Operational Safety of Gravel Roads in Rural and Tribal Communities: Vulnerability to Structural Failures and Geo-Hazards

FINAL PROJECT REPORT

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rural · isolated · tribal · indigenous

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16. Abstract

Of the 4.1 million miles of federal and state highways in the U.S., 2.2 million miles (or 54%) are unpaved, gravel roads. In the Pacific Northwest and Alaska, unpaved gravel roads provide critical transportation access, with some communities relying on just a single highway for access into and out of town. In such cases, these highways become a critical component of the infrastructure, and there is a need to ensure that safe access is always available to the communities. The Idaho highway database has been used to identify unpaved, gravel roads in Idaho that are critical for access to rural communities. Once identified, information regarding their existing condition has been used to assess their vulnerability and other impacts. The results of this study are considered an initial evaluation that relies on information that is readily available in the database. The project outcomes include a comprehensive literature review of unpaved roads including data produced from field visits. In addition, a questionnaire survey was sent to local jurisdictions authorities for investigating locations, reasons of road closures, and population size of the affected communities. Finally, 37 responses have been received by the research team indicating five rural communities that have experienced closures and isolation. The reasons for the closure of the unpaved roads were due to the lack of funding for snow removal, excessive dirt, unstable gravel roads, tornados, and heavy rains. The location of those communities was spread across the state of Idaho with corresponding populations range from 25 to 8,500 people.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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EXECUTIVE SUMMARY

Unpaved gravel roads are classified in a class that comes after paved roads with lowest or no service provided to the surrounding community. There are over 2.1 million miles (almost 54% of all roads including federal and state highways) of unpaved roads in the United States. Unpaved roads in the Pacific Northwest are being used as main corridors in various locations. In many cases, these unpaved roads are considered the only means of transporting agricultural products, transferring logs from forestry or as access to a remote area. Low maintenance of unpaved roads can lead to structural failures and geo hazards. Similar to paved roads, the main factors affecting the performance of unpaved roads are materials, construction activities, traffic characteristics, and environmental and drainage conditions. The major differences are that gravel roads have much greater maintenance frequency and susceptibility to moisture damage compared to paved roads. Most often, the excessive snowfall in winter causes hazardous issues for the unpaved roads in the Pacific Northwest and Alaska. In such cases, these highways become a critical component of the infrastructure system, especially for the communities which do not have alternative access in or out. Therefore, ensuring safe access year round has become a necessity for those communities.

The study aimed at finding gravel road safety issues which are currently affecting the operational characteristics of people and goods in rural communities. Much of this initial evaluation relies on information that is readily available in the Idaho highway database. The research team has contacted the Latah County in the state of Idaho, and well-established maps were provided for all accessible gravel roads. The goal of this study was to identify affected communities by unpaved road closures and report the reasons for such closures

This project is considered a pilot study to identify unpaved, and gravel roads which have experienced road closures in the state of Idaho. The project results include a comprehensive literature review of unpaved roads, field visits, and a questionnaire sent to all local highway jurisdictions in the state of Idaho to investigate whether a rural community experienced unpaved road closures or not, the location of the community, and the reason(s) for closure. Finally, 37 responses were received by the research team indicating five rural communities that have experienced closures and isolation. The reasons for the closure of the unpaved roads were the lack of funding for snow removal, excessive dirt, unstable gravel roads, tornados, and heavy rains. The location of those communities is spread across the state of Idaho with corresponding populations ranges from 25 to 8,500 people. The PIs have also developed a simple guideline for unpaved/gravel roads assessment for local highway jurisdictions to use, which will help to report various kind of damage or potential hazards. Finally, and based on the information provided by ITD, most of Idaho unpaved roads were reported improved and in acceptable condition.

CHAPTER 1. LITERATURE REVIEW

1.1 Introduction

Unpaved gravel roads, paved roads, and means of transportation are crucial for economic development and growth of a country. Poorly maintained unpaved roads not only constrain mobility and significantly raise vehicle operating costs but also increase accident rates and their associated human and property costs. Moreover, inadequately designed gravel roads aggravate isolation, poverty, poor health, and illiteracy in rural communities. Like paved roads, the main factors affecting the performance of unpaved roads are materials, construction, traffic, environment and drainage; though the major differences are gravel roads' much greater maintenance frequency and susceptibility to moisture damage (Huntington and Ksaibati, 2016). Studies have examined the impact of loads and the adjustment of gravel thicknesses based on performance (Légère and Mercier, 2006), but predictions of the life of a gravel road are not readily available. Planning, location, survey, design, construction and maintenance are the basic steps performed for making a road project successful. This study depicts the recent studies conducted for developing design guidelines, maintenance practices, geo-hazard rating systems, drainage performance of unpaved gravel roads and identifying the factors affecting the operational safety of gravel roads.

1.2 Planning and Location of gravel roads

Without planning and good location, a road may not adequately serve its users; it may be overbuilt, or it may be in a problematic area. Survey and design are needed to fit the road to the ground and have it function properly (Kellerr and Sherar, 2003). Before constructing a road, key issues should be addressed during the planning phase. Understanding the effects on area growth, land use, and deforestation, will help the designer in the determination of the optimum road location. Therefore efficient road location with system appropriate minimum design, will lead to avoid local water quality impacts, minimize impacts on local plants, animals, and provide sufficient long-term road maintenance robust plan. In addition, optimum road planning identify and avoide problem areas such as landslides, wet areas, poor soils, excessively steep grades.

A comprehensive literature search identified recent studies performed on the performance of rural unpaved, gravel roads (e.g. Keller & Sherar, 2008, Skorseth & Selim, 2000), and their effect on the surrounding communities. The literature covers design and construction policies and maintenance practices. Geo-hazard rating systems, drainage performance of unpaved roads, and flood data were reviewed thoroughly. Additional work concerning the performance assessment of unpaved gravel roads (Walker, 1985, Eaton, et al., 1987)) has been reviewed to select best practices. The assessment of geohazards associated with landslides, mudflows, erosion, washouts, frost heave, wildfires, and adverse seasonal effects has been reported by Godfrey, et al. (2016). The study established procedures used in practice (Godfrey, et al., 2016). The main components that were covered in the literature are:

(1) Relevant factors affecting the operational safety of gravel roads.
(2) Databases of information related to all hazard potentials.
(3) Review of procedures used for evaluation of gravel roads by other states and the how close we are from those processes.
(4) Collect information about the most recent practices in maintenance data.
(5) Determine the availability of resources for mitigation of gravel roads from potential hazards.

1.3 Design guidelines for gravel roads

Elements of roadway design include geometry, design speed, drainage, stream-crossing structures, slope stabilization needs, materials types and use, and road grades (Charles, R., 1997). Table 1.1 shows some of the design guidelines developed by Oregon Department of Forestry (2000) for the forest roads which can also be adopted for low volume gravel roads. In addition, Tables 1.2 and 1.3 present the typical design standards for low volume roads and minimum geometric and structural guides for local roads and streets.

Table 1.1. Guidelines for forest roads (Oregon department of forestry, 2000)

Type	**Usage**	**Subgrade (feet)**	**Drainage**	**Surfacing**	**Minimum curve radius**	**Grade limitations**
Low use	Short term	12-16	out-sloped or in-sloped (no ditch)	optional (pit or jaw run, if used)	50 feet plus curve widening	up to 30%, roads over 20% will be vacated after use
Medium use	Semi-permanent	14-16	in sloped or crowned with ditch	optional (crushed rock, jaw or pit run if used)	50 feet plus curve widening	up to 20%, usually under 18%
High use	Permanent	16-22	crowned, with ditches	pit run, jaw run or crushed rock for base and crushed rock for driving surface	70 feet plus curve widening	up to 14%

**Grades over 20% require assist vehicles (OAR 437-80-065). Rock surfaced grades over 16% require special surfacing design to alleviate traction problems (consult geotechnical specialist or staff engineer).*

Table 1.2 Typical design standards for low volume roads

Design Element	**Rural Access road**	**Collector load**
Design Speed	23-35 kph	45-60 kph
Road Width	3.5-4.5 m	4-5.5 m
Road grade	15% max	12% max
Curve Radius	15m min.	25 m min.
Crown/Slope	Out slope/ In slope (5%)	In/out slope or crown (5%)
Surfacing Type	Native or Gravel	Gravel/ Cobble-stone or Pavement

Table 1.3 summarizes the design standards suggested by New Hampshire Department of Transportation.

