States. In 1989, after multiple revisions, the Federal Highway Administration (FHWA) released *Highway Functional Classification: Concept, Criteria, and Procedures* (FHWA 1989). However, the FHWA's functional classification is only a general guideline for classifying roadways into three broad categories: arterial, collector and local roads. In some cases, this roadway classification cannot meet the needs for local agencies. For instance, some very low volume roads ($ADT \leq 400$) have unique characteristics and usage (AASHTO 2001). Simply classifying all these roads into one local category is not adequate for maintenance and operation needs. Therefore, other extension systems were developed to supplement FHWA's system. Moreover, some states have unique geographical characteristics and historical backgrounds that require them to develop their own classification systems.

### 2.3.1 FHWA's Functional Classification

#### 2.3.1.1 The Concept of the Functional Classification

Functional classification is the process by which streets and highways are grouped into classes or systems according to the character of service they are intended to provide (FHWA 1989). A typical trip contains six stages: main movement, transition, distribution, collection, access, and termination (AASHTO 2004). Most travel cannot be completed within just one or two stages, but instead requires different classes of roads that work together as a network. More importantly, trips should be channelized within the network in a logical and efficient manner. Figure 2.1 shows a hypothetical trip from freeway to destination. A vehicle's main movements are on the freeway, high speed and uninterrupted. When the vehicle approaches its destination, it uses freeway ramps as transition to reduce speed. Then the vehicle enters distributor facilities that bring it near the destination neighborhoods and enters collector roads to go through neighborhoods. Finally, the vehicle enters local access roads that directly connect to its destination. Function classification defines the nature of this channelization process by defining the part of function that any particular roadway plays in serving the flow of trips (AASHTO 2004).

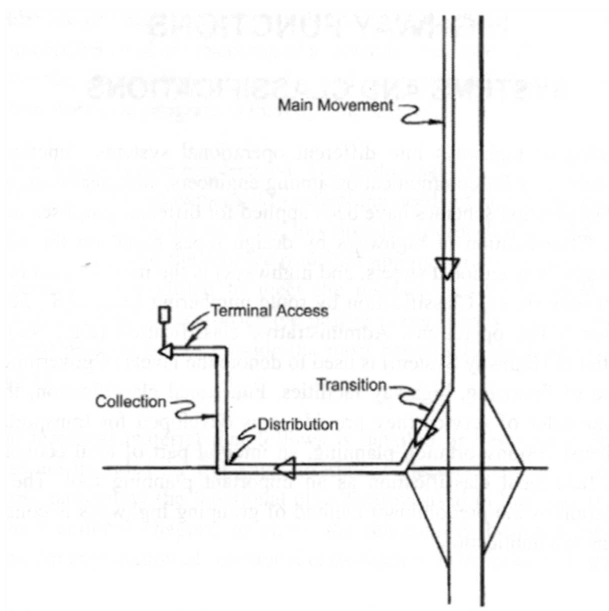


**Figure 2.1** Hierarchy of Movement
(Source: A Policy on Geometric Design of Highway and Streets, 2004)

Mobility and access are two major considerations in functionally classifying roadways. As illustrated in Figure 2.2, for different functional classes, the relative importance of the mobility and access functions are emphasized differently. Freeways are the highest functional class. They are mainly intended to serve through traffic but not to access to adjacent land. Arterials and collectors gradually put less emphasis on mobility for through traffic and more emphasis on access to adjacent land. Local roads are primarily intended to provide access to adjacent property and residences.

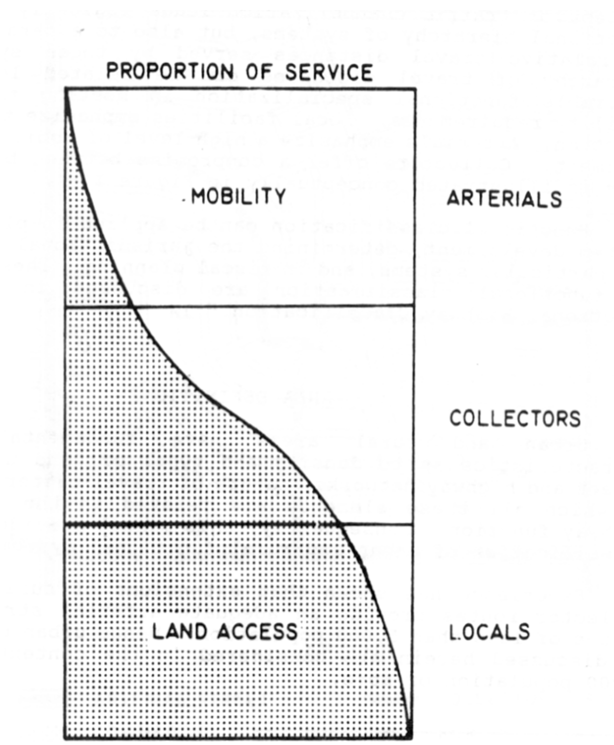


**Figure 2.1** Relationship of Functionally Classified Systems in Serving Traffic Mobility and Land Access. (Source: A Policy on Geometric Design of Highway and Streets 2004)

### 2.3.1.2 Arrangement of the Highway Functional Classification System

Figure 2.3 shows the hierarchical arrangement of the highway functional classification system. Urban and rural areas have different characteristics with regard to the density and type of land use, density of street and highway networks, nature of travel patterns, and the way in which these elements are related (AASHTO 2004). Therefore, urban and rural areas have different functional classification systems and associated criterion.

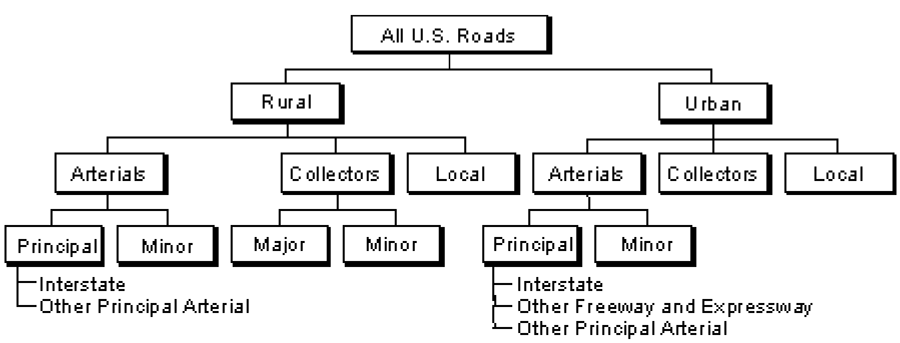


**Figure 2.3** Hierarchy Arrangement of the Highway Functional Classification System (Source: A Policy on Geometric Design of Highway and Streets, 2004)

#### 2.3.1.3 Urban and Rural Definitions

Urban areas are places within boundaries set by state and local officials having a population of 5,000 or more. Urban areas are further subdivided into urbanized areas and small urban areas. Urbanized areas have a population of 50,000 and over; small urban areas have a population between 5,000 and 50,000. Rural areas are areas outside the boundaries of small urban and urbanized areas (AASHTO 2004).

### 2.3.2 AASHTO's Functional Classification

The functional classification system described in the American Association of State Highway and Transportation Officials' (AASHTO) green book (A Policy on Geometric Design of Highways and Streets 2004) is identical to the FHWA's system. The green book uses the FHWA's *Functional Classification: Concept, Criteria, and Procedures* as a major reference. In the green book, roadways are stratified into the same classes as stated in the FHWA's system.

### 2.3.3 Functional Classification for Low-Volume Roads

The functional classification system for low-volume roads is a supplement to the FHWA's functional classification system (AASHTO 2001). Because of the unique characteristics of the very low-volume local roads, these roads are further classified into six functional subclasses in rural areas and three functional subclasses in urban areas. The arrangement of functional classification is listed in

Table **2.**2.

**Table 2.2** The Arrangement of the Functional Classification System for Very Low Volume Local Roads (Source: Guidelines for Geometric Design of Very Low-Volume Local Roads 2001)

| Rural Roads | Urban Roads |
|---|---|
| Major Access Roads | Major Access Roads |
| Minor Access Roads<br>Industrial/Commercial Access Roads | Industrial/Commercial Access Roads<br>Residential Street |
| Agricultural Access Roads | Residential Street |
| Recreational and Scenic Road | |
| Resource Recovery Roads | |

## 2.4 Crash Prediction

Crash prediction models offer an estimate of expected accident frequency as a function of traffic flow characteristics and roadway geometries. Regression equations that relate crash experience to traffic and other geometric conditions are widely used in modern highway safety analysis (NCHRP 2001). Extensive research had been performed to examine the relationship between vehicle crashes and traffic flow features (e.g., traffic volume, speed) or geometric designs (e.g., lane width, shoulder width). In previous safety studies, linear regression, Poisson regression, and negative binomial regression were three techniques used to develop a regression model (Wang 2008).

### 2.4.1 Linear Regression

Several previous safety studies used multiple linear regression to study the relationships between vehicle accident and geometric features (Miaou 1993). Several researches such as (Okamoto 1989) tried to use multiple linear regression to analyze accident rates related to geometric design elements. They found that linear regression was not suitable to model vehicle accidents. The underlying assumption of linear regression is that events follow a normal distribution. Therefore, the linear model may predict a negative value. However, in real life traffic crash data are always discrete and regarded as a random variable that takes non-negative integer values. These characteristics imply that crash data may follow the Poisson distribution.

### 2.4.2 Poisson Regression

Miaou utilized the Poisson regression to model truck accident data (Miaou 1992). From the model, it was found that truck accidents were strongly related to traffic volume and the roadway geometric factors, such as vertical grade and horizontal curvature.

Poisson regression was used to analyze traffic count data. It can be used to model the number of occurrences (or the rate) of an event of interest, as a function of some independent variables. In Poisson regression, it is assumed that the dependent variable Y, number of occurrence of an event (number of crashes per mile in this study), has a Poisson distribution given the independent variables $X_1$, $X_2$, …..,$X_i$. The general form of the Poisson regression is as follows:

$$f(Y) = \frac{\mu^Y \exp(-\mu)}{Y!} \tag{2.1}$$

Where: $f(Y)$ is the probability that the outcome is $Y$.

In exponential form, equation 2.1 can be rewritten as:

$$\mu_i = \exp\left(\beta_0 + \sum_{j=1}^{n} X_i \beta_j\right) \tag{2.2}$$

Where: $\mu_i$ is the expected crash per mile on road i.

$X_1$, $X_2$…..$X_i$ are the values of the roadway variables (traffic volume, speed, etc) on road i.

$\beta_{1,}$…. $\beta_j$ are the coefficients to be estimated by modeling.

The expected crash rate is the number of crashes adjusted for intensity, and it is assumed to be an exponential value applied to a suitable combination of roadway variables. Thus, the model falls under the heading of a generalized linear model. The exponential function guarantees that the mean (the number of expected crashes) is non-negative.

The most widely accepted way to estimate the parameters in β is to use the Maximum Likelihood Estimation (MLE) procedure (Wang 2008). The likelihood function can be written as:

$$L(\bar{\beta}) = \prod_{i=1}^{n} f_i\,(Y_i) = \prod \frac{[\mu(X_i,\beta)]^{Y_i} \exp[-\mu(X_i,\beta)]}{Y_i!} \tag{2.3}$$

Where: $\mu(X_i, \beta)$ is the function which relates $\mu_i$ to $X_i$

Miaou (Miaou 1993) also pointed out the limitation of using the Poisson Regression. The Poisson distribution's fundamental assumption is that the variance should be equal to its mean. However, real crash data rarely have their variance equal to their mean. In most cases, the variance is larger than its mean. This phenomenon causes what is called overdispersion. The consequence of the overdispersion is that the variances of the estimated parameters tend to be underestimated. In other words, the estimated $\beta$ from MLE under the Poisson regression model is still close to the true parameter, but the significance levels of the estimated parameters may be overstated.

### 2.4.3 Negative Binomial Regression (NBR)

In dealing with the overdispersion in crash data, negative binomial regression, an alternative to Poisson regression, has been used in accident modeling. In 1995, Shankar (Shankar 1995) tried to use the NBR to overcome the overdispersion problem. He used both Poisson regression and NBR to model the effects of road geometry and environmental factors on the number of crashes. He found that NBR modeled the crash data better than Poisson regression when the crash data were overdispersed. Caliendo (Caliendo 2007) used both Poisson regression and NBR to examine the relationship between geometric features and accident frequency on multilane roadways in Italy. They found that Poisson regression was inappropriate to model the random variation of the number of crashes if there was clear evidence that overdispersion was present.

NBR generalizes the Poisson regression by permitting the variance to be overdispersed. In the NBR model, the variance equals to the mean plus a quadratic term in the mean whose coefficient is called the overdispersion parameter $\alpha$ (Equation 2.4).

$$\mathrm{Var}\,[Y_i] = E\,[Y_i][1 + \alpha E[Y_i] = E\,[Y_i] + \alpha E[Y_i]^2 \tag{2.4}$$

The selection between the two models, Poisson regression or NBR, depends on the value of $\alpha$. When this parameter is equal or close to zero, a Poisson model is appropriate. When it is larger than zero, it represents the variance above and beyond the mean. This overdispersion phenomenon is commonly due to the variation of the highway variables present in the model, such as accident-related factors pertaining to drivers, vehicles, and location not encompassed by the highway variables (Wang 2008). For the NBR model, the expected accident frequency for a section i is rewritten as:

$$\mu_i = \exp\left(\beta_0 + \sum_{j=1}^{n} X_i \beta_j\right) \tag{2.5}$$

Where: $\mu_i = EY_i|X_i$ for $Y_i|X_i$ distributed as a negative random binominal variable

One of the forms of NBR distribution can be written as:

$$f(Y) = \frac{\Gamma\left(\frac{1}{\alpha}+Y_i\right)}{\Gamma(Y_i+1)\Gamma\left(\frac{1}{\alpha}\right)}\left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha}+\mu_i}\right)\left(\frac{\mu_i}{\frac{1}{\alpha}+\mu_i}\right)^{Y_i} \tag{2.6}$$

Where: $\Gamma$ ( ) is a gamma function

### 2.4.4 Other Techniques

Another method of estimating number of crashes is the Empirical Bayes (EB) method. This method is used in the Interactive Highway Safety Design Model (IHSDM) and it will be used in the Comprehensive Highway Safety Improvement Model (CHSIM) (Hauer 2002). The EB method recognizes that historic accident counts are not the only source to estimate safety performance. The expected number of accidents based on analyses of similar roadways can also be used to estimate number of crashes (Hauer 2002). The EB method is expressed as:

Expected Accidents of a Roadway =
Weight*Accidents Expected on Similar Roadway + (1-Weight)*Annual Crash Count (2.7)

One advantage of this method is that it can increase the precision of the estimates when only two or three years of crash data are used. The other advantage is that it can correct the regression-to-mean bias. Short period accident counts often show decreases in number of crashes after undergoing a period of a high number of crashes even if no safety improvements were installed. This phenomena is called regression-to-mean (Pham 2005). To overcome this problem, the EB method employs both prediction model and historical crash data to estimate the expected number of crashes (Hauer 2002), as shown in equation 2.7. However, implementing the EB method will generally encounter two problems: selecting the appropriate crash prediction model and choosing the correct weights (Pham 2005).

The EB method will not be used in this safety study. For one thing, 10-year crash data obtained from WYDOT help eliminate the imprecision estimation and regression-to-mean bias caused by the short period of crash counts. Typically, 10 years of data are not used in safety studies because of the high likelihood that the roadway was changed in some manner during that period. However, for this safety study involving rural gravel roads in Wyoming, the likelihood that improvements were made to the road is minimal. The other reason for not using the EB method is that it would unnecessarily add to the complexity of implementing crash prediction model. Given the rural nature of this program and its implementation by small county agencies, the goal is to develop a methodology that can be used by counties in Wyoming.

## 2.5 Economic Analysis

The primary purpose of a safety improvement is to reduce the number and/or severity of crashes. Economic analysis involves the estimation and comparison of the expected costs and benefits from the proposed safety improvements. The estimated cost effectiveness of safety improvements gives crucial information to the decision makers and it greatly affects the way that funding will be allocated. In 2000, NCHRP conducted a survey (NCHRP 2001) to assess current practices in highway safety analysis. The survey indicated that 88% of the respondents perform economic analysis. When considering whether or not to make large capital expenditures on a safety project, most of the transportation agencies perform economic evaluation of different alternatives.

A typical economic analysis of the alternatives consists of the following six steps (FHWA 2002):

1. Identify the candidate sites and evaluated countermeasures.
2. Select the economic criterion used in the economic appraisal.
3. Perform economic appraisal for the particular sites and countermeasures.
4. Display economic appraisal results.
5. Rank alternatives based on selected criteria.

6. Determine the improvement alternatives that should be implemented to maximize safety benefits given a budgetary constraint.

Several methods can be used to perform the economic analysis described in Step 2. The software tools called "Safety Analyst" that were developed by FHWA for safety management of specific roadway sections employ three economic criteria to do the economic appraisal analysis. They include cost-effectiveness, benefit-cost ratio (BCR), and net benefits. Although each method will produce the same results they have their own merits and drawbacks.

### 2.5.1 Cost-Effectiveness

The cost-effectiveness of the candidate improvement is expressed in terms of the dollars spent per accident reduced. Projects with a lower cost per accident reduced are more likely to maximize the benefits of an improvement program than projects with higher cost per accident reduced (FHWA 2002). The equation for calculating cost-effectiveness is expressed as:

Cost-effectiveness = Total Cost/ Expected Number of Accidents Reduced (2.7)

The main advantage of this method is its simplicity. It does not incorporate any estimates of accident reduction benefits in monetary terms. The major disadvantage of this approach is that it does not explicitly consider the severity of the accidents reduced. To overcome this disadvantage, severity weighting such as Equivalent Property Damage Only (EPDO) could be incorporated into the analysis. Another disadvantage is that this method cannot clearly provide information about which alternatives can maximize safety benefits (FHWA 2002).

### 2.5.2 Benefit-Cost Ratio (BCR)

Similar to cost-effective analysis, the purpose of the BCR economic analysis is to provide an economic assessment of the extent to which a project or program may achieve its ultimate goal of reducing the number and/or severity of accidents. The BCR analysis provides a means of selecting the most cost-effective countermeasure(s) for any given project. It is one of the most widely used methods for screening programs and projects that are being considered for development (FHWA 2002). The FHWA uses BCR approach for economic justification of safety improvements, funded through the Highway Safety Improvement Program (HSIP) (FHWA 2002).

The BCR is the ratio of expected benefits (accident savings) to the costs incurred for a countermeasure. If a safety improvement project is economically justified, its benefit-cost ratio should be greater than 1.0. Among the alternatives, the one with a larger BCR generally indicates better economical appraisal. The BCR is calculated as:

BCR = Benefit/Cost (2.8)

The benefit is the anticipated reduction in the total annual number of accidents, or accident frequency, per countermeasure. The total annual accident cost saving (benefit) can be obtained from FHWA's comprehensive motor vehicle accident costs and then multiply by appropriate accident reduction factors (ARF). The cost is not easy to determine. It varies with different factors (project scope, location, service life, etc.). Thus, it needs to be estimated based on the specific project. Unlike the cost-effectiveness approach, BCR considers accident severity by estimating accident cost savings according to severity level. The disadvantage of this method is that if there is multiple benefits and cost terms, it is not always clear whether specific terms belong in the numerator (benefit) or the denominator (cost). As an example, it is not always clear whether some maintenance costs should be treated as a decrease in the annual safety benefit or should be converted to a present value and treated as an increase in the project cost (FHWA 2002). Therefore, a different BCR value is calculated depending on which approach is used.

If multiple alternatives have their BCR value greater than one. Selecting the alternative with the highest BCR is not appropriate. Sometimes, the alternative with the highest BCR value may not achieve the best economic effectiveness. The incremental BCR method can be used to determine whether extra increments of costs are justified. The equation of calculating the incremental BCR presents as follows (Newnan 2004):

$$\text{Incremental BCR}_{2\text{-}1} = (\text{Benefit}_2\text{-Benefit}_1)/(\text{Cost}_2\text{-Cost}_1) \quad (2.9)$$

Where:

Incremental $BCR_{2-1}$ is the incremental BCR of alternative 2 compared with alternative 1
$Benefit_2$ is benefit from alternative 2
$Benefit_1$ is benefit from alternative 1
$Cost_2$ is the cost of alternative 2
$Cost_1$ is the cost of alternative 1

The steps of using incremental BCR are as follows (Arizona DOT 2004):

1. Determine the benefits, cost, and the BCR for each alternative.
2. List alternatives with BCR greater than 1.0 in order of increasing cost.
3. Calculate the incremental BCR of the second lowest-cost alternative compared with lowest-cost alternative. If the ratio is negative, pick the second lowest-cost alternative; otherwise pick the lowest-cost one.
4. Continue in order of increasing cost to calculate the incremental BCR for each countermeasure compared to the last-picked countermeasure.
5. Stop when the incremental BCR is less than 1.0.

A detailed example of calculating the incremental BCR will be presented in Section 7.

**Net Benefit**

The net benefit approach uses the value of an alternative's benefits minus its costs to assess the economical appraisal. It is calculated as:

$$\text{Net Benefit} = \text{Benefit- Costs} \quad (2.10)$$

If a safety countermeasure is economically justified, its net benefit should be a positive value. This method eliminates the issue of whether particular cost items should appear in the numerator or denominator of the BCR (FHWA 2002). However, similar to the cost effectiveness, this approach cannot explicitly consider the cost for each severity level of crash.

## 2.6 Chapter Summary

In this chapter, the results of the literature reviews were presented. It was found that the FHWA's functional classification system is adopted nationwide. However, in some cases (such as low volume local roads), the FHWA's guidelines may not satisfy all agencies' needs.

Traffic crash data are a type of discrete random variable and their probabilities typically follow the Poisson distribution. However, in most cases, the traffic crash data are overdispersed. This phenomena limits the use of Poisson regression in crash modeling. According to the literature review of previous safety studies, negative binominal regression is more suitable to deal with the overdispersed crash data. Therefore, the NBR method will be used in the model development process for this safety study.

Before investing large capital expenditures in safety projects, most highway agencies perform economic evaluation on the different alternatives. The BCR approach is one of the most popular methods for evaluating economic appraisal of safety improvements. Unlike the net benefit method, it can provide a scaled value that is more easily understood by the decision makers. When the BCR values of two or more alternatives are greater than 1.0, the incremental BCR method should be used to select the best alternative. The WRRSP will use BCR approach to perform economic analysis.

# 3. WYOMING RURAL ROAD SAFETY PROGRAM

## 3.1 Methodology

In this research study, the Wyoming LTAP Center developed a Wyoming Rural Road Safety Program (WRRSP) with funding from WYDOT, MPC, FHWA, and in cooperation with Wyoming counties. The primary objective of this research program was to help counties identify high risk rural locations and then develop a strategy to obtain funding for the top-ranked sections to reduce crashes and fatalities on rural roads statewide.

As part of this study, a Local Road Safety Advisory Group (LRSAG) was established. This group included representatives from WYDOT, Wyoming LTAP, Wyoming Association of County Engineers and Road Supervisors (WACERS), Wyoming Association of Municipalities (WAM), and FHWA. Three Wyoming counties were included in the pilot phase of this study. The program involved the collection of data for the three counties: Carbon, Laramie, and Johnson. The geographical locations of these three counties are shown in Figure 3.1. These counties were selected to cover the variations in traffic patterns, crashes, and populations among Wyoming counties.

A five-step procedure was developed by the research team and approved by the LRSAG. These five steps are:

1. Crash data analysis
2. Level I field evaluation
3. Combined ranking to identify potential high risk locations based on steps 1 and 2
4. Level II field evaluation to identify countermeasures
5. Benefit/cost analysis

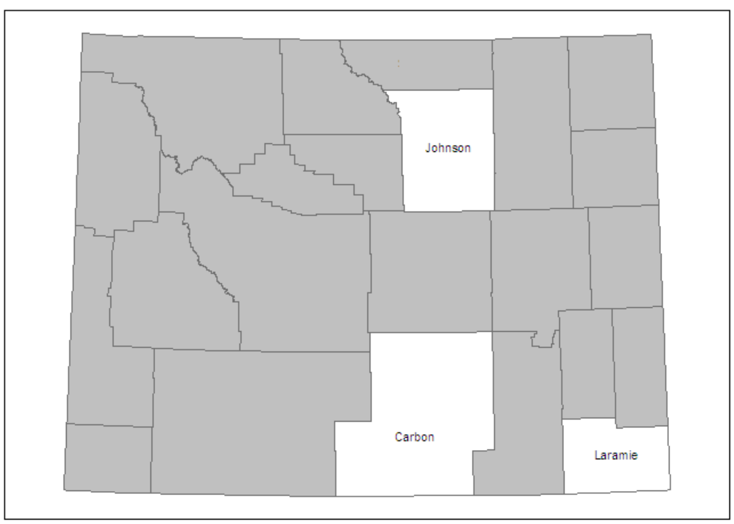


**Figure 3.2** Locations of Carbon, Johnson, and Laramie Counties

The five-step procedure is shown graphically in Figure 3.2. This program utilizes the combination of historical crash records and field safety evaluations in identifying high risk locations. A benefit/cost analysis can then be applied to determine the most cost effective countermeasures at the high risk locations.

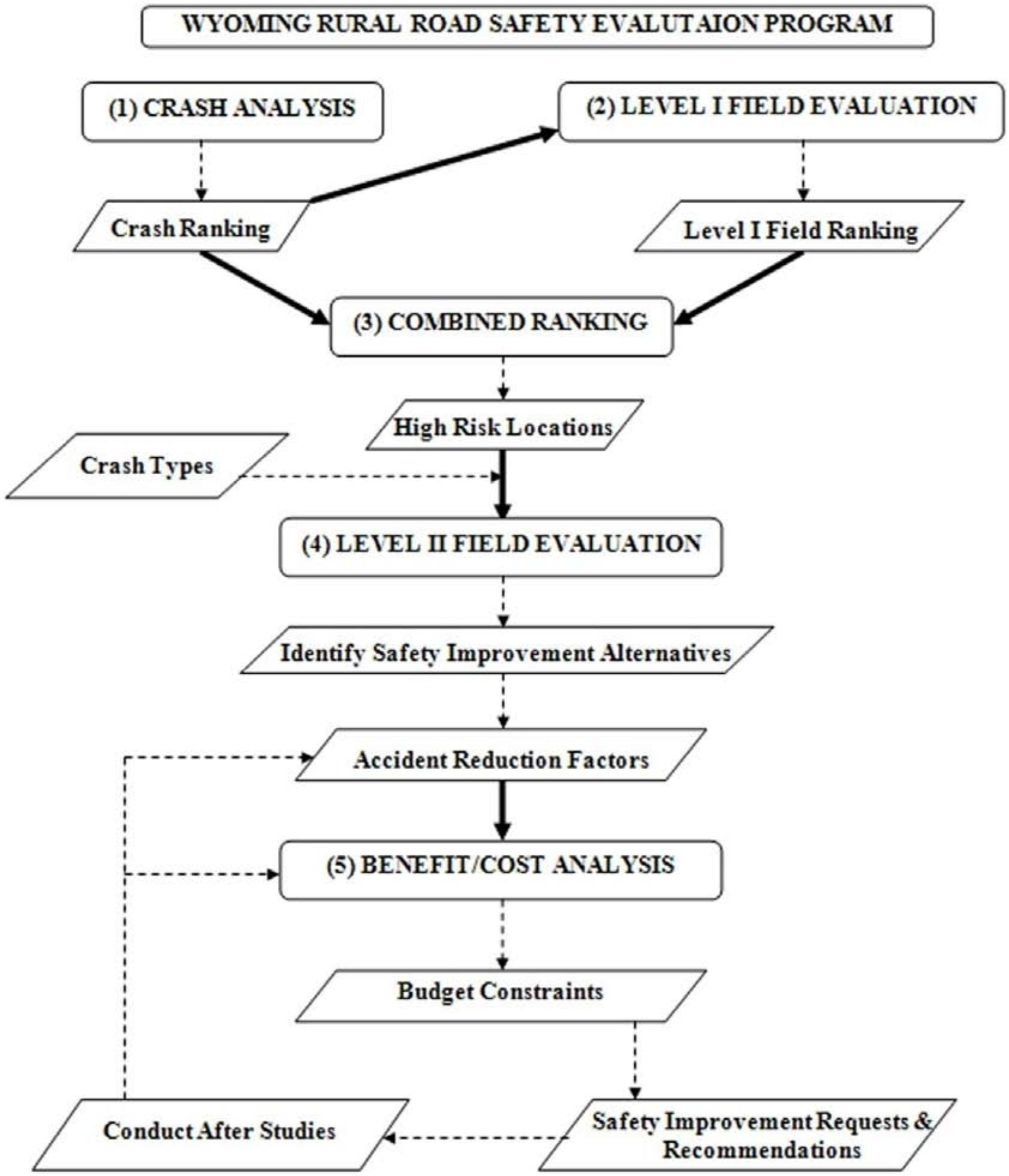


**Figure 3.3** The five step process to identify high risk rural roads

## 3.2 Program Description

As described above, the five steps included in the WRRSP will insure selecting high risk locations based on both field conditions and historical crashes. This section describes these five steps in detail and shows how these steps were applied in the three counties included in the pilot study.

## 3.3 Step 1: Crash Data Analysis

As seen in Figure 3.2, the output from Step 1 is the crash ranking, which will be used as the input of Step 2 to select candidate roads for level I safety evaluation. It is also the input to Step 3 that will provide information to generate the combined ranking.

The Wyoming Department of Transportation (WYDOT) collects data on all reported crashes on all rural county roads. The crash data obtained from WYDOT contain information such as the location of the crashes (including route number and mile post), severity of crashes (PDO, Injury, fatal), road surface conditions, weather conditions, and first harmful event (FHE). Wyoming rural roads have a relatively small number of crashes. Therefore, longer analysis periods are needed to identify high risk locations. The WRRSP utilized the ten-year period (1995-2005) crash data for analysis.

The program developed in this research applies only to rural roads that are not interstate or state highways. The crash records on these rural roads can be summarized in many different ways. The research team selected the following ten potential procedures for identifying high risk locations:

1. Total number of crashes (based on 10 years)
2. Total number of crashes/mile (based on 10 years)
3. Fatal and injury crashes/mile (based on 10 years)
4. Equivalent Property Damage Only method (EPDO) (based on 10 years)
5. Total number of crashes/mile (based on 3 year moving average)
6. Fatal and injury crashes/mile (based on 3 year moving average)
7. Total crash rate (based on 10 years)
8. Fatal and injury crash rate (based on 10 years)
9. Total crash rate (based on 3 year moving average)
10. Fatal and injury crash rate (based on 3 year moving average)

The LRSAG provided direction to the research team to place every crash into the actual single-mile strip for a road on which it occurred, i.e., Road 10, mile 2.01-3.00. On rural roads, the crash location information is not precise. For example, if a crash actually occurred at milepost 2.3, the crash record only showed that the crash occurred within the 2.00 to 3.00 mile post range. So every PDO, injury, and fatal crash should be recorded per each single-mile strip of roadway in an Excel spreadsheet. The data can be then sorted from largest to smallest based on total number of crashes. The top 30 single-mile strips are then identified for the follow-up analysis. Finally, the top 10 to 15 roads that have high ranking segments in the crash analysis are selected as candidate roads. Carbon, Laramie, and Johnson counties were selected for inclusion in this pilot study. The final candidate roads selected in these three counties are listed (in route number order) in Tables 3.1, 3.2, and 3.3. It should be mentioned that Johnson County provided the research team with only traffic volume data on several roadways. However, developing a crash prediction model needs further information about traffic speed. Therefore, in this evaluation, only the data (8 roads) collected by the research team were included in the analysis.

The analysis can be conducted on the EPDO or fatal crashes, but the LRSAG and the research team agreed that fatal crashes were too limited in number and this would not result in a meaningful analysis. In addition, the EPDO analysis would put too much emphasis on fatal and injury-related crashes which might skew the analysis. Ranking sections based on the actual number of crashes on specific one-mile segments was identified as the procedure to follow in this study.

**Table 3.1** Candidate Roads of Carbon County

| Route No. | Road Name | Total Crashes | Road Length |
|---|---|---|---|
| 203 | Brush Creek | 6 | 7.62 |
| 291 | Hanna Leo, Kortes | 42 | 57.43 |
| 324 | Golf Course Road | 8 | 5.17 |
| 353 | Finley Hill | 3 | 6.6 |
| 385 | North Spring Creek Road | 7 | 16.25 |
| 401 | Sage Creek | 39 | 34.53 |
| 500 | Jack Creek | 16 | 23.94 |
| 504 | Ryan Park Road | 15 | 16.05 |
| 550 | Buck Creek | 1 | 1.48 |
| 561 | Savery North | 8 | 8.13 |
| 603 | Four Mile | 3 | 3.67 |
| 660 | Holms French Creek | 9 | 14.52 |
| 700 | Poison Butte | 8 | 17.2 |
| 701 | Dad | 8 | 19.13 |
| 702 | Baggs Dixon | 7 | 7.32 |
| 710 | Snake River Spur | 4 | 3.09 |

**Table 3.2** Candidate Roads of Laramie County

| Route No. | Road Name | Total Crashes | Road Length |
|---|---|---|---|
| 102-1 | Harriman | 15 | 7.32 |
| 109 | Gilchrist | 26 | 9.48 |
| 120-1 | Telephone | 23 | 22.73 |
| 124 | Old Yellowstone | 17 | 10.84 |
| 136 | Durham | 11 | 8.23 |
| 143-2 | Hillsdale North | 18 | 28.38 |
| 149-1 | A149-1 | 4 | 0.69 |
| 162-2 | Albin South | 29 | 10.95 |
| 164-1 | Cemetery/Pine Bluff South | 9 | 12.26 |
| 203-1 | Chalk Bluff | 30 | 36.8 |
| 209 | Campstool | 16 | 7.33 |
| 210 | Crystal Lake | 30 | 10.8 |
| 212-1 | Old Highway Burns | 9 | 4.11 |
| 215 | Railroad | 42 | 18.47 |

**Table 3.3** Candidate Roads of Johnson County

| Route No. | Road Name | Total Crashes | Road Length |
|---|---|---|---|
| 3 | Hazelton | 9 | 32.70 |
| 14 | Crazy Woman Canyon | 6 | 8.49 |
| 40 | Kumor | 8 | 8.32 |
| 85 | Shell Creek | 5 | 5.90 |
| 91H | French Creek | 25 | 12.20 |
| 132 | Klondike | 7 | 12.94 |
| 212 | Airport | 3 | 1.60 |
| 256 | Upper Clear Creek | 8 | 1.69 |

## 3.4 Step 2: Level I Field Evaluation

From the Step 1 crash analysis output, the level I field evaluation needs to be performed on roadway sections that are identified as high risk locations. Then the field ranking can be obtained from the level I field evaluation. It is anticipated that county engineers and road supervisors will be performing the level I field evaluation. To insure the evaluation consistency among different counties, the Wyoming $T^2$ LTAP Center will provide statewide training on level I field evaluation in November.

The counties can perform the level I field evaluation on shorter segments with high number of crashes or on the entire length of the selected roads. On certain roads, for example, if most of the crashes occurred in short concentrated segments, only these segments need to be evaluated. If crashes were scattered throughout the entire length of the road, the entire length of the road should be evaluated. Five categories are used in the level I field evaluation. The road should be evaluated in the field and analyzed for each single-mile segment. Each single-mile segment will be given a score of 0 to 10 for each of the five categories, with 0 being the most dangerous and 10 being the least dangerous. The five categories are:

1. General
2. Intersection and Rail Road Crossings
3. Signage and Pavement Markings
4. Fixed Objects and Clear Zones
5. Shoulder and ROW (Right of Way)

The final score for each single-mile segment is the total sum of the score from the five categories and is used for the level I field evaluation ranking. A lower score means a single-mile segment is more dangerous than other segments. The lowest score will result in the highest level I field ranking. The level I field evaluation form shown in Appendix A-1 is used to perform the level I field evaluation for each high risk location. Two types of information need to be entered in this form: general information and the specific score for each single-mile segment being evaluated. General guidelines for estimating the score for each category are provided in Appendix A-2. Appendix A-3 shows an example of performing level I field evaluation on one Wyoming rural road.

## 3.5 Step 3: Combined Ranking

The level I field evaluation ranking in conjunction with the crash ranking are used to generate the combined ranking. The combined rankings will be used to select the roads that need to be included in the level II field evaluation. The final score is calculated as:

Final Score = Crash Rankings * Weight + Level I field Rankings *Weight (3.1)

Before calculating the score, the weights that are assigned to total crashes rankings and level I field rankings must be determined.

### 3.5.1 Sensitivity Analysis

Different weights (e.g., 40% assigned to total crashes rankings, 60% assigned to level I field rankings) may affect the final score and consequently affect the combined rankings. Thus, a sensitivity analysis was performed to determine the effects of weights in combined rankings. The basic idea of the sensitivity analysis was to assign various combinations of different weights (e.g., 45-55%, 40-60%) to total crash rankings and field rankings and then evaluate the impacts on the combined rankings. The following procedure was used to perform the sensitivity analysis:

1. Using 50-50% weight scheme (50% of the final score from crash rankings and 50% of the final score from the field rankings) to calculate the final score. The rankings based on this score are set as reference rankings.
2. Using various combinations of weights to calculate the combined rankings. The top 10, 20, 30, and 50 high risk locations were used to evaluate the impact of the weight on the rankings. The absolute rankings differences between the 50-50% ranking scheme and other ranking schemes were calculated and then averaged. The standard deviations of the absolute rankings differences were also calculated. The detailed results when using different combination of weights can be found in Appendix A-4.

As an example, when analyzing the impact of the 45-55% weight scheme on the top 10 high risk locations in Carbon County, the absolute rank differences between the 50-50% scheme and 45-55% were calculated (shown in Appendix A-4) and then averaged (shown in Table 3.4). From

**Table 3.4** and Table 3.5, it can be seen that the weights assigned to crash rankings and field rankings have little impact on the top 10 high risk locations in both Carbon and Laramie counties. It should be noted that Johnson County was not included in the sensitivity analysis because the dataset was not available at the time when this analysis was conducted. When using different weights, the average rankings differences and standard deviation in the top 10 are small. This means that even though the weight scheme is deviated from the 50-50% scheme, the top 10 high risk locations can still be screened out. The rankings maintain stable up to the 40-60% ranking scheme. As the schemes become more and more deviated from the 50-50%, the average rank difference and standard deviation are getting bigger. However, the impact is negligible up to top 20.

The 50-50% scheme is employed in this study. This treats crash rankings and filed rankings equally important in identifying high risk locations.

**Table 3.4** Average Rank Difference and Standard Deviation (Carbon County)

| Weight % | Top 10 | | Top 20 | | Top 30 | | Top 50 | |
|---|---|---|---|---|---|---|---|---|
| | Avg | Std | Avg | Std | Avg | Std | Avg | Std |
| 45-55 | 0.60 | 0.681 | 0.73 | 0.933 | 1.45 | 1.854 | 2.34 | 2.288 |
| 40-60 | 0.95 | 0.945 | 1.35 | 1.805 | 2.85 | 2.863 | 4.04 | 3.484 |
| 35-65 | 1.70 | 1.261 | 2.33 | 2.515 | 4.20 | 4.041 | 6.15 | 4.885 |
| 30-70 | 2.15 | 1.348 | 3.50 | 3.530 | 5.93 | 5.641 | 8.08 | 6.465 |
| 55-45 | 0.5 | 0.707 | 0.95 | 1.099 | 1.83 | 2.135 | 2.2 | 2.365 |
| 60-40 | 0.7 | 0.949 | 1.65 | 1.927 | 3.13 | 3.082 | 3.96 | 3.464 |
| 65-35 | 1.5 | 1.354 | 2.75 | 2.511 | 4.50 | 4.049 | 6.2 | 4.660 |
| 70-30 | 1.7 | 1.337 | 3.9 | 3.698 | 6.33 | 5.683 | 8.6 | 6.058 |

**Table 3.5** Average Rank Difference and Standard Deviation (Laramie County)

| Weight % | Top 10 | | Top 20 | | Top 30 | | Top 50 | |
|---|---|---|---|---|---|---|---|---|
| | Avg | Std | Avg | Std | Avg | Std | Avg | Std |
| 45-55 | 0.30 | 0.657 | 0.83 | 1.010 | 1.02 | 1.295 | 1.30 | 1.521 |
| 40-60 | 0.65 | 1.268 | 1.28 | 1.710 | 1.70 | 1.880 | 2.32 | 2.278 |
| 35-65 | 1.95 | 2.605 | 2.80 | 2.775 | 3.13 | 3.072 | 3.62 | 3.446 |
| 30-70 | 2.50 | 3.380 | 3.50 | 3.367 | 4.08 | 3.980 | 4.79 | 4.484 |
| 55-45 | 0.10 | 0.316 | 0.50 | 0.889 | 0.60 | 0.968 | 0.94 | 1.331 |
| 60-40 | 0.10 | 0.316 | 0.55 | 0.999 | 0.93 | 1.258 | 1.80 | 1.938 |
| 65-35 | 0.60 | 1.265 | 1.55 | 1.605 | 1.97 | 2.059 | 2.88 | 3.280 |
| 70-30 | 0.60 | 1.265 | 1.75 | 2.268 | 2.60 | 2.860 | 3.92 | 4.299 |

### 3.5.2 Results

Higher number of crashes generally indicates one road is more dangerous than another, therefore, it should be assigned a lower crash rankings. Similarly, lower level I field scores result in lower field rankings for roads evaluated as more hazardous. In this study, the combined ranking is calculated as:

Combined Ranking = Crash ranking* 50% + Field Score ranking* 50% (3.2)

Road segments identified as high crash locations for Carbon County and Laramie County are listed in Appendix A-4 (in 50%-50% column).

## 3.6 Step 4: Level II Field Evaluation

Level II field evaluation is aimed at identifying causative factors on each road section and selecting corresponding countermeasures. It will be performed on roadways that are identified as high risk locations based on the combined rankings from Step 3. Crash records contain the crash information (e.g., run off road crash, animal related crash, etc). The crash records associated with these high risk locations will be helpful to identify causative factors and select appropriate safety countermeasures. As an example, if most of the crashes are animal related at one road segment, installing an animal fence at this segment might be helpful to reduce the number of crashes. Level II field evaluation consists of three major steps:

1. Collect traffic volumes on the selected roads for seven days.
2. Review the list of safety issues to look for, as shown in Appendix A-5.
3. Perform level II field evaluation for each high risk road, using the level II field evaluation form shown Appendix A-6.

General guidelines are provided in Appendix A-7 to help in performing level II field evaluation. An example of performing level II field evaluation is shown in Appendix A-8.

## 3.7 Step 5: Benefit/Cost Analysis

After determining the causative factors from Step 4, different countermeasures may result in the same effect of reducing or mitigating crashes. However, the costs of the countermeasures could vary dramatically from each other. Therefore, benefit/cost analysis must be performed to evaluate which countermeasure can most effectively reduce the crashes while keeping the lowest cost. The detailed procedure of performing such analysis will be presented in Section 6.

## 3.8 Chapter Summary

This section introduced the recommended five steps of the WRRSP. They are crash analysis, level I field evaluation, combined ranking, level II field evaluation, and benefit/cost analysis. By implementing WRRSP, counties can identify high risk locations on rural roads and select safety countermeasures for the top-ranked sections to reduce crashes and fatalities on rural roads.

According to the developed methodology, historical crash data should be analyzed to identify rural roads with a high number of crashes. These roads would then be evaluated and assigned field scores based on the level I field evaluation described in this paper. A combined ranking based on the crash analysis and the level I field evaluation is then obtained to identify the high risk rural locations. These high risk locations should be subjected to the level II field evaluation, which is similar in nature to a road safety audit. This evaluation will result in recommending specific safety countermeasures. The proposed benefit cost analysis will insure that only cost effective measures will be selected for funding.

The Wyoming LRSAG approved the Wyoming Rural Road Safety Program (WRRSP) described in this paper and recommended statewide implementation. In addition, WYDOT and the FHWA division office approved the WRRSP for eligibility to receive funding from the High Risk Rural Road (HRRR) Program. Counties interested in applying for funding from the HRRR program would need to follow the methodology described in this paper. Requests from all Wyoming counties will be submitted to the local government office of WYDOT. The Wyoming Safety Management System (SMS) Committee will select a subcommittee to allocate the funding from the HRRR program for eligible and cost-effective requests. The Wyoming LTAP Center has already implemented the program in the three counties included in the pilot study. In addition, training materials have been developed to help counties implement the program statewide.

The methodology developed in this research can be implemented by other states interested in developing a high risk rural road program. Some minor changes in the five-step safety program may be needed to reflect local conditions in other states.

The Wyoming LTAP Center will monitor the roads receiving funding under this program to report the actual benefit of this program in terms of accident reduction.

# 4. ROADWAY CLASSIFICATION SYSTEM

## 4.1 Introduction

In 1968, Congress's Federal Aid Highway Act mandated the National Highway Functional Classification study (OKDOT 2006). This study was aimed at developing procedures to functionally classify all existing public roads and streets according to their logical usage. From this study, it was found that the federal aid highway systems classification was inconsistent with the function of roads and streets. Some modifications to these systems were needed. In 1973, the Federal Aid Highway Act required the use of an updated functional highway classification to modify federal aid highway systems by July 1, 1976. Through state transportation agencies and local officials' efforts, the functional classification study by FHWA and federal aid highway systems were realigned. After the completion of the mandated functional classification system in 1976, states began to make adjustments to their own functional classification system to meet the requirements of federal aid highway programs. This, however, caused inconsistencies among the states. In 1991, the Intermodal Surface Transportation Act (ISTEA) required each state to functionally reclassify its public roads and streets to provide an interconnected system of principal arterial routes before designation of the National Highway System (ADOT, OKDOT 2006). In 1993, this reclassification was completed, and the National Highway System was established in November 1995. From then on, functional classification has been updated routinely.

In Wyoming, it is important to determine if there is a uniform roadway classification system employed by agencies at all levels. If local jurisdictions are using various systems in the state, it will make it more difficult to allocate resources and compare projects from different counties.

## 4.2 Survey Summary

The survey was conducted by the Wyoming $T^2$ LTAP Center. It was prepared and mailed in January 2007 to all counties in the state and a few cities and towns. To increase the level of participation, the Wyoming $T^2$ LTAP Center contacted county engineers to encourage them to provide their feedback.

### 4.2.1 Objectives of the Survey

The survey consisted of two parts, part one: Roadway Classification System and part two: Minimum Geometric Standards. There were two main objectives of this survey. The first objective was to determine which roadway classification systems are in use. The second objective was to determine if counties are using minimum geometric standards for local roadways in Wyoming.

### 4.2.2 Survey

The local jurisdiction roads survey contained seven roadway classification questions and six minimum geometric standard questions. A full version of this survey can be found in Appendix B.

### 4.2.3 Survey Results

Seventy-six surveys were sent out to corresponding local jurisdictions. These jurisdictions included major cities and towns in all 23 counties in Wyoming. The initial survey and the follow-up phone calls to counties resulted in 23 responses to the survey. Among these responses, 15 were from counties, 5 from towns and 3 from cities. The list of the respondents is shown in

**Table 4.6**.

**Table 4.6** List of Respondents to The Survey

| | |
|---|---|
| **Counties** | Bighorn, Campbell, Fremont, Goshen, Hot Springs, Johnson, Laramie, Natrona, Park, Platte, Sublette, Teton, Washakie, Carbon, Lincoln |
| **Towns** | Lovell, Greybull, Dubois, Buffalo, Mountain View |
| **Cities** | Riverton, Cody, Casper |

#### 4.2.3.1 Local Jurisdictions with Roadway Classification Systems

Of 23 respondents, only four jurisdictions (towns of Dubois, Greybull, Lovell, and Platte County) indicated that they do not currently have any roadway classification system. This implies that most Wyoming local jurisdictions utilize roadway classification systems.

