LTAP
KANSAS LOCAL TECHNICAL ASSISTANCE PROGRAM

Field Guide for Grader Operators

2020 EDITION

A guide for grader operators related to maintenance of unpaved roads.

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Kansas LTAP meets the needs of road and bridge departments in local governments for information, training and technical assistance.

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Cover photo: Courtesy of Nebraska LTAP

▪▪FIELD GUIDE FOR GRADER OPERATORS▪▪

Purpose

The purpose of this guide is to provide assistance to grader operators who are responsible for day to day maintenance of unpaved roads. It provides a convenient reference to help address safety and maintenance issues commonly encountered in the field. To provide a safer road environment always look for potential safety issues during your daily operations and report these issues to your supervisor.

Disclaimer

This field guide is not all encompassing and should not be considered a legal document. This guide offers suggestions and guidance for many typical situations that arise on rural roads, but specific site conditions may make that guidance inappropriate. As it relates to traffic control devices this guide is meant to provide completely compatible, supplementary material as an aid to understanding and complying with the *Manual on Uniform Traffic Control Devices* (MUTCD). In the case of any actual or implied difference between this guide and the MUTCD, the MUTCD would govern.

Acknowledgment and History

The principal author of this guide is Norman Bowers, P.E., Local Road Engineer with the Kansas Association of Counties. Special thanks to Dale Dorsch, a long-time grader operator, and instructor for Kansas LTAP who assisted with this publication. Much of the information provided in this guide came from gravel road maintenance training provided by both the Kansas and Nebraska LTAPs. Another major source of information was the publication *Gravel Roads Construction & Maintenance Guide*, FHWA, August 2015.

CONTENTS

SECTION 1
GENERAL GUIDELINES FOR ROAD WORKERS

Follow your Agency's Standards, Policies, and Procedures

Every city, township and county is unique in many ways, with its own terrain, soil, available maintenance materials, weather patterns, and expectations of citizens. In general, the suggestions in this guide are based on common best practices. However, they may not apply in all jurisdictions or all situations. Each jurisdiction has its own set of operating procedures, best practices, and ways of conducting roadway maintenance activities. Failure to follow agency policy may result in legal liability for the agency. Always follow your agency's standards, policies, and procedures, or check with your supervisor before deviating from normal practice.

Duty to the Motorist

Generally, road agencies have a duty to construct and maintain public roads reasonably safe for use by motorists. In addition, Kansas state law has specified these three duties:

- Counties and townships are required to keep their roads in repair and remove or cause to be removed all obstructions (KSA 68-115).
- Cities, counties and townships are required to place and maintain traffic control devices upon roads under their jurisdiction as they may deem necessary to regulate, warn or guide traffic (KSA 8–2005).
- All traffic control devices on public roads must comply with the *Manual on Uniform Traffic Control Devices* abbreviated as MUTCD (KSA 8-2003).

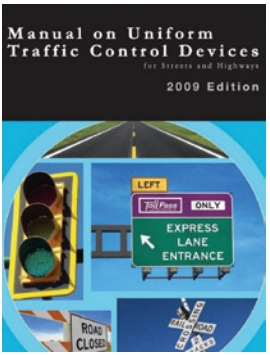
Signing Requirements

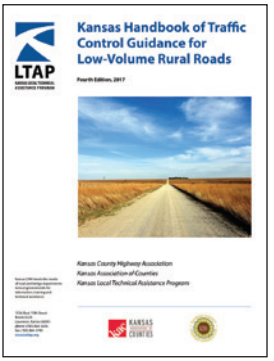
MUTCD: The Secretary of Transportation has adopted the *Manual on Uniform Traffic Control Devices* (MUTCD) (2009 Edition as of this writing) as the standard for public roads in Kansas including city, county and township roads (KSA 8-2003). The MUTCD is a national standard developed by the Federal Highway Administration (FHWA), and contains over 700 pages. The MUTCD covers almost all situations that might be encountered on freeways, expressways, city streets, rural roads and bike trails. The MUTCD is available online at the MUTCD website; just Google "MUTCD."

LVR Guide: The *Kansas Handbook of Traffic Control Guidance for Low-Volume Rural Roads*, Fourth Edition, 2017 (aka LVR Guide), is just for rural roads with less than 400 vehicles per day. The LVR Guide covers situations that are unique to low volume roads and so it is smaller and easier to use than the MUTCD.

The intent of the LVR Guide is to meet the standards in the MUTCD; it is not a separate standard. The LVR Guide is available from Kansas LTAP. A link is available at the end of this guide.

Figure 1-1. MUTCD & LVR Guide.





Think Safety

In all your decisions, "think safety." If something you are about to do could adversely affect the safety of the public, it is likely not the right decision. For maintenance work where there are no plans or design, the project should be thought-out in terms of safety for the traveling public. For instance, it may not be a good idea to cut a deep road ditch if the only reason for the deeper ditch is to drain a farmer's field. Road ditches are for road drainage, not for field drainage.

Report Problem Areas and Items Needing Attention

Field personnel are the eyes and ears of the agency. All employees should keep an eye out for road hazards and unusual situations that can affect the road or road right-of-way.

Following are a list of items that should be reported to your supervisor:

a. Downed, damaged, and faded signs.

b. Signs obscured by brush and trees.

c. Collapsed or damaged bridges and culverts.

d. Oil-field or other activity that is damaging the road or leaving debris on the road.

e. New driveways, culvert headwalls and landscaping.

f. Blocked ditches or change in drainage by a landowner.

g. Ornamental mailboxes that could be a safety hazard.

h. Utility work.

i. Oil or chemical spills.

j. Dumped trash.

k. New fences closer to the road.

Public Contact

Field personnel are the most prominent representatives of the agency and an important link between the citizens and the agency. Listen to all requests and comments and treat each citizen with respect. Take the name and phone number of the citizen and follow agency policy in reporting the citizen's request to supervisors.

SECTION 2
TRAFFIC SAFETY

Uniform Road Surface

Drivers have a tendency to drive in accordance with general road conditions. It is a good policy to maintain roads so that road conditions do not surprise a driver. For instance, a rough spot in a good road is more likely to surprise a driver and lead to a crash than a rough spot in a bad road. Areas of loose gravel, potholes and washboards are the most common irregularities that may cause an issue with drivers.

Take Care When Backing

It is not unusual for a vehicle to follow just behind the grader while waiting for an opportunity to pass. Always check behind the grader before backing up. It would be a good risk management practice to put a "Stay Back 75 Feet" sign on the back of a grader to discourage vehicles from following in the grader's "blind spot."

Dragging Contrary to the Flow of Traffic

Sometimes it is necessary to drag a road contrary to the flow of traffic. Construction and maintenance vehicles when actually working on the road are exempt from most traffic laws (KSA 8-1505), so dragging contrary to the flow of traffic is lawful. However, motorists may be confused when observing the grader coming toward them in "their" lane. It is a good idea to minimize operating the graders on the wrong side of the road. In hilly areas or on blind curves consider a warning sign for approaching traffic.

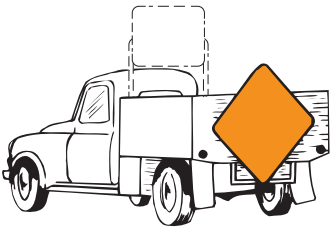
Traffic Warning for Road Maintenance (Dragging)

The LVR Guide states the following related to dragging of unpaved roads: A motor grader shall be equipped with a slow moving vehicle emblem, flashing lights, and a beacon. Flags at the ends of the moldboard are optional. Windrows should begin where they can be seen from a distance. Large windrows should not extend across intersections. Consider optional ROAD WORK AHEAD signs on main roads with poor visibility of the grader.

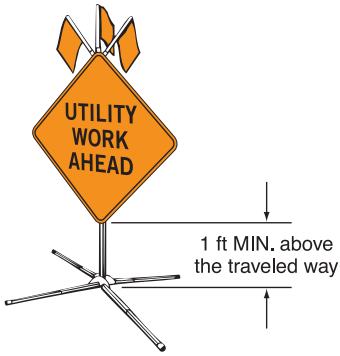
Temporary Traffic Control Signs

Temporary traffic control signs on low-volume roads that will be in place for long periods, such as a week or two, should be mounted on crash-worthy posts or a barricade. Signs that will be in place for a shorter period of time may be mounted on a barricade, tripod, sign stand or on the back of a truck. The bottom of signs on barricades and stands should be a minimum of 1 ft above the road surface.

Figure 2-1. Method of mounting signs other than on posts. (Source: MUTCD Figure 6F-2)



PORTABLE AND TEMPORARY MOUNTINGS



For rural roads the advance placement distance and the distance between advance warning signs is approximately 500 ft. The advance placement distance and the distance between signs on low-volume roadways with speeds of 30 miles per hour or less may be as small as 100 ft.

SECTION 3
OPERATOR SAFETY

Operator Attitude

Safety is the prime concern in everything we do and the most important part of the job. This includes:

- Safety for yourself
- Safety for co-workers
- Safety for the traveling public

To be safe the operator has to stay alert and maintain awareness of other people, machines and objects nearby. Like any driver the operator must avoid distractions such as talking on a cell phone or otherwise not concentrating on the task at hand. It only takes a brief distraction to cause injury or equipment damage.

Seat Belts & Safety Equipment

The most important piece of safety equipment for the operator is the seat belt. The seat belt should be secured before starting the machine and worn continually while the machine is running. The seatbelt should be fairly tight and positioned across the hip bones. In addition, wear proper clothing and carry safety equipment such as:

- Reflective vest
- Close fitting clothing
- Hard hat
- Work gloves
- Radio or phone
- ROAD WORK AHEAD sign.

