Crow Tribal Transportation Department
BIA 91 Corridor Study

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Prepared by:

KLJ

ENGINEERING, REIMAGINED

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1.0 EXECUTIVE SUMMARY

The purpose of this BIA 91 Corridor Study is to assess the current pavement condition, assess the current roadway safety measures, review historical crash data, provide recommendations for roadway improvements, and provide estimated project limits and cost within the corridor.

BIA 91 is a 44.8-mile-long, two lane, rural major collector highway in Big Horn County with a posted speed limit of 50 mph between Pryor and St. Xavier and a posted speed of 35 mph within the two communities. The condition of the pavement throughout the corridor is in generally fair. A system called Pavement Surface Evaluation and Rating (PASER) method developed by the Federal Highway Administration (FHWA) was utilized for evaluating the existing pavement condition. This method is based on visual assessment of the current highway condition and provides recommended roadway treatments based on the current pavement condition. The roadway slide slopes are generally within current design standards, with exception within some areas of the corridor and areas near existing bridges may exceed those slopes. These locations are identified in the recommendations section of the study.

Currently on BIA 91 many of the existing roadway signs are missing or are in poor condition. The corridor is lacking adequate guardrail in areas of steep side slopes and near the bridge ends.

Our recommendations for improvements to this highway are comprehensive in nature. They will improve the structural capabilities of the highway, improve ride quality, and improve highway safety. Below is a list of project phasing recommendations throughout the corridor:

Recommended BIA 91 Project Phasing	
Route Improvement	*Project Costs*
Phase 1: RP 0.0 – RP 7.0	$3,251,820
Phase 2: RP 7.0 – RP 13.0	$5,811,426
Phase 3: RP 13.0 – RP 18.1	$4,787,209
Phase 4: RP 18.1 – RP 28.0	$1,840,939
Phase 5: RP 28.0 – RP 34.0	$5,213,440
Phase 6: RP 34.0 – RP 40.5	$1,132,700
Phase 7: RP 40.5 – RP 44.8	$4,515,389
Pryor Gap Road	$340,922

Table 1.1: Recommended BIA 91 Project Phasing

These proposed project limits will need final roadway design plans and specifications, survey, right-of-way, and an approved environmental document prior to beginning construction. It is also recommended that a geotechnical engineer perform soil borings throughout the corridor to provide the final full depth pavement repair recommendations and a pavement design for BIA 91.

The project phases recommend in this report do not need to be designed and constructed in the order in which they are given. The Crow Tribal Transportation may choose which phase to begin first depending on their desire and the available funds. It is recommended if the Tribe wishes to start with Phase 7 that the remaining projects go to design and construction from east to west and vice versa if the Tribe wishes to Start with Phase 1 the remaining projects go to design and construction from west to east.

2.0 INTRODUCTION

The Crow Indian Reservation was established in 1868 and is the homeland of the Crow Tribe. The Reservation encompasses approximately 2.3 million acres (3,566 square miles) in southcentral Montana and sits in Yellowstone and Big Horn counties, bordered by Wyoming on the south and the northwestern boundary approximately 10 miles from Billings, MT. The Crow Tribe has over 13,000 enrolled tribal members about 75% (9,750) reside on the reservation. Where 85% speak Crow as their first language.

Currently, the main uses of land in the area are for agriculture and ranching. Coal has been developed since the 1970's. The Crow Tribe does not have the capacity to generate the same revenue generated by the coal industry. The Tribe recognizes its need to steer away from its reliance on coal revenue.

BIA 91 is a 44.8-mile-long, two lane, rural major collector highway in Big Horn County with a posted speed limit of 50 mph between Pryor and St. Xavier and a posted speed of 35 mph within the two communities. The route begins at the intersection of Montana Secondary Highway 418 in Pryor and heads east transitioning between many horizontal curves and tangent stretches of roadway to the intersection of Montana Secondary Highway 313 and BIA 91 in St. Xavier. A map of the route location is attached in Appendix A.

An additional 0.8-mile roadway section was evaluated for this report, Pryor Gap Road. This roadway is a two lane, rural major collector highway with a posted speed limit of 35 mph. The route begins at the intersection of Montana State Highway 418 and BIA 91 and heads west through a horizontal curve and terminates at the intersection Pryor Road and Pryor Gap Road near Chief Plenty Coups State Park.

The purpose of this report is to review the following corridor features:

- Current Pavement Conditions
- Existing Safety Conditions
- Existing Roadway Signs
- Pavement Markings
- Historical Crash Data

Reviewing these features will assist in providing recommendations for improving the pavement surface condition and improving roadway safety along the route. This report will deliver recommended improvement projects for BIA 91.

Figure 2.1: BIA 91 Existing Conditions



3.0 Existing Roadway Condition

The corridor field inventory was completed August 10-13, 2020. The inventory consisted of inventorying the pavement width and condition every mile, all existing signs, guardrail, side slopes of the roadway, and other roadside safety features. The following sections discuss the findings of the field inventory.

Existing Pavement Conditions

The PASER rating system was used to document the pavement condition throughout the corridor. The PASER system provides a 1-10 rating for pavement conditions. A rating of 10 means the pavement is in new condition. A rating of 1 indicates a gravel road. The pavement width and roadway in slopes at 1-mile increments and noticeable roadway surface changes were also documented. The complete PASER manual is attached in the appendices. The conditions are summarized in the table below:

BIA 91 Existing Roadway Conditions				
Reference Post	*Roadway Width (Feet)*	*PASER Score*	*In Slope Left (H:V)*	*In Slope Right (H:V)*
0.00	29.0	6	4.9:1	4.1:1
1.00	29.0	5	7.5:1	5.1:1
2.00	29.0	5	4.1:1	5.3:1
3.00	29.0	5	25.0:1	8.5:1
4.00	29.0	6	5.5:1	5.5:1
5.00	29.0	6	4.3:1	3.9:1
6.00	29.0	5.5	5.7:1	4.8:1
7.00	29.0	6	6.9:1	4.4:1
8.00	28.0	6	2.7:1	3.3:1
9.00	29.0	5.5	2.3:1	2.4:1
10.00	29.0	5.5	6.5:1	5.1:1
10.20	28.0	5.5	10.3:1	12.8:1
10.50	27.0	7	15.9:1	7.9:1
11.00	29.0	6	2.6:1	1.8:1
12.00	28.0	5.5	5.3:1	6.2:1
13.00	28.0	4.5	8.8:1	5.8:1
14.00	27.0	5	2.0:1	2.2:1
15.00	27.0	6	6.3:1	19.2:1
16.00	26.0	5	9.2:1	5.0:1
17.00	26.0	5.5	5.5:1	26.3:1
18.00	27.0	6	4.3:1	38.5:1
19.00	27.0	6	7.7:1	7.0:1
20.00	26.0	6	9.1:1	6.7:1
21.00	27.0	6	7.6:1	8.1:1
22.00	27.0	6	20.8:1	7.9:1
23.00	27.0	6	7.8:1	8.5:1
24.00	28.0	6	10.4:1	8.1:1
25.00	29.0	6	6.8:1	4.1:1
26.00	29.0	6	8.3:1	5.5:1
27.00	27.0	6.5	9.6:1	8.9:1
28.00	27.0	6	10.1:1	8.9:1
29.00	27.0	5.5	9.8:1	7.2:1
30.00	27.0	6	5.6:1	6.9:1
30.95	28.0	1	~	~
31.00	28.0	5	9.2:1	6.6:1

BIA 91 Existing Roadway Conditions (Continued)				
Reference Post	*Roadway Width (Feet)*	*PASER Score*	*In Slope Left (H:V)*	*In Slope Right (H:V)*
31.00	28.0	5	9.2:1	6.6:1
32.00	27.0	4.5	7.9:1	7.4:1
33.00	27.0	5	13.2:1	3.9:1
34.00	28.0	6	6.2:1	9.5:1
35.00	27.0	6.5	17.9:1	6.1:1
36.00	28.0	6.5	7.9:1	9.0:1
37.00	27.0	6.5	5.4:1	12.0:1
38.00	27.0	6.5	13.2:1	5.3:1
39.00	29.0	6	5.2:1	6.3:1
40.00	29.0	4.5	5.2:1	6.3:1
41.00	28.0	5.5	5.9:1	4.7:1
42.00	28.0	5	4.5:1	4.4:1
43.00	27.0	5	19.2:1	4.0:1
44.00	28.0	5	5.4:1	4.4:1
44.80	27.0	5	5.6:1	3.7:1

Table 3.1: BIA 91 Existing Roadway Conditions

Generally, the pavement is in fair condition based on the average PASER Rating of 5.5. This indicates that currently the pavement is in fair condition but is need of some form of rehabilitation to extend the life of the pavement. The average pavement top width is 27.8-feet and the in slopes are generally within current design standards, however there are sections that will need to be flattened or need guardrail installed depending on the limits of right-of-way for the corridor.

During the field inventory, locations where potholes, rutting, low points, heaving and pavement patches were observed. These locations were inventoried throughout the corridor and will require subgrade stabilization. The following table identifies these areas:

BIA 91 Pavement Distress Areas			
Reference Post		Type of Pavement Distress	Roadway Area (yds^2)
Begin	End		
1.28	1.29	Multiple Potholes	161.1
1.41	1.42	Multiple Potholes	161.1
2.78	2.79	Multiple Potholes	161.1
5.26	5.27	Rutting and Multiple Potholes	161.1
5.75	5.76	Multiple Potholes	161.1
6.48	6.49	Multiple Potholes	161.1
6.60	6.61	Multiple Potholes	161.1
6.90	6.90	Pavement Dipping & Raveling	32.2
7.76	7.77	Multiple Potholes	161.1
8.31	8.33	Deep Rutting	334.4
8.91	8.91	Dip	31.7
9.28	9.47	Heaving	3,232.5
10.17	10.18	Multiple Potholes	161.1
11.70	11.70	Dip	31.7
12.52	12.53	Multiple Potholes	164.3
12.60	12.93	Raveling	5,420.8
13.36	13.37	Multiple Potholes	164.3
13.46	13.47	Multiple Potholes	164.3

BIA 91 Pavement Distress Areas (Continued)			
Reference Post		Type of Pavement Distress	Roadway Area (yds^2)
Begin	End		
13.79	13.86	Raveling and Multiple Potholes	1,129.3
14.19	14.24	Raveling	792.0
15.05	15.07	Deep Rutting	316.8
15.74	15.75	Multiple Potholes	158.4
15.79	15.85	Multiple Potholes	158.4
16.50	16.50	Heaving	57.8
17.77	17.78	Multiple Potholes	161.1
20.01	20.01	Culvert Blown Out	57.8
23.48	23.49	Multiple Potholes	161.3
23.67	23.70	Heaving	484.0
27.35	27.40	Heaving	792.0
28.55	28.73	Heaving	2,851.2
30.31	30.32	Multiple Potholes	161.3
31.07	31.11	Raveling	492.8
31.48	31.51	Deep Rutting	484.0
31.75	31.79	Multiple Potholes	645.3
32.55	32.77	Heaving	3,484.8
38.46	38.46	Dip	62.2
38.92	38.92	Dip	62.2
39.65	39.69	Rutting	680.5
40.53	40.54	Multiple Potholes	167.2
40.56	40.57	Multiple Potholes	167.2
40.87	40.88	Block Cracking	167.2
40.90	40.91	Multiple Potholes	167.2
41.00	41.06	Multiple Potholes	985.6
41.53	41.55	Longitudinal and Transverse Cracking	328.5
42.09	42.11	Multiple Potholes	328.5
42.45	42.46	Dip	164.3
43.01	43.05	Multiple Potholes	633.6
43.21	43.27	Bridge Dig Out Area	950.4
43.40	43.42	Bridge Dig Out Area	316.8
43.65	43.66	Multiple Potholes	164.3
44.41	44.43	Bridge Dig Out Area	328.5
44.44	44.46	Bridge Dig Out Area	328.5

Table 3.2: BIA 91 Pavement Destress Locations

Existing Traffic Conditions

Traffic counts were completed in August 2020. These counts included two volume and vehicle classification counts at Mile Post 0.43 and Mile Post 44.33. BIA 91 carried an AADT volume of 226 vehicles per day (vpd) in 2020 with a directional split of 50/50 at Mile Post 0.43 and carried an AADT volume of 148 vpd in 2020 with a directional split of 50/50 at Mile Post 44.33. **Table 3.3** and **Table 3.4** summarizes the different vehicle classifications observed during the volume counts. The vehicle classification uses the standardized vehicle system developed by FHWA.

BIA 91 Vehicle Classification at Mile Post 0.43		
Vehicle Classification	Vehicles Per Day	Percentage
Class 1	9	4.0%
Class 2	81	35.8%
Class 3	28	12.4%
Class 4	2	0.9%
Class 5	78	34.5%
Class 6	0	0.0%
Class 7	0	0.0%
Class 8	5	2.2%
Class 9	22	9.7%
Class 10	0	0.0%
Class 11	0	0.0%
Class 12	0	0.0%
Class 13	1	0.4%
Total	226	100%