#### 4.2.3.2 Currently Used Roadway Classification Systems

There are various roadway classification systems used by local jurisdictions in Wyoming. Classes and associated criteria vary among different systems. A point of interest in this survey was to determine which roadway classification systems are used in Wyoming. According to the survey results, the most widely utilized systems are:

1. WYDOT roadway classification system
2. AASHTO roadway classification system, based on the “Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT≤400)”
3. AASHTO roadway classification system, based on “A policy on Geometric Design of Highways and Streets”
4. The local jurisdiction’s own system
5. Other roadway classification system

As shown in
Figure **4.4**, among the local jurisdictions which are currently using a roadway classification system, the most commonly used system in Wyoming is the WYDOT roadway classification system. More than 50% of local jurisdictions that responded to this survey indicated they are using it now. Among local jurisdictions, 26% use their own systems; 16% of local jurisdictions use AASHTO roadway classification system, based on the “Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT≤400)”; 5% of local jurisdictions use the AASHTO roadway classification system, based on “A policy on Geometric Design of Highways and Streets”; the remaining 26% use other classification systems. It should be mentioned that some local jurisdictions use more than one classification system. All responses were included in the percentages shown in Figure 4.1.

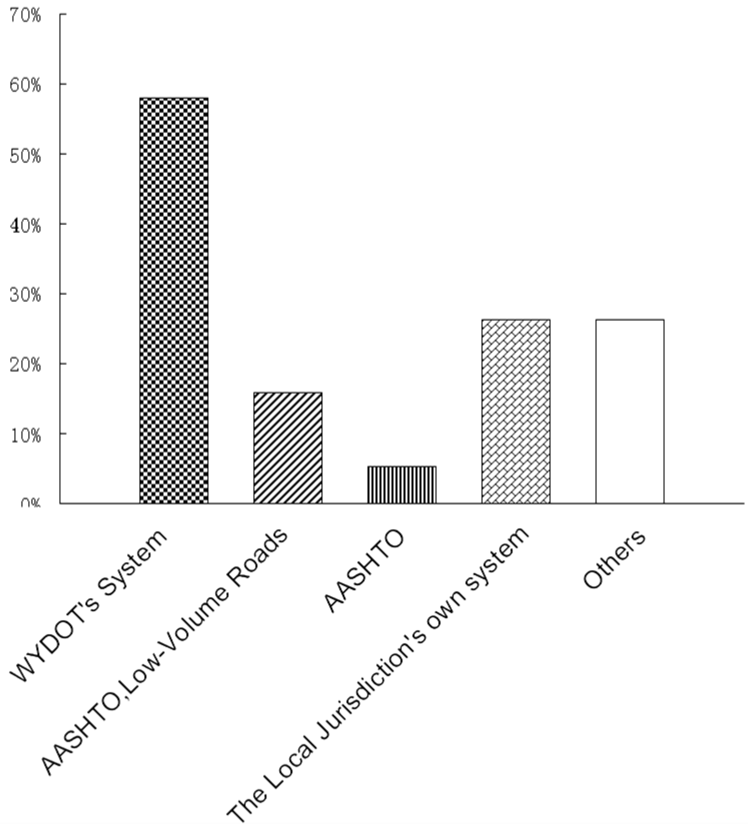


**Figure 4.4** Commonly Used Roadway Classification Systems

Table **4.7** summarizes the classification systems used by various local jurisdictions in Wyoming.

**Table 4.7** List of Local Jurisdictions and Their Roadway Classification System

| Classification systems | Counties | Towns | Cities |
|---|---|---|---|
| WYDOT roadway classification system | Lincoln, Johnson, Fremont, Sublette, Carbon, Hot Springs, Goshen, Washakie | Mountain View | Casper, Riverton |
| AASHTO roadway classification system, based on the “Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT≤400)” | Carbon, Campbell | Mountain View | |
| AASHTO roadway classification system, based on “A policy on Geometric Design of Highways and Streets” | Campbell | | |
| The local jurisdiction’s own system | Park, Campbell, Goshen | Buffalo | Cody |

| | | | |
|---|---|---|---|
| Other roadway classification system | Lincoln Bighorn Laramie, Teton, Natrona | | |

#### 4.2.3.3 Purpose of Using Roadway Classification System

According to the survey results, although Wyoming local jurisdictions use various roadway classification systems, the reasons behind using such systems can be classified into two main categories: first, setting priorities for snow removal and maintenance; second, determining future needed improvements.

#### 4.2.3.4 Criterion Used to Classify Roadways

Another point of interest in this survey was to identify the criteria that were commonly used to classify roadways. Fifteen potential criteria were listed in the survey for selection: surface type, terrain type, roadway function, design speed, traffic volume, roadway width, number of lanes, rural vs. urban, truck percentage, vehicle type, school bus route, postal route, land use, access to public lands, and political input. Based on the responses of the survey, most local agencies used about five criteria to classify a roadway.

Figure **4.5** summarizes the percentage of responses identifying each criterion used by the local jurisdictions to classify roadways. According to the nineteen respondents who are using roadway classification systems, roadway function and traffic volume are the two most popular criteria. Among respondents, 84% take them into consideration when classifying roadways. The next two popular criterions are surface type and roadway width.

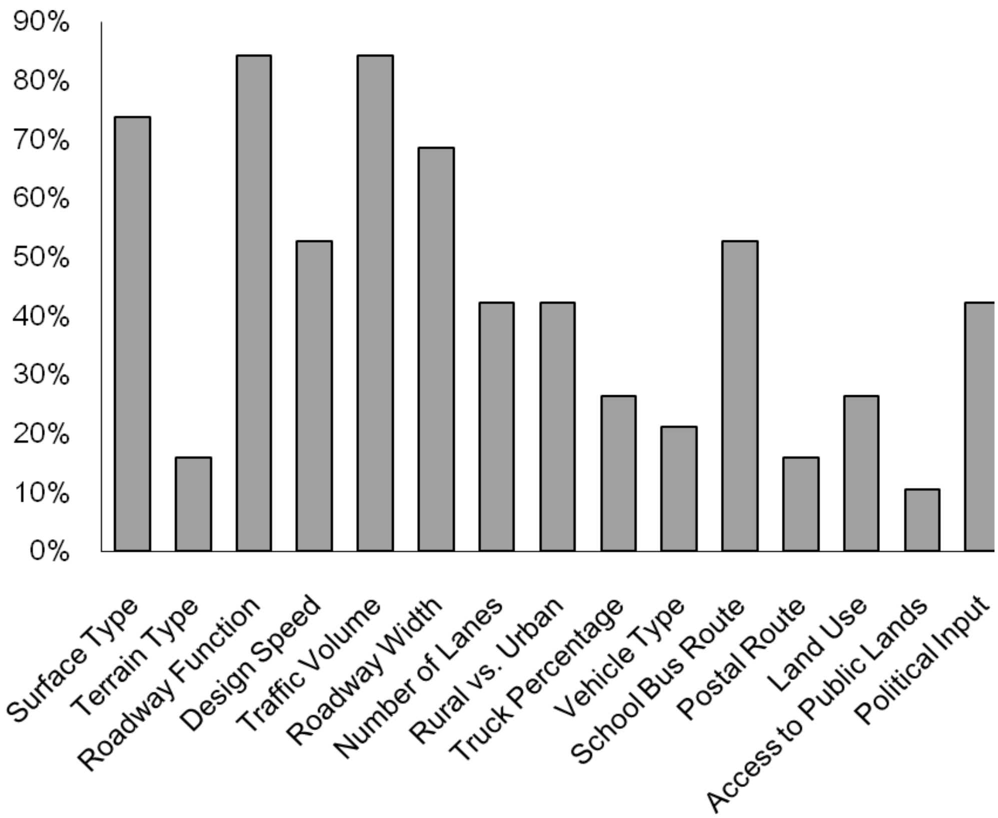


**Figure 4.5** Criterions Used to Classify Roadways

The respondents were also asked, among the 15 criteria, which one they thought was the most important for classifying roadways. As illustrated in

Figure **4.6**, among the 19 respondents, 44% selected traffic volume, 39% selected roadway function, and 17% selected surface type as the most important criteria.

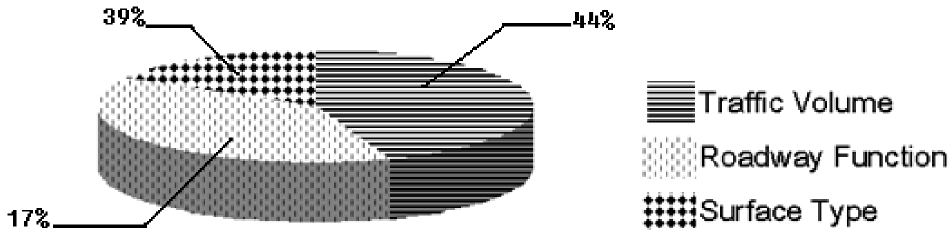


**Figure 4.6** The Most Important Criteria for Classifying Roadways

#### 4.2.3.5 Opinions on Currently Used Roadway Classification System

In the survey, the respondents were asked if they were satisfied with the currently used roadway classification system. Their opinions were ranked in four levels: Very good, Good, Fair, and Unsatisfied.

The satisfaction status is shown in
Figure **4.7**. Only 17% indicated they were not satisfied with the currently used classification system, 28% thought the current system was very good, 22% thought the system was good, and the remaining 33% thought the current system was just fair.

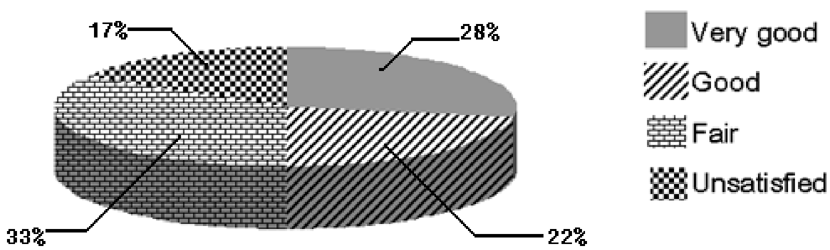


**Figure 4.7** Satisfaction Level with Currently Used Roadway Classification Systems

#### 4.2.3.6 Opinions on Utilizing a Uniform Statewide Roadway Classification System in Wyoming

When asked if a uniform statewide roadway classification system in Wyoming should be utilized, most local jurisdictions (79% of the respondents) agreed as shown in
Figure **4.8**.

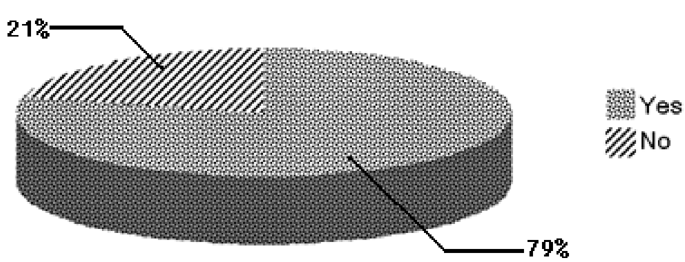


**Figure 4.8** Opinions on Utilizing a Uniform Classification System

However, some opponents to this idea were concerned about municipal streets. They stated that each town is different and has different roadway needs. One supporter was also worried that state funding could be tied too closely to classification.

#### 4.2.3.7 Minimum Geometric Standards

The second objective of this survey was to determine if local jurisdictions in Wyoming had minimum geometric standards. All 19 respondents who were currently using roadway classification systems indicated having minimum geometric standards for roadways. In this survey, the commonly used minimum geometric standards were divided into four categories: County Road Fund Manual, AASHTO "Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT≤400),"AASHTO "A policy on Geometric Design of Highways and Streets," and others.

As shown in
Figure **4.9**, among these local jurisdictions, the County Road Fund Manual was the most widely used for minimum geometric standards in Wyoming. It should be mentioned here that some of these local jurisdictions used more than one standard. In
Figure **4.9**, all responses were included in the percentages.

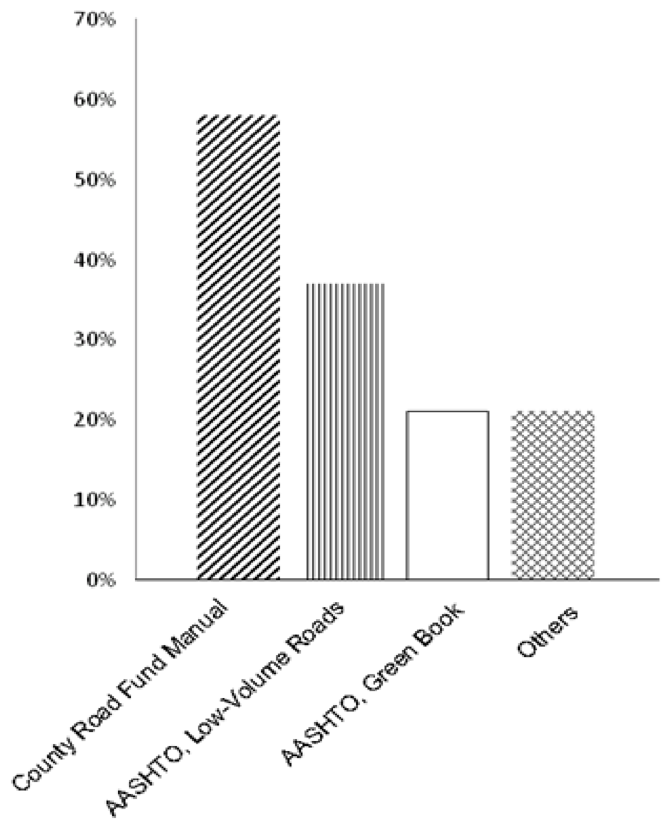


**Figure 4.9** Commonly Used Minimum Geometric Standards

#### 4.2.3.8 Traffic Studies

Availability of data from traffic studies is essential for conducting safety project evaluations. Since this survey was performed as part of a larger transportation safety project, the respondents were also asked if they normally perform traffic studies and how they utilize the collected data. The responses to this question are summarized in
Figure **4.10**.

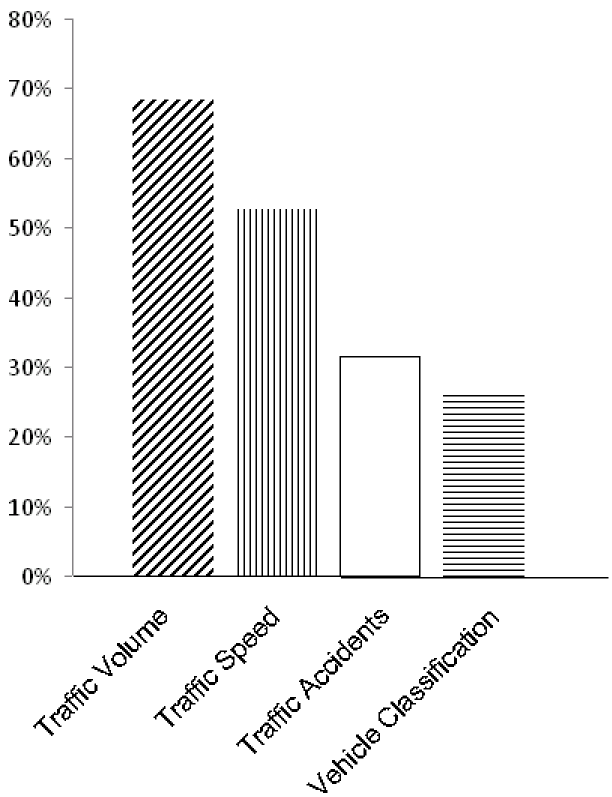


**Figure 4.10** Percentages of Local Jurisdictions Performing Traffic Study

Among jurisdictions, 68% indicated they performed traffic volume studies, 53% conducted speed studies, 32% performed traffic accidents studies, and only 26% collected data on vehicle classification. It is important to mention that although some local jurisdictions conducted traffic studies, these studies were only on limited locations. In addition, some local jurisdictions' data had not been updated for several years, while other local jurisdictions had just started conducting traffic studies. The utilization of the collected data varied significantly among local jurisdictions. The following reasons were behind conducting traffic studies: prioritizing road repairs, securing funding from granting agencies, identifying the need of traffic calming, managing pavement, classifying roads and contracts, evaluating new development, verifying citizen complaints and providing data to the public and to the police department to help with enforcement issues, planning and designing pavement structure, and bridge restrictions.

## 4.3 Chapter Summary

It is clear from the survey, although WYDOT's classification system is widely used in Wyoming, variations among local jurisdictions still exist. Several other classification systems are currently used in Wyoming. This safety program focuses on Wyoming rural roads. A uniform roadway classification will be helpful in screening rural roads.

The minimum geometric standards used by local jurisdictions are also different. Although a large portion of local jurisdictions used the standards from the "County Funds Manual," other standards were adopted by other jurisdictions.

# 5. A METHODOLOGY FOR CRASH PREDICTION ON HIGH RISK RURAL ROADS

## 5.1 Introduction

Developing a methodology for crash prediction on rural roads in Wyoming will be beneficial to the WRRSP by predicting high risk roads. This section first introduces the method for determining candidate roads for traffic data collection. Then it describes crash data used and the methodology of collecting traffic data for developing a crash prediction model. The detailed process of model developing is introduced in sub-section 5.5 of this Section. This process includes outlier identification, predictor selection, regression method selection, and the results interpretation. Finally, conclusions are made based on the findings from the developed model.

## 5.2 Candidate Roads Selection

In order to develop a crash prediction model for low volume rural roads in Wyoming, roads were selected for inclusion in the evaluation from three Wyoming counties: Laramie, Carbon, and Johnson. All 36 roads included in developing the prediction model were identified by the WRRSP as high risk roads. These roads were summarized in Tables 3.1, 3.2, and 3.3 in Section 3.

## 5.3 Crash Data

The reported crash records between 1995 and 2005 were obtained from the Wyoming Department of Transportation (WYDOT). This dataset contains all types of crashes that occurred on all roadway classifications. Since this project focuses on rural roads, only the crashes that occurred on rural county roads were included in the analysis. The crash records from WYDOT contain various attributes for every crash: accident route number and name, accident mile point, accident year, number of vehicles involved in the accident, number of injuries and fatalities in the accident, accident severity, light condition, weather conditions, and road surface types. In this study, the key attribute retrieved from the crash records for modeling was the total number of all severity levels of crashes that occurred during the 10-year period between 1995 and 2005. Table 5.1 summarizes the crashes on all the roads included in this experiment.

**Table 5.8** Summary of Crash Data

| County | Road Number | Road Length (miles) | PDO | Injury | Fatal | Total Crashes | Crashes per Mile |
|---|---|---|---|---|---|---|---|
| Carbon | 385 | 16.25 | 1 | 6 | 0 | 7 | 0.431 |
| Carbon | 291 | 57.43 | 25 | 14 | 3 | 42 | 0.731 |
| Carbon | 603 | 3.67 | 3 | 0 | 0 | 3 | 0.817 |
| Carbon | 702 | 7.32 | 7 | 0 | 0 | 7 | 0.956 |
| Carbon | 353 | 6.6 | 2 | 1 | 0 | 3 | 0.455 |
| Carbon | 550 | 1.48 | 1 | 0 | 0 | 1 | 0.676 |
| Carbon | 203 | 7.62 | 5 | 1 | 0 | 6 | 0.787 |
| Carbon | 660 | 14.52 | 5 | 4 | 0 | 9 | 0.620 |
| Carbon | 500 | 23.94 | 10 | 5 | 1 | 16 | 0.668 |
| Carbon | 561 | 8.13 | 5 | 3 | 0 | 8 | 0.984 |
| Carbon | 504 | 16.05 | 4 | 11 | 0 | 15 | 0.935 |
| Carbon | 324 | 5.17 | 6 | 2 | 0 | 8 | 1.547 |
| Carbon | 401 | 34.53 | 25 | 12 | 2 | 39 | 1.129 |
| Carbon | 710 | 3.09 | 4 | 0 | 0 | 4 | 1.294 |
| Carbon | 701 | 19.13 | 4 | 4 | 0 | 8 | 0.418 |
| Carbon | 700 | 17.2 | 3 | 5 | 0 | 8 | 0.465 |
| Laramie | 210 | 10.8 | 11 | 19 | 0 | 30 | 2.778 |
| Laramie | 109 | 9.48 | 13 | 12 | 1 | 26 | 2.743 |
| Laramie | 136 | 8.23 | 5 | 6 | 0 | 11 | 1.337 |
| Laramie | 143-2 | 28.38 | 10 | 6 | 2 | 18 | 0.634 |
| Laramie | 212-1 | 4.11 | 4 | 5 | 0 | 9 | 2.190 |
| Laramie | 102-1 | 7.32 | 7 | 8 | 0 | 15 | 2.049 |
| Laramie | 120-1 | 22.73 | 14 | 8 | 1 | 23 | 1.012 |
| Laramie | 124 | 10.84 | 9 | 8 | 0 | 17 | 1.568 |
| Laramie | 215 | 18.47 | 17 | 24 | 1 | 42 | 2.274 |
| Laramie | 209 | 7.33 | 10 | 6 | 0 | 16 | 2.183 |
| Laramie | 203-1 | 36.8 | 14 | 16 | 0 | 30 | 0.815 |
| Laramie | 164-1 | 12.26 | 4 | 5 | 0 | 9 | 0.734 |
| Laramie | 162-2 | 10.95 | 15 | 13 | 1 | 29 | 2.648 |
| Laramie | A149-1 | 0.69 | 4 | 0 | 0 | 4 | 5.797 |
| Johnson | 212 | 1.6 | 2 | 1 | 0 | 3 | 1.875 |
| Johnson | 14 | 8.49 | 4 | 2 | 0 | 6 | 0.707 |
| Johnson | 91H | 12.2 | 19 | 6 | 0 | 25 | 2.049 |
| Johnson | 3 | 32.7 | 8 | 1 | 0 | 9 | 0.275 |
| Johnson | 132 | 12.94 | 7 | 0 | 0 | 7 | 0.541 |
| Johnson | 40 | 8.32 | 5 | 3 | 0 | 8 | 0.962 |
| Johnson | 85 | 5.9 | 4 | 1 | 0 | 5 | 0.847 |
| Johnson | 256 | 1.69 | 4 | 4 | 0 | 8 | 4.734 |

## 5.4 Traffic Counts and Speeds

One interest of this safety study was to determine the effect of traffic volume and speed in relation to the number of crashes. Therefore, traffic volume and the 85$^{th}$ percentile speed data were considered key factors in developing the crash prediction model. Unfortunately, Wyoming local governments did not collect traffic data on these roads. Therefore, traffic data on all the candidate roads were collected by the research team. The traffic counter locations were determined mainly based on the risk locations identified from the crash analysis. Another consideration was major intersections which may result in changing traffic volumes. As an example, if a rural road stretches a long distance and connects with a higher level of roads, it is very likely that the two ends that connect a higher level of roads will have high traffic volumes. Two or more automatic traffic counters were installed at these spots. When developing the prediction model, the traffic data collected from the highest traffic volume spots will be used. A type of automatic traffic counter, "TRAX RD," which is manufactured by JAMAR Technology Inc., was used to collect traffic data for this study. Properly installed traffic counters can collect traffic volume, speed, and vehicle classification data. The TRAX RD employs two road tubes to record the traffic data. The tubes connected with TRAX RD are placed perpendicular to the flow of the traffic and set to 8 feet apart. When vehicles cross over the road tubes, air impulses are generated to trigger the two air-impulse switches inside the traffic counter.

Various tube layouts can be selected to record different traffic flow patterns. In this safety study, the selected tube layout is shown in Figure 5.1. In this layout, the traffic data are recorded separately in each direction.

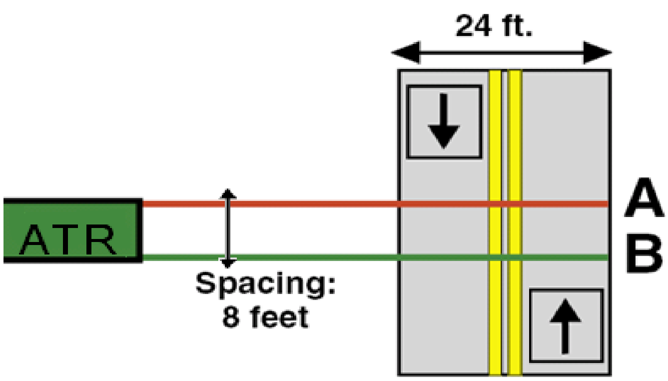


**Figure 5.11** Tube Layout for Collecting Traffic Data (Source: Jamar Technology, Trax RD Manual)

TRAX RD is solar powered and its battery can last more than one week. In this safety study, at each data collection site, traffic counters were installed for approximately one week to collect the weekday and weekend traffic data. The simple axle vehicle classification scheme was used to classify vehicles. Any type of vehicle that has more than or equal to three axles was categorized as a truck. Table 5.2 shows an example of the traffic data collected on each section.

**Table 5.9** Traffic Data on County Road 324

| | Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars & Trucks | Cars & Trucks | Cars | Trucks | Cars | Trucks | Cars & Trucks | Cars & Trucks |
| Wed 7/11/2007 | 90 | 91 | 89 | 1 | 91 | 0 | 61 | 60 |
| Thu 7/12/2007 | 83 | 82 | 78 | 5 | 80 | 2 | 63 | 61 |
| Fri 7/13/2007 | 98 | 96 | 97 | 1 | 94 | 2 | 62 | 62 |
| Sat 7/14/2007 | 168 | 172 | 166 | 2 | 170 | 2 | 57 | 59 |
| Sun 7/15/2007 | 99 | 96 | 99 | 0 | 96 | 0 | 59 | 61 |
| Mon 7/16/2007 | 70 | 67 | 67 | 3 | 65 | 2 | 59 | 58 |
| Tue 7/17/2007 | 75 | 75 | 74 | 1 | 75 | 0 | 60 | 59 |
| Average | 98 | 97 | 96 | 2 | 96 | 1 | 60 | 60 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 47 | 53 | 98 | 2 | 99 | 1 | | |

The collected traffic data indicate that truck volumes account for only a small percentage. Therefore, it is not necessary to consider truck volumes separately. Combined ADTs were used in this study. The traffic counters recorded traffic volume separately for each direction. Traffic volume used in this study is the sum of both directions of daily average over the traffic counter duration period (approximately one week). The daily 85th percentile speed can be easily obtained from TRAX RD software after processing the data collected by the traffic counter. Similar to the traffic volume, the 85th percentile speed used for this study is the average of the daily 85th percentile speed of the traffic counter duration period.

Surface type indicates on which type of road surface the traffic counter was installed. It was defined as a categorical variable. As seen from Table 5.3, “0” indicates that the traffic counter was installed on gravel or dirt surface, while “1” indicates an asphalt surface.

**Table 5.10** Summary of Traffic Data

| County | Road Number | Road Length (miles) | Surface Type | Volume (ADT) | Speed (mph) |
|---|---|---|---|---|---|
| Carbon | 385 | 16.25 | 0 | 37 | 49.5 |
| Carbon | 291 | 57.43 | 0 | 35 | 47.5 |
| Carbon | 603 | 3.67 | 0 | 200 | 50.5 |
| Carbon | 702 | 7.32 | 0 | 48 | 38 |
| Carbon | 353 | 6.6 | 0 | 99 | 29.5 |
| Carbon | 550 | 1.48 | 0 | 247 | 47 |
| Carbon | 203 | 7.62 | 0 | 161 | 35.5 |
| Carbon | 660 | 14.52 | 0 | 112 | 48 |
| Carbon | 500 | 23.94 | 0 | 293 | 44.5 |
| Carbon | 561 | 8.13 | 0 | 192 | 33.5 |
| Carbon | 504 | 16.05 | 1 | 218 | 62.5 |
| Carbon | 324 | 5.17 | 1 | 195 | 60 |
| Carbon | 401 | 34.53 | 1 | 324 | 66.5 |
| Carbon | 710 | 3.09 | 1 | 112 | 47 |
| Carbon | 701 | 19.13 | 0 | 722 | 51.5 |
| Carbon | 700 | 17.2 | 1 | 164 | 49 |
| Laramie | 210 | 10.8 | 0 | 173 | 42 |
| Laramie | 109 | 9.48 | 0 | 357 | 46 |
| Laramie | 136 | 8.23 | 0 | 238 | 46.2 |
| Laramie | 143-2 | 28.38 | 0 | 308 | 51.5 |
| Laramie | 212-1 | 4.11 | 0 | 46 | 55.5 |
| Laramie | 102-1 | 7.32 | 0 | 138 | 52 |
| Laramie | 120-1 | 22.73 | 0 | 256 | 42.8 |
| Laramie | 124 | 10.84 | 1 | 747 | 51.1 |
| Laramie | 215 | 18.47 | 1 | 395 | 56.5 |
| Laramie | 209 | 7.33 | 1 | 898 | 52.2 |
| Laramie | 203-1 | 36.8 | 1 | 156 | 68.5 |
| Laramie | 164-1 | 12.26 | 1 | 200 | 61.3 |
| Laramie | 162-2 | 10.95 | 1 | 160 | 68 |
| Laramie | A149-1 | 0.69 | 1 | 373 | 68.5 |
| Johnson | 212 | 1.6 | 1 | 583 | 36.5 |
| Johnson | 14 | 8.49 | 0 | 174 | 44.5 |
| Johnson | 91H | 12.2 | 1 | 1468 | 51.3 |
| Johnson | 3 | 32.7 | 1 | 125 | 39.4 |
| Johnson | 132 | 12.94 | 1 | 253 | 52.9 |
| Johnson | 40 | 8.32 | 0 | 229 | 33 |
| Johnson | 85 | 5.9 | 0 | 350 | 31.3 |
| Johnson | 256 | 1.69 | 1 | 510 | 42.7 |

### 5.4.1 Difficulties of Installing Traffic Counters on Gravel and Dirt Roads

A significant portion of the rural roads in this study is gravel or dirt roads. This adds to the difficulties of installing the traffic counter. The major problem was fixing the road tubes on the road surface. There are no traffic counters specifically designed to collect traffic data on gravel or dirt roads. The road tubes work well on paved roads but not on gravel or dirt roads. The rubber tubes need special treatment before installation. Otherwise, it is very likely that the tubes could be pierced by sharp gravel. If the tubes leak, they cannot generate accurate air impulses to the counter. One method of protecting the tubes is enclosing the rubber tube inside a cover such as a fire hose. However, this causes another problem of being able to fix the tubes on the ground. Without any cover, the tubes can be easily fixed by metal clamps on asphalt. But a tube inside a fire hose is difficult to fix. Sometimes, the tubes are displaced from their original installed position. In order to calculate the speeds of the vehicles, the traffic counter needs the precise time stamp (generated by the air impulse) with an accurate distance of the two tubes. Tubes' displacement changes the distance between the two tubes. As a result, the traffic counter will not get the accurate vehicle classification and speed data. For this reason, the speed data from some roads are not available or inaccurate. However, from the traffic data (Appendix C-1), it can found that at most locations the daily traffic volumes and speeds were consistent and the variation can be neglected. Therefore, the inaccurate data due to the displacement of the tubes were deleted. At these locations, two or three days' data were used to calculated ADT and 85$^{th}$ percentile speed.

## 5.5 Data Analysis and Prediction Model Development

Traffic data from the three counties were combined in one dataset for developing a crash prediction model. The dataset contains a total of 38 records. Table 5.3 summarizes the traffic and surface type data. It was clear from the traffic data collected in this study that the 85$^{th}$ percentile speeds were significantly higher than the posted speed limits. In some cases, the measured 85$^{th}$ percentile speeds were 15 MPH higher than the posted speed limits.

### 5.5.1 Outlier Identification

Outliers are extreme observations in the dataset. They may stem from errors in data collection or miscalculation. The negative binominal regression method uses the maximum likelihood method to estimate the predictor variables' coefficients. The result is that outliers may lead to serious distortions in the estimated regression function (Kutner 2003). During the model development process, two outliers were identified. One outlier was County Road 701 in Carbon County, and the other was County Road A149 in Laramie County. County Road 701 has a relatively high traffic volume but a very low crash rate. It is very likely that new developments around this road have occurred in recent years, which resulted in increasing current traffic flow. However, the recent high traffic volume has not yet translated into high crash rates. A149 is a unique section. It is very short, less than one mile. The crash records indicate that only four property damage only (PDO) occurred on this road in the ten-year analysis period. The extremely short length was behind the abnormally high crash rate on this road. Due to the reasons explained above, these two observations were discarded from the dataset, which resulted in 36 roads remaining in the final dataset for modeling.

### 5.5.2 Crash Prediction Model Development

From the literature review, previous safety studies had used geometric factors, such as, lane width, shoulder width, and horizontal and vertical distance as the predictor variables in the prediction model. However, such information was not available for this safety study. More importantly, the developed crash prediction model needs to be simple and practical enough to be used by the local governments. From the roadway classification survey, traffic volume and traffic speed were common studies conducted by counties. Therefore, traffic volume, traffic speed, road surface type, and an interaction variable (the product of traffic volume and speed) were used as the predictor variables in modeling. Crash rate per mile was the response variable in the model. In this study, the statistical analysis software, SAS (proc genmod), was used for modeling. The SAS code is shown in Appendix C-2.

As stated before, one interest of this study was to evaluate the combined and individual effects of traffic volume and speed on crash rates of rural roads. Therefore, various combinations of the predictor variables were tested in modeling. The basic process is as follows:

1. Put one predictor variable alone in the model and use SAS to run this model.
2. Add the surface type into the model while keeping the predictor variable and run the new model again to see if there is any interaction between the predictor variable and surface type.

Similar steps were performed on traffic volume and traffic speed. Finally, traffic volume and speed were analyzed in the model simultaneously.

When using different combinations of the predictor variables to develop a crash prediction model, Poisson regression and negative binominal regression (NBR) were evaluated separately. Tables 5.4 and 5.5 summarize these results. The estimated coefficients of the predictor variables are summarized in the estimate column. The p-values of the predictor variables reflect the goodness of fit. Simply speaking, p-value indicates a predictor variable's probability of being associated with the response as strongly as is seen in the observed data set, or if in reality there is no association. In other words, small p-values indicate that a predictor variable should probably be included in the model. The usual convention for p-value is that they need to be smaller than 0.05 (95% significance level) to keep a predictor variable in the model.

**Table 5.11** Using Poisson Regression to Fit the Crash Data

| Model Number | Predictor Variables | Estimate | P-Value | Goodness of Fit | | |
|---|---|---|---|---|---|---|
| | | | | **Deviance** | **Degree of Freedom (DF)** | **Deviance/DF** |
| 1 | Volume*Speed | 15.8596 | <.0001 | 157.0424 | 34 | 4.6189 |
| 2 | Volume*Speed<br>Surface | 16.5071<br>-0.0519 | <.0001<br>0.5981 | 156.7640 | 33 | 4.7504 |
| 3 | Speed | 0.0117 | 0.0061 | 184.4524 | 34 | 5.4251 |
| 4 | Speed<br>Surface | 0.0105<br>0.0407 | 0.0528<br>0.7150 | 184.3195 | 33 | 5.5854 |
| 5 | Volume | 0.0001 | <.0001 | 158.5255 | 34 | 4.6625 |
| 6 | Volume<br>Surface | 0.0008<br>0.0018 | <.0001<br>0.9853 | 158.5251 | 33 | 4.8038 |
| 7 | Volume<br>Speed | 0.0008<br>0.0105 | <.0001<br>0.0164 | 152.8154 | 33 | 4.6308 |

*indicates an interaction between two variables

**Table 5.12** Using Negative Binominal Regression to Fit the Crash Data

| Model Number | Predictor Variables | Estimate | P-Value | Goodness of Fit | | | Log Likelihood |
|---|---|---|---|---|---|---|---|
| | | | | Deviance | Degree of Freedom (DF) | Deviance/ DF | |
| 1 | Volume*Speed | 16.0736 | 0.0267 | 36.3341 | 34 | 1.0686 | 975.8060 |
| 2 | Volume*Speed<br>Surface<br>Volume*Speed*Surface | 30.2164<br>0.1381<br>-15.2914 | 0.3093<br>0.7064<br>0.6200 | 36.3908 | 32 | 1.1372 | 975.9298 |
| 3 | Speed | 0.0122 | 0.2522 | 36.7000 | 34 | 1.0794 | 973.7859 |
| 4 | Speed<br>Surface<br>Speed* Surface | 0.0196<br>1.2329<br>-0.0218 | 0.3413<br>0.4108<br>0.4579 | 35.2631 | 32 | 1.1020 | 974.3200 |
| 5 | Volume | 0.0008 | 0.0267 | 36.1447 | 34 | 1.0631 | 975.8185 |
| 6 | Volume<br>Surface<br>Volume*Surface | 0.0011<br>0.1123<br>-0.0003 | 0.4164<br>0.7572<br>0.8162 | 36.1312 | 32 | 1.1291 | 975.8663 |
| 7 | Volume<br>Speed | 0.0008<br>0.0111 | 0.0286<br>0.2540 | 36.0422 | 33 | 1.0922 | 976.4679 |

*indicates an interaction between two variables

#### 5.5.2.1 Goodness of Fit

The standard Poisson regression and negative binominal regression are both forms of generalized linear models (Dobson and Pavneh 2008). In the generalized linear model, one of the goodness of fit criteria, deviance has an approximate chi-square distribution with n-p degrees of freedom, where n is the number of the observations and p is the number of predictor variables (including the intercept). The expected value of a chi-square random variable is equal to the degrees of freedom. If the model fits the data well, the ratio of the deviance to df (degree of freedom) should be close to one. If this ratio is significantly larger than one, it may indicate that the model fails to account for the data's variability.

Based on the examination of the Poisson regression results summarized in Table 5.4, it can be found that the crash data are overdispersed (the ratio of the deviance/df is significantly larger than 1). When using Poisson regression, although the independent variables seemed significant in the model (with p-value smaller than 0.05), the results may be misleading due to the overdispersion. Standard errors of the estimated coefficients are incorrectly estimated, implying an invalid chi-square test (UCLA 2007). In contrast, when using NB regression, Table 5.5 shows that the NB regression fits the data reasonably well (the ratio of the deviance/df is very close to 1). Therefore, in this study, NB regression is selected for modeling.

#### 5.5.2.2 Interpretations of the Results

It is clear from Table 5.5 that if the interaction variable (the product of volume and speed) is analyzed in the model alone, it was significant. However, if the interaction variable and the surface type were both in the model, none of them were significant. As an example, in Model 2, "Volume*Speed," "Surface," and "Volume*Speed*Surface" were all in the model. According to their p-values, none of them were significant in the model. This suggests that there was no interaction between the interaction variable and the surface type. Similar phenomena applies to the traffic volume and speed variable.

From another aspect, the speed variable alone in the model was statistically insignificant. However, when it was combined with traffic volume as the interaction variable and added in the model, it became significant. This implies that on the analyzed rural roads in Wyoming, traffic speed has a significant effect on road safety, but its effect is masked unless it is combined with higher traffic volume.

From Table 5.5, it can be found that Models 1 and 5 have very close Deviance/DF and log likelihood values. A common comparator of GLM that accounts for model complexity is the Akaike Information Criterion (AIC). Simply speaking, smaller AIC value of a model generally means this model is better than the other. It is expressed as:

$$AIC = -2*\text{Log likelihood} + 2*k \qquad (5.1)$$

Where k is the number of parameters in the model.

For example, from Table 5.5, the AIC value for Model 1 that includes the "Volume*Speed" predictor is -2*975.8060+ 2*2 =-1947.612. The AIC value for Model 5 that includes the "Volume" predictor is -2*975.8185+2*2= -1947.637. From the AIC value, Model 5 is formally better than Model 1. However, there is no clear superiority showing that Model 5 is remarkably better than Model 1. Therefore, both Models 1 and 5 are proposed based on the NB regression analysis. The total number of crashes that will occur in 10 years are:

$$\text{Total crash} = \exp(-0.0340+16.0736* \text{Volume*Speed}/1{,}000{,}000)* \text{Road Length} \qquad (5.2)$$

$$\text{Total crash} = \exp(-0.0428+0.0008* \text{Volume})* \text{Road Length} \qquad (5.3)$$

Where: exp is the exponential function and Road length is the length of the analyzed road

Another concern of the model's goodness fit is the Proportionate Reduction in Variation (PRV), and it is usually evaluated by the value $R^2$. It measures the proportionate reduction of total variation in response variable associated with the use of the set of predictor variables (Kurt 2003). In ordinarily least square (OLS) regression, $R^2$ takes the value between 0 and 1. Larger $R^2$ indicates that the model can explain more observed variability. In generalized linear models (GLM), no such equivalent $R^2$ exists. In the GLM, the coefficients of the predictor variables are estimated from the maximum likelihood procedure (UCLA 2007). Therefore, unlike the OLS regression, the coefficients are not calculated to minimize variance. However, to evaluate the goodness of fit of the GLM, several pseudo-$R^2$ were proposed. Although all pseudo-$R^2$ measures are imperfect, they still help describe PRV in a general way. One pseudo-$R^2$ proposed by Cox & Snell (Cox and Snell 1989) is expressed as follows:

$$R^2 = 1 - \exp\left[-\frac{2}{n}\{l(\hat{\beta}) - l(0)\}\right] \qquad (5.4)$$

Where: $l(\hat{\beta})$ is the log likelihood of the fitted model
$l(0)$ is the log likelihood of the null model
n is the sample size

For Model 1, the log likelihood of the null model is 973.1323. The pseudo-$R^2$ of the fitted model is 1-exp$[-\frac{2}{36}\{975.8060-973.1323\}]$= 0.138, which means the model can explain the 13.8% of the observed variability. Using the same equation, the pseudo-$R^2$ of Model 5 is 0.1386. The relatively low pseudo-$R^2$ may result from two respects: the number of predict variables and sample size. Introducing other prediction variables, such as geometric features (road width, shoulder width), to the model may be helpful in improving the predictability of the model. However, this safety project is aimed at helping counties in Wyoming identify high risk locations. Therefore, the developed model is not for predicting the precise number of crashes. Instead, it should be used to evaluate if a road is potentially high risk. Meanwhile, a simplified model will be easier to be used by counties. A relatively small sample size may also have effects on pseudo-$R^2$ value. This project does not have enough human resources and time to collect more comprehensive traffic data. If more comprehensive and complete data could be obtained from future study, the predictability of the model would be improved.

This regression model was developed based on the crash and traffic data from the roads selected by the WRRSP. These roads have the highest crash rates among the county rural roads in the three counties included in the pilot study. The developed model would provide counties with a useful tool to determine if a specific road has a higher than normal crash rate. As an example, if a road in a county has actual 7 crashes in a ten-year period and the model predicts 15 crashes based on the prevailing traffic condition, then this road should not be considered a high risk road. However, if a road has 20 actual crashes and the model predicts only 15 crashes, then this road should be considered a high risk road.

## 5.6 Chapter Summary

Based on the analysis performed in this study, the NB regression is superior to the Poisson regression in fitting the overdispersed Wyoming crash data. The developed model by the NB regression method is consistent with other safety studies presented in the literature review.

From the model building process, relations between traffic volume and speed and the crash rates were found. High volume in conjunction with high speed will generally result in more crashes. Road surface type is not a significant variable in relation to the road safety on the analyzed rural roads. Although the predictability of the model is relatively limited, the developed model can be used to evaluate if a road is potentially high risk.

# 6. ECONOMIC ANALYSIS

## 6.1 Introduction

This section introduces the basic steps of performing the economic analysis to evaluate the cost effectiveness of safety countermeasures. Economic analysis is the Fifth Step of the WRRSP and provides crucial information for the decision makers to prioritize projects and select appropriate safety countermeasures that can achieve best economic effectiveness. The first sub-section of this section briefly discusses some of the selected candidate countermeasures for improving rural road safety in Wyoming. The second sub-section describes using a benefit cost ratio (BCR) as the economic criterion to perform benefit cost analysis. The final sub-section introduces Excel worksheets designed for this safety study to calculate the BCR.

## 6.2 Identification of the countermeasures

It is important to note that one reason rural roads have higher fatality rates than urban roads is because rural roads are less likely to have adequate safety features. Most rural roads were constructed a long time ago with narrow lanes, limited shoulders, excessive curves, and steep slopes. As a result, they often lack consistent design features, such as lane widths, curves, shoulders, and clearance zones along roadways. Fatalities on non-interstate rural roadways are more likely to occur than on all other routes once a vehicle has left the roadway. Between 1999 and 2003, 47% of all fatal accidents on non-interstate rural roads involved a vehicle leaving the roadway. In contrast, only 35% of fatal traffic accidents on all other routes involved a vehicle leaving the roadway (The Road Information Program 2005).

Various roadway safety improvements can be made to reduce serious accidents and traffic fatalities. In this safety study, the FHWA “Desktop Reference for Crash Reduction Factors” was used as a source for selecting potential countermeasures. The reference summarized the crash reduction factors developed by several transportation agencies.

Most fatal crashes on rural roads were due to vehicles departure from roadways. The selected candidate safety countermeasures for this safety study are largely aimed at keeping vehicles from leaving the roadway or reducing the consequences of a vehicle leaving the roadway. All the candidate countermeasures for rural roads and associated crash reduction factors for this project are listed in Table 6.13.

The selected countermeasures have a relative low cost and short time frame for implementation. If counties need other types of countermeasures not listed in this table, they can refer to the FHWA’s full list.

**Table 6.13** Countermeasures and Crash Reduction Factors

| Countermeasures | Crash Type | Crash Reduction Factors | | | Service Life |
|---|---|---|---|---|---|
| | | Fatal | Injury | PDO | |
| Install guide signs (general) | All | 15% | 15% | 15% | 5 |
| Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | 5 |
| Install chevron signs on horizontal curves | All | 35% | 35% | 35% | 5 |
| Install curve advance warning signs | All | 30% | 30% | 30% | 5 |
| Install delineators (general) | All | 11% | 11% | 11% | 4 |
| Install delineators (on bridges) | All | 40% | 40% | 40% | 4 |
| Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | 4 |
| Install centerline markings | All | 33% | 33% | 33% | 2 |
| Improve sight distance to intersection | All | 56% | 37% | 0% | 15 |
| Flatten crest vertical curve | All | 20% | 20% | 20% | 15 |
| Flatten horizontal curve | All | 39% | 39% | 39% | 15 |
| Improve horizontal and vertical alignments | All | 58% | 58% | 58% | 15 |
| Flatten side slopes | All | 43% | 43% | 43% | 15 |
| Install guardrail (at bridge) | All | 22% | 22% | 22% | 10 |
| Install guardrail (at embankment) | All | 0% | 42% | 0% | 10 |
| Install guardrail (outside curves) | All | 63% | 63% | 0% | 10 |
| Improve guardrail | All | 9% | 9% | 9% | 10 |
| Improve superevlevation | All | 40% | 40% | 40% | 15 |
| Widen bridge | All | 45% | 45% | 45% | 15 |
| Install shoulder | All | 9% | 9% | 9% | 5 |
| Pave shoulder | All | 15% | 15% | 15% | 5 |
| Install transverse rumble strips on approaches | All | 35% | 35% | 35% | 3 |
| Improve pavement friction | All | 13% | 13% | 13% | 5 |
| Install animal fencing | Animal | 80% | 80% | 80% | 10 |
| Install snow fencing | Snow | 53% | 53% | 53% | 10 |

It is recommended by the FHWA that when selecting countermeasures to reduce the number and/or severity of roadway departure crashes, the county engineers should first consider countermeasures designed to reduce the likelihood of vehicles leaving the roadway. Next, they should select strategies that minimize the likelihood of crashing into an object or overturning the vehicle if it travels beyond the edge of the shoulder. Finally, the county engineers should consider countermeasures that reduce the severity of the crash, such as improving the design and application of barrier and attenuation systems (FHWA 2008). In the next sub-section, some of these safety improvements are briefly discussed.

### 6.2.1 Most Relevant Safety Countermeasures

The countermeasures introduced in this sub-section are either low cost or easy to be implemented by counties.

#### 6.2.1.1 Pavement Marking and Signs

Forty-two percent of traffic fatalities on rural, non-interstate routes from 1999 to 2003 occurred while it was dark (The Road Information Program 2005). Traffic signs and pavement markings provide information to drivers and can help improve visibility during nighttime. Signs with greater retro reflectivity, more visible pavement markings, and raised reflective lane markings can assist drivers to stay on a roadway, particularly at night.