High-Visibility Safety Apparel

The MUTCD requires that all workers within the right-of-way of a road open to traffic must wear high-visibility apparel. The apparel requirement is ANSI/ISEA Class 2 for daytime and Class 3 for nighttime. (For more information, go to this link: https://www.workzonesafety.org/training-resources/fhwa_wz_grant/atssa_high_visibility_pocket_guide/.) This requirement applies to flaggers as well as other workers when outside their equipment or vehicle. The grader operator should wear a high visibility vest or coat when working outside the grader on an open road.

Entering and Exiting the Cab

The majority of the injuries to a grader operator occur when entering and exiting the cab. Be aware that boarding and exiting equipment puts you in danger of slipping, tripping, or falling. Use a three-point (two feet and one hand *or* one foot and two hands) approach when entering or exiting the cab. Keep these tips in mind:

- Face the machine at all times while entering and exiting.
- Maintain three points of contact at all times.
- Keep boots and steps as clean as possible.
- Do not jump out of the grader or off the steps.

Railroad Crossings

A collision with a train is usually fatal. When smoothing the gravel to match the crossing it is easy to forget that a train could be approaching. When grading at a railroad crossing, turn off the radio, air conditioning or heater, and open the door to the cab so that you can hear a train horn.

SECTION 4
RIGHT-OF-WAY ISSUES

A road agency is the custodian of many miles of road right-of-way. In a way, the road agency is a neighbor with every landowner and resident located in their jurisdiction. With that many neighbors many issues can arise.

Road Easements

Most rural road right-of-way is what is called an easement. An easement is a right to use the land in a certain way, and when the easement is no longer needed, it can be vacated and the land would then revert back to the adjacent owner. The road easement allows the agency to do almost anything necessary to construct and maintain a road for public travel. State law (KSA 68-545) prohibits any work on the right-of-way without written permission from the road agency. Unfortunately, not all landowners are aware of the law and may damage the road or construct an obstruction or traffic hazard. The road agency may need to take action to correct the situation or remove the obstruction. On the other hand, the road agency should be aware they just have an easement and do not have unlimited authority to do anything they want on the right-of-way.

Work by Adjacent Landowners on the Right-of-Way

State law requires that all work on the right-of-way by private individuals must be approved in writing by the road agency (KSA 68-545). It is not unusual for property owners to work in the right-of-way without permission. This work might include installing a culvert, landscaping, blading the road, digging a deeper ditch, etc. Landowners may not build, store, or grow anything in the right-of-way that creates a traffic hazard or leads to road deterioration. Storing hay bales, vehicles, heavy equipment, or other property in the right-of-way creates an obstruction to wide farm equipment and a hazard to a vehicle that accidentally leaves the roadway. Entrance-culvert end walls, large solid mailboxes, retaining walls, and large trees are obvious hazards for vehicles that leave the roadway, but landowners do not always see their work as being a serious issue. If private work is observed on the right-of-way, notify your supervisor.

Figure 4-1. Hay bales in right-of-way obstruct wide farm equipment and can be a safety issue to errant vehicles. (Source: Marion County)

Public Utilities in the Right-of-Way

Generally public utilities have authority to install their facilities on the road right-of-way provided that the facilities do not seriously impede or endanger public travel or unnecessarily interfere with the reasonable use of the highway. Many road agencies have a permit system that authorizes utilities to be placed in the right-of-way in accordance with plans furnished by the utility and construction requirements specified by the agency. Any utility activity should be reported to your supervisor, especially if work is endangering public travel or has damaged road facilities.

Tree Removal

Because a rural road typically is a road easement, trees on the right-of-way belong to the adjacent owner. The agency has authority to remove obstructions; tree limbs and most trees could be considered an obstruction. Generally, agencies can remove, when needed for road purposes, trees where the trunks are entirely on road right-of-way. Consult with the landowner prior to removing trees with landscape or wood value, as the landowner may want to salvage the wood. A good road-related reason is needed to remove trees with value, and if the decision is arbitrary the agency can be sued for damages. Agencies cannot remove or kill trees that are on the right-of-way line without permission from the landowner, except within 350 feet of a corner. KSA 19-2612 authorizes the board of county commissioners to cut all hedge fences, trees and shrubs growing upon the highway right-of-way, or on a right-of-way boundary, within three hundred fifty (350) feet of a railroad grade crossing or abrupt corner on the highway, and thereafter keep the same trimmed to provide clear vision.

Trimming Trees

Trees, brush, and overhanging limbs are obstructions to maintenance and travel on the road and are sometimes a traffic hazard or cause sight distance restriction. Trees can be trimmed back to the right-of-way line. Trimming past

the right-of-way line is trespassing and could subject the agency to liability for damages. This is especially important for evergreen trees, that when trimmed, do not grow back.

Intersection Sight Triangle

The driver of a vehicle approaching an intersection needs a view of vehicles approaching the intersection from the intersecting roads. The unobstructed views to intersecting traffic form triangular areas known as sight triangles. Approach sight triangles provide the driver of a vehicle approaching an intersection an unobstructed view of potential conflicting vehicles. Long sight triangles provide better safety. Many times sight distance can be improved by mowing, tree removal, flattening back slopes, and lowering hills.

Many low volume rural road intersections are uncontrolled (no STOP or YIELD signs). Right-of-way at uncontrolled intersections is based on state law. The law is that when two vehicles approach or enter an intersection from different roads at approximately the same time, the driver of the vehicle on the left shall yield the right-of-way to the vehicle on the right (KSA 8-1526). If the sight triangle is restricted, it may be appropriate to install YIELD or STOP signs. The decision to install regulatory signs is normally based on an engineering study, then followed with a resolution by the county commission or city council. Since these kinds of decisions are made by management field, personnel should report sight distance issues and citizen concerns to their supervisor.

SECTION 5
TRAFFIC CONTROL DEVICES (SIGNS)

General Sign Requirements and Placement

Traffic control devices are all signs, markings, and devices placed on or along a road to assist the driver in traveling the road in a safe and efficient manner. Traffic control devices should comply with the MUTCD and LVR Guide which were described in Section 1 of this guide. This guide provides limited information on signing, with the limited intent to provide the grader operator sufficient information to properly repair and replace existing signing. If it seems like additional signing may be needed at a particular location, notify your supervisor of your concern.

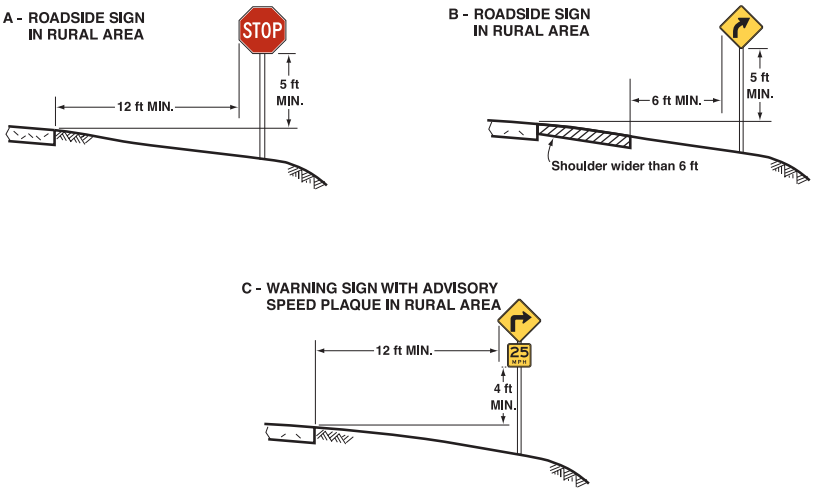
Division of Responsibilities for Signing

Outside of cities, KDOT is responsible for the STOP signs on side roads approaching a state highway, as well as STOP AHEAD signs installed by KDOT. The county is responsible for erecting and maintaining traffic control signs on county roads. In counties where townships maintain roads, KSA 8-2005 makes the county responsible for signs related to county culverts and county bridges, and construction signage related to county projects on township roads. Counties may maintain street name signs on township roads. Townships are responsible for all other signing. All regulatory signs on township roads must be authorized by a resolution of the county commission.

Sign Placement

Signs should be located on the right side of the roadway where they are easily recognized and understood by road users. Normally, signs on the left side of the road should be considered only as supplementary to signs on the right side of the road. The MUTCD establishes a standard that signs installed at the side of the road in rural districts shall be at least 5 ft high, measured vertically from the bottom of the sign to the near edge of the pavement (edge of traveled way on unpaved roads). Where parking or pedestrian movements occur, the clearance to the bottom of the sign shall be at least 7 ft. The height to the bottom of a secondary sign or plaque-mounted below another sign may be 1 ft less than the height specified. The MUTCD contains guidance for post-mounted signs and states that the minimum lateral offset should be 12 ft from the edge of the traveled way. To minimize the possibility of drivers colliding with signs, traffic signs should be located as far as practical from the edge of the roadway. On many roads, placing signs 12 ft from the edge of road will put the sign in a ditch or visibility will be blocked by brush or trees. In these cases, the agency should use engineering judgment to establish appropriate offset for visibility and maintenance but not less than 2 ft from the roadway edge to the roadside edge of a sign.