Table 1.3 Minimum Geometric & Structural Guides for Local Roads and Streets

ADT (vpd)		**0-50**	**51-200**	**201-750**	**751-1500**	**1500+**
Pavement Width (ft.)		18 minimum	20	20	22	24
Shoulder Width (ft.)		2	2	4	4	8-10
Center of Road to Ditch Line (ft.)		15	16	18	19-21	Varies
Pavement Type		Gravel	Asphalt Surface Treated	Hot Bituminous	Hot Bituminous	Hot Bituminous
Slope of Roadway		4%	3%	2%	2%	2%
Base Course Depth (in.)	**Gravel**	12	12	12	12	18
	Cr. Gravel	-	-	4	6	6

Notes:

1. Gravel surface should be paved where steep grades occur
2. For ADT greater than 1000 vpd, paved shoulders should be considered
3. Base course depths may need to be increased in areas of poor soils

Wiegand, P. and Stevens, L. (2007) conducted an extensive study on developing uniform guidelines for rural and suburban roadways in Iowa. To provide an easier transition to the traditional urban facilities, the following guidelines in Table 1.4 can be adopted.

The design and construction standards can vary in different states but the ultimate objective of providing a safe, economical and low maintenance road should be met. The American Association of State Highway and Transportation Officials (AASHTO) provides guidelines for very low-volume roads. They have defined low-volume roads as those with daily traffic volumes fewer than 400 vehicles per day (vpd). AASHTO indicates that low-volume roads can be constructed with granular surface with a total width of 18 feet, including shoulders. 1990 AASHTO Green Book design guidelines generally used as standards which is listed in Table 1.5.

Table 1.4 Rural subdivision cross-section geometrics

Design Elements	Connector		Collector		Local	
	Desirable	***Minimum***	***Desirable***	***Minimum***	***Desirable***	***Minimum***
Design speed (mph)	60	60	55	50	45	45
Avg. daily Traffic	> 1500	>1500	400-1500	400-1500	<400	<400
Pavement width	24’	24’-striped at 22’	24’	22’	22’	22’
Shoulder width	8’	8’	6’	5’	4’	4’
Shoulder type	4’ paved/4’ rock	Rock	Rock	rock	rock	Earth
Right-of-way width	100’	80’	80’	66’	66’	66’
Slopes	6:1	4:1	4:1	3:1	4:1	3:1
Parking allowed	none	None	None	none	none	None
Stopping sight distance	570’	570’	495’	425’	360’	360’
Horiz. curve (min)*	1340’	1205’	965’	760’	500’	500’
Maximum grade	5%	8%	6%	8%	8%	10%

*Horizontal curve minimum values are based on 6% super-elevation for desirable sections and 8% for minimum sections for connector and collector roads. The 8% super-elevation will require special design elements. For grades, greater than 3%, the stopping site distance is increased.

Table 1.5 1990 AASHTO Green Book design guidelines (ASCE highway division)

Maximum Super-elevation		4% (for icy areas)
Curb Radius		≥15 ft.
Cul-de-Sac Radii		≥30 ft.
Tapers	**Straight Bay Taper**	Vary from 4:1 to 15:1
	Straight or Reverse Curve Taper	Ranges from 80-120 ft.
	Curved Bay Taper	Typically, 100-120 ft.
Minimum Grade		0.5% for curbed roadways, (0.3% may be acceptable where a high type pavement with stable subgrade is utilized)
Lane Width		12 ft. (9 ft. minimum)
Cross Slope		1.5% to 2.0% for good surface quality 2.0% to 6.0% for poor surface quality
Shoulder Width		≥2 ft. and ≤ 8 ft.
Shoulder Cross Slope		4% (6% maximum)
Pavement Width		26 ft., 12 ft. lane with two 7 ft. parking lanes 34 ft., two 10 ft. lanes with two 7 ft. parking Lanes
Gutter Grade		≥ 0.30% (≥ 0.2% in very flat areas)
Curb Height		4-9 inches (6 inches is average)
Sidewalks		Preferably near ROW lines
Sidewalk Width		≥ 4 ft.

Table 1.6 summarizes the geometric design tables / design appendices of Minnesota Department of Transportation.

Table 1.6 Minimum Geometric Design Standards; Rural and Suburban Undivided; New or Reconstruction Projects

Projected ADT	**Land Width, Ft.**	**Shoulder Width, ft.**	**In-Slope, rise:run**	**Recovery Area, ft.**	**Design Speed, mph**	**Surfacing**	**Structural Design Strength, tons**	**Roadway Width C-C, ft.**
0-49	11	1	1:3	7	30-60	Aggregate		22
50-149	11	3	1:4	9	40-60	Aggregate		22
150-749	12	4	1:4	15	40-60	Paved	9	28
750-1499	12	4	1:4	25	40-60	Paved	9	28
1500+	12	6	1:4	30	40-60	Paved	10	30

Selim and Skorseth (2000) reported two different design approaches for predicting the thickness of gravel layer. The Design Chart Procedure considers several parameters including predicted future traffic (W_{18}), roadbed soil resilient modulus (M_R) in psi, length of season, elastic modulus of aggregate sub-base layer (E_{SB}) and aggregate base layer (E_{BS}) in psi, design serviceability loss (ΔPSI), allowable rutting (RD) in surface layer, aggregate loss of surface layer etc. Design catalog is adopted when sufficient information is not available. The thicknesses shown in Table 1.7 are based on specific ranges of 18-kip ESAL applications at traffic levels (AASHTO, 1993).

Table 1.7 Aggregate Surfaced Road Design Catalog: Recommended Aggregate Base Thickness (in Inches) For Six U.S. Regions, Five Relative Qualities of Roadbed Soil, and Three Traffic Levels. (AASHTO, 1993)

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very Good	High	8*	10	15	7	9	15
	Medium	6	8	11	5	7	11
	Low	4	4	6	4	4	6
Good	High	11	12	17	10	11	17
	Medium	8	9	12	7	9	12
	Low	4	5	7	4	5	7
Fair	High	13	14	17	12	13	17
	Medium	11	11	12	10	10	12
	Low	6	6	7	5	5	7
Poor	High	**	**	**	**	**	**
	Medium	**	**	**	15	15	**
	Low	9	10	9	8	8	9
Very Poor	High	**	**	**	**	**	**
	Medium	**	**	**	**	**	**
	Low	11	11	10	8	8	9

* Thickness of aggregate base required (in inches) ** Higher type pavement design recommended

A similar approach to the above procedure was suggested for local and other agencies in the state of South Dakota to determine gravel layer thickness. Table 1.8 represents suggested thickness.

Table 1.8 Suggested Gravel Layer Thickness for New or Reconstructed Rural Roads. Selim and Skorseth (2000).

Estimated Daily Number of Heavy Trucks	Subgrade Support Condition[1]	Suggested Minimum Gravel Layer Thickness,mm (in.)
	Low	165 (6.5)
0 to 5	Medium	140 (5.5)
	High	115 (4.5)
	Low	215 (8.5)
5 to 10	Medium	180 (7.0)
	High	140 (5.5)
	Low	290 (11.5)
10 to 25	Medium	230 (9.0)
	High	180 (7.0)
	Low	370 (14.5)
25 to 50	Medium	290 (11.5)
	High	215 (8.5)

Notes: [1] Low Subgrade support: CBR ≤ 3 percent;
Medium Subgrade support: $3 < \text{CBR} \leq 10$ percent;
High Subgrade support: CBR >10 percent.