Table 3.3: BIA 91 Vehicle Classification at Mile Post 0.43

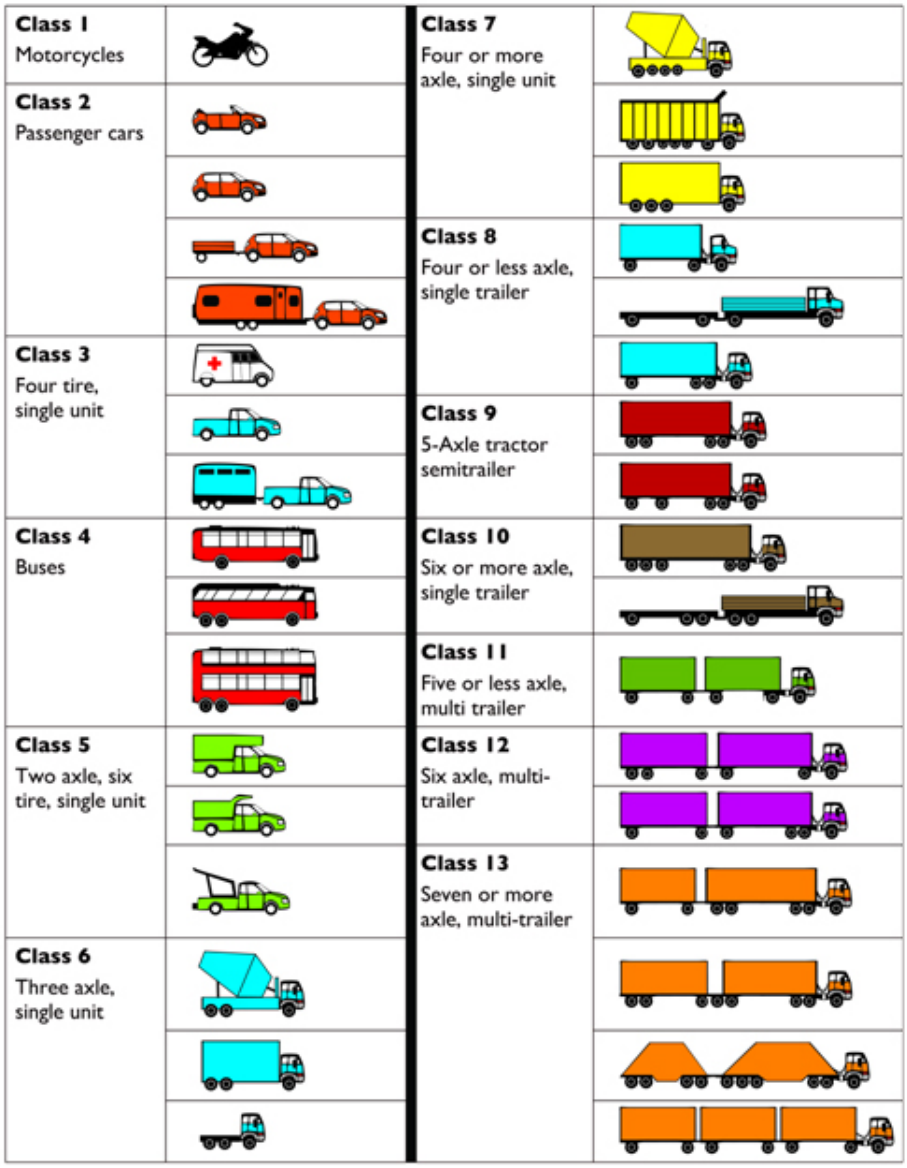
BIA 91 Vehicle Classification at Mile Post 44.33		
Vehicle Classification	Vehicles Per Day	Percentage
Class 1	1	0.7%
Class 2	37	25.0%
Class 3	22	14.9%
Class 4	1	0.7%
Class 5	78	52.7%
Class 6	0	0.0%
Class 7	1	0.7%
Class 8	7	4.7%
Class 9	0	0.0%
Class 10	0	0.0%
Class 11	0	0.0%
Class 12	0	0.0%
Class 13	1	0.7%
Total	148	100%

Table 3.4: BIA 91 Vehicle Classification at Mile Post 0.43

Truck traffic makes up 47.7% of the total traffic near mile post 0.43 and 59.5% of total traffic near mile post 44.33 on BIA 91 with a vehicle classification of Class #4 or higher. The highest percentage of vehicles that is a Class # 4 or higher were Class #5. Class #5 vehicles are two axle, six tire single unit vehicle. **Figure 3.1** summarizes the different types of classifications used by FHWA.

Along with the vehicle classification data, vehicle speed was also collected. The average speed observed on BIA 91 was approximately 48 mph with the 85th percentile speed of approximately 60 mph. Majority of the traffic is traveling at a speed close to the posted speed limit of 50 mph with exception of approximately 5% of the traffic were traveling at speeds greater than 60 mph.

Figure 3.1: FHWA Vehicle Classifications[1]



Existing Signing, Pavement Markings and Guardrail

All the existing signs along the corridor were inventoried. Generally, all the signs are in poor condition and the reflective sheeting is worn. Furthermore, many of the horizontal curves are missing warning signs and chevrons indicating the curve. The existing pavement markings were in fair condition. The existing guardrail that exists along the corridor is outdated comparing today's standards and is in generally fair condition. The existing bridge rail appeared to be in fair condition.

[1] https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

Figure 3.2: Existing Guardrail Condition



During the inventory process it was noticed that the mile markers appeared to be off on the physical location. The distance between some mile marker were either less than or greater than one mile. The greatest distance observed was between mile post 38 and mile post 39 with a distance of 1.29 miles. The shortest distance observed was between mile post 43 and mile post 44 with a distance of 0.91 miles. For the purpose of this report all locations called out by mile post will be referred to how it was observed in the field. When project phases go into design, stationing will be used to give more precise locations.

Chapter 6 breaks down the recommended project splits for the corridor and suggest treatments.

Figure 3.3: Existing Rutting Located Approximately at Mile Post 31.5



Pryor Gap Road

This section of Pryor Road is narrow and has a single sharp horizontal curve. Although the pavement is in generally fair condition, the road currently has only minimal shoulders, no rumble strips, and inadequate signage. This section of roadway has experienced significant number or serious crashes and is further discussed in Chapter 4: Historical Crash Data.

Figure 3.4: Existing Sharp Horizontal Curve on Pryor Gap Road



4.0 HISTORICAL CRASH DATA

Historical crash data contained in the MDT Crash Database, occurring on the BIA 91 was provided by MDT Traffic and Safety Bureau for a ten-year time interval covering January 1, 2010 through December 31, 2019. Crash data is submitted to the MDT Crash Database by the Montana Highway Patrol (MHP). Historical crash data was also provided by the Indian Health Services (IHS) for a 20-year time interval covering January 1, 1997 through December 31, 2017. The IHS crash data reflected the same data that was also provided by the MDT Traffic and Safety Bureau. Historical crash data is not available from the Bureau of Indian Affairs (BIA) Law Enforcement. The crashes, which they respond to and the crash information collected are not reported to the MHP.

The accuracy of reported crash data to the MDT Crash Database is only limited to two sources, the Montana Highway Patrol and the Indian Health Service. The Montana Highway Patrol response may be limited to Montana State roadways within the reservation, such as State Route 313 from Hardin to Fort Smith, Interstate I-90 and State Routes 416 and 418, from Pryor to Billings. If the MHP responds to crashes on BIA and tribally owned roads, then it is discretionary.

Tribal members seeking crash information must submit a request to release information from FOIA, the Freedom of Information Act. The FOIA process can be frustrating. The information released to the applicant can take years with redacted information. Thus, resulting in a long process to obtain the information.

With crash data only being limited to what was reported to the MDT Crash Database, the data only shows a smaller portion of actual crashes that may have occurred on BIA 91. During the studied ten-year time interval, six reported crashes occurred on BIA 91. The table below summarizes the approximate location, crash type, and injury type for the six reported crashes.

Reference Post	*Crash Type*	*Injury Type*
0.40	Domestic Animal	Property Damage Only
2.88	Roll Over	Fatal
4.63	Roll Over	Property Damage Only
10.34	Roll Over	Fatal
16.76	Roll Over	Minor Injury
17.98	Fixed Object	Minor Injury

Table 4.1: Reported Crashes Occurring on BIA 91 (2010-2019)

Of the six crashes, three of the reported crashes occurred on tangent sections of the roadway and the remaining three occurred within a horizontal curve.

The six crashes that were reported could be higher if crash information was available through BIA Law Enforcement. A systemic approach was used for analysis on BIA 91 due to the low number of reported crashes.

In addition to analyzing crash data on BIA 91, crash data was analyzed for the additional roadway section, Pryor Gap Road within the same ten-year study period. There were reported three crashes within this roadway section. The type of crashes that occurred were a fixed object crash, pedestrian crash, and right-angle crash. Two of these crashes resulted in a fatal injury and the remaining crash resulted in a property damage only injury. **Figure 4.1** shows the location of these crashes.

Figure 4.1: Pryor Gap Road Reported Crashes (2010-2019)



The three crashes that were reported could be higher if crash information was available through BIA Law Enforcement. A systemic approach was used for analysis on Pryor Gap Road due to the low number of reported crashes.

There has been significant anecdotal/neighborhood information that would indicate more crashes have occurred in this location compared to what has been reported to the state agency. According to information provided by neighbors living in the direct vicinity of the Pryor Gap curve, between 1995 and 2018, there were 8 accidents resulting in 5 fatalities and an additional 6 injury accidents.

In 2015, a Tribal Transportation Safety Management Plan was implemented to address transportation safety with engineering, enforcement, education and emergency disaster services. The safety plan identified existing programs on the reservation and identified additional strategies that needed to be implemented to address safety issues. The 2015 Tribal Transportation Safety Plan provided an in-depth analysis of available crash data and trends from 1996 through 2012. The Safety Plan provides strategies and recommendations to improve education, enforcement/EMS, engineering and safety planning/other provisions to address safety needs within the reservation. Please refer to that document for additional recommendations to improve safety on the Crow Indian Reservation.

5.0 HIGHWAY SAFETY COUNTERMEASURES

Safety issues along the studied corridor were assigned specific countermeasure based on the available crash data. Recommended countermeasure includes the following:

- Install Guardrail
- Install Centerline and Shoulder Rumble Strips
- Install Delineators
- Flatten Inslopes
- Install Retroreflective Pavement Marking
- Install Retroreflective Signs
- Install Horizontal Alignment Signs
- Install Advisory Speed Plaque with Horizontal Alignment Signs
- Install Chevron Alignment Signs
- Improve Culverts
- Improve Roadway Surface
- Improve Bridge Ends
- Flatten Horizontal Curve

Safety issues prevalent along the BIA 91 include poor road surfaces, steep insplopes, guardrail not meeting National Cooperative Highway Research Program (NCHRP) 350 and Manual for Assessing Safety Hardware (MASH), deteriorating roadway signs, and pavement marking issues. Discretion was used in deciding whether a safety issue should be addressed with countermeasures. Although this report focuses on BIA 91 and the small section on Pryor Gap Road, these countermeasures can be used on other routes that the tribe maybe experiencing similar issues.

Where applicable, Crash Reduction Factors (CRF) were listed for each countermeasure. These CRF's were taken from the FHWA's Crash Modification Factors Clearinghouse located at https://safety.fhwa.dot.gov/tools/crf/resources/. A CRF is an estimate of the percentage reduction in crashes due to a particular countermeasure. The CRF's gives the Crow Tribe staff additional information on the expected benefit of implementing a particular countermeasure. The intent is to support the process used by the Crow Tribe to prioritize future projects. Table 5.1 summarizes the CRF's for the recommended countermeasures.

Recommended Countermeasure	CRF (%)
Install Guardrail	26
Install Centerline and Shoulder Rumble Strips	23
Flatten Inslopes	42
Install Retroreflective Pavement Markings	24
Install Retroreflective Signs	18
Install Horizontal Alignment Signs	18
Install Advisory Speed Plaque with Horizontal Alignment Signs	18
Install Chevron Alignment Signs	18
Improve Culverts	N/A
Improve Roadway Surface	N/A
Improve Bridge Ends	N/A
Flatten Horizontal Curve	68.5

Table 5.1: Crash Reduction Factors for Recommended Countermeasures

Guidance for application of these countermeasures is contained in the Manual on Uniform Traffic Control Devices (MUTCD) and American Association of State highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets. It is strongly recommended that these manuals be consulted and adhered to prior to application of these countermeasures.

Guardrail

Guardrail is a safety barrier that is intended to prevent vehicles leaving the roadway in areas that have objects inside of the clear zone that cannot be removed, steep embankments or side slopes. Given the high cost of guardrail, significant discretion was used in selecting the locations where the greatest need appeared to exist. Decisions regarding the extent and type of guardrail to serve the needs of given location will need to be addressed as projects are programmed for implementation. Figure 5.1 shows an example of guardrail used on the roadway that has steep side slopes.

Figure 5.1: Guardrail Installed for Steep Side Slopes



Centerline and Shoulder Rumble Strips

Centerline rumble strips are at the centerline of the paved roadway intended to alert motorist crossing over to the opposing driving lane. Shoulder rumble strips are placed on the edge of the driving lane to warn drivers that they are departing the roadway not intended for routine traffic use. They are an effective countermeasure for reducing roadway departure crashes and head on crashes. Rumble strips are used on highspeed rural roads. Figure 5.2 shows an example of shoulder rumble strips.

Figure 5.2: Shoulder Rumble Strips



Delineators

Proper delineation along the roadway is used for motorist guidance at night and during adverse weather. Delineators are also beneficial at locations where roadway alignment changes and are considered as guidance devices rather than warning devices. They come in various sizes and designs to address varying applications. Delineators are typically used on rural roadways with no street lighting and marking approaches. Figure 5.3 shows various examples of delineators. The MUTCD and the Montana Department of Transportation (MDT) Detailed Drawings gives recommendations and guidance for placement of delineators.

Figure 5.3: Roadside Delineators Example



Flatten Inslopes

It is desirable to have inslopes be 4:1 or flatter if site conditions allow for it. This allows for a greater recovery area if a vehicle departs the roadway. Where slopes exceed a 4:1, flatting (regrading) them could significantly reduce crashes and severity and is a cheaper alternative to roadside barriers. Information on desirable side slopes can be found in the AASHTO Roadside Design Guide.

Roadway Surface

Several locations throughout BIA 91 are showing signs of distress for the asphalt pavement. Potholes, low points, heaving and pavement patches were inventoried throughout the corridor. Other distresses observed throughout the corridor include longitudinal and transverse cracking, alligator cracking, raveling and rutting. This creates and undesirable surface to drive on and possible damage to the roadways subsurface. The PASER Manual by the Transportation Information Center by the University of Wisconsin-Madison provides guidance on how to identify different types of distresses and best practices to correct them. Chapter 6 discusses a strategy to address the different types of distresses observed on BIA 91. Figure 5.4 shows an example of some of the observed asphalt pavement distresses.

Figure 5.4: Pavement Distress on BIA 91



Pavement Markings

Pavement markings communicate to motorist the intended travel path on roadways and roadway alignment for long-range delineation. The delineation of pavement markings improves nighttime highway visibility and guide the motorist of the intended travel path. Pavement markings are typically either a waterborne traffic paint or epoxy traffic paint with glass beads mixed into the paint to provide retroreflectivity. Epoxy traffic paint has shown in the past to have a longer service life when comparing to waterborne traffic paint.

Retroreflective Signs

Roadway signs provide valuable information to motorist. For these signs to be effective, traffic sign visibility must be maintained during daytime and nighttime conditions. The reflective sheeting used on roadway signs allows better visibility for motorist at nighttime. Many of the signs on the BIA 91 are deteriorated and have little to no reflectivity. It is recommended that signs be checked and replaced if needed every five years to maintain proper reflective sheeting. It is also recommended that an inventory of signs be completed using GPS and photos to give tribal transportation staff a list of signs that need to be maintained. Current practices use Type IV reflective sheeting or XI high intensity reflective sheeting for signs. Fluorescent yellow type XI-high intensity reflective sheeting should be used for horizontal alignment warning signs. Fluorescent yellow green type XI-high intensity reflective sheeting should be used for roadway signs used for school areas. Figure 5.5 shows examples of the different types of reflective sheeting for roadway signs.

