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HAUL ROAD INSPECTION HANDBOOK

PREFACE

This handbook provides guidance for conducting a safety inspection of a mine's haulage roads. It is intended to serve as an aid to personnel in both Metal and Nonmetal Mine Safety and Health, and Coal Mine Safety and Health.

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Table of Contents

CHAPTER 1 - INTRODUCTION

Authority

The Federal Mine Safety and Health Act of 1977 requires that authorized representatives of the Secretary of Labor make mine inspections and investigations for the purpose of determining whether there is compliance with the mandatory safety and health standards and for disseminating information related to safety and health conditions.

Purpose

The design and maintenance of haul roads plays an important part in surface haulage safety. This handbook is intended to provide mine inspectors with information to assist them in evaluating the safety of a mine's haul roads. Inspectors can use the information in this handbook to help identify potentially hazardous haul road conditions or conditions that warrant a more in-depth evaluation.

A critical concern is that design features such as the width, steepness, and layout of the roads be compatible with the driving characteristics and performance capabilities of the equipment that will use the roads, as well as provide for some reasonable variability in the level of skill and experience of the equipment operators. If equipment characteristics and limitations are not adequately taken into account, either little margin for error will be provided for the equipment operators or, in the worst case, the equipment will simply not be capable of being safely operated. In either case the likelihood of accidents increases.

Standards:

The standards related to haul roads, in both Coal and Metal/Nonmetal, are summarized in each chapter. For easier reference, this information is always placed in a box like this one.

Responsibility

The Administrators for Coal Mine Safety and Health (CMS&H) and Metal and Nonmetal Mine Safety and Health (MNMMS&H) have primary responsibility for enforcing the Mine Act and Title 30 of the Code of Federal Regulations (30CFR). This responsibility ultimately rests with the authorized representatives (ARs) - mine inspectors, specialists, and their supervisors. The ARs are responsible for conducting thorough inspections which include evaluating safety issues related to the haul roads at a mine.

Inspection Procedure Considerations

As you travel the mine property in the course of your overall inspection, you can get an idea of potential problem areas on the haul roads. Pay special attention to areas where the grades are steep, the curves sharp, the sight distance limited, the road narrow, or the road surface slippery. And note conditions at intersections, in congested areas, and any place where it may not be clear who has the right-of-way. Spend some time observing the traffic in all of these areas. Look for any indications such as skidding, "close calls," or over-reliance on service brakes on downgrades, where it appears that operations are at, or near, the performance limits of either the vehicles or the drivers.

Where problems may be indicated, refer to the information in this handbook to help decide how serious the problem may be. Consider that the best perspective on the roads would be obtained by accompanying a driver in the truck cab on a haulage cycle. This way you can get a driver's-eye perspective of the roads and discuss any potential problem areas with the driver.

To investigate a situation further you may need a measuring tape, a stopwatch, and a device for measuring grade steepness, such as an Abney level. An Abney level is a hand-held device which allows you to measure the steepness of a grade by sighting the instrument down the grade, parallel to the surface of the road, and aligning a leveling bubble.

If you think a more detailed analysis of the haul road situation is called for, discuss the situation with your supervisor. Additional technical assistance can be obtained from the District Office or through Technical Support. In Technical Support, requests for technical assistance concerning haul roads are handled by the Mine Waste and Geotechnical Engineering Division, Pittsburgh Safety and Health Technology Center. Requests for assistance concerning haulage equipment and braking systems are handled by the Mechanical Safety Division, Approval and Certification Center.

CHAPTER 2 - SIGHT DISTANCE

Sight Distance for Stopping

"Sight distance" is simply how far down the road a driver can see ahead of his or her vehicle. Roads must be designed to give drivers a sufficient distance of clear vision ahead so they can avoid unexpected obstacles. **A basic rule of safe driving is that, at all times, a vehicle operator must be able to stop the vehicle within the available sight distance.** If a driver sees a problem, such as a boulder on the road or a stalled vehicle, he or she must be able to stop in time to avoid it.

The layout of the haul road affects the available sight distance. The sight distance decreases, for example, when a vehicle approaches a curve or the crest of a hill. The available sight distance should be considered anytime there is a significant change in the horizontal or vertical alignment of the road.