According to the "Pavement Design Manual" prepared by the United Republic of Tanzania Ministry of Works 1999, the required gravel thickness should include both thicknesses required to avoid compressive strain in the subgrade (D1) as well as gravel loss (GL). To estimate the annual gravel loss, the following equation can be adopted:

$$Gl = \frac{fT^2}{(T^2 + 50)}(4.2 + 0.092\,T + 3.50R^2 + 1.88\,V) \qquad 1.1$$

Where,

GL	=	the annual gravel loss measured in mm
T	=	the total traffic volume in the first year in both directions, measured in thousands of vehicles.
R	=	the average rainfall measured in m
V	=	the total (rise + fall) as a percentage of the length of the road
f	=	0.94 to 1.29 for lateritic gravels
	=	1.1 to 1.51 for quarzitic gravels
	=	0.7 to 0.96 for volcanic gravels
	=	1.5 for coral gravels
	=	1.38 for sandstone gravels

This manual also stated that the total thickness of the wearing course, D can be calculated by the following expression:

$$D = D1 + N.Gl$$

where, N = the period between re-gravelling operations in years.

Roadway geometrics are the main parameters to ensure well-designed roadway and are dependent on design speed. The design speed can be determined by the usage of the road and surrounding land growth. Once the design speed is determined, it becomes easier to figure out the horizontal and vertical alignment from the guidelines. Figure. 1.1 shows the components of the roadway cross section. Another important decision to make is whether the road will be paved or unpaved depending on the expected traffic volume and adjacent land use. Although the construction of granular road will cost less, it will have long-term maintenance cost.

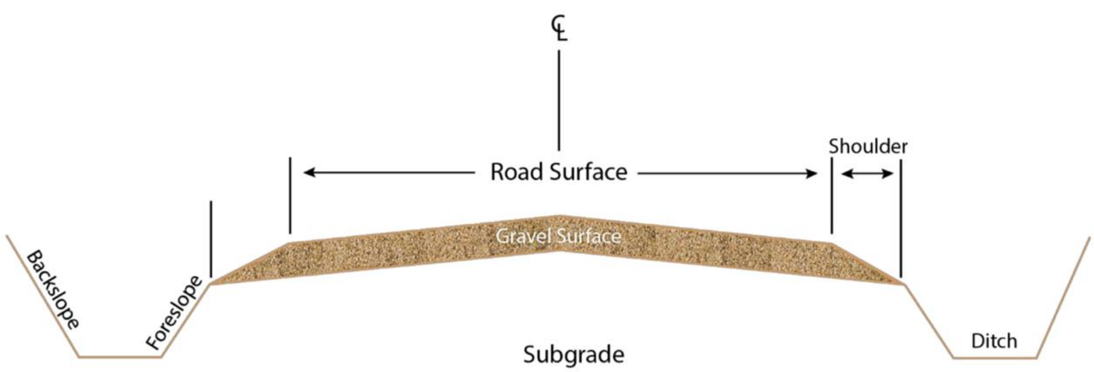


Figure 1.1 Components of roadway cross section

1.4 Maintenance Practice

The major components of a well-designed gravel surface include a crowned driving surface, a shoulder area that slopes directly away from the edge of the driving surface, and a ditch. These components should be regularly monitored to maintain a gravel road properly. Generally, a careful attention has always been provided to design a paved road but unfortunately gravel roads might have less consideration. Unpaved and gravel roads are usually vulnerable to wet weather which arise a major concern for maintenance to provide adequate slope of drainage for excessive water flow. The following subsections present brief definitions of unpaved road characteristics that the owner should pay attention to.

1.4.1 Crown

Maintaining a proper crown is the most important parameter in unpaved road design for avoiding rutting and therefore adversely affect ridability of traffic on gravel surface. A flat crown may lead to the collection of water during rainstorms and accelerate the penetration of water into the subgrade. On the other hand, if the road has excessive crown, it will also produce unsafe condition for the drivers. Divers will not feel comfortable driving in their lane despite driving on the right. In the snow and ice prone states, this phenomenon may cause high risk of accidents. A simple method is to use a cutting torch and straighten the cutting edge whenever 1/2 to 3/4 inch or more of center wear exists. Another method is to use a thicker, harder section of cutting edge in the middle of the moldboard to resist wear. This will retard excess center wear, but generally, will not eliminate it.

1.4.2 Road Shoulder

The road shoulder plays a major role in a safe roadway, i.e. it provides a safety area for the driver to get control over a vehicle, it carries away water to ditches and most importantly it supports the edge of the roadway. The shoulder should not be higher or lower than the edge of the driveway. A lower shoulder can cause severe safety hazards along with reducing edge support. On the other hand, a high shoulder is prone to creating secondary ditches. When a gravel road develops secondary ditches, it destroys the drainage system and water seeps into the subgrade. Beside this, in rolling and rugged terrain, the water quickly flows downhill along the secondary ditch, often eroding away a large amount of gravel and even eroding into the subgrade (Skorseth and Selim, 2000). Motor-grader along with some commonly used pulverizers can be used to eliminate secondary ditches.

1.4.3 Ditches

A roadside ditch is the most common drainage system in unpaved roads, and it is a critical component. If the ditch is obstructed, the water will penetrate through the surface and soften the soil. Maximum effort should be provided to keep ditches clean from eroded soil or debris. Sometimes this can be a major project requiring loaders, excavators, trucks or other equipment. However, in dry season, ditches can be easily restored by using only a grader.

1.5 Performance Study

The performance of a gravel road depends on many factors such as traffic speed and volume, weather, materials, construction activities, drainage etc. Although gravel roads are less expensive to construct, they require more frequent maintenance. Also gravel roads are more vulnerable to moisture damage due to the high permeability of gravel surfaces. In addition, insufficient quantity of binder may lead to washing away gravel materials. An imperfect crown can cause potholes and rutting if the materials' strength is inadequate. Very few data are available on gravel roads' performance and few studies have observed the effect of loads and thickness of gravel layer on deterioration (Légère and Mercier, 2006).

Huntington and Ksaibati (2016) conducted an extensive study for service life prediction of gravel roads by examining 20 sections in the state of Wyoming. Climatic effects, traffic characteristics, gravel properties, gravel thicknesses, and drainage were used as tools to predict a gravel road's service life. Potholes, rutting and wash boards were found to deteriorate significantly with time. The average service life of a gravel road without maintenance was found to be from several weeks to one year.

Surface erosion from unpaved roads is found to be a dominant sediment source in Australia (Grayson et al., 1993), New Zealand (Fahey and Coker, 1989; Fransen et al., 2001), Malaysia (Douglas et al., 1993), the United States (e.g. Reid and Dunne, 1984; Burroughs et al.,1991), Poland (Froehlich and Walling, 1997; Froehlich, 1991), Ghana (Kumapley, 1987), and Kenya (Dunne, 1979). Unpaved roads can increase surface erosion rates by two or more orders of magnitude relative to undisturbed hillslopes (MacDonald and Coe, 2007). Ramos-Scharrón and Macdonald (2005) conducted research on measurement of sediment production from unpaved roads in US Virgin Islands. It was observed from the study that sediment production rates were linearly related to total precipitation for most of the 21 road segments. Also, roads with higher slope were found to produce more sediment than gently sloping roads.

The unpaved roads naturally produce dust to a greater or lesser extent. However, the dust production rate greatly depends on the quality of gravel material, the speed and volume of the traffic and the climate. If the traffic volume is high enough, it will produce large quantity of dust which will eventually impact the health of people and surrounding animals. Applying dust control and stabilization treatments can significantly reduce dust production. Chloride, resins, natural clays, petroleum oils, Portland cement, and organic non-petroleum oil are some of the stabilization products used for reducing dust production, gravel loss, and blade maintenance.