Figure 5.5: Different Types of Reflective Sheeting for Roadway signs



Type IV Reflective Sheeting



Type XI Fluorescent Yellow Reflective Sheeting



Type XI Fluorescent Yellow Green Reflective Sheeting

Horizontal Alignment Signs

Advance horizontal alignment signs provide a warning to motorist of the presence of a curve ahead and of the need to possible slow down to safely navigate a curve. If the difference of the speed to safely navigate a curve differs by 10 miles per hour or greater from the posted speed limit on the roadway, a supplemental advisory speed plaque is required to alert motorist to slow down. The advisory speed is determined by an engineering study that follows established engineering practices. Traditionally a ball-bank indicator is used to establish an advisory speed and should be determined based on free-flowing traffic conditions. **Figure 5.6** shows an example of the use of a horizontal alignment sign with a supplemental advisory speed plaque.

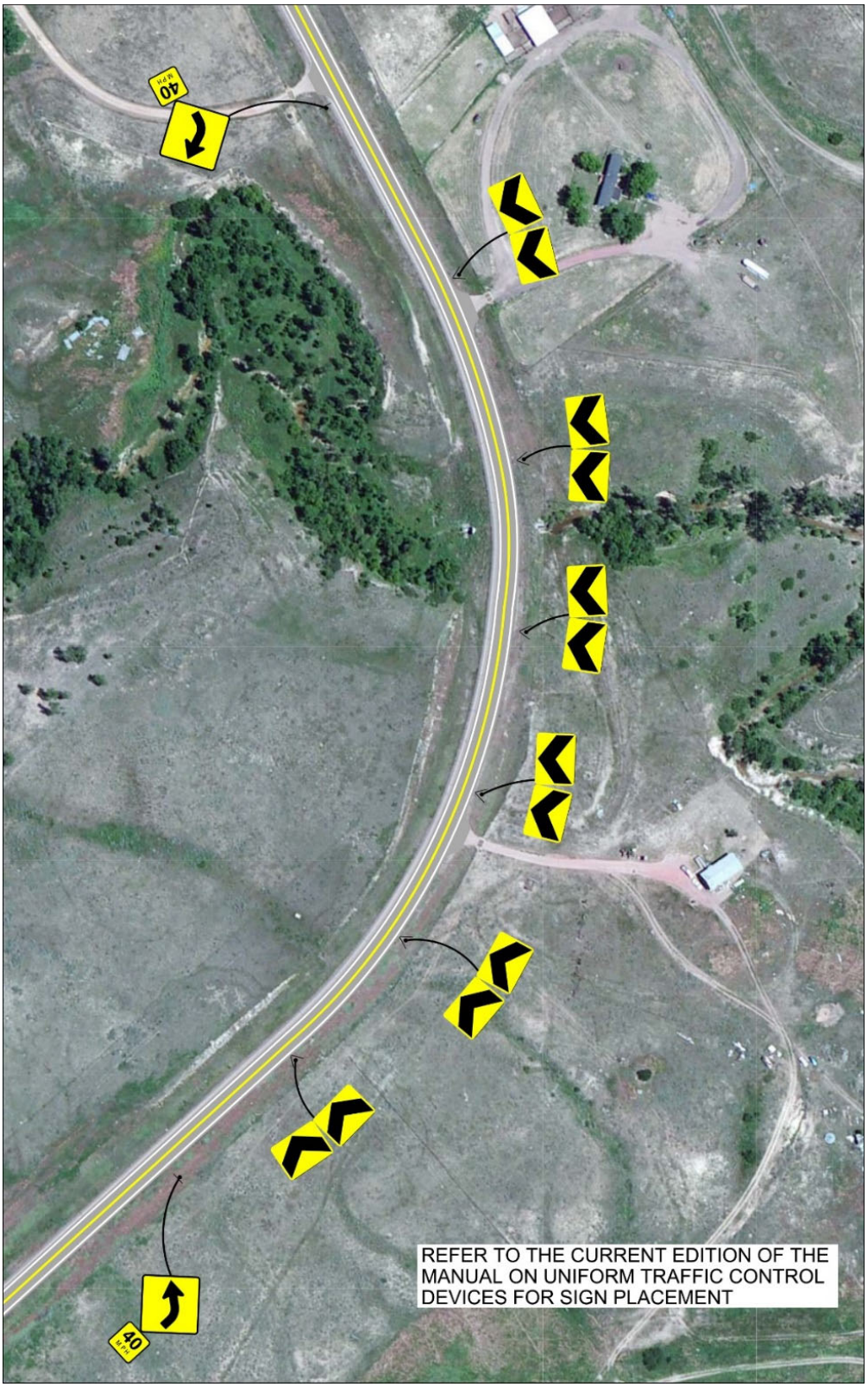
Figure 5.6: Horizontal Alignment Sign with Supplemental Advisory Speed Plaque



Chevrons

A chevron is a type of horizontal alignment warning sign used instead of or in addition to standard delineators to highlight the presence of a change in the roadway alignment. In some location's chevrons were missing and/or the spacing between the signs were not consistent. The MUTCD provides guidance for the placement of chevrons and spacing requirements depending on the radius of the curve. **Figure 5.7** shows an example of chevron spacing.

Figure 5.7: Curve Warning Signs Example



6.0 RECOMMENDED IMPROVEMENTS

The Crow Tribal Transportation is responsible for maintaining this route. We have reviewed all the proposed countermeasures in Chapter 5 and have developed a list of proposed projects. It should be noted that all these projects will need survey, a geotechnical investigation, construction plans and specifications, an approved Environmental document, and right-of-way prior to construction starting.

Ultimately to improve the pavement surface, subgrade stabilization will need to be performed throughout the corridor at the locations identified during the geotechnical investigation. Overall, we recommend the following improvements:

1. Perform Geotechnical Investigation for each of project phase.
2. Removing the existing pavement, base course and subgrade at all the areas identified from the geotechnical investigation and areas identified in Table 3.2 in Chapter 3 of this study, replacing the material with a geotextile fabric, new crushed base course and an asphalt patch.
3. Milling the existing surface and performing a hot bituminous pavement overlay at a thickness to be determined after the geotechnical investigation.
4. Maintain/replace existing snow fencing or install new where needed between RP 18.5-20.5
5. Replace the existing guardrail where it exists, and additional guardrail should be installed at the locations identified in Table 6.1 listed below.
6. Replace all delineators throughout the corridor.
7. Replace all existing signs and install additional horizontal curve warning signs and chevrons when warranted by the MUTCD and engineering judgement.
8. Install centerline rumble strips and modified shoulder rumble strips.
9. Place all new epoxy pavement markings.

BIA 91 Recommended Guardrail or Slope Flattening Locations				
Reference Post		In Slope Left (H:V)	In Slope Right (H:V)	Comments
Begin	End			
1.30	1.45	2.5	2.3	Guardrail LT & RT
2.30	2.40	1.5	2.2	Guardrail LT & RT
3.70	3.80	2.5	2.3	Guardrail LT & RT
4.20	4.40	2.4	2.2	Guardrail LT & RT
4.20	4.50	~	~	Power Poles on LT
4.80	5.00	2.3	21.3	Guardrail LT & RT
5.70	6.00	~	2.5	Guardrail RT
6.50	6.70	~	2.2	Guardrail RT
7.20	7.70	~	2.1	Guardrail RT
7.20	7.60	1.8	~	Guardrail LT
7.90	8.20	1.3	1.7	Guardrail LT & RT
8.50	8.60	1.9	2.0	Guardrail LT & RT
8.80	9.20	2.0	~	Guardrail LT
8.90	9.20	~	1.3	Guardrail RT
9.60	9.80	1.9	2.0	Guardrail LT & RT
9.90	10.10	~	~	Cliff LT approximately 15' from EOP
10.00	10.10	~	1.7	Guardrail RT
10.20	10.40	2.4	1.7	Guardrail LT & RT (5:1 first 10-feet)
10.90	11.05	~	1.8	Guardrail RT
11.20	11.30	1.4	1.3	Guardrail LT & RT (5:1 first 10-feet)
11.40	11.60	~	2.3	Guardrail RT (around curve)
11.90	12.30	~	2.3	Guardrail RT (5:1 first 10-feet)
12.70	12.90	1.9	~	Guardrail LT (5:1 first 10-feet)

BIA 91 Recommended Guardrail or Slope Flattening Locations (Continued)				
Reference Post		In Slope Left (H:V)	In Slope Right (H:V)	Comments
Begin	Begin			
13.90	14.10	1.6	1.8	Guardrail LT & RT (5:1 first 10-feet)
14.50	14.60	1.9	1.8	Guardrail LT & RT (5:1 first 10-feet)
15.05	15.20	~	2.2	Guardrail RT (5:1 first 10-feet)
15.10	15.20	2.3	~	Guardrail LT (5:1 first 10-feet)
15.35	15.50	1.9	~	Guardrail LT (5:1 first 10-feet)
15.36	15.50	~	2.0	Guardrail RT (5:1 first 10-feet) (Large Tree)
16.05	16.30	2.2	~	Guardrail LT (5:1 first 10-feet)
16.10	16.30	~	2.4	Guardrail RT (5:1 first 10-feet)
16.50	16.65	~	2.4	Guardrail RT (5:1 first 10-feet)
17.10	17.20	~	1.7	Guardrail RT (5:1 first 10-feet)
17.60	17.75	1.7	2.0	Guardrail LT & RT (5:1 first 10-feet)
18.20	18.40	1.7	1.8	Guardrail LT & RT (5:1 first 10-feet)
20.30	20.50	~	2.1	Guardrail RT (4:1 first 5-feet)
20.35	20.50	2.6	~	Guardrail LT (4:1 first 5-feet)
20.75	20.80	2.3	2.3	Guardrail LT & RT (5:1 first 10-feet)
21.40		~	~	Large Tree LT
24.60	24.70	1.3	2.2	Guardrail LT & RT (Culvert)
27.80	27.90	~	2.1	Guardrail RT
31.70		~	~	12-foot culvert possible guardrail LT & RT
33.40	33.50	~	1.6	Guardrail RT (4:1 first 10-feet)
33.80	34.00	1.6	~	Guardrail LT (5:1 first 10-feet)
35.70		~	~	Large Tree RT
42.30	42.45	1.9	~	Guardrail LT (5:1 first 10-feet)
42.40	42.50	~	1.6	Guardrail RT (4:1 first 10-feet)
42.70	43.05	~	1.9	Guardrail RT (4:1 first 10-feet)
42.72	42.78	2.2	~	Guardrail LT (4:1 first 10-feet)
43.15	43.25	~	1.5	Guardrail RT connect to bridge ends
43.17	43.25	1.9	~	Guardrail LT connect to bridge ends
43.25	43.35	~	~	Concrete Bridge (Update Bridge Ends)
43.35	43.45	~	2.1	Extend Bridge End RT
44.40	44.45	~	~	Concrete Bridge (Update Bridge Ends)

Table 6.1: Recommended Guardrail or Slope Flatting Locations

Final limits and location of the above recommended guardrail locations should be finalized during the final design phase of each project. If slope flatting is a viable choice over guardrail and can be completed within the existing right-of-way, it is recommended that slope flatting be used to save overall cost the project phase.

Due to the limited right-of-way, pavement condition, and project costs we recommend splitting the project into the following phases:

Recommended BIA 91 Project Phasing	
Route Improvement	*Project Costs*
Phase 1: RP 0.0 – RP 7.0	$3,251,820
Phase 2: RP 7.0 – RP 13.0	$5,811,426
Phase 3: RP 13.0 – RP 18.1	$4,787,209
Phase 4: RP 18.1 – RP 28.0	$1,840,939
Phase 5: RP 28.0 – RP 34.0	$5,213,440
Phase 6: RP 34.0 – RP 40.5	$1,132,700
Phase 7: RP 40.5 – RP 44.8	$4,515,389
Pryor Gap Road	$340,922

Table 6.2: Recommended BIA Project Phasing

During the inventory process it was noticed that the mile markers appeared to be off on the physical location. The distance between some mile marker were either less than or greater than one mile. The greatest distance observed was between mile post 38 and mile post 39 with a distance of 1.29 miles. The shortest distance observed was between mile post 43 and mile post 44 with a distance of 0.91 miles. For the purpose of this report all locations called out by mile post will be referred to how it was observed in the field. When project phases go into design, stationing will be used to give more precise locations.

Below summarize the additional recommendations for each of the suggested phases.

Phase 1: RP 0.0 – RP 7.0

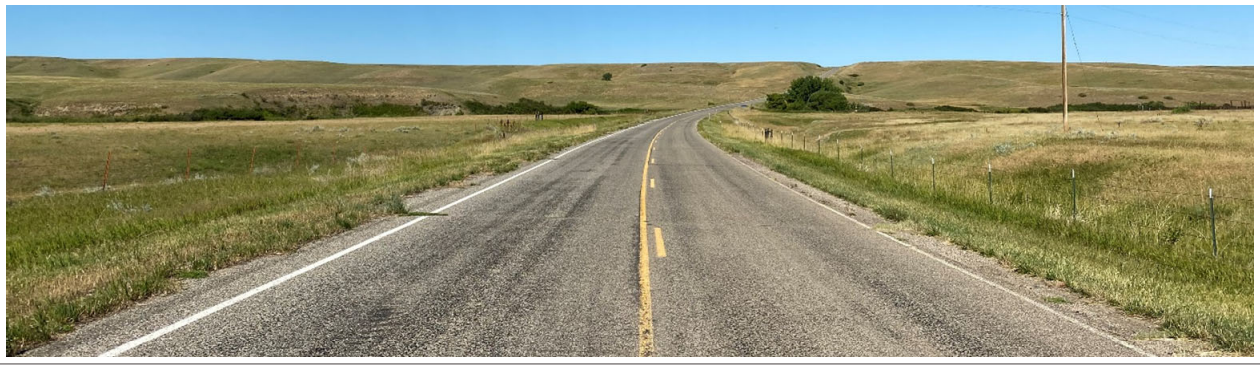
This section of roadway has an approximate roadway width of 29-feet. The average PASER score is 5.6. The roadway is showing signs of minor rutting (1/2-inch-deep or less), transverse and longitudinal cracking, bleeding and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. This section of roadway would benefit with crack sealing, patching and subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study, a non-structural overlay (less than 2 inches), course leveling for the minor rutting and a seal and cover to help extend the life of the pavement. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $3,251,820.