A 2002 study (The Road Information Program 2005) identified the currently used markings among transportation agencies in the United States, Canada, and other countries. A total of 29 (of 50) state DOTs use wider markings (wider than MUTCD standard) for standard centerline, edge line, and/or lane line applications. The most widely cited reason for using wider markings is improved marking visibility (57% of respondents). From the findings of the existing literature and a survey of agency practices, this study concluded that wider markings would likely have the greatest benefit when used in the following situations:

- Horizontal curves
- Roadways with narrow shoulders or no shoulders
- Construction work zones
- Locations where low luminance contrast of markings is common
- Locations where older drivers are prevalent and thus require added roadway visibility under all conditions

The candidate countermeasures from pavement markings and signs utilized in the WRRSP are centerline markings, edge lines, guide signs, and curve advanced warning signs.

#### 6.2.1.2 Chevrons and Delineators

Chevrons or post-mounted delineators have been found to be effective in reducing crashes at curves by providing drivers with better visual cues about the presence and geometry of a curve. However, studies have found that the effectiveness of delineators on reducing crashes is mixed (NCHRP 2004). They could be effective in some locations, but other studies have reported that the delineation did not have any significant effect on the crash rate. Several researchers have reported that post-mounted roadside delineation reduced the crash rate only on relatively sharp curves during periods of darkness (NCHRP 2004). Studies by the Arizona Highway Department suggest that neither edge lines nor post-mounted delineation have any significant effect on the crash rate on open tangent sections (Texas Transportation Institute 2002).

The “Roadway Delineation Practices Handbook” (FHWA 1994) was developed to assist in making decisions about roadway delineation systems. It covers current and newly developed devices, materials, and installation equipment, and presents each item’s expected performance based on actual experience or field and laboratory tests.

#### 6.2.1.3 Rumble Strips

Transverse rumble strips are raised or depressed areas of the roadway surface designed to alert the driver to unusual conditions. Through noise and vibration, rumble strips attract the driver’s attention to such features as unexpected changes in alignment and to conditions requiring a stop.

#### 6.2.1.4 Guardrails

Guardrails prevent vehicles from crashing against roadside objects or falling into a ravine. Another objective of installing guardrails is to keep the vehicle upright while deflected along the guardrail. Adding or improving guardrails has been found to reduce traffic fatality rates by between 50-58% (The Road Information Program 2005). However, the installation of guardrails on low-volume roads can add costs and other safety and maintenance problems, which may outweigh the benefits. The guardrail itself is a fixed object within the clear zone and a significant proportion of vehicles' impact with guardrails produce injuries (Boone County Missouri).

## 6.3 Benefit-Cost Analysis

Benefit cost analysis will be used to determine which competing countermeasure is the most advantageous at the analysis site. Before performing the analysis, the anticipated benefits from implementing countermeasures and the costs of countermeasures must be determined.

### 6.3.1 Anticipated Benefits

The anticipated benefit of a safety countermeasure is the cost-savings, which is due to the reduction in traffic crashes. The saved costs are determined by applying the Crash Reduction Factor (CRF) to the number of expected crashes that occur at each severity level at the analysis site. The anticipated benefits can be expressed as the number of crashes saved or converted to a monetary value by using crash cost. In WRRSP, the benefits of the countermeasures are converted to the monetary value as:

$$\text{Anticipated Benefits} = \text{Expected PDO crashes}^{*}\ CRF_{PDO}{}^{*}\text{Crash Cost}_{PDO} + \text{Expected Injury crashes}^{*}\ CRF_{Injury}\ {}^{*}\text{Crash Cost}_{Injury} + \text{Expected Fatal crashes}\ {}^{*}CRF_{Fatal} + \text{Crash Cost}_{Fatal} \quad (6.1)$$

Where: $CRF_{PDO}$ is the crash reduction factor of reducing PDO crashes.
$CRF_{Injury}$ is the crash reduction factor of reducing Injury crashes.
$CRF_{Fatal}$ is the crash reduction factor of reducing Fatal crashes.

### 6.3.2 Crash Reduction Factors

The benefits of a safety project are measured by the percent are reduction in the number and severity of crashes. The crash reduction factor (CRF) is an estimate of the percentage reduction that might be expected after implementing a given countermeasure. A CRF should be regarded as a generic estimate of the effectiveness of a countermeasure. This estimate is a useful guide, but it is necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions, which will affect the safety impact of a countermeasure (FHWA 1989).

It is recommended by the FHWA that if crash reduction factors are not available in a local agency, they may be obtained from the state DOT or from existing literature. However, the FHWA also warned that although hundreds of the CRF tables can be found in highway safety literature, a great majority of them are dubious values due to poor experimental designs and evaluation methods (FHWA 1989). Therefore, practitioners must ensure that a countermeasure applies to the particular conditions under consideration.

When using CRFs to calculate expected benefits from implementation of combined safety countermeasures, it is important to calculate the combined CRF. The combined CRF should not be simply combined in additive fashion. As an example, if a project will install both guide signs and delineators to address a safety concern, the percentage reduction of the combined CRFs for fatalities should not simply be 11%+15% = 26%. Instead, the combined CRFs are calculated in a multiplicative approach as (FHWA 2002):

$$CRF_{combined} = 1- [(1-CRF_1)*(1-CRF_2)*(1-CRF_3)] \quad (6.2)$$

Where: $CRF_{combined}$ is the combined crash reduction factor.
$CRF_1$, $CRF_2$, $CRF_3$ are the individual reduction factors from different countermeasures.

In the above example, the combined CRFs of installing guide signs and delineators should be calculated as 1-(1-11%)(1-15%) =24.35%.

### 6.3.3 Crash Cost

Table 6.2 shows the estimated cost of calculating the anticipated benefits in this safety study. These estimates were based on a survey conducted by AASHTO in 2007. This survey identified the crash cost used by different highway agencies in the United States. The crash cost values presented in Table 6.2 are the averages of the crash costs from different highway agencies. These values were used as the default crash cost estimates for WRRSP.

**Table 6.14** Crash Cost

| **Crash Severity Level** | Fatal | Injury | PDO |
|---|---|---|---|
| **Crash Cost** | $2,500,000 | $60,000 | $6,000 |

### 6.3.4 Costs of Countermeasures

Several factors affect the cost of the countermeasures. These factors are initial implementation costs, operation and maintenance cost, service life, and salvage value.

#### 6.3.4.1 Initial Cost

The initial implementation costs include right-of-way acquisition, construction, site preparation, equipment, design, traffic maintenance, administration, and any other aspects of implementation (FHWA 1989). The costs of countermeasures are difficult to estimate and vary due to several factors, such as project scope, location and time. They can be estimated from the results of recently completed similar projects or by the experts who have been involved in similar projects. In this study, the cost of each countermeasure is not provided for the counties. The counties are encouraged to estimate their own cost values according to their specific situations.

#### 6.3.4.2 Operation and Maintenance Cost

The operation and maintenance costs are the difference in cost to operate and maintain the facilities before and after the safety improvement is implemented. In some cases, operating or maintenance costs of new countermeasures may be lower than the original projects. This will result in a negative value of operating maintenance cost and it would be subtracted from the initial implementation costs. As an example, if a road currently has low visibility signs and the safety countermeasure to address safety concerns on this road is to replace the old signs with high visibility signs. Furthermore, the maintenance costs of the new signs are lower than the original signs. In this case, the operation and maintenance costs are the differences in the cost of maintaining new signs minus the cost of maintaining old signs. The differences result in negative values and they should be subtracted from the initial costs.

This safety study is aiming at providing the general guidelines to the counties. Incorporating operating and maintenance cost will add complexities to the implementation of this safety program. Therefore, the operation and maintenance cost was not included when calculating the cost of the countermeasures.

#### 6.3.4.3 Service Life and Salvage Value

The service life represents the time period that the countermeasure can effectively perform its intended function (FHWA 1989). The service life of each selected countermeasure for this safety project is listed in Table 6.1. Values from "Illinois DOT Safety Engineering Policy Memorandum" and the "Kentucky Transportation Center Development of Procedures for Identifying High-Crash Locations and Prioritizing Safety Improvements" were used as references. In cases where no service life information is available, the default value of ten year will be used. In this safety project, the salvage values of most countermeasures are neglectable and they are set to zero.

#### 6.3.4.4 Interest Rate

To simplify calculating the cost, the interest rate is assumed to equal the inflation rate. For example, the cost of installing an advanced warning sign is $500 at year 2008, assuming both interest and inflation rates are 4%. If the service life of the sign is two years, then cost of the sign at year 2010 will be $\$500*(1+4\%)^2= 540.8$. Considering the inflation rate, the equivalent present cost at 2008 will be $540.8/(1+4\%)^2=500$.

## 6.4 Benefit/Cost Ratio (BCR)

In this safety study, the BCR method is employed for performing benefit cost analysis. The BCR method uses a benefit to cost ratio to compare the effectiveness of various safety improvements. If a safety countermeasure is economically justifiable, its BCR should be larger than one, which means this countermeasure has greater return than its associated cost. The equation of calculating BCR is:

BCR = Present value of benefits/ Present value of costs (6.3)

To compare the economic effectiveness among mutually exclusive countermeasures, a common used method is the incremental benefit cost ratio (Newnan 2004). It is not proper to simply calculate the BCR of each alternative and choose the one with the highest value. The result may be misleading. As an example, there are four mutually exclusive alternative countermeasures to address safety concerns at one location. The cost, benefit, and BCR of each alternative are shown in Table 6.3. It is clear from the table that B has the highest BCR. However, it should not be simply concluded that B is best alternative.

**Table 6.15** An Example of Performing Incremental BCR

| | A | B | C | D |
|---|---|---|---|---|
| **Cost** | 4005 | 2010 | 6002 | 1060 |
| **Benefit** | 7310 | 4750 | 8630 | 1440 |
| **B/C** | 1.83 | 2.36 | 1.44 | 1.36 |

To perform the incremental BCR analysis, it first is necessary to arrange the alternatives in ascending order of investment as shown in Table 6.4.

**Table 6.16** An Example of Performing Incremental BCR Step 1

| | D | B | A | C |
|---|---|---|---|---|
| **Cost** | 1060 | 2010 | 4005 | 6002 |
| **Benefit** | 1440 | 4750 | 7310 | 8630 |
| **B/C** | 1.36 | 2.36 | 1.83 | 1.44 |

Then, compare the incremental BCR between different countermeasures as shown in Table 6.5. If the Δ B/ Δ C is greater than one, it represents a desirable increment of investment.

**Table 6.17** An Example of Performing Incremental BCR Step 2

| | Increment B-D | Increment A-B | Increment C-A |
|---|---|---|---|
| **Δ Cost** | 950 | 1995 | 1997 |
| **Δ Benefit** | 3310 | 2560 | 1320 |
| **Δ B/ Δ C** | 3.48 | 1.28 | 0.66 |

From Table 6.5, it is clear that the increment C-A is not attractive, as the Δ B/ Δ C is 0.66. Therefore, C is eliminated from the selection. Comparing B with D, B is more attractive. Comparing A with B, the incremental BCR is greater than one. Finally, we can conclude that A is the best alternative. Although B has the highest BCR among the alternatives, it is not the best alternative.

### 6.4.1 An Example of Calculating BCR

An example of calculating BCR will be helpful to understand this method more thoroughly. If improving the guardrail is selected as a countermeasure for a specific road segment, the crash reduction factors (Table 6.1) for all levels of severity of crashes are 9%. The estimated cost of each level of severity of crashes can be obtained from Table 6.2. Supposing that the cost of improving the guardrail is $50,000 and on this road segment, during the past 10 years, there were 3 fatalities, 2 injuries and 10 PDOs, the BCR on this road segment is:

Benefit: 3*2,500,000*0.09+2*60,000*0.09+10*6,000*0.09= $691,200

Cost of the countermeasures: $50,000

$$B/C = \frac{691{,}2000}{50{,}000} = 13.82$$

In this example, the BCR is greater than one and it implies that the selected countermeasure on this segment is economic applausive. The BCRs of other countermeasures are calculated in the same way.

### 6.4.2 An Example of Using Excel to Calculate BCR

The Wyoming $T^2$ Center developed simple Excel worksheets to calculate the BCRs for all proposed countermeasures. The followings steps illustrate how to use the worksheets to calculate BCR on County Road 136-1 in Laramie County:

Step 1: Input the general and site information into

Table **6.18**.

**Table 6.18** General and Site Information

| General Information | | Site Information | |
|---|---|---|---|
| Analyst | Cheng Zhong | Facility | 136-1 |
| Agency/Company | | Segment | |
| Project | Laramie County | Analysis Time Period | 1995-2005 |
| Date Performed | 9-15-2008 | Analysis Year | |
| | | Segment Length (mi.) | |

Step 2: Input the following items into

Table **6.19** for each road segment:

- Road number
- The number of crashes that occurred in 10 years
- The corresponding number of the countermeasures (
-

- **Table 6.20**) will be used on this road segment As an example, on this road segment, two countermeasures: “install advance warning signs” and “widen bridge” are evaluated. The corresponding numbers “2” and “19” should be inputted in column A and column B respectively.

**Table 6.19** Benefit to Cost Analysis Input Menu

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 109-1 | 1 | 12 | 13 | 2 | 19 | | | |

Step 3: Input the costs of the countermeasures in

**Table 6.20** (In this example, $22,500 for installing 45 advance warning signs and $21,000 for bridge widening )

**Table 6.20** Crash Cost Input Menu

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors | | | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| | | | Fatal | Injury | PDO | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $22,500 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | $21,000 | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

After all the information is in, the worksheet will automatically calculate the benefit and the BCR value for each countermeasure and the combined BCR if both “2” and “19” are implemented (

Table **6.21**).

**Table 6.21** An example of Calculating B/C Ratio

| | Countermeasures | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $45,000.00 | $21,000.00 | | | | $66,000.00 |
| **Benefit** | $1,319,200.00 | $1,484,100.00 | | | | $2,209,660.00 |
| **B/C Ratio** | 29.32 | 70.67 | | | | 33.48 |

Generally, the higher the BCR value, the greater the cost effectiveness of the countermeasures. Manually calculating the incremental BCR by comparing countermeasure number “19” in column B and countermeasure number “2” in column A of Table 6.9, it could be found that “19”: widen bridge, is a better alternative.

$$\text{Incremental BCR}_{\text{B-A}} = \frac{\text{Benefit}_\text{B} - \text{Benefit}_\text{A}}{\text{Cost}_\text{B} - \text{Cost}_\text{A}} = \left|\frac{1484{,}100 - 1319{,}200}{21{,}000 - 45{,}000}\right| = 6.87$$

## 6.5 Chapter Summary

This chapter introduces the essential steps of performing benefit cost analysis. As stated in the literature review, before implementing any safety improvement countermeasure, this type of analysis is widely accepted by most highway agencies in the United States. According to the WRRSP, the BCR method is employed to perform benefit cost analysis. An Excel worksheet was developed to help counties in calculating BCR.

The key factors of calculating BCR, such as CRF and project costs are not universal. Counties in Wyoming need to determine these factors according to their specific situations.

# 7. WRRSP IMPLEMENTATION

The five-step safety program described in this research report has already been implemented in the three counties included in the pilot study. In addition, the $WYT^2$/LTAP is in the process of helping four other counties implement the program. The developed program provides decision makers with a simple and systematic procedure to improve safety on county roads. Those counties interested in implementing the program will be able to justify the needs for safety improvements, which would enable them to pursue local, state, or federal funding. This chapter describes the statewide implementation effort of the WRRSP.

## 7.1 Implementation in the Three Pilot Counties

The $WYT^2$/LTAP has implemented the WRRSP in Carbon, Laramie, and Johnson counties. The five-step program resulted in multiple safety projects in these three counties. The Wyoming Department of Transportation has already approved funding these safety projects out of the HRRRP fund. Appendices D, E, and F summarize the results of the WRRSP implementation in Carbon, Laramie, and Johnson counties, respectively. All proposed safety improvements are low cost with high benefit to cost ratios. These safety improvements will be implemented in 2009.

## 7.2 Statewide Implementation of the Program

WYDOT worked closely with the $WYT^2$/LTAP to develop guidelines for the statewide implementation of the WRRSP. As a result of this effort, a program guide was developed in March 2009. This guide can be seen in Appendix G. The $WYT^2$/LTAP will help counties in implementing the guidelines established in the guide so that they establish safety programs in their counties. The $WYT^2$/LTAP has already helped Lincoln, Sheridan, and Albany counties in implementing the program. In addition, the center is in the process of communicating with other counties so that they can take advantage of implementing safety projects in their counties to reduce crashes and fatalities around the state. The Wyoming LTAP Center will monitor the roads receiving funding under this program to report the actual benefit of safety improvements in terms of crash reduction.

Information included in the guide are a program summary, important WYDOT contact information, project schedules, sections on funding and requirements, necessary forms for implementing a safety program, and information on public interest finding.

## 7.3 Technology Transfer

The $WYT^2$/LTAP has presented the findings of this study at the following state, regional, and national professional meetings and conferences:

1. The Annual NLTAP meeting in Chicago
2. The safety regional meeting, which was held November 2007 in Bismarck, North Dakota
3. The Annual Wyoming Transportation and Safety Congress in 2007 and 2008
4. The Annual LTAP meeting in Breckenridge, Colorado, 2008
5. The Regional Local Road Conference in Rapid City, South Dakota, October 2008
6. Two Wyoming LTAP workshops in Riverton and Douglas on November 18 and 19, 2009
7. The Transportation Research Board meeting in Washington D.C., January 2009

This study receives extensive exposure locally, regionally, and nationally.

## 7.4 Implementations by Other States

The methodology developed in this report can be implemented by other states interested in developing a high risk rural road program. Some minor changes to the five-step safety program may be needed to reflect local conditions in other states.

# 8. CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

In this research project, the Wyoming Rural Road Safety Program (WRRSP) was developed to help local governments implement a rural road safety program. The WRRSP consists of five simple steps which would insure selecting high risk rural locations based on not only historical crash data but also field conditions. This section summarizes the conclusions of this research study.

### 8.1.1 WRRSP

According to the developed WRRSP, historical crash data should be analyzed to identify rural roads with a high number of crashes. These roads would be then evaluated and assigned field scores based on the level I field evaluation described in this report. A combined ranking based on the crash analysis and the level I field evaluation is then obtained to identify the high risk rural locations. These high risk locations should be subjected to the level II field evaluation, which is similar in nature to a road safety audit. This evaluation will result in recommending specific safety countermeasures. The proposed benefit cost analysis will insure that only cost effective measures will be selected for funding.

The Wyoming LRSAG approved the Wyoming Rural Road Safety Program (WRRSP) described in this report and recommended statewide implementation. In addition, WYDOT and the FHWA Division office approved the WRRSP for eligibility to receive funding from the High Risk Rural Road (HRRR) Program. Counties interested in applying for funding from the HRRR program would need to follow the methodology described in this report. Requests from all Wyoming counties will be submitted to the local government office of WYDOT. The Wyoming Safety Management System (SMS) Committee has selected a subcommittee to allocate the funding from the HRRR program for eligible and cost-effective requests. The Wyoming LTAP Center has already implemented the program in the three counties included in the pilot study. In addition, training materials have been developed to help other counties implement the program statewide.

In addition to pursuing funding from the WRRSP, counties are encouraged to use the methodology developed in this study to document their transportation safety needs. Such documentation will help counties pursue local as well as other funding sources to enhance safety on local roads.

### 8.1.2 Roadway Classification System

Roadway functional classification is widely adopted by state DOTs. Most of the state DOTs employed the FHWA's guidelines as the principle reference to develop states' own systems. However, in some cases (e.g., low volume local roads), the FHWA's guidelines may not satisfy agency needs. Thus, some states developed their own roadway functional classification systems.

The statewide survey performed in this study contained questions dealing with currently used roadway classification systems and minimum geometric standards among local jurisdictions. In all, 23 local jurisdictions responded. These responses lead to the following conclusions:

1. Most of the respondents are currently using some form of a roadway classification system.
2. Although nearly 60% of the respondents use WYDOT's classification system, other classification systems are widely used.
3. A small number of local jurisdictions utilize more than one roadway classification system.
4. The main reasons behind using roadway classification systems are consistent: setting priorities

for snow removal and maintenance, and determining future needed improvements.
5. When classifying roadways, roadway function, traffic volume, and surface type are the three most important criteria considered.
6. A large portion of respondents (83%) were satisfied with their current roadway classification system.
7. Most of the respondents agreed that establishing a uniform statewide roadway classification system in Wyoming would be beneficial.
8. All the respondents have minimum geometric standards. However, the standards vary among local jurisdictions. The County Road Fund Manual is the most widely used for setting minimum standards.
9. Traffic volume and speed studies are conducted by most local jurisdictions in Wyoming. The utilization of the collected data varied among jurisdictions.

### 8.1.3 Crash Prediction Model

One of the objectives of this study was to develop a prediction model for crashes on high risk rural roads. The findings from the model development process are summarized as follows:

1. The negative binomial regression (NBR) and the Poisson regression methods were both examined in the study. The NBR was found to be superior to the Poisson regression in fitting the overdispersed Wyoming crash data.
2. The p-value of the surface type in the model is not significant when interacting with other traffic variables. Therefore, road surface type, gravel vs. paved, had statistically similar crash rates in the dataset analyzed in this study.
3. According to the regression model, high speed by itself does not significantly correlate with high crash rates. High traffic volume in conjunction with high speed resulted in higher crash rates. This lack of correlation may result, however, from the small range of speed values observed.
4. The prediction model should only be used to determine if a specific rural road should be considered as high risk.

### 8.1.4 Economic Analysis

Economic analysis should be used in the selection of countermeasures. "This analysis not only ensures that cost-effective measures are implemented, but also facilitates the ranking of measures at a specific location and the rankings of all possible improvements in a jurisdiction, given the usual budgetary and other resource constraints" (NCHRP 1999). Therefore, this type of analysis plays a key role in the safety countermeasure selection of this safety program. In this study, the findings from the economic analysis are as follows:

1. Several methods can be used to perform economic analysis. The popular economic criterions employed by the highway agencies to perform economic appraisal analysis are benefit-cost ratio, cost effectiveness, and net benefits.
2. A simple procedure was developed in this study to perform the benefit cost analysis. As part of this procedure, safety countermeasures should be identified first. The benefits can then be determined based on historical crash records and the crash reduction factors. The costs of countermeasures are determined by county engineers. The benefit cost analysis can then be performed based on the identified costs and benefits.
3. The Excel worksheets designed in this study can help county engineers in calculating BCR. It is simple to use and it can automatically calculate benefits and BCRs for each selected safety countermeasures.

## 8.2 Recommendations

### 8.2.1 Implementation

The methodology developed in this report can be implemented by other states interested in developing a high risk rural road program. Some minor changes in the five-step safety program may be needed to reflect local conditions in other states.

The Wyoming LTAP Center will monitor the roads receiving funding under this program to report the actual benefit of this program in terms of accident reduction.

### 8.2.2 Roadway Classification System

Based on the findings, the following recommendations are made for the roadway classification system in Wyoming:

1. Publicizing the importance of using a uniform roadway classification system is suggested. Although it is clear that WYDOT's classification system is the most widely used roadway classification systems in Wyoming, variations among local jurisdictions still exist. Most survey respondents agreed that a uniform classification system would be beneficial.
2. The currently used WYDOT classification system is based on the FHWA system. In certain cases, this system may not satisfy all local jurisdictions' needs, especially for unpaved county roads with very low traffic volume. It is recommended that additional considerations are given to such roads.

### 8.2.3 Crash Prediction Model

The dataset used for developing the prediction model contained only 36 effective observations. The absence of adequate traffic data on Wyoming rural roads made it difficult to increase the sample size. The relatively small size of the dataset may have reduced the predictability of the model. It is recommended that Wyoming local governments and WYDOT should start collecting traffic data on rural roads. The availability of such data should help in confirming and refining the prediction model developed in this study.

### 8.2.4 Benefit Cost Analysis

Counties should refine the proposed crash reduction factors for countermeasures to reflect their local conditions. The counties are also encouraged to estimate their own cost values according to their specific situations.

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## APPENDIX A-1.  LEVEL I FIELD EVALUATION FORM

| **Level I Field Evaluation** | Evaluator: | Date: | Page: |
|---|---|---|---|
| **Notes:** | | Road Name: | Road Length: |
| | | Road No.: | Road Surface: |
| | | Road Class: | Speed Limit: |

| Mile Post | General | Intersections / RR Crossings | Signage / Pavement Markings | Fixed Objects/ Clear Zones | Shoulder / ROW | Segment Score | Comments |
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# APPENDIX A-2. GUIDELINES FOR ESTIMATING SCORES OF LEVEL I FIELD EVALUATION

**a) General:** Use the following questions to get a general score for the segment:

1. Are there sharp horizontal or vertical curves?
2. Is there good visibility along the road way?
3. Is the pavement free of defects that could result in safety problems (e.g., loss of steering control)?
4. Is the pavement free of areas where ponding or sheet flow of water may occur resulting in safety problems?
5. Is the pavement free of loose aggregate/gravel, which may cause safety problems?

**b) Intersections and Rail Road Crossings:** Enter the rated score of 0 to 10 on the evaluation form. Use the following questions to get the intersections and rail road score:

1. Are intersections free of sight restrictions that could result in safety problems?
2. Are intersections free of abrupt changes in elevation or surface condition?
3. Are advance warning signs installed when intersection traffic control cannot be seen a safe distance ahead of the intersection?
4. Are railroad crossing (crossbucks) signs used on each approach at railroad crossings?
5. Are railroad advance warning signs used at railroad crossing approaches?
6. Are railroad crossings free of vegetation and other obstructions that have the potential to restrict sight distance?
7. Are roadway approach grades to railroad crossings flat enough to prevent vehicle snagging?

**c) Signage and Pavement Markings:** Enter the rated score of 0 to 10 on the evaluation form. Use the following questions to get the signage and pavement marking score:

1. Is the road free of locations where signing is needed to improve safety?
2. Is the road free of unnecessary signing which may cause safety problems?
3. Are signs effective for existing conditions?
4. Does the road have pavement markings?
5. Is the road free of pavement markings that are not effective for the conditions present?
6. Is the road free of old pavement markings that affect the safety of the roadway?
7. Does the road need delineation?
8. Is the road free of locations with improper or unsuitable delineation (post delineators, chevrons, object markers)?

**d) Fixed Objects and Clear Zone**: Enter the rated score of 0 to 10 on the evaluation form. Use the following questions to get the fixed object and clear zones score:

1. Are clear zones free of hazards and non-traversable side slopes without safety barriers?
2. Are there narrow bridges or cattle guards?
3. Are there culverts not extended far enough?

**e) Shoulder and ROW**: Enter the rated score of 0 to 10 on the evaluation form. Use the following questions to get the intersections and rail road score:

1. Is shoulder width to standard?
2. Is the slope greater than 3:1?
3. Is there hazard along the shoulder?
4. Is there high rollover potential?

# APPENDIX A-3.  LEVEL I FIELD EVALUATION EXAMPLES

EXAMPLE 1

- **General**: **9 –** Very good alignment, visibility, road surface matched to volume, has an overall good feel, and has a good width.

- **Intersections and Railroad Crossings**: **9 –** One intersection on mile segment, not signed but has good visibility, angle and alignment are good.

- **Signage and Pavement Markings**: **9 –** Good pavement and edge markings, with delineators, no signs are needed.

- **Fixed Objects and Clear Zone: 10 –** No major fixed objects.

- **Shoulder and ROW: 9 –** Less than 3 to 1 slope, good shoulders, very low rollover potential, good ROW.

**Segment Score: 46**

EXAMPLE 2

- **General: 8** – Straight stretch with one slight vertical curve on mile segment, good visibility, the road surface is in fairly good shape, and width is adequate.

- **Intersections and Railroad Crossings**: **9** – One intersection on mile segment, not signed but has good visibility, angle and alignment is good.

- **Signage and Pavement Markings: 1** – No pavement markings, no delineators, no signs on vertical curve or at intersection.

- **Fixed Objects and Clear Zone**: **9 –** Minor sagebrush.

- **Shoulder and ROW**: **7** – 3 to1 slope, good width, minor rollover potential on back slope, and ROW is good.

**Mile Segment Score: 34**

EXAMPLE 3

- **General**: **9** – Straight stretch on mile segment, good visibility, the road surface is in fairly good shape, and width is adequate.

- **Intersections and Railroad Crossings: 10 –** No intersection or R.R. crossing on mile segment.

- **Signage and Pavement Markings**: **4 –** Faded centerline and no edge markings, few delineators are missing, no signs are needed.

- **Fixed Objects and Clear Zone: 9 –** No major fixed objects.

- **Shoulder and ROW: 9 –** Less than 3 to 1 slope, good shoulders, very low rollover potential, good ROW.

**Segment Score: 41**

EXAMPLE 4

- **General: 6 –** Minor horizontal curves with minor visibility issues, the road surface is in fairly good shape, and width is adequate.

- **Intersections and Railroad Crossings: 6 –** One intersection on mile segment, not signed with minor visibility issue, angle and alignment is good.

- **Signage and Pavement Markings**: **4 –** Advance warning signs are needed on minor curves and at the intersection.

- **Fixed objects and Clear Zone: 7 –** No major objects but there are a few rocks.

- **Shoulder and ROW: 4 –** Couple of areas have rollover potential, good ROW.

**Segment Score: 27**

## EXAMPLE 5

- **General**: **6** – Minor horizontal curves on mile segment, good visibility, the road surface in fairly good shape, and width is adequate.
- **Intersections and Railroad Crossings: 5 –** Several intersections on mile segment, not signed, none has visibility issue, angle and alignment good.
- **Signage and Pavement Markings**: **7 –** No great need for advance warning signs, except for intersection warning signs.
- **Fixed Objects and Clear Zone: 2 –** Large brick sign just off shoulder, cattleguard and large poles at drive ways.
- **Shoulder and ROW: 8 –** Shoulder slope and width are good, low rollover potential ROW wide enough.

**Segment Score: 28**

EXAMPLE 6

- **General**: **2** – Several horizontal curves on mile segment, poor visibility, the road surface is in poor shape, and width is not wide enough.
- **Intersections and Railroad Crossings: 8 –** One intersection on mile segment, not signed, but have good visibility, angle and alignment good.
- **Signage and Pavement Markings**: 2 **–** There are no curve signs and need more delineators or chevrons.
- **Fixed Objects and Clear Zone:4 –** Clear zone is poor on both sides along the mile segment.
- **Shoulder and ROW: 1 –** Shoulder slope and width poor, high rollover potential, side slopes not traversable, steep drop offs, and no guardrails.

**Segment Score: 17**

EXAMPLE 7

- **General: 5** – Couple minor horizontal curves on mile segment, average visibility, the road surface is in average shape, and width is adequate except at cattleguard.

- **Intersections and Railroad Crossings: 7 –** Two intersections on mile segment, not signed, but have good visibility, angle and alignment good.

- **Signage and Pavement Markings**: **5 –** No curve signs on minor curves cattleguard has object markers.

- **Fixed Objects and Clear Zone: 3 –** Narrow cattleguard, adequate clear zone on the mile segment.

- **Shoulder and ROW**: **8** – 3 to 1 slope, good width, low rollover potential on back slope, and ROW good.

**Segment Score: 28**

EXAMPLE 8

- **General: 6 –** Straight stretch, three slight vertical curves on mile segment, good visibility, the road surface is in fairly good shape, and width is adequate.

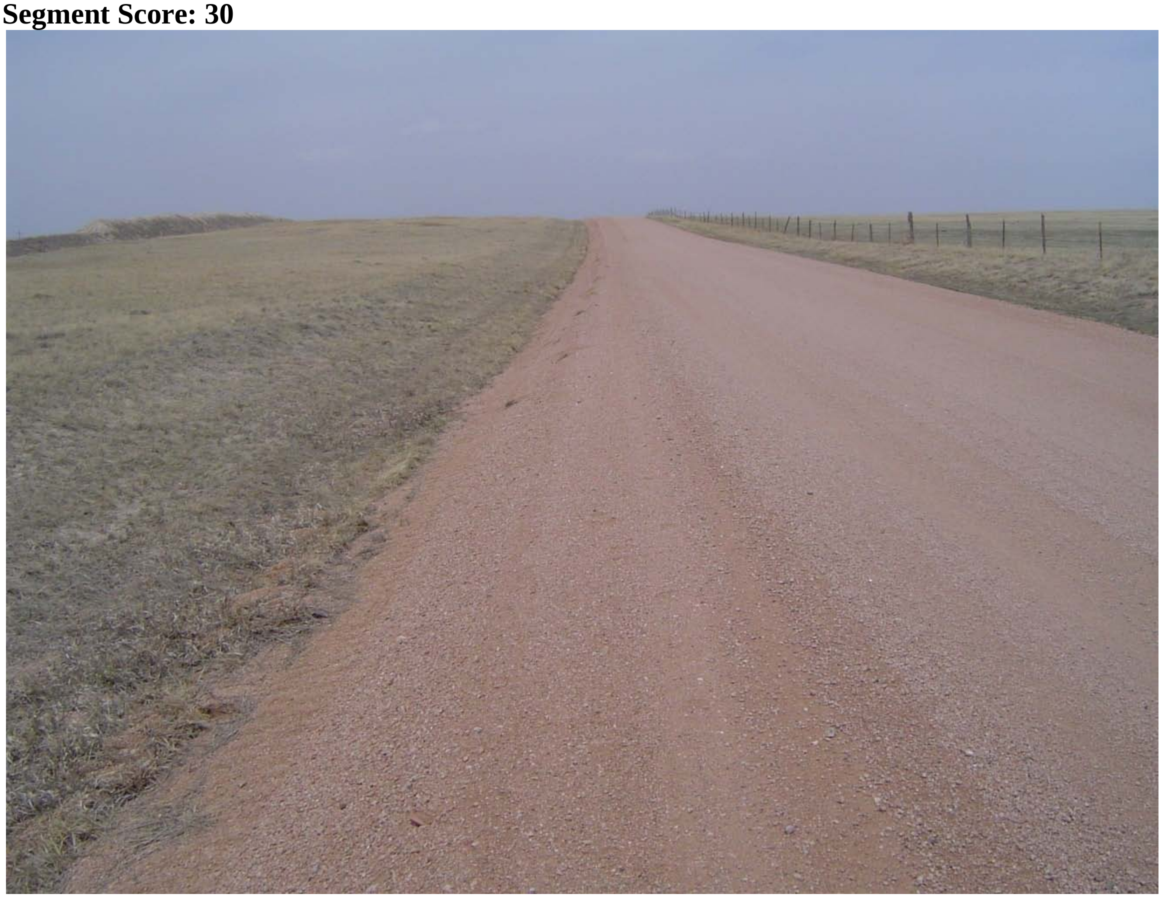
- **Intersections and Railroad Crossings**: **7** – Three intersections on mile segment, not signed, but have good visibility, angle and alignment good.

- **Signage and Pavement Markings: 7 – I**ntersection warning sign needed.

- **Fixed Objects and Clear Zone**: **8** – Fence close on right side.

- **Shoulder and ROW**: **2** – Fore slope very steep, high rollover potential, poor shoulder width.

**Segment Score: 30**



EXAMPLE 9

- **General: 2 –** Several sharp horizontal curves with poor visibility on mile segment, several sharp horizontal curves with poor visibility on mile segment, the road width in some areas not adequate.

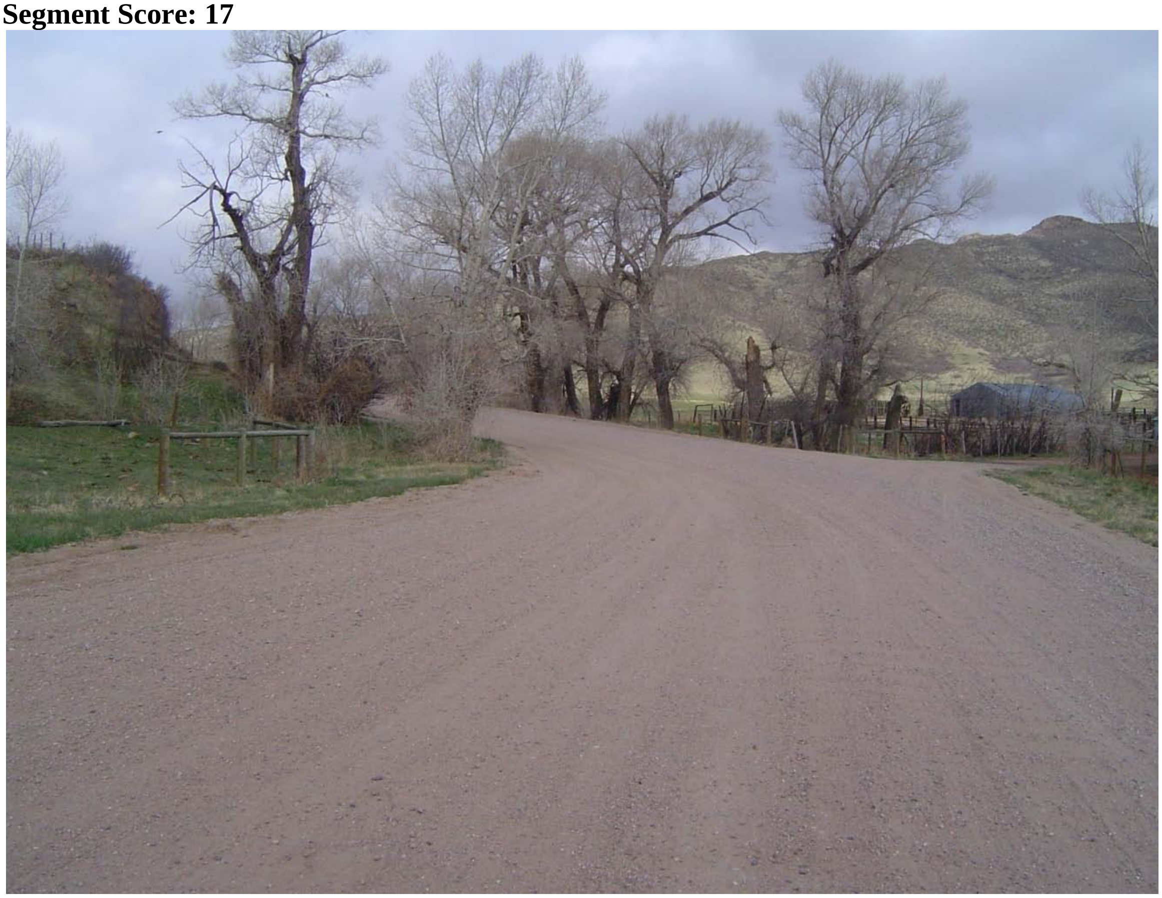
- **Intersections and Railroad Crossings: 2** – Two intersections on mile segment, one intersection is at a poor angle, it is on a on a curve with poor visibility and no warning signs.

- **Signage and Pavement Markings: 4 –** Curve signs in place for all curves which meet code, warning signs needed for one intersection.

- **Fixed Objects and Clear Zone**: **1 –** Fence close on both sides and large trees in clear zone.

- **Shoulder and ROW**: **8 –** Shoulder slope and width are good, no steep drop-offs with low rollover potential on mile segment.

**Segment Score: 17**



EXAMPLE 10

- **General: 4** – One 90-degree curve, signed on both ends, a couple minor horizontal curves with minor visibility issues on mile segment, good road surface and road width.

- **Intersections and Railroad Crossings: 5** – One intersection on mile segment, it has minor visibility problems and no warning signs.

- **Signage and Pavement Markings: 7 –** Curve and reduced speed signs in place for all curves, in good condition, placement close to shoulder, no intersection warning signs.

- **Fixed Objects and Clear Zone**: **8 –** Fence on right side.

- **Shoulder and ROW**: **8** – Shoulder slope and width are good, no steep drop-offs with low rollover potential on mile segment.

**Segment Score: 32**

EXAMPLE 11

- **General**: **9** – Straight stretch no horizontal or vertical curves on mile segment, good visibility, the road surface is in fairly good shape, and width is adequate overall feel very good.

- **Intersections and Railroad Crossings: 9 –** One intersection on mile segment, signed has good visibility, angle and alignment are good.

- **Signage and Pavement Markings**: **10 –** No signs or pavement markings are needed.

- **Fixed Objects and Clear Zone**: **8** – Fence on both sides.

- **Shoulder and ROW: 9** – Shoulder slope and width good, no steep drop-offs with low rollover potential on mile segment, minor fore slope in few areas.

**Segment Score: 45**

EXAMPLE 12

- **General: 7 –** Mostly a straight stretch, one slight horizontal curve and one vertical curve on mile segment, good visibility, the road surface is in fairly good shape, and width is adequate.

- **Intersections and Railroad Crossings: 10 –** No intersection or R.R. crossing on mile segment.

- **Signage and Pavement Markings**: **5 –** Curve and reduced speed sign in place and meet code. Centerline markings, no edge marking, few delineators missing.

- **Fixed Objects and Clear Zone**: **4** – A few boulders in clear zone.

- **Shoulder and ROW: 5** – Narrow shoulders, slope is 3 to 1 and width average, no steep drop-offs with low rollover potential on mile segment.

**Segment Score: 31**

EXAMPLE 13

- **General: 5** – Couple minor horizontal curves on mile segment, average visibility, the road surface and condition is in average shape, and width is adequate.

- **Intersections and Railroad Crossings: 10** – No intersections or RR crossings on mile segment.

- **Signage and Pavement Markings**: **5-** No curve signs on minor curves.

- **Fixed Objects and Clear Zone**: **5** – A fence on both sides and power poles just outside ROW.

- **Shoulder and ROW: 5** – Shoulder slope and width good average for gravel road, minor drop-offs with low rollover potential on mile segment.

**Segment Score: 30**

EXAMPLE 14

- **General**: **2** – Several horizontal\vertical curves along mile segment, poor visibility, the road surface is in good shape, and width is wide enough.

- **Intersections and Railroad Crossings: 8 –** One intersection on mile segment, not signed, but has good visibility, angle and alignment are good.

- **Signage and Pavement Markings: 1 –** No curve signs and need more delineators or chevrons.

- **Fixed Objects and Clear Zone: 6 –** Fence on both sides of road and some small rocks.

- **Shoulder and ROW: 2 –** Minor rollover potential and side slopes not traversable in a few areas along mile segment, steep drop offs, and no guardrails.

**Segment Score: 19**

EXAMPLE 15

- **General**: **4** – Several horizontal curves along mile segment, poor visibility, but low speed and volume, the road surface is in good shape.

- **Intersections and Railroad Crossings: 8 –** One intersection on mile segment, signed, has good visibility, angle and alignment are good.

- **Signage and Pavement Markings: 1 –** No curve signs and signs are not to code.

- **Fixed Objects and Clear Zone: 1 –** Several large trees in clear zone.

- **Shoulder and ROW: 9 –** Shoulder slope and width are very good, no rollover potential and side slopes traversable along mile segment.

**Segment Score: 23**

EXAMPLE 16

- **General: 7 –** Straight stretch one slight vertical curve on mile segment, good visibility, the road surface is in fairly good shape, and width could be wider.

- **Intersections and Railroad Crossings**: **3** – One intersection on mile segment close to a vertical curve, not signed, has poor visibility, angle and alignment good.

- **Signage and Pavement Markings: 1 –** No pavement markings, missing delineators, no sign (do not pass) on vertical curve, or at intersection.

- **Fixed Objects and Clear Zone**: **9** – Minor sagebrush.

- **Shoulder and ROW**: **5** – 3 to 1 slope on most of the mile segment, 2 to1 in a couple of areas, shoulder width average, moderate rollover potential and side slopes traversable.

**Segment Score: 25**

EXAMPLE 17

- **General: 4 –** Several horizontal curves on mile segment with poor visibility, the road surface is in good shape, and width is wide enough, not a good overall feel.

- **Intersections and Railroad Crossings: 5 –** Four intersections on mile segment, not signed, but all have good visibility, angle and alignment.

- **Signage and Pavement Markings**: **1 –** No warning signs.

- **Fixed Objects and Clear Zone: 4 –** Bushes and fence in clear zone.

- **Shoulder and ROW: 5 –** Shoulder slope good, minor rollover potential on back slope.

**Segment Score: 19**

EXAMPLE 18

- **General: 5 –** Average overall feel for mile segment, a 90-degree curve but well signed with low speed and good visibility and good road width.

- **Intersections and Railroad Crossings: 6 –** One intersection is close to a curve, not signed, but has good visibility, angle and alignment good, but just after a curve.

- **Signage and Pavement Markings: 9 –** Signs are to code, have good visibility**.**

- **Fixed Objects and Clear Zone: 3 –** Power poles and mail boxes in clear zone on curve.

- **Shoulder and ROW: 9 –** Shoulder slope and width are very good, low rollover potential, side slopes traversable, no steep drop offs.

**Segment Score: 32**

EXAMPLE 19

- **General: 7 –** Good overall feel, straight mile segment, good road surface and adequate road width.

- **Intersections and Rail Road Crossings: 7 –** Two intersections on mile segment, with good visibility, angle and alignment good.

- **Signage and Pavement Markings: 8 –** No are signs needed except for possible intersection warning sign.

- **Fixed objects and Clear Zone: 4 –** Power poles and fence in clear zone on straight mile segment.

- **Shoulder and ROW: 9 –** Shoulder slope and width are very good, low rollover potential, side slopes traversable, no steep drop offs.

**Segment Score: 35**

EXAMPLE 20

- **General**: **3** – Two horizontal\vertical curves along mile segment, poor visibility, the road surface is in reasonable shape, and road width could be wider.

- **Intersections and Railroad Crossings: 10 –** No intersections or rail road crossing on mile segment.

- **Signage and Pavement Markings: 4 –** Warning signs at curves, condition in fair shape, may need to be replaced soon.

- **Fixed Objects and Clear Zone: 6 –** Fence on both sides of road and some small rocks.

- **Shoulder and ROW: 2 –** High rollover potential and side slopes not traversable in a few area along mile segment, steep drop offs, and no guardrails.