Most adverse impacts from roads can be prevented with good engineering and management practices which includes careful selection of load location, good gradation of gravel, adequate drainage facility, stable cut and fill slopes, erosion control measures and stabilized surface. A well designed and properly constructed gravel road can reduce long-term maintenance costs and have good economic and social impact.

1.6 Status of Gravel roads in Idaho

In Idaho, there are currently no uniform guidelines for gravel road design which may create inconsistency and confusion among developers. Hence, studies should be conducted to assess the performance and potential geo hazards by identifying unpaved roads in Idaho. Additionally, it is important to evaluate the condition of existing roads, as these roads might have been poorly designed, constructed with low quality materials, might suffer general degradation due to lack of maintenance, unstable cut-slope fill, and poor drainage system. Table 1.9 shows the total miles by county provided by Idaho Transportation Department. The data show that a significant number of miles (990 miles) are classified as unimproved and need major maintenance activities.

Table 1.9 Road miles in Idaho

IDAHO TRANSPORTATION DEPARTMENT
ROAD MILES BY COUNTY BY SURFACE TYPE
Total Actual Reported Miles, 2012

COUNTIES, TOTAL ACTUAL REPORTED MILES	UNIMPROVED MILES	GRADED & DRAINED EARTH	GRADED & DRAINED GRAVEL	LESS THAN ONE INCH BITUMEN	LOW BITUMEN	HIGH BITUMEN	PORTLAND CEMENT	TOTAL MILES
ADA	0.000	0.000	30.222	4.512	0.000	605.315	0.000	640.049
ADAMS	9.004	52.157	223.403	4.100	33.560	42.938	0.000	365.162
BANNOCK	15.224	5.463	189.100	65.443	217.810	135.986	0.000	629.026
BEAR LAKE	68.295	4.927	250.133	25.493	80.718	13.601	0.000	443.167
BENEWAH	18.397	18.659	305.854	14.976	31.652	39.744	0.000	429.282
BINGHAM	10.529	14.936	528.221	0.250	543.676	107.023	0.000	1,204.635
BLAINE	33.392	49.189	244.447	2.188	90.056	31.411	0.000	450.683
BOISE	0.000	40.486	158.637	0.835	36.771	47.893	0.000	284.622
BONNER	1.396	1.469	229.302	163.704	116.401	192.059	0.000	704.331
BONNEVILLE	132.376	103.091	326.377	0.000	261.531	236.627	0.000	1,060.002
BOUNDARY	2.092	10.775	158.625	1.852	121.776	36.963	0.000	332.083
BUTTE	35.423	13.855	257.201	0.000	80.370	5.860	0.000	392.709
CAMAS	14.227	24.114	360.678	0.000	13.523	7.876	0.000	420.418
CANYON	1.065	0.000	34.804	0.886	870.098	205.150	0.000	1,112.003
CARIBOU	28.337	19.918	456.879	1.009	194.608	37.990	0.000	738.741
CASSIA	79.972	23.310	562.409	130.963	295.973	145.930	0.000	1,238.557
CLARK	14.121	25.837	247.882	0.603	68.867	28.607	0.000	385.917
CLEARWATER	0.258	2.785	186.752	42.959	37.139	65.101	0.329	335.323
CUSTER	3.453	3.220	392.872	34.090	106.710	5.727	0.000	546.072
ELMORE	13.798	22.129	587.957	6.298	253.797	95.650	0.000	979.629
FRANKLIN	59.054	6.622	193.140	0.000	113.759	34.482	0.000	407.057
FREMONT	81.787	34.761	237.130	0.000	274.782	85.791	0.000	714.251
GEM	0.000	4.945	140.121	2.291	114.696	76.583	0.000	338.636
GOODING	11.443	1.808	82.276	11.265	338.063	45.513	0.000	490.368
IDAHO	3.032	29.202	805.289	80.706	210.440	134.896	0.000	1,263.565
JEFFERSON	12.272	0.537	249.691	25.496	388.495	61.592	0.000	738.083
JEROME	7.197	1.064	142.564	10.025	367.149	61.509	0.000	589.508
KOOTENAI	0.555	4.371	177.979	113.321	367.355	235.346	0.684	899.611
LATAH	1.739	56.479	554.642	29.088	152.700	21.328	0.000	815.976
LEMHI	10.832	11.370	265.155	0.333	112.073	0.259	0.000	400.022
LEWIS	3.498	8.380	430.610	6.588	6.439	29.318	0.000	484.833
LINCOLN	13.729	38.436	232.891	4.300	139.830	6.462	0.000	435.648
MADISON	14.416	9.600	180.655	0.166	223.360	51.208	0.000	479.405
MINIDOKA	1.031	0.106	307.670	7.500	0.000	314.383	0.000	630.690
NEZ PERCE	6.745	11.244	396.736	28.126	50.030	133.053	0.008	625.942
ONEIDA	107.020	15.856	201.337	43.006	163.187	20.143	0.000	550.549
OWYHEE	80.713	88.624	541.275	3.927	292.594	4.706	0.000	1,011.839
PAYETTE	0.000	0.000	48.385	0.000	173.973	78.661	0.000	301.019
POWER	40.951	7.228	297.356	144.275	193.932	31.093	0.000	714.835
SHOSHONE	0.972	4.376	128.250	50.080	(9.076)	200.701	0.000	375.303
TETON	37.456	3.716	207.087	21.548	47.176	26.360	0.000	343.343
TWIN FALLS	0.412	26.281	372.211	8.264	728.181	138.033	0.000	1,273.382
VALLEY	12.332	6.815	500.289	14.795	145.571	84.957	0.000	764.759
WASHINGTON	1.280	41.123	349.555	(0.369)	90.732	70.182	0.000	552.503
TOTAL	989.825	849.264	12,774.049	1,104.892	8,140.477	4,034.010	1.021	27,893.538

CHAPTER 2. METHODOLOGY

2.1 Introduction

A low-volume road is a road with relatively low traffic (Gravel Roads Manual 2015), and low design speeds based on the geometric design of roads (Gravel roads Design Manual 2000). Gravel roads have various safety concerns against unconventional loads (unusual trucks, and agricultural vehicles) and natural hazards (rainfall runoff and extreme wind). Guidelines have been suggested by the PIs for local highway jurisdictions in Idaho. Part of the study produced guidelines to address the safety of gravel roads under the 129,000-pounds trucks, (Ibrahim et al. 2017). In addition to the unconventional loads, there is an urgent need to identify and assess potential geo-hazards that may affect operation and performance of rural gravel roads. Additionally, evaluation of existing road condition is important to ensure safe access to the isolated communities. The proposed study intends to establish baseline data of unpaved road conditions in Idaho through a questionnaire survey sent to local highway jurisdictions and to propose an assessment method for unpaved roads in rural communities. The survey was incorporated with very brief questions about the reasons of closure of unpaved roads, location of those communities, and the population of the affected communities. The survey questions are presented in Appendix A.

In the current phase of the project, the PIs reviewed information that is readily accessible in the Idaho highway database and through the technical local highway assistance program. The results of this project are considered a pilot study to document the structural safety, and geo-hazards associated with landslides, mudflows, erosion, washouts, frost heave, wildfires, and adverse seasonal effects in the state of Idaho. The PIs have collected information from rural areas to determine highway segments that are perceived to be unsafe and to identify the hazards in each case. The input has included a number of routes based on the availability and time constraint of the project. The PIs have collected information as much as they can to represent the actual route conditions and its vulnerability to any kind of structural failures and geo-hazards.