Figure 6.1: Existing Roadway Conditions along Phase 1 Project Limits



Phase 2: RP 7.0 – RP 13.0

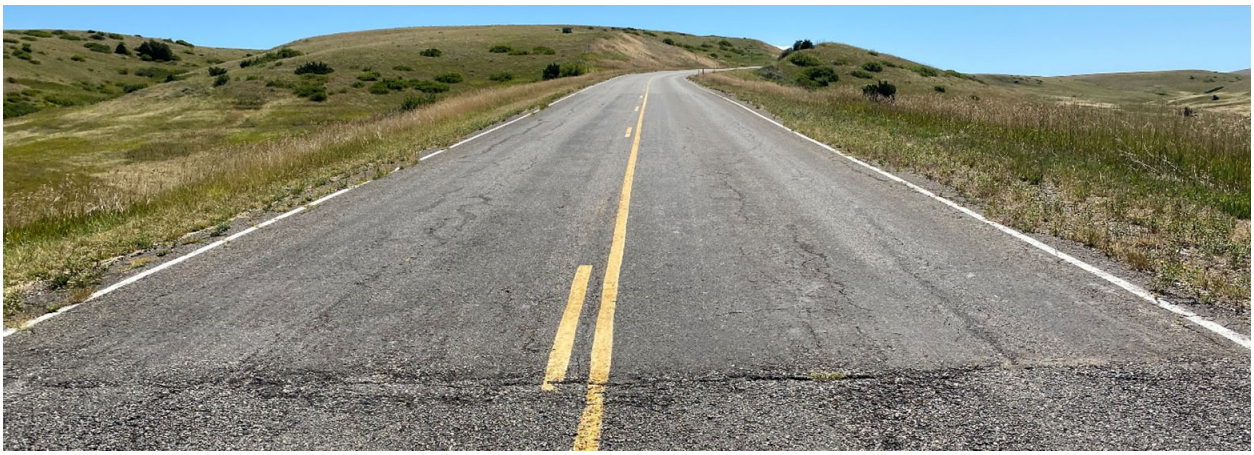
This section of roadway has an approximate roadway width of 28.3-feet. The average PASER score is 5.9. The roadway is showing signs of longitudinal and transverse cracking, minor rutting (1/2-inch-deep or less) alligator cracking, minor bleeding and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. This section of roadway would benefit with crack sealing, patching and subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study, a non-structural overlay (less than 2 inches), course leveling for the minor rutting and a seal and cover to help extend the life of the pavement. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $5,811,426.

Figure 6.2: Existing Roadway Conditions Along Phase 2 Project Limits



Phase 3: RP 13.0 – RP 18.1

This section of roadway has an approximate roadway width of 26.8-feet. The average PASER score is 5.4. The roadway is showing signs of raveling, longitudinal and transverse cracking, alligator cracking, minor bleeding and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. This section of roadway would benefit with Full Depth Reclamation (pulverization) of the existing asphalt surface to mix with the existing base course. The pulverization will blend the materials uniformly and provide an upgraded homogeneous material. It is recommended that either additional virgin crushed coarse aggregate and/or a chemical stabilization material be added to the pulverization mix. A structural overlay of 4-inch asphalt is recommended to be paved over the newly pulverized material. Prior to the pulverization, subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study should be completed. A seal and cover to help extend the life of the pavement after all other paving operations are completed is also recommended. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications

- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $4,787,209.

Figure 6.3: Existing Roadway Conditions Along Phase 3 Project Limits



Phase 4: RP 18.1 – RP 28.0

This section of roadway has an approximate roadway width of 27.4-feet. The average PASER score is 6.0. The roadway is showing signs transverse and longitudinal cracking (up to a ½-inch wide), heaving and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. This section of roadway would benefit with crack sealing, patching and subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study, and a seal and cover to help extend the life of the pavement. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

It also should be noted that there were various locations between RP 18.5 to RP 20.5 that had damaged snow fence along the roadway and snow drifting was seen along the roadway during a field visit in early March 2021. It is recommended that these snow fences be repaired or replace in their existing locations. If snow drifting is experienced in other locations throughout the corridor, it is recommended that the Crow Tribal Maintenance Program install snow fence in those locations experiencing snow drifting along the roadway.

If desired, the Crow Tribal Transportation Program could split this phase into two separate projects, depending on available funding.

The estimated cost for this project is $1,840,939.

Figure 6.4: Existing Roadway Conditions Along Phase 4 Project Limits



Phase 5: RP 28.0 – RP 34.0

This section of roadway has an approximate roadway width of 27.4-feet. The average PASER score is 4.9. The roadway is showing signs of heaving, block cracking, longitudinal and transverse cracking, alligator cracking, rutting and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. This section of roadway would benefit with Full Depth Reclamation (pulverization) of the existing asphalt surface to mix with the existing base course. The pulverization will blend the materials uniformly and provide an upgraded homogeneous material. It is recommended that either additional virgin crushed coarse aggregate and/or a chemical stabilization material be added to the pulverization mix. A structural overlay of 4-inch asphalt is recommended to be paved over the newly pulverized material. Prior to the pulverization, subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study should be completed. A seal and cover to help extend the life of the pavement after all other paving operations are completed is also recommended. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $5,213,440.

Figure 6.5: Existing Roadway Conditions Along Phase 5 Project Limits



Phase 6: RP 34.0 – RP 40.5

This section of roadway has an approximate roadway width of 27.9-feet. The average PASER score is 6.3. The roadway is showing signs transverse and longitudinal cracking, bleeding, minor rutting and potholes in various locations throughout the suggested project limits. Some minor crack sealing was observed throughout the suggested project limits. Only one location was noted were possible guardrail would be recommended, RP 35.70. In this location a large tree was within the existing clear zone and acts as a fix object. Removal of the tree would be a cost benefit versus installing guardrail new guardrail and is the recommended countermeasure. This section of roadway would benefit with crack sealing, patching and subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study, and a seal and cover to help extend the life of the pavement. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $1,132,700.

Figure 6.6: Existing Roadway Conditions Along Phase 6 Project Limits



Phase 7: RP 40.5 – RP 44.8

This section of roadway has an approximate roadway width of 29-feet. The average PASER score is 5.0. The roadway is showing signs of bleeding, block cracking, longitudinal and transverse cracking, rutting and potholes in various locations throughout the suggested project limits. There are locations that would benefit from either slope flattening or guardrail as shown in Table 6.1. There are two bridges located within these project limits one located near RP 43.3 and the other located at RP 44.4. It is recommended that the bridge end be upgraded to current guardrail practices and bridge dig outs on each end of each bridge be completed to stabilize the surface. This section of roadway would benefit with Full Depth Reclamation (pulverization) of the existing asphalt surface to mix with the existing base course. The pulverization will blend the materials uniformly and provide an upgraded homogeneous material. It is recommended that either additional virgin crushed coarse aggregate and/or a chemical stabilization material be added to the pulverization mix. A structural overlay of 4-inch asphalt is recommended to be paved over the newly pulverized material. Prior to the pulverization, subgrade stabilization as shown in Table 3.2 in Chapter 3 of this study should be completed. A seal and cover to help extend the life of the pavement after all other paving operations are completed is also recommended. Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of Chapter 6

By completing a geotechnical investigation and taking roadway borings, this will assist in determining the existing depth of the asphalt pavement and the depth of the gravel base existing underneath the asphalt. Any deficiencies or anomalies of the depth of pavement or base course might suggest a different treatment needed than what the PASER rating alone might suggest.

The estimated cost for this project is $4,515,389.

Figure 6.7: Existing Bridge End Near Mile Post 43.3



Pryor Gap Curve

Pryor Gap Road is a two-lane road that connects the town of Pryor, the primary community on the west end of the Crow Indian Reservation, with several residences and with Chief Plenty Coup State Park. Currently, the road has only a minimal shoulder, steep slopes and a sharp curve with no rumble strips, and minimal signage to assist drivers in preparing for that curve. The project proposes to finalize design and complete construction to flatten the curve, improve side slopes, widen shoulders to 4-foot, install shoulder and centerline rumble strips, and provide appropriate curve delineation signs.

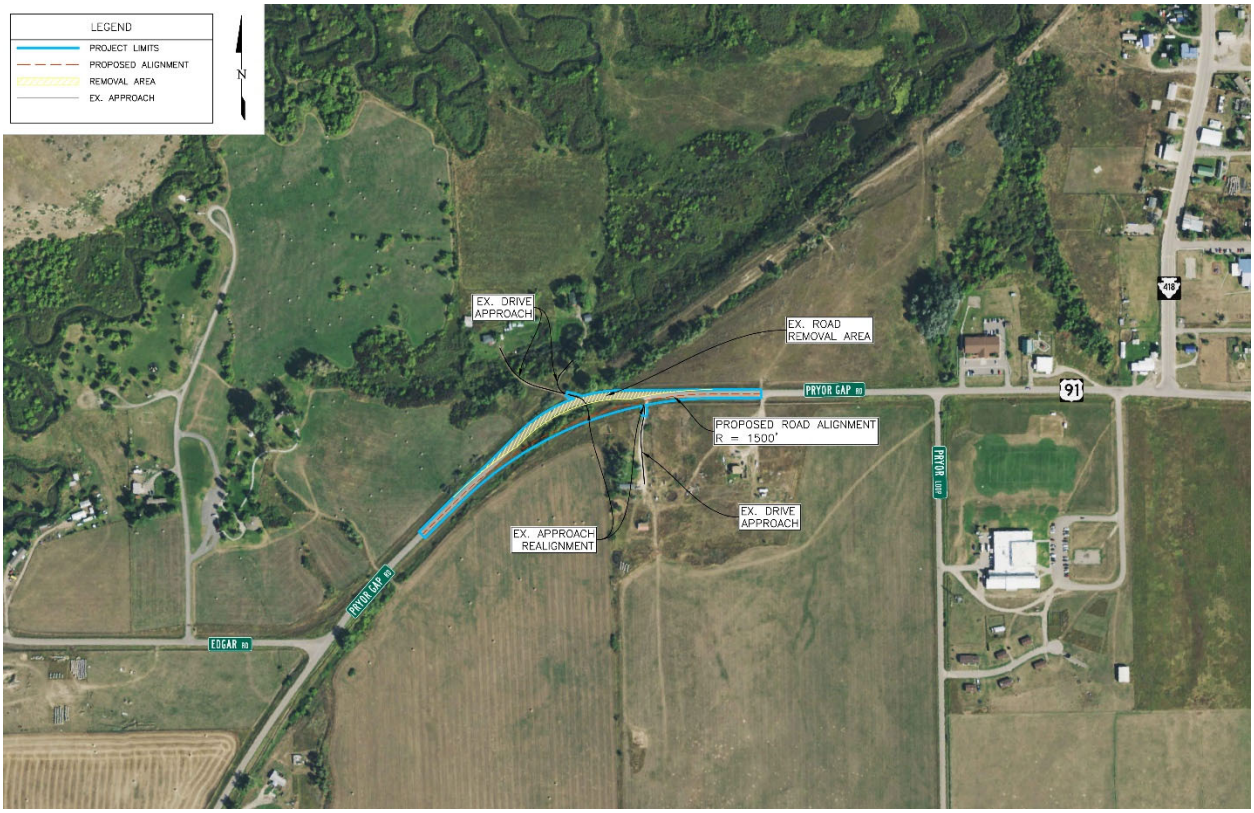
The Crow Tribal Transportation Program was recently awarded TTPSF money for the project in the amount of $272,794 with the tribe contributing an additional 20 percent ($68,198) resulting in a total of $340,992 for the project.

Prior to completing the work, the following should be completed:

- A full geotechnical investigation
- Engineering plans and specifications
- Incorporate recommendations as mention in the beginning of **Chapter 6**
- Complete Right-of-Way negotiations for the additional right-of-way needed for the project

The estimated cost for this project is **$340,992**

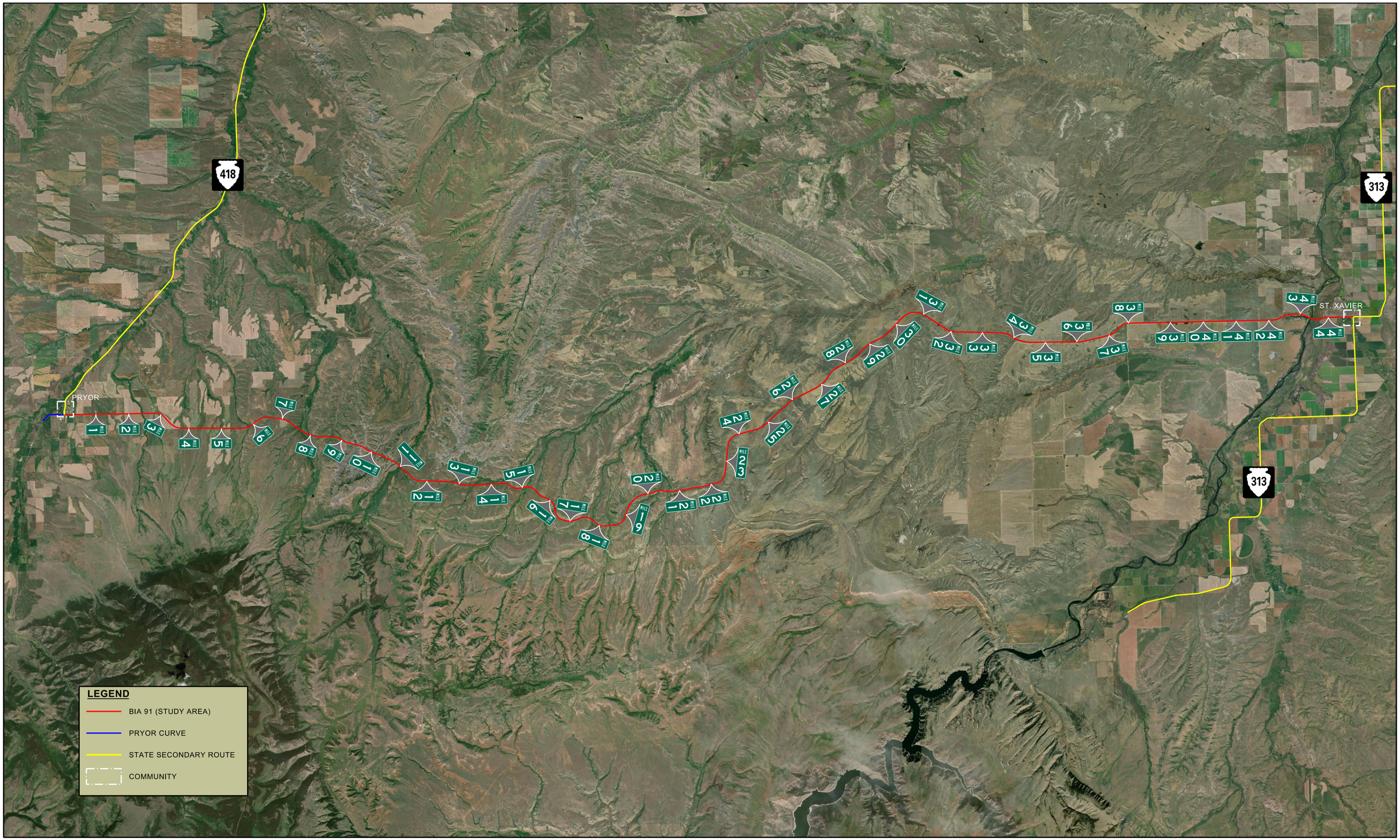
Figure 6.8: Proposed Realignment of Pryor Gap Road



Project Phases and Construction Sequence

The project phases recommend in the chapter do not need to be designed and constructed in the order in which they are given. The Crow Tribal Transportation may choose which phase to begin first depending on their desire and the available funds. It is recommended if the Tribe wishes to start with Phase 7 that the remaining projects go to design and construction from east to west and vice versa if the Tribe wishes to Start with Phase 1 the remaining projects go to design and construction from west to east.