Figure 5-1. Example of height and lateral location of signs. (Source: MUTCD)



Sign Posts

The MUTCD states that post-mounted sign supports shall be yielding, or breakaway (crashworthy). There are 4 types of crashworthy posts currently in use:

a. "U" channel: 3 lb. max, direct-bury or spliced

b. Round pipe: 2 inches inside diameter max

c. Square perforated steel: 2.25 inches max

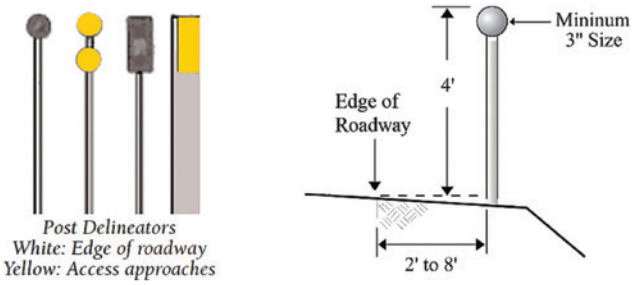
d. Wood: 4 inches x 4 inches max undrilled.

Do not splice sign posts except near the ground line. The top of a splice or anchor section should be 4 inches or less above the ground line to prevent snagging if hit. Square perforated steel posts should have the top of the anchor section a maximum of 1.5 inches above ground line.

Delineators

Delineators may be used based on engineering judgment, such as for curves, T-intersections, and abrupt changes in the roadway width. In addition, they may be used to mark the location of driveways or other minor roads entering the road.

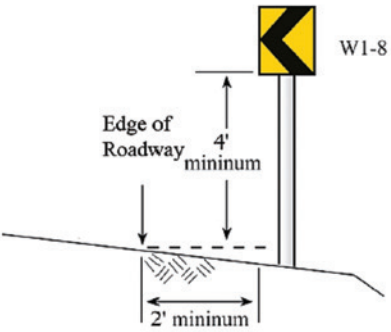
Figure 5-2. Delineators and delineator placement. (Source: MUTCD)



Chevrons

A Chevron Alignment sign is intended to provide additional emphasis and guidance for a change in horizontal alignment. It may be used as an alternate or supplement to standard delineators. Chevron Alignment signs, if used, are installed on the outside of a turn or curve in line with and at approximately a right angle to approaching traffic.

Figure 5-3. Chevron location and height. (Source: MUTCD)



Object Markers

The purpose of object markers is to mark obstructions located within or adjacent to the roadway, such as bridge abutments, drainage structures, and other physical objects.

Type 2 Object Markers (OM2) are used to mark obstructions adjacent to the roadway. The most commonly used option is 6 inch x 12 inch yellow sheeting.

Type 3 Object Markers (OM3) are used to mark obstructions in or adjacent to the roadway. The OM3 is a 12 inch x 36 inch black and yellow striped panel

with the stripes sloping downward toward the side of the obstruction on which traffic is to pass.

Type 4 Object Markers (OM4) are used to mark the end of a roadway. The most commonly used option is 18 inch x 18 inch red sheeting.

The edge of the OM2 or OM3 closest to the road user shall be installed in line with the closest edge of the obstruction. The typical mounting height to the bottom of the object marker should be 4 ft above the near edge of the traveled way. When the marker is placed down the foreslope, the mounting height to the bottom of the object marker should be at least 4 ft above the ground.

For low volume roads where wide farm equipment tend to damage normal object markers, there is an optional OM-2 consisting of a flexible delineator with 24 inches of reflective sheeting.

Figure 5-4. Example of mounting of object markers. (Source: MUTCD)

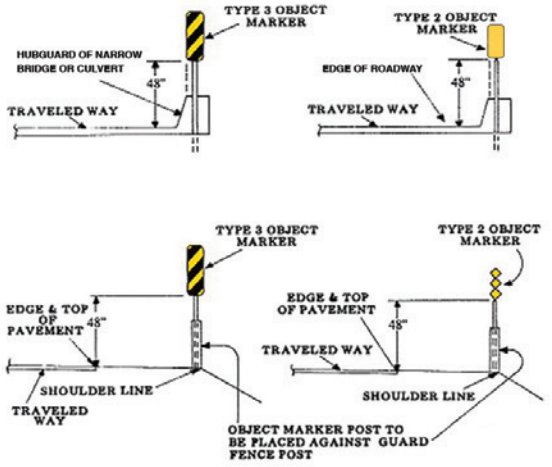


Figure 5-5. Flexible OM-2 for low volume roads with wide farm equipment. (Source: Norm Bowers)

Railroad Crossbucks and Signals

Traffic control devices at a grade crossing include the crossbuck assembly, advance warning signs, and pavement markings on paved road. Additionally, on some roads, there are flashing light signals and gates. The crossbuck assembly, flashing lights and gates are the responsibility of the railroad. Advance warning signs as well as pavement markings on paved roads are the responsibility of the agency that maintains the road. Report damaged crossbucks and signal malfunctions to the railroad using the emergency number located on the sign at the crossing.

Sign Maintenance

Maintenance of traffic control devices should assure that legibility is retained for good visibility both day and night. Adequate retroreflectivity of a sign is necessary for good visibility at night. Maintenance includes removing weeds, brush, etc., which obstruct driver's view of the device.

SECTION 6
COMPONENTS OF A GOOD UNPAVED ROAD

Aggregates in Kansas: Gravel-Sand, Rock, and White Rock

The type of surfacing in Kansas generally is gravel or sand west of US-81 Highway and crushed limestone rock east of US-81. Gravel is just big sand, and roads using this material are sometimes called gravel roads and sometimes sand roads. Gravel-sand is obtained from river floodplains and hillside deposits. Some sand is available from sand plants along the Kansas River. Hill gravel, river gravel and creek gravel is available in some areas, but supplies are limited. Most of the larger gravel in Kansas comes from the Arkansas River area. Many areas have difficulty finding adequate clay-type binder to mix with the rounded sand-gravel resulting in continual problems with washboards. Since the sand-gravel particles are rounded these roads also have a tendency to rut in wet weather.

Ellis County (Hays area) and a few counties north of Hays use what they call white rock, which is *Fort Hays Limestone*. The white rock is not crushed but ripped with a dozer and reduced on the road with a grid roller. People familiar with eastern Kansas limestone might think this white rock is soft shale. There are also a couple of volcanic ash pits in the Hill City-Norton area. White rock is so soft it is treated much differently than rock or sand roads. Much of the information in this guide may not apply to white rock roads.

Crushed limestone is obtained from quarries in various limestone ledges throughout eastern Kansas. The quality of the limestone varies, and generally the limestone becomes softer as you go west. Crushed rock is angular, which provides good wet weather stability and resists washboards. However, limestone is softer than sand, and is degraded by traffic and maintenance blading which results in more road dust and loss of material. Crushed rock roads are sometimes called gravel roads. This nomenclature originated in the 1930's when the State Highway Commission applied gravel to state highways. These days any surfaced road is commonly called a gravel road, and in this guide, the term unpaved road is mostly refers to a gravel road.

Definition of a Good Unpaved Road

A well maintained unpaved road has the following characteristics: The road has a four to six percent cross slope (crown) with good crust and a minimum amount of loose material on the surface. There are no or few potholes, washboards, ruts, or secondary ditches (high shoulders), and a road ditch handles most rains. Poor drainage contributes to most road defects and so there is an old saying by road managers: "Think drainage, drainage, drainage and

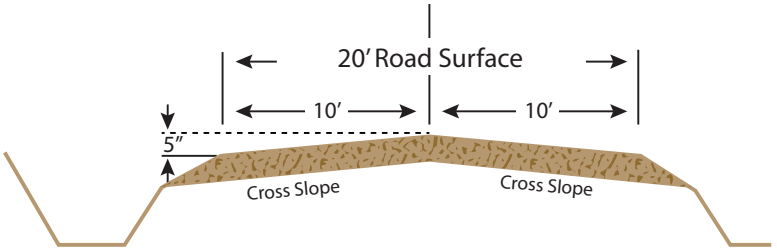
drainage." Effective drainage includes impervious road surface (crust); road crown; shoulder; and road ditch. Details of these four characteristics are:

Drainage #1 — Impervious road surface (crust):
The crust is the top two or three inches of roadway that has been compacted into a dense, tight mass with an almost impervious surface. One purpose of the road surface is to shed water which protects the underlying areas. On a gravel road an ideal surface is one with a tight crust containing well graded material with sufficient fines to be almost impervious. Aggregates with too few fines will not form a crust, and excess fines will make the road slick in wet weather. For the crust to reform after blading, the surfacing material must be moist to allow the fines and larger materials to bond and compact.

Drainage #2 — Crown:
Creating a crown in the road so it is higher along the centerline than at the edges forces the water to flow off the road surface. An adequate, A-shaped crown is important for drainage; an ideal cross section is shown in Figure 6-1. If a rock road has too little crown, water from rain or melted snow will collect on the road surface and soften the crust, which can lead to rutting and potholes. If there is too much crown, motorists may drive in the middle of the road because they feel as if their vehicles might slip off the road. Also, farm equipment may high-center and drag.

A four to six percent crown is generally optimum. The cross section should look much like the pitch of a roof, or a flat A shape.

Figure 6-1. Cross section of a road with a proper "A" shaped crown. (Source: FHWA Gravel Roads Construction & Maintenance Guide)



Worn blades will cause a parabolic crown with a flat spot running down the center of the road, which will pothole easily. The road will be too steep near the shoulder and too flat near the center of the road. See Figure 6-2. Section 10 of this guide has more information on crown.