The data and safety information were collected from various Idaho counties and local highway jurisdictions via general survey (Appendix A). Although, extensive field visits were outside the scope of the study, two sites in Latah county, ID were visited by the research team to check gravel road conditions. The information collected through the questionnaire was used to identify the condition of low volume roads and identify the critical issues that affect the accessibility of rural communities to major highway corridors. The survey was sent to all the Idaho local jurisdictions with the help of the Local Highway Technical Assistance Council (LHTAC) in Boise, Idaho. The email list had 594 subscribers and some of the agencies in the list have more than one employee, and there are some people on list who were not local highway Jurisdictions (but do work with them). The LHTAC could not filter the list to have a specific number of subscribers. Out of the 594 subscribers, 213 opened the survey email and 96 of them clicked on the survey link and only 37 responses were received by the research team. The survey email (Appendix B) was originally sent on November 2018 and followed up with another reminder on January 2019.

2.2 Field visits

1,357,430 miles of road are unpaved in the United States which is almost 35% of the total roadway (FHWA, 2012) as shown in Figure 2.1. Gravel roads are mostly found in cold climates regions because they are less vulnerable to freeze/thaw damage than asphalt roads. Nationally unpaved roads only account for approximately 2 % of vehicle fatalities. In some states these roadways account for up to 20 % of the fatalities. In Idaho, rural local roads accounted for 14% of the fatalities. (2017 Idaho Highway Safety Improvement Program).

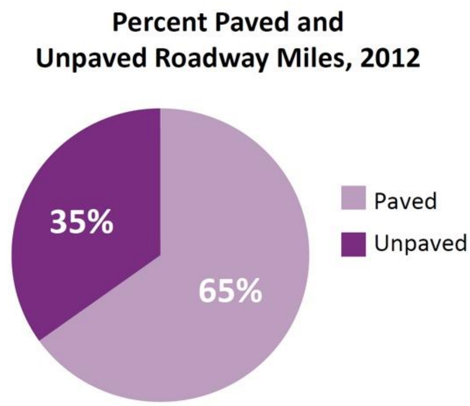


Figure 2.1 Percent of paved to unpaved roads in the USA.

A field visit was conducted by the research team to two of the gravel roads in Troy, ID as shown in Figure 2.2. The roads were selected based on information in the database of gravel roads provided by Idaho Transportation Department. The ditch width, drainage slopes, and the shoulder width were measured by the team and the roads were found in reasonably good condition as shown in Figures 2.3 to 2.6.

Figure 2.2 Gravel road (Troy, ID)

Figure 2.3 Proper ditch and drainage (Troy, ID).

Figure 2.4 Sufficient ditch width

Figure 2.5 Sufficient shoulder width

Figure 2.6 Proper drainage

In addition, information on Idaho gravel roads with improved road characteristics of various kinds and degrees of road surface drainage generally encountered throughout Idaho was collected by the research team. Figures 2.7 and 2.8 show the acceptable and the unacceptable gravel road characteristics in the state of Idaho (ITD 2019). Table 2.1 shows the improved road surface type definition (ITD 2019).

Idaho Code, Title 40-110 defines an improved road as follows:
"Improved highway" means a graded and drained earth traveled way or better, to include one graded and graveled or with paved surface, and a graded and drained earth highway means a traveled way of natural earth, aligned and graded to permit reasonably convenient use by motor vehicles, and drained by a longitudinal and transverse system, natural or artificial, sufficiently to prevent serious impairment of the highway by surface water.

To accumulate more information about the present gravel roads' condition in Latah county, contact personnel were reached and the 2016 report card with the status of all accessible gravel roads in the county was collected. An improved status for all accessible roads was found from the report card as shown in Table 2.2 and Figure 2.9.

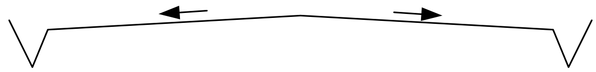
Table 2.1 improved road surface type definition (ITD 2019)

Surface Type	Description
C Earth graded & drained	**Earth Graded and Drained.** A road of natural earth aligned and graded to permit reasonably convenient use by motor vehicles and drained by longitudinal and transverse drainage systems (natural or artificial) sufficiently to prevent serious impairment of the road by normal surface water.
E Gravel Graded & Drained	**Gravel Graded and Drained**. A graded and drained road aligned and graded to permit reasonably convenient use by motor vehicles and drained by longitudinal and transverse drainage systems (natural or artificial) sufficiently to prevent serious impairment of the road by normal surface water. The surface consists of gravel, basalt, broken stone, slag, chert, caliche, ore, shale, disintegrated rock or granite, or similar fragmented material (coarser than sand), with or without a stabilizing admixture.

Acceptable

Where right of way is available, flatter slopes combine a safety feature with satisfactory drainage.

Restricted right of way may require steeper, less safe slopes to achieve proper drainage.

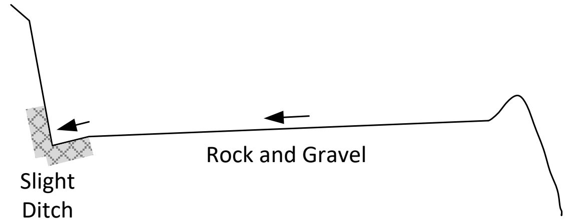


Flat sections in good gravel must be crowned to insure drainage to the outside.

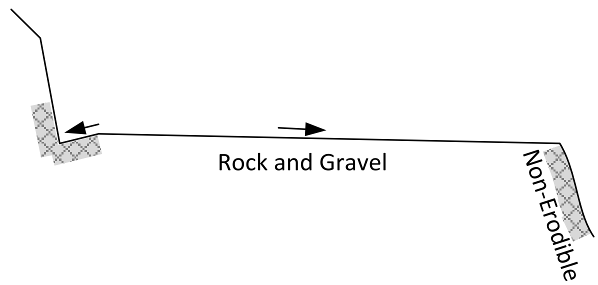
This profile depicts a road surface with a definite crown and minimal side-ditching. Drainage may be barely adequate.

Acceptable

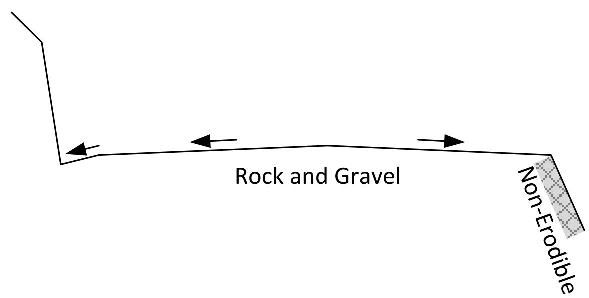
Entire traveled surface is sloped to a shallow ditch at the toe of the hill. In extremely difficult conditions involving essentially solid rock, ditching is not mandatory.



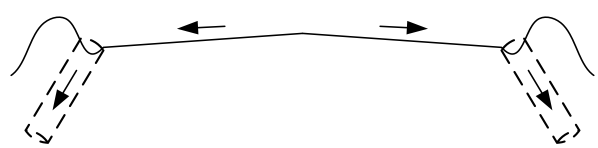
When material is non-erodible, or erosion is controlled, drainage can be accomplished by sloping away from the hillside. Consideration should be given to hazards in this type of drainage where surface may become slick.



When erosion is controlled, a normal crown may be appropriate.



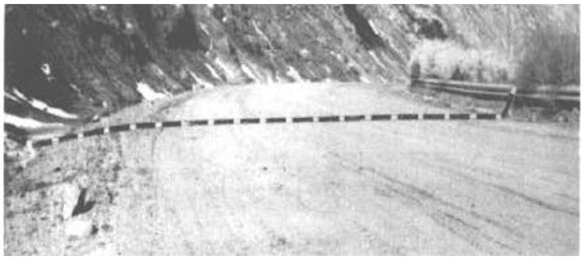
Protection against erosion in this fill section is provided by soil curbs and drain pipes.

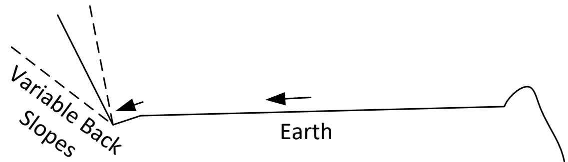


Acceptable

Drainage in hillside sections can be accomplished in the following ways:

Entire traveled surface is sloped to the ditch at the toe of the hill.