Appendix A: Project Location


418
313
313
PRYOR
ST. XAVIER
1 MILE
2 MILE
3 MILE
4 MILE
5 MILE
6 MILE
7 MILE
8 MILE
9 MILE
10 MILE
11 MILE
12 MILE
13 MILE
14 MILE
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32 MILE
33 MILE
34 MILE
35 MILE
36 MILE
37 MILE
38 MILE
39 MILE
40 MILE
41 MILE
42 MILE
43 MILE
44 MILE
LEGEND
BIA 91 (STUDY AREA)
PRYOR CURVE
STATE SECONDARY ROUTE
COMMUNITY

Appendix B: Engineer's Opinion of Probable Construction Costs for Projects Phase 1 – 7 and Pryor Gap Road

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)

Phase 1 - RP 0.0 - RP 7.0

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 61,000.00	$61,000.00
109200050	Mobilization	1	LS	$ 211,000.00	$211,000.00
202020140	Remove Bituminous Pavement	1,160	SY	$ 45.00	$52,200.00
203020278	Excavation-Digouts	1,160	CY	$ 35.00	$40,600.00
208010150	Temporary Erosion Control	1	LS	$ 61,300.00	$61,300.00
301020345	Crushed Aggregate Course	2,146	TON	$ 45.00	$96,570.00
401020045	Plant Mix Surf GR S 3/4 in	12,176.5	TON	$ 50.00	$608,825.00
402020092	Asphalt Cement PG 64-28	657.5	TON	$ 640.00	$420,820.00
402020305	Emulsified Asphalt SS-1	5,681.0	GAL	$ 6.00	$34,086.00
402020368	Emulsified Asphalt CRS-2P	203	TON	$ 725.00	$147,175.00
403010255	Crack Sealing	10,591.0	LB	$ 7.00	$74,137.00
409000000	Final Sweep and Broom	6.9	CRMI	$ 750.00	$5,175.00
409000010	Cover Aggregate-Type1	113,620	SY	$ 1.00	$113,620.00
411011125	Centerline Rumble Strips-Type 2	6.9	MILE	$ 1,801.14	$12,428.00
411011135	Rumble Strips	13.8	MILE	$ 1,170.00	$16,146.00
606010140	Guardrail End Section Widening	24	EA	$ 1,600.00	$38,400.00
606010330	MGS Guardrail	8,312.5	LF	$ 25.00	$207,813.00
606010335	MASH W-Beam Terminal Section	24	EA	$ 3,515.00	$84,360.00
611010300	Reset Cattle Guard	4	EA	$ 3,700.00	$14,800.00
618030080	Traffic Control	1	LS	$ 97,300.00	$97,300.00
619010086	Signs-Alum Refl Sheet IV	63.5	SF	$ 40.00	$2,538.00
619010090	Signs-Alum Refl Sheet XI	44	SF	$ 38.00	$1,663.00
619010230	Remove Sign	20.0	EA	$ 95.00	$1,900.00
619010310	Posts-Steel U Sign	133.0	LB	$ 10.00	$1,330.00
619010340	Posts-Tubular-Steel-SQ-Perf	174.0	LB	$ 15.00	$2,610.00
619010480	Poles-Treated Wood 4 in.	100	LF	$ 20.00	$2,000.00
619010490	Poles-Treated Wood 5 in.	28	LF	$ 22.00	$616.00
619011010	Delineator DES A	250	EA	$ 35.00	$8,750.00
619011040	Delineator DES D	8	EA	$ 45.00	$360.00
620013000	Striping-White Paint	254	GAL	$ 45.00	$11,430.00
620013960	Striping-White Epoxy	338	GAL	$ 100.00	$33,800.00
620014000	Striping-Yellow Paint	141	GAL	$ 45.00	$6,345.00
620014960	Striping-Yellow Epoxy	188	GAL	$ 100.00	$18,800.00
622011084	Geotextile Stabilization	1,160	SY	$ 5.00	$5,800.00

Subtotal	$2,495,697.00
20% Contingency	$374,400.00
Subtotal	$2,870,097.00
Engineering, Geotech & Construction Admin	$287,010.00
3% TERO Fees	$94,713.00
Total	$3,251,820.00

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)
Phase 2 - RP 7.0 - RP 13.0

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 92,000.00	$92,000.00
109200050	Mobilization	1	LS	$ 315,000.00	$315,000.00
202020140	Remove Bituminous Pavement	9,538	SY	$ 45.00	$429,210.00
203020278	Excavation-Digouts	9,538	CY	$ 35.00	$333,830.00
208010150	Temporary Erosion Control	1	LS	$ 91,700.00	$91,700.00
301020345	Crushed Aggregate Course	17,645	TON	$ 45.00	$794,025.00
401020045	Plant Mix Surf GR S 3/4 in	10,462	TON	$ 50.00	$523,120.00
402020092	Asphalt Cement PG 64-28	565	TON	$ 640.00	$361,580.00
402020305	Emulsified Asphalt SS-1	4,881.3	GAL	$ 6.00	$29,288.00
402020368	Emulsified Asphalt CRS-2P	174	TON	$ 725.00	$126,150.00
403010255	Crack Sealing	8,880.4	LB	$ 7.00	$62,163.00
409000000	Final Sweep and Broom	5.9	CRMI	$ 750.00	$4,425.00
409000010	Cover Aggregate-Type1	97,625	SY	$ 1.00	$97,625.00
411011125	Centerline Rumble Strips-Type 2	5.9	MILE	$ 1,801.14	$10,627.00
411011135	Rumble Strips	11.9	MILE	$ 1,170.00	$13,923.00
606010140	Guardrail End Section Widening	36	EA	$ 1,600.00	$57,600.00
606010330	MGS Guardrail	25,987.5	LF	$ 25.00	$649,688.00
606010335	MASH W-Beam Terminal Section	36	EA	$ 3,515.00	$126,540.00
618030080	Traffic Control	1	LS	$ 117,500.00	$117,500.00
619010086	Signs-Alum Refl Sheet IV	28.8	SF	$ 40.00	$1,152.00
619010230	Remove Sign	7.0	EA	$ 95.00	$665.00
619010310	Posts-Steel U Sign	122.0	LB	$ 10.00	$1,220.00
619010480	Poles-Treated Wood 4 in.	14	LF	$ 15.00	$210.00
619011010	Delineator DES A	200	EA	$ 35.00	$7,000.00
620013000	Striping-White Paint	217	GAL	$ 45.00	$9,765.00
620013960	Striping-White Epoxy	290	GAL	$ 100.00	$29,000.00
620014000	Striping-Yellow Paint	117	GAL	$ 45.00	$5,265.00
620014960	Striping-Yellow Epoxy	156	GAL	$ 100.00	$15,600.00
622011084	Geotextile Stabilization	9,538	SY	$ 5.00	$47,690.00
				Subtotal	**$4,353,561.00**
				20% Contingency	$870,700
				Subtotal	$5,224,261
				Engineering, Geotech & Construction Admin	$417,900
				3% TERO Fees	$169,265
				Total	$5,811,426

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)
Phase 3 - RP 13.0 - RP 18.1

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 83,000.00	$83,000.00
109200050	Mobilization	1	LS	$ 284,000.00	$284,000.00
202020140	Remove Bituminous Pavement	3,103	SY	$ 45.00	$139,635.00
203020278	Excavation-Digouts	3,103	CY	$ 35.00	$108,605.00
208010150	Temporary Erosion Control	1	LS	$ 82,700.00	$82,700.00
301020345	Crushed Aggregate Course	5,741	TON	$ 45.00	$258,345.00
302000000	Pavement Pulverization	82,829	SY	$ 2.50	$207,073.00
401020045	Plant Mix Surf GR S 3/4 in	17,739.0	TON	$ 50.00	$886,950.00
402020092	Asphalt Cement PG 64-28	957.9	TON	$ 640.00	$613,062.00
402020305	Emulsified Asphalt SS-1	4,141.5	GAL	$ 6.00	$24,849.00
402020368	Emulsified Asphalt CRS-2P	148	TON	$ 725.00	$107,300.00
409000000	Final Sweep and Broom	5.0	CRMI	$ 750.00	$3,780.00
409000010	Cover Aggregate-Type1	82,829	SY	$ 1.00	$82,829.00
411011125	Centerline Rumble Strips-Type 2	5.0	MILE	$ 1,801.14	$9,078.00
411011135	Rumble Strips	10.1	MILE	$ 1,170.00	$11,817.00
606010140	Guardrail End Section Widening	28	EA	$ 1,600.00	$44,800.00
606010330	MGS Guardrail	11,037.5	LF	$ 25.00	$275,938.00
606010335	MASH W-Beam Terminal Section	28	EA	$ 3,515.00	$98,420.00
618030080	Traffic Control	1	LS	$ 120,500.00	$120,500.00
619010086	Signs-Alum Refl Sheet IV	24.0	SF	$ 40.00	$960.00
619010230	Remove Sign	6.0	EA	$ 95.00	$570.00
619010310	Posts-Steel U Sign	140.0	LB	$ 10.00	$1,400.00
619010480	Poles-Treated Wood 4 in.	14	LF	$ 15.00	$210.00
619011010	Delineator DES A	100	EA	$ 35.00	$3,500.00
620013000	Striping-White Paint	185	GAL	$ 45.00	$8,325.00
620013960	Striping-White Epoxy	246	GAL	$ 100.00	$24,620.00
620014000	Striping-Yellow Paint	131	GAL	$ 45.00	$5,895.00
620014960	Striping-Yellow Epoxy	174	GAL	$ 100.00	$17,400.00
622011084	Geotextile Stabilization	3,103	SY	$ 5.00	$15,515.00
				Subtotal	**$3,521,076.00**
				20% Contingency	$704,200
				Subtotal	$4,225,276
				Engineering, Geotech & Construction Admin	$422,500
				3% TERO Fees	$139,433
				Total	$4,787,209

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)

Phase 4 - RP 18.1 - RP 28.0

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 31,000.00	$31,000.00
109200050	Mobilization	1	LS	$ 106,000.00	$106,000.00
202020140	Remove Bituminous Pavement	1,496	SY	$ 45.00	$67,320.00
203020278	Excavation-Digouts	1,496	CY	$ 35.00	$52,360.00
208010150	Temporary Erosion Control	1	LS	$ 30,800.00	$30,800.00
301020345	Crushed Aggregate Course	2,768	TON	$ 45.00	$124,560.00
402020368	Emulsified Asphalt CRS-2P	288	TON	$ 725.00	$208,800.00
403010255	Crack Sealing	14,494.0	LB	$ 7.00	$101,458.00
409000000	Final Sweep and Broom	9.8	CRMI	$ 750.00	$7,365.00
409000010	Cover Aggregate-Type1	161,286	SY	$ 1.00	$161,286.00
411011125	Centerline Rumble Strips-Type 2	9.8	MILE	$ 1,801.14	$17,687.00
411011135	Rumble Strips	19.6	MILE	$ 1,170.00	$22,932.00
603016090	Clean Culvert Pipe	38.0	LF	$ 320.00	$12,160.00
606010140	Guardrail End Section Widening	18	EA	$ 1,600.00	$28,800.00
606010330	MGS Guardrail	4,875.0	LF	$ 25.00	$121,875.00
606010335	MASH W-Beam Terminal Section	18	EA	$ 3,515.00	$63,270.00
618030080	Traffic Control	1	LS	$ 75,900.00	$75,900.00
619010086	Signs-Alum Refl Sheet IV	46.4	SF	$ 40.00	$1,856.00
619010090	Signs-Alum Refl Sheet XI	10	SF	$ 38.00	$380.00
619010230	Remove Sign	13.0	EA	$ 95.00	$1,235.00
619010310	Posts-Steel U Sign	280.0	LB	$ 10.00	$2,800.00
619010480	Poles-Treated Wood 4 in.	42	LF	$ 15.00	$630.00
619011010	Delineator DES A	350	EA	$ 45.00	$15,750.00
620013000	Striping-White Paint	359	GAL	$ 45.00	$16,155.00
620013960	Striping-White Epoxy	478	GAL	$ 100.00	$47,800.00
620014000	Striping-Yellow Paint	148	GAL	$ 45.00	$6,660.00
620014960	Striping-Yellow Epoxy	197	GAL	$ 100.00	$19,700.00
622011084	Geotextile Stabilization	1,496	SY	$ 5.00	$7,480.00
				Subtotal	**$1,354,019.00**
				20% Contingency	$270,800
				Subtotal	$1,624,819
				Engineering, Geotech & Construction Admin	$162,500
				3% TERO Fees	$53,620
				Total	$1,840,939

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)
Phase 5 - RP 28.0 - RP 34.0