Figure 6-2. Worn blades cause parabolic crown and false shoulders. (Source: FHWA Gravel Roads Construction & Maintenance Guide)

Drainage #3 — Shoulder:
For the road crown to work properly the road shoulders must also be sloped away from the road to continue carrying the water to the ditch. High shoulders will hold water on the road; this is a common issue on dirt and gravel roads. Windrowed material along the sides of the road should have slots (aka weep holes) cut occasionally to allow water to run to the ditch.

Drainage #4 — Road Ditch:
Road ditches serve two purposes: They allow precipitation that falls on the road to flow over the shoulder, and they prevent surface water from adjacent land from flowing onto the roadway. There is no minimum ditch depth; the ditch only needs to be deep enough to serve these two purposes. Ditches will need to be deeper where the adjacent field slopes toward the road and on longer hills where more water accumulates in the ditch. Usually a ditch has inadequate capacity if you can see erosion occurring along the shoulder after a moderate rain as shown in Figure 6-3.

Figure 6-3. Washing of shoulder indicates inadequate ditch capacity. (Source: Norm Bowers)

SECTION 7
DRAGGING (SMOOTHING)

Dragging — What Is It?

Dragging is light blading that redistributes the surfacing material and partially corrects surface defects. It should result in a uniform driving surface. The term "dragging" originated in the 1800's when the primary maintenance technique was to drag a railroad tie or large timber behind a mule to knock down the ruts in a dirt road. Smoothing more accurately describes the maintenance process we use today, but in this guide we use the commonly-used term "dragging." Dragging is typically a two-pass system of moving the windrow, if any, from one side of the road to the other. On wider roads it may take three passes to move the windrow across the road. Dragging barely cuts into the crust — only as necessary to obtain material to restore some crown and fill irregularities. Like any blading, dragging should occur when the bladed material is moist so that the material will compact and form a crust with little loose aggregate. Typically dragging is done as soon as possible after a rain to cover as many miles as possible while moisture is present.

Dragging Weather Considerations

The purpose of any blading is to correct surface defects and maintain a uniform surface for traffic. During winter and wet weather, the major road defects are potholes, lack of crown, rutting, and occasional erosion on hills and in low spots. In summer and dry periods, the major road defects are washboards and dust. When and how to drag a road is dependent on the season and the major defects present at the time. During the winter months and wet weather, the primary purpose of blading a rock road is to restore cross slope, evenly distribute the surface material, and correct defects before the road becomes unduly out of shape or rough. During the summer and dry spells, you can protect the crust and minimize dust and loss of surfacing material by reducing the frequency of blading, doing lighter cutting, and by spot-blading problem areas. In any season, effective dragging should result in a smooth road with a minimum of dry, loose material on the road surface.

Timing

If possible, drag roads when moisture is present so most of the loose material will be compacted by traffic. In the Great Plains, moisture conditions are generally best for blading in the spring and fall. Conditions are also good during the first two or three days after a summer rainfall. Dragging cuts aggregate and exposes fines, which accelerates loss of rock surfacing and binder to rain, wind, and passing traffic, so blading should only be performed when necessary and effective.

Considerations in Determining Number of Passes

Many agencies use a two-pass maintenance system which moves the windrow or loose material from one side of the road to the other. The two-pass system covers the most miles in the shortest amount of time. In the drier times of year the two-pass system reaches the most miles before the surface becomes too dry for the material to repack.

The two-pass system just smooths the road and does not correct crown. Potholes and washboards are just filled in and not cut out. Also, there is a tendency to not blade all the way to the shoulder, so false shoulders develop. To offset these two-pass issues, some agencies prefer to do light shaping with a three-pass system for their regular maintenance program, rather than just smoothing. The three-pass system provides shaping, better mixing of material, re-establishes crown, corrects surface defects, and avoids false shoulders and flattening of the crown.

Limitations of Two-Pass Dragging

It is important to understand the limitations of the two-pass system. Dragging with two passes just smooths the road and rarely restores crown, and there is actually a tendency for crown to be reduced. Due to the light blading, smoothing just fills in potholes and washboards which only marginally improves these areas. In some instances the operator avoids the grass near the shoulder and false shoulders develop. False shoulders and lack of crown are common with the two-pass method and where dragging is the only maintenance performed. In the long term, dragging alone will not keep unpaved roads in shape; occasional shaping is required. Agencies that use the two-pass method should consider light shaping a couple of miles per blading round to offset issues that develop from the two-pass method.

Shaping — What Is It?

Shaping is a three or more passes method where both edges of the road are cut and moved to the center. Cutting while shaping is heavier than while dragging and involves cutting into the crust and mixing material so the material can be shaped to the proper crown and then compacted. Heavy cutting is required when potholes and washboards are present, and where major crown restoration is necessary. After the road is shaped it is sometimes appropriate to high-blade a round with the grader articulated to compact the surface.

SECTION 8
GRADER OPERATIONS FOR DRAGGING (SMOOTHING)

Articulation

Articulation is a valuable tool for most operations. Articulation makes the grader more stable and provides better compaction. The biggest mistake an operator will make is not utilizing articulation. Articulation will allow a greater reach with the moldboard. For example, the front wheels can be placed out on the shoulder to better recover material with the moldboard while keeping the rear axles on the roadway for stability. There are too many applications for articulation to cover here, but operators should learn to use this feature to their advantage in both routine and rehabilitation operations. A new operator should consult with more experienced operators on proper use of articulation. There are also YouTube videos on using articulation; this subject is also covered in Kansas LTAP gravel road maintenance classes.

Operating Speed

Operating speed while dragging is dependent on factors such as miles assigned, season of the year and condition of the road. A slower speed is appropriate when doing minor shaping. A higher speed may be appropriate after a rain when trying to cover as many miles as possible while moisture is present. Speeds usually range between 3 to 5 mph. The operating speed must be slow enough to be sure the machine remains stable and the operator has sufficient time to adjust the moldboard for changing conditions. When the road surface is uniform, higher speeds may be possible, but a slower speed is more effective in washboarded and uneven areas. The top speed is always limited by the speed at which the grader begins to hop. When the machine begins to hop it will cut depressions and leave ridges in the road surface, so the speed must be reduced.

Grader Hop (Bounce)

It can sometimes be hard to keep a machine stable, especially while carrying a light load of material. Counteracting machine bounce or "loping" requires experience in knowing the cause and then finding a solution. If a motor grader begins to rock from side to side, often called "duck walking," it is usually caused by a blade angle that closely matches the angle from corner to corner of the tires on the rear tandem axles. In general, the solution is to stop, change the moldboard angle slightly and slowly resume blading. Simply reducing speed will also often eliminate the loping effect of a machine. Experimenting with different tire inflation pressures in the tandems can help stabilize a machine. Higher tire pressure should be considered in opposite side front & rear tires; for example, give the right front tandem and left rear tandem 3 lb higher pressure. Some operators prefer a different pressure in each of the tandem tires. Sometimes it will help to increase or adjust the front wheel lean. Adding extra weight at the

front of the grader may also help. Filling tires with liquid ballast to about 70 percent capacity is sometimes done to increase traction, weight and stability of the grader. The ballast used most often is a solution of calcium chloride and water. Stability problems that are constant and severe should be brought to the attention of your equipment dealer and/or tire supplier.

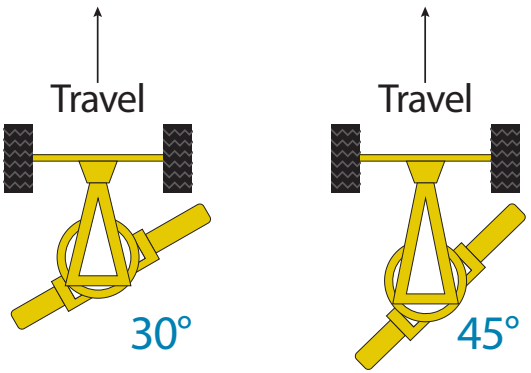
RPMs and Gearing

It is important to pick the right gearing and RPMs for fuel economy and motorgrader longevity. Dragging does not involve heavy pulling but there is a tendency for operators to select too low of a gear which results in higher engine RPMs and lower fuel economy. When a new motorgrader is placed into operation, or when there is a new operator, the daily fuel consumption should be monitored at different gearings. Choose a gear to drag for one day, then pick another gear for a different day, then standardize on the gear that provides the greatest fuel economy. Some motorgraders may have a fuel consumption indicator that makes gear selection much faster.

Moldboard Angle

The angle of the moldboard is also critical for good maintenance. It is important to keep the angle somewhere between 30 and 45 degrees as illustrated in Figure 8-1. It is a challenge to recover loose aggregate from the shoulder of the roadway without spilling material around the leading edge (toe) of the moldboard. Operating without enough angle is a primary cause of this spilling, which does not allow enough material to be carried for good maintenance.

Figure 8-1. Blade angle range for dragging. (Source: Nebraska LTAP)



Moldboard Tilt

Along with correct angle, it is important to understand proper pitch or "tilt" of a moldboard. The moldboard is tilted back for cutting and spreading material, and tilted forward for dragging or minor shaping. When dragging, if the moldboard is pitched back too far, the material will tend to push and build up in front of the moldboard rather than roll and mix. The mixing action is essential for the material to fill in depressed areas and move along properly to the heel of the blade. Tilt the moldboard forward enough to maintain a mixing action of the bladed material. As the materials differ from place to place, so will the required moldboard tilt.