**Segment Score: 25**

# APPENDIX A-4. SENSITIVITY ANALYSIS

# Carbon County

| | Road # | Mile Post | Total Crashes | Field Score | Field Score Rank | Total Crash Rank | 50%-50% Rank | 55%-45% Rank | Difference | 60%-40% Rank | Difference | 65%-35% Rank | Difference | 70%-30% Rank | Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Top 10 | 401 | 2.01-3.00 | 4 | 44 | 15 | 6 | 1 | 2 | 1 | 3 | 2 | 4 | 3 | 4 | 3 |
| | 504 | 4.01-5.00 | 3 | 43 | 7 | 14 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 1 |
| | 401 | 22.01-23.00 | 4 | 45 | 19 | 6 | 3 | 5 | 2 | 5 | 2 | 7 | 4 | 7 | 4 |
| | 401 | 1.01-2.00 | 2 | 39 | 2 | 25 | 4 | 3 | 1 | 2 | 2 | 2 | 2 | 1 | 3 |
| | 291 | 0.00-1.00 | 2 | 41 | 3 | 25 | 5 | 4 | 1 | 4 | 1 | 3 | 2 | 3 | 2 |
| | 291 | 1.01-2.00 | 2 | 43 | 7 | 25 | 6 | 6 | 0 | 6 | 0 | 5 | 1 | 5 | 1 |
| | 401 | 3.01-4.00 | 2 | 43 | 7 | 25 | 6 | 6 | 0 | 6 | 0 | 5 | 1 | 5 | 1 |
| | 401 | 5.01-6.00 | 3 | 45 | 19 | 14 | 8 | 8 | 0 | 8 | 0 | 8 | 0 | 8 | 0 |
| | 561N | 4.01-5.00 | 2 | 44 | 15 | 25 | 9 | 9 | 0 | 9 | 0 | 9 | 0 | 9 | 0 |
| | 504 | 2.01-3.00 | 3 | 47 | 27 | 14 | 10 | 10 | 0 | 10 | 0 | 12 | 2 | 12 | 2 |
| Top 20 | 660 | 4.01-5.00 | 4 | 49 | 39 | 6 | 11 | 13 | 2 | 13 | 2 | 16 | 5 | 20 | 9 |
| | 203 | 2.01-3.00 | 2 | 46 | 21 | 25 | 12 | 11 | 1 | 11 | 1 | 10 | 2 | 10 | 2 |
| | 504 | 1.01-2.00 | 2 | 46 | 21 | 25 | 12 | 11 | 1 | 11 | 1 | 10 | 2 | 10 | 2 |
| | 291 | 2.01-3.00 | 2 | 47 | 27 | 25 | 14 | 14 | 0 | 14 | 0 | 13 | 1 | 18 | 4 |
| | 401 | 23.01-24.00 | 2 | 47 | 27 | 25 | 14 | 14 | 0 | 14 | 0 | 13 | 1 | 18 | 4 |
| | 291 | 3.01-4.00 | 4 | 51 | 57 | 6 | 16 | 19 | 3 | 23 | 7 | 26 | 10 | 30 | 14 |
| | 291 | 7.01-8.00 | 2 | 49 | 39 | 25 | 17 | 16 | 1 | 21 | 4 | 21 | 4 | 21 | 4 |
| | 401 | 13.01-14.00 | 2 | 49 | 39 | 25 | 17 | 16 | 1 | 21 | 4 | 21 | 4 | 21 | 4 |
| | 660 | 12.01-13.00 | 1 | 41 | 3 | 70 | 19 | 18 | 1 | 16 | 3 | 15 | 4 | 12 | 7 |
| | 603 | 0.00-1.00 | 2 | 50 | 49 | 25 | 20 | 24 | 4 | 24 | 4 | 27 | 7 | 31 | 11 |
| Top 30 | 504 | 6.01-7.00 | 1 | 42 | 5 | 70 | 21 | 20 | 1 | 17 | 4 | 17 | 4 | 14 | 7 |
| | 702 | 1.01-2.00 | 1 | 42 | 5 | 70 | 21 | 20 | 1 | 17 | 4 | 17 | 4 | 14 | 7 |
| | 401 | 25.01-26.00 | 1 | 43 | 7 | 70 | 23 | 22 | 1 | 19 | 4 | 19 | 4 | 16 | 7 |
| | 561N | 7.01-8.00 | 1 | 43 | 7 | 70 | 23 | 22 | 1 | 19 | 4 | 19 | 4 | 16 | 7 |
| | 702 | 0.00-1.00 | 4 | 53 | 75 | 6 | 25 | 28 | 3 | 32 | 7 | 38 | 13 | 46 | 21 |
| | 401 | 9.01-10.0 | 2 | 52 | 65 | 25 | 26 | 33 | 7 | 36 | 10 | 39 | 13 | 43 | 17 |
| | 401 | 20.01-21.00 | 2 | 52 | 65 | 25 | 26 | 33 | 7 | 36 | 10 | 39 | 13 | 43 | 17 |
| | 401 | 24.01-25.00 | 2 | 52 | 65 | 25 | 26 | 33 | 7 | 36 | 10 | 39 | 13 | 43 | 17 |
| | 385 | 2.01-3.00 | 1 | 46 | 21 | 70 | 29 | 25 | 4 | 25 | 4 | 23 | 6 | 23 | 6 |
| | 504 | 7.01-8.00 | 1 | 46 | 21 | 70 | 29 | 25 | 4 | 25 | 4 | 23 | 6 | 23 | 6 |
| Top 50 | 603 | 3.01-4.00 | 1 | 46 | 21 | 70 | 29 | 25 | 4 | 25 | 4 | 23 | 6 | 23 | 6 |
| | 351 | 9.01-10.0 | 7 | 55 | 94 | 1 | 32 | 39 | 7 | 45 | 13 | 54 | 22 | 59 | 27 |
| | 203 | 6.01-7.00 | 1 | 47 | 27 | 70 | 33 | 29 | 4 | 28 | 5 | 28 | 5 | 26 | 7 |
| | 291 | 38.01-39.00 | 1 | 47 | 27 | 70 | 33 | 29 | 4 | 28 | 5 | 28 | 5 | 26 | 7 |
| | 401 | 29.01-30.00 | 1 | 47 | 27 | 70 | 33 | 29 | 4 | 28 | 5 | 28 | 5 | 26 | 7 |
| | 702 | 3.01-4.00 | 1 | 47 | 27 | 70 | 33 | 29 | 4 | 28 | 5 | 28 | 5 | 26 | 7 |
| | 351 | 8.01-9.00 | 4 | 55 | 94 | 6 | 37 | 45 | 8 | 50 | 13 | 58 | 21 | 61 | 24 |
| | 504 | 0.00-1.00 | 2 | 53 | 75 | 25 | 37 | 40 | 3 | 41 | 4 | 49 | 12 | 52 | 15 |
| | 504 | 10.01-11.00 | 2 | 53 | 75 | 25 | 37 | 40 | 3 | 41 | 4 | 49 | 12 | 52 | 15 |
| | 561N | 0.00-1.00 | 2 | 53 | 75 | 25 | 37 | 40 | 3 | 41 | 4 | 49 | 12 | 52 | 15 |
| | 291 | 13.01-14.00 | 1 | 48 | 34 | 70 | 41 | 36 | 5 | 33 | 8 | 32 | 9 | 33 | 8 |
| | 291 | 42.01-43.00 | 1 | 48 | 34 | 70 | 41 | 36 | 5 | 33 | 8 | 32 | 9 | 33 | 8 |
| | 401 | 6.01-7.00 | 1 | 48 | 34 | 70 | 41 | 36 | 5 | 33 | 8 | 32 | 9 | 33 | 8 |
| | 291 | 4.01-5.00 | 1 | 49 | 39 | 70 | 44 | 43 | 1 | 39 | 5 | 36 | 8 | 39 | 5 |
| | 700 | 3.01-4.00 | 1 | 49 | 39 | 70 | 44 | 43 | 1 | 39 | 5 | 36 | 8 | 39 | 5 |
| | 351 | 7.01-8.00 | 6 | 57 | 108 | 2 | 46 | 50 | 4 | 58 | 12 | 60 | 14 | 70 | 24 |
| | 203 | 1.01-2.00 | 1 | 50 | 49 | 70 | 47 | 46 | 1 | 46 | 1 | 45 | 2 | 47 | 0 |
| | 203 | 5.01-6.00 | 1 | 50 | 49 | 70 | 47 | 46 | 1 | 46 | 1 | 45 | 2 | 47 | 0 |
| | 385 | 4.01-5.00 | 1 | 50 | 49 | 70 | 47 | 46 | 1 | 46 | 1 | 45 | 2 | 47 | 0 |
| | 702 | 2.01-3.00 | 1 | 50 | 49 | 70 | 47 | 46 | 1 | 46 | 1 | 45 | 2 | 47 | 0 |

## Laramie County

| | Road # | Mile Post | Total Crashes | Field Score | Field Score Rank | Total Crash Rank | 50%-50% Rank | 45%-55% Rank | Difference | 40%-60% Rank | Difference | 35%-65% Rank | Difference | 30%-70% Rank | Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Top 10 | 2101 | 5–6 | 99 | 32 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| | 1242 | 1–2 | 8 | 36 | 3 | 4 | 2 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| | 2101 | 4–5 | 6 | 38 | 5 | 8 | 3 | 3 | 0 | 3 | 0 | 3 | 0 | 3 | 0 |
| | 1361 | 3–4 | 4 | 34 | 2 | 18 | 4 | 4 | 0 | 4 | 0 | 6 | 2 | 11 | 7 |
| | 109-1 | 6–7 | 4 | 36 | 3 | 18 | 5 | 5 | 0 | 5 | 0 | 8 | 3 | 12 | 7 |
| | 1641 | 11–12 | 4 | 38 | 5 | 18 | 6 | 6 | 0 | 7 | 1 | 13 | 7 | 13 | 7 |
| | 2101 | 0–1 | 4 | 40 | 7 | 18 | 7 | 8 | 1 | 9 | 2 | 14 | 7 | 14 | 7 |
| | 2101 | 6–7 | 5 | 44 | 14 | 11 | 7 | 7 | 0 | 6 | 1 | 5 | 2 | 7 | 0 |
| | 1021 | 2–3 | 4 | 42 | 10 | 18 | 9 | 11 | 2 | 13 | 4 | 15 | 6 | 17 | 8 |
| | 109-1 | 3–4 | 4 | 42 | 10 | 18 | 9 | 11 | 2 | 13 | 4 | 15 | 6 | 17 | 8 |
| Top 20 | 1242 | 0–1 | 4 | 42 | 10 | 18 | 9 | 11 | 2 | 13 | 4 | 15 | 6 | 17 | 8 |
| | 1021 | 3–4 | 5 | 46 | 18 | 11 | 12 | 9 | 3 | 11 | 1 | 10 | 2 | 9 | 3 |
| | 2092 | 1–2 | 5 | 46 | 18 | 11 | 12 | 9 | 3 | 11 | 1 | 10 | 2 | 9 | 3 |
| | 1622 | 9–10 | 7 | 48 | 25 | 6 | 14 | 15 | 1 | 9 | 5 | 7 | 7 | 6 | 8 |
| | 1622 | 5–6 | 4 | 44 | 14 | 18 | 15 | 17 | 2 | 18 | 3 | 20 | 5 | 20 | 5 |
| | 2031 | 7–8 | 4 | 44 | 14 | 18 | 15 | 17 | 2 | 18 | 3 | 20 | 5 | 20 | 5 |
| | 2153 | 2–3 | 9 | 50 | 31 | 1 | 15 | 14 | 1 | 8 | 7 | 4 | 11 | 4 | 11 |
| | 2153 | 0–1 | 8 | 50 | 31 | 4 | 18 | 16 | 2 | 16 | 2 | 10 | 8 | 8 | 10 |
| | 1201 | 4–5,8-9 | 5 | 48 | 25 | 11 | 19 | 20 | 1 | 20 | 1 | 18 | 1 | 15 | 4 |
| | 1432 | 0–1 | 5 | 48 | 25 | 11 | 19 | 20 | 1 | 20 | 1 | 18 | 1 | 15 | 4 |
| Top 30 | 1622 | 10–11 | 4 | 46 | 18 | 18 | 19 | 22 | 3 | 22 | 3 | 22 | 3 | 22 | 3 |
| | 109-1 | 1–2 | 9 | 52 | 36 | 1 | 22 | 19 | 3 | 17 | 5 | 9 | 13 | 5 | 17 |
| | 2092 | 5–6 | 4 | 48 | 25 | 18 | 23 | 23 | 0 | 23 | 0 | 23 | 0 | 23 | 0 |
| | 109-1 | 4–5 | 3 | 46 | 18 | 32 | 24 | 24 | 0 | 28 | 4 | 28 | 4 | 29 | 5 |
| | 1361 | 1–2 | 3 | 46 | 18 | 32 | 24 | 24 | 0 | 28 | 4 | 28 | 4 | 29 | 5 |
| | 1021 | 0–1 | 2 | 40 | 7 | 47 | 26 | 32 | 6 | 32 | 6 | 35 | 9 | 40 | 14 |
| | 109-1 | 0–1 | 4 | 52 | 36 | 18 | 26 | 27 | 1 | 27 | 1 | 27 | 1 | 27 | 1 |
| | 2071 | 2–3 | 5 | 54 | 44 | 11 | 28 | 26 | 2 | 24 | 4 | 24 | 4 | 26 | 2 |
| | 1021 | 1–2 | 2 | 42 | 10 | 47 | 29 | 33 | 4 | 35 | 6 | 38 | 9 | 42 | 13 |
| | 1201 | 1–2,5-6 | 3 | 48 | 25 | 32 | 29 | 30 | 1 | 30 | 1 | 30 | 1 | 31 | 2 |
| Top 50 | 2092 | 0–1 | 3 | 48 | 25 | 32 | 29 | 30 | 1 | 30 | 1 | 30 | 1 | 1 | 0 |
| | 2031 | 17–18 | 6 | 56 | 50 | 8 | 32 | 28 | 4 | 25 | 7 | 25 | 7 | 2 | 0 |
| | 2127 | 3–4 | 6 | 56 | 50 | 8 | 32 | 28 | 4 | 25 | 7 | 25 | 7 | 3 | 0 |
| | 2031 | 18–19 | 3 | 50 | 31 | 32 | 34 | 34 | 0 | 33 | 1 | 33 | 1 | 11 | 7 |
| | 2031 | 20-21 | 3 | 50 | 31 | 32 | 34 | 34 | 0 | 33 | 1 | 33 | 1 | 12 | 7 |
| | 1622 | 4–5 | 3 | 52 | 36 | 32 | 36 | 36 | 0 | 36 | 0 | 36 | 0 | 13 | 7 |
| | 2101 | 7–8 | 3 | 52 | 36 | 32 | 36 | 36 | 0 | 36 | 0 | 36 | 0 | 14 | 7 |
| | 1242 | 2–3 | 1 | 40 | 7 | 62 | 38 | 38 | 0 | 45 | 7 | 46 | 8 | 7 | 0 |
| | 1361 | 0–1 | 1 | 44 | 14 | 62 | 39 | 45 | 6 | 48 | 9 | 50 | 11 | 17 | 8 |
| | 1622 | 6–7 | 3 | 54 | 44 | 32 | 39 | 39 | 0 | 39 | 0 | 42 | 3 | 17 | 8 |
| | 1201 | 5–6,9-10 | 3 | 56 | 50 | 32 | 41 | 43 | 2 | 43 | 2 | 43 | 2 | 17 | 8 |
| | 1432 | 1–2 | 3 | 56 | 50 | 32 | 41 | 43 | 2 | 43 | 2 | 43 | 2 | 9 | 3 |
| | 1021 | 4–5 | 2 | 52 | 36 | 47 | 43 | 46 | 3 | 47 | 4 | 47 | 4 | 9 | 3 |
| | 2153 | 1–2 | 7 | 62 | 78 | 6 | 44 | 40 | 4 | 38 | 6 | 32 | 12 | 6 | 8 |
| | 1491 | 0–0.69 | 4 | 60 | 67 | 18 | 45 | 41 | 4 | 40 | 5 | 39 | 6 | 20 | 5 |
| | 1622 | 8–9 | 4 | 60 | 67 | 18 | 45 | 41 | 4 | 40 | 5 | 39 | 6 | 20 | 5 |
| | 2031 | 15–16 | 3 | 58 | 58 | 32 | 47 | 48 | 1 | 46 | 1 | 45 | 2 | 4 | 11 |
| | 1201 | 3–4,7-8 | 2 | 54 | 44 | 47 | 48 | 49 | 1 | 49 | 1 | 51 | 3 | 8 | 10 |
| | 2127 | 0–1 | 5 | 64 | 81 | 11 | 49 | 47 | 2 | 42 | 7 | 41 | 8 | 15 | 4 |
| | 109-1 | 5–6 | 1 | 50 | 31 | 62 | 50 | 52 | 2 | 52 | 2 | 55 | 5 | 15 | 4 |

# Laramie County

| | Road # | Mile Post | Total Crashes | Field Score | Field Score Rank | Total Crash Rank | 50%-50% Rank | 55%-45% Rank | Difference | 60%-40% Rank | Difference | 65%-35% Rank | Difference | 70%-30% Rank | Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Top 10 | 2101 | 5--6 | 99 | 32 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| | 1242 | 1--2 | 8 | 36 | 3 | 4 | 2 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| | 2101 | 4--5 | 6 | 38 | 5 | 8 | 3 | 3 | 0 | 3 | 0 | 3 | 0 | 3 | 0 |
| | 1361 | 3--4 | 4 | 34 | 2 | 18 | 4 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 |
| | 109-1 | 6--7 | 4 | 36 | 3 | 18 | 5 | 5 | 0 | 5 | 0 | 5 | 0 | 5 | 0 |
| | 1641 | 11--12 | 4 | 38 | 5 | 18 | 6 | 6 | 0 | 6 | 0 | 6 | 0 | 6 | 0 |
| | 2101 | 0--1 | 4 | 40 | 7 | 18 | 7 | 7 | 0 | 7 | 0 | 7 | 0 | 7 | 0 |
| | 2101 | 6--7 | 5 | 44 | 14 | 11 | 7 | 8 | 1 | 8 | 1 | 11 | 4 | 11 | 4 |
| | 1021 | 2--3 | 4 | 42 | 10 | 18 | 9 | 9 | 0 | 9 | 0 | 8 | 1 | 8 | 1 |
| | 109-1 | 3--4 | 4 | 42 | 10 | 18 | 9 | 9 | 0 | 9 | 0 | 8 | 1 | 8 | 1 |
| Top 20 | 1242 | 0--1 | 4 | 42 | 10 | 18 | 9 | 9 | 0 | 9 | 0 | 8 | 1 | 8 | 1 |
| | 1021 | 3--4 | 5 | 46 | 18 | 11 | 12 | 12 | 0 | 12 | 0 | 14 | 2 | 14 | 2 |
| | 2092 | 1--2 | 5 | 46 | 18 | 11 | 12 | 12 | 0 | 12 | 0 | 14 | 2 | 14 | 2 |
| | 1622 | 9--10 | 7 | 48 | 25 | 6 | 14 | 16 | 2 | 16 | 2 | 17 | 3 | 18 | 4 |
| | 1622 | 5--6 | 4 | 44 | 14 | 18 | 15 | 14 | 1 | 14 | 1 | 12 | 3 | 12 | 3 |
| | 2031 | 7--8 | 4 | 44 | 14 | 18 | 15 | 14 | 1 | 14 | 1 | 12 | 3 | 12 | 3 |
| | 2153 | 2--3 | 9 | 50 | 31 | 1 | 15 | 17 | 2 | 18 | 3 | 20 | 5 | 22 | 7 |
| | 2153 | 0--1 | 8 | 50 | 31 | 4 | 18 | 21 | 3 | 21 | 3 | 22 | 4 | 25 | 7 |
| | 1201 | 4--5,8-9 | 5 | 48 | 25 | 11 | 19 | 19 | 0 | 19 | 0 | 18 | 1 | 19 | 0 |
| | 1432 | 0--1 | 5 | 48 | 25 | 11 | 19 | 19 | 0 | 19 | 0 | 18 | 1 | 19 | 0 |
| Top 30 | 1622 | 10--11 | 4 | 46 | 18 | 18 | 19 | 18 | 1 | 17 | 2 | 16 | 3 | 16 | 3 |
| | 109-1 | 1--2 | 9 | 52 | 36 | 1 | 22 | 22 | 0 | 22 | 0 | 27 | 5 | 28 | 6 |
| | 2092 | 5--6 | 4 | 48 | 25 | 18 | 23 | 23 | 0 | 23 | 0 | 23 | 0 | 25 | 2 |
| | 109-1 | 4--5 | 3 | 46 | 18 | 32 | 24 | 24 | 0 | 25 | 1 | 24 | 0 | 23 | 1 |
| | 1361 | 1--2 | 3 | 46 | 18 | 32 | 24 | 24 | 0 | 25 | 1 | 24 | 0 | 23 | 1 |
| | 1021 | 0--1 | 2 | 40 | 7 | 47 | 26 | 26 | 0 | 24 | 2 | 21 | 5 | 17 | 9 |
| | 109-1 | 0--1 | 4 | 52 | 36 | 18 | 26 | 28 | 2 | 30 | 4 | 31 | 5 | 32 | 6 |
| | 2071 | 2--3 | 5 | 54 | 44 | 11 | 28 | 31 | 3 | 32 | 4 | 35 | 7 | 35 | 7 |
| | 1021 | 1--2 | 2 | 42 | 10 | 47 | 29 | 27 | 2 | 27 | 2 | 26 | 3 | 21 | 8 |
| | 1201 | 1--2,5-6 | 3 | 48 | 25 | 32 | 29 | 29 | 0 | 28 | 1 | 29 | 0 | 29 | 0 |
| Top 50 | 2092 | 0--1 | 3 | 48 | 25 | 32 | 29 | 29 | 0 | 28 | 1 | 29 | 0 | 29 | 0 |
| | 2031 | 17--18 | 6 | 56 | 50 | 8 | 32 | 32 | 0 | 35 | 3 | 38 | 6 | 40 | 8 |
| | 2127 | 3--4 | 6 | 56 | 50 | 8 | 32 | 32 | 0 | 35 | 3 | 38 | 6 | 40 | 8 |
| | 2031 | 18--19 | 3 | 50 | 31 | 32 | 34 | 34 | 0 | 33 | 1 | 33 | 1 | 33 | 1 |
| | 2031 | 20-21 | 3 | 50 | 31 | 32 | 34 | 34 | 0 | 33 | 1 | 33 | 1 | 33 | 1 |
| | 1622 | 4--5 | 3 | 52 | 36 | 32 | 36 | 37 | 1 | 38 | 2 | 36 | 0 | 36 | 0 |
| | 2101 | 7--8 | 3 | 52 | 36 | 32 | 36 | 37 | 1 | 38 | 2 | 36 | 0 | 36 | 0 |
| | 1242 | 2--3 | 1 | 40 | 7 | 62 | 38 | 36 | 2 | 31 | 7 | 28 | 10 | 27 | 11 |
| | 1361 | 0--1 | 1 | 44 | 14 | 62 | 39 | 39 | 0 | 35 | 4 | 32 | 7 | 31 | 8 |
| | 1622 | 6--7 | 3 | 54 | 44 | 32 | 39 | 40 | 1 | 40 | 1 | 42 | 3 | 44 | 5 |
| | 1201 | 5--6,9-10 | 3 | 56 | 50 | 32 | 41 | 42 | 1 | 44 | 3 | 45 | 4 | 45 | 4 |
| | 1432 | 1--2 | 3 | 56 | 50 | 32 | 41 | 42 | 1 | 44 | 3 | 45 | 4 | 45 | 4 |
| | 1021 | 4--5 | 2 | 52 | 36 | 47 | 43 | 41 | 2 | 41 | 2 | 43 | 0 | 42 | 1 |
| | 2153 | 1--2 | 7 | 62 | 78 | 6 | 44 | 50 | 6 | 51 | 7 | 56 | 12 | 61 | 17 |
| | 1491 | 0--0.69 | 4 | 60 | 67 | 18 | 45 | 46 | 1 | 48 | 3 | 49 | 4 | 54 | 9 |
| | 1622 | 8--9 | 4 | 60 | 67 | 18 | 45 | 46 | 1 | 48 | 3 | 49 | 4 | 54 | 9 |
| | 2031 | 15--16 | 3 | 58 | 58 | 32 | 47 | 51 | 4 | 50 | 3 | 48 | 1 | 53 | 6 |
| | 1201 | 3--4,7-8 | 2 | 54 | 44 | 47 | 48 | 49 | 1 | 47 | 1 | 47 | 1 | 47 | 1 |
| | 2127 | 0--1 | 5 | 64 | 81 | 11 | 49 | 52 | 3 | 57 | 8 | 64 | 15 | 67 | 18 |
| | 109-1 | 5--6 | 1 | 50 | 31 | 62 | 50 | 46 | 4 | 46 | 4 | 44 | 6 | 43 | 7 |

# APPENDIX A-5. SAFETY ISSUES TO LOOK FOR

**a) Roadside Features**

1. Are clear zones free of hazards and non-traversable side slopes without safety barriers?
2. Are the clear zones free of nonconforming and/or dangerous obstructions that are not properly shielded?

**b) Road Surface-Pavement Condition**

1. Is the pavement free of defects that could result in safety problems (e.g., loss of steering control)?
2. Are changes in surface type (e.g., pavement ends or begins) free of poor transitions?
3. Is the pavement free of locations that appear to have inadequate skid resistance that could result in safety problems, particularly on curves, steep grades, and approaches to intersections?
4. Is the pavement free of areas where ponding or sheet flow of water may occur resulting in safety problems?
5. Is the pavement free of loose aggregate/gravel, which may cause safety problems?

**c) Road Surface-Pavement Markings**

1. Is the road free of locations with pavement marking safety deficiencies?
2. Is the road free of pavement markings that are not effective for the conditions present?
3. Is the road free of old pavement markings that affect the safety of the roadway?

**d) Road Surface-Unpaved Roads**

1. Is the road surface free of defects that could result in safety problems (e.g., loss of steering control)?
2. Is the road surface free of areas where ponding or sheet flow of water may occur resulting in safety problems?
3. Is the road surface free of loose gravel or fines that may cause safety problems (control, visibility, etc.)?
4. Are changes in surface type (e.g., pavement ends or begins) free of drop-offs or poor transitions?

**e) Signing and Delineation**

1. Is the road free of locations where signing is needed to improve safety?
2. Are existing regulatory, warning, and directory signs conspicuous?
3. Is the road free of locations with improper signing which may cause safety problems?
4. Is the road free of unnecessary signing which may cause safety problems?
5. Are signs effective for existing conditions?
6. Can signs be read at a safe distance?
7. Is the road free of signing that impairs safe sight distances?
8. Is the road free of locations with improper or unsuitable delineation (post delineators, chevrons, object markers)?

**f) Intersections and Approaches**

1. Are intersections free of sight restrictions that could result in safety problems?
2. Are intersections free of abrupt changes in elevation or surface condition?
3. Are advance warning signs installed when intersection traffic control cannot be seen a safe distance ahead of the intersection?

**g) Special Road Users, Railroad Crossings, Consistency**

1. Are travel paths and crossing points for pedestrians and cyclists properly signed and/or marked?
2. Are bus stops and mail boxes safely located with adequate clearance and visibility from the traffic lane?
3. Is appropriate advance signing provided for bus stops and refuge areas?
4. Are railroad crossing (crossbucks) signs used on each approach at railroad crossings?
5. Are railroad advance warning signs used at railroad crossing approaches?
6. Are railroad crossings free of vegetation and other obstructions that have the potential to restrict sight distance?
7. Are roadway approach grades to railroad crossings flat enough to prevent vehicle snagging?
8. Is the road section free of inconsistencies that could result in safety problems?

## APPENDIX A-6. LEVEL II FIELD EVALUATION FORM

| Level II Field Evaluation | Evaluator: | Date: | Page: |
|---|---|---|---|

Notes:

| | |
|---|---|
| Road Name: | Road Length: |
| Road No.: | Road Surface: |
| Road Class: | Speed Limit: |

| Condition # | Locations | Horizontal Middle Ordinate (M) | Horizontal Degree of Curvature (D) | Horizontal Curve Stopping Sight Dist. | Vertical Curve: Crest or Sag | Vertical Curve Stopping Sight Dist. | Steep Slope | Intersection Stopping Sight Dist. | Signs | Pavement Markings | Delineators | Roadway Width | Shoulder Width | Bridge Width | Fixed Objects in ROW | Fencing | Cattle Guard |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #1 | | | | | | | | | | | | | | | | | |
| #2 | | | | | | | | | | | | | | | | | |
| #3 | | | | | | | | | | | | | | | | | |
| #4 | | | | | | | | | | | | | | | | | |
| #5 | | | | | | | | | | | | | | | | | |
| #6 | | | | | | | | | | | | | | | | | |
| #7 | | | | | | | | | | | | | | | | | |
| #8 | | | | | | | | | | | | | | | | | |
| #9 | | | | | | | | | | | | | | | | | |
| #10 | | | | | | | | | | | | | | | | | |

**Immediate Safety Improvements:**

**Low-Cost Safety Improvements:**

**High-Cost Safety Improvements:**

| Level II Field Evaluation | Evaluator: F. Jones | Date: 7/22/07 | Page: 1 of 1 |
|---|---|---|---|

**Notes:**

| | |
|---|---|
| **Road Name: Test** | **Mile Post: 1.00 to 2.00** |
| **Road No.: 401** | **Road Surface: Asphalt** |
| **Road Class: Minor Collector** | **Speed Limit: 55** |

| Condition # | Locations | Horizontal Middle Ordinate (M) | Horizontal Degree of Curvature (D) | Horizontal Curve Stopping Sight Dist. | Vertical Curve: Crest or Sag | Vertical Curve Stopping Sight Dist. | Steep Slope | Intersection Stopping Sight Dist. | Signs | Pavement Markings | Delineators | Roadway Width | Shoulder Width | Bridge Width | Fixed Objects in ROW | Fencing | Cattle Guard |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #1 | 1.0 - 2.0 | | | | | | | | | Needed | Needed | | | | | Needed | |
| #2 | 1.2 | | | | | | | | 2 | | | | | | | | |
| #3 | 1.25 | | | | | | 2 | | | | | | | | | | |
| #4 | 1.5 | 4 | 18d15' | | Crest | 350' | | | 4 | | | | | | | | |
| #5 | 1.7 | 9 | 40d00' | | | | | | 2 | | | | | | | | |
| #6 | | | | | | | | | | | | | | | | | |
| #7 | | | | | | | | | | | | | | | | | |
| #8 | | | | | | | | | | | | | | | | | |
| #9 | | | | | | | | | | | | | | | | | |
| #10 | | | | | | | | | | | | | | | | | |

**Immediate Safety Improvements:** 1.2 - Minor horizontal curve, Check placement and retroreflection of curve sign and/or add MPH curve sign W13-5,
install Do Not Pass sign R4-1 on both ends of curve.
1.25 - Minor steep foreslope, Install additional delineator posts, install guardrail.
1.5 - Vertical and horizontal curve, stopping sight distance is 350', Install Curve sign W1-2 or MPH curve sign W13-15. Install Do Not Pass Sign R4-1 on both ends.
1.7 - Minor horizontal curve, Install curve signs W1-2, or MPH sign W13-15 on both ends.

**Low-Cost Safety Improvements:** 1.0 to 2.0 - Install pavement markings, replace broken and missing delineator posts.

**High-Cost Safety Improvements:** 1.2 - Improve alignment.
1.25 - Extend culvert, fill and flatten foreslope.
1.5 - Improve alignment.
1.7 - Improve alignment.

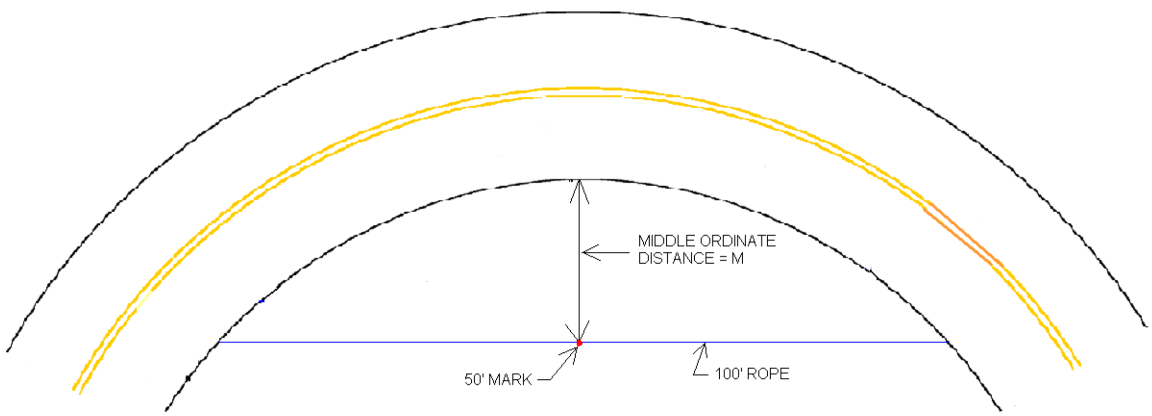
# APPENDIX A-7.  GUIDELINES FOR LEVEL II FIELD EVALUATION

The following instructions are helpful when conducting the level II field evaluations.

**a) Horizontal Curve Evaluation:**

1. The WYT[2] /LTAP Center developed a simple procedure to measure a curve's radius in the field. As shown in Figure 1, use a 100 foot rope having a mark at 50 foot. Lay it on the shoulder of the road, pulling tight. At the 50 foot mark, measure the distance from the rope to the shoulder of the road. This measurement will give you the middle ordinate of the curve.

**Figure 1. Measuring to find radius of horizontal curve**




2. Use Table 1 to find the radius and degree of curvature of the curve that corresponds to the measured middle ordinate middle ordinate.

**Table 1 Radius and Degree of Curvature**

| M | Radius | Degree of Curvature | M | Radius | Degree of Curvature |
|---|---|---|---|---|---|
| 0.5 | 2500 | 2˚15′ | 10.5 | 124 | 46˚ |
| 0.75 | 1667 | 3˚30′ | 11 | 119 | 48˚ |
| 1 | 1251 | 4˚30′ | 11.5 | 114 | 50˚ |
| 1.5 | 834 | 6˚45′ | 12 | 110 | 52˚ |
| 2 | 626 | 9˚15′ | 12.5 | 106 | 54˚ |
| 2.5 | 501 | 11˚30′ | 13 | 103 | 55˚45′ |
| 3 | 418 | 13˚45′ | 13.5 | 99 | 57˚45′ |
| 3.5 | 359 | 16˚ | 14 | 96 | 59˚30′ |
| 4 | 315 | 18˚15′ | 14.5 | 93 | 61˚15′ |
| 4.5 | 280 | 20˚30′ | 15 | 91 | 63˚ |
| 5 | 253 | 22˚45′ | 15.5 | 88 | 64˚45′ |
| 5.5 | 230 | 25˚ | 16 | 86 | 66˚30′ |
| 6 | 211 | 27˚ | 16.5 | 84 | 68˚15′ |
| 6.5 | 196 | 29˚15′ | 17 | 82 | 69˚45′ |
| 7 | 182 | 31˚30′ | 17.5 | 80 | 71˚30′ |
| 7.5 | 170 | 33˚30′ | 18 | 78 | 73˚ |
| 8 | 160 | 35˚45′ | 18.5 | 77 | 74˚30′ |
| 8.5 | 151 | 37˚45′ | 19 | 75 | 76˚ |
| 9 | 143 | 40˚ | 19.5 | 74 | 77˚30′ |
| 9.5 | 136 | 42˚ | 20 | 73 | 79˚ |
| 10 | 130 | 44˚ | | | |

3. Compare the measured radius and degree of curvature to the minimum requirements out of the county fund manual. These requirements are summarized in Appendix Table 2. As an alternative, counties can use the minimum requirements from the AASHTO policy on Geometric Design of Highways and Streets or the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads.

**Table 2 Geometric Design Criteria**

[redacted]

**b) Horizontal Curve Stopping Sight Distance:**

1. Measure the stop sight distance. As shown in Figure 2, topping sight distance on all horizontal curves are measured along the travel path of the vehicle using a driver's eye height of 42 inches, looking at an object 24 inches high. To measure sight distance, kneel and use a 42-inch sighting stick to get your eyes at the proper height. Have an assistant move a 24-inch target stick until you cannot see the target. Measure the distance between the two to get the stopping sight distance.

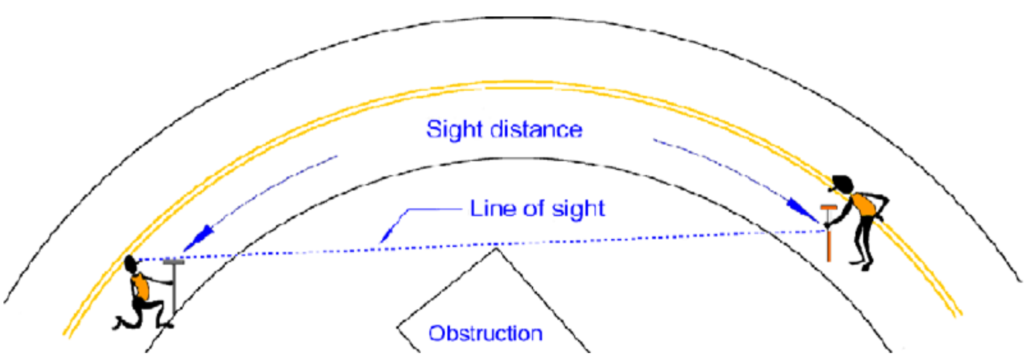



**Figure 2. Measuring stopping sight distance for horizontal curves**

2. Use the table in Table 3 to determine if the stopping sight distance is acceptable for the speed limit and traffic volumes.

**Table 3 Stopping Sight Distance Form**

| Traffic speed[1], mph | Stopping Sight Distance, feet | | | | |
|---|---|---|---|---|---|
| | 0-100 veh/day | 100-250 veh/day | | 250-400 veh/day | >400 veh/day |
| | | Lower risk locations[2] | Higher risk locations[2] | | |
| 25 | 115 | 115 | 125 | 125 | 155 |
| 30 | 135 | 135 | 165 | 165 | 200 |
| 35 | 170 | 170 | 205 | 205 | 250 |
| 40 | 215 | 215 | 250 | 250 | 305 |
| 45 | 260 | 260 | 300 | 300 | 360 |
| 50 | 310 | 310 | 350 | 350 | 425 |
| 55 | 365 | 365 | 405 | 405 | 495 |
| 60 | 435 | 435 | 470 | 470 | 570 |

*[1]Choose a speed that includes most traffic on the road. If you know it, use the 85th percentile speed. This is the speed that 85% of traffic is not exceeding, and 15% is exceeding.*

*[2]Higher risk locations include features like intersections, narrow bridges, railroad grade crossings, sharp curves or steep downgrades. Lower risk locations are areas without such features*

*Based on AASHTO Geometric Design of Very Low-Volume Local Roads and "Green Book".*

**c) Vertical Curve Stopping Sight Distance:**

1. Measure stopping sight distance. As shown in Figure 3, stopping sight distance on all vertical curves are measured along the travel path of the vehicle using a driver's eye height of 42 inches, looking at an object 24 inches high. To measure sight distance, kneel and use a 42-inch sighting stick to get your eyes at the proper height. Have an assistant move a 24-inch target stick until you cannot see the target. Measure the distance between the two to get the stopping sight distance.

2. Use the stopping sight distance in Table 3 to determine if the measured stopping sight distance is acceptable given the speed limit and traffic volumes.

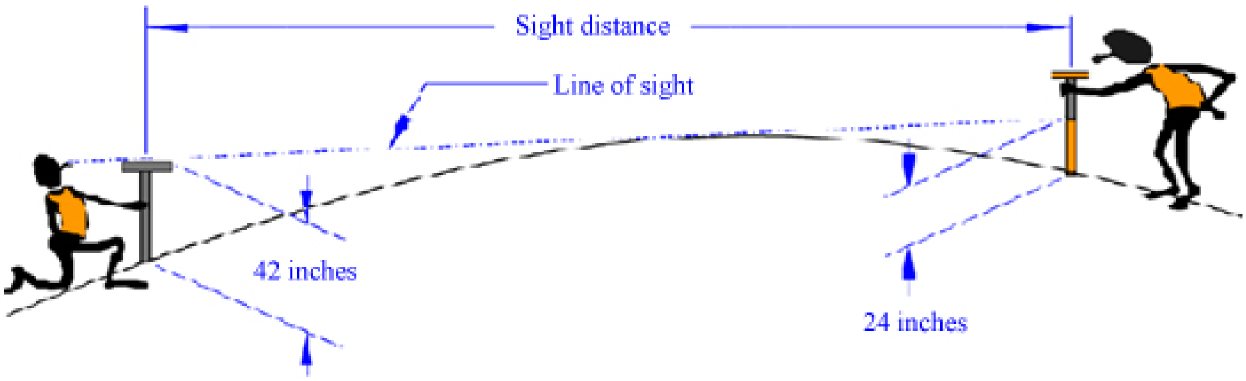



**Figure 3. Measuring stopping sight distance for vertical curve**

**d)** **Steep Slope:**
Determine if the fore-slope exceed maximum allowed per the Wyoming County Road Fund Manual of 3:1, or AASHTO policy on Geometric Design of Highways and Streets or the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads.

**e)** **Intersections:**
Determine if safety improvements are needed at intersections.

**f)** **Signs Needed:**
Are signs needed? Determine if existing signs meet the MUTCD requirements. Also determine if additional signs are needed.

**g)** **Pavement Markings:**
Are pavement markings needed? Determine if existing pavement markings meet the MUTCD requirements. Also determine if additional pavement markings are needed.

**h)** **Delineators:**
Are delineators needed? Determine if existing delineators meet the MUTCD requirements. Also determine if additional delineators are needed.

**i)** **Fencing:**
Is fencing needed? Determine if existing fencing meets the MUTCD requirements. Also determine if additional fencing is needed.

**j)** **Fixed objects in ROW:**
Determine if clear zones and ROWs free of hazardous objects, and if there are nonconforming and/or dangerous objects that are not properly shielded in the clears zones and ROWs.

**k)** **Bridge:**
Determine if the bridge is narrower than the width of the road.

**l)** **Cattle Guard:**
Determine if the cattle guard is narrower than the width of the road.

**m)** **Shoulder:**
Determine if the shoulder needs to be wider and verify if it has a steep drop off.

# APPENDIX A-8.  LEVEL II FIELD EVALUATION EXAMPLES

## EXAMPLE 1

Add object marker OM-3C on power poles. 

Add intersection warning sign W2-4. 

Need winding road W1-5 sign. 

## EXAMPLE 2

Install Object Markers OM-3C on utility poles.

Install Intersections Sign W2-1.

Install stop ahead sign W3-1.

## EXAMPLE 3

Vertical Edge Drop-off.

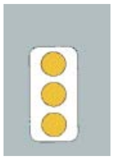
Apply filled and compacted shoulder material.


## EXAMPLE 4

Replace stop ahead sign W3-1. 

## EXAMPLE 5

Install chevrons W1-8.



Install post delineators.
If possible install guardrail.

Install curve W1-2 and advisory speed sign W13-1.


## EXAMPLE 6

Advance Warning Sign + Advisory Speed + Chevrons = “Safer”


# EXAMPLE 7

Install delineators 

Apply centerline and edge line markings

# EXAMPLE 8

Replace 12-foot cattleguard with a 24-foot guard

# EXAMPLE 9

Sight Distance Obstructed by row of trees, cut trees if possible

Install intersection sign W2-1 

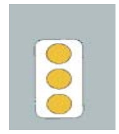
# EXAMPLE 10

Flatten fore slope to 3-1.

# EXAMPLE 11

Install curve sign W1-1 with a speed reduction sign W13-1.


Cut trees if possible, if not install delineators or



Install intersection sign W2-4.

Install intersection sign W2-4.

## EXAMPLE 12

Cut back slope if possible and install curve sign W1-2. 

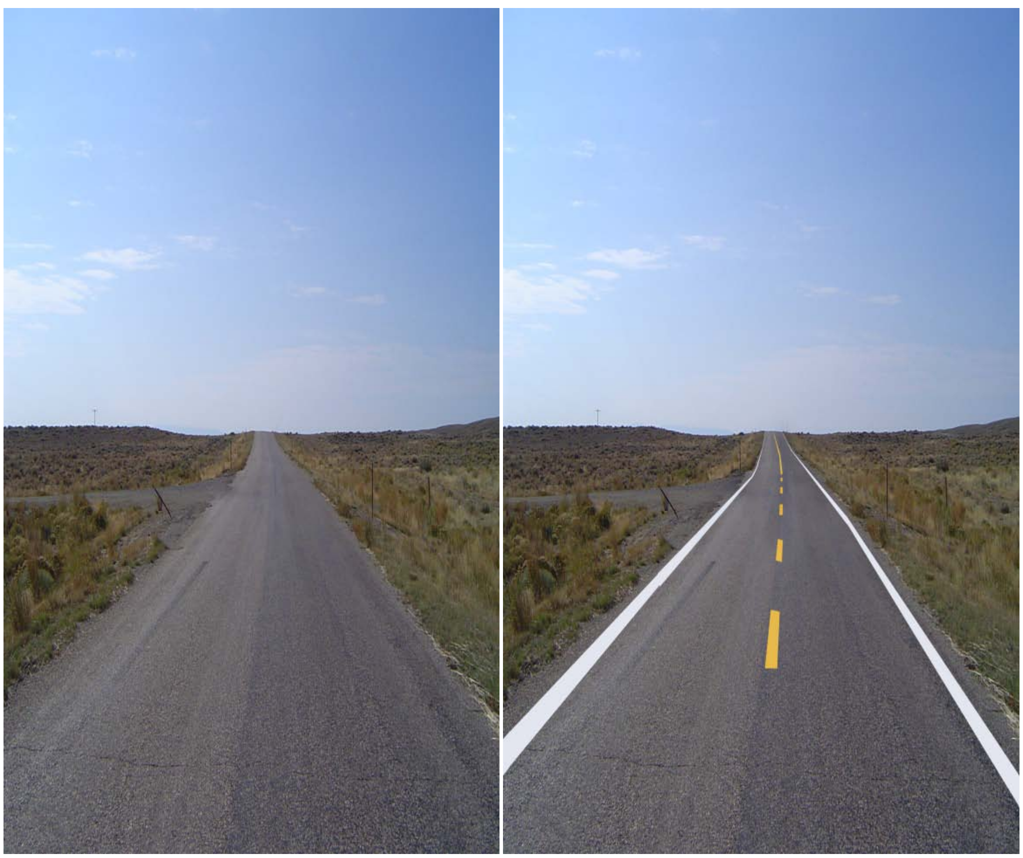
# EXAMPLE 13


Install stop sign R1-1and stop ahead sign W3-1.

Install delineators.

Install intersections sign W2-2.

Apply centerline/edge markings.



## EXAMPLE 14

Install more delineators OR 

Extend culvert and fill.

## EXAMPLE 15

Highway-Rail Crossings.

Every crossing is different.

Reference Part 8 of the MUTCD.

# APPENDIX B. ROADWAY CLASSIFICATION SYSTEM & MINIMUM GEOMETRIC DESIGN STANDARDS SURVEY

Wyoming Technology Transfer Center WY T2 LTAP Local Technical Assistance Program

# County Roads Survey

This survey is performed as part of a Transportation Safety Study conducted by the Wyoming $T^2$ Center. One of the objectives of this survey is to identify a uniform roadway classification system for all counties in the state. Such system will help in comparing safety projects from different counties. A secondary objective of this survey is to identify minimum geometric standards for roadways in the state. The survey consists of two parts. Part One: Roadway Classification System and Part Two: Minimum Geometric Standards.

Please answer all questions as clearly as possible. Your input is very important to us and we appreciate your answers. If you have any questions please contact Khaled at the Wyoming $T^2$ Center (1-800-231-2815).

Name and address of person completing this survey:

________________________________________

________________________________________

________________________________________

Tel No.______________________________ Fax No.________________________

Email: ______________________________ Date: _________________________

## Part One: Roadway Classification System

**1. Does your county currently use any roadway classification system?**

- ☐ Yes
- ☐ No (If no, please explain why a functional classification system is not utilized in your county and return this survey in the enclosed envelope)

______________________________________________________________________

______________________________________________________________________

2. **Please identify all road classification systems currently used in your county.**

- ☐ The county's own system (Please include a copy of this classification system with this survey)
- ☐ AASHTO roadway classification system, based on the "*Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤400)*"
- ☐ AASHTO roadway classification system, based on "*A policy on Geometric Design of Highways and Streets*"
- ☐ WYDOT roadway classification system
- ☐ Other roadway classification system ___________________________

**3. When classifying roadways, which of the following criterions are considered? (Please check all that apply)**

| | | |
|---|---|---|
| ☐ Surface Type | ☐ Terrain Type | ☐ Roadway Function |
| ☐ Design Speed | ☐ Traffic Volume | ☐ Roadway Width |
| ☐ Number of Lanes | ☐ Rural vs. Urban | ☐ Truck Percentage |
| ☐ Vehicle Type | ☐ School Bus Route | ☐ Postal Route |

☐ Others (Please Specify)___________________________________

4. **Among the criterions above, which one is the most important for classifying roadways?**

   ________________________________________________________________

5. **How do you use your roadway classifications?**

   __________________________________________________________

   __________________________________________________________

   __________________________________________________________

6. **What do you think of your currently used roadway classification system? Does it work well?**

   ________________________________________________________________

   ________________________________________________________________

7. **Do you think that it is useful to establish and implement a uniform statewide roadway classification system in Wyoming?**

   ________________________________________________________________

   ________________________________________________________________

## Part Two: Minimum Geometric Standards

1. **Please specify the mileage for both paved and unpaved roadways in your county.**

   Unpaved roadway: ____________________miles

   Paved roadway: _______________________miles

2. **Does your county perform any of the following traffic studies? (Please check all that apply)**

   | **Yes** | **No** | |
   |---|---|---|
   | ☐ | ☐ | Traffic Volume |
   | ☐ | ☐ | Speed |
   | ☐ | ☐ | Traffic Accidents |

   **If yes, please describe how you utilize the collected data. Would traffic counts/speed data be available for conducting future safety studies?**

   __________________________________________________________

   __________________________________________________________

   __________________________________________________________

**3. Does your county have minimum geometric standards for each class of roadways?**

☐ Yes (Please answer questions 4 through 6.)