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 99,000.00	$99,000.00
109200050	Mobilization	1	LS	$ 340,000.00	$340,000.00
202020140	Remove Bituminous Pavement	8,120	SY	$ 10.00	$81,200.00
203020278	Excavation-Digouts	8,120	CY	$ 35.00	$284,200.00
208010150	Temporary Erosion Control	1	LS	$ 98,900.00	$98,900.00
301020345	Crushed Aggregate Course	15,022	TON	$ 20.00	$300,440.00
302000000	Pavement Pulverization	96,809	SY	$ 2.50	$242,023.00
401020045	Plant Mix Surf GR S 3/4 in	20,733.2	TON	$ 50.00	$1,036,660.00
402020092	Asphalt Cement PG 64-28	1,119.6	TON	$ 640.00	$716,538.00
402020305	Emulsified Asphalt SS-1	4,840.5	GAL	$ 6.00	$29,043.00
402020368	Emulsified Asphalt CRS-2P	173	TON	$ 725.00	$125,425.00
409000000	Final Sweep and Broom	5.9	CRMI	$ 740.00	$4,366.00
409000010	Cover Aggregate-Type1	96,809	SY	$ 1.00	$96,809.00
411011125	Centerline Rumble Strips-Type 2	5.9	MILE	$ 1,770.00	$10,443.00
411011135	Rumble Strips	11.8	MILE	$ 1,005.00	$11,859.00
606010140	Guardrail End Section Widening	8	EA	$ 1,350.00	$10,800.00
606010330	MGS Guardrail	2,612.5	LF	$ 25.00	$65,313.00
606010335	MASH W-Beam Terminal Section	8	EA	$ 3,515.00	$28,120.00
618030080	Traffic Control	1	LS	$ 157,000.00	$157,000.00
619010086	Signs-Alum Refl Sheet IV	26.2	SF	$ 40.00	$1,048.00
619010090	Signs-Alum Refl Sheet XI	10	SF	$ 35.00	$350.00
619010230	Remove Sign	9.0	EA	$ 95.00	$855.00
619010310	Posts-Steel U Sign	168.0	LB	$ 10.00	$1,680.00
619010480	Poles-Treated Wood 4 in.	42	LF	$ 15.00	$630.00
619011010	Delineator DES A	200	EA	$ 35.00	$7,000.00
620013000	Striping-White Paint	217	GAL	$ 40.00	$8,680.00
620013960	Striping-White Epoxy	290	GAL	$ 75.00	$21,750.00
620014000	Striping-Yellow Paint	99	GAL	$ 40.00	$3,960.00
620014960	Striping-Yellow Epoxy	132	GAL	$ 75.00	$9,900.00
622011084	Geotextile Stabilization	8,120	SY	$ 5.00	$40,600.00

Subtotal	**$3,834,592.00**
20% Contingency	$766,900
Subtotal	$4,601,492
Engineering, Geotech & Construction Admin	$460,100
3% TERO Fees	$151,848
Total	$5,213,440

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
BIA Route 91
Crow Tribe of Indians
March 2021
(PRELIMINARY)
Phase 6 - RP 34.0 - RP 40.5

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
62014000	Striping-Yellow Paint	94	GAL	$ 45.00	$4,230.00
62014960	Striping-Yellow Epoxy	126	GAL	$ 100.00	$12,600.00
104030011	Taxes, Bond, & Insurance	1	LS	$ 17,000.00	$17,000.00
109200050	Mobilization	1	LS	$ 59,000.00	$59,000.00
202020140	Remove Bituminous Pavement	805	SY	$ 45.00	$36,225.00
203020278	Excavation-Digouts	805	CY	$ 35.00	$28,175.00
208010150	Temporary Erosion Control	1	LS	$ 171,000.00	$171,000.00
301020345	Crushed Aggregate Course	1,490	TON	$ 45.00	$67,050.00
402020368	Emulsified Asphalt CRS-2P	190	TON	$ 725.00	$137,750.00
403010255	Crack Sealing	9,542.1	LB	$ 7.00	$66,795.00
409000000	Final Sweep and Broom	6.5	CRMI	$ 750.00	$4,860.00
409000010	Cover Aggregate-Type1	106,403	SY	$ 1.00	$106,403.00
411011125	Centerline Rumble Strips-Type 2	6.5	MILE	$ 1,801.14	$11,671.00
411011135	Rumble Strips	13.0	MILE	$ 1,170.00	$15,152.00
618030080	Traffic Control	1	LS	$ 33,200.00	$33,200.00
619010086	Signs-Alum Refl Sheet IV	31.2	SF	$ 40.00	$1,248.00
619010090	Signs-Alum Refl Sheet XI	47	SF	$ 38.00	$1,775.00
619010480	Poles-Treated Wood 4 in.	134	LF	$ 20.00	$2,680.00
619011010	Delineator DES A	200	EA	$ 35.00	$7,000.00
620013000	Striping-White Paint	235	GAL	$ 45.00	$10,575.00
620013960	Striping-White Epoxy	314	GAL	$ 100.00	$31,400.00
622011084	Geotextile Stabilization	805	SY	$ 5.00	$4,025.00
916010310	Posts-Steel U Sign	168.0	LB	$ 10.00	$1,680.00
919010230	Remove Sign	17.0	EA	$ 95.00	$1,615.00

Subtotal	**$833,109.00**
20% Contingency	$166,600
Subtotal	$999,709
Engineering, Geotech & Construction Admin	$100,000
3% TERO Fees	$32,991
Total	$1,132,700

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

BIA Route 91

Crow Tribe of Indians

March 2021

(PRELIMINARY)

Phase 7 - RP 40.5 - RP 44.8

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
104030011	Taxes, Bond, & Insurance	1	LS	$ 86,000.00	$86,000.00
109200050	Mobilization	1	LS	$ 294,000.00	$294,000.00
202020140	Remove Bituminous Pavement	5,198	SY	$ 45.00	$233,910.00
203020278	Excavation-Digouts	5,198	CY	$ 35.00	$181,930.00
208010150	Temporary Erosion Control	1	LS	$ 85,700.00	$85,700.00
301020345	Crushed Aggregate Course	9,616	TON	$ 45.00	$432,720.00
302000000	Pavement Pulverization	66,588	SY	$ 2.50	$166,470.00
401020045	Plant Mix Surf GR S 3/4 in	14,260.8	TON	$ 50.00	$713,040.00
402020092	Asphalt Cement PG 64-28	770.1	TON	$ 640.00	$492,864.00
402020305	Emulsified Asphalt SS-1	3,329.4	GAL	$ 6.00	$19,976.00
402020368	Emulsified Asphalt CRS-2P	119	TON	$ 725.00	$86,275.00
409000000	Final Sweep and Broom	4.1	CRMI	$ 750.00	$3,038.00
409000010	Cover Aggregate-Type1	66,588	SY	$ 1.00	$66,588.00
411011125	Centerline Rumble Strips-Type 2	4.1	MILE	$ 1,801.14	$7,295.00
411011135	Rumble Strips	8.1	MILE	$ 1,170.00	$9,489.00
606010140	Guardrail End Section Widening	14	EA	$ 1,600.00	$22,400.00
606010150	Guardrail-STL/BR APPR-TY 1	4	EA	$ 3,200.00	$12,800.00
606010230	Guardrail-STL/BR APPR-TY 3	4	EA	$ 3,150.00	$12,600.00
606010330	MGS Guardrail	4,775.0	LF	$ 25.00	$119,375.00
606010335	MASH W-Beam Terminal Section	14	EA	$ 3,515.00	$49,210.00
606010386	Remove and Salvage Guardrail	536	LF	$ 10.00	$5,356.00
611010300	Resert Cattel Guard	1	EA	$ 3,700.00	$3,700.00
618030080	Traffic Control	1	LS	$ 123,000.00	$123,000.00
619010086	Signs-Alum Refl Sheet IV	22.7	SF	$ 40.00	$908.00
619010090	Signs-Alum Refl Sheet XI	82	SF	$ 38.00	$3,124.00
619010230	Remove Sign	23.0	EA	$ 95.00	$2,185.00
619010310	Posts-Steel U Sign	112.0	LB	$ 10.00	$1,120.00
619010480	Poles-Treated Wood 4 in.	210	LF	$ 20.00	$4,200.00
619011010	Delineator DES A	150	EA	$ 35.00	$5,250.00
619011040	Delineator DES D	6	EA	$ 45.00	$270.00
620013000	Striping-White Paint	156	GAL	$ 45.00	$7,020.00
620013960	Striping-White Epoxy	208	GAL	$ 100.00	$20,800.00
620014000	Striping-Yellow Paint	126	GAL	$ 45.00	$5,670.00
620014960	Striping-Yellow Epoxy	169	GAL	$ 100.00	$16,900.00
622011084	Geotextile Stabilization	5,198	SY	$ 5.00	$25,990.00
				Subtotal	**$3,321,173.00**
				20% Contingency	$664,200
				Subtotal	$3,985,373
				Engineering, Geotech & Construction Admin	$398,500
				3% TERO Fees	$131,516
				Total	$4,515,389

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

BIA Route 91

Crow Tribe of Indians

March 2021

(PRELIMINARY)

Pryor Gap Road

Item #	Description	Quantity	Unit	Unit Price	TOTAL COST
203020100	Excavation-Unclassified	1,958	CY	$ 16.51	$32,327.00
301020340	Crushed Aggregate Course	1,262	TON	$ 34.20	$43,160.00
401020022	Commerical Mix PG 64-28	1,078	TON	$ 95.53	$102,981.00
402020305	Emulsified Asphalt SS-1	970	GAL	$ 10.67	$10,350.00
411011130	Centerline Rumble Strips-Type 3	0.3	MILE	$ 1,422.28	$427.00
411011135	Rumble Strips	0.6	MILE	$ 1,677.16	$1,006.00
610010100	Topsoil	340	CY	$ 28.46	$9,676.00
618030190	Construction Traffic Control	1	LS	$ 10,000.00	$10,000.00
619010090	Signs-Alum Refl Sheet XI	49	SF	$ 29.56	$1,448.00
619010480	Poles-Treated Wood 4 in.	57	LF	$ 15.77	$899.00
620013000	Striping-White Paint	11	GAL	$ 20.40	$216.00
620013960	Striping-White Epoxy	14	GAL	$ 44.85	$632.00
620014000	Striping-Yellow Paint	11	GAL	$ 19.57	$209.00
620014960	Striping-Yellow Epoxy	14	GAL	$ 48.61	$695.00
622011087	Separation Geotextile -MOD	6,236	SY	$ 1.03	$6,423.00
999109200	Mobilization	1	LS	$ 31,562.00	$31,562.00
				Subtotal	**$252,011.00**
				10% Contingency	$25,162
				Subtotal	$277,173
				Preliminary & Construction Engineering	$55,434
				3% TERO Fees	$8,315
				Total	$340,922

Appendix C: PASER Manual

Pavement Surface Evaluation and Rating

PASER Manual

Asphalt Roads



Transportation Information Center
University of Wisconsin–Madison

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This manual is intended to assist local officials in understanding and rating the surface condition of asphalt pavement. It describes types of defects and provides a simple system to visually rate pavement condition. The rating procedure can be used as condition data for the Wisconsin DOT local road inventory and as part of a computerized pavement management system like PASERWARE.

The PASER system described here and in other T.I.C. publications is based in part on a roadway management system originally developed by Phil Scherer, transportation planner, Northwest Wisconsin Regional Planning Commission.

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Wisconsin Transportation Information Center

432 North Lake Street
Madison, WI 53706

phone 800/442-4615
fax 608/263-3160
e-mail tic@epd.engr.wisc.edu
URL http://tic.engr.wisc.edu

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Pavement Surface Evaluation and Rating

PASER Manual

Asphalt Roads

Donald Walker, T.I.C. Director, *author*
Lynn Entine, Entine & Associates, *editor*
Susan Kummer, Artifax, *designer*

Transportation Information Center
University of Wisconsin–Madison

Pavement Surface Evaluation and Rating

Asphalt PASER Manual

A local highway agency's major goal is to use public funds to provide a comfortable, safe and economical road surface—no simple task. It requires balancing priorities and making difficult decisions in order to manage pavements. Local rural and small city pavements are often managed informally, based on the staff's judgment and experience. While this process is both important and functional, using a slightly more formalized technique can make it easier to manage pavements effectively.

Experience has shown that there are three especially useful steps in managing local roads:

1. Inventory all local roads and streets.
2. Periodically evaluate the condition of all pavements.
3. Use the condition evaluations to set priorities for projects and select alternative treatments.

A comprehensive pavement management system involves collecting data and assessing several road characteristics: roughness (ride), surface distress (condition), surface skid characteristics, and structure (pavement strength and deflection). Planners can combine this condition data with economic analysis to develop short-range and long-range plans for a variety of budget levels. However, many local agencies lack the resources for such a full-scale system.

Since surface condition is the most vital element in any pavement management system, local agencies can use the simplified rating system presented in this ***Asphalt PASER Manual*** to evaluate their roads. The PASER ratings combined with other inventory data (width, length, shoulder, pavement type, etc.) from the WisDOT local roads inventory (WISLR) can be very helpful in planning future budgets and priorities.

WISLR inventory information and PASER ratings can be used in a computerized pavement management system, PASERWARE, developed by the T.I.C and WisDOT. Local officials can use PASERWARE to evaluate whether their annual road budgets are adequate to maintain or improve current road conditions and to select the most cost-effective strategies and priorities for annual projects.

PASER Manuals for gravel, concrete, and other road surfaces, with compatible rating systems are also available (page 29). Together they make a comprehensive condition rating method for all road types. PASER ratings are accepted for WISLR condition data.

Asphalt pavement distress

PASER uses visual inspection to evaluate pavement surface conditions. The key to a useful evaluation is identifying different types of pavement distress and linking them to a cause. Understanding the cause for current conditions is extremely important in selecting an appropriate maintenance or rehabilitation technique.

There are four major categories of common asphalt pavement surface distress:

Surface defects
Raveling, flushing, polishing.

Surface deformation
Rutting, distortion—rippling and shoving, settling, frost heave.

Cracks
Transverse, reflection, slippage, longitudinal, block, and alligator cracks.

Patches and potholes

Deterioration has two general causes: environmental due to weathering and aging, and structural caused by repeated traffic loadings.

Obviously, most pavement deterioration results from both environmental and structural causes. However, it is important to try to distinguish between the two in order to select the most effective rehabilitation techniques.

The rate at which pavement deteriorates depends on its environment, traffic loading conditions, original construction quality, and interim maintenance procedures. Poor quality materials or poor construction procedures can significantly reduce the life of a pavement. As a result, two pavements constructed at the same time may have significantly different lives, or certain portions of a pavement may deteriorate more rapidly than others. On the other hand, timely and effective maintenance can extend a pavement's life. Crack sealing and seal coating can reduce the effect of moisture in aging of asphalt pavement.

With all of these variables, it is easy to see why pavements deteriorate at various rates and why we find them in various stages of disrepair. Recognizing defects and understanding their causes helps us rate pavement condition and select cost-effective repairs. The pavement defects shown on the following pages provide a background for this process.

Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that PASER ratings be updated every two years, and an annual update is even better.

SURFACE DEFECTS

Raveling

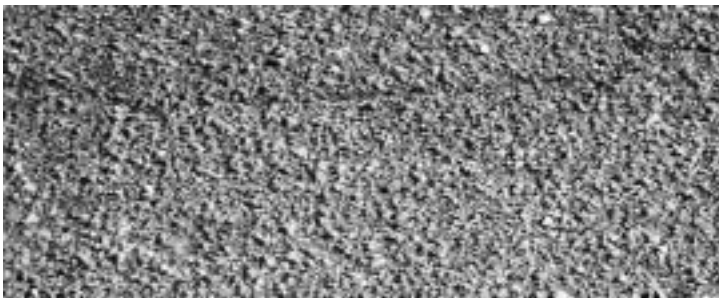
Raveling is progressive loss of pavement material from the surface downward, caused by: stripping of the bituminous film from the aggregate, asphalt hardening due to aging, poor compaction especially in cold weather construction, or insufficient asphalt content. Slight to moderate raveling has loss of fines. Severe raveling has loss of coarse aggregate. Raveling in the wheelpaths can be accelerated by traffic. Protect pavement surfaces from the environment with a sealcoat or a thin overlay if additional strength is required.