Figure 8-2. Tilt the blade forward for dragging.
(Source: FHWA Gravel Roads Construction & Maintenance Guide)

Front Wheel Lean

Front wheels should always be leaned to offset the side force caused by the blade when cutting into the road surface and carrying the loose material. The front wheels should always lean so the top of the tires are leaned toward the heel of the blade where the material is being discharged.

SECTION 9
COMMON PROBLEMS WHEN BLADING

Dry Weather & Road Dust

Dust (also known as "fines") is a very important component of a gravel road. It is the binder that holds the coarser material together the same way cement holds stone and sand together in concrete. Big clouds of road dust are an indicator of surface material loss and deterioration. General dragging in dry weather is seldom productive, as it loosens the crust and causes more road dust. Only a minimum amount of dragging should be performed in dry weather. Spot blading may be necessary to cut out potholes and washboards for safety reasons. Loose material may need to be windrowed until adequate moisture is present when it can by laid back on the road and recompacted by traffic. If dragging in dry weather, consider laying out only one or two miles at a time and immediately wheel rolling with the grader to provide compaction while moisture is present.

Potholes

Potholes are caused by lack of crown, resulting in water standing in wheel tracks. Potholes are more likely to develop on high traffic roads and during prolonged wet spells and rains. Typical locations are flat areas on top of hills and over cross-road culverts. See Figure 9-1. Prevent potholes by maintaining adequate crown on the roadway, and consider increasing crown in problem areas. Perform temporary repairs of potholes by blading loose material into the holes. Such repairs will not last long. For a permanent repair, blade deep enough to cut out the potholes, reshape the roadway to a proper crown, and compact the surface.

Figure 9-1. Inadequate crown is the major cause of potholed areas in a gravel road. (Source: Norm Bowers)

Rutting

Rutting may be caused by poor drainage, lack of crown, and/or inadequate surfacing material for the amount of traffic. See Figure 9-2. To minimize rutting pay attention to drainage by making sure there is proper crown. Cuts should be made through windrows on long hills and low areas to allow water to reach the ditch. False shoulders may also hold water on the road and should be eliminated if practical. To correct rutting and prevent it from recurring, reshape the crown, place additional surfacing material, and then blade and compact the surface.

Mudholes

Mudholes occur in low areas where the surfacing material is marginal and where there is a lack of crown combined with false shoulders, or where the windrow traps water on the road. To correct a mudhole it is essential cut off any false shoulders and establish the proper crown in the road prior to adding surfacing material.

Figure 9-2. Rutting and mudholes caused by poor drainage including lack of crown, false shoulders, and windrow without weep holes. (Source: Norm Bowers)

Washboards

Washboards, as shown in Figure 9-3, are caused by repeated small horizontal forces (friction) from tires interacting with the surface of the road. The most common location for washboards is near intersections where traffic frequently starts and stops. This starting and stopping imposes horizontal forces on the rock and will start dislodging particles, resulting in washboards. Other common places are curves and up steep hills where tires exert more horizontal force on the road surface. Washboards are more common on sand and gravel roads due to the more rounded particles combined with a lack of cohesive material.

Figure 9-3. Washboards are caused by lack of cohesive binder and excess loose material on the road surface. (Source: Norm Bowers)

Washboards are more prevalent in dry weather because the road surface dries out and does not have moisture to hold the particles together. This makes it easier for the abrasion of tires to displace material. Prevention is always best, and that is accomplished by timely blading when moisture is right. Also, avoid leaving dry loose material on the road surface in washboard-prone areas because loose material will washboard rapidly. During dry periods it may be appropriate to windrow loose material, rather than spread the dry material on the road where it will washboard again within a few days.

If the washboards are not too deep, sometimes right after a rain a blade can rough-up the surface and recompact it by running the motor grader over the area a number of times. There has to be adequate moisture in the surfacing, so the timing after a rain is really critical. For long-lasting repairs of washboards, cut out the washboards to the bottom of the low areas. Then reshape the areas, carefully remixing and compacting fine and coarse materials. Adequate moisture content is critical, and a water truck may be necessary during dry weather.

Figure 9-4. Washboard area being scarified with bullet blades to the bottom of the washboards. (Source: Pawnee County)

To minimize washboards, knowing the characteristics of the surfacing material is critical. The surfacing should be well-graded so it will compact to a tight surface. If there are too many large particles and not enough fines, the large particles will easily come loose and create washboards. The rock surface has to be cohesive when dry, and for dry cohesion you need fine clay-like particles or a chemical. Washboarding can be reduced by using rock with more clay (with a higher plasticity index (PI) value), or adding clay or caliche to gravel or sand surfacing. The use of calcium chloride or magnesium chloride makes the surfacing more cohesive in dry weather, because the chemical holds moisture in the surfacing.

Grass and Sod

Grass, weeds and related sod are a primary challenge when eliminating false shoulders and pulling shoulders. To start, it is best to burn or at least mow these areas. In sandy soil, the soil breaks apart from the roots fairly easily and the vegetation may blow away. In clay, the root balls tend to form clods and are difficult to break down without proper equipment. It is almost essential to use a one-way disc or tiller to break up the clay soil, and as much as possible to separate the vegetation from the soil. Breaking up the material with a blade is possible but involves windrowing the material and allowing weather and time to mellow out the material prior to working it.

False Shoulders

A false shoulder is when a low ridge develops at the edge of the road and prevents water from flowing over the shoulder and into the ditch. Water then flows along the edge of the roadway and begins eroding the road, or holds water at a low area as shown in Figure 9-2. False (or high) shoulders have two causes: 1) the natural lowering of the roadway surface due to loss of surfacing material through dust erosion or washing, and 2) by improper blading techniques. Improper blading includes not blading all the way to the foreslope, and the use of worn blades that are hollow in the middle. Worn blades make it difficult to carry adequate material along the moldboard without gouging a ridge near the foreslope, as shown in Figure 6-2. Prevent the formation of false shoulders by blading all the way to the foreslope with a proper crown. False shoulders are much more common in eastern and central Kansas where there is clay soil and the vegetation is more vigorous.

If false shoulders are present, they need to be eliminated so the water can flow directly off the road and down the foreslope. The first item to consider is why the false shoulder developed, and what is going to change so it doesn't happen again. Also consider vegetation, as described in a preceding section. If a road is scheduled to be re-graveled, it is an excellent time to do remove the false shoulder and to restore the proper crown. Obviously, this work is best done when there is minimal vegetation, such as early spring or soon after a mowing or burning. Some operators try to cut just a little of the false shoulder when they drag the road. This is pointless unless done consistently to an extent that

the false shoulder is eventually eliminated. Usually the false shoulder can be eliminated in one operation rather than gradually.

The second item to consider is the material in the false shoulder. Usually the material is a mixture of soil and surfacing material that can be either combined with the surfacing material or worked into the roadbed and then surfacing laid on top.

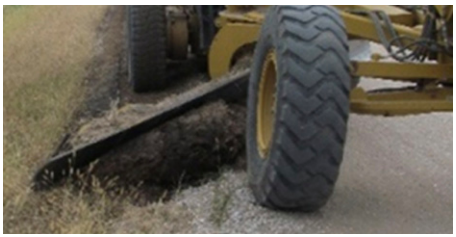
There are many different ways to eliminate false shoulders. Following is one suggestion that could be modified based on local conditions and material: Start with straight blades, and tight-blade the windrow and any loose surfacing to the opposite side of the road. Inside the false shoulder, cut deep enough to remove most of the surfacing material. Cut off the false shoulder and blade it toward the center of the road and back to the shoulder. Try to place as much material as possible in the groove next to the false shoulder. Try to work any big rocks, beer bottles, etc. over the shoulder. Analyze the remaining material to see if it is better to mix this material with the windrowed surfacing or to lay it onto the road, pack it down and blade the surfacing over the top. This operation needs to be performed so that it results with the proper crown in the road.

Removing false shoulders is much more time-consuming than routine maintenance, and signs should be placed to warn motorists of roadwork being done. If possible, it is suggested agencies consider closing the section of road being worked on to avoid problems with having to maintain traffic through the project area.

Pulling Shoulders

An unpaved road seems to widen out over the years with just routine maintenance. Occasionally it is necessary to restore the narrower road width by pulling the shoulder. If you are actually restoring the shoulder, the shoulder material will be a mixture of surfacing material, dirt and vegetation. If the blade cuts into native soil, that is not pulling the shoulders; that is ditching. When pulling shoulders be sure to keep the point of the blade away from the ditch bottom. If the ditch bottom is disturbed, erosion will occur.

Figure 9-5. Pulling a shoulder. Note minimal amount of vegetation, front tire compacting the road edge and rear tires compacting the foreslope. (Source: Nebraska LTAP)



When pulling shoulders there are many of the same issues as removing false shoulders. It is a more complicated process as there will be more vegetation and recovered material that has to be worked. The recovered material from pulling shoulders is less likely to be suitable for reuse on the roadway than false shoulder material. It is sometimes best to cut the material loose, pull it onto the roadway, load it, and remove it. Although removal is expensive and time consuming, it may better to remove it than to place it on the surface and contaminate the existing surfacing.

First you have to plan on how to deal with vegetation. Second, evaluate the material that will be pulled up into the road. Sometimes the foreslope material has enough rock or gravel that it can be blended with the surfacing material. At other times it may be necessary to move the surfacing material to the other side of the road, work the foreslope material in as a base, and then try to cover the foreslope material with the surfacing material. In sandy areas the foreslope material may lack fines and it will be necessary to mix the material into the existing roadbed or haul in cohesive material.