☐ No (Please explain why minimum geometric standards are not needed in your county and skip the rest of the questions.)

____________________________________________________________

____________________________________________________________

**4. Please list the different roadway classifications and the corresponding *Minimum Roadway Widths* and *Design Speeds* in your county. If you do not have minimum standards, write "N/A".**

| Roadway Classifications | Minimum Roadway Width (ft) | Design Speed (mph) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**5. Please list the different roadway classifications and the corresponding *Minimum Stopping Sight Distance (Horizontal Curves)*, *Minimum Curve Radius* and *Maximum Superelevation Rate* in your county. If you do not have minimum standards, write "N/A".**

| Roadway Classifications | Minimum Stopping Sight Distance (ft) | Minimum Curve Radius (ft), $R_{min}$ | Maximum Superelevation Rate(%), $e_{max}$ |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**6. Please list the different roadway classifications and the corresponding *Minimum Stopping Sight Distance (Vertical Curve)* and *Minimum Rate of Vertical Curvature, K,* in your county. If you do not have minimum standards, write "N/A". (*K, the rate of vertical curvature, is the length of curve (L) percent algebraic difference in intersecting grades (A); K=L/A.*)**

| Roadway Classifications | Minimum Stopping Sight Distance (ft) | Minimum Rate of Vertical Curvature, K |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Do you want to get a copy of the report summarizing the results of the survey?**

☐ Yes

☐ No

**Thank you for taking your time to answer these questions. The information you provided is essential to our project.**

# APPENDIX C-1. TRAFFIC VOLUME AND SPEED DATA

| | Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 7/4/2007 | 99 | 91 | 98 | 1 | 88 | 3 | 61 | 60 |
| Thu 7/5/2007 | 146 | 153 | 136 | 10 | 143 | 10 | 61 | 61 |
| Fri 7/6/2007 | 124 | 118 | 123 | 1 | 111 | 7 | 63 | 64 |
| Sat 7/7/2007 | 107 | 94 | 101 | 6 | 91 | 3 | 61 | 64 |
| Sun 7/8/2007 | 91 | 83 | 86 | 5 | 76 | 7 | 63 | 62 |
| Mon 7/9/2007 | 104 | 98 | 100 | 4 | 93 | 5 | 61 | 63 |
| Average | 112 | 106 | 107 | 5 | 100 | 6 | 62 | 63 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 95.98 | 4.02 | 94.51 | 5.49 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on **Ryan Park Road (Road #504)**
Road Surface Type: Asphalt

| | Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 7/4/2007 | 18 | 14 | 15 | 3 | 14 | 0 | 50 | 51 |
| Thu 7/5/2007 | 19 | 16 | 12 | 7 | 16 | 0 | 50 | 51 |
| Fri 7/6/2007 | 19 | 20 | 17 | 2 | 20 | 0 | 51 | 51 |
| Sat 7/7/2007 | 28 | 17 | 24 | 4 | 17 | 0 | 50 | 46 |
| Sun 7/8/2007 | 21 | 17 | 18 | 3 | 15 | 2 | 49 | 49 |
| Mon 7/9/2007 | 15 | 15 | 12 | 3 | 15 | 0 | 50 | 48 |
| Average | 20 | 17 | 16 | 4 | 16 | 1 | 50 | 49 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 54 | 46 | 80 | 20 | 94 | 6 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on **North Spring Creek Road (Road# 385)**
Road Surface Type: Gravel

| | Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 7/11/2007 | 90 | 91 | 89 | 1 | 91 | 0 | 61 | 60 |
| Thu 7/12/2007 | 83 | 82 | 78 | 5 | 80 | 2 | 63 | 61 |
| Fri 7/13/2007 | 98 | 96 | 97 | 1 | 94 | 2 | 62 | 62 |
| Sat 7/14/2007 | 168 | 172 | 166 | 2 | 170 | 2 | 57 | 59 |
| Sun 7/15/2007 | 99 | 96 | 99 | 0 | 96 | 0 | 59 | 61 |
| Mon 7/16/2007 | 70 | 67 | 67 | 3 | 65 | 2 | 59 | 58 |
| Tue 7/17/2007 | 75 | 75 | 74 | 1 | 75 | 0 | 60 | 59 |
| Average | 98 | 97 | 96 | 2 | 96 | 1 | 60 | 60 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 47 | 53 | 98 | 2 | 99 | 1 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on **Golf Course Road** (**Road #324**)
Road Surface Type: Asphalt

| | Volume | | Vehicle Classification | | | | $85^{th}$ percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 7/19/2007 | 26 | 25 | 23 | 3 | 24 | 1 | 49 | 50 |
| Fri 7/20/2007 | 17 | 19 | 17 | 0 | 18 | 0 | 49 | 45 |
| Sat 7/21/2007 | 11 | 14 | 10 | 1 | 13 | 1 | 46 | 45 |
| Sun 7/22/2007 | 22 | 21 | 22 | 0 | 21 | 0 | 45 | 49 |
| Mon 7/23/2007 | 7 | 12 | 7 | 0 | 12 | 0 | 50 | 47 |
| Tue 7/24/2007 | 21 | 22 | 20 | 1 | 22 | 0 | 45 | 51 |
| Average | 17 | 18 | 16 | 1 | 18 | 0 | 47 | 48 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 94 | 6 | 100 | 0 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on **Hanna Draw Road, (Road #291** )
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 8/2/2007 | 91 | 76 | 75 | 16 | 67 | 9 | 45 | 47 |
| Fri 8/3/2007 | 64 | 65 | 48 | 15 | 55 | 10 | 51 | 49 |
| Sat 8/4/2007 | 28 | 31 | 25 | 3 | 30 | 1 | 42 | 43 |
| Sun 8/5/2007 | 38 | 26 | 35 | 3 | 26 | 0 | 44 | 45 |
| Mon 8/6/2007 | 71 | 71 | 48 | 23 | 61 | 10 | 50 | 49 |
| Tue 8/7/2007 | 51 | 52 | 39 | 12 | 47 | 5 | 49 | 49 |
| Wed 8/8/2007 | 63 | 59 | 45 | 18 | 55 | 4 | 50 | 47 |
| Average | 58 | 54 | 45 | 13 | 49 | 6 | 47 | 47 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 52 | 48 | 78 | 22 | 90 | 10 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Snake River Spur (Road #710)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 8/2/2007 | 116 | 118 | 81 | 35 | 94 | 24 | 40 | 36 |
| Fri 8/3/2007 | 112 | 91 | 80 | 32 | 71 | 20 | 48 | 46 |
| Sat 8/4/2007 | 93 | 55 | 52 | 41 | 40 | 15 | 46 | 43 |
| Sun 8/5/2007 | 105 | 38 | 62 | 43 | 27 | 11 | 47 | 42 |
| Mon 8/6/2007 | 109 | 101 | 89 | 20 | 78 | 23 | 52 | 75 |
| Tue 8/7/2007 | 112 | 107 | 89 | 23 | 83 | 24 | 51 | 63 |
| Wed 8/8/2007 | 134 | 109 | 110 | 24 | 85 | 24 | 55 | 68 |
| Average | 112 | 88 | 81 | 31 | 68 | 20 | 48 | 53 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 56 | 44 | 72 | 28 | 77 | 23 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on **Four Mile (Road #603)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 8/2/2007 | 24 | 22 | 12 | 12 | 19 | 3 | 39 | 37 |
| Fri 8/3/2007 | 23 | 30 | 18 | 5 | 28 | 2 | 39 | 34 |
| Sat 8/4/2007 | 23 | 24 | 22 | 1 | 24 | 0 | 43 | 38 |
| Average | 23 | 25 | 17 | 6 | 24 | 1 | 40 | 36 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 48 | 52 | 74 | 26 | 96 | 4 | | |

Traffic Counter ID: 13840
Traffic Volumes and Speeds on **Baggs Dixon (Road #702)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 8/10/2007 | 55 | 62 | 52 | 3 | 59 | 3 | 33 | 28 |
| Sat 8/11/2007 | 65 | 66 | 64 | 1 | 63 | 3 | 31 | 29 |
| Sun 8/12/2007 | 63 | 38 | 62 | 1 | 38 | 0 | 32 | 28 |
| Mon 8/13/2007 | 43 | 45 | 42 | 1 | 45 | 0 | 33 | 30 |
| Tue 8/14/2007 | 37 | 39 | 37 | 0 | 39 | 0 | 32 | 29 |
| Wed 8/15/2007 | 51 | 48 | 51 | 0 | 45 | 3 | 29 | 26 |
| Thu 8/16/2007 | 44 | 48 | 42 | 2 | 46 | 2 | 31 | 28 |
| Fri 8/17/2007 | 57 | 61 | 57 | 0 | 60 | 1 | 33 | 28 |
| Sat 8/18/2007 | 57 | 61 | 55 | 2 | 59 | 2 | 30 | 27 |
| Sun 8/19/2007 | 70 | 53 | 68 | 2 | 53 | 0 | 30 | 27 |
| Mon 8/20/2007 | 42 | 42 | 41 | 1 | 42 | 0 | 31 | 29 |
| Tue 8/21/2007 | 48 | 43 | 47 | 1 | 43 | 0 | 32 | 29 |
| Wed 8/22/2007 | 44 | 41 | 42 | 2 | 41 | 0 | 33 | 29 |
| Thu 8/23/2007 | 31 | 35 | 30 | 1 | 34 | 1 | 30 | 26 |
| Fri 8/24/2007 | 39 | 37 | 36 | 3 | 35 | 2 | 31 | 25 |
| Sat 8/25/2007 | 60 | 57 | 59 | 1 | 54 | 3 | 31 | 30 |
| Average | 50 | 49 | 49 | 1 | 47 | 2 | 31 | 28 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 98 | 2 | 96 | 4 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Finley Hill (Road #353)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Car s | Truc ks | Cars &Trucks | Cars &Trucks |
| Thu 8/30/2007 | 42 | 46 | 39 | 3 | 42 | 4 | 33 | 42 |
| Fri 8/31/2007 | 56 | 61 | 55 | 1 | 60 | 1 | 30 | 39 |
| Sat 9/1/2007 | 48 | 36 | 48 | 0 | 33 | 3 | 32 | 37 |
| Sun 9/2/2007 | 89 | 66 | * | * | * | * | 31 | 36 |
| Mon 9/3/2007 | 68 | 70 | * | * | * | * | * | * |
| Tue 9/4/2007 | 93 | 57 | * | * | * | * | * | * |
| Wed 9/5/2007 | 96 | 63 | * | * | * | * | * | * |
| Thu 9/6/2007 | 90 | 88 | * | * | * | * | * | * |
| Fri 9/7/2007 | 93 | 87 | * | * | * | * | * | * |
| Sat 9/8/2007 | 83 | 85 | * | * | * | * | * | * |
| Sun 9/9/2007 | 189 | 170 | * | * | * | * | * | * |
| Mon 9/10/2007 | 63 | 75 | * | * | * | * | * | * |
| Tue 9/11/2007 | 91 | 79 | * | * | * | * | * | * |
| **Average** | 85 | 76 | 41 | 1 | 45 | 3 | 32 | 39 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 53 | 47 | 94 | 6 | 94 | 6 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on **Brush Creek (Road #203)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 8/10/2007 | 151 | 131 | 127 | 24 | 130 | 2 | 50 | 46 |
| Sat 8/11/2007 | 131 | 114 | 116 | 15 | 113 | 2 | 48 | 44 |
| Sun 8/12/2007 | 88 | 82 | 81 | 7 | 80 | 2 | 49 | 44 |
| Mon 8/13/2007 | 124 | 125 | 115 | 9 | 124 | 2 | 50 | 48 |
| Tue 8/14/2007 | 140 | 149 | 137 | 3 | 146 | 5 | 50 | 45 |
| Average | 127 | 120 | 115 | 12 | 119 | 3 | 49 | 45 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 91 | 9 | 98 | 2 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on **Buck Creek (Road #550)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 8/30/2007 | 32 | 30 | 26 | 6 | 26 | 4 | 44 | 44 |
| Fri 8/31/2007 | 49 | 43 | 47 | 2 | 41 | 2 | 44 | 42 |
| Sat 9/1/2007 | 39 | 38 | 31 | 8 | 30 | 8 | 59 | 56 |
| Sun 9/2/2007 | 74 | 79 | * | * | * | * | * | * |
| Mon 9/3/2007 | 54 | 61 | * | * | * | * | * | * |
| Tue 9/4/2007 | 59 | 55 | * | * | * | * | * | * |
| Wed 9/5/2007 | 45 | 51 | * | * | * | * | * | * |
| Thu 9/6/2007 | 50 | 39 | * | * | * | * | * | * |
| Fri 9/7/2007 | 67 | 66 | * | * | * | * | * | * |
| Sat 9/8/2007 | 57 | 49 | * | * | * | * | * | * |
| Sun 9/9/2007 | 83 | 82 | * | * | * | * | * | * |
| Mon 9/10/2007 | 58 | 51 | * | * | * | * | * | * |
| Tue 9/11/2007 | 82 | 66 | * | * | * | * | * | * |
| **Average** | 57 | 55 | 35 | 5 | 32 | 5 | 49 | 47 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 50 | 50 | 88 | 12 | 86 | 14 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Holm Frencr (Road #660)**
Road Surface Type: Gravel

| Dad 701 North | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 9/13/2007 | 360 | 313 | 309 | 51 | 281 | 32 | 46 | 49 |
| Fri 9/14/2007 | 284 | 292 | 239 | 45 | 261 | 31 | 50 | 53 |
| Sat 9/15/2007 | 162 | 178 | 139 | 23 | 160 | 18 | 52 | 54 |
| Sun 9/16/2007 | 141 | 161 | 117 | 24 | 134 | 27 | 54 | 51 |
| Mon 9/17/2007 | 371 | 381 | * | * | * | * | * | * |
| Tue 9/18/2007 | 366 | 784 | * | * | * | * | * | * |
| Wed 9/19/2007 | 520 | 616 | * | * | * | * | * | * |
| Thu 9/20/2007 | 572 | 627 | * | * | * | * | * | * |
| Fri 9/21/2007 | 390 | 710 | * | * | * | * | * | * |
| Sat 9/22/2007 | 118 | 463 | * | * | * | * | * | * |
| Sun 9/23/2007 | 147 | 200 | * | * | * | * | * | * |
| Mon 9/24/2007 | 233 | 346 | * | * | * | * | * | * |
| Tue 9/25/2007 | 234 | 422 | * | * | * | * | * | * |
| Wed 9/26/2007 | 234 | 482 | * | * | * | * | * | * |
| **Average** | 295 | 427 | 201 | 35.75 | 209 | 27 | 51 | 52 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 41 | 59 | 85 | 15 | 89 | 11 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Dad (Road #701)** Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 9/13/2007 | 101 | 87 | 86 | 15 | 80 | 7 | 46 | 44 |
| Fri 9/14/2007 | 85 | 128 | 79 | 6 | 105 | 23 | 45 | 44 |
| Sat 9/15/2007 | 154 | 195 | * | * | * | * | 47 | 44 |
| Sun 9/16/2007 | 164 | 134 | * | * | * | * | * | * |
| Mon 9/17/2007 | 134 | 116 | * | * | * | * | * | * |
| Tue 9/18/2007 | 137 | 134 | * | * | * | * | * | * |
| Wed 9/19/2007 | 129 | 147 | * | * | * | * | * | * |
| Thu 9/20/2007 | 174 | 123 | * | * | * | * | * | * |
| Fri 9/21/2007 | 136 | 164 | * | * | * | * | * | * |
| Sat 9/22/2007 | 191 | 194 | * | * | * | * | * | * |
| Sun 9/23/2007 | 187 | 123 | * | * | * | * | * | * |
| Mo 9/24/2007 | 214 | 178 | * | * | * | * | * | * |
| Tue 9/25/2007 | 144 | 145 | * | * | * | * | * | * |
| Average | 150 | 143 | 82.5 | 10.5 | 92.5 | 15 | 45 | 44 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 51 | 49 | 88.7 | 11.3 | 86 | 14 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on **Jack Creek (Road #500)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 9/28/2007 | 77 | 78 | 68 | 9 | 74 | 4 | 33 | 37 |
| Sat 9/29/2007 | 114 | 89 | 108 | 6 | 87 | 2 | 29 | 37 |
| Sun 9/30//2007 | 112 | 106 | 106 | 6 | 103 | 3 | 32 | 34 |
| Average | 101 | 91 | 94 | 7 | 89 | 3 | 31 | 36 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 53 | 47 | 93 | 7 | 97 | 3 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on **Savory (Road #561)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 9/28/2007 | 115 | 112 | 101 | 14 | 99 | 13 | 48 | 48 |
| Sat 9/29/2007 | 101 | 112 | 91 | 10 | 98 | 14 | 49 | 47 |
| Sun 9/30//2007 | 25 | 26 | 24 | 1 | 25 | 1 | 53 | 50 |
| Average | 81 | 83 | 72 | 8 | 74 | 9 | 50 | 48 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 5 | 90 | 10 | 91 | 9 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Poisonb (Raod #700)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/6/2007 | 84 | 78 | 80 | 4 | 74 | 4 | 43 | 41 |
| Wed 11/7/2007 | 100 | 94 | 96 | 4 | 90 | 4 | 44 | 40 |
| Thu 11/8/2007 | 86 | 79 | 81 | 5 | 75 | 4 | 45 | 40 |
| Fri 11/9/2007 | 125 | 99 | 124 | 1 | 96 | 3 | 44 | 42 |
| Sat 11/10/2007 | 100 | 89 | 94 | 6 | 87 | 2 | 41 | 40 |
| Sun 11/11/2007 | 86 | 61 | 84 | 2 | 59 | 2 | 42 | 40 |
| Mon 11/12/2007 | 79 | 54 | 76 | 3 | 52 | 2 | 44 | 43 |
| Average | 94 | 79 | 91 | 4 | 76 | 3 | 43 | 41 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 53 | 47 | 96 | 4 | 96 | 4 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on **Crystal Lake (Road #210-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/6/2007 | 195 | 207 | 189 | 6 | 194 | 13 | 48 | 46 |
| Wed 11/7/2007 | 195 | 186 | 192 | 3 | 171 | 15 | 47 | 45 |
| Thu 11/8/2007 | 199 | 199 | 197 | 2 | 189 | 10 | 46 | 44 |
| Fri 11/9/2007 | 205 | 204 | 204 | 1 | 193 | 11 | 47 | 44 |
| Sat 11/10/2007 | 147 | 156 | 145 | 2 | 152 | 4 | 46 | 44 |
| Sun 11/11/2007 | 118 | 123 | 118 | 0 | 118 | 5 | 46 | 45 |
| Mon 11/12/2007 | 183 | 174 | 181 | 2 | 164 | 10 | 46 | 46 |
| Average | 178 | 179 | 175 | 3 | 169 | 10 | 47 | 45 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 98 | 2 | 94 | 6 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on **Gilchrist (Road #109-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 11/14/2007 | 394 | 372 | 384 | 10 | 366 | 6 | 49 | 55 |
| Thu 11/15/2007 | 399 | 378 | 390 | 9 | 372 | 6 | 49 | 54 |
| Fri 11/16/2007 | 396 | 372 | 388 | 8 | 367 | 5 | 48 | 53 |
| Sat 11/17/2007 | 336 | 352 | 325 | 11 | 346 | 6 | 48 | 53 |
| Sun 11/18/2007 | 338 | 315 | 331 | 7 | 306 | 9 | 48 | 53 |
| Mon 11/19/2007 | 424 | 405 | 421 | 3 | 401 | 4 | 49 | 54 |
| Average | 381 | 366 | 373 | 8 | 360 | 6 | 48.5 | 53.7 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 97.9 | 2.1 | 98.3 | 1.7 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on: **Old Yellowstone (Road #124-2)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 11/14/2007 | 184 | 196 | 174 | 10 | 192 | 4 | 56 | 56 |
| Thu 11/15/2007 | 197 | 218 | 186 | 11 | 212 | 6 | 57 | 57 |
| Fri 11/16/2007 | 214 | 210 | 201 | 13 | 205 | 5 | 57 | 56 |
| Sat 11/17/2007 | 193 | 204 | 189 | 4 | 200 | 4 | 56 | 57 |
| Sun 11/18/2007 | 156 | 151 | 145 | 11 | 148 | 3 | 59 | 54 |
| Mon 11/19/2007 | 222 | 219 | 213 | 9 | 214 | 5 | 58 | 55 |
| Average | 195 | 200 | 185 | 10 | 195 | 5 | 57 | 56 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 49 | 51 | 95 | 5 | 97.5 | 2.5 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on: **Railroad (Road #215-3)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/27/2007 | 531 | 492 | 491 | 40 | 471 | 21 | 55 | 53 |
| Wed 11/28/2007 | 505 | 498 | 480 | 25 | 482 | 16 | 54 | 51 |
| Thu 11/29/2007 | 500 | 493 | 480 | 20 | 480 | 13 | 54 | 51 |
| Fri 11/30/2007 | 518 | 472 | 494 | 24 | 463 | 9 | 54 | 52 |
| Sat 12/1/2007 | 322 | 317 | 311 | 11 | 309 | 8 | 53 | 47 |
| Sun 12/2/2007 | 294 | 307 | 290 | 4 | 307 | 0 | 49 | 52 |
| Mon 12/3/2007 | 526 | 507 | 500 | 26 | 496 | 11 | 55 | 50 |
| Average | 457 | 441 | 435 | 21 | 430 | 11 | 53.4 | 50.9 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50.9 | 49.1 | 95.4 | 4.6 | 97.5 | 2.5 | | |

Traffic Counter ID: 13841
Traffic Volumes and Speeds on: **Campstool (Road #209-2)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/27/2007 | 136 | 129 | 134 | 2 | 122 | 7 | 44 | 49 |
| Wed 11/28/2007 | 150 | 126 | 140 | 10 | 120 | 6 | 40 | 48 |
| Thu 11/29/2007 | 116 | 114 | 113 | 3 | 105 | 9 | 46 | 49 |
| Fri 11/30/2007 | 135 | 121 | 134 | 1 | 119 | 2 | 46 | 52 |
| Sat 12/1/2007 | 100 | 90 | 100 | 0 | 90 | 0 | 43 | 51 |
| Sun 12/2/2007 | 98 | 84 | 97 | 1 | 82 | 2 | 44 | 48 |
| Mon 12/3/2007 | 134 | 138 | 131 | 3 | 128 | 10 | 40 | 47 |
| Average | 124 | 114 | 121 | 3 | 109 | 5 | 43.2 | 49.1 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 52 | 48 | 97.6 | 2.4 | 95.6 | 4.4 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on: **Durham (Road #136-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 4/24/2008 | 161 | 149 | 156 | 5 | 140 | 9 | 47 | 59 |
| Fri 4/25/2008 | 167 | 163 | 160 | 7 | 153 | 10 | 49 | 56 |
| Sat 4/26/2008 | 94 | 77 | 89 | 5 | 69 | 8 | 48 | 49 |
| Sun 4/27/2008 | 120 | 128 | 113 | 7 | 115 | 13 | 49 | 56 |
| Mon 4/28/2008 | 176 | 167 | 163 | 13 | 152 | 15 | 47 | 55 |
| Tue 4/29/2008 | 169 | 173 | 159 | 10 | 158 | 15 | 47 | 54 |
| Wed 4/30/2008 | 216 | 190 | 205 | 11 | 175 | 15 | 48 | 58 |
| Average | 158 | 150 | 149 | 8 | 137 | 12 | 48 | 55 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 95 | 5 | 92 | 8 | | |

Traffic Counter ID: 020098
Traffic Volumes and Speeds on: **Hills Dale (Road #143-2)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 4/24/2008 | 26 | 21 | 21 | 5 | 18 | 3 | 54 | 60 |
| Fri 4/25/2008 | 28 | 20 | 28 | 0 | 20 | 0 | 60 | 48 |
| Sat 4/26/2008 | 15 | 14 | 12 | 3 | 13 | 1 | 61 | 60 |
| Sun 4/27/2008 | 10 | 16 | 10 | 0 | 16 | 0 | 54 | 50 |
| Mon 4/28/2008 | 30 | 23 | 28 | 2 | 19 | 4 | 55 | 51 |
| Tue 4/29/2008 | 34 | 29 | 31 | 3 | 27 | 2 | 60 | 54 |
| Wed 4/30/2008 | 35 | 26 | 33 | 2 | 22 | 4 | 55 | 54 |
| Average | 25 | 21 | 23 | 2 | 19 | 2 | 57 | 54 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 54 | 46 | 92 | 8 | 90 | 10 | | |

Traffic Counter ID: 20099
Traffic Volumes and Speeds on: **Old Highway Burns (Road #212-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 5/7/2008 | 79 | 76 | 72 | 7 | 75 | 1 | 51 | 52 |
| Thu 5/8/2008 | 69 | 73 | 67 | 2 | 69 | 4 | 54 | 53 |
| Fri 5/9/2008 | 83 | 74 | 75 | 8 | 71 | 3 | 53 | 50 |
| Sat 5/10/2008 | 65 | 70 | 64 | 1 | 69 | 1 | 50 | 53 |
| Sun 5/11/2008 | 55 | 60 | 52 | 3 | 56 | 4 | 48 | 54 |
| Mon 5/12/2008 | 63 | 64 | 59 | 4 | 62 | 2 | 51 | 49 |
| Tue 5/13/2008 | 63 | 71 | 54 | 9 | 70 | 1 | 56 | 53 |
| Average | 68 | 70 | 63 | 5 | 67 | 2 | 52 | 52 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 49 | 50 | 93 | 7 | 97 | 3 | | |

Traffic Counter ID: 20140
Traffic Volumes and Speeds on: **Harriman (Road #102-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 5/7/2008 | 76 | 98 | 68 | 8 | 80 | 18 | 70 | 67 |
| Thu 5/8/2008 | 85 | 83 | 80 | 5 | 74 | 9 | 71 | 64 |
| Fri 5/9/2008 | 89 | 90 | 87 | 2 | 75 | 15 | 72 | 67 |
| Sat 5/10/2008 | 66 | 68 | 62 | 4 | 61 | 7 | 72 | 66 |
| Sun 5/11/2008 | 68 | 62 | 62 | 6 | 61 | 1 | 72 | 67 |
| Mon 5/12/2008 | 74 | 79 | 69 | 5 | 62 | 17 | 72 | 64 |
| Tue 5/13/2008 | 64 | 89 | 59 | 5 | 71 | 18 | 70 | 66 |
| Average | 75 | 81 | 70 | 5 | 69 | 12 | 71 | 66 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 48 | 52 | 93 | 7 | 85 | 15 | | |

Traffic Counter ID: 20393
Traffic Volumes and Speeds on: **Chalk Bluff (Road #203-1)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 5/7/2008 | 210 | 218 | 118 | 92 | 118 | 100 | 67 | 69 |
| Thu 5/8/2008 | 211 | 229 | 103 | 108 | 114 | 115 | 65 | 68 |
| Fri 5/9/2008 | 201 | 198 | 116 | 85 | 127 | 71 | 65 | 70 |
| Sat 5/10/2008 | 133 | 105 | 102 | 31 | 101 | 4 | 68 | * |
| Sun 5/11/2008 | 159 | 126 | 131 | 28 | 124 | 2 | 72 | * |
| Mon 5/12/2008 | 220 | 205 | 147 | 73 | 191 | 14 | 69 | * |
| Tue 5/13/2008 | 216 | 181 | 140 | 76 | 163 | 18 | 67 | * |
| Average | 193 | 180 | 122 | 70 | 134 | 46 | 68 | 69 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 52 | 48 | 64 | 36 | 74 | 26 | | |

Traffic Counter ID: 20099
Traffic Volumes and Speeds on: **A-149-1**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 5/16/2008 | 125 | 131 | 123 | 2 | 128 | 3 | 41 | 44 |
| Sat 5/17/2008 | 145 | 133 | 144 | 1 | 129 | 4 | 43 | 45 |
| Sun 5/18/2008 | 111 | 116 | 109 | 2 | 114 | 2 | 42 | 45 |
| Mon 5/19/2008 | 148 | 139 | 144 | 4 | 138 | 1 | 42 | 44 |
| Tue 5/20/2008 | 164 | 166 | 151 | 13 | 153 | 13 | 39 | 43 |
| Wed 5/21/2008 | 143 | 145 | 142 | 1 | 144 | 1 | 44 | 43 |
| Thu 5/22/2008 | 112 | 95 | 112 | 0 | 95 | 0 | 42 | 43 |
| Fri 5/23/2008 | 136 | 132 | 135 | 1 | 130 | 2 | 43 | 45 |
| Sat 5/24/2008 | 101 | 108 | 99 | 2 | 107 | 1 | 40 | 44 |
| Sun 5/25/2008 | 111 | 119 | 110 | 1 | 119 | 0 | 43 | 43 |
| Mon 5/26/2008 | 104 | 103 | 99 | 5 | 101 | 2 | 41 | 43 |
| Tue 5/27/2008 | 135 | 128 | 132 | 3 | 125 | 3 | 43 | 43 |
| Wed 5/28/2008 | 139 | 132 | 136 | 3 | 131 | 1 | 42 | 43 |
| Average | 129 | 127 | 126 | 3 | 124 | 3 | 41.9 | 43.7 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50.4 | 49.6 | 98 | 2 | 98 | 2 | | |

Traffic Counter ID: 20099
Traffic Volumes and Speeds on: **Telephone (Road #120-1)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Truc ks | Cars | Truck s | Cars &Trucks | Cars &Trucks |
| Fri 5/16/2008 | 100 | 89 | 89 | 11 | 81 | 8 | 70 | 65 |
| Sat 5/17/2008 | 93 | 79 | 87 | 6 | 72 | 7 | 72 | 66 |
| Sun 5/18/2008 | 62 | 98 | 59 | 3 | 91 | 7 | * | 69 |
| Mon 5/19/2008 | 77 | 87 | 65 | 12 | 79 | 8 | * | 74 |
| Tue 5/20/2008 | 90 | 87 | 84 | 6 | 79 | 8 | * | 75 |
| Wed 5/21/2008 | 89 | 86 | 82 | 7 | 76 | 10 | * | 72 |
| Thu 5/22/2008 | 77 | 75 | 74 | 3 | 68 | 7 | 75 | 62 |
| Fri 5/23/2008 | 74 | 67 | 71 | 3 | 64 | 3 | * | 55 |
| Sat 5/24/2008 | 83 | 80 | 79 | 4 | 76 | 4 | * | 58 |
| Sun 5/25/2008 | 73 | 66 | 71 | 2 | 65 | 1 | * | 55 |
| Mon 5/26/2008 | 48 | 68 | 43 | 5 | 67 | 1 | * | 55 |
| Tue 5/27/2008 | 83 | 71 | 76 | 7 | 65 | 6 | 75 | 54 |
| Wed 5/28/2008 | 94 | 87 | 81 | 13 | 78 | 9 | * | 58 |
| Average | 80 | 80 | 74 | 6 | 74 | 6 | 73 | 62.9 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | *traffic counts not available | |
| | 50 | 50 | 92.5 | 7.5 | 92.5 | 7.5 | | |

Traffic Counter ID: 20393
Traffic Volumes and Speeds on: Albin (Road #162-2)
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Fri 5/16/2008 | 117 | 122 | 110 | 7 | 114 | 8 | 59 | 60 |
| Sat 5/17/2008 | 79 | 83 | 79 | 0 | 81 | 2 | 61 | 62 |
| Sun 5/18/2008 | 99 | 86 | 98 | 1 | 85 | 1 | 63 | 63 |
| Mon 5/19/2008 | 115 | 102 | 113 | 2 | 100 | 2 | 61 | 60 |
| Tue 5/20/2008 | 101 | 112 | 93 | 8 | 102 | 10 | 63 | 59 |
| Wed 5/21/2008 | 94 | 86 | 90 | 4 | 80 | 6 | 64 | 60 |
| Average | 101 | 99 | 97 | 4 | 94 | 5 | 61.8 | 60.7 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50.5 | 49.5 | 96 | 4 | 95 | 5 | | |

Traffic Counter ID: 20394
Traffic Volumes and Speeds on: **Cemetery (Road #164-1)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 6/11/2008 | 30 | 27 | 29 | 1 | 27 | 0 | 37 | 36 |
| Thu 6/12/2008 | 30 | 37 | 28 | 2 | 31 | 6 | 36 | 38 |
| Fri 6/13/2008 | 45 | 93 | 42 | 3 | 85 | 8 | 44 | 40 |
| Sat 6/14/2008 | 97 | 108 | 92 | 5 | 100 | 8 | 43 | 39 |
| Sun 6/15/2008 | 136 | 82 | 128 | 8 | 79 | 3 | 42 | 40 |
| Mon 6/16/2008 | 53 | 49 | 52 | 1 | 46 | 3 | 40 | 39 |
| Tue 6/17/2008 | 44 | 46 | 42 | 2 | 41 | 5 | 39 | 39 |
| Average | 62 | 63 | 59 | 3 | 58 | 5 | 40.1 | 38.7 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 95 | 5 | 92 | 8 | | |

Traffic Counter ID: 20394
Traffic Volumes and Speeds on: **Hazelton (Road #3)**
Road Surface Type: Asphalt

| | **Traffic Volume** | | **Vehicle Classification** | | | | **85th percentile Speed, MPH** | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Truc ks | Cars | Truck s | Cars &Trucks | Cars &Trucks |
| Wed 6/11/2008 | 87 | 84 | 83 | 4 | 79 | 5 | 43 | 49 |
| Thu 6/12/2008 | 92 | 89 | 88 | 4 | 85 | 4 | 43 | 48 |
| Fri 6/13/2008 | 90 | 94 | 83 | 7 | 89 | 5 | 42 | 44 |
| Sat 6/14/2008 | 84 | 81 | 82 | 2 | 79 | 2 | 41 | 44 |
| Sun 6/15/2008 | 85 | 95 | 83 | 2 | 92 | 3 | 41 | 45 |
| Mon 6/16/2008 | 85 | 91 | 74 | 11 | 81 | 10 | 43 | 48 |
| Tue 6/17/2008 | 78 | 82 | 71 | 7 | 76 | 6 | 43 | 48 |
| Average | 86 | 88 | 81 | 5 | 83 | 5 | 42.4 | 46.6 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 49 | 51 | 94 | 6 | 94 | 6 | | |

Traffic Counter ID: 20393
Traffic Volumes and Speeds on: **Crazy Women Can (Road #14)**
Road Surface Type: Asphalt

| | **Traffic Volume** | | **Vehicle Classification** | | | | **85th percentile Speed, MPH** | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Truc ks | Cars | Truck s | Cars &Trucks | Cars &Trucks |
| Wed 6/11/2008 | 123 | 121 | 119 | 4 | 118 | 3 | 53 | 55 |
| Thu 6/12/2008 | 125 | 126 | 117 | 8 | 115 | 11 | 53 | 53 |
| Fri 6/13/2008 | 136 | 139 | 134 | 2 | 135 | 4 | 51 | 54 |
| Sat 6/14/2008 | 118 | 109 | 115 | 3 | 108 | 1 | 51 | 55 |
| Sun 6/15/2008 | 125 | 115 | 123 | 2 | 109 | 6 | 50 | 54 |
| Mon 6/16/2008 | 132 | 138 | 130 | 2 | 136 | 2 | 51 | 54 |
| Tue 6/17/2008 | 137 | 127 | 134 | 3 | 118 | 9 | 53 | 54 |
| Average | 128 | 125 | 125 | 3 | 120 | 5 | 51.7 | 54.1 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50.6 | 49.4 | 97.7 | 2.3 | 96 | 4 | | |

Traffic Counter ID: 20140
Traffic Volumes and Speeds on: **Fulerton (Road #132)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Wed 6/11/2008 | 231 | 274 | 228 | 3 | 270 | 4 | 43 | 44 |
| Thu 6/12/2008 | 208 | 270 | 206 | 2 | 266 | 4 | 41 | 42 |
| Fri 6/13/2008 | 268 | 296 | 262 | 6 | 290 | 6 | 42 | 43 |
| Sat 6/14/2008 | 219 | 239 | 213 | 6 | 232 | 7 | 43 | 43 |
| Sun 6/15/2008 | 214 | 223 | 208 | 6 | 219 | 4 | 43 | 43 |
| Mon 6/16/2008 | 275 | 305 | 266 | 9 | 295 | 10 | 42 | 43 |
| Tue 6/17/2008 | 260 | 289 | 256 | 4 | 284 | 5 | 43 | 43 |
| Average | 239 | 271 | 234 | 5 | 265 | 6 | 42.4 | 43 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 46.9 | 53.1 | 98 | 2 | 98 | 2 | | |

Traffic Counter ID: 13839
Traffic Volumes and Speeds on: **Up Clear Creek (Road #256)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 6/19/2008 | 301 | 300 | 294 | 7 | 295 | 5 | 35 | 38 |
| Fri 6/20/2008 | 315 | 319 | 309 | 6 | 313 | 6 | 35 | 38 |
| Sat 6/21/2008 | 245 | 247 | 244 | 1 | 246 | 1 | 35 | 38 |
| Sun 6/22/2008 | 226 | 227 | 222 | 4 | 223 | 4 | 35 | 38 |
| Mon 6/23/2008 | 322 | 325 | 314 | 8 | 318 | 7 | 35 | 38 |
| Tue 6/24/2008 | 315 | 316 | 308 | 7 | 313 | 3 | 35 | 37 |
| Wed 6/25/2008 | 308 | 304 | 301 | 7 | 298 | 6 | 35 | 38 |
| Average | 291 | 292 | 285 | 6 | 287 | 5 | 35 | 38 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 98 | 2 | 98 | 2 | | |

Traffic Counter ID: 20099
Traffic Volumes and Speeds on: **Airport (Road #212)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 6/19/2008 | 848 | 760 | 809 | 39 | 749 | 11 | 53 | 49 |
| Fri 6/20/2008 | 833 | 814 | 813 | 20 | 797 | 17 | 54 | 49 |
| Sat 6/21/2008 | 849 | 805 | 833 | 16 | 790 | 15 | 53 | 49 |
| Sun 6/22/2008 | 547 | 564 | 535 | 12 | 554 | 10 | 54 | 49 |
| Mon 6/23/2008 | 738 | 717 | 697 | 41 | 690 | 27 | 53 | 49 |
| Tue 6/24/2008 | 722 | 713 | 701 | 21 | 702 | 11 | 54 | 49 |
| Wed 6/25/2008 | 686 | 678 | 675 | 11 | 668 | 10 | 53 | 49 |
| Average | 746 | 722 | 723 | 23 | 707 | 14 | 53.5 | 49 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 97 | 3 | 98 | 2 | | |

Traffic Counter ID: 20393
Traffic Volumes and Speeds on: **French Creek (Road #91H)**
Road Surface Type: Asphalt

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 6/19/2008 | 280 | 278 | 246 | 34 | 233 | 45 | 31 | 30 |
| Fri 6/20/2008 | 248 | 213 | 213 | 35 | 175 | 38 | 31 | 30 |
| Sat 6/21/2008 | 74 | 75 | 70 | 4 | 71 | 4 | 35 | 31 |
| Sun 6/22/2008 | 67 | 65 | 65 | 2 | 60 | 5 | 35 | 29 |
| Mon 6/23/2008 | 210 | 212 | 170 | 40 | 168 | 44 | 32 | 29 |
| Tue 6/24/2008 | 185 | 186 | 157 | 28 | 157 | 29 | 32 | 30 |
| Average | 178 | 172 | 154 | 24 | 144 | 28 | 32.7 | 29.8 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 51 | 49 | 87 | 13 | 84 | 16 | | |

Traffic Counter ID: 13842
Traffic Volumes and Speeds on: **Shell Creek (Road #85)**
Road Surface Type: Gravel

| | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Truc ks | Cars | Truck s | Cars &Trucks | Cars &Trucks |
| Thu 6/19/2008 | 116 | 156 | 101 | 15 | 132 | 24 | 32 | 33 |
| Fri 6/20/2008 | 102 | 136 | 97 | 5 | 129 | 7 | 32 | 34 |
| Sat 6/21/2008 | 82 | 111 | 75 | 7 | 109 | 2 | 33 | 34 |
| Sun 6/22/2008 | 78 | 91 | 73 | 5 | 87 | 4 | 31 | 33 |
| Mon 6/23/2008 | 120 | 152 | 108 | 12 | 148 | 4 | 32 | 33 |
| Tue 6/24/2008 | 106 | 130 | 97 | 9 | 122 | 8 | 33 | 34 |
| Wed 6/25/2008 | 92 | 123 | 84 | 8 | 118 | 5 | 34 | 35 |
| Average | 100 | 129 | 91 | 9 | 121 | 8 | 32 | 34 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 44 | 56 | 91 | 9 | 94 | 6 | | |

Traffic Counter ID: 20394
Traffic Volumes and Speeds on: **Kumor (Road #40)**
Road Surface Type: Gravel

# APPENDIX C-2. STATISTICAL (SAS) CODE

```
data all;

set work.all;
vs =(volume*speed)/1000000;
logn= log(length);



run;
proc genmod data=all;

      model total  = vs / dist =poisson link = log offset= logn;

      run;

      proc genmod data=all;

      model total  = vs surface / dist =poisson link = log offset=
logn;

      run;

      proc genmod data=all;

      model total  =volume / dist =poisson link = log offset= logn;


      run;

      proc genmod data=all;

      model total  =volume surface/ dist =poisson link = log offset=
logn;

      run;

      proc genmod data=all;

      model total  =speed / dist =poisson link = log offset= logn;


      run;

      proc genmod data=all;

      model total  =speed surface / dist =poisson link = log offset=
logn;

      run;

      proc genmod data=all;

      model total  =volume speed / dist =poisson link = log offset=
logn;

      run;
/*nb*/
      proc genmod data=all;
```

```
model total  = vs / dist =nb link = log offset= logn;
run;
proc genmod data=all;
model total  = vs surface / dist =nb link = log offset= logn;

run;
proc genmod data=all;
model total  =volume / dist =nb link = log offset= logn;
run;
proc genmod data=all;
model total  =volume surface/ dist =nb link = log offset= logn;

run;
proc genmod data=all;
model total  =speed / dist =nb link = log offset= logn;
run;
proc genmod data=all;
model total  =speed surface / dist =nb link = log offset= logn;

run;
proc genmod data=all;
model total  =volume speed / dist =nb link = log offset= logn;

run;
```

# APPENDIX C-3. STATISTICAL (SAS) OUTPUTS

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Poisson | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 157.0424 | 4.6189 |
| Scaled Deviance | 34 | 157.0424 | 4.6189 |
| Pearson Chi-Square | 34 | 193.6462 | 5.6955 |
| Scaled Pearson X2 | 34 | 193.6462 | 5.6955 |
| Log Likelihood | | 939.9995 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.1753 | 0.0594 | -0.2916 | -0.0589 | 8.71 | 0.0032 |
| vs | 1 | 15.8596 | 2.4226 | 11.1114 | 20.6078 | 42.86 | <.0001 |
| Scale | 0 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | | |

NOTE: The scale parameter was held fixed.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Poisson | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 158.5255 | 4.6625 |
| Scaled Deviance | 34 | 158.5255 | 4.6625 |
| Pearson Chi-Square | 34 | 193.3165 | 5.6858 |
| Scaled Pearson X2 | 34 | 193.3165 | 5.6858 |
| Log Likelihood | | 939.2580 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.1713 | 0.0593 | -0.2876 | -0.0550 | 8.34 | 0.0039 |
| Volume | 1 | 0.0008 | 0.0001 | 0.0006 | 0.0011 | 41.27 | <.0001 |
| Scale | 0 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | | |

NOTE: The scale parameter was held fixed.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Poisson | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 158.5251 | 4.8038 |
| Scaled Deviance | 33 | 158.5251 | 4.8038 |
| Pearson Chi-Square | 33 | 193.3066 | 5.8578 |
| Scaled Pearson X2 | 33 | 193.3066 | 5.8578 |
| Log Likelihood | | 939.2582 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.1719 | 0.0675 | -0.3042 | -0.0396 | 6.48 | 0.0109 |
| Volume | 1 | 0.0008 | 0.0001 | 0.0005 | 0.0011 | 35.10 | <.0001 |
| Surface | 1 | 0.0018 | 0.0948 | -0.1841 | 0.1876 | 0.00 | 0.9853 |
| Scale | 0 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | | |

NOTE: The scale parameter was held fixed.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Poisson | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 184.4524 | 5.4251 |
| Scaled Deviance | 34 | 184.4524 | 5.4251 |
| Pearson Chi-Square | 34 | 223.1784 | 6.5641 |
| Scaled Pearson X2 | 34 | 223.1784 | 6.5641 |
| Log Likelihood | | 926.2945 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.5445 | 0.2250 | -0.9855 | -0.1036 | 5.86 | 0.0155 |
| Speed | 1 | 0.0117 | 0.0043 | 0.0033 | 0.0200 | 7.53 | 0.0061 |
| Scale | 0 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | | |

NOTE: The scale parameter was held fixed.

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The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Poisson | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 184.3195 | 5.5854 |
| Scaled Deviance | 33 | 184.3195 | 5.5854 |
| Pearson Chi-Square | 33 | 222.0526 | 6.7289 |
| Scaled Pearson X2 | 33 | 222.0526 | 6.7289 |
| Log Likelihood | | 926.3610 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.5019 | 0.2526 | -0.9969 | -0.0069 | 3.95 | 0.0469 |
| Speed | 1 | 0.0105 | 0.0054 | -0.0001 | 0.0210 | 3.75 | 0.0528 |
| Surface | 1 | 0.0407 | 0.1113 | -0.1775 | 0.2588 | 0.13 | 0.7150 |
| Scale | 0 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | | |

NOTE: The scale parameter was held fixed.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 36.3327 | 1.0686 |
| Scaled Deviance | 34 | 36.3327 | 1.0686 |
| Pearson Chi-Square | 34 | 44.3323 | 1.3039 |
| Scaled Pearson X2 | 34 | 44.3323 | 1.3039 |
| Log Likelihood | | 975.8060 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.0340 | 0.1433 | -0.3148 | 0.2468 | 0.06 | 0.8123 |
| vs | 1 | 16.0738 | 7.2185 | 1.9258 | 30.2218 | 4.96 | 0.0260 |
| Dispersion | 1 | 0.2406 | 0.0741 | 0.0954 | 0.3859 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 36.3384 | 1.1012 |
| Scaled Deviance | 33 | 36.3384 | 1.1012 |
| Pearson Chi-Square | 33 | 44.3509 | 1.3440 |
| Scaled Pearson X2 | 33 | 44.3509 | 1.3440 |
| Log Likelihood | | 975.8061 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.0336 | 0.1495 | -0.3266 | 0.2594 | 0.05 | 0.8223 |
| vs | 1 | 16.1164 | 8.3201 | -0.1907 | 32.4235 | 3.75 | 0.0527 |
| Surface | 1 | -0.0024 | 0.2291 | -0.4514 | 0.4467 | 0.00 | 0.9918 |
| Dispersion | 1 | 0.2406 | 0.0743 | 0.0950 | 0.3861 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 36.1436 | 1.0630 |
| Scaled Deviance | 34 | 36.1436 | 1.0630 |
| Pearson Chi-Square | 34 | 43.6190 | 1.2829 |
| Scaled Pearson X2 | 34 | 43.6190 | 1.2829 |
| Log Likelihood | | 975.8185 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.0428 | 0.1462 | -0.3293 | 0.2436 | 0.09 | 0.7696 |
| Volume | 1 | 0.0008 | 0.0004 | 0.0001 | 0.0016 | 4.97 | 0.0258 |
| Dispersion | 1 | 0.2421 | 0.0742 | 0.0966 | 0.3876 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 36.0548 | 1.0926 |
| Scaled Deviance | 33 | 36.0548 | 1.0926 |
| Pearson Chi-Square | 33 | 43.3557 | 1.3138 |
| Scaled Pearson X2 | 33 | 43.3557 | 1.3138 |
| Log Likelihood | | 975.8382 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.0527 | 0.1542 | -0.3549 | 0.2495 | 0.12 | 0.7325 |
| Volume | 1 | 0.0008 | 0.0004 | -0.0000 | 0.0016 | 3.82 | 0.0507 |
| Surface | 1 | 0.0432 | 0.2180 | -0.3841 | 0.4705 | 0.04 | 0.8428 |
| Dispersion | 1 | 0.2426 | 0.0743 | 0.0969 | 0.3883 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 34 | 36.7003 | 1.0794 |
| Scaled Deviance | 34 | 36.7003 | 1.0794 |
| Pearson Chi-Square | 34 | 42.9102 | 1.2621 |
| Scaled Pearson X2 | 34 | 42.9102 | 1.2621 |
| Log Likelihood | | 973.7859 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.3858 | 0.5337 | -1.4318 | 0.6603 | 0.52 | 0.4698 |
| Speed | 1 | 0.0122 | 0.0107 | -0.0087 | 0.0331 | 1.32 | 0.2513 |
| Dispersion | 1 | 0.2760 | 0.0812 | 0.1167 | 0.4352 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 36.1258 | 1.0947 |
| Scaled Deviance | 33 | 36.1258 | 1.0947 |
| Pearson Chi-Square | 33 | 40.9594 | 1.2412 |
| Scaled Pearson X2 | 33 | 40.9594 | 1.2412 |
| Log Likelihood | | 973.9871 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.2115 | 0.6014 | -1.3903 | 0.9674 | 0.12 | 0.7252 |
| Speed | 1 | 0.0072 | 0.0133 | -0.0190 | 0.0333 | 0.29 | 0.5921 |
| Surface | 1 | 0.1656 | 0.2619 | -0.3477 | 0.6789 | 0.40 | 0.5271 |
| Dispersion | 1 | 0.2777 | 0.0814 | 0.1181 | 0.4372 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

The GENMOD Procedure

Model Information

| | | |
|---|---|---|
| Data Set | WORK.ALL | |
| Distribution | Negative Binomial | |
| Link Function | Log | |
| Dependent Variable | Total | Total |
| Offset Variable | logn | |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Criteria For Assessing Goodness Of Fit

| Criterion | DF | Value | Value/DF |
|---|---|---|---|
| Deviance | 33 | 36.0413 | 1.0922 |
| Scaled Deviance | 33 | 36.0413 | 1.0922 |
| Pearson Chi-Square | 33 | 44.1770 | 1.3387 |
| Scaled Pearson X2 | 33 | 44.1770 | 1.3387 |
| Log Likelihood | | 976.4679 | |

Algorithm converged.