Flushing

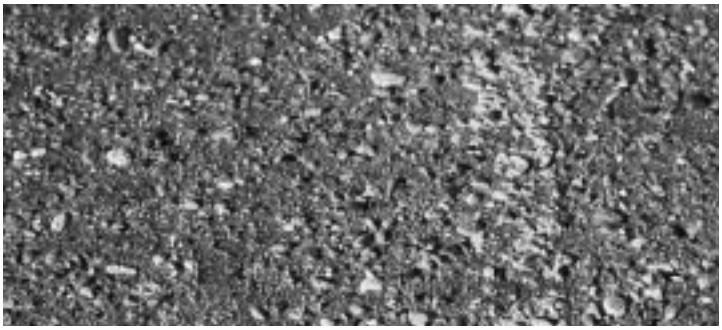
Flushing is excess asphalt on the surface caused by a poor initial asphalt mix design or by paving or sealcoating over a flushed surface. Repair by blotting with sand or by overlaying with properly designed asphalt mix.

Polishing

Polishing is a smooth slippery surface caused by traffic wearing off sharp edges of aggregates. Repair with sealcoat or thin bituminous overlay using skid-resistant aggregate.



◄ **Slight raveling. Small aggregate particles have worn away exposing tops of large aggregate.**



◄ **Moderate to severe raveling. Erosion further exposes large aggregate.**

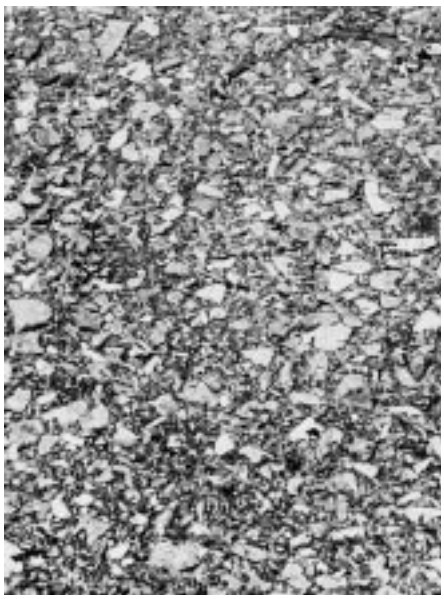


◄ **Severe raveling and loss of surface material.**

Polished, worn aggregate needs repair. ▼

► **Flushing. Dark patches show where asphalt has worked to surface.**







SURFACE DEFORMATION

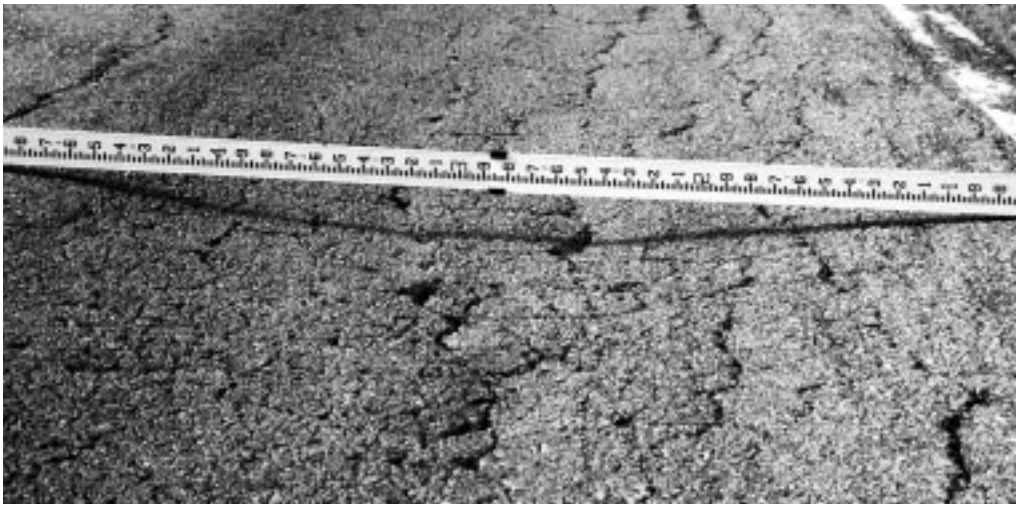
Rutting

Rutting is displacement of material, creating channels in wheelpaths. It is caused by traffic compaction or displacement of unstable material. Severe rutting (over 2") may be caused by base or subgrade consolidation. Repair minor rutting with overlays. Severe rutting requires milling the old surface or reconstructing the roadbed before resurfacing.

◄ **Even slight rutting is evident after a rain.**



◄ **Severe rutting over 2" caused by poor mix design.**



◄ **Severe rutting caused by poor base or subgrade.**

Distortion

Shoving or rippling is surfacing material displaced crossways to the direction of traffic. It can develop into washboarding when the asphalt mixture is unstable because of poor quality aggregate or improper mix design. Repair by milling smooth and overlaying with stable asphalt mix.

Other pavement distortions may be caused by settling, frost heave, etc. Patching may provide temporary repair. Permanent correction usually involves removal of unsuitable subgrade material and reconstruction.

▼ **Heavy traffic has shoved pavement into washboard ripples and bumps.**





► **Severe settling from utility trench.**



► **Frost heave damage from spring break-up.**

▼ **Widely spaced, well-sealed cracks.**





CRACKS

Transverse cracks

A crack at approximately right angles to the center line is a transverse crack. They are often regularly spaced. The cause is movement due to temperature changes and hardening of the asphalt with aging.

Transverse cracks will initially be widely spaced (over 50'). Additional cracking will occur with aging until they are closely spaced (within several feet). These usually begin as hairline or very narrow cracks; with aging they widen. If not properly sealed and maintained, secondary or multiple cracks develop parallel to the initial crack. The crack edges can further deteriorate by raveling and eroding the adjacent pavement.

Prevent water intrusion and damage by sealing cracks which are more than ¼" wide.

◄ **Sealed cracks, a few feet apart.**



▲ **Tight cracks less than ¼" in width.**



▲ **Open crack – ½" or more in width.**



▲ **Water enters unsealed cracks softening pavement and causing secondary cracks.**



▲ **Pavement ravels and erodes along open cracks causing deterioration.**

Reflection cracks

Cracks in overlays reflect the crack pattern in the pavement underneath. They are difficult to prevent and correct. Thick overlays or reconstruction is usually required.



► **Concrete joints reflected through bituminous overlay.**

Slippage cracks

Crescent or rounded cracks in the direction of traffic, caused by slippage between an overlay and an underlying pavement. Slippage is most likely to occur at intersections where traffic is stopping and starting. Repair by removing the top surface and resurfacing using a tack coat.



► **Crescent-shaped cracks characteristic of slippage.**



► **Loss of bond between pavement layers allows traffic to break loose pieces of surface.**

Centerline crack (still tight). ►



Edge cracking from weakened subbase and traffic loads. ▼



Longitudinal cracks

Cracks running in the direction of traffic are longitudinal cracks. Center line or lane cracks are caused by inadequate bonding during construction or reflect cracks in underlying pavement. Longitudinal cracks in the wheel path indicate fatigue failure from heavy vehicle loads. Cracks within one foot of the edge are caused by insufficient shoulder support, poor drainage, or frost action. Cracks usually start as hairline or vary narrow and widen and erode with age. Without crack filling, they can ravel, develop multiple cracks, and become wide enough to require patching.

Filling and sealing cracks will reduce moisture penetration and prevent further subgrade weakening. Multiple longitudinal cracks in the wheel path or pavement edge indicate a need for strengthening with an overlay or reconstruction.

► First stage of wheelpath cracking caused by heavy traffic loads.



Load-related cracks in wheel path plus centerline cracking. ▼

Multiple open cracks at center line, wheelpaths and lane center. ▼





Block cracks

Block cracking is interconnected cracks forming large blocks. Cracks usually intersect at nearly right angles. Blocks may range from one foot to approximately 10′ or more across. The closer spacing indicates more advanced aging caused by shrinking and hardening of the asphalt over time. Repair with sealcoating during early stages to reduce weathering of the asphalt. Overlay or reconstruction required in the advanced stages.



► **Large blocks, approximately 10′ across.**



► **Intermediate-size block cracking, 1′-5′ across with open cracks.**



▲ **Extensive block cracking in an irregular pattern.**



► **Severe block cracking – 1′ or smaller blocks. Tight cracks with no raveling.**

Alligator cracks

Interconnected cracks forming small pieces ranging in size from about 1" to 6". This is caused by failure of the surfacing due to traffic loading (fatigue) and very often also due to inadequate base or subgrade support. Repair by excavating localized areas and replacing base and surface. Large areas require reconstruction. Improvements in drainage may often be required.



◄
Alligator crack pattern. Tight cracks and one patch.



◄
Characteristic "chicken wire" crack pattern shows smaller pavement pieces and patching.



◄
Open raveled alligator cracking with settlement along lane edge most likely due to very soft subgrade.

PATCHES AND POTHOLES

Patches

Original surface repaired with new asphalt patch material. This indicates a pavement defect or utility excavation which has been repaired. Patches with cracking, settlement or distortions indicate underlying causes still remain. Recycling or reconstruction are required when extensive patching shows distress.



► **Typical repair of utility excavation. Patch in fair to good condition.**



► **Edge wedging. Pavement edges strengthened with wedges of asphalt. Patch is in very good condition.**



► **Extensive patching in very poor condition.**

Potholes

Holes and loss of pavement material caused by traffic loading, fatigue and inadequate strength. Often combined with poor drainage. Repair by excavating or rebuilding localized potholes. Reconstruction required for extensive defects.



◄
Small pothole where top course has broken away.



◄
Multiple potholes show pavement failure, probably due to poor subgrade soils, frost heave, and bad drainage.



◄
Large, isolated pothole, extends through base. Note adjacent alligator cracks which commonly deteriorate into potholes.

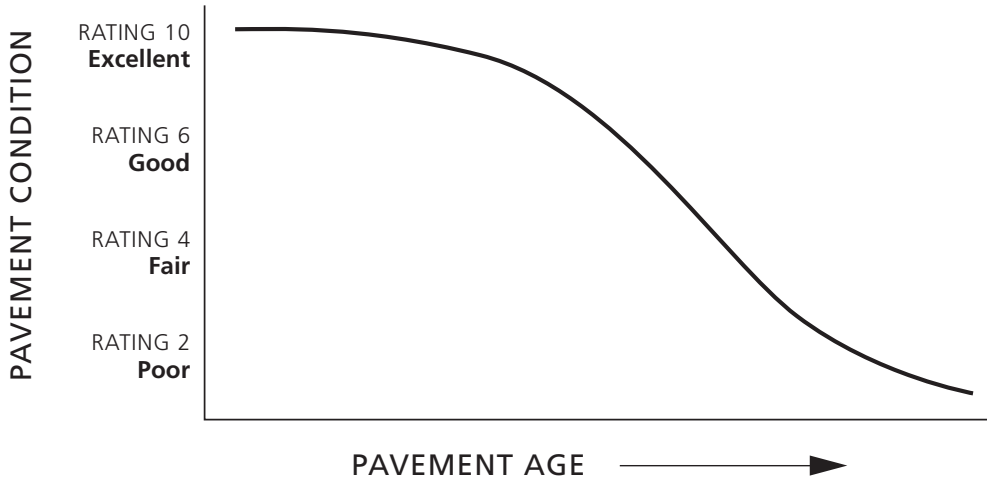
Rating pavement surface condition

With an understanding of surface distress, you can evaluate and rate asphalt pavement surfaces. The rating scale ranges from **10–excellent** condition to **1–failed**. Most pavements will deteriorate through the phases listed in the rating scale. The time it takes to go from excellent condition (10) to complete failure (1) depends largely on the quality of the original construction and the amount of heavy traffic loading.

Once significant deterioration begins, it is common to see pavement decline rapidly. This is usually due to a combination of loading and the effects of additional moisture. As a pavement ages and additional cracking develops, more moisture can enter the pavement and accelerate the rate of deterioration.

Look at the photographs in this section to become familiar with the descriptions of the individual rating categories. To evaluate an individual pavement segment, first determine its general condition. Is it relatively new, toward the top end of the scale? In very poor condition and at the bottom of the scale? Or somewhere in between? Next, think generally about the appropriate maintenance method. Use the rating categories outlined below.

Finally, review the individual pavement distress and select the appropriate surface rating. Individual pavements will ***not*** have all of the types of distress listed for any particular rating. They may have only one or two types.



In addition to indicating the surface condition of a road, a given rating also includes a recommendation for needed maintenance or repair. This feature of the rating system facilitates its use and enhances its value as a tool in ongoing road maintenance.

RATINGS ARE RELATED TO NEEDED MAINTENANCE OR REPAIR

Rating 9 & 10	No maintenance required
Rating 8	Little or no maintenance
Rating 7	Routine maintenance, cracksealing and minor patching
Rating 5 & 6	Preservative treatments (sealcoating)
Rating 3 & 4	Structural improvement and leveling (overlay or recycling)
Rating 1 & 2	Reconstruction

Rating system

Surface rating	*Visible distress**	*General condition/ treatment measures*
10 Excellent	None.	New construction.
9 Excellent	None.	Recent overlay. Like new.
8 Very Good	No longitudinal cracks except reflection of paving joints. Occasional transverse cracks, widely spaced (40′ or greater). All cracks sealed or tight (open less than ¼″).	Recent sealcoat or new cold mix. Little or no maintenance required.
7 Good	Very slight or no raveling, surface shows some traffic wear. Longitudinal cracks (open ¼″) due to reflection or paving joints. Transverse cracks (open ¼″) spaced 10′ or more apart, little or slight crack raveling. No patching or very few patches in excellent condition.	First signs of aging. Maintain with routine crack filling.
6 Good	Slight raveling (loss of fines) and traffic wear. Longitudinal cracks (open ¼″–½″), some spaced less than 10′. First sign of block cracking. Sight to moderate flushing or polishing. Occasional patching in good condition.	Shows signs of aging. Sound structural condition. Could extend life with sealcoat.
5 Fair	Moderate to severe raveling (loss of fine and coarse aggregate). Longitudinal and transverse cracks (open ½″) show first signs of slight raveling and secondary cracks. First signs of longitudinal cracks near pavement edge. Block cracking up to 50% of surface. Extensive to severe flushing or polishing. Some patching or edge wedging in good condition.	Surface aging. Sound structural condition. Needs sealcoat or thin non-structural overlay (less than 2″)
4 Fair	Severe surface raveling. Multiple longitudinal and transverse cracking with slight raveling. Longitudinal cracking in wheel path. Block cracking (over 50% of surface). Patching in fair condition. Slight rutting or distortions (½″ deep or less).	Significant aging and first signs of need for strengthening. Would benefit from a structural overlay (2″ or more).
3 Poor	Closely spaced longitudinal and transverse cracks often showing raveling and crack erosion. Severe block cracking. Some alligator cracking (less than 25% of surface). Patches in fair to poor condition. Moderate rutting or distortion (1″ or 2″ deep). Occasional potholes.	Needs patching and repair prior to major overlay. Milling and removal of deterioration extends the life of overlay.
2 Very Poor	Alligator cracking (over 25% of surface). Severe distortions (over 2″ deep) Extensive patching in poor condition. Potholes.	Severe deterioration. Needs reconstruction with extensive base repair. Pulverization of old pavement is effective.
1 Failed	Severe distress with extensive loss of surface integrity.	Failed. Needs total reconstruction.