Sight distance can vary for different vehicles based on the height of the driver's eyes. The sight distance from a large haul truck may be much better than the sight distance from a pickup truck. The higher vantage point in the larger truck may allow the driver to see over some objects. The sight distance needs to be adequate for all types of equipment that use the roadway. But keep in mind that a pickup truck would require a shorter sight distance than a large haul truck, because normally the pickup truck can stop in a shorter distance.

At any particular point along the haul road, you are concerned with the minimum sight distance, since this is the most critical condition. The sight distance for a particular vehicle can best be determined by viewing the road from the driver's position in the vehicle. Where sight distance is a concern, measure the distance along the road from the front of the vehicle to the farthest point that you can see ahead in the vehicle's lane (See Figure 1). This distance can be measured with a tape, or it can be estimated by pacing it off. Compare this distance to the distance it would take to stop the vehicle. If the stopping distance is greater than the sight distance, there is a potential hazard. Methods of estimating the stopping distance are explained in the next chapter of this handbook.

If the sight distance is inadequate, the preferred method to remedy the situation is to increase the sight distance. Around curves, this may involve removing obstacles that are limiting the sight distance, such as vegetation or piles of material, or making the curve more gradual. At the crest of a hill, the sight distance can be increased by cutting down the crest and making it more rounded. If measures to increase the sight distance are not practical, the situation must be handled by reducing the stopping distance. This would require driving at a lower speed through the area of concern. This remedy is less desirable, however, because of the possibility that a driver, perhaps in a moment of inattention, will not make the necessary adjustment in speed. The safest haul roads reduce the opportunity for human error to cause an accident by allowing for safe vehicle operation at normal operating speeds, without requiring special driving measures.

If pull-off areas are required to allow vehicles to pass one another, the location of the pull-offs must be carefully determined with respect to sight distances. In these cases, two-way radio communication between the drivers is important to avoid hazardous situations. Under these conditions, equipment drivers need to be especially alert for visitors driving on the property.

Coal: Section 77.1607(c) requires that equipment operating speeds be prudent and consistent with conditions of roadway, grades, clearance, visibility, traffic, and the type of equipment used.

Metal/Nonmetal:
Section 56/57.9101 requires, in part, that equipment operating speeds be consistent with conditions of roadways, grades, clearance, visibility, traffic, and the type of equipment used.

Sight Distance in Bad Weather or After Dark

The sight distance can be reduced during inclement weather, such as rain, snow, or fog. Under these conditions, drivers must slow down to the point where they can stop within the available sight distance. Effective headlights and taillights improve the ability to see and be seen.

When driving after dark, sight distance may be defined by the distance illuminated by the vehicle's headlights. Drivers must reduce their speed so that they can bring the vehicle to a stop within the illuminated distance. This distance will vary with the type of headlight. Headlights now available can provide illumination of 250 feet or more with low beams and over 350 feet with high beams. To be most effective, mine operators need to ensure that headlights are aimed properly. Speeds should also be reduced at night because drivers typically have reduced depth perception and peripheral vision and don't react to an emergency situation as quick as during daylight.

It should be noted that the ability to see at night tends to decrease with age. Studies have shown, for example, that to see at night with the same visual acuity, a 50 year-old typically needs at least twice as much light as a 35-year old. Furthermore, on mine property there is often little contrast in brightness between the background and other objects. In this regard, a good practice is for mine operators to install roadside reflectors to help define the roadway and intersections during nighttime operations. Another good practice is to make sure that vehicles used at night have lights that can be seen from the side of the vehicle, as well as the front and rear.

Coal: Section 77.1605 (d) requires, in part, that lights be provided on both ends of mobile equipment when required.

Coal: Section 77.404 requires, in part, that mobile equipment be maintained in safe operating condition and that equipment in unsafe condition be removed from service immediately.

Coal: The Program Policy Manual indicates, under Section 77.404, that the failure of headlights, taillights and brake lights can contribute to serious accidents, and that mine operators should be aware that lighting systems and other safety features can be rendered inoperable by accumulations of dust, mud, or grease, as well as defective parts.

Metal and Nonmetal:
Section 56/57.9100(a) requires, in part, that rules governing the use of headlights to assure appropriate visibility, be established and followed at each mine.