Analysis Of Parameter Estimates

| Parameter | DF | Estimate | Standard Error | Wald 95% Confidence Limits | | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -0.5901 | 0.4969 | -1.5640 | 0.3838 | 1.41 | 0.2350 |
| Volume | 1 | 0.0008 | 0.0004 | 0.0001 | 0.0015 | 4.96 | 0.0260 |
| Speed | 1 | 0.0111 | 0.0098 | -0.0080 | 0.0302 | 1.30 | 0.2540 |
| Dispersion | 1 | 0.2313 | 0.0717 | 0.0908 | 0.3718 | | |

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

# APPENDIX D.  CARBON COUNTY

This section shows the WRRSP implementation on Hanna Leo, Kortes Road 291 in Carbon County.

## D.1 Crash Analysis

The potential high risk roads were identified as shown in Table 3.1 in Chapter 3. Eleven of the roads were included in the level I field evaluation.

## D.2 Combined Rankings

Road segments identified as high crash locations were listed and ranked based on the total number of crashes. Higher numbers of crashes resulted in lower rankings (as shown in the left part of Table D.1). Road segment scores obtained from level I field evaluations were also used to rank the sections. Lower field scores resulted in a lower rank. The right side of Table D.1 shows the level I field rankings for Carbon County.

**Table D.1 Crash Rankings and Level I Field Score Rankings**

| TOTAL CRASHES | ROAD NO. | MILE POST | CRASH RANKING | | LEVEL I FIELD SCORE | ROAD NO. | MILE POST | LEVEL I RANKING |
|---|---|---|---|---|---|---|---|---|
| 7 | 351 | 9.01-10.00 | 1 | | 35 | 291 | 8.01-9.00 | 1 |
| 6 | 351 | 7.01-8.00 | 2 | | 39 | 401 | 1.01-2.00 | 2 |
| 6 | 351 | 17.01-18.00 | 2 | | 41 | 291 | 0.00-1.00 | 3 |
| 6 | 351 | 19.01-20.00 | 2 | | 41 | 660 | 12.01-13.00 | 3 |
| 5 | 351 | 25.01-26.00 | 5 | | 42 | 504 | 6.01-7.00 | 3 |
| 4 | 401 | 2.01-3.00 | 6 | | 42 | 702 | 1.01-2.00 | 3 |
| 4 | 401 | 22.01-23.00 | 6 | | 43 | 504 | 4.01-5.00 | 7 |
| 4 | 660 | 4.01-5.00 | 6 | | 43 | 291 | 1.01-2.00 | 7 |
| 4 | 291 | 3.01-4.00 | 6 | | 43 | 401 | 3.01-4.00 | 7 |
| 4 | 702 | 0.00-1.00 | 6 | | 43 | 401 | 25.01-26.00 | 7 |
| 4 | 351 | 8.01-9.00 | 6 | | 43 | 561N | 7.01-8.00 | 7 |
| 4 | 351 | 28.01-29.00 | 6 | | 43 | 504 | 13.01-14 | 7 |
| 4 | 351 | 29.01-30.00 | 6 | | 43 | 702 | 4.01-5 | 7 |
| 3 | 504 | 4.01-5.00 | 14 | | 43 | 702 | 5.01-6 | 7 |
| 3 | 401 | 5.01-6.00 | 14 | | 44 | 401 | 2.01-3.00 | 15 |
| 3 | 504 | 2.01-3.00 | 14 | | 44 | 561N | 4.01-5.00 | 15 |
| 3 | 324 | 3.01-4.00 | 14 | | 44 | 504 | 11.01-12.00 | 15 |
| 3 | 351 | 0.00-1.00 | 14 | | 44 | 561N | 6.01-7.00 | 15 |
| 3 | 500 | 0.00-1.00 | 14 | | 45 | 401 | 22.01-23.00 | 19 |
| 3 | 385 | 1.01-2.00 | 14 | | 45 | 401 | 5.01-6.00 | 19 |
| 3 | 351 | 6.01-7.00 | 14 | | 46 | 203 | 2.01-3.00 | 21 |
| 3 | 351 | 15.01-16.00 | 14 | | 46 | 504 | 1.01-2.00 | 21 |
| 3 | 351 | 14.01-15.00 | 14 | | 46 | 385 | 2.01-3.00 | 21 |
| 3 | 351 | 5.01-6.00 | 14 | | 46 | 504 | 7.01-8.00 | 21 |
| 2 | 401 | 1.01-2.00 | 25 | | 46 | 603 | 3.01-4.00 | 21 |
| 2 | 291 | 0.00-1.00 | 25 | | 46 | 660 | 3.01-4.00 | 21 |
| 2 | 291 | 1.01-2.00 | 25 | | 47 | 504 | 2.01-3.00 | 27 |
| 2 | 401 | 3.01-4.00 | 25 | | 47 | 291 | 2.01-3.00 | 27 |
| 2 | 561N | 4.01-5.00 | 25 | | 47 | 401 | 23.01-24.00 | 27 |
| 2 | 203 | 2.01-3.00 | 25 | | 47 | 203 | 6.01-7.00 | 27 |
| 2 | 504 | 1.01-2.00 | 25 | | 47 | 291 | 38.01-39.00 | 27 |
| 2 | 291 | 2.01-3.00 | 25 | | 47 | 401 | 29.01-30.00 | 27 |
| 2 | 401 | 23.01-24.00 | 25 | | 47 | 702 | 3.01-4.00 | 27 |
| 2 | 291 | 7.01-8.00 | 25 | | 48 | 291 | 13.01-14.00 | 34 |
| 2 | 401 | 13.01-14.00 | 25 | | 48 | 291 | 42.01-43.00 | 34 |
| 2 | 603 | 0.00-1.00 | 25 | | 48 | 401 | 6.01-7.00 | 34 |
| 2 | 401 | 20.01-21.00 | 25 | | 48 | 291 | 27.01-28.00 | 34 |
| 2 | 401 | 24.01-25.00 | 25 | | 48 | 401 | 26.01-27.00 | 34 |

The crashes and Level I rankings for each segment of roadway were added together to obtain the combined rankings. The overall score and combined rankings for the 11 evaluated roadways are shown in Table D.2.

**Table D.2 Combined ranking for high risk roads in Carbon County**

| ROAD NO. | MILE POST | OVERALL SCORE | COMBINED RANKING |
|---|---|---|---|
| 401 | 2.01-3.00 | 21 | 1 |
| 504 | 4.01-5.00 | 21 | 1 |
| 401 | 22.01-23.00 | 25 | 3 |
| 401 | 1.01-2.00 | 27 | 4 |
| 291 | 0.00-1.00 | 28 | 5 |
| 291 | 1.01-2.00 | 32 | 6 |
| 401 | 3.01-4.00 | 32 | 6 |
| 401 | 5.01-6.00 | 33 | 8 |
| 561N | 4.01-5.00 | 40 | 9 |
| 504 | 2.01-3.00 | 41 | 10 |
| 660 | 4.01-5.00 | 45 | 11 |
| 203 | 2.01-3.00 | 46 | 12 |
| 504 | 1.01-2.00 | 46 | 12 |
| 291 | 2.01-3.00 | 52 | 14 |
| 401 | 23.01-24.00 | 52 | 14 |
| 291 | 3.01-4.00 | 63 | 16 |
| 291 | 7.01-8.00 | 64 | 17 |
| 401 | 13.01-14.00 | 64 | 17 |

## D.3 Level II Field Evaluation Hanna Leo, Kortes Road 291

After consulting with the Carbon County engineer, it was decided to improve county road 291 since 401 is already scheduled for improvement. The 10-year crash data between 1995 and 2005 for Carbon County Hanna Leo, Kortes Lake Road 291 is shown in Table D.3. Carbon County Road 291 has a paved surface for the first 3.6 miles and has a gravel surface on the rest of the 11 miles. It starts on the North town limits of Hanna, Wyoming. The end of the 11 miles ends in T.24N., R.81W. Road 291 is classified as a minor collector. As shown in Table D.4, the average daily traffic (ADT) is 35 vehicles per day. The ADT data was collected between 7/19/07 and 7/24/07. The road is used for industrial, recreational, and agricultural activities.

**Table D.3 10-Year Crash Data on Hanna Leo, Kortes Road 291**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 291 | 00041 | 00 | 2 | 1 | 1 |
| 291 | 00160 | 95 | 1 | 0 | 0 |
| 291 | 00200 | 00 | 1 | 0 | 0 |
| 291 | 00200 | 95 | 1 | 0 | 0 |
| 291 | 00240 | 98 | 1 | 0 | 0 |
| 291 | 00250 | 95 | 1 | 1 | 0 |
| 291 | 00320 | 97 | 4 | 3 | 0 |
| 291 | 00330 | 95 | 2 | 0 | 0 |
| 291 | 00374 | 04 | 2 | 1 | 0 |
| 291 | 00380 | 96 | 1 | 1 | 0 |
| 291 | 00430 | 97 | 6 | 4 | 0 |
| 291 | 00800 | 03 | 3 | 0 | 0 |
| 291 | 00800 | 97 | 3 | 2 | 0 |
| 291 | 01040 | 99 | 1 | 1 | 0 |
| 291 | 01338 | 99 | 2 | 0 | 1 |
| 291 | 01420 | 97 | 2 | 0 | 0 |
| 291 | 01870 | 99 | 3 | 0 | 0 |
| 291 | 02000 | 99 | 2 | 0 | 0 |
| 291 | 02370 | 03 | 2 | 0 | 0 |
| 291 | 03010 | 97 | 2 | 2 | 0 |
| 291 | 03260 | 04 | 1 | 0 | 1 |
| 291 | 03300 | 05 | 1 | 0 | 0 |
| 291 | 03400 | 03 | 4 | 0 | 0 |
| 291 | 03840 | 97 | 2 | 2 | 0 |
| 291 | 04100 | 00 | 1 | 0 | 0 |
| 291 | 04100 | 96 | 1 | 0 | 0 |
| 291 | 04120 | 98 | 1 | 0 | 0 |
| 291 | 04270 | 00 | 1 | 0 | 0 |
| 291 | 04380 | 01 | 1 | 1 | 0 |
| 291 | 04400 | 98 | 1 | 1 | 0 |
| 291 | 04700 | 01 | 2 | 0 | 0 |
| 291 | 04800 | 03 | 2 | 1 | 0 |
| 291 | 04800 | 96 | 1 | 0 | 0 |
| 291 | 04840 | 05 | 4 | 0 | 0 |
| 291 | 04900 | 96 | 4 | 4 | 0 |
| 291 | 04970 | 03 | 4 | 0 | 0 |
| 291 | 05000 | 96 | 2 | 1 | 0 |
| 291 | 05100 | 99 | 1 | 0 | 0 |
| 291 | 05200 | 03 | 1 | 0 | 0 |
| 291 | 05300 | 96 | 3 | 0 | 0 |
| 291 | 05400 | 95 | 3 | 0 | 0 |
| 291 | X | 01 | 1 | 0 | 0 |

X = mile post unavailable

**Table D.4 Traffic Data on Hanna Leo, Kortes Road 291**

| Hanna Draw Road #291 | Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Thu 7/19/2007 | 26 | 25 | 23 | 3 | 24 | 1 | 49 | 50 |
| Fri 7/20/2007 | 17 | 19 | 17 | 0 | 18 | 0 | 49 | 45 |
| Sat 7/21/2007 | 11 | 14 | 10 | 1 | 13 | 1 | 46 | 45 |
| Sun 7/22/2007 | 22 | 21 | 22 | 0 | 21 | 0 | 45 | 49 |
| Mon 7/23/2007 | 7 | 12 | 7 | 0 | 12 | 0 | 50 | 47 |
| Tue 7/24/2007 | 21 | 22 | 20 | 1 | 22 | 0 | 45 | 51 |
| **Average** | **17** | **18** | **16** | **1** | **18** | **0** | **47** | **48** |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 94 | 6 | 100 | 0 | | |

As shown in Table D.5, alignment and overturn crashes are the most common on County Road 291.

**Table D.5 Causative Factors for Crashes on Hanna Leo, Kortes Road 291**

| Causative Factors | # of Crashes | Causative Factors | # of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 8 | ***Curve And Level*** | ***3*** |
| Gravel | 3 | ***Curved Downgrade*** | ***3*** |
| Dirt | 3 | ***Curved Hillcrest*** | ***1*** |
| | | ***Curved Upgraded*** | ***2*** |
| **Lighting** | | Straight Hillcrest | 0 |
| Dark | 6 | Straight Level | 2 |
| Dawn or Dusk | 1 | Straight Downgrade | 2 |
| Daylight | 7 | Straight Upgrade | 1 |
| | | Other | 0 |
| **Road Conditions** | | | |
| Dry | 8 | **Traffic Control** | |
| Icy | 3 | None | 0 |
| Muddy | 0 | Other | 0 |
| Slush | 1 | Pavement Marking | 0 |
| Snowy | 2 | Stop Sign | 0 |
| Wet | 0 | Warning | 0 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **First Harmful Event** | |
| Clear | 12 | Antelope | 1 |
| Sleet/Hail | 1 | Berm/Ditch | 2 |
| Snowing | 1 | Cow | 1 |
| Strong Wind | 0 | Deer | 1 |
| Dust | 0 | Mv-Mv | 1 |
| Fog | 0 | ***Overturn*** | ***8*** |
| Rain | 0 | Snow Embankment | 0 |
| Unknown | 0 | Parked Vehicle | 0 |
| Ground Blizzard | 0 | Mail Box | 0 |
| | | Guard Rail | 0 |
| **Roadway Junction** | | Fence | 0 |
| Non-Junction | 0 | Post | 0 |
| Drive Way Access | 0 | Barricade | 0 |
| Intersection | 0 | Other | 0 |

The WYT[2]/LTAP Center and the Carbon County Road & Bridge Superintendent reviewed the safety needs of the first 11 miles of Hanna Leo, Kortes road and it was determined that 48 advance warning signs, 148 delineators and 5-20 foot culvert extensions, along with gravel to cover the extensions are needed to reduce the alignment -related and overturn crashes. Table D.6 summarizes the proposed safety items and their locations.

**Table D.6 Proposed Safety Items and Locations for Hanna Leo, Kortes Road 291**

**County:** Carbon | **Road Name:** Hanna Leo, Kortes | **Road #:** 291 | **Date:** 7/28/08

**Road Class:** Minor Collector | **ADT:** 35 | **85th Speed:** 48 | **Road Surface:** Pave & Gravel

| LOCATION | STOP R1-1 | STOP AHEAD W3-1 | PAVEMENT ENDS W8-3 | CURVE LT W1-1 | CURVE RT W1-1 | CURVE LT W1-2 | CURVE RT W1-2 | T W2-2 | WINDING ROAD W1-5 | SPEED LIMIT 40 W13-1 | SPEED LIMIT 15 W13-1 | ARROW W1-6 | CHEVRONS | DELINEATORS | 20' CULVERT EXTENSION & FILL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 to 3.6 | | | | | | | | | | | | | | 128 | |
| 1.1R | | | | | | | | 1 | | | | | | | |
| 1.6L | | | | | | | | 1 | | | | | | | |
| 1.2R | | | | | | 1 | | | | | | | | | |
| 1.4L | | | | | | | 1 | | | | | | | | |
| 1.9R | | | | | | 1 | | | | | | | | | |
| 2.2L | | | | | | | 1 | | | | | | | | |
| 2.2L | | | | | | | | | | 1 | | | | | |
| 3.3R | | | | | | | | 1 | | | | | | | |
| 3.4R | 1 | | | | | | | | | | | | | | |
| 3.5R | | | 1 | | | | | | | | | | | | |
| 3.6L | | | | | | | | 1 | | | | | | | |
| 3.8R | | | | | | 1 | | | | | | | | | |
| 4.0L | | | | | | | 1 | | | | | | | | |
| 5.3R | | | | | | | 1 | | | | | | | | |
| 5.6L | | | | | | 1 | | | | | | | | | |
| 5.6R | | | | | | | | | 1 | | | | | | |
| 6.4L | | | | | | | | | 1 | | | | | | |
| 6.4R | | | | | | | | | | | | | | | 24" |
| 7.3R | | | | | | 1 | | | | | | | | | |
| 7.3R | | | | | | | | | | | 1 | | | | |
| 7.3 to 7.5 | | | | | | | | | | | | | 5 | | |
| 7.3 to 7.5 | | | | | | | | | | | | | | 10 | |
| 7.6L | | | | | | | | 1 | | | | | | | |
| 7.6R | | | | | | | | | | | | | | | 36" |
| 7.8R | | | | | | | | | 1 | | | | | | |
| 7.8 to 7.9 | | | | | | | | | | | | | | 10 | |
| 7.8 to 7.9 | | | | | | | | | | | | | 5 | | |
| 8.0 to 8.2 | | | | | | | | | | | | | 10 | | |
| 8.3L | | | | | | | | | 1 | | | | | | |
| 8.4R | | | | | | | | | | | | | | | 36" |
| 8.6R | | | | | | | | | | | | | | | 24" |
| 8.7R | | | | | | | | | 1 | | | | | | |
| 9.1L | | | | | | | | | 1 | | | | | | |
| 9.2R | | | | | | | | | | | | | | | 48" |
| 9.5R | | | | | | 1 | | | | | | | | | |
| 9.7L | | | | | | | 1 | | | | | | | | |
| 10.9R | | | | | | 1 | | | | | | | | | |
| 11.1L | | | | | | | 1 | | | | | | | | |
| TOTAL | 1 | 0 | 1 | 0 | 0 | 7 | 6 | 5 | 6 | 1 | 1 | 0 | 20 | 148 | 5 |

## D.4 Benefit/Cost Analysis

A benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Hanna Leo, Kortes Road 291. Tables D.7 and D.8 summarizes the results of the benefit cost analysis. Table D.9 summarizes the funding request for safety improvements.

## Table D.7 Benefit/Cost Analysis for Hanna Leo, Kortes Road 291

### Benefit to Cost (B/C) Ratio Analysis for Safety Improvement

| General Information | | Site Information | |
|---|---|---|---|
| Analyst | Cheng Zhong | Facility | Carbon Hanna Leo, Kortes |
| Agency/Company | U W | Segment | 291 |
| Project | | Analysis Time Period | 1995-2005 |
| Date Performed | 9-16-2008 | Analysis Year | 2008 |
| | | Segment Length (mi.) | |

**Inputs**

| Crash Cost | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 291 | 3 | 14 | 25 | 2 | 5 | 19 | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| Cost | $48,000.00 | $11,100.00 | $26,705.00 | | | $85,805.00 |
| Benefit | $3,396,000.00 | $933,900.00 | $3,820,500.00 | | | $5,996,487.00 |
| B/C Ratio | 70.75 | 84.14 | 143.06 | | | 69.89 |

## Table D.8 Cost and Service Life for Proposed Improvements

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors | | | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| | | | Fatal | Injury | PDO | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $24,000 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | $4,440 | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | $26,705 | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table 7.9 Funding Request for safety Improvements for Hanna Leo, Kortes Road 291

| Causative Factors Behind Crashes : | 2. Alignment | | 5 | | | |
|---|---|---|---|---|---|---|
| | 3 | | 6 | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
| Advance warning signs | 1 & 2 | 48 | $24,000 | 70.75 | | |
| Delineators | 1 & 2 | 148 | $4,440 | 84.14 | | |
| 20' Culvert Extension | 1 & 2 | 5 | $6,705 | 143.06 | | |
| Gravel Cover for Extensions | 1 & 2 | 220 cu yds | $20,000 | " " | | |
| | | **Total Request:** | $55,145 | **Total Approved:** | $0 | |

# APPENDIX E.  LARAMIE COUNTY

## E.1 Crash Analysis

Similar to Carbon County, crash per mile was the criterion to select the potential high risk roads in Laramie County as shown in Table E.1.

**Table E.1 Results from Crash Analysis in Laramie County**

| ROAD NO. | MILE POST | TOTAL CRASHES | PDOS | INJURIES | FATALS | EPDO |
|---|---|---|---|---|---|---|
| 210-1 | 5.01-6.00 | 9 | 4 | 5 | 0 | 21.5 |
| 215-3 | 2.01-3.00 | 9 | 3 | 6 | 0 | 24 |
| 109-1 | 1.01-2.00 | 9 | 1 | 7 | 1 | 34.5 |
| 124-2 | 1.01-2.00 | 8 | 5 | 3 | 0 | 15.5 |
| 215-3 | 0.00-1.00 | 8 | 3 | 5 | 0 | 20.5 |
| 162-2 | 9.01-10.00 | 7 | 2 | 5 | 0 | 19.5 |
| 215-3 | 1.01-2.00 | 7 | 4 | 3 | 0 | 14.5 |
| 210-1 | 4.01-5.00 | 6 | 2 | 4 | 0 | 16 |
| 212-7 | 3.01-4.00 | 6 | 1 | 5 | 0 | 18.5 |
| 203-1 | 17.01-18.00 | 6 | 2 | 4 | 0 | 16 |
| 210-1 | 6.01-7.00 | 5 | 0 | 5 | 0 | 17.5 |
| 102-1 | 3.01-4.00 | 5 | 2 | 3 | 0 | 12.5 |
| 209-2 | 1.01-2.00 | 5 | 2 | 3 | 0 | 12.5 |
| 143-2 | 0.00-1.00 | 5 | 2 | 1 | 2 | 23.5 |
| 207-1 | 2.01-3.00 | 5 | 5 | 0 | 0 | 5 |
| 136-1 | 3.01-4.00 | 4 | 1 | 3 | 0 | 11.5 |
| 109-1 | 6.01-7.00 | 4 | 3 | 1 | 0 | 6.5 |
| 164-1 | 11.01-12.00 | 4 | 1 | 3 | 0 | 11.5 |
| 210-1 | 0.00-1.00 | 4 | 2 | 2 | 0 | 9 |
| 102-1 | 2.01-3.00 | 4 | 1 | 3 | 0 | 11.5 |
| 109-1 | 3.01-4.00 | 4 | 1 | 3 | 0 | 11.5 |
| 124-2 | 0.00-1.00 | 4 | 2 | 2 | 0 | 9 |
| 162-2 | 5.01-6.00 | 4 | 0 | 4 | 0 | 14 |
| 203-1 | 7.01-8.00 | 4 | 1 | 3 | 0 | 11.5 |
| 162-2 | 10.01-11.00 | 4 | 2 | 2 | 0 | 9 |
| 209-2 | 5.01-6.00 | 4 | 3 | 1 | 0 | 6.5 |
| 109-1 | 0.00-1.00 | 4 | 4 | 0 | 0 | 4 |
| 162-2 | 8.01-9.00 | 4 | 2 | 2 | 0 | 9 |
| 149-1 | 0.00-0.69 | 4 | 4 | 0 | 0 | 4 |

The $WYT^2$/LTAP Center selected 15 roads that have high ranking segments out of Table E.1. Table E.2 summarizes the selected high risk roads in Laramie County.

**Table E.2 Selected High Risk Rural Roads in Laramie County**

| Road No. | Road Name | Road Length | Evaluated Section |
|---|---|---|---|
| 210-1 | Crystal Lake | 10.8 | 10.8 |
| 109-1 N | Gilchrist | 9.48 | 9.48 |
| 124-2 | Old Yellowstone | 10.84 | 3 |
| 215-3 E | Railroad Hillside Ridge | 18.47 | 11 |
| 136-1 S | Durham | 8.23 | 5 |
| 209-2 | Campstool | 7.33 | 7.33 |
| 207-1 | Arcola | 17.18 | 4 |
| 143-2 | Hillside North/Midway | 28.38 | 7 |
| 212-7 | Old Hwy Burns East | 4.11 | 4.11 |
| 203-1 | Chalk Bluff | 36.8 | 16 |
| 102-1 | Harriman | 7.32 | 7.32 |
| 162-2 | Albin/LaGrange | 10.95 | 10.95 |
| 164-1 | Cemetery/Pine Bluff South | 12.26 | 2 |
| 120-1 | Roundtop | 26.81 | 9 |
| 149-1 | A-149-1 | 0.69 | 0.69 |

## E.2 Level I Field Evaluation

The WYT$^2$/LTAP Center performed level I field evaluations on the 15 selected roads. As shown on the right side of Table E.3, the Laramie County sections were ranked based on the results from the level I field evaluation. In addition to conducting the level I field evaluation, traffic volumes were collected on all 15 roads for a period of seven days.

**Table E.3 Crash Data and Level I Field Rankings for Laramie County**

| TOTAL CRASHES | ROAD NO. | MILE POST | CRASH RANKING |
|---|---|---|---|
| 9 | 210-1 | 5.01-6.00 | 1 |
| 9 | 215-3 | 2.01-3.00 | 1 |
| 9 | 109-1 | 1.01-2.00 | 1 |
| 8 | 124-2 | 1.01-2.00 | 4 |
| 8 | 215-3 | 0.00-1.00 | 4 |
| 7 | 162-2 | 9.01-10.00 | 6 |
| 7 | 215-3 | 1.01-2.00 | 6 |
| 6 | 210-1 | 4.01-5.00 | 8 |
| 6 | 203-1 | 17.01-18.00 | 8 |
| 6 | 212-7 | 3.01-4.00 | 8 |
| 5 | 210-1 | 6.01-7.00 | 11 |
| 5 | 102-1 | 3.01-4.00 | 11 |
| 5 | 209-2 | 1.01=2.00 | 11 |
| 5 | 143-2 | 0.00-1.00 | 11 |
| 5 | 120-1 | 4-5, 8-9 | 11 |
| 5 | 207-1 | 2.01-3.00 | 11 |
| 4 | 136-1 | 3.01-4.00 | 17 |
| 4 | 109-1 | 6.01-7.00 | 17 |
| 4 | 164-1 | 11.01-12.00 | 17 |
| 4 | 210-1 | 0.00-1.00 | 17 |
| 4 | 102-1 | 2.01-3.00 | 17 |
| 4 | 109-1 | 3.01-4.00 | 17 |
| 4 | 124-2 | 0.00-1.00 | 17 |
| 4 | 162-2 | 5.01-6.00 | 17 |
| 4 | 203-1 | 7.01-8.00 | 17 |
| 4 | 162-2 | 10.01-11.00 | 17 |
| 4 | 209-2 | 5.01-6.00 | 17 |
| 4 | 109-1 | 0.00-1.00 | 17 |
| 4 | 162-2 | 8.01-9.00 | 17 |
| 4 | 149-1 | 0.00-0.69 | 17 |

| LEVEL I FIELD SCORE | ROAD NO. | MILE POST | LEVEL I RANKING |
|---|---|---|---|
| 16 | 210-1 | 5.01-6.00 | 1 |
| 17 | 136-1 | 3.01-4.00 | 2 |
| 18 | 124-2 | 1.01-2.00 | 3 |
| 18 | 109-1 | 6.01-7.00 | 3 |
| 19 | 210-1 | 4.01-5.00 | 5 |
| 19 | 164-1 | 11.01-12.00 | 5 |
| 20 | 210-1 | 0.00-1.00 | 7 |
| 20 | 102-1 | 0.00-1.00 | 7 |
| 20 | 124-2 | 2.01-3.00 | 7 |
| 21 | 102-1 | 2.01-3.00 | 10 |
| 21 | 109-1 | 3.01-4.00 | 10 |
| 21 | 124-2 | 0.00-1.00 | 10 |
| 21 | 102-1 | 1.01-2.00 | 10 |
| 22 | 210-1 | 6.01-7.00 | 14 |
| 22 | 162-2 | 5.01-6.00 | 14 |
| 22 | 203-1 | 7.01-8.00 | 14 |
| 22 | 136-1 | 0.00-1.00 | 14 |
| 23 | 102-1 | 3.01-4.00 | 18 |
| 23 | 209-2 | 1.01-2.00 | 18 |
| 23 | 162-2 | 10.01-11.00 | 18 |
| 23 | 136-1 | 1.01-2.00 | 18 |
| 23 | 109-1 | 4.01-5.00 | 18 |
| 23 | 136-1 | 4.01-5.00 | 18 |
| 23 | 210-1 | 8.01-9.00 | 18 |
| 24 | 162-2 | 9.01-10.00 | 25 |
| 24 | 143-2 | 0.00-1.00 | 25 |
| 24 | 120-1 | 4-5, 8-9 | 25 |
| 24 | 209-2 | 5.01-6.00 | 25 |
| 24 | 209-2 | 0.00-1.00 | 25 |
| 24 | 120-1 | 1-2, 5-6 | 25 |

## E.3 Combined Ranking

Road segments identified as high crash locations were listed and ranked based on the total number of crashes as shown on the left side of Table E.3. Higher numbers of crashes resulted in lower rankings. Road segment scores obtained from level I field evaluations were also used to rank the sections. Lower field scores resulted in a lower rank. The right side of Table E.3 shows the level I field rankings for Laramie County. The crashes and level I rankings for each segment of roadway were added together to obtain the combined rankings. The overall score and combined rankings for the 15 evaluated roadways are shown in Table E.4.

**Table E.4 Combined Ranking for High Risk Roads in Laramie County**

| ROAD NO. | MILE POST | OVERALL SCORE | COMBINED RANKING |
|---|---|---|---|
| 210-1 | 5.01-6.00 | 2 | 1 |
| 124-2 | 1.01-2.00 | 7 | 2 |
| 210-1 | 4.01-5.00 | 13 | 3 |
| 136-1 | 3.01-4.00 | 19 | 4 |
| 109-1 | 6.01-7.00 | 20 | 5 |
| 164-1 | 11.01-12.00 | 22 | 6 |
| 210-1 | 0.00-1.00 | 24 | 7 |
| 210-1 | 6.01-7.00 | 25 | 8 |
| 102-1 | 2.01-3.00 | 27 | 9 |
| 109-1 | 3.01-4.00 | 27 | 10 |
| 124-2 | 0.00-1.00 | 27 | 11 |
| 102-1 | 3.01-4.00 | 29 | 12 |
| 209-2 | 1.01-2.00 | 29 | 13 |
| 162-2 | 5.01-6.00 | 31 | 14 |
| 162-2 | 9.01-10.00 | 31 | 15 |
| 203-1 | 7.01-8.00 | 31 | 16 |

## E.4 Level II Field Evaluation

The WYT$^2$/LTAP Center selected the three roads with the highest combined ranking out of Table E.4. These roads are 210-1, 124-2, and 109-1. Subsequently, road 124-2 was dropped and 136-1 was added because a major project is already planned for road 124-2. The causative factors behind the crashes were identified from the WYDOT crash data and traffic volumes were obtained on the three selected roads prior to performing the level II field evaluation.

## E.5 Benefit/Cost Analysis

After conducting the level II field evaluations, appropriate safety countermeasures were selected. Benefit cost analyses were conducted to determine the cost effectiveness of the proposed countermeasures. The WYT$^2$/LTAP Center developed simple Excel worksheets to calculate the benefit/cost ratios for all proposed countermeasures.

## E.6 Level II Field Evaluation for Crystal Lake Road 210-1

Laramie County Crystal Lake Road 210-1 has a gravel surface. It is 10.80 miles in length. It starts at the West ROW of Wyoming State Highway 210 between mile posts 14 and 15. This road ends at the Laramie/Albany County line. Road 210-1 is classified as a minor collector. The road is used for residential access, recreational purposes, and agricultural activities. The ten-year crash data between 1995 and 2005 for Crystal Lake Road 210-1 is shown in Table E.5. As shown in Table E.6, the average daily traffic (ADT) is 173 vehicles per day. The ADT data were collected between 11/6/07 and 11/12/07.

**Table E.5 Ten -Year Crash Data for Crystal Lake Road 210-1**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 210-1 | 00020 | 02 | 2 | 2 | 0 |
| 210-1 | 00030 | 02 | 1 | 0 | 0 |
| 210-1 | 00090 | 96 | 4 | 0 | 0 |
| 210-1 | 00100 | 02 | 2 | 1 | 0 |
| 210-1 | 00247 | 04 | 1 | 0 | 0 |
| 210-1 | 00250 | 03 | 3 | 3 | 0 |
| 210-1 | 00330 | 99 | 1 | 1 | 0 |
| 210-1 | 00430 | 02 | 2 | 1 | 0 |
| 210-1 | 00450 | 95 | 2 | 2 | 0 |
| 210-1 | 00450 | 97 | 1 | 1 | 0 |
| 210-1 | 00450 | 98 | 6 | 2 | 0 |
| 210-1 | 00470 | 96 | 4 | 0 | 0 |
| 210-1 | 00470 | 99 | 3 | 0 | 0 |
| 210-1 | 00510 | 99 | 4 | 0 | 0 |
| 210-1 | 00510 | 03 | 3 | 3 | 0 |
| 210-1 | 00530 | 96 | 1 | 0 | 0 |
| 210-1 | 00530 | 04 | 2 | 2 | 0 |
| 210-1 | 00530 | 05 | 1 | 1 | 0 |
| 210-1 | 00550 | 96 | 2 | 1 | 0 |
| 210-1 | 00550 | 02 | 2 | 2 | 0 |
| 210-1 | 00560 | 00 | 1 | 0 | 0 |
| 210-1 | 00590 | 05 | 1 | 0 | 0 |
| 210-1 | 00650 | 97 | 4 | 1 | 0 |
| 210-1 | 00650 | 05 | 1 | 1 | 0 |
| 210-1 | 00660 | 97 | 1 | 1 | 0 |
| 210-1 | 00670 | 96 | 2 | 1 | 0 |
| 210-1 | 00680 | 01 | 1 | 1 | 0 |
| 210-1 | 00730 | 05 | 2 | 0 | 0 |
| 210-1 | 00750 | 03 | 2 | 0 | 0 |
| 210-1 | 00770 | 97 | 1 | 1 | 0 |

**Table E.6 Traffic Volume, Vehicle Classification, and Speed for Crystal Lake Road 210-1**

| Crystal Lake #210-1 | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/6/2007 | 84 | 78 | 80 | 4 | 74 | 4 | 43 | 41 |
| Wed 11/7/2007 | 100 | 94 | 96 | 4 | 90 | 4 | 44 | 40 |
| Thu 11/8/2007 | 86 | 79 | 81 | 5 | 75 | 4 | 45 | 40 |
| Fri 11/9/2007 | 125 | 99 | 124 | 1 | 96 | 3 | 44 | 42 |
| Sat 11/10/2007 | 100 | 89 | 94 | 6 | 87 | 2 | 41 | 40 |
| Sun 11/11/2007 | 86 | 61 | 84 | 2 | 59 | 2 | 42 | 40 |
| Mon 11/12/2007 | 79 | 54 | 76 | 3 | 52 | 2 | 44 | 43 |
| Average | 94 | 79 | 91 | 4 | 76 | 3 | 43 | 41 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 53 | 47 | 96 | 4 | 96 | 4 | | |

The WYT[2]/LTAP Center performed a level I field evaluation on the entire 10.8 miles of Crystal Lake road 210-1. Table E.7 shows the results of the level I field evaluation.

**Table E.7 Level I Field Evaluation Data Results for Crystal Lake Road 210-1**

| MILE POST | GENERAL | SHOULDER | INTSC/RR | SIGN/PVM | FIX OBJ | SUM | COMMENTS |
|---|---|---|---|---|---|---|---|
| 00--1 | 5 | 5 | 2 | 3 | 5 | 20 | SEVERAL INTERSECTIONS |
| 01--2 | 5 | 6 | 5 | 6 | 7 | 29 | COUPE VERT CURVES |
| 02--3 | 5 | 7 | 7 | 6 | 5 | 30 | GOOD ROAD |
| 03--4 | 5 | 6 | 6 | 4 | 7 | 28 | MINOR HORIZ CURVES |
| 04--5 | 3 | 4 | 4 | 3 | 5 | 19 | HORIZ S S DIST NEED MORE SIGNS, STEEP SHOULDER |
| 05--6 | 3 | 3 | 4 | 2 | 4 | 16 | VERT & HORIZ STOP S DIST NO SIGNS, COUPE STEEP SHOULDERS |
| 06--7 | 4 | 4 | 3 | 4 | 7 | 22 | COUPLE INTERSEC, S-CURVE ON HILL |
| 08--9 | 5 | 8 | 3 | 4 | 3 | 23 | MANY INTERSECTIONS, POWER POLES IN ROW |
| 09--10 | 8 | 8 | 9 | 8 | 7 | 40 | GOOD ROAD |
| 10--10.8 | 6 | 6 | 5 | 5 | 5 | 27 | LOW SPEED LOW ADT |

As shown in Table E.8, alignment and overturn crashes are the most common on Crystal Lake Road 210-1.

**Table E.8 Causative Factors for Crashes on Crystal Lake Road 210-1**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 0 | Curve And Level | 0 |
| Gravel | 19 | ***Curved Downgrade*** | ***23*** |
| Dirt | 11 | ***Curved Hillcrest*** | ***2*** |
| | | Curved Upgraded | 0 |
| **Lighting** | | Straight Hillcrest | 0 |
| Dark | 4 | Straight Level | 4 |
| Dawn or Dusk | 5 | Straight Downgrade | 1 |
| Daylight | 21 | Straight Upgrade | 0 |
| | | Other | 0 |
| **Road Conditions** | | | |
| Dry | 29 | **Traffic Control** | |
| Icy | 0 | None | 26 |
| Muddy | 1 | Other | 0 |
| Slush | 0 | Pavement Marking | 0 |
| Snowy | 0 | Stop Sign | 0 |
| Wet | 0 | Warning | 4 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 29 | Antelope | 0 |
| Sleet/Hail | 0 | Berm/Ditch | 2 |
| Snowing | 1 | Cow | 0 |
| Strong Wind | 0 | Deer | 1 |
| Dust | 0 | Mv-Mv | 2 |
| Fog | 0 | ***Overturn*** | ***21*** |
| Rain | 0 | Snow Embankment | 0 |
| Unknown | 0 | Parked Vehicle | 0 |
| Ground Blizzard | 0 | Mail Box | 0 |
| | | Guard Rail | 0 |
| **Roadway Junction** | | Fence | 4 |
| Non-Junction | 30 | Post | 0 |
| Drive Way Access | 0 | Barricade | 0 |
| Intersection | 0 | Other | 0 |

The WYT$^2$/LTAP Center and the Laramie County Road & Bridge director reviewed the safety needs of Crystal Lake road and it was determined that 31 advance warning signs are needed to reduce the alignment-related and overturn crashes. Table E.9 summarizes the proposed signs and their locations.

# Table E.9 Proposed Signs and Locations for Crystal Lake 210-1

**County:** Laramie | **Road Name:** Crystal Lake | **Road #:** 210-1 | **Date:** 7/16/08

**Road Class:** Minor Collector | **ADT:** 173 | **85th Speed: 42** | **Road Surface:** Gravel

| LOCATION | STOP R1-1 | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | CURVE LT W1-2 | CURVE RT W1-2 | CURVE LT W1-4 | CURVE RT W1-4 | WINDING ROAD W1-5 | SPEED LIMIT 40 R2-1 | SPEED LIMIT 35 R2-1 | SPEED LIMIT 20 R2-1 | SPEED LIMIT 25 W13-1 | SPEED LIMIT 30 W13-1 | SPEED LIMIT 35 W13-1 | T W2-4 | ARROW W1-6 | RAILROAD W10-1 | OPEN RANGE | SHOULDER DROP OFF W8-9A | HILLS NEXT 10 MILES KEEP RIGHT | COUNTY ROAD SIGN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0L | 1 | | | | | | | | | | | | | | | | | | | | | |
| 0.1N | | | | | | | | | | 1 | | | | | | | | | | | | |
| 0.1S | | 1 | | | | | | | | | | | | | | | | | | | | |
| 0.3N | | | | | 1 | | | | | | | | | | | | | | | | | |
| 0.5S | | | | | | 1 | | | | | | | | | | | | | | | | |
| 0.8N | | | | | | 1 | | | | | | | | | | | | | | | | |
| 1.0S | | | | | 1 | | | | | | | | | | | | | | | | | |
| 3.4N | | | | | | | 1 | | | | | | | | | | | | | | | |
| 3.6S | | | | | | | | | | 1 | | | | | | | | | | | | |
| 3.6N | | | | | | | | | | 1 | | | | | | | | | | | | |
| 3.8S | | | | | | | | 1 | | | | | | | | | | | | | | |
| 4.4N | | | | | | | | 1 | | | | | | | | | | | | | | |
| 4.6N | | | | | | | | | 1 | | | | | | | | | | | | | |
| 4.9S | | | | | | | | | 1 | | | | | | | | | | | | | |
| 5.2N | | | | | | | | | 1 | | | | | | | | | | | | | |
| 5.7S | | | | | | | | | 1 | | | | | | | | | | | | | |
| 6.0N | | | | | | | | | | | | | | | | 1 | | | | | | |
| 6.2S | | | | | | | | | | | | | | | | 1 | | | | | | |
| 6.2N | | | | | | | | | 1 | | | | | | | | | | | | | |
| 6.2N | | | | | | | | | | | | | | 1 | | | | | | | | |
| 6.7S | | | | | | | | | 1 | | | | | | | | | | | | | |
| 6.9N | | | | | | | 1 | | | | | | | | | | | | | | | |
| 7.3S | | | | | | | | 1 | | | | | | | | | | | | | | |
| 7.6S | | | | | | | | | 1 | | | | | | | | | | | | | |
| 7.6S | | | | | | | | | | | | | 1 | | | | | | | | | |
| 7.8S | | | | | | | | | | | | | | | | | | | | | 1 | |
| 8.0S | | | | | | | | | | | | | | 1 | | | | | | | | |
| 8.0N | | | | | | | | | | | | | | 1 | | | | | | | | |
| 10.1N | | | | | | | | | 1 | | | | | | | | | | | | | |
| 10.5S | | | | | | | | | 1 | | | | | | | | | | | | | |
| 10.6S | | | | | | | | | | | | | | | | | | | | | | 1 |
| TOTAL | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 3 | 9 | 3 | 0 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 1 |

The benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Crystal Lake Road 210-1. Table E.10 summarizes the results of the benefit cost analysis. Table E.11 summarizes the funding request for safety improvements for Crystal Lake Road.

**Table E.10 Benefit/Cost Analysis on Crystal Lake Road 210-1**

**Benefit to Cost (B/C) Ratio Analysis for Safety Improvement**

| General Information | | Site Information | |
|---|---|---|---|
| Analyst | Cheng Zhong | Facility | Laramie, Crystal Lake |
| Agency/Company | U W | Segment | 210-1 |
| Project | | Analysis Time Period | 1995-2005 |
| Date Performed | 9-16-2008 | Analysis Year | 2008 |
| | | Segment Length (mi.) | |

**Inputs**

| Crash Cost | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 210-1 | 0 | 19 | 11 | 2 | | | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $18,600.00 | | | | | $18,600.00 |
| **Benefit** | $482,400.00 | | | | | $482,400.00 |
| **B/C Ratio** | 25.94 | | | | | 25.94 |

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors | | | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| | | | Fatal | Injury | PDO | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $9,300 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

## Table E.11 Funding Request for Safety Improvements on Crystal Lake Road 210-1

| | | | | | | |
|---|---|---|---|---|---|---|
| **County:** Laramie | **Road Name:** Crystal Lake | | **Road #:** 210-1 | | **Date:** | 7/16/2008 |
| **Road Class:** Minor Collector | **ADT :** 173 | **85th Speed:** 42 MPH | **Road Surface:** Gravel | | | |
| **Causative Factors Behind Crashes :** | 1. Alignment | | 4 | | | |
| | 2. Overturns | | 5 | | | |
| | 3 | | 6 | | | |

| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
|---|---|---|---|---|---|---|
| Advance warning signs | 1 & 2 | 31 | $9,300 | 25.94 | | |
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| | | | | | | |
| | | **Total Request:** | $9,300 | **Total Approved:** | | |

## E.7 Level II Field Evaluation for Crystal Lake Road 210-1

Laramie County Durham Road 136-1 has a gravel surface. It is 11.3 miles in length and starts at the ROW of Old Wyoming State Highway 30 near mile post 374. This road ends at the junction with Laramie County Road 222-1. Road 136-1 is classified as a local road. The ten-year crash data between 1995 and 2005 for Laramie County Durham Road 136-1 is shown in Table E.12. As shown in Table E.13, the average daily traffic (ADT) is 238 vehicles per day. The ADT data were collected between 11/27/07 and 12/3/07.

**Table E.12 Ten-Year Crash Data for Durham Road 136-1**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 136-1 | 00000 | 01 | 01 | 00 | 00 |
| 136-1 | 00060 | 98 | 01 | 01 | 00 |
| 136-1 | 00104 | 03 | 02 | 01 | 00 |
| 136-1 | 00167 | 96 | 01 | 00 | 00 |
| 136-1 | 00260 | 96 | 01 | 00 | 00 |
| 136-1 | 00300 | 95 | 02 | 01 | 00 |
| 136-1 | 00310 | 99 | 01 | 00 | 00 |
| 136-1 | 00330 | 03 | 01 | 01 | 00 |
| 136-1 | 00363 | 98 | 05 | 05 | 00 |
| 136-1 | 00396 | 96 | 02 | 02 | 00 |
| 136-1 | 00530 | 01 | 03 | 00 | 00 |

**Table E.13 Traffic Volume, Vehicle Classification, and Speed for Durham Road 136-1**

| Durham #136-1 | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/27/2007 | 136 | 129 | 134 | 2 | 122 | 7 | 44 | 49 |
| Wed 11/28/2007 | 150 | 126 | 140 | 10 | 120 | 6 | 40 | 48 |
| Thu 11/29/2007 | 116 | 114 | 113 | 3 | 105 | 9 | 46 | 49 |
| Fri 11/30/2007 | 135 | 121 | 134 | 1 | 119 | 2 | 46 | 52 |
| Sat 12/1/2007 | 100 | 90 | 100 | 0 | 90 | 0 | 43 | 51 |
| Sun 12/2/2007 | 98 | 84 | 97 | 1 | 82 | 2 | 44 | 48 |
| Mon 12/3/2007 | 134 | 138 | 131 | 3 | 128 | 10 | 40 | 47 |
| Average | 124 | 114 | 121 | 3 | 109 | 5 | 43.2 | 49.1 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 52 | 48 | 97.6 | 2.4 | 95.6 | 4.4 | | |

The WYT$^2$/LTAP Center performed a level I field evaluation on the first five miles of Durham Road 136-1 because the first five miles had a higher number of crashes. Table E.14 shows the results of the level I field evaluation for Laramie County Road 136-1.