When erosion is controlled, a normal crown may be appropriate.

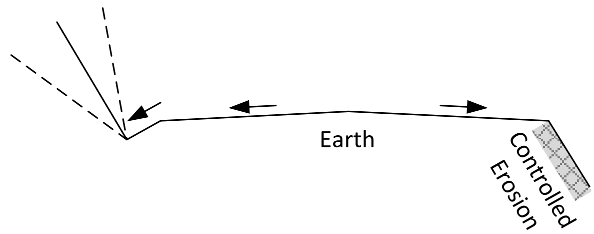
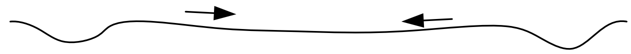


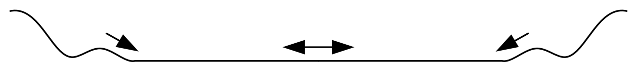
Figure 2.7 Acceptable levels of road characteristics in Idaho (ITD 2019)

Unacceptable

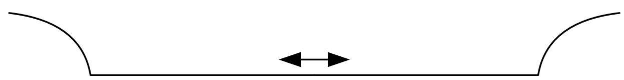
Concave surface prevents proper drainage. Limited corrective measures could change classification to acceptable.



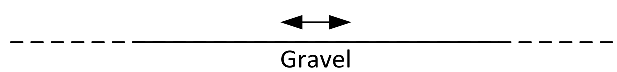
Inadequate maintenance has allowed drainage features to disappear. Side ditches, culverts and crowning are needed.



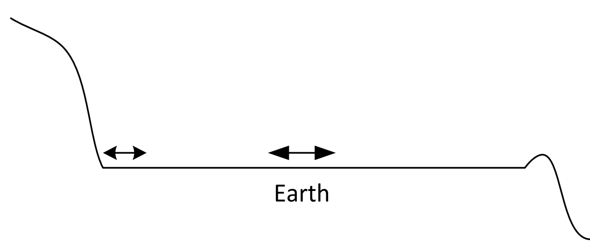
Repeated float-blade maintenance has created a virtual canal.



Flat sections in good gravel must be crowned for adequate drainage to the outside.



Hillside section in earth must have proper slope and ditch at the toe of the hill, or a normal crown when erosion is controlled to provide adequate drainage.



Unacceptable

Hillside section in rock and gravel must have a proper slope either to the toe of the hill or to the outside, or, have a normal crown. If the slope is to the toe of the hill, ditching is necessary unless material is essentially solid rock. If the slope is to the outside, or a normal crown is used, ditching is required and erosion on the outside must be controlled.

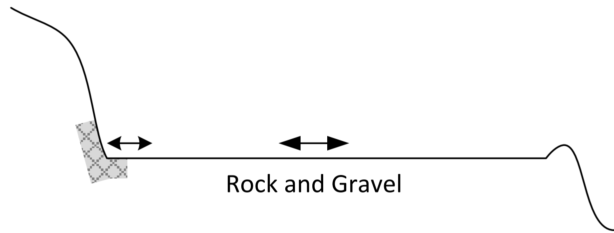


Figure 2.8 Unacceptable levels of gravel road characteristics in Idaho

Table 2.2 Latah county gravel road conditions

FID	Shape	OBJECTID	ID	MACSID	County	HDJ	HDJ2	BMP	EMP	Length	Surface	Status	PayWeight	PayMileage	NonPayWeig	NonPayMile	Method	InvDate	EffDate
2058	Polyline ZM	2736	273	002055	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	100	101.729	1.729	GRAVEL	IMPROVED	1	1.729	0	0	DMI	19990428	19990428
2059	Polyline ZM	2734	273	002054	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	101.162	101.973	0.811	GRAVEL	IMPROVED	1	0.811	0	0	DMI	19990429	19990429
2063	Polyline ZM	2732	273	002054	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	100.862	101.082	0.22	GRAVEL	IMPROVED	1	0.22	0	0	DMI	19990429	19990429
2071	Polyline ZM	2730	273	002053	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	100	100.804	0.804	GRAVEL	IMPROVED	1	0.805	0	0	DMI	19990429	19990429
2073	Polyline ZM	2753	275	002061	LATAH	NORTH LATAH HD	NORTH LATAH HD	100.537	102.637	2.1	GRAVEL	IMPROVED	1	2.1	0	0	DMI	19990512	19990512
2080	Polyline ZM	2750	275	002060	LATAH	NORTH LATAH HD	NORTH LATAH HD	105.335	105.421	0.086	GRAVEL	IMPROVED	1	0.086	0	0	DMI	19990428	20011231
2085	Polyline ZM	2748	274	002060	LATAH	NORTH LATAH HD	NORTH LATAH HD	101.675	104.63	2.955	GRAVEL	IMPROVED	1	2.955	0	0	DMI	19990428	20011231
2100	Polyline ZM	2746	274	002059	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	100	100.742	0.742	GRAVEL	IMPROVED	1	0.74	0	0	DMI	19990429	19990429
2104	Polyline ZM	2744	274	002058	LATAH	NORTH LATAH HD	NORTH LATAH HD	101.854	104.805	2.951	GRAVEL	IMPROVED	1	2.951	0	0	DMI	19990428	19990428
2106	Polyline ZM	2743	274	002058	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	101.79	101.854	0.064	GRAVEL	IMPROVED	1	0.064	0	0	DMI	19990428	19990428
2113	Polyline ZM	2741	274	002058	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	100	100.507	0.507	GRAVEL	IMPROVED	1	0.507	0	0	DMI	19990428	19990428
2116	Polyline ZM	2740	274	002057	LATAH	NORTH LATAH HD	NORTH LATAH HD	103.055	103.329	0.274	GRAVEL	IMPROVED	1	0.274	0	0	DMI	19990428	19990428
2119	Polyline ZM	2738	273	002056	LATAH	SOUTH LATAH HD	SOUTH LATAH HD	101.324	102.074	0.75	GRAVEL	IMPROVED	1	0.75	0	0	DMI	19990505	19990505
2128	Polyline ZM	2797	279	002125	LATAH	NORTH LATAH HD	NORTH LATAH HD	104.264	105.584	1.32	GRAVEL	IMPROVED	1	1.32	0	0	DMI	19990512	19990512
2131	Polyline ZM	2794	279	002125	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	100.509	0.509	GRAVEL	IMPROVED	1	0.509	0	0	DMI	19990512	19990512
2132	Polyline ZM	2793	279	002124	LATAH	NORTH LATAH HD	NORTH LATAH HD	101.404	104.942	3.538	GRAVEL	IMPROVED	1	3.538	0	0	DMI	19990513	19990513
2133	Polyline ZM	2821	282	002174	LATAH	NORTH LATAH HD	NORTH LATAH HD	101.399	105.851	4.452	GRAVEL	IMPROVED	1	4.452	0	0	DMI	19990513	20021231
2136	Polyline ZM	2791	279	002119	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	101.194	1.194	GRAVEL	IMPROVED	1	1.194	0	0	DMI	19990510	19990510
2137	Polyline ZM	2788	278	002118	LATAH	NORTH LATAH HD	NORTH LATAH HD	107.988	110.538	2.55	GRAVEL	IMPROVED	1	2.55	0	0	GEO	19990510	20141231
2138	Polyline ZM	2819	281	002173	LATAH	NORTH LATAH HD	NORTH LATAH HD	103.659	104.75	1.091	GRAVEL	IMPROVED	1	1.091	0	0	DMI	19990513	19990513
2139	Polyline ZM	2787	278	002118	LATAH	NORTH LATAH HD	NORTH LATAH HD	100.118	103.854	3.736	GRAVEL	IMPROVED	1	3.736	0	0	DMI	19990504	20031231
2141	Polyline ZM	2817	281	002173	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	103.322	3.322	GRAVEL	IMPROVED	1	3.322	0	0	DMI	19990513	19990513
2143	Polyline ZM	2816	281	002172	LATAH	NORTH LATAH HD	NORTH LATAH HD	100.499	101.931	1.432	GRAVEL	IMPROVED	1	1.432	0	0	DMI	19990513	19990513
2145	Polyline ZM	2785	278	002117	LATAH	NORTH LATAH HD	NORTH LATAH HD	101.264	101.774	0.51	GRAVEL	IMPROVED	1	0.51	0	0	DMI	19990511	19990511
2147	Polyline ZM	2814	281	002171	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	103.364	3.364	GRAVEL	IMPROVED	1	3.364	0	0	DMI	19990513	19990513
2150	Polyline ZM	2782	278	002116	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	101.292	1.292	GRAVEL	IMPROVED	1	1.292	0	0	DMI	19990511	20021231
2153	Polyline ZM	2779	277	002078	LATAH	NORTH LATAH HD	NORTH LATAH HD	100	100.952	0.952	GRAVEL	IMPROVED	1	0.952	0	0	GEO	19990511	19990511