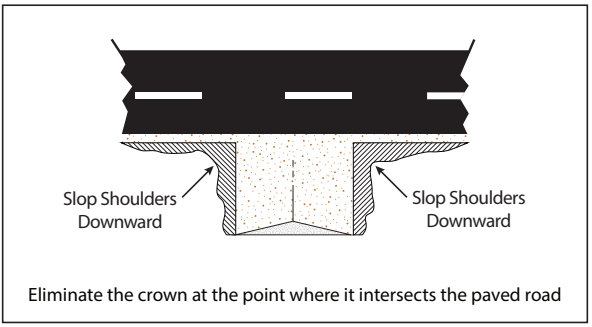
Windrows

Windrows along the shoulder are problematic because they keep water from running directly off the road into the ditch. Large windrows may be a safety issue, too, as they tend to narrow the driving surface and may cause loss of control if hit by a vehicle that strays into the windrow. Windrows should be minimized or eliminated in autumn so they do not complicate snow removal. Many agencies have a policy to limit windrows to dry weather to minimize loose material on the road itself. If the policy of the agency is to have a windrow, slots should be cut in the windrow at low areas and intermittently on long hills to allow for roadway drainage. Some agencies prohibit windrows except under certain circumstances. Those agencies feather out the loose material on the last pass of the grader. Obviously, that requires good crown in the road to allow feathering the loose material. The grader operator should follow agency policy on windrows.

Intersection With a Paved Road

At intersections with pavement, the gravel surface has to match the level of the pavement, so transition the crown on the gravel road approximately 100 ft from the edge of the pavement. The transition requires continual maintenance attention because potholes and washboards tend to develop in this area. When potholes and washboards occur, the gravel crust needs to be cut out and re-layed to correct the problem. However, be careful not to push gravel out onto the pavement. Simply pick up the moldboard and set it down in front of the material, backdrag the excess back on the gravel road, and then wheel-roll the loose material.

Figure 9-6. Gravel road intersecting a paved road or a gravel road with stop or yield signs on the side road. (Source: Field Guide for Rural Roads, 2013)



Intersection of Two Gravel Roads

If the intersection is controlled by STOP signs, the primary road should retain the normal crown, and the side roads should have a transition as described above for a paved road approach. When the intersection is uncontrolled, the roads should all have the crown gradually eliminated beginning approximately 100 ft from the intersection. The intersection itself becomes virtually flat, allowing vehicles to pass through without feeling a noticeable bump or dip from any direction. At a T-intersection, maintain the normal crown on the through-road, and transition the side road like an approach to a paved road as shown in Figure 9-6.

Railroad Crossings

At railroad crossings, zero-out the crown on both sides of the crossing for a distance of 20 to 30 ft. Be careful not to blade aggregate onto the crossing and rails. Backdrag any loose material off the crossing and wheel-roll the loose material. Be careful not to get aggregate in the flangeways along the rails, and not to snag a rail. If the crossing is damaged, report it immediately to the railroad by calling the emergency number on the sign at the crossing, and also call your supervisor. Crashes involving trains are severe and often result in fatalities, so extra precautions are necessary. See the safety section of this guide.

Driveways

The public road should retain the normal crown across a driveway. Residents do not appreciate a windrow or cut across a driveway. For those agencies that maintain a windrow it seems like the operator might raise the blade a little at the driveway to minimize the windrow; however, the cumulative effect is the public road still has a hump and the driveway is raised. That is not a good practice. When reshaping the road, the driveway approach will also need to be reshaped, usually cut down to match the normal shoulder.

Bridge Approaches

Bridge approaches are problematic due to poor drainage and settlement near the abutment. Bridge decks usually have less crown than recommended for a gravel road so you should gradually reduce the road crown to match the bridge crown. Potholes often form near the deck; cut them out and fill them. Backdrag any excess material off the bridge deck. Occasionally check to see that surface water can drain under the guardrail and is not blocked by a false shoulder or windrow.

SECTION 10
TIPS & SUGGESTIONS

Proper Crown

An A-shaped crown is important for drainage; an ideal cross section is shown in Figure 6-1. Lack of crown is the primary cause of potholes and is a major factor in rutting. Experts agree that the cross slope should be four to six percent. A four percent cross slope is ½ inch per ft and six percent is ¾ inches per ft. This cross slope means the center needs to be higher than the road edge by between 5–7 inches for a 20 ft wide road and between 6–9 inches for a 24 ft road. The crown can be easily checked by two people using two rulers and a string line. Every motorgrader should be equipped with a slope meter in easy view of the operator. The proper crown is achieved when the bubble is between 4 and 6.

Figure 10-1. Slope meter. Proper cross slope is between 4 and 6. (Source: tigersupplies.com)

Worn Blades

The proper crown and road shape cannot be attained with worn cutting edges. Worn blades are a primary cause of false shoulders and improper crown. The cross section should look much like the pitch of a roof, or a flat A shape. Worn blades will cause a parabolic crown with a flat spot in the center part of the road, which will pothole easily. To avoid a parabolic crown, cutting edges should be rotated when worn about ¾ inch. Rotating cutting edges will save money by wearing the blade evenly so it will last longer. On some motorgraders the moldboard can rotate from under the grader where the cutting edges can be changed easier. There is also a blade-changing tool that will save some time and labor. Carbide-embedded blades last about 10 times longer than regular cutting edges and should be considered for normal dragging.

Figure 10-2 Leachrod blade changing tool. (Source: leachrod.com)

Compaction

Compaction helps the road surface shed water. Don't underestimate the benefit of compaction with the motorgrader tires. Too often operators leave loose material on the road and rely on traffic to pack it down, but by then the material has dried and just blows away or rolls around before traffic compacts it. This results in a layer of dry loose material, excess dust and loss of aggregate until the next rain. Moisture is required for compaction to occur and the moisture content is usually best at the time of blading. After repairing bridge approaches, intersections, potholed areas, washboards, and spreading new material, it is good practice to wheel roll the surface to compact it. If the grader is articulated, a couple of passes should provide good coverage.

Spreading New Surfacing

Properly spreading new surfacing is an art that varies by weather conditions, gradation and moisture content of the surfacing material, and composition of the existing roadbed. Spreading the new surfacing material with a dump truck and just knocking down the high spots ("dump and go"), is rarely proper. The dump and go method leaves loose material on top of the road crust, leading to loss of fine cohesive material and excess dust, and can be a surprise to drivers. When the roadbed is soft, the dump and go method is not as problematic, but still isn't a good practice.

Prior to resurfacing is a good time to check the crown and cut off false shoulders. To get new surfacing material to bind to the existing roadbed the crust needs to be roughed up and the material has to be moist so it will compact. Typically the crust is roughened by tight blading, bullet blades, or by a very light scarifying. During dry weather consider windrowing the new material and wait until a rain has dampened the windrow. If the new material does not have adequate fines, consider incorporating material from the existing roadbed.

Typical Resurfacing Procedure:

- Windrow the new surfacing.
- Rough up the existing roadbed if not roughed up prior to laying down new material.
- Move the windrow to the other side of the road incorporating material in the existing roadbed as needed for proper fines.
- Spread the material across the road, trying to leave the larger material in the center of the road.
- Compact the material by making a few high blade passes with the grader articulated.

When complete, if the remaining windrow is mostly coarse material, you did something wrong.

SECTION 11
APPROACHES TO NARROW BRIDGES AND CULVERTS

Bridges and culverts that are narrower than the approach roadway, and obstacles at the edge or adjacent to the roadway, may be unexpected conditions for a driver. The options available to advise the road user of narrow and one-lane structures as well as roadside obstacles include:

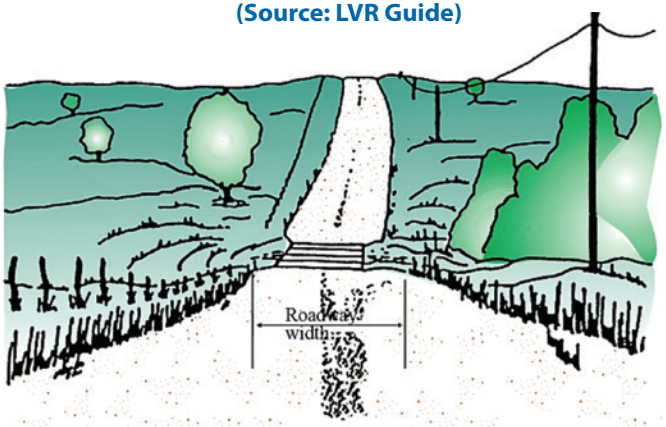
1. Object markers;
2. Advance warning signs;
3. Tapering to provide positive guidance; and
4. Delineators.

Bridges and culverts as wide or wider than the approach travel lanes can be just marked with object markers.