**Table E.14 Level I Field Evaluation on Durham Road 136-1**

| MILE POST | GENERAL | SHOULDER | INTSC \ RR | SIGN \ PVM | FIX OBJ | SUM | COMMENTS |
|---|---|---|---|---|---|---|---|
| 0--1 | 5 | 7 | 1 | 4 | 5 | 22 | 12 INTERSECTIONS POWER POLES IN ROW |
| 1--2 | 5 | 7 | 2 | 4 | 5 | 23 | EIGHT INTERSECTIONS, POWER POLES IN ROW |
| 2--3 | 8 | 9 | 5 | 8 | 9 | 39 | ONE MINOR VERT |
| 3--4 | 3 | 6 | 2 | 2 | 4 | 17 | TWO MAJOR INTERSECTIONS, THREE OTHERS,VERT. & A HORIZ CURVE, P P IN ROW |
| 4--5 | 4 | 7 | 3 | 3 | 6 | 23 | TEN INTERSECTIONS,TWO VERTICAL CURVES |

As shown in Table E.15 the causative factor behind the crashes on Durham Road 136-1 are overturn crashes.

**Table E.15 Causative Factors for Crashes on Durham Road 136-1**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 0 | Curve And Level | 1 |
| Gravel | 8 | Curved Downgrade | 0 |
| Dirt | 3 | Curved Hillcrest | 0 |
| | | Curved Upgraded | 1 |
| **Lighting** | | Straight Hillcrest | 2 |
| Dark | 4 | Straight Level | 2 |
| Dawn or Dusk | 1 | Straight Downgrade | 5 |
| Daylight | 6 | Straight Upgrade | 0 |
| | | Other | 0 |
| **Road Conditions** | | | |
| Dry | 9 | **Traffic Control** | |
| Icy | 0 | None | 8 |
| Muddy | 1 | Other | 2 |
| Slush | 0 | Pavement Marking | 0 |
| Snowy | 0 | Stop Sign | 1 |
| Wet | 1 | Warning | 0 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 9 | Antelope | 0 |
| Sleet/Hail | 0 | Berm/Ditch | 2 |
| Snowing | 1 | Cow | 0 |
| Strong Wind | 0 | Deer | 1 |
| Dust | 0 | Mv-Mv | 1 |
| Fog | 1 | ***Overturn*** | ***5*** |
| Rain | 0 | Snow Embankment | 0 |
| Unknown | 0 | Parked Vehicle | 0 |
| Ground Blizzard | 0 | Mail Box | 0 |
| | | Guard Rail | 0 |
| **Roadway Junction** | | Fence | 1 |
| Non-Junction | 8 | Post | 0 |
| Drive Way Access | 0 | Barricade | 0 |
| Intersection | 3 | Other | 1 |

The WYT$^2$/LTAP Center determined that 19 advance warning signs are needed to reduce the number of overturn crashes occurring on Road 136-1. Table E.16 summarizes the proposed signs and their locations.

Table E.16 Proposed Sign Types and Locations on Durham Road 136-1

| **County:** Laramie | | | **Road Name:** Durham | | | **Road #:** 136-1 | **Date:** 7/16/08 | |
|---|---|---|---|---|---|---|---|---|
| **Road Class:** Local | | **ADT:** 238 | **85th Speed:** 45 | | | **Road Surface:** Gravel | | |
| LOCATION | STOP R1-1 | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | SPEED LIMIT 35 R2-1 | SPEED LIMIT 20 R2-1 | ARROW W1-6 | RAILROAD W10-1 |
| 0.0lL | 1 | | | | | | | |
| 0.1L | | 1 | | | | | | |
| 0.2R | | | | | 1 | | | |
| 1.0L | | | | | 1 | | | |
| 2.0R | | | | | 1 | | | |
| 2.0L | | | | | 1 | | | |
| 3.0R | | | | 1 | | | | |
| 3.0R | | | | | | 1 | | |
| 3.05L | | | | | | | 1 | |
| 3.05L | | | | | | | 1 | |
| 3.1L | | | 1 | | | | | |
| 3.1L | | | | | | 1 | | |
| 3.2R | | | | | | | | 1 |
| 3.2R | | 1 | | | | | | |
| 3.3L | | | | | | | | 1 |
| 3.3R | 1 | | | | | | | |
| 3.3R | | | | | | | 1 | |
| 3.5L | 1 | | | | | | | |
| 3.6L | | 1 | | | | | | |
| TOTAL | 3 | 3 | 1 | 1 | 4 | 2 | 3 | 2 |
| | | | | | | | | TOTAL SIGNS = 19 |

The benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Durham Road 136-1**.** Table E.17 summarizes the results of the benefit cost analysis and Table E.18 summarizes the funding request for safety improvements.

## Table E.17 Benefit/Cost Analysis for Durham Road 136-1

**Benefit to Cost (B/C) Ratio Analysis for Safety Improvement**

| General Information | | Site Information | |
|---|---|---|---|
| Analyst | Cheng Zhong | Facility | Laramie, Durham |
| Agency/Company | U W | Segment | 136-1 |
| Project | | Analysis Time Period | 1995-2005 |
| Date Performed | 9-16-2008 | Analysis Year | 2008 |
| | | Segment Length (mi.) | |

**Inputs**

| Crash Cost | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 136-1 | 0 | 6 | 5 | 2 | | | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $11,400.00 | | | | | $11,400.00 |
| **Benefit** | $156,000.00 | | | | | $156,000.00 |
| **B/C Ratio** | 13.68 | | | | | 13.68 |

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors | | | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| | | | Fatal | Injury | PDO | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $5,700 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table E.18 Funding Request for Safety Improvements on Durham Road 136-1

| | | | | | | |
|---|---|---|---|---|---|---|
| **County:** Laramie | **Road Name:** Durham | | **Road #:** 136-1 | | **Date:** | 7/16/2008 |
| **Road Class:** Local | **ADT:** 238 | **85th Speed:** 45 | **Road Surface:** Gravel | | | |
| **Causative Factors Behind Crashes :** | 1. Overturn | | 4 | | | |
| | 2 | | 5 | | | |
| | 3 | | 6 | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
| Advance warning signs | 1 | 19 | $5,700 | 13.68 | | |
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| | | **Total Request:** | $5,700 | **Total Approved:** | | |

## E.8 Level II Field Evaluation for Laramie County Gilchrist Road 109-1

Laramie County Gilchrist Road 109-1 has a gravel surface, it is 9.48 miles in length, and starts at the ROW of Wyoming State Highway 210 near mile post 15. This road ends at the ROW of Wyoming State Highway 211 near mile post 17. Road 109-1 is classified as a minor collector. As shown in Table E.19, the average daily traffic (ADT) is 257 vehicles per day. The ADT data were collected between 11/6/07 and 11/12/07. The road is used for residential access and agricultural activities. The ten-year crash data between 1995 and 2005 for Laramie County Gilchrist Road 109-1 are shown in Table E.20.

**Table E.19 Traffic volume, Vehicle Classification, and Speed for Gilchrist Road 109-1**

| Gilchrist #109-1 | Traffic Volume | | Vehicle Classification | | | | 85th percentile Speed, MPH | |
|---|---|---|---|---|---|---|---|---|
| | Direction 1 | Direction 2 | Direction 1 | | Direction 2 | | Direction 1 | Direction 2 |
| | Cars &Trucks | Cars &Trucks | Cars | Trucks | Cars | Trucks | Cars &Trucks | Cars &Trucks |
| Tue 11/6/2007 | 195 | 207 | 189 | 6 | 194 | 13 | 48 | 46 |
| Wed 11/7/2007 | 195 | 186 | 192 | 3 | 171 | 15 | 47 | 45 |
| Thu 11/8/2007 | 199 | 199 | 197 | 2 | 189 | 10 | 46 | 44 |
| Fri 11/9/2007 | 205 | 204 | 204 | 1 | 193 | 11 | 47 | 44 |
| Sat 11/10/2007 | 147 | 156 | 145 | 2 | 152 | 4 | 46 | 44 |
| Sun 11/11/2007 | 118 | 123 | 118 | 0 | 118 | 5 | 46 | 45 |
| Mon 11/12/2007 | 183 | 174 | 181 | 2 | 164 | 10 | 46 | 46 |
| Average | 178 | 179 | 175 | 3 | 169 | 10 | 47 | 45 |
| | Directional Distribution (%) | | Percent of Vehicles (%) | | | | | |
| | 50 | 50 | 98 | 2 | 94 | 6 | | |

**Table E.20 Ten Year Crash Data for Gilchrist Road 109-1**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 109-1 | 00002 | 02 | 1 | 0 | 0 |
| 109-1 | 00002 | 02 | 3 | 0 | 0 |
| 109-1 | 00004 | 96 | 3 | 0 | 0 |
| 109-1 | 00040 | 98 | 2 | 0 | 0 |
| 109-1 | 00140 | 00 | 1 | 1 | 0 |
| 109-1 | 00170 | 95 | 1 | 1 | 0 |
| 109-1 | 00170 | 95 | 1 | 1 | 0 |
| 109-1 | 00170 | 05 | 1 | 1 | 0 |
| 109-1 | 00180 | 95 | 2 | 0 | 0 |
| 109-1 | 00180 | 96 | 2 | 2 | 0 |
| 109-1 | 00180 | 96 | 2 | 2 | 0 |
| 109-1 | 00180 | 99 | 1 | 1 | 0 |
| 109-1 | 00190 | 98 | 3 | 1 | 1 |
| 109-1 | 00359 | 96 | 6 | 3 | 0 |
| 109-1 | 00372 | 03 | 1 | 1 | 0 |
| 109-1 | 00390 | 03 | 1 | 1 | 0 |
| 109-1 | 00399 | 97 | 3 | 0 | 0 |
| 109-1 | 00440 | 03 | 3 | 0 | 0 |
| 109-1 | 00465 | 95 | 2 | 0 | 0 |
| 109-1 | 00498 | 02 | 1 | 0 | 0 |
| 109-1 | 00581 | 95 | 2 | 1 | 0 |
| 109-1 | 00625 | 97 | 4 | 0 | 0 |
| 109-1 | 00640 | 98 | 3 | 2 | 0 |
| 109-1 | 00648 | 03 | 1 | 0 | 0 |
| 109-1 | 00695 | 04 | 1 | 0 | 0 |
| 109-1 | 00750 | 96 | 1 | 0 | 0 |

The $WYT^2$/LTAP Center performed a level I field evaluation on the entire 9.48 miles of Gilchrist Road 109-1. Table E.21 shows the results of the level I field evaluation for Laramie County Road 109-1.

**Table E.21 Level I Field Evaluation on Gilchrist Road 109-1**

| MILE POST | GENERAL | SHOULDER | INTSC \ RR | SIGNPVM | FIX \ OBJ | SUM | COMMENTS |
|---|---|---|---|---|---|---|---|
| 0--1 | 5 | 6 | 4 | 5 | 6 | 26 | INTERSEC WITH WYO HWY |
| 1--2 | 5 | 6 | 5 | 4 | 6 | 26 | SEVERAL MINOR HORIZ CURVES |
| 2--3 | 7 | 8 | 5 | 7 | 6 | 33 | GOOD MILE |
| 3--4 | 5 | 5 | 2 | 4 | 5 | 21 | SEVERAL INTERSECTIONS |
| 4--5 | 5 | 6 | 2 | 4 | 6 | 23 | SEVERAL INTERSECTIONS |
| 5--6 | 4 | 6 | 4 | 5 | 6 | 25 | SOME INTERSECTIONS AND MINOR HORIZ CURVES |
| 6--7 | 4 | 5 | 5 | 1 | 3 | 18 | NEED MORE SIGNS, 1 NARROW CG |
| 7--8 | 5 | 3 | 8 | 7 | 4 | 27 | NARROW CG, STEEP SHOULDER |
| 8--9 | 5 | 7 | 5 | 6 | 5 | 28 | 2 90 HORIZ CURV |
| 9--9.48 | 8 | 7 | 4 | 5 | 8 | 32 | GOOD ROAD |

As shown in Table E.22, alignment related and overturn crashes are the most common occurrences on Gilchrist Road 109-1.

**Table E.22 Causative factors for every crash on Gilchrist Road 109-1**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 0 | ***Curve And Level*** | ***10*** |
| Gravel | 21 | Curved Downgrade | 4 |
| Dirt | 5 | Curved Hillcrest | 0 |
| | | Curved Upgraded | 2 |
| **Lighting** | | Straight Hillcrest | 0 |
| Dark | 11 | Straight Level | 6 |
| Dawn or Dusk | 1 | Straight Downgrade | 1 |
| Daylight | 14 | Straight Upgrade | 3 |
| | | Other | 0 |
| **Road Conditions** | | | |
| Dry | 21 | **Traffic Control** | |
| Icy | 3 | None | 25 |
| Muddy | 1 | Other | 0 |
| Slush | 0 | Pavement Marking | 0 |
| Snowy | 0 | Stop Sign | 0 |
| Wet | 0 | Warning | 1 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 23 | Antelope | 0 |
| Sleet/Hail | 0 | Berm/Ditch | 1 |
| Snowing | 2 | Cow | 0 |
| Strong Wind | 0 | Deer | 1 |
| Dust | 0 | Mv-Mv | 1 |
| Fog | 0 | ***Overturn*** | ***19*** |
| Rain | 0 | Snow Embankment | 0 |
| Unknown | 0 | Parked Vehicle | 0 |
| Ground Blizzard | 1 | Mail Box | 1 |
| | | Guard Rail | 0 |
| **Roadway Junction** | | Fence | 2 |
| Non-Junction | 25 | Post | 0 |
| Drive Way Access | 0 | Barricade | 0 |
| Intersection | 1 | Other | 1 |

The WYT$^2$/LTAP Center determined that 45 advance warning signs, and three 24-foot cattle guards are needed to reduce the alignment related and overturn crashes. Table E.23 summarizes the proposed signs and cattle guards and their locations.

**Table E.23 Need Signs and Cattle guard on Gilchrist Road 109-1**

| County: Laramie | | | | Road Name: Gilchrist | | | Road #: 109-1 | | | | | | Date: 7/16/08 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Road Class: Minor Collector | | | | ADT: 179 | | | 85th Speed: 46 | | Road Surface: Gravel | | | | | | | |
| LOCATION | STOP R1-1 | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | CURVE LT W1-2 | CURVE RT W1-2 | WINDING ROAD W1-5 | SPEED LIMIT 40 R2-1 | SPEED LIMIT 35 R2-1 | SPEED LIMIT 20 R2-1 | SPEED LIMIT 35 W13-1 | ARROW W1-6 | RAILROAD W10-1 | OPEN RANGE | SHOULDER DROP OFF W8-9A | 24' CATTLE GUARD |
| 0.0L | 1 | | | | | | | | | | | | | | | |
| 0.1R | | | | | | | | | | | | | | 1 | | |
| 0.1R | | | | | | | | | 1 | | | | | | | |
| 1.1R | | | | | | 1 | | | | | | | | | | |
| 1.1L | | 1 | | | | | | | | | | | | | | |
| 1.4L | | | | | 1 | | | | | | | | | | | |
| 1.5L | | | | | | | | | | | | | | 1 | | |
| 2.7L | | | | | | | | | | | 1 | | | | | |
| 2.7R | | | | | | | | | | | 1 | | | | | |
| 2.8L | | | | | | | | | | | | | | 1 | | |
| 3.1R | | | | | | | 1 | | | | | | | | | |
| 3.6L | | | | | | | 1 | | | | | | | | | |
| 3.9R | | | | | | 1 | | | | | | | | | | |
| 4.0L | | | | | | | | | | | 1 | | | | | |
| 4.2R | | | | | 1 | | | | | | | | | | | |
| 4.5R | | | | | | 1 | | | | | | | | | | |
| 4.7L | | | | | 1 | | | | | | | | | | | |
| 5.20 | | | | | | | | | | | | | | | | 1 |
| 5.2R | | | | | | | | | | | | | | 1 | | |
| 5.2R | | | | | | | | | | | 1 | | | | | |
| 5.2R | | | | | 1 | | | | | | | | | | | |
| 5.2R | | | | | | | | | | | 1 | | | | | |
| 5.5L | | | | | | 1 | | | | | | | | | | |
| 5.6R | | | | | | | | | | | | | | | 1 | |
| 6.3 | | | | | | | | | | | | | | | | 1 |
| 6.3R | | | | | | | 1 | | | | | | | | | |
| 6.6L | | | | | | | 1 | | | | | | | | | |
| 6.6R | | | | | 1 | | | | | | | | | | | |
| 6.8L | | | | | | 1 | | | | | | | | | | |
| 7.90 | | | | | | | | | | | | | | | | 1 |
| 8.0R | | | | 1 | | | | | | | | | | | | |
| 8.0R | | | | | | | | | | 1 | | | | | | |
| 8.1L | | | | | | | | | 1 | | | | | | | |
| 8.1R | | | | | | | | | | | | | 1 | | | |
| 8.2L | | | | | | | | | | | | | | | 1 | |
| 8.2L | | | | | | | | | | | | 1 | | | | |
| 8.2L | | | | | | | | | | | | 1 | | | | |
| 8.3L | | | | | | | | | | | | | 1 | | | |
| 8.3R | | | 1 | | | | | | | | | | | | | |
| 8.4L | | | | 1 | | | | | | | | | | | | |
| 8.4R | | | | | | | | | | | | | | | 1 | |
| 9.3L | | | | | | | | | | | 1 | | | | | |
| 9.3L | | | | | | | | | | | | | | | 1 | |
| 9.3R | | 1 | | | | | | | | | | | | | | |
| 9.4R | 1 | | | | | | | | | | | | | | | |
| TOTAL | 2 | 2 | 1 | 2 | 5 | 5 | 4 | 0 | 2 | 1 | 6 | 2 | 2 | 4 | 4 | 3 |

A benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Gilchrist Road 109-1. The results of the benefit cost analysis is shown in Table E.24. Table E.25 summarizes the funding request for safety improvements for Gilchrist Road 109-1.

### Table E.24 Benefit/Cost analysis on Gilchrist Road 109-1

**Benefit to Cost (B/C) Ratio Analysis for Safety Improvement**

| General Information | | Site Information | |
|---|---|---|---|
| Analyst | Cheng Zhong | Facility | Laramie, Gilchrist |
| Agency/Company | U W | Segment | 109-1 |
| Project | | Analysis Time Period | 1995-2005 |
| Date Performed | 9-16-2008 | Analysis Year | 2008 |
| | | Segment Length (mi.) | |

**Inputs**

| Crash Cost | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 109-1 | 1 | 12 | 13 | 2 | 19 | | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $27,000.00 | $22,500.00 | | | | $49,500.00 |
| **Benefit** | $1,319,200.00 | $1,484,100.00 | | | | $2,209,660.00 |
| **B/C Ratio** | 48.86 | 65.96 | | | | 44.64 |

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors Fatal | Injury | PDO | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $13,500 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | $22,500 | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table E.25 Funding Request for Safety Improvements on Gilchrist Road 109-1

| | | | | | | |
|---|---|---|---|---|---|---|
| **County:** Laramie | **Road Name:** Gilchrist | | **Road #:** 109-1 | | | **Date:** 7/16/2008 |
| **Road Class:** Minor Collector | **ADT:** 179 | **85th Speed:** 46 MPH | **Road Surface:** Gravel | | | |
| **Causative Factors Behind Crashes :** | 1. Overturns | | 4 | | | |
| | 2. Alignment | | 5 | | | |
| | 3 | | 6 | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
| Advance warning signs | 1 & 2 | 45 | $13,500 | 48.86 | | |
| Replace Cattleguards | 1 & 2 | 3 | $22,500 | 65.96 | | |
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| | | | | | | |
| | | **Total Request:** | $36,000 | **Total Approved** | $0 | |

# APPENDIX F.  JOHNSON COUNTY

## F.1 Crash Data Analysis

The WYT$^2$/LTAP Center selected 13 roads that have high ranking segments out of Table F.1. Table F.2 summarizes the selected high risk roads in Johnson County.

**Table F.1. Results from Crash Analysis in Johnson County**

| County Road | Mile Post | CRASHES | INJURIES | FATELS | PDOS |
|---|---|---|---|---|---|
| 8 | 0.00-1.00 | 12 | 3 | 0 | 9 |
| 1 | 4.01-5.00 | 5 | 0 | 0 | 5 |
| 91H | 2.01-3.00 | 5 | 2 | 0 | 3 |
| 91H | 3.01-4.00 | 5 | 0 | 0 | 5 |
| 1 | 8.01-9.00 | 4 | 3 | 0 | 1 |
| 14 | 1.01-2.00 | 4 | 2 | 0 | 2 |
| 252 | 0.00-1.00 | 4 | 1 | 0 | 3 |
| 252 | 1.01-2.00 | 4 | 1 | 0 | 3 |
| 256 | 0.00-1.00 | 4 | 3 | 0 | 1 |
| 256 | 1.01-2.00 | 4 | 1 | 0 | 3 |
| 91H | 0.00-1.00 | 4 | 1 | 0 | 3 |
| 1 | 2.01-3.00 | 3 | 0 | 0 | 3 |
| 1 | 11.01-12.00 | 3 | 0 | 0 | 3 |
| 3 | 0.00-1.00 | 3 | 1 | 0 | 2 |
| 13 | 4.01-5.00 | 3 | 0 | 0 | 3 |
| 40 | 0.00-1.00 | 3 | 1 | 0 | 2 |
| 85 | 4.01-5.00 | 3 | 1 | 0 | 2 |
| 132 | 2.01-3.00 | 3 | 0 | 0 | 3 |
| 212 | 0.00-1.00 | 3 | 1 | 0 | 2 |
| 55A | 1.01-2.00 | 3 | 1 | 0 | 2 |
| 55A | 3.01-4.00 | 3 | 0 | 0 | 3 |
| 91H | 1.01-2.00 | 3 | 0 | 0 | 3 |
| 91H | 4.01-5.00 | 3 | 1 | 0 | 2 |
| 91H | 7.01-8.00 | 3 | 1 | 0 | 2 |
| 1 | 5.01-6.00 | 2 | 1 | 0 | 1 |
| 1 | 9.01-10.00 | 2 | 0 | 0 | 2 |
| 1 | 12.01-13.00 | 2 | 1 | 0 | 1 |
| 3 | 1.01-2.00 | 2 | 0 | 0 | 2 |
| 3 | XXXXXXXX | 2 | 0 | 0 | 2 |
| 11 | 0.00-1.00 | 2 | 2 | 0 | 0 |
| 11 | 1.01-2.00 | 2 | 1 | 0 | 1 |
| 13 | 6.01-7.00 | 2 | 0 | 0 | 2 |
| 40 | 1.01-2.00 | 2 | 2 | 0 | 0 |
| 40 | XXXXXXXX | 2 | 0 | 0 | 2 |
| 78 | 14.01-15.00 | 2 | 1 | 0 | 1 |
| 85 | 3.01-4.00 | 2 | 0 | 0 | 2 |
| 114 | 2.01-3.00 | 2 | 1 | 0 | 1 |
| 195 | 10.01-11.00 | 2 | 1 | 0 | 1 |
| 204 | 0.00-1.00 | 2 | 0 | 0 | 2 |

XXXXXXXX = no mile post available

**Table F.2 Selected High Risk Rural Roads in Johnson County**

| Road No. | Road Name | Road Length | Evaluated Section |
|---|---|---|---|
| 1 | Rock Creek | 13.00 | 13 |
| 3 | Hazelton | 32.70 | 11 |
| 8 | Stockyard | 1.60 | 1.6 |
| 13 | Trabing | 15.50 | 15.5 |
| 14 | Crazy Woman Canyon | 8.49 | 8.49 |
| 40 | Kumor | 8.32 | 5 |
| 55A | Wagon Box | 4.30 | 4.3 |
| 85 | Shell Creek | 5.90 | 5.9 |
| 91H | French Creek | 12.20 | 12.2 |
| 132 | Klondike | 12.94 | 12.94 |
| 212 | Airport | 1.60 | 1.6 |
| 252 | North By-Pass/South By-Pass | 1.98 | 1.98 |
| 256 | Upper Clear Creek | 1.69 | 1.69 |

## F.2 Level I Field Evaluation

The WYT$^2$/LTAP Center performed level I field evaluations on the 13 selected roads. As shown on the right side of Table F.3, the Johnson County sections were ranked based on the results from the level I field evaluation. In addition to conducting the level I field evaluation, traffic volumes were collected on all 13 roads for a period of seven days.

**Table F.3 Crash Data and Level I Field Rankings for Johnson County**

| TOTAL CRASHES | County Road | Mile Post | CRASH RANKING |
|---|---|---|---|
| 12 | 8 | 0.00-1.00 | 1 |
| 5 | 1 | 4.01-5.00 | 2 |
| 5 | 91H | 2.01-3.00 | 2 |
| 5 | 91H | 3.01-4.00 | 2 |
| 4 | 1 | 8.01-9.00 | 5 |
| 4 | 14 | 1.01-2.00 | 5 |
| 4 | 252 | 0.00-1.00 | 5 |
| 4 | 252 | 1.01-2.00 | 5 |
| 4 | 256 | 0.00-1.00 | 5 |
| 4 | 256 | 1.01-2.00 | 5 |
| 4 | 91H | 0.00-1.00 | 5 |
| 3 | 1 | 2.01-3.00 | 12 |
| 3 | 1 | 11.01-12.00 | 12 |
| 3 | 3 | 0.00-1.00 | 12 |
| 3 | 13 | 4.01-5.00 | 12 |
| 3 | 40 | 0.00-1.00 | 12 |
| 3 | 85 | 4.01-5.00 | 12 |
| 3 | 132 | 2.01-3.00 | 12 |
| 3 | 212 | 0.00-1.00 | 12 |
| 3 | 55A | 1.01-2.00 | 12 |
| 3 | 55A | 3.01-4.00 | 12 |
| 3 | 91H | 1.01-2.00 | 12 |
| 3 | 91H | 4.01-5.00 | 12 |
| 3 | 91H | 7.01-8.00 | 12 |
| 2 | 1 | 5.01-6.00 | 25 |
| 2 | 1 | 9.01-10.00 | 25 |
| 2 | 1 | 12.01-13.00 | 25 |
| 2 | 3 | 1.01-2.00 | 25 |

| LEVEL I FIELD SCORE | ROAD NO. | MILE POST | LEVEL I RANKING |
|---|---|---|---|
| 17 | 55A | 3 to 4 | 1 |
| 18 | 55A | 2 to 3 | 2 |
| 19 | 1 | 4 to 5 | 3 |
| 19 | 55A | 1 to 2 | 3 |
| 20 | 1 | 11 to 12 | 5 |
| 20 | 13 | 4 to 5 | 5 |
| 20 | 13 | 5 to 6 | 5 |
| 20 | 13 | 6 to 7 | 5 |
| 20 | 13 | 7 to 8 | 5 |
| 20 | 256 | 0 to1 | 5 |
| 21 | 1 | 5 to 6 | 5 |
| 21 | 1 | 12 to 13 | 12 |
| 21 | 91.5 | 1 to 2 | 12 |
| 21 | 91.5 | 2 to 3 | 12 |
| 21 | 91.5 | 3 to 4 | 12 |
| 22 | 1 | 8 to 9 | 16 |
| 22 | 13 | 2 to 3 | 16 |
| 22 | 13 | 3 to 4 | 16 |
| 22 | 91.5 | 0 to 1 | 16 |
| 23 | 1 | 9 to 10 | 20 |
| 23 | 1 | 10 to 11 | 20 |
| 23 | 13 | 0 to 1 | 20 |
| 23 | 13 | 1 to 2 | 20 |
| 23 | 13 | 8 to 9 | 20 |
| 23 | 13 | 9 to 10 | 20 |
| 23 | 13 | 10 to 11 | 20 |
| 23 | 256 | 1 to 1.69 | 20 |
| 24 | 3 | 2 to 3 | 28 |

## F.3 Combined Ranking

Road segments identified as high crash locations were listed and ranked based on the total number of crashes as shown on the left side of Table F.3. Higher numbers of crashes resulted in lower rankings. Road segment scores obtained from level I field evaluations were also used to rank the sections. Lower field scores resulted in a lower rank. The right side of Table F.3 shows the level I field rankings for Johnson County. The crashes and level I rankings for each segment of roadway were added to obtain the combined rankings. The overall score and combined rankings for the 13 evaluated roadways are shown in Table F.4.

**Table F.4. Combined Ranking for High Risk Roads in Johnson County**

| ROAD NO. | MILE POST | OVERALL SCORE | COMBINED RANKING |
|---|---|---|---|
| 1 | 4 to 5 | 5 | 1 |
| 256 | 0 to1 | 10 | 2 |
| 55A | 3 to 4 | 13 | 3 |
| 91.5 | 2 to 3 | 14 | 4 |
| 91.5 | 3 to 4 | 14 | 4 |
| 55A | 1 to 2 | 15 | 6 |
| 1 | 11 to 12 | 17 | 7 |
| 13 | 4 to 5 | 17 | 7 |
| 1 | 8 to 9 | 21 | 9 |
| 91.5 | 0 to 1 | 21 | 9 |
| 91.5 | 1 to 2 | 24 | 11 |
| 256 | 1 to 1.69 | 25 | 12 |
| 13 | 6 to 7 | 30 | 13 |
| 1 | 5 to 6 | 30 | 13 |
| 1 | 12 to 13 | 37 | 15 |
| 8 | 0 to 1 | 37 | 15 |
| 14 | 1 to 2 | 41 | 17 |
| 55A | 2 to 3 | 45 | 18 |
| 1 | 9 to 10 | 45 | 18 |
| 1 | 2 to 3 | 48 | 20 |
| 91.5 | 4 to 5 | 48 | 20 |
| 91.5 | 7 to 8 | 48 | 20 |
| 212 | 0 to 1 | 48 | 20 |
| 13 | 5 to 6 | 49 | 24 |
| 13 | 7 to 8 | 49 | 24 |

## F.4 Level II Field Evaluation

The $WYT^2$/LTAP Center and the Johnson County Road & Bridge supervisor selected three roads which had a high combined ranking out of Table F.4. These roads are 1, 8, and 55A. The causative factors behind the crashes were identified from the WYDOT crash data, and traffic volumes were obtained on the three selected roads prior to performing the level II field evaluation.

## F.5 Benefit/Cost Analysis

After conducting the level II field evaluations, appropriate safety countermeasures were selected. Benefit cost analyses were conducted to determine the cost effectiveness of the proposed countermeasures. The $WYT^2$/LTAP Center developed simple Excel worksheets to calculate the benefit/cost ratios for all proposed countermeasures.

## F.6 Level II Field Evaluation for Johnson County Rock Creek Road 1

Rock Creek Road 1 has a paved surface for the first 6.2 miles and has a gravel surface on the final 6.8 miles. It is 13.00 miles in length. It starts at the North ROW of Highway 90 between mile posts 56 and 57. This road ends at a ranch driveway. It is classified as a minor collector. The average daily traffic (ADT) at three different locations is 261, 425, and 307 vehicles per day. The road is used for residential access, recreational purposes, and agricultural activities. The ten-year crash data between 1995 and 2005 for Rock Creek Road 1 are shown in Table F.5.

**Table F.5 Ten Year Crash Data for Rock Creek Road 1**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 1 | 00004 | 97 | 6 | 4 | 0 |
| 1 | 00260 | 05 | 1 | 0 | 0 |
| 1 | 00270 | 00 | 2 | 0 | 0 |
| 1 | 00300 | 02 | 1 | 0 | 0 |
| 1 | 00370 | 00 | 2 | 0 | 0 |
| 1 | 00420 | 00 | 2 | 0 | 0 |
| 1 | 00440 | 02 | 1 | 0 | 0 |
| 1 | 00471 | 97 | 1 | 0 | 0 |
| 1 | 00494 | 98 | 1 | 0 | 0 |
| 1 | 00500 | 04 | 1 | 0 | 0 |
| 1 | 00530 | 03 | 1 | 1 | 0 |
| 1 | 00575 | 97 | 1 | 0 | 0 |
| 1 | 00624 | 97 | 4 | 2 | 0 |
| 1 | 00800 | 03 | 2 | 0 | 0 |
| 1 | 00810 | 99 | 1 | 1 | 0 |
| 1 | 00880 | 05 | 1 | 1 | 0 |
| 1 | 00890 | 97 | 5 | 2 | 0 |
| 1 | 00890 | 03 | 2 | 0 | 0 |
| 1 | 00980 | 97 | 1 | 0 | 0 |
| 1 | 01000 | 97 | 3 | 0 | 0 |
| 1 | 01110 | 99 | 2 | 0 | 0 |
| 1 | 01150 | 96 | 1 | 0 | 0 |
| 1 | 01170 | 98 | 3 | 0 | 0 |
| 1 | 01220 | 99 | 2 | 1 | 0 |
| 1 | 01280 | 01 | 2 | 0 | 0 |
| 1 | X | 01 | 4 | 0 | 0 |

The WYT$^2$/LTAP Center performed a level I field evaluation on the entire 13.00 miles of Rock Creek Road 1. Table F.6 shows the results of the level I field evaluation.

**Table F.6 Level I Field Evaluation Data Results on Rock Creek Road 1**

| MILE POST | GENERAL | SHOULDER | INTSC\ RR | SIGN\PVM | FIX OBJ | SUM | COMMENTS | MILE POST |
|---|---|---|---|---|---|---|---|---|
| 0 to 1 | 8 | 6 | 7 | 3 | 5 | 29 | No Del. Posts Poor Pave Markin No Warning Signs | 0 to 1 |
| 1 to 2 | 8 | 5 | 5 | 3 | 5 | 26 | Same As Above | 1 to 2 |
| 2 to 3 | 8 | 5 | 5 | 3 | 5 | 26 | Same As Above | 2 to 3 |
| 3 to 4 | 7 | 5 | 5 | 3 | 5 | 25 | Same As Above | 3 to 4 |
| 4 to 5 | 4 | 4 | 5 | 1 | 5 | 19 | Same As Above | 4 to 5 |
| 5 to 6 | 4 | 5 | 5 | 2 | 5 | 21 | Need Warning Signs | 5 to 6 |
| 6 to 7 | 6 | 6 | 5 | 4 | 5 | 26 | 6.2 Pavement Ends-Gravel Need Warning Signs | 6 to 7 |
| 7 to 8 | 6 | 6 | 5 | 4 | 5 | 26 | Need Warning Signs | 7 to 8 |
| 8 to 9 | 5 | 5 | 5 | 2 | 5 | 22 | Need Warning Signs | 8 to 9 |
| 9 to 10 | 5 | 5 | 5 | 3 | 5 | 23 | Need Warning Signs | 9 to 10 |
| 10 to 11 | 5 | 5 | 5 | 3 | 5 | 23 | Need Warning Signs | 10 to 11 |
| 11 to 12 | 4 | 4 | 5 | 2 | 5 | 20 | Need Warning Signs | 11 to 12 |
| 12 to 13 | 4 | 4 | 5 | 3 | 5 | 21 | Need Warning Signs | 12 to 13 |

As shown in Table F.7, alignment-related, leaving the ROW, and motor vehicle to motor vehicle crashes are the most common on Rock Creek Road 1.

The WYT$^2$/LTAP Center and the Johnson County Road & Bridge supervisor reviewed the safety needs of Rock Creek Road and it was determined that 27 advance warning signs, 112 delineators, and 6.2 miles of pavement markings are needed to reduce the alignment–related, leaving the ROW, and motor vehicle to motor vehicle crashes. Table F.8 summarizes the proposed signs and their locations.

**Table F.7 Causative Factors for Crashes on Rock Creek Road 1**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 12 | ***Curve And Level*** | ***10*** |
| Gravel | 13 | ***Curved Downgrade*** | ***8*** |
| Dirt | 1 | Curved Hillcrest | 1 |
| | | Curved Upgraded | |
| **Lighting** | | Straight Hillcrest | |
| Dark | 13 | Straight Level | 4 |
| Dawn or Dusk | 1 | Straight Downgrade | 3 |
| Daylight | 12 | Straight Upgrade | |
| | | Other | |
| **Road Conditions** | | | |
| Dry | 17 | **Traffic Control** | |
| Icy | 7 | None | 19 |
| Muddy | | Yield Sign | 1 |
| Slush | | Pavement Marking | 4 |
| Snowy | 1 | Stop Sign | 1 |
| Wet | 1 | Warning | |
| Unknow | | Flagman | 1 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 23 | Antelope | |
| Sleet/Hail | | ***Berm/Ditch*** | ***2*** |
| Snowing | 2 | Cow | |
| Strong Wind | | ***Deer*** | ***2*** |
| Dust | | ***Mv-Mv*** | ***6*** |
| Fog | | Overturn | 4 |
| Rain | 1 | ***Boulder/Rock*** | ***1*** |
| Unknown | | ***Shrub/Tree*** | ***1*** |
| Ground Blizzard | | Mail Box | |
| | | ***Bridge/Rail*** | ***1*** |
| **Roadway Junction** | | ***Fence*** | ***8*** |
| Non-Junction | 23 | Post | |
| Drive Way Access | 0 | Barricade | |
| Intersection | 3 | Other | 1 |

**Table F.8 Needed Safety Items and Locations for Rock Creek Road 1**

| **County:** Johnson | | | | **Road Name:** Rock Creek | | **Road #: 1** | | | | | **Date: 8-25-08** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Road Class:** | | **ADT:** 425 | | | | **85th Speed:** ? | | **Road Surface:** Pavement & Gravel | | | | |
| LOCATION | PAVEMENT MARKINGS | DELINEATORS | STOP R1-1 | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | CURVE LT W1-2 | CURVE RT W1-2 | WINDING ROAD W1-5 | ONE LANE BRIDGE W5-3 | END OF PAVEMENT W8-3 | ARROW W1-6 |
| 0.0-6.2 | 6.2 Miles | | | | | | | | | | | |
| 0.0-6.2 | | 112 | | | | | | | | | | |
| 0.7R | | | | | | | 1 | | | | | |
| 1.0L | | | | | | | | 1 | | | | |
| 1.5R | | | | | | | | | | | | 1 |
| 4.6R | | | | | | | | | 1 | | | |
| 4.8R | | | | 1 | | | | | | | | |
| 4.9L | | | | | | | | | 1 | | | |
| 4.9L | | | | | | | | | | | | 1 |
| 5.2L | | | | | | | | 1 | | | | |
| 5.3R | | | | | | | 1 | | | | | |
| 5.6L | | | | | | | 1 | | | | | |
| 6.2R | | | | | | | | | | | 1 | |
| 6.3R | | | | | | | | | 1 | | | |
| 6.8R | | | | | | | | | 1 | | | |
| 7.5R | | | | | | | | 1 | | | | |
| 7.8L | | | | | | | 1 | | | | | |
| 7.9R | | | | | | | | | 1 | | | |
| 8.3L | | | | | | | | | 1 | | | |
| 8.7R | | | | | | | | | 1 | | | |
| 9.1L | | | | | | | | | 1 | | | |
| 9.2R | | | | | | | | | 1 | | | |
| 10.2L | | | | | | | | | 1 | | | |
| 11.5R | | | | | | | | | 1 | | | |
| 11.8R | | | | | | | | | | 1 | | |
| 12.0L | | | | | | | | | | 1 | | |
| 12.1L | | | | | | | | | 1 | | | |
| 12.7L | | | | | | | | | | 1 | | |
| 12.5R | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | |
| TOTAL | 6.2 Miles | 112 | 0 | 1 | 0 | 0 | 4 | 3 | 12 | 4 | 1 | 2 |

A benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Rock Creek Road 1. Table F.9 summarizes the results of the benefit cost analysis. Table F.10 summarizes the funding request for safety improvements for Rock Creek Road 1.

**Table F.9 Benefit/Cost Analysis on Rock Creek Road 1**

**Benefit to Cost (B/C) Ratio Analysis for Safety Improvement**

| General Information | |
|---|---|
| Analyst | Bart Evans |
| Agency/Company | UW |
| Project | Rock Creek |
| Date Performed | 11/24/2008 |

| Site Information | |
|---|---|
| Facility | Johnson County |
| Road | 1 |
| Analysis Time Period | 1996-2005 |
| Analysis Year | |
| Segment Length (mi.) | |

**Inputs**

| Crash Cost | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 1 | 0 | 7 | 19 | 2 | 5 | 8 | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $18,900.00 | $8,400.00 | $12,500.00 | | | $39,800.00 |
| **Benefit** | $213,600.00 | $58,740.00 | $176,220.00 | | | $342,945.48 |
| **B/C Ratio** | 11.30 | 6.99 | 14.10 | | | 8.62 |

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors | | | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| | | | Fatal | Injury | PDO | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $9,450 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | $3,360 | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | $2,500 | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table F.10 Funding Request for Safety Improvements on Rock Creek Road 1

| | | | | | | |
|---|---|---|---|---|---|---|
| **County:** Johnson | **Road Name:** Rock Creek | | **Road #:** 1 | | **Date:** | 8/25/2008 |
| **Road Class:** Minor Collector | **ADT:** 425 | **85th Speed:** | **Road Surface:** Pavement & Gravel | | | |
| **Causative Factors Behind Crashes :** | 1. Alignment | | 4 | | | |
| | 2. Leaving the right of way | | 5 | | | |
| | 3. Motor vehicle to motor vehicle | | 6 | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
| Advance warning signs | 1, 2 &3 | 27 | $9,450 | 11.3 | | |
| Delineators | 1, 2 &3 | 112 | $3,360.00 | 6.99 | | |
| Pavement Markings | 1, 2 &3 | 6.2 Miles | $9,300.00 | 3.79 | | |
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| | | | | | | |
| | | **Total Request:** | $22,110.00 | **Total Approved:** | | |

## F.7 Level I Field Evaluation for Johnson County Stockyard Road 8

Johnson County Stockyard Road 8 has a gravel surface and is 1.6 miles in length. It starts at the East ROW of Johnson County Road 252 near mile post 0.5. This road ends at the South ROW of Johnson County Road 204. Road 8is classified as a local road. The 10-year crash data between 1995 and 2005 for Johnson County Stockyard Road 8 are shown in Table F.11. The average daily traffic (ADT) is 134 vehicles per day.

**Table F.11 10-Year Crash Data for Stockyard Road 8**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 8 | 00001 | 98 | 2 | 0 | 0 |
| 8 | 00002 | 95 | 2 | 0 | 0 |
| 8 | 00025 | 05 | 1 | 0 | 0 |
| 8 | 00060 | 96 | 1 | 0 | 0 |
| 8 | 00080 | 95 | 3 | 0 | 0 |
| 8 | 00080 | 00 | 4 | 0 | 0 |
| 8 | 00080 | 01 | 2 | 0 | 0 |
| 8 | 00095 | 96 | 2 | 0 | 0 |
| 8 | 00100 | 99 | 4 | 4 | 0 |
| 8 | 00100 | 00 | 5 | 0 | 0 |
| 8 | 00100 | 01 | 3 | 2 | 0 |
| 8 | 00100 | 05 | 1 | 1 | 0 |
| 8 | 00140 | 03 | 2 | 0 | 0 |

The WYT$^2$/LTAP Center performed a level I field evaluation on the entire 1.6 miles of Stockyard Road 8. Table F.12 shows the results of the level I field evaluation for Johnson County Road 8.

**Table F.12 Level I Field Evaluation for Stockyard Road 8**

| MILE POST | GENERAL | SHOULDER | INTSC \RR | SIGN\PVM | FIX OBJ | SUM | COMMENTS | MILE POST |
|---|---|---|---|---|---|---|---|---|
| 0 to 1 | 7 | 5 | 2 | 5 | 7 | 26 | 2 curves (90) Not signed | 0 to 1 |
| 1 to 2 | 7 | 5 | 3 | 5 | 7 | 27 | 1 curve not signed | 1 to 2 |

As shown in Table F.13, the causative factor behind the crashes on Stockyard Road 8 are alignment and overturn crashes.

**Table F.13 Causative Factors for Crashes for Stockyard Road 8**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 0 | ***Curve And Level*** | ***3*** |
| Gravel | 12 | ***Curved Downgrade*** | ***7*** |
| Dirt | 1 | Curved Hillcrest | 0 |
| | | ***Curved Upgraded*** | ***1*** |
| **Lighting** | | Straight Hillcrest | 0 |
| Dark | 7 | Straight Level | 0 |
| Dawn or Dusk | 1 | Straight Downgrade | 0 |
| Daylight | 5 | Straight Upgrade | 2 |
| | | Other | |
| **Road Conditions** | | | |
| Dry | 13 | **Traffic Control** | |
| Icy | 0 | None | 12 |
| Muddy | 0 | Other | 0 |
| Slush | 0 | Pavement Marking | 0 |
| Snowy | 0 | Stop Sign | 1 |
| Wet | 0 | Warning | 0 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 13 | Antelope | 0 |
| Sleet/Hail | 0 | Berm/Ditch | 1 |
| Snowing | 0 | Cow | 0 |
| Strong Wind | 0 | Deer | 0 |
| Dust | 0 | Mv-Mv | 0 |
| Fog | 0 | ***Overturn*** | ***9*** |
| Rain | 0 | Snow Embankment | 0 |
| Unknown | 0 | Parked Vehicle | 0 |
| Ground Blizzard | 0 | Mail Box | 0 |
| | | Guard Rail | 0 |
| **Roadway Junction** | | Fence | 2 |
| Non-Junction | 13 | Post | 1 |
| Drive Way Access | 0 | Barricade | 0 |
| Intersection | 0 | Other | 0 |

The WYT[2]/LTAP Center determined that 11 advance warning signs are needed to reduce the number of alignment-related and overturn crashes occurring on Road 8. Table F.14 summarizes the proposed signs and their locations.

**Table F.14. Proposed Sign Types and Locations for Stockyard Road 8**

| **County:** Johnson | | | | **Road Name:** Stockyard | | **Road #:** 8 | | | | | **Date:** 8-25-08 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Road Class:** | | **ADT:** 134 | | | | **85th Speed:** 37 | | **Road Surface:** Gravel | | | | |
| LOCATION | STOP R1-1 | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | CURVE LT W1-2 | CURVE RT W1-2 | CURVE & T LT W1-10 | CURVE & T RT W1-10 | SPEED LIMIT 35 R2-1 | SPEED LIMIT 20 R2-1 | SPEED LIMIT 35 W13-1 | ARROW W1-6 |
| 0.1L | | 1 | | | | | | | | | | |
| 0.3R | | | 1 | | | | | | | | | |
| 0.4R | | | | | | | | | | | | 1 |
| 0.5L | | | | 1 | | | | | | | | |
| 0.6R | | | | | | | | 1 | | | | |
| 0.8L | | | | | | | 1 | | | | | |
| 0.8L | | | | | | | | | 1 | | | |
| 0.8R | | | | | | | | | 1 | | | |
| 1.0R | | | | | | | 1 | | | | | |
| 1.2L | | | | | | | | 1 | | | | |
| 1.5R | | 1 | | | | | | | | | | |
| | | | | | | | | | | | | |
| TOTAL | 0 | 2 | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 1 |

| | |
|---|---|
| TOTAL SIGNS= | 11 |

A benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Stockyard Road 8**.** Table F.15 summarizes the results of the benefit cost analysis. Table F.16 summarizes the funding request for safety improvements for Stockyard Road 8.