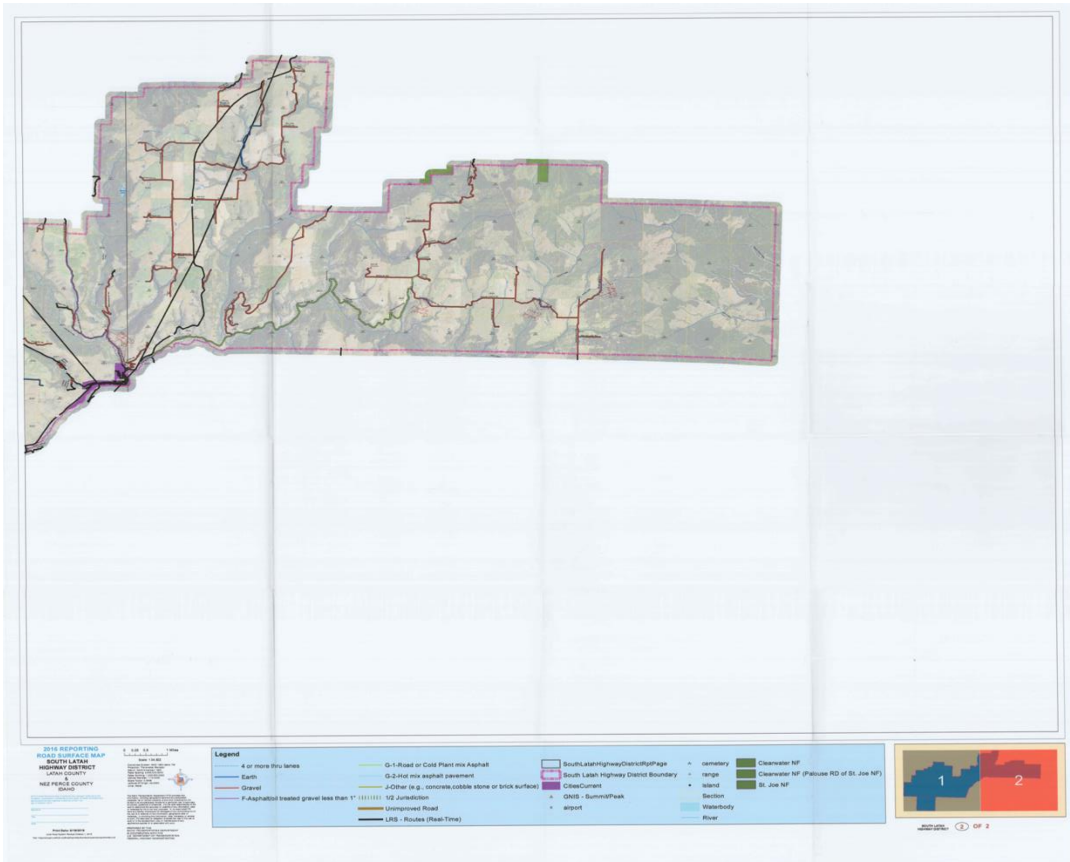


Figure 2.9 South Latah county accessible gravel roads

Finally, a brief questionnaire was sent to all local jurisdictions in the state of Idaho to establish baseline data of gravel road conditions if they experienced past road closures. So far, 37 responses were received by the research team as shown in Table 2.3. Most of the responses did not identify any road closures. Five reported gravel road closures due to landslide (city of Atlanta), snow (City of Dayton), dirt, unstable gravel (Clearwater county), heavy rainfall (Oneida County), and tornados (Cuprum, Idaho). A description of each individual location that experienced road closures is described below:

- Atlanta is an independent community in Elmore County, Idaho, United States. Atlanta is about 40 miles from two paved highways. It is located of the east of State Highway 21, accessed on unimproved U.S. Forest Service roads. It is north of U.S. Highway 20, which is accessed from Atlanta by heading south on USFS roads through Rocky Bar, Featherville, and Pine. The total population reported is 54.
- Dayton is a city in Franklin County, Idaho, United States. The population was 463 at the 2010 census. It is part of the Logan, Utah-Idaho Metropolitan Statistical Area.
- Clearwater County is a county located in the U.S. state of Idaho. As of the 2010 census, the population was 8,500. The county is home to North Fork of the Clearwater River, and a small portion of the South Fork and the main Clearwater.

- Oneida County name is an Indian word for a member of an Iroquoian tribe once in New York State, was chosen by the legislature because some of the early settlers were from Oneida, New York. Its population is approximately 4,286.
- Cuprum is an unincorporated community in Adams County in the U.S. state of Idaho. The community is located 27 mi northwest of Council with a population of 25 people.

2.3 Procedure to Assess Gravel Roads

Jurisdictions should consider the following components to determine if the gravel roads are adequate to safely carry the loads under consideration:

2.3.1 Amount of Crown

The crown is that part of roadway shape in which the center of the road is higher than the outer edges of the surface to provide drainage of water from the center of the road surface to curbs or ditches.

It is recommended there be no more than 1/2 inch of crown per foot (FHWA Gravel Roads Manual).

Figure 2.10 shows a gravel road with good shape of the entire cross section. The road has a driving surface with adequate crown that slopes directly to the edge of the shoulder.

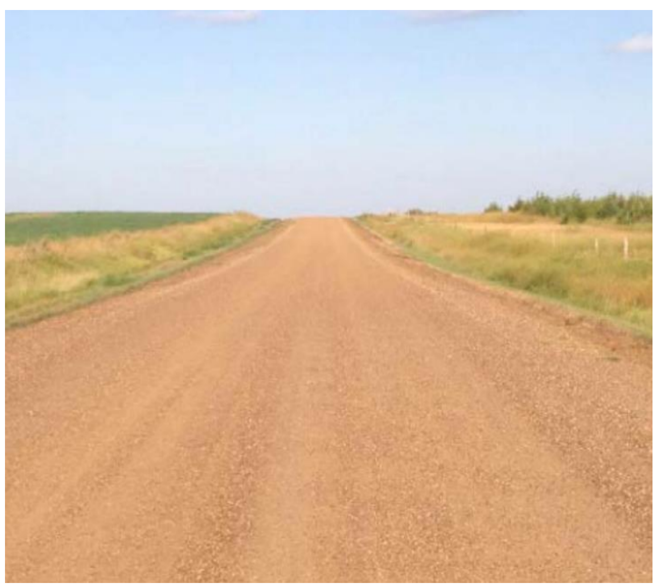


Figure 2.10 Gravel road with adequate crown.

Figure 2.11 shows a gravel road that lacks adequate crown. As a result, potholes and corrugation are forming because the lack of a crown prevents water from draining off the road surface.