Tapering

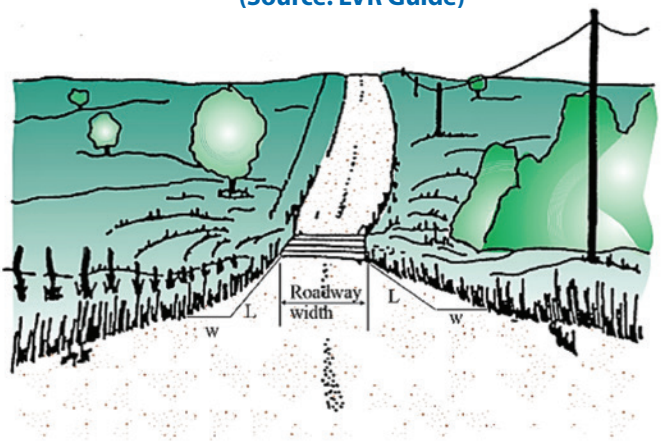
"Positive guidance" is the concept that drivers can be given sufficient information where they need it and in a form they can best use it—to safely avoid an obstacle. Positive guidance can be given to the driver through combinations of signs, object markers, advisory speed signs, and probably most important of all, the view of the road ahead. Studies have shown that the edge of the roadway ahead provides important guidance information for the driver. Tapering the edge of a roadway provides an easy and effective way of providing positive guidance at narrow bridges and culverts. "Tapering" is a simple technique in which the traveled way (the maintained part of the road) is gradually narrowed (tapered) some distance in advance of say, a narrow culvert. If tapering is not used, drivers may miss seeing the end of the short culvert and if they continue to follow the edge of roadway they may drop a wheel off the end of the culvert. This is illustrated in Figure 11-1. If tapering is used, drivers simply follow, as usual, the edge of roadway and thus are guided away from the roadside obstacle the road tapers away from (See Figure 11-2).

Figure 11-1. Narrow bridge approach before tapering road. (Source: LVR Guide)



Notes: Roadway wider than structure (e.g. culvert or bridge) with Edges leading into culvert headwall, bridge railing or ditch.

Figure 11-2. Narrow bridge approach after tapering road. (Source: LVR Guide)



Note: Tapered Section – Roadway width is gradually reduced to width of structure with edges leading away from ditch or culvert ends.

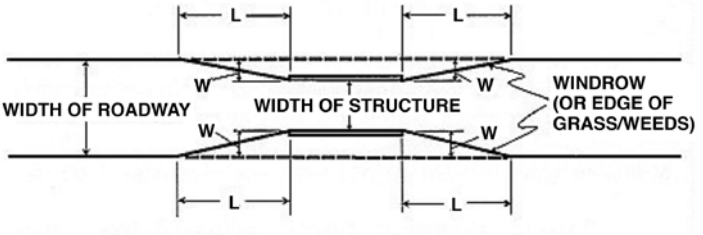
Tapering Technique

A tapered roadway edge may be used to guide the driver away from hazardous obstacles such as bridge abutments, edge drop-offs, culverts or other objects, which narrow the traveled way. The grader operator forms the taper by gradually narrowing the roadway. Minimum recommended taper lengths are shown in Table 11-1, with a graphic depiction of L and W in Figure 11-3.

Table 11-1. Minimum taper length for narrow structures, L(feet). (Source: LVR Guide)

Offset W (feet)	Speed Limit or Prevailing Speed		
	Less than 30 mph	30-40 mph	Over 40 mph
2	30'	50'	100'
3	45'	75'	150'
4	60'	100'	200'
5	75'	125'	250'
6	90'	150'	300'

Figure 11-3. Taper details for narrow structures. (Source: LVR Guide)



Object markers should be used at the narrow structure. If a taper is constructed, an OM-2 can be used instead of an OM-3. This is important where wide farm equipment tends to damage standard object markers.

SECTION 12
PLOWING SNOW

When to Plow
Each agency has a policy or rule of thumb on when to start plowing snow. A common policy is to not plow snow until there is a 4 inch accumulation. Many agencies do not plow late at night or when the snow is drifting. Plowing when the snow is drifting may result in ridges that collect snow on the road. Make sure you understand and follow agency policy on when to plow snow.

Blade Float & Loss of Aggregate
It is not unusual for a new operator to inadvertently blade a windrow of gravel into the ditch—a major concern to road agencies. To avoid this issue many agencies have a policy to eliminate or minimize windrows before snow season. Blade float, if available on the grader, is a good feature to have when the surface is tight and hard or frozen. Consider setting the blade on the center of the road with less than normal crown to minimize throwing gravel that normally accumulates near the shoulder. The operator should be aware of any areas where gravel has been spread but not yet compacted, because much aggregate will be lost in these areas if the blade float is on. Blade float will usually not work if the road surface is soft.

Moldboard Plowing
Most snows are light enough that moldboard plowing is adequate. The moldboard should be tilted forward but not as much as for dragging. Tilting the moldboard forward reduces the tendency to cut the surface, will reduce blade wear, and allows the blade to better skip over high areas. Articulate the grader so the rear wheels will not ride on the snow windrow, for stability. Tilt the top of the front wheels toward the side with the blade heel, similar to any blading.

Speed When Plowing
Most operators try to plow as fast as possible based on the conditions; the usual range is 10 to 20 mph. Higher speeds throw the snow farther, which minimizes accumulating snow next to the road. Speed is limited by visibility, grader stability, amount and type of snow, and road conditions. Fasten your seat belt; you will need it.

"V" Plowing
A V-Plow is used when the snow is too thick for moving with the moldboard or when there is drifting snow. On hard gravel roads, set the shoes so the plow rides about 2 inches above the road surface and set on float. On soft roads, skid shoes will not work, so set the plow and turn off the float. If stopped by a drift, back up and widen out before hitting the drift again. This will allow hitting the drift at a higher speed and avoid being hung up while backing out.

Plow or Let it Melt?

During light snow falls there is always the question of whether to plow or let the snow melt on the road. The effect of the snow on driving conditions is the first concern. The decision to plow should be based on projected weather and what might happen if the snow is not removed. Snow melting on the road makes the road sloppy and can lead to potholes and rutting. It never hurts to plow a light snow off the road as long as gravel is not lost. A long cold spell may result in the snow being packed on the road and becoming slick as shown in Figure 12-1.

Figure 12-1. An icy road could be avoided by carefully blading snow off the road. (Source: Coffey County)

If icy roads are expected, it may be a wise plan to carefully blade the snow off hills, curves and near intersections. Since time is not so much an issue when plowing light snows, slower speeds are appropriate to minimize gravel loss. Figure 12-2 shows a road where a light snow was bladed to the road edge. This results in a road that is less icy, and will not be as sloppy when the snow melts. If more snow and drifting is expected, set the blade a couple of inches above the road surface and wing the windrowed snow into the ditch.

Figure 12-2. Road was carefully bladed after a light snow. (Source: Coffey County)

SECTION 13
BEST PRACTICES FOR UNPAVED ROADS

This section provides suggestions to a road agency for developing best practices for unpaved roads.

1. Define a Good Gravel Road

Agency leadership has to agree on what a well maintained road is, so that information can be communicated to the workers. The characteristics should be listed in priority order. Here is typical listing.

1. Impervious crust.
2. Proper crown (cross slope) ½ to ¾ inches per ft (4 to 6 percent).
3. Minimum amount of loose material & dust.
4. Few potholes, washboards, or ruts.
5. No secondary ditches (high shoulders).
6. Reasonable size windrow (6 inches in winter, 12 inches in summer).
7. Roadside ditch sized to carry most rains.

Note that in this list there is more concern about loose material and dust than a few potholes.

2. Have Adequate Supervision

Grader operators typically work alone, and it can be easy for a grader operator to develop a routine that may be contrary to good practice and agency policy. A supervisor has a broader perspective and can see what is working well in different areas and can provide guidance to the grader operator. The supervisor also provides needed coordination related to culvert replacements, gravel surfacing priorities, drainage work, complaints, etc.

3. Provide Written Grader Instructions

All grader operators should have written instructions on standard procedures. The instructions should include such things as crown, windrows, how to blade, when to blade, when not to blade, high shoulder repair, how to handle complaints, etc. Without written instructions you will often hear: "Nobody told me." Sample instructions are available on the Kansas County Highway Association (KCHA) website. These instructions should be modified for the situations in a particular agency.

4. Check the Crown Regularly

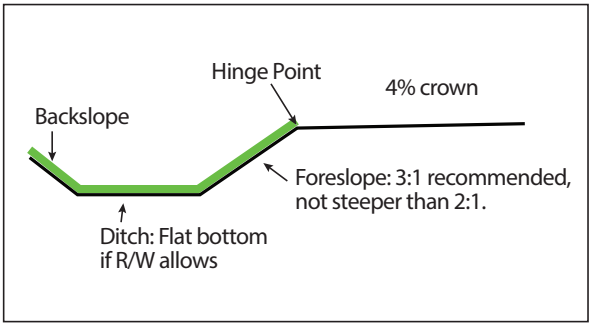
In the two-pass grading method that most agencies use, too little crown is much more predominant than too much crown. Too little crown results in potholes

and mudholes. Probably over half the surface defects on unpaved roads are due to lack of crown. Every grader should have a slope meter in it, with the 4 percent and 6 percent marked in red. The operator's supervisor should get with the grader operator annually to spot check crown; it is an eye opener for the grader operator. Also check crown in potholed areas; potholed areas almost always have too little crown.

5. Blade to the Hinge Point

The entire road surface should be bladed from hinge point to hinge point. The hinge point is the edge of the road, which is where the normal road slope meets the foreslope. If the entire road surface is not bladed, high shoulders develop and drainage suffers.

Figure 13-1. Typical section of a road showing the hinge point. (Source: Norm Bowers)



6. Control Grass Inside the Hinge Point

Grass tends to grow on the road surface next to the foreslope. The grader operator may start avoiding the grass and the result is high shoulders. Blading to the hinge point helps some, but the agency usually needs to mow or spray so there is not too much grass bladed into the windrow. Blading to the hinge point with the tandems riding the shoulder will keep the shoulder compacted, which retards grass and weeds.