**Table F.15 Benefit/Cost analysis for Stockyard Road 8**

**Benefit to Cost (B/C) Ratio Analysis for Safety Improvement**

| **General Information** | |
|---|---|
| Analyst | Bart Evans |
| Agency/Company | UW |
| Project | Stockyard |
| Date Performed | 11/24/2008 |

| **Site Information** | |
|---|---|
| Facility | Johnson County |
| Road | 8 |
| Analysis Time Period | 1996-2005 |
| Analysis Year | |
| Segment Length (mi.) | |

**Inputs**

| **Crash Cost** | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| **Number of Crashes** | | | | **Countermeasures** | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 8 | 0 | 3 | 10 | 2 | | | | |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $7,700.00 | | | | | $7,700.00 |
| **Benefit** | $96,000.00 | | | | | $96,000.00 |
| **B/C Ratio** | 12.47 | | | | | 12.47 |

| **Countermeasure Number** | **Countermeasures** | **Crash Type** | **Crash Reduction Factors** | | | **Cost** | **Service Life** |
|---|---|---|---|---|---|---|---|
| | | | **Fatal** | **Injury** | **PDO** | | |
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $3,850 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table F.16 Funding Request for Safety Improvements on Stockyard Road 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **County:** Johnson | **Road Name:** Stockyard | | **Road #:** 8 | | | **Date:** | 8/25/2008 |
| **Road Class:** Local | **ADT:** 134 | **85th Speed:** 37 | **Road Surface:** Gravel | | | | |
| **Causative Factors Behind Crashes :** | 1. Alignment | | 4 | | | | |
| | 2. Overturns | | 5 | | | | |
| | 3 | | 6 | | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** | |
| Advance warning signs | 1 & 2 | 11 | $3,850 | 12.47 | | | |
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| | | | | | | | |
| | | **Total Request:** | $3,850.00 | **Total Approved:** | | | |

### F.8 Level I Field Evaluation for Johnson County Wagon Box Road 55A

Johnson County Wagon Box Road 55A has a paved surface for the first 0.4 miles and has a gravel surface on the final 5.6 miles. It is 6.00 miles in length and starts at the South ROW of Wyoming State Highway 193 near mile post 0.5. This road ends at the Johnson-Sheridan County line. Road 55A is classified as a minor collector. The average daily traffic (ADT) is 180 vehicles per day. The road is used for residential access and agricultural activities. The ten-year crash data between 1995 and 2005 for Johnson County Wagon Box Road 8 are shown in Table F.17.

**Table F.17 10-Year Crash Data for Wagon Box Road 55A**

| County Road | Milepost | Year | # Persons | # Injured | # Fatalities |
|---|---|---|---|---|---|
| 55A | 00170 | 00 | 1 | 1 | 0 |
| 55A | 00180 | 95 | 5 | 0 | 0 |
| 55A | 00190 | 99 | 2 | 0 | 0 |
| 55A | 00240 | 96 | 3 | 3 | 0 |
| 55A | 00330 | 04 | 1 | 0 | 0 |
| 55A | 00400 | 95 | 2 | 0 | 0 |
| 55A | 00400 | 03 | 1 | 0 | 0 |
| 55A | 00480 | 97 | 2 | 0 | 0 |
| 55A | X | 03 | 1 | 0 | 0 |

The WYT$^2$/LTAP Center performed a level I field evaluation on the entire 6.0 miles of Wagon Box Road 55A. Table F.18 shows the results of the level I field evaluation for Johnson County Road 55A.

**Table F.18 Level I Field Evaluation for Wagon Box Road 55A**

| MILE POST | GENERAL | SHOULDER | INTSC\ RR | SIGN\PVM | FIX OBJ | SUM | COMMENTS | MILE POST |
|---|---|---|---|---|---|---|---|---|
| 0 to 1 | 8 | 7 | 6 | 5 | 4 | 30 | Few trees in R.O.W | 0 to 1 |
| 1 to 2 | 4 | 5 | 3 | 3 | 4 | 19 | Narrow Windy, Many Intersections, Poor S. S. Distance | 1 to 2 |
| 2 to 3 | 4 | 4 | 4 | 3 | 3 | 18 | Same as above | 2 to 3 |
| 3 to 4 | 4 | 4 | 3 | 3 | 3 | 17 | Same as above | 3 to 4 |
| 4 to 4.3 | 7 | 5 | 7 | 3 | 4 | 26 | End | 4 to 4.3 |

As shown in Table F.19, alignment related, leaving the ROW and motor vehicle to motor vehicle crashes are the most common occurrences on Wagon Box Road 8.

**Table F.19 Causative Factors for Every Crash for Wagon Box Road 55A**

| Causative Factors | No. of Crashes | Causative Factors | No. of Crashes |
|---|---|---|---|
| | | | |
| **Road Surface** | | **Road Alignment** | |
| Asphalt | 0 | ***Curve And Level*** | ***4*** |
| Gravel | 5 | ***Curved Downgrade*** | ***2*** |
| Dirt | 3 | Curved Hillcrest | 0 |
| | | Curved Upgraded | 0 |
| **Lighting** | | Straight Hillcrest | 0 |
| Dark | 2 | Straight Level | 1 |
| Dawn or Dusk | 0 | Straight Downgrade | 1 |
| Daylight | 7 | Straight Upgrade | 1 |
| | | Other | 0 |
| **Road Conditions** | | | |
| Dry | 1 | **Traffic Control** | |
| Icy | 5 | None | 9 |
| Muddy | 0 | Other | 0 |
| Slush | 0 | Pavement Marking | 0 |
| Snowy | 2 | Stop Sign | 0 |
| Wet | 1 | Warning | 0 |
| Unknow | 0 | Barrels/Cone | 0 |
| | | | |
| **Weather** | | **FHE** | |
| Clear | 7 | Antelope | |
| Sleet/Hail | | ***Berm/Ditch*** | ***2*** |
| Snowing | 1 | Cow | |
| Strong Wind | | Deer | |
| Dust | | ***Mv-Mv*** | ***2*** |
| Fog | | Overturn | 1 |
| Rain | 1 | Snow Embankment | |
| Unknown | | Parked Vehicle | |
| Ground Blizzard | | ***Mail Box*** | ***1*** |
| | | Guard Rail | |
| **Roadway Junction** | | Fence | |
| Non-Junction | 8 | Post | |
| Drive Way Access | 1 | Barricade | |
| Intersection | 0 | ***Shrub/Tree*** | ***3*** |

The WYT$^2$/LTAP Center determined that 13 advance warning signs, 16 object markers, 18 delineators, three 24-foot cattleguards, and 0.4 miles of pavement markings are needed to reduce the alignment related, leaving the ROW, and motor vehicle to motor vehicle crashes. Table F.20 summarizes the proposed signs and cattleguards and their locations.

**Table F.20 Needed Safety Items and Locations for Wagon Box Road 55A**

**County:** Johnson **Road Name:** Wagon Box **Road #:** 55A **Date:** 8-25-08

**Road Class:** **ADT:** 179 **85th Speed:** ? **Road Surface:** Pavement and Gravel

| LOCATION | PAVEMENT MARKINGS | DELINEATORS | OBJECT MARKERS OM-3C | STOP AHEAD W3-1 | CURVE LT W1-1 | CURVE RT W1-1 | WINDING ROAD W1-5 | 4 WAY INTERSECTION W2-1 | T INTERSECTION W2-2 | 24' CATTLE GUARD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0-0.4 | | 18 | | | | | | | | |
| 0.0-0.4 | 0.4 Miles | | | | | | | | | |
| 0.1L | | | | 1 | | | | | | |
| 0.3R | | | | | | 1 | | | | |
| 0.3R | | | | | | | | 1 | | |
| 0.40 | | | | | | | | | | 1 |
| 0.40 | | | 4 | | | | | | | |
| 0.5L | | | | | | | | 1 | | |
| 0.5L | | | | | 1 | | | | | |
| 0.5R | | | | | | | | | 1 | |
| 0.6L | | | | | | | | | 1 | |
| 1.30 | | | | | | | | | | 1 |
| 1.30 | | | 4 | | | | | | | |
| 1.5R | | | | | | | 1 | | | |
| 1.9L | | | | | | | 1 | | | |
| 1.9R | | | | | | | 1 | | | |
| 2.3L | | | | | | | 1 | | | |
| 2.30 | | | | | | | | | | 1 |
| 2.30 | | | 4 | | | | | | | |
| 2.50 | | | | | | | | | | 1 |
| 2.50 | | | 4 | | | | | | | |
| 3.7R | | | | | | | 1 | | | |
| 4.4L | | | | | | | 1 | | | |
| | | | | | | | | | | |
| TOTAL | 0.4 Miles | 18 | 16 | 1 | 1 | 1 | 6 | 2 | 2 | 4 |

A benefit cost analysis was conducted to determine the cost effectiveness of the proposed countermeasures for Wagon Box Road 55A. The results of the benefit cost analysis are shown in Table F.21. Table F.22 summarizes the funding request for safety improvements for Wagon Box Road 55A

## Table F.21 Benefit/Cost Analysis for Wagon Box Road 55A

### Benefit to Cost (B/C) Ratio Analysis for Safety Improvement

**General Information**

| | |
|---|---|
| Analyst | Bart Evans |
| Agency/Company | UW |
| Project | Wagon Box |
| Date Performed | 11/24/2008 |

**Site Information**

| | |
|---|---|
| Facility | Johnson County |
| Road | 55A |
| Analysis Time Period | 1996-2005 |
| Analysis Year | |
| Segment Length (mi.) | |

**Inputs**

**Crash Cost**

| | |
|---|---|
| Fatal | 2,500,000 |
| Injury | 60,000 |
| Property Damage Only (PDO) | 6,000 |

| Number of Crashes | | | | Countermeasures | | | | |
|---|---|---|---|---|---|---|---|---|
| *Road Segment* | *Fatal* | *Injury* | *PDO* | *A* | *B* | *C* | *D* | *E* |
| 55A | 0 | 2 | 7 | 2 | 3 | 5 | 8 | 19 |

**Calculation**

| | *Countermeasures* | | | | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | Combined |
| **Cost** | $9,100.00 | $1,440.00 | $1,350.00 | $5,000.00 | $32,000.00 | $48,890.00 |
| **Benefit** | $64,800.00 | $56,700.00 | $17,820.00 | $53,460.00 | $72,900.00 | $141,279.17 |
| **B/C Ratio** | 7.12 | 39.38 | 13.20 | 10.69 | 2.28 | 2.89 |

| Countermeasure Number | Countermeasures | Crash Type | Crash Reduction Factors Fatal | Injury | PDO | Cost | Service Life |
|---|---|---|---|---|---|---|---|
| 1 | Install guide signs (general) | All | 15% | 15% | 15% | | 5 |
| 2 | Install advance warning signs (positive guidance) | All | 40% | 40% | 40% | $4,550 | 5 |
| 3 | Install chevron signs on horizontal curves | All | 35% | 35% | 35% | $720 | 5 |
| 4 | Install curve advance warning signs | All | 30% | 30% | 30% | | 5 |
| 5 | Install delineators (general) | All | 11% | 11% | 11% | $540 | 4 |
| 6 | Install delineators (on bridges) | All | 40% | 40% | 40% | | 4 |
| 7 | Install edgelines, centerlines and delineators | All | 0% | 45% | 0% | | 4 |
| 8 | Install centerline markings | All | 33% | 33% | 33% | $1,000 | 2 |
| 9 | Improve sight distance to intersection | All | 56% | 37% | 0% | | 15 |
| 10 | Flatten crest vertical curve | All | 20% | 20% | 20% | | 15 |
| 11 | Flatten horizontal curve | All | 39% | 39% | 39% | | 15 |
| 12 | Improve horizontal and vertical alignments | All | 58% | 58% | 58% | | 15 |
| 13 | Flatten side slopes | All | 43% | 43% | 43% | | 15 |
| 14 | Install guardrail (at bridge) | All | 22% | 22% | 22% | | 10 |
| 15 | Install guardrail (at embankment) | All | 0% | 42% | 0% | | 10 |
| 16 | Install guardrail (outside curves) | All | 63% | 63% | 0% | | 10 |
| 17 | Improve guardrail | All | 9% | 9% | 9% | | 10 |
| 18 | Improve superevlevation | All | 40% | 40% | 40% | | 15 |
| 19 | Widen bridge | All | 45% | 45% | 45% | $32,000 | 15 |
| 20 | Install shoulder | All | 9% | 9% | 9% | | 5 |
| 21 | Pave shoulder | All | 15% | 15% | 15% | | 5 |
| 22 | Install transverse rumble strips on approaches | All | 35% | 35% | 35% | | 3 |
| 23 | Improve pavement friction | All | 13% | 13% | 13% | | 5 |
| 24 | Install animal fencing | Animal | 80% | 80% | 80% | | 10 |
| 25 | Install snow fencing | Snow | 53% | 53% | 53% | | 10 |

Table F.22 Funding Request for Safety Improvements on Wagon Box Road 55A

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **County:** Johnson | **Road Name:** Wagon Box | | | **Road #:** 55A | | **Date:** | 8/26/2008 |
| **Road Class:** Local | **ADT: 179** | | **85th Speed:** | **Road Surface:** Pavement and Gravel | | | |
| **Causative Factors Behind Crashes :** | 1. Alignment | | | 4 | | | |
| | 2. Leaving Right of way | | | 5 | | | |
| | 3. Motor Vehicle to Motor Vehicle | | | 6 | | | |
| **Counter Measure** | **Crash Type Affected** | **Quantity** | | **Estimated Cost** | **Benefit/Cost** | **Approved Amount** | **Funding Source** |
| Advance warning signs | 1 & 2 | 13 | | $4,550 | 7.12 | | |
| Object Markers | 1 & 2 | 16 | | $720.00 | 39.38 | | |
| Delineators | 1 & 2 | 18 | | $540.00 | 13.2 | | |
| Pavement Marking | 1 & 2 | 0.4 Miles | | $1,000.00 | 10.69 | | |
| 24' Cattleguards | 1 & 2 | 4 | | $32,000.00 | 2.89 | | |
| | | **Total Request:** | | $38,810 | **Total Approved:** | | |

# APPENDIX G. WRRSP GUIDE

# TABLE OF CONTENTS

# Introduction

The High Risk Rural Roads Program (HRRRP) was introduced by Section148 (f) of the 2005 *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.* This new safety Program is a component of a State's overall Highway Safety Improvement Plan (HSIP) and comes with annual dedicated funding.

A High Risk Rural Road, as defined by Federal Statutory requirements, are those public roadways functionally classified as rural major or minor collectors or rural local roads, and have or will have, based on increasing traffic volumes, a crash history that ranks that road, or section of road, as a high risk rural roadway. The required crash history must be based on comprehensive crash data able to identify the location of crashes and crash types. Eligible projects will provide construction and operational improvements on high risk rural roads with identified crash histories.

WYDOT Highway Safety Program, as the administrative agency for the HSIP and in accordance with the Wyoming Strategic Highway Safety Plan – Special Safety Area, has developed a High Risk Rural Roads Program to implement construction and operational improvements on high risk rural roads, off of the State Highway System. Delivery of the HRRRP is a Highway Safety Program effort with assistance from the Wyoming Technology Transfer Center Local Technical Assistance Program (LTAP), and in cooperation with Local Government project sponsors.

## Wyoming Department of Transportation Contacts

Project Proposals
Attn: Rich Douglass, LGC
5300 Bishop Blvd.
Planning Building Room 215
Cheyenne, WY 82009
307-777-4759
rich.douglass@dot.state.wy.us

HRRRP Information & Reimbursement
Attn: Matt Carlson, P.E.
State Highway Safety Engineer
5300 Bishop Blvd.
Cheyenne, WY 82009
307-777-4450 Fax: 307-777-4250
Matt.Carlson@dot.state.wy.us

District Contacts

Attn: District Engineer
WYDOT District 1
3411 South 3rd Street
Laramie, WY 82070

Attn: District Engineer
WYDOT District 2
900 Bryon Stock Trail
Casper, WY 82601

Attn: District Engineer
WYDOT District 3
3200 Elk Street
Rock Springs, WY 82901

Attn: District Engineer
WYDOT District 4
10 East Brundage Lane
Sheridan, WY 82801

Attn: District Engineer
WYDOT District 5
218 West C.
Basin, WY 82410

# High Risk Rural Roads Program (HRRRP)

A. Purpose

The purpose of this Program is to correct safety deficiencies on an identified statewide system of rural roads where, due to low traffic volumes, major improvements do not appear to be cost effective.

B. Goal

The goal of this Program is to reduce traffic fatalities and injuries on Wyoming's high risk rural roads.

C. Eligible Use of Funds

Program funds are directed to a statewide listing of projects, off of the State Highway System, for construction and operational improvements on the high risk rural roads selected through the LTAP Wyoming Rural Road Safety Program.

## Identification of High Risk Roads and Countermeasures/Improvements

A Local government project sponsor is any public, tax-supported County government. The project sponsor is responsible for developing project proposals meeting the Program Purpose and contributing to the Program Goal. All projects must be on public right-of-way and under the legal jurisdiction of the sponsor. Wyoming counties, interested in the HRRRP, must contact the Wyoming Technology Transfer Center Local Technical Assistance Program (LTAP) to initiate implementation of their safety program (see Appendix A).

WYDOT has contracted with the LTAP to develop a Wyoming Rural Road Safety Program (WRRSP) by County, and to assist each Sponsor in assuring that their project proposal complies with Program Eligible Use of Funds. The WRRSP uses a five step approach, summarized as:

1) Crash Data Analysis - Crash Data, for each County, has been developed and supplied by the WYDOT Highway Safety Program to assist in the evaluation of a County's road system and further support their submission of a project proposal. Crash data is specific to location and crash type, and provides the data needed to determine crash histories. This effort complies with Federal program requirements for use of Comprehensive Crash Data.

2) Level 1 Field Evaluation - Roadway functional classification and the Crash Data Analysis are used in this field evaluation, with analysis by one mile segments, to gain a condition rating of each roadway, from worst to best. Condition ratings are tailored to each county and use between five and ten ratings selected from the following roadway elements: General, Road Alignment, Road Surface, Shoulders/Clear Zones/ROW Widths, Intersection and Rail Road Crossings, Signage and Pavement Markings, Fixed Objects/Clear Zones, Bridges and Culverts, Visibility, and Environmental. Traffic volumes are collected for these same roadways.

3) Identification of High Risk Locations - A combined ranking is developed by roadway segment, using total number of crashes and roadway condition ratings.

A listing of high risk rural roads is developed and prioritized based on these combined rankings. This effort complies with Federal program requirements for identification of a High Risk Rural Road, eligible for Program funding.

4) Level II Field Evaluation to Identify Countermeasures – The prioritized listing of high risk rural roads provides specific routes that are moved to a detailed evaluation of crash types, causative crash factors, and contributing roadway elements. Countermeasures/ improvements, to correct identified safety deficiencies, are then recommended with the goal for reducing traffic fatalities and injuries on the selected high risk rural road. The range of countermeasures/ improvements, selected from national research as contributing to crash reductions, are presented later as a listing of project types for packaging into a project proposal. This effort complies with Federal program requirements for identification of eligible projects that provide construction and operational improvements on high risk rural roads with documented crash histories.

5) Benefit/cost Analysis – Benefit cost analyses are conducted to determine the cost effectiveness of the proposed safety countermeasure/improvement. Project costs are based on the summation of labor, equipment and material costs; project benefits are based on the use of Crash Reduction Factors (CRF), by safety countermeasure, times a crash cost identified as $2,500,000. for each fatal, $60,000.00 for each injury, and $6,000.00 for each property-damage-only (PDO) crash.

Crash Reduction Factors are given for the range of countermeasures/ improvements presented later as a listing of project types for packaging into a project proposal.

The final product of the WRRSP is a funding request form, included as part of the sponsor's project proposal.

## Project Proposals – Schedule and Content

As previously noted, Wyoming Counties, as the project sponsor, are responsible for developing project proposals meeting the Program Purpose and contributing to the Program Goal. The proposal must be submitted on an application, initiated as the final product of the WRRSP, furnished by WYDOT; the application is in Appendix B.

**Project Proposal Schedule**

April: Each County/project sponsor must submit a Project Proposal to the WYDOT Office of Local Government Coordination (LGC) by April 20 of each year.

April – June: The Highway Safety Program, through the SMS Project Subcommittee, evaluates each Project Proposal against Program purpose and available Program funding, and develops a statewide project list and funding priorities. The statewide project list is presented to and adopted by the Wyoming Transportation Commission, at its June Meeting.

July – September: WYDOT LGC, develops a Cooperative Agreement, for each project on the statewide project list, and coordinates the execution of the Agreement with project sponsor. Project sponsors are advised of Agreement provisions and Program requirements consistent with the project work type. A Cooperative Agreement is executed. The LGC will coordinate issuance of an Authority for Expenditure.

September: WYDOT Highway Safety Program issues a Notice to Proceed to each project sponsor.

**Project Proposal Content**

The Local government, before developing a project proposal for HRRRP funding, must contact the LTAP and assist in completing a WRRSP for their county. As noted above, completion of the

WRRSP will identify and prioritize a listing of high risk rural roads in their county, and recommend safety countermeasures/ improvements. The information and data in the WRRSP are used to initiate a Project Proposal, consistent with the above schedule.

HRRRP funding is available to complete preliminary and final engineering, environmental documentation, utility accommodation, right-of-way acquisition and project construction activities; however each project must result in the construction of the proposed safety countermeasure/improvement. The LTAP will assist project sponsors with these activities.

A listing of safety countermeasures/improvements, used in the WRRSP and eligible for HRRRP funding, are presented in Table 1, along with Crash Reduction Factors.
Project sponsors, through participation in the WRRSP, may identify other countermeasures that contribute to crash reductions, and include those improvements in a Project Proposal. The LTAP should be contacted to assist in determining and documenting an appropriate CRF for those countermeasures.

**Table 1 - Countermeasures/Improvements and Crash Reduction Factors**

| Safety Countermeasure/Improvement | CRF Fatal | CRF Injury | CRF PDO | Design Reference |
|---|---|---|---|---|
| Install Guide Signs (general) | 15% | 15% | 15% | 1 |
| Install Advance Warning Signs (positive guidance) | 40% | 40% | 40% | 1 |
| Install chevron signs on horizontal curves | 35% | 35% | 35% | 1 |
| Install curve advance warning signs | 30% | 30% | 30% | 1 |
| Install delineators (general) | 11% | 11% | 11% | 1 |
| Install delineators on bridges | 40% | 40% | 40% | 1 |
| Install edgelines, centerlines, and delineators | 0% | 45% | 0% | 1 |
| Install centerline markings | 33% | 33% | 33% | 1 |
| Install guardrail at bridge | 22% | 22% | 22% | 2 |
| Install guardrail at embankment | 0% | 42% | 0% | 2 |
| Install guardrail outside of horizontal curves | 63% | 63% | 0% | 2 |
| Improve sight distance to intersection | 56% | 37% | 0% | 3 |
| Flatten crest vertical curve | 20% | 20% | 20% | 3 |
| Flatten horizontal curve | 39% | 39% | 39% | 3 |
| Improve horizontal and vertical alignments | 58% | 58% | 58% | 3 |
| Flatten side slopes | 43% | 43% | 43% | 3 |
| Improve super-elevation | 40% | 40% | 40% | 3 |
| Widen bridge | 45% | 45% | 45% | 3 |
| Install shoulder | 9% | 9% | 9% | 3 |
| Pave shoulder | 15% | 15% | 15% | 3 |
| Install transverse rumble strips on approaches | 35% | 35% | 35% | 3 |
| Improve pavement friction | 13% | 13% | 13% | 3 |
| Install animal fencing | 80% | 80% | 80% | 3 |
| Install snow fencing | 53% | 53% | 53% | 3 |
| Other | TBD | TBD | TBD | TBD |

1 - *Manual on Uniform Traffic Control Devices*
2 - NCHRP *Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features*
3 - *County Road Fund Manual* and WYDOT *Standard Plans*

Each County/project sponsor must submit a Project Proposal to the WYDOT Office of Local Government Coordination (LGC) by April 20 of each year.
***<u>The proposal must be submitted on an application, initiated as the final product of the WRRSP, furnished by WYDOT, and shown in Appendix B.</u>***

## Project Funding, Sponsor Match, Eligible Costs, Reimbursement

The HRRRP is a federally funded program administered by the WYDOT Highway Safety Program. WYDOT will annually allocate Program funding to support the efforts of the project sponsor in identifying and implementing eligible safety projects.

**Project Funding including Project Sponsor Match**
Each project, selected for the statewide project listing, will be funded at 90.49% of project cost up to a maximum of $100,000.00 of federal funds and will require a 9.51% project sponsor cash match, or project sponsor over-match as described later. For example, a project at the maximum federal funding of $100,000.00 will require a project sponsor match of $10,509.00 providing for a maximum cost, per project, of $110,509.00.

**Project Sponsor Overmatch**
Projects selected for the statewide listing with costs exceeding the above limits may be over-matched by the project sponsor, when necessary to fully fund construction of the safety countermeasure/improvement. The maximum amount of federal funds, for each project, cannot exceed $100,000.00, but the project sponsor may elect to over-match, as needed, if the cost to construct exceeds Program funding limits.

For example, an eligible project where the summation of labor, equipment and material costs equals $250,000.00 may be submitted with the understanding that HRRRP funding is limited to $100,000.00 and the project sponsor would be responsible for the remaining $150,000.00.

Project sponsors are advised that a funded project, even when overmatched, will remain a federal project requiring the inclusion of federal contracting requirements.

**Project Sponsor In-Kind Match**
The project sponsor, as part of the proposal, may use an in-kind match in lieu of the minimum 9.51% cost match discussed above. In-kind match requires WYDOT advance approval.

An in-kind match must have equal value to the cost match and can come from sources including:

+ credit from donation of funds, materials, or services
+ credit from County Force Account Work – labor, materials, equipment – provided or performed by the project sponsor. The use of Force Account must be supported by a Public Interest Finding (see Appendix C) documented on WYDOT Form LGC-PIF and submitted with the Project Proposal, and approved by WYDOT.

The above are allowable providing appropriate documentation is available to support the credited amount.

**Eligible Costs**
The WYDOT Notice to Proceed establishes the beginning date for eligible project costs; any costs incurred prior to the Notice to Proceed will not be reimbursed. Extra work/ claims must be within the scope of the Cooperative Agreement and within project funding limitations.

**Reimbursement of Project Costs**
WYDOT will make payment of project funds to the project sponsor on a cost-reimbursement basis, with reimbursement forms provided by WYDOT at Notice to Proceed. The project sponsor will complete the reimbursement form and submit to the WYDOT Highway Safety Program.

**Final Payment**
The project sponsor, when requesting final reimbursement, shall also complete and submit WYDOT Form LPE-3 Acceptance Certificate and Final Completion.
LPE-3 will require the project sponsor certify to WYDOT that the project has been completed in substantial conformance with the plans and specifications, including compliance with Wyoming State Statute 16-6-116 Final Settlement and Payment.

## Project Completion

The executed Cooperative Agreement will require that each project be completed within 2 years of WYDOT Notice to Proceed.

## HRRRP Project Requirements

The executed Cooperative Agreement will require that the project sponsor comply with the following Agreement provisions. The project sponsor is advised to be familiar with contract provisions, during development of the project proposal, outlined in the Cooperative Agreement.

***The LTAP will assist project sponsors with developing project proposals that comply with these provisions.***

**Pre-Construction Requirements**
The executed Cooperative Agreement will require that the project sponsor comply with the following pre-construction provisions.

Design Standards**:** Project sponsors are responsible for completion of project plans and contracts and compliance with applicable design standards. As presented in Table 1, project designs and contract plans must comply with provisions of the *Manual on Uniform Traffic Control Devices* for signs and pavement markings; compliance NCHRP *Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features* for installation of roadside safety hardware; and compliance with the County Road Fund Manual or WYDOT *Standard Plans*, for roadway design and construction elements. All references to design standards are the current and adopted editions.

Environmental Compliance**:** Project sponsor is responsible for compliance with all applicable environmental and other local, state, and federal laws and regulations. The sponsor must satisfy the requirements of the National Environmental Policy Act and complete the required environmental documentation, typically a Categorical Exclusion. LTAP will provide assistance, as needed.

Rights-of-way Acquisition: The sponsor must certify, in their project proposal, that the public roadway rights-of-way are held by the local government entity (Rights-of-Way Certificate).
The acquisition of additional rights-of-way is not anticipated with HRRRP project types, however if additional rights-of-way or construction permits are required, the project sponsor will comply with the applicable provisions of an executed Cooperative Agreement between the Wyoming Department of Transportation and the Project Sponsor. LTAP will provide assistance, as needed.

Utility Adjustments**:** The project sponsor will make all arrangements, by agreement with affected utility owners, for utility relocations or adjustments. All arrangements will be in compliance with the *State's Utility Accommodation Regulations.* Project sponsor must certify, in their project proposal that utility accommodation have been or will be completed (Utility Certificate). LTAP will provide assistance, as needed.

Project Plans and Contracts: The contract will specify, at a minimum, the project plan and specifications and include bid units with method of measurement and basis of payment. Specifications will determine the method of acceptance of all materials incorporated in the project.

Letting**:** The letting and the award of a HRRRP project will be completed by the project sponsor. Construction shall be performed by private construction firms, qualified by the sponsor; no in-State preference will apply for materials, labor, contracts or subcontracts. Project bidding shall follow accepted local government bidding procedures for open and public competitive bidding, including public advertising. WYDOT reserves the right to review all contract bids prior to contract award. After bid analysis, the sponsor will award to the lowest responsive bidder and proceed with project construction.

Additional Federal Contracting Requirements: The HRRRP is a federally funded program and requires compliance with Federal contracting requirements.

Required Federal Contract Provisions: All contracts shall include the federal form PR-1273, Required Contract Provisions for Federal-aid Construction Contracts.

Disadvantaged Business Enterprises (DBE): The sponsor should encourage the participation of DBE contractors and sub-contractors in design and construction of the project. If the project does not specifically require DBE participation goal, the contract should so state.

Payment of Predetermined Minimum Labor Rates: Contract documents must include provisions for compliance with payment of wages and fringe benefits as required by the form PR-1273.

Public - Owned Equipment, Material, or Labor: Contract provisions requiring the use of public-owned equipment, materials, or labor, including the use of County Force Account as In-kind Match, must be supported by a Public Interest Finding documented on WYDOT Form LGC-PIF and submitted with the Project Proposal.

**Construction Requirements**

The executed Cooperative Agreement will require that the project sponsor comply with the following construction provisions.

Construction**:** Construction of the project will be completed in accordance with the plans and specifications; extra work/claims must be within the scope of the contract and project funding limitations. Project sponsor shall conduct project inspections during active construction; WYDOT representatives may inspect the project at their discretion.

Construction Engineering: Construction Engineering for the project will be performed by and under the immediate direction, control, and supervision of the project sponsor and will document, at a minimum, the methods of measurement, basis of payments, and method of acceptance of all materials incorporated in the project.

Project Final Inspection: The sponsor will final inspect the completed project and notify WYDOT of final inspection; WYDOT representatives may participate in final inspection at their discretion.

Project Acceptance: The sponsor will certify to WYDOT that the project has been completed in substantial conformance with the plans and specifications, including compliance with Wyoming State Statute 16-6-116 Final Settlement and Payment. This effort should be coordinated with the sponsor's request for final reimbursement.

**Post-Construction Requirements**
The executed Cooperative Agreement will require that the project sponsor comply with the following post-construction provisions.

Maintenance: Upon completion and acceptance of the project by the project sponsor and WYDOT, with assistance from LTAP, the sponsor shall maintain at its sole expense the safety improvements in their original constructed condition.

In-Service: The sponsor agrees to maintain the public road in-service and not permanently close or abandon the public road without written consent of WYDOT.

## HRRRP Project Monitoring and Evaluation Process

The project sponsor, consistent with responsibilities presented above for Construction Engineering, will monitor the completion of each project and prepare summary reports to be submitted to WYDOT LGC. Summary reports will be at contract award, project final inspection, and project final acceptance.

LTAP will select project sponsors to assist in conducting a project closeout review and evaluation. This Project-Level evaluation is intended to address the effectiveness of each project in meeting the Program Purpose, Goal, and Eligible Use of Funds, and provide lessons learned to improve delivery of future projects.

Project sponsors will be asked to cooperate with the LTAP in the evaluation process.

Annually, the Highway Safety Program will develop a Program-Level report for the Executive Staff.

# Appendix A – OVERVIEW of PROJECT PROPOSAL PROCESS & PROJECT CONSTRUCTION

The Project Proposal Process identifies time-frames and responsibilities for the delivery of project proposals that meet the HRRRP Purpose and Project Requirements.

Wyoming counties, interested in the HRRRP, must contact and work with the Wyoming Technology Transfer Center Local Technical Assistance Program (LTAP) to develop a Wyoming rural road safety program (WRRSP). The LTAP will also assist the project sponsor in all responsibilities noted below.

LTAP Contact: Khaled Ksaibati, Ph.D, P.E., Director, khaled@uwyo.edu
Bart Evans, Road Safety Analyst, mevans2@uwyo.edu
Wyoming Technology Transfer Center
Department of Civil and Architectural Engineering
1000 E. University Ave. Dept. 3295
Laramie, WY 82071 PH: 307-766-6230
http://wwweng.uwyo.edu/wyt2/

## Pre-Construction Process

| **Annual Timeframe** | **Project Sponsor** | **WYDOT LGC** | **WYDOT Highway Safety Program & SMS Project Sub-Comm.** |
|---|---|---|---|
| February Prior Year | Coordinate with LTAP Develop WRRSP | | |
| December Prior Year | | | Solicit Project Proposals |
| April 20 Current Year | Submit Proposal to WYDOT LGC | Collects Project Proposals | |
| April – May | | Screen Project Proposals | Screen Project Proposals |
| May | | | Recommended Project Listing to Transportation Commission |
| June | | Approval Listing to Programming for STIP | Transportation Commission Approves Project Listing |
| July | | Prepare Cooperative Agreements<br><br>Advise Sponsor of Agreement Requirements | Process Cooperative Agreements with Sponsor, through Districts<br><br>Advise Sponsor of Program Requirements |
| August | | Executes Agreements with Project Sponsor<br><br>Coordinates AFE | |
| September | After Notice to Proceed, Sponsor Completes Program Requirements, e.g. NEPA and Other | Develops Notice to Proceed for Highway Safety<br><br>Reimbursement Form issued to Project Sponsor | Notice to Proceed issued to Project Sponsor |

## Construction Process

| Annual Timeframe | Project Sponsor | WYDOT Highway Safety Program | WYDOT Representative or LTAP |
|---|---|---|---|
| September to Finish | Completes all Pre-Construction Functions: Design, Environmental, ROW, Utility<br><br>Submits CE, ROW Certification Utility Certification, if needed | Receives Environmental documentation<br><br>Receives CE, ROW and Utility Certifications | |
| Project Sponsor to Determine | Lets Project to open, competitive bidding<br><br>Completes bid analysis | | Reserves the right to review all bids |
| Project Sponsor to Determine | Awards project to lowest responsive bidder, cc: WYDOT | | Receives notice of award |
| Project Sponsor to Determine | Issues Notice to Proceed to Construction Contractor<br><br>Submits Reimbursement Form to Highway Safety Program | Processes Reimbursement Form through Federal-aid for payment | |
| Project Sponsor to Determine | Completes Construction Engineering and Project Monitoring | | Reserves the right to inspect project records and construction progress |
| Project Sponsor to Determine | Conducts Final Inspection with Notification to WYDOT Representative | | Reserves the right to final inspect project and records |
| Project Sponsor to Determine<br><br>SEE NOTE | Completes Final Acceptance with Certification to WYDOT Highway Safety Program<br><br>Submits Final Payment Reimbursement Form and LPE-3 Acceptance Certificate | Receives Certification<br><br>Receives and Processes Reimbursement Form through Federal-aid for payment | |

NOTE: The executed Cooperative Agreement will require that each project be completed within 2 years of WYDOT Notice to Proceed.

## Post-Construction Process

| Timeframe | Project Sponsor | LTAP | WYDOT Representative |
|---|---|---|---|
| To Be Determined | Assists LTAP in project evaluation | Conducts project closeout review and evaluation | |
| Perpetuity | Maintains project safety improvements | | Reserves the right to assure maintenance |
| Perpetuity | Road remains in-service | | Reserves the right to assure road remains in-service |

# Appendix B - Application
# WYDOT Highway Safety Program
# High Risk Rural Road Program (HRRRP)

**Application is available at** http://wwweng.uwyo.edu/wyt2/

## Instructions to Applicants

| | | | |
|---|---|---|---|
| ☐ | Complete all sections of the attached application<br><br>Consult the *HRRRP Program Guide* and LTAP to aid in completing the application | ☐ | A Funding Request for Safety Improvement table, provided by LTAP, of the proposed HRRRP project site must be attached to this application (8.5" X 11" is preferred for reproduction purposes) |
| ☐ | Application must be signed and dated on the spaces below by the individual(s) authorized to sign for the Project Sponsor | ☐ | Please include any pictures, maps or other visual aids of the proposed project with this application (8.5" X 11" is preferred for reproduction purposes) |
| ☐ | An Authorizing Resolution from the sponsor must be attached to this application | ☐ | **Application deadline:** the application must be postmarked/ received by the agency shown below no later than September 30, 2009. |

Mail completed application to:

**University of Wyoming**
**Technology Transfer Center**
**Wyoming T$^2$/LTAP**
**Dept. 3295**
**100 E. University Avenue**
**Laramie, WY 82071**
*Attn: Khaled Ksaibati, Director*

Phone #: 800-231-2815
Fax #: (307) 766-6784
Email: khaled@uwyo.edu

**http://wwweng.uwyo.edu/wyt2**

Name of Applicant / Project Sponsor: ______________________________

Date of Application: ______________________________

Signature of Authorized Official: ______________________________

Title of Authorized Official: ______________________________

## ***Project Name and Sponsor***

**Note:** The project sponsor is a Wyoming County Government. The sponsor must initiate appropriate authorizing action – Authorizing Resolution – approved at a public meeting and signed by the sponsoring body. A sample copy of this resolution is included with this application. A copy of the Authorizing Resolution and/or reference to the meeting minutes should be included with this application. If the project application is approved by the Wyoming Transportation Commission, the Project Sponsor agrees to enter into a project agreement with WYDOT for funding and project responsibilities.

**Project Sponsor:** ____________________

**Project Name:** ____________________

## ***Sponsor Information***

| | Primary Contact | Secondary Contact (if Applicable) |
|---|---|---|
| Contact Person and Title: | | |
| | | |
| Address: | | |
| | | |
| | | |
| | | |
| Phone: | | |
| Fax: | | |
| Email: | | |

## ***Project Type***

Identify the type of project being proposed for funding with the High Risk Rural Road Program (HRRRP) funding: The type of project must be taken from the Wyoming Rural Road Safety Program (WRRSP) developed jointly by the County and LTAP. The needed information is summarized in the WRRSP Funding Request for Safety Improvements.

## ***Project Description***

**Please give a brief, but concise description of the proposed project.** Include a description of any geographical or environmental features which may be sensitive and will be impacted by this project i.e., a stream crossing or wetland intrusion to the work site. Please include a map of the general project area. It is preferred, for reproduction purposes, that this map and other supporting documents are in standard letter size (8.5" X 11") format.
**If available, attach photo(s) which illustrate current road conditions.**

## ***Planning and Preliminary Considerations***

Please describe the project planning and road selection criteria prior to this application being submitted. Please include the following information in the spaces provided below:

| | |
|---|---|
| 1. Has the County completed a WRRSP and coordinated with the Local Technical Assistance Program (LTAP)? | |
| 2. Does the project conform to the applicable design standards? | |
| 3. Will the County use an in-kind match in lieu of the required cost match? | |

**Note:** If the County uses its own equipment, workforce, or materials, a Public Interest Finding must be sent to and approved by the WYDOT prior to beginning work (see Appendix C).

## ***Real Property Acquisition***

The ownership of the ROW or easement, for a HRRR project must vest with the County. It is advised that the ROW for any project be secured before the application for the project is submitted. The location of the roadway may be assumed under the County Road System, yet encumbered in some way. The title to the property must not be encumbered with conditions or reservations which prohibit the requested HRRR project. If the there is any question as to ownership or title for the property is in question, a title search would be advisable.
***The county will be required to complete a WYDOT Right-of-Way Certification Form, WYDOT Form LP-2, prior to constructing the proposed HRRRP Project.*** A copy of WYDOT Form LP-2 is included with this application and must be submitted to WYDOT, as required by Appendix A of the *HRRRP Program Guide*. Please identify the current status of rights-of-way ownership and proposed project acquisitions.

☐ The project will be constructed within existing right-of-way and ownership is vested with the County. No additional acquisitions are needed.

☐ The project will require additional right-of-way acquisitions and they have been secured with ownership vested with the County.

☐ The project will require additional right-of-way and it will be secured, using HRRRP funds, with ownership vested with the County.

## ***Environmental Considerations***

The sponsor must comply with all Federal and State environmental regulations. Projects involving construction or combined with a larger construction/reconstruction project will require completion of an ***Environmental Document***, typically a Categorical Exclusion. The sponsor must identify the type of document required for compliance with Federal environmental regulations.
Three types of Categorical Exclusions are available for use by the project sponsor.

☐ *Categorical Exclusion Type 1*: This document is available for use on those project types presented in the *HRRRP Program Guide* Table 1. with a **design reference 1. and 2**, as these project types are all within existing rights-of-way, require minimal ground disturbance, and are not associated with any stream or drainage. For these types of projects, NEPA requirements are satisfied when the sponsor provides WYDOT with a letter presenting the project description followed by: This project is a Programmatic Categorical Exclusion under 23 CFR 771.117 (c) or (d) as approved by the Federal Highway Administration, as CE 02-27, on April 3, 2002.

☐ *Categorical Exclusion Type 2*: This document is available for use on those project types, presented in the *HRRRP Program Guide Table 1*. with a **design reference 3**, and are within existing rights-of-way, require minimal ground disturbance, and are not in proximity to a stream or drainage. For these types of projects, NEPA requirements are satisfied when the sponsor provides WYDOT with a letter presenting the project description followed by: This project is a Programmatic Categorical Exclusion under 23 CFR 771.117 (d) as approved by the Federal Highway Administration, as CE 02-27, on April 3, 2002.

☐ *Categorical Exclusion Type 3*: This document is available for use for those project types, presented in the *HRRRP Program Guide Table 1*. with a **design reference 3**, and may require minor amounts of additional rights-of-way or construction permits, or may require ground disturbance for cuts or fills, or may require work in or adjacent to streams or drainages. For these types of projects, NEPA requirements are satisfied when the sponsor analyzes project impacts to environmental resources present in the project area and provides WYDOT with a letter presenting the project description and, at a minimum, addressing the following: 1) impacts to water quality and wetlands if the project includes excavation or fill into or adjacent to streams for drainages (proposed work must qualify for a Nationwide Permit by the U.S. Army Corps of Engineers); 2) impacts to threatened or endangered species or habitat if the project includes excavation or fill into or adjacent to streams or drainages; 3) impacts to cultural resources to include a cultural survey and coordination under Section 106 of the National Historic Preservation Act.
The analysis should identify all impacts and the efforts made to avoid or minimize impacts including any proposed mitigation. This Categorical Exclusion must be signed by the Federal Highway Administration (FHWA) prior to construction.

## ***Utility Accommodation***

The sponsor must certify, prior to project construction, that utility accommodation has been completed. Please identify the current status of utility accommodation.

☐ Project will not require the relocation or adjustment of utilities.

☐ Project may require the relocation or adjustment of utilities, using HRRRP funds, and a Utility Certification will be completed, as required by Appendix A of the *HRRRP Program Guide.*

## ***Project Maintenance***

Project maintenance and perpetual care will be the responsibility of the project sponsor. Another party may do the actual physical maintenance, if an agreement is entered into between that party and the project sponsor. Should the public interest and ownership change in the future, the public maintenance responsibility can be passed along with the public title. (i.e.: County road ownership would be changed from County to City via annexation). Please state whether the project sponsor will be responsible for the maintenance directly or whether an agreement for maintenance will be entered into with another party. A copy of that agreement must be on file in the Local Government Office and should be included with this application.

## ***Project Administration***

Please provide the following information:

| | |
|---|---|
| Name & Contact Information of the Project Administrator<br>(if different than the contact person listed in section 2 above).<br>The County's Administrator will also act as the liaison between the sponsor and WYDOT/LTAP. The project administrator will ensure compliance with various State and Federal Program requirements. | |
| Will the project design and contract bidding documents be produced by the sponsor's staff or by a consultant? If a consultant is used, WYDOT Operating Policy 40-1 must be followed. | |
| Who will review the project design and contract bid documents for the sponsor, or sponsor staff? | |
| What governing body awards the contract? | |
| Who will perform the construction management, including final inspection and final acceptance? | |

## ***Project Budget***

Cost estimates should be incorporated in this budget to reflect the costs that are expected to be incurred in the project. While project totals may exceed $100,000, Federal participation in this project is limited to $100,000.00 and must be matched at the 90.49/9.51% ratio. Any amount in excess of the required 9.51% match contributed by the sponsor is allowable and will be considered overmatch as noted below. This budget will aid in the process of selection of any project proposal for a HRRR project. The budget line items should not be understood to be absolute, as they may be changed later, if necessary, to reflect actual costs after the project has begun.

| Project Element | HRRRP Funds (90.49%) | Local Match (9.51%) | Total (100%) |
|---|---|---|---|
| **Engineering Costs** | | | |
| **ROW Costs** | | | |
| **Utility Adjustment Costs** | | | |
| **Construction Engineering Costs** | | | |
| **Construction Costs** | | | |
| **Total** | | | |

**Note:** A cash match is much easier to track, with little documentation. Also, please include a line item summary of the details of the proposed project cost estimate to include charges for engineering, design, ROW, utilities and construction items. Again, if there questions about these items, please do not hesitate to call the WYDOT office listed on the cover of this application.

## ***Project Funding Summary***

Federal HRRR funds requested (90.49% of project costs) ______________________________

Local Match (cash or other match) (9.51% of project costs) ______________________________

Other funds available as overmatch (not required) ______________________________

Total Project Cost ______________________________

# Appendix C - Public Interest Finding

The WYDOT Highway Safety Program has determined that the HRRR Program will allow the project sponsor, as part of its proposal, to use an in-kind match in lieu of the minimum 9.51% cost match. The use of in-kind match requires WYDOT LGC advance approval, and will require that the project sponsor provide appropriate documentation to support the credited amount.

An in-kind match must have equal value to the cost match and can come from sources including: + a credit from donation of funds, materials, or services, and/or

> + a credit from County Force Account Work – equipment, labor, and materials, provided or performed by the project sponsor. The use of Force Account must be supported by a Public Interest Finding documented on WYDOT Form LGC-PIF and submitted with the Project Proposal.

This Appendix provides additional guidance on the documentation required to support the use of in-kind matches.

> Public-owned Equipment: The project proposal must identify the type of equipment, the proposed use, the equipment hourly rental rate, and the hours of use. Mobilization, Standby, Overhead, and Profit costs will not be eligible for reimbursement, except as provided by the agreed hourly rental rate. The hourly rental rate should be determined using established Rental Rate Guides, such as Blue Book, with regional adjustments. The transporting of equipment or materials to the project site will be reimbursed using applicable equipment rental rates and operator labor rates.

> Labor: Public employee equipment operator and labor rates will be supported by Sponsor records of actual standard pay, and may be adjusted to include the value of employee benefits. Overtime pay is not eligible for reimbursement.

> Materials: Manufactured materials, provided by the Project Sponsor, must be acquired through open, competitive bidding and will be reimbursed at invoice costs, including delivery to the project. Local materials, such as borrow, aggregates, or recycled materials, must be identified in the Proposal and identified by the type, the proposed use, the quantity, and a unit cost based on prices typical to the area.

> Donated Materials and Labor: The monetary value of donated materials must be supported by evidence of current retail market value. The monetary value of donated labor/services must be consistent with public employee labor rates for similar services.