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

RATING 10 & 9

EXCELLENT —
No maintenance required

Newly constructed or recently overlaid roads are in excellent condition and require no maintenance.



► **RATING 10**
New construction.



► **RATING 9**
Recent overlay, rural.



► **RATING 9**
Recent overlay, urban.



RATING 8

VERY GOOD —
Little or no maintenance required

This category includes roads which have been recently sealcoated or overlaid with new cold mix. It also includes recently constructed or overlaid roads which may show longitudinal or transverse cracks. All cracks are tight or sealed.

◄ **Recent chip seal.**



◄ **Recent slurry seal.**



▲ **New cold mix surface.**



▼ **Widely spaced, sealed cracks.**

RATING 7

GOOD —
Routine sealing recommended

Roads show first signs of aging, and they may have very slight raveling. Any longitudinal cracks are along paving joint. Transverse cracks may be approximately 10′ or more apart. All cracks are ¼″ or less, with little or no crack erosion. Few if any patches, all in very good condition. Maintain a crack sealing program.



► **Tight and sealed transverse and longitudinal cracks. Maintain crack sealing program.**



► **Tight and sealed transverse and longitudinal cracks.**



► **Transverse cracks about 10′ or more apart. Maintain crack sealing program.**



RATING 6

GOOD —
Consider preservative treatment

Roads are in sound structural condition but show definite signs of aging. Seal-coating could extend their useful life. There may be slight surface raveling. Transverse cracks can be frequent, less than 10′ apart. Cracks may be 1/4–1/2″ and sealed or open. Pavement is generally sound adjacent to cracks. First signs of block cracking may be evident. May have slight or moderate bleeding or polishing. Patches are in good condition.

◄ **Slight surface raveling with tight cracks, less than 10′ apart.**



◄ **Transverse cracking less than 10′ apart; cracks well-sealed.**

▼ **Large blocks, early signs of raveling and block cracking.**



▼ **Open crack, 1/2″ wide; adjoining pavement sound.**



▼ **Moderate flushing.**



RATING 5

FAIR —
Preservative maintenance treatment required

Roads are still in good structural condition but clearly need sealcoating or overlay. They may have moderate to severe surface raveling with significant loss of aggregate. First signs of longitudinal cracks near the edge. First signs of raveling along cracks. Block cracking up to 50% of surface. Extensive to severe flushing or polishing. Any patches or edge wedges are in good condition.

▼ **Block cracking with open cracks.**





► **Moderate to severe raveling in wheel paths.**

▼ **Severe flushing.**





▲ **Wedges and patches extensive but in good condition.**

RATING 4

FAIR —
Structural improvement required

Roads show first signs of needing strengthening by overlay. They have very severe surface raveling which should no longer be sealed. First longitudinal cracking in wheel path. Many transverse cracks and some may be raveling slightly. Over 50% of the surface may have block cracking. Patches are in fair condition. They may have rutting less than 1/2" deep or slight distortion.

Severe raveling with ▼ extreme loss of aggregate.



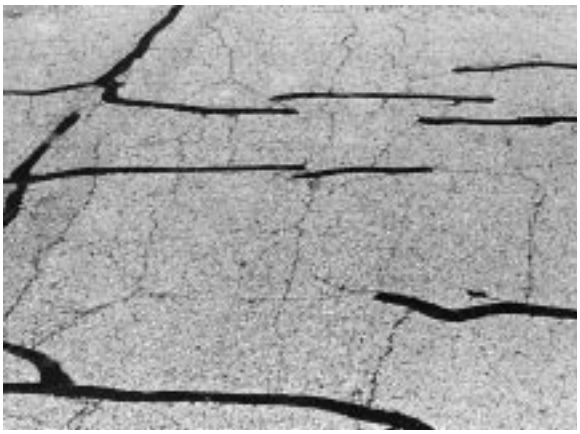
Load cracking and slight ▼ rutting in wheel path.

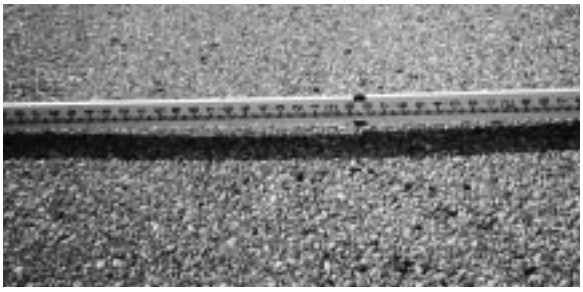




◄ Longitudinal cracking; early load-related distress in wheel path. Strengthening needed.

▼ Slight rutting; patch in good condition.







▼ Extensive block cracking. Blocks tight and sound.

◄ Slight rutting in wheel path.

RATING 3

POOR—
Structural improvement required

Roads must be strengthened with a structural overlay (2" or more). Will benefit from milling and very likely will require pavement patching and repair beforehand. Cracking will likely be extensive. Raveling and erosion in cracks may be common. Surface may have severe block cracking and show first signs of alligator cracking. Patches are in fair to poor condition. There is moderate distortion or rutting (1-2") and occasional potholes.



► **Many wide and raveled cracks indicate need for milling and overlay.**



► **2" ruts need mill and overlay.**



► **Open and raveled block cracks.**



RATING 3

POOR — (continued)
Structural improvement required

◄ **Alligator cracking. Edge needs repair and drainage needs improvement prior to rehabilitation.**

▼ **Distortion with patches in poor condition. Repair and overlay.**



RATING 2

VERY POOR—
Reconstruction required

Roads are severely deteriorated and need reconstruction. Surface pulverization and additional base may be cost-effective. These roads have more than 25% alligator cracking, severe distortion or rutting, as well as potholes or extensive patches in poor condition.



► **Extensive alligator cracking. Pulverize and rebuild.**





▲ **Severe rutting. Strengthen base and reconstruct.**

▲ **Patches in poor condition, wheelpath rutting. Pulverize, strengthen and reconstruct.**



► **Severe frost damage. Reconstruct.**



RATING 1

FAILED —
Reconstruction required

Roads have failed, showing severe distress and extensive loss of surface integrity.

◄
Potholes from frost damage. Reconstruct.



◄
Potholes and severe alligator cracking. Failed pavement. Reconstruct.



◄
Extensive loss of surface. Rebuild.

Practical advice on rating roads

Inventory and field inspection

Most agencies routinely observe roadway conditions as a part of their normal work and travel. However, an actual inspection means looking at the entire roadway system as a whole and preparing a written summary of conditions. This inspection has many benefits over casual observations. It can be helpful to compare segments, and ratings decisions are likely to be more consistent because the roadway system is considered as a whole within a relatively short time.

An inspection also encourages a review of specific conditions important in roadway maintenance, such as drainage, adequate strength, and safety.

A simple written inventory is useful in making decisions where other people are involved. You do not have to trust your memory, and you can usually answer questions in more detail. Having a written record and objective information also improves your credibility with the public.

Finally, a written inventory is very useful in documenting changing roadway conditions. Without records over several years it is impossible to know if road conditions are improving, holding their own, or declining.

Annual budgets and long range planning are best done when based on actual needs as documented with a written inventory.

The Wisconsin DOT local road inventory (WISLR) is a valuable resource for managing your local roads. Adding PASER surface condition ratings is an important improvement.

Averaging and comparing sections

For evaluation, divide the local road system into individual segments which are similar in construction and condition. Rural segments may vary from ½ mile to a mile long, while sections in urban areas will likely be 1-4 blocks long or more. If you are starting with the WISLR Inventory, the segments have already been established. You may want to review them for consistent road conditions.

Obviously, no roadway segment is entirely consistent. Also, surfaces in one section will not have all of the types of distress listed for any particular rating. They may have only one or two types. Therefore, some averaging is necessary.

The objective is to rate the condition that represents the majority of the roadway. Small or isolated conditions should not influence the rating. It is useful to note these special conditions on the inventory form so this information can be used in planning specific improvement projects. For example, some spot repairs may be required.

Occasionally surface conditions vary significantly within a segment. For example, short sections of good condition may be followed by sections of poor surface conditions. In these cases, it is best to rate the segment according to the worst conditions and note the variation on the form.

The overall purpose of condition rating is to be able to compare each segment relative to all the other segments in your roadway system. On completion you should be able to look at any two pavement segments and find that the better surface has a higher rating.

Within a given rating, say 6, not all pavements will be exactly the same. However, they should all be considered to be in better condition than those with lower ratings, say 5. Sometimes it is helpful in rating a difficult segment to compare it to other previously rated segments. For example, if it is better than one you rated 5 and worse than a typical 7, then a rating of 6 is appropriate. Having all pavement segments rated in the proper relative order is most important and useful.

Assessing drainage conditions

Moisture and poor pavement drainage are significant factors in pavement deterioration. Some assessment of drainage conditions during pavement rating is highly recommended. While you should review drainage in detail at the project level, at this stage simply include an overview drainage evaluation at the same time as you evaluate surface condition.



Urban drainage.

RATING: Excellent

Good rural ditch and driveway culvert. Culvert end needs cleaning.

RATING: Good



High shoulder and no ditch lead to pavement damage. Needs major ditch improvement for a short distance.

RATING: Fair



No drainage leads to failed pavement.

RATING: Poor



Consider both pavement surface drainage and lateral drainage (ditches or storm sewers). Pavement should be able to quickly shed water off the surface into the lateral ditches. Ditches should be large and deep enough to drain the pavement and remove the surface water efficiently into adjacent waterways.

Look at the roadway crown and check for low surface areas that permit ponding. Paved surfaces should have approximately a 2% cross slope or crown across the roadway. This will provide approximately 3" of fall on a 12' traffic lane. Shoulders should have a greater slope to improve surface drainage.

A pavement's ability to carry heavy traffic loads depends on both the pavement materials (asphalt surfacing and granular base) and the strength of the underlying soils. Most soils lose strength when they are very wet. Therefore, it is important to provide drainage to the top layer of the subgrade supporting the pavement structure.

In rural areas, drainage is provided most economically by open ditches that allow soil moisture to drain laterally. As a rule of thumb, the bottom of the ditch ought to be at least one foot below the base course of the pavement in order to drain the soils. This means that minimum ditch depth should be about 2' below the center of the pavement. Deeper ditches, of course, are required to accommodate roadway culverts and maintain the flow line to adjacent drainage channels or streams.

You should also check culverts and storm drain systems. Storm drainage systems that are silted in, have a large accumulation of debris, or are in poor structural condition will also degrade pavement performance.

The T.I.C. publication, ***Drainage Manual: Local Road Assessment and Improvement,*** describes the elements of drainage systems, depicts them in detailed photographs, and explains how to rate their condition. Copies are available from the Transportation Information Center.

Planning annual maintenance and repair budgets

We have found that relating a normal maintenance or rehabilitation procedure to the surface rating scheme helps local officials use the rating system. However, an individual surface rating should not automatically dictate the final maintenance or rehabilitation technique.

You should consider future traffic projections, original construction, and pavement strength since these may dictate a more comprehensive rehabilitation than the rating suggests. On the other hand, it may be appropriate under special conditions to do nothing and let the pavement fully deteriorate, then rebuild when funds are available.

Summary

Using local road funds most efficiently requires good planning and accurate identification of appropriate rehabilitation projects. Assessing roadway conditions is an essential first step in this process. This asphalt pavement surface condition rating procedure has proved effective in improving decision making and using highway funds more efficiently. It can be used directly by local officials and staff. It may be combined with additional testing and data collection in a more comprehensive pavement management system.

Transportation Information Center Publications

Pavement Surface Evaluation and Rating (PASER) Manuals

Asphalt PASER Manual, 2002, 28 pp.

Brick and Block PASER Manual, 2001, 8 pp.

Concrete PASER Manual, 2002, 28 pp.

Gravel PASER Manual, 2002, 20 pp.

Sealcoat PASER Manual, 2000, 16 pp.

Unimproved Roads PASER Manual, 2001, 12 pp.

Drainage Manual
Local Road Assessment and Improvement, 2000, 16 pp.

SAFER Manual
Safety Evaluation for Roadways, 1996, 40 pp.

Flagger's Handbook (pocket-sized guide), 1998, 22 pp.

Work Zone Safety, Guidelines for Construction, Maintenance, and Utility Operations, (pocket-sized guide), 1999, 55 pp.

Wisconsin Transportation Bulletins

#1 Understanding and Using Asphalt
#2 How Vehicle Loads Affect Pavement Performance
#3 LCC—Life Cycle Cost Analysis
#4 Road Drainage
#5 Gravel Roads
#6 Using Salt and Sand for Winter Road Maintenance
#7 Signing for Local Roads
#8 Using Weight Limits to Protect Local Roads
#9 Pavement Markings
#10 Seal Coating and Other Asphalt Surface Treatments
#11 Compaction Improves Pavement Performance
#12 Roadway Safety and Guardrail
#13 Dust Control on Unpaved Roads
#14 Mailbox Safety
#15 Culverts-Proper Use and Installation
#16 Geotextiles in Road Construction/Maintenance and Erosion Control
#17 Managing Utility Cuts
#18 Roadway Management and Tort Liability in Wisconsin
#19 The Basics of a Good Road
#20 Using Recovered Materials in Highway Construction
#21 Setting Speed Limits on Local Roads

Transportation Information Center
University of Wisconsin–Madison

432 North Lake Street
Madison, WI 53706
phone 800/442-4615
fax 608/263-3160
e-mail tic@epd.engr.wisc.edu
URL http://tic.engr.wisc.edu

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University of Wisconsin–Madison

PASER

Asphalt Roads