7. Mow the Shoulders Occasionally

It is difficult to have a good gravel roads unless the shoulder is mowed occasionally. There are so many benefits to mowing the shoulder, that it has to be worth the cost. The benefits include:

- Stunts grass inside hinge point
- Allows grader operator to:
    - Cut off high shoulders
    - Correct crown on dirt roads
    - Pull shoulders
- Provides better drainage
    - Increases capacity of ditch
    - Creates less silting in shorter grass
- Controls brush and trees
- Provides better sight distance to improves safety
- Discourages farmers from farming right-of-way
- Creates good public relations

The shoulder of the road needs to be mowed at least once a year and preferably twice so the operator can cut off any developing high shoulder and perhaps recover gravel at the shoulder line. Just a 4 ft swath is wide enough. The cost of mowing is offset by improved maintenance. Consider having the grader operator mow his zone during dry weather when blading does little good. To control brush and trees it is helpful to mow the entire right-of-way annually, but at least every other year.

8. Occasionally Shape the Road

Many agencies use a two-pass maintenance system that moves the windrow or loose material from one side of the road to the other. The two-pass system covers the most miles in the shortest amount of time: however, it is important to understand that limitations of the two-pass system. The two-pass system just smooths the road and does not correct crown. Potholes and washboards are just filled in and not cut out. Also, there is a tendency to not blade all the way to the shoulder, so false shoulders develop. Agencies that use the two-pass method should consider light-shaping a couple of miles per blading round to offset issues that develop from the two-pass method.

9. Test the Aggregate

Some agencies spend hundreds of thousands of dollars on aggregate and don't know what they are buying. They say: "We just buy what the quarry makes." Whether you purchase the gravel or rock or you produce it from your own pit or quarry it is important to know the top size, amount of clay, and the amount of fines. Poor material always results in poor roads. If you don't know the composition of your gravel and rock, you can make some poor decisions. Quarries usually run tests on their material. Ask for a test to see what kind of material you are buying. If your agency is producing your own material it should

still be tested on occasion. Each agency should develop a specification on the type of material that works best for them. By the way, you won't get the type of rock or gravel you need from a commercial quarry or pit unless you ask for it.

10. Equipment: It Takes More Than Just the Motorgrader

It takes more than a motorgrader to take care of gravel roads. An agency will spend $350,000 for a motorgrader and then not provide the other less expensive equipment needed to properly maintain an unpaved road. Having the proper equipment saves money in time and material; it doesn't cost—it pays. The most important secondary piece of equipment is a mower. Another essential piece of equipment is a shouldering disc, which is just a one-way disc to retrieve material from the shoulder and break up sod in the windrow. A grader-mounted roller can help with compaction. Too often an operator will leave loose material on the road and rely on traffic to pack it down, but by then the material has dried and just blows away or rolls around. A pull-behind roller can pack the loose material before it dries. A scarifier with bullet teeth is helpful to rough-up an area with washboards. A towed blading device like a Road Groom can cover a lot of miles in a short period. The Road Groom might be an alternative to dragging to fill in potholes and distribute material just before or after a rain.

USEFUL REFERENCE MATERIAL

Conversion factors

Length 1 sta. = 100 ft. 1 mile = 5280 ft. 1 ft. = 12 inches	Area 1 s.y. = 9 s.f. 1 acre = 43,560 s.f.
Volume 1 c.y. = 27 c.f. 1.c.f. = 7.485 gallons	Weight 1 lb. = 16 oz. 1 ton = 2000 lbs.

Waterway openings for culvert pipe

Round Pipe

Pipe Diameter In.	Nominal W.W. Area Sq. Ft.
12	0.8
15	1.2
18	1.8
24	3.1
30	4.9
36	7.1
42	9.6
48	12.5
54	15.9
60	19.6
66	23.7
72	28.3
78	33.2

Arched Pipe

KDOT Bid Designation Sq. Ft.	Nominal W.W. Area Sq. Ft.	Pipe Arch Span & Rise
1.0	1.1	17" x 13"
1.5	1.6	21" x 15"
2.0	2.2	24" x 18"
2.5	2.9	28" x 20"
3.0 or 4.0	4.5	35" x 24"
5.0 or 6.0	6.5	42" x 29"
7.0 or 8.5	8.9	49" x 33"
10.0 or 11.0	11.7	53" x 41"
10.0 or 11.0	11.6	57" x 38"
12.5 or 14.0	15.6	60" x 46"
12.5 or 14.0	14.7	64" x 43"
16.5	19.3	66" x 51"
16.5	18.1	71" x 47"
21.0	23.2	73" x 55"
21.0	21.9	77" x 52"
25.0	27.4	81" x 59"
25.0	26.0	83" x 57"
32.0	32.1	87" x 63"
36.0	37.0	95" x 67"
42.0	42.4	103" x 71"
47.0	48.0	112" x 75"

Typical Material Weights

Material	Statewide Average	Comments
Concrete	150 lbs per c.f.	In place
Hotmix	145 lbs per c.f.	Compacted
Coldmix	140 lbs per c.f.	Compacted
Aggregates		
AB-3(dry wt.)(KDOT)	140 lbs per c.f.	Compacted
AB-3(wet wt)(KDOT)	156 lbs per c.f.	Compacted
AS-1(dry wt.)(KDOT)	135 lbs per c.f.	Compacted
AS-1(wet wt.)(KDOT)	150 lbs per c.f.	Compacted
Road Rock(dry wt.)*	125 lbs per c.f.	Compacted
Road Rock(wet wt.)*	135 lbs per c.f.	Compacted
Screened rock 3/8"	96 lbs per c.f.	In stockpile
Screened rock 3/4"	100 lbs per c.f.	In stockpile
AB-3(pile-wet)	105 lbs per c.f.	In stockpile
Sand(dry)	95 lbs per c.f.	In stockpile
Sand(damp)	101 lbs per c.f.	In stockpile
Soil	110 lbs per c.f.	Compacted
Road Salt	80 lbs per c.f.	In stockpile
Liquids		
Asphalt (AC)	8.33 lbs per gal	
Asphalt cutback	7.81 lbs per gal	
Asphalt-emulsion	8.24 lbs per gal	
Water	8.435 lbs per gal	
Water	62.43 lbs per c.f.	
MGCL(summer)(30%)	10.8 lbs per gal.	
CACL (winter)(32%)	11.0 lbs per gal.	
CACL(summer)(38%)	11.5 lbs per gal.	

**Road Rock is good crusher run or screened limestone with no more than 12% passing the 200 sieve.*

SUGGESTED RESOURCES AND REFERENCES

1. National Center for Rural Road Safety. https://ruralsafetycenter.org/

2. Federal Highway Administration, Office of Safety. http://safety.fhwa.dot.gov/

3. FHWA: Training, Tools, Guidance and Countermeasures for Locals. http://safety.fhwa.dot.gov/local_rural/training/

4. Gravel Roads Construction & Maintenance Guide, FHWA, August 2015. https://www.fhwa.dot.gov/construction/pubs/ots15002.pdf

5. Kansas Handbook of Traffic Control Guidance for Low Volume Rural Roads, Kansas LTAP, 2017. https://kutc.ku.edu/sites/kutc.ku.edu/files/docs/ltap-news/LVR%20guide%202017_interactive.pdf

6. Manual on Uniform Traffic Control Devices for Streets and Highways, FHWA, 2009 Edition with Revisions 1 and 2. http://mutcd.fhwa.dot.gov/index.htm.

7. Kansas Local Road Management Handbook, Kansas LTAP, 2015. https://kutc.ku.edu/sites/kutc.ku.edu/files/docs/ltap-news/LRMH-2015.pdf

8. Maintenance of Drainage Features for Safety—A Guide for Local Highway and Street Maintenance Personnel, FHWA, July 2009. https://safety.fhwa.dot.gov/local_rural/training/fhwasa09024/

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LTAP
KANSAS LOCAL TECHNICAL ASSISTANCE PROGRAM

Kansas Local Technical Assistance Program

Kansas LTAP serves road and bridge and public works officials through training, information-sharing, and technology transfer activities. Kansas LTAP also provides both one-on-one problem solving and wider outreach at state, regional and national professional meetings. Services include:

Newsletters. Each year four issues of the KS LTAP e-newsletter are provided without charge to city, county, state, and township highway agencies across Kansas. The newsletter covers a broad range of technical topics and policy news of interest to road and bridge officials. Updates on training and resources available to local agencies in Kansas are available by email every other week.

Training. Each year Kansas LTAP holds dozens of workshops across the state. Common topics include road maintenance (asphalt, concrete, gravel), culverts and drainage, snow and ice control, work zone signing, workplace safety, roadway safety, and leadership topics. Visit our website at www.ksltap.org and click on "Training Calendar" to view a list of upcoming training opportunities.

Kansas Roads Scholar Program. This program provides a curriculum of training to increase knowledge of road maintenance operations and improve technical, supervisory, and managerial/administrative skills. Kansas LTAP administers this program for the Kansas County Highway Association and the American Public Works Association's Kansas Chapter. Other partners are the Kansas Association of Counties and the Kansas DOT. All Kansas public works and road and bridge employees are welcome to participate in the program. More information is available through KS LTAP at (785) 864-2594 and at ksroadsscholar.org

Technical Resources. Online and print resource offerings are available in a searchable format on the Kansas LTAP website.

On-Site Assistance. LTAP's Local Field Liaisons visit agencies on-site with technical assistance related to roadway safety and operations.

Equipment for Loan. LTAP loans equipment for no charge for traffic studies and will analyze the data if needed. Other equipment is also for loan. Visit the KS LTAP website to learn more.

Website. Visit ksltap.org to learn more about LTAP and to access our services.