Figure 2.11 Gravel road with inadequate crown

Figure 2.12 shows a gravel road that is wide (25 feet surface width) with traffic predominately driving in the middle. The primary reason is excessive crown.

Figure 2.12 Gravel road with excessive crown.

2.3.2 Condition of Shoulder

The shoulder should begin no higher or no lower than the edge of the roadway. By maintaining this shape, the low shoulder (or drop-off), which is a safety hazard, is eliminated and improves roadway edge support. Figure 2.13 shows one example of gravel shoulders that match the edge of the roadway very well and drain water to the ditch.

Figure 2.13 Example of good gravel shoulders.

The steps to assess whether the gravel road conditions are adequate to safely carry the load under consideration are as follows:
Step 1: Determine if the gravel road is approved for 80,000-pound trucks. If yes, go to step 2. If no, the request shall be denied.
Step 2: Inspect the road to determine the condition of the crown. If the crown is ½ inch or less per foot of roadway width, the crown is adequate. If more than ½ inch of crown per foot of roadway width, the request shall be denied.
Step 3: Inspect the road to determine the condition of the shoulder. If the shoulder is no higher or no lower than the edge of the roadway, the condition of the shoulder is adequate. If the shoulder is higher or lower than the edge of the roadway, the request shall be denied.

Table 2.3 Survey responses

	Name of the personnel filling the Survey:	**Agency Name**	**Q1**	**Q2**	**Q3**	**Q4**
1	Shelly Hammons, City Clerk-Treasurer	City of Potlatch	None	None	None	None
2	Shannon Wheeler	Union Independent Highway District	None	None	None	None
3	Wendy A. Sandino	City of Juliaetta	none	n/a	n/a	n/a

	Name of the personnel filling the Survey:	Agency Name	Q1	Q2	Q3	Q4
4	Steve Sprague	HW Lochner	Atlanta	Elmore county--road was US 20	approximately 54	Landslide
5	Eric	Winona highway district				
6	Tami Firzlaff, City Clerk-Treasurer	City of Peck				
7	Scott Butigan	City of stanthony	None	None	Na	Na
8	Julie Bishop, Clerk	Independent Highway District, Sandpoint	None	None	None	None
9	Brendan	Keuterville Highway Dist.	None	None	None	None
10	Mark Kime	Shoshone Hiway Dist # 2	None	None	None	We had no closures
11	Jason Freeman	City of Ririe	None	None	None	None
12	Mayor Hyrum F. Johnson	City of Driggs	none	none	none	none
13	Bryce Somsen	Caribou county commisioner	None	None	None	None
14	Aaron M. Beutler, City of Dayton Engineer	City of Dayton, Idaho	City of Dayton	City	463	We do not have enough budget to keep the road open during winter, due to snow.
15	MIchael Campbell	City of Weiser	None	None	None	None
16	Tom McCauley	City of Buhl	None	none	n/a	n/a
17	TIM R FORSMANN, CLERK	FENN HIGHWAY DISTRICT	None	None	None	None
18	TIM R FORSMANN, CLERK	COTTONWOOD HIGHWAY DISTRICT	None	None	None	None
19	Rick Winkel	Clearwater County	Clearwater County	North central Idaho	8500 population	They slide away, dirt or gravel is instantly unstable. More so when not maintained.
20	Robert Simpson Public Works Director	City of Carey	None	None	None	None
21	Gordon Bates, Director of Highways	Golden Gate Highway District #3	None	None	None	None
22	Kraig Spelman	Adams County Road and Bridge Department	Cuprum, Idaho	Adams County	25	Tornado knocked down a significant number of trees

	Name of the personnel filling the Survey:	Agency Name	Q1	Q2	Q3	Q4
23	Lisa Baker	Oneida County Road & Bridge	Woodruff, Head of Malad, Pleasant view, Dairy Creek	Oneida County	4300	roads washed out during a spring runoff and heavy rain occurrence
24	Darryl Johnson, Public Works Director	Teton County	None	None	None	None
25	Bilejo Klapprich	Grangeville Highway District	None	None	None	None
26	Alan Porath	Power County Highway Dist.	None	None	None	None
27	Shelly Hammons, City Clerk-Treasurer	City of Potlatch	N/A	N/A	N/A	N/A
28	Kent Fugal	City of Idaho Falls	None	None	None	None
29	Mike Hensley	City of Jerome	None	None	12000	None
30	Patty Parkinson	City of St. Anthony	None	None	None	None
31	Jeff McFadden	Valley County Road Dept	None	None	None	None
32	Arlen L Wilkins	Washington County Road & Bridge	None	None	None	None
33	Susan Lott	City of Newdale	NA	NA	NA	NA
34	Regie Finney	City of Buhl	N/A	N/A	N/A	N/A
35	Travis Brewer	Filer Highway District	None	None	None	None
36	Tim R Forsmann, Clerk	Cottonwood Highway District	No roads were closed	n/a	n/a	n/a
37	Steve Thompson	Blaine County Road and Bridge	None	None	None	None

CHAPTER 3. CONCLUSIONS

In the USA, gravel roads are still very common consisting 2.2 million miles of total 4.1 million miles roads (or 54%). For some communities in the Pacific Northwest and Alaska, unpaved gravel roads are the only way of access to the highways. Proper maintenance of these unpaved gravel roads is required to ensure safe access, and sustainable traffic operation throughout the year. The primary objective of the project was to evaluate the present condition of gravel roads in the Pacific Northwest, and Alaska. Much of this initial evaluation relied on the readily available information in the Idaho Transportation Department database. A pilot study was conducted in the state of Idaho to find gravel road closures due to extreme weather. The project outcomes include a comprehensive literature review of unpaved roads, and field visits. In addition, a questionnaire survey was sent to local jurisdictions to investigate the locations, reasons of road closures, and population size of the affected communities.

A total of 37 responses were received by the research team indicating five rural communities had experienced road closures and isolation. The reasons for the road closure include but not limited to the lack of funding for snow removal, excessive dirt, unstable gravel roads, tornados, and heavy rains. The location of the communities was spread across the state of Idaho with corresponding populations ranging from 25 to 8,500 people. The goal of this study was only to identify those communities and report the reasons for all the road closures. Also, a simple guideline for unpaved/gravel roads assessment was developed by the PIs for use by local highway jurisdictions, which will help to report any kind of damage or potential hazards. Based on the information provided by ITD, most of Idaho unpaved roads were found improved and in acceptable condition.

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.APPENDIX A

University of Idaho

Please answer this 1 minute (4 Questions Survey). Your feedback will help better understand the effects of unpaved road closures in rural Idaho areas.

What: The following survey is to develop an in-depth understanding of gravel and unpaved road safety issues (road closures) currently affecting the operational characteristics of people and goods in rural and tribal communities.

Why: Once unpaved roads' safety issues are identified, the results of this research will potentially help those communities by enhancing the condition of the unpaved roads and increase their mobility.

P.S: Please type "None" in the test box below each question if you do not have enough information

Name of the personnel filling the Survey:

Agency Name:

Email:

Phone no. :

Q1: What is the name of rural or tribal community that was isolated due to unpaved road closure?

Q2: Where is the location (city or county) of that road experienced closure?

Q3: What is the population of the community that was impacted by the closure?

Q4: Why was the road closed? Please describe the reason briefly

→

APPENDIX B

University of Idaho

Unpaved Road Survey

Please answer this 1 minute (4 Questions Survey). Your feedback will help better understand the effects of gravel road closures in rural Idaho areas.

Survey: https://uidaho.co1.qualtrics.com/jfe/form/SV_4Iasav2Zjl5UD7T

What: The following survey is to develop an in-depth understanding of gravel road safety issues (road closures) currently affecting the operational characteristics of people and goods in rural and tribal communities.

Why: Once unpaved roads' safety issues are identified, the results of this research will potentially help those communities by enhancing the condition of the unpaved roads and increase their mobility.

If you have additional questions regarding this survey contact:

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