Sight Distance at Intersections

Sight distance is important at intersections, where a driver must be able to see on coming traffic far enough away to be able to judge when it is safe to turn onto, or cross, the road. Ideally, drivers should be able to pull onto the road, or cross the road, without requiring approaching traffic to slow down. So the main factors in the safe sight distance at intersections are the acceleration ability of the vehicles pulling onto the road and the speed of the on coming traffic. Because of the limited acceleration ability of large haulage trucks, ample sight distance should be provided. The higher the speed on the road, the longer the sight distance must be. On level roads, intersection sight distances of at least 225, 300, and 375 feet are recommended for speed limits of 15, 20 and 25 miles per hour, respectively, to allow ample time for vehicles on the main road to see and adjust to intersection traffic.

Mine operators should avoid locating intersections near hill crests or sharp curves. In these situations the sight distance will be limited. Intersections should be kept as flat as possible and sight distance should be considered in all directions.

In laying out intersections, the effect of the large blind spot to the right side of haulage trucks, in limiting the driver’s right-side sight distance, should be taken into consideration. Intersections where trucks will need to stop, or yield to other traffic, should be angled to optimize the driver’s ability to see traffic coming from both the right and left sides. Roads intersecting at an angle of less than 90 degrees to the right side of the truck, where the stopping or yielding driver would have difficulty seeing traffic approaching from the right side, should be strictly avoided, or compensating safety measures should be taken.

You should pay special attention to areas where public or private roads intersect mine roads. The concern is that in such areas other drivers may not be familiar with the operation of mining equipment or the mine’s traffic pattern. Drivers on public roads may underestimate the speed of mining equipment or may not be aware of the problems with equipment blind spots. In any area where a public road intersects a mine road, there should be plenty of sight distance and appropriate warning signs.

Sight Distance for Passing

Sight distance is important when one vehicle is going to pass another, if the passing vehicle is required to enter the lane of oncoming traffic. In these instances, the driver of the passing vehicle must be able to see enough of the road ahead to have sufficient time to pass and then return to the lane without cutting off the passed vehicle and before meeting on-coming traffic.

Coal: Section 77.1607(a) requires that passing be limited to areas of adequate clearance and visibility, and that vehicles follow at a safe distance.

Because of the limited acceleration ability of large haulage equipment, a long sight distance is generally required to safely complete a passing maneuver. A big factor in this distance is the relative speeds of the two vehicles. As a point of reference, consider that on a public highway, if the vehicle to be passed is traveling at a speed of 20 or 30 mph, the minimum recommended passing-sight-distance for the passing vehicle is 800 or 1100 feet, respectively.

Sight Distance - Summary of What You Can Do

Where there is concern that a vehicle rounding a curve, cresting a hill, descending a grade, or approaching an intersection would not be able to stop in time to avoid an object in the road or a vehicle pulling onto the road:

- Determine by measurement, or estimate by pacing, the available sight distance.
- Compare this distance with the distance needed to stop a vehicle under likely operating conditions. Information to help estimate the stopping distance is provided in the following chapter of this handbook.
- If the sight distance is less than the estimated stopping distance, a potentially hazardous condition may exist.

Use this information to help identify potentially hazardous conditions that need to be corrected or further investigated. Note whether sight distance could be improved by measures such as cutting back trees or brush, relocating a stockpile, or realigning the road or intersection.

In considering the sight distance at intersections, keep in mind the blind-spot to the driver’s right side in haulage trucks. Where necessary, point out to mine operators that they should align intersections, or take other compensating safety measures, to minimize the problems that haul truck drivers have in seeing traffic approaching from their right side.

CHAPTER 3 - STOPPING DISTANCE

Since the distance that it takes to stop a piece of haulage equipment is obviously a critical element of haulage safety, this section will provide information for estimating the stopping distance under various driving conditions. Actual stopping distances will depend on several factors, so use these estimates only to help identify potentially hazardous conditions.

The distance that it takes to bring a vehicle to a stop is made up of three components:

1. the distance the vehicle travels during the time it takes for the driver to recognize a need to stop and push on the brake pedal (i.e., the operator response time factor); plus
2. the distance the vehicle travels during the time it takes the brakes to actually be applied, once the brake pedal is pushed (i.e., the vehicle's brake-system-response-time factor); plus
3. the distance the vehicle travels while coming to a stop under the braking effort.

The sum of the three distances is the total stopping distance. The calculations involved in determining these three components are explained in Part D of the Appendix.

Factors Affecting Stopping Distance

Some judgment is involved in arriving at an estimate of stopping distance. Obviously the speed of the vehicle is a big factor. Under normal driving conditions, from a safety standpoint, a vehicle should be able to stop within the available sight distance while traveling at the posted speed limit. Another major factor is driver perception and reaction time. This will vary by individual and circumstance. In this handbook, a perception and reaction time of 2.5 seconds, as recommended by the American Association of State Highway and Transportation Officials (AASHTO), is used.

The stopping distance also depends on the vehicle's brake-system-response time. In the stopping distance estimates given in this handbook, this response time is considered to vary with a truck's gross vehicle weight (GVW), as indicated in Table 1. Brake-system-response times ranging from 0.5 to 2.5 seconds are used. These values are derived from the Society of Automotive Engineers (SAE) standard J1152 and are the same values used in Table M-1 of sections 56/57.14101 of the Metal/Nonmetal regulations. The brake-system-response time can have a significant effect on the stopping distance. The change in velocity of the vehicle and the distance that the vehicle travels during the lag created by brake-system-response time, are taken into account in the stopping distance estimates provided in this handbook.

Stopping distances depend on the rate of deceleration that can be attained. When the brakes are applied, friction is developed between the brake components and subsequently between the tires and the road surface. The stopping distance may be governed by the friction achievable by the brakes, or the friction available between the tire and the road, whichever is less. The amount of friction available is represented by a “friction coefficient.” The vehicle’s deceleration rate is equal to the friction coefficient times the acceleration due to gravity (32.2 feet per second per second).

So, the higher the friction coefficient, the larger the deceleration rate and the shorter the stopping distance. For loaded trucks, a coefficient of 0.30 is generally considered to be a reasonable, average value for the friction that the brakes can provide. Higher values of braking friction may be available, especially for empty trucks. For the friction between the tires and road surface, the coefficient can vary from up to 0.9 for dry concrete to less than 0.10 for ice (see Table 2). If the brakes are capable of exceeding the friction between the road surface and the tires, then the friction coefficient between the road surface and the tires would be used in estimating the stopping distance. Otherwise, the friction coefficient (and deceleration rate) corresponding to what the brakes can provide would be used.

Remember that operation during rainy or watered-road conditions should be considered and that the road surface friction value will be less under wet conditions. The road surface friction value will be lower in snow or icy conditions, but it is reasonable to consider that equipment operators will further reduce their speed, and required braking force, to compensate under those conditions.

A final factor that has an effect on the stopping distance is the “rolling resistance.” The “rolling resistance” represents all physical resistance impeding the free rolling of the vehicle, including irregularities in the road, deformation of the road surface, and flexing of the tires. A typical value for a firm, smooth road is equivalent to the resistance encountered in going up a 2% grade. Rolling resistance values for other road surface conditions can be found in Table 3.

Stopping Distance Estimates

Considering all of the factors indicated above, stopping distance estimates are given in **Tables 4 through Table 11** at the back of this handbook**.** Stopping distances are given for grades varying from zero to 14%, speeds varying from 10 to 30 mph, and friction factors varying from 0.15 to 0.6. (Remember to use the lower friction factor that applies, depending on whether the friction between the brake components or between the tires and the road surface governs.) If stopping distances for other values of perception and reaction time, brake system response time, friction, speed, grade, or rolling resistance are needed, they can be estimated using the equations in Part D of the Appendix.

You should note that there is a difference between the stopping distances given in the Tables in this handbook and those given in Table M-1 of sections 56 and 57.14101 of the Metal and Nonmetal regulations. The values in Table M-1 are used in evaluating service brake performance. Table M-1 uses a one-second driver response time, versus the 2.5 second perception and reaction time used in Table 4, because in conducting the braking test the driver would be anticipating making a stop. The values given in Table M-1 are based on a deceleration rate of 9.66 feet per second per second, which is equivalent to having an available coefficient of friction of 0.3.

EXAMPLE: On a 4 percent grade where the speed limit is posted as 25 mph, you estimate the available sight distance as 180 feet. Will a loaded truck with a gross vehicle weight (GVW) of 120,000 pounds (60 ton) have adequate sight distance when traveling this road at the posted speed limit? For the conditions, you estimate that a friction coefficient of 0.3 would apply.

Since the grade is 4%, Table 6 can be used to get an estimate of the stopping distance. To use Table 6, find the section for a friction coefficient of 0.3. Then find the line for the appropriate gross vehicle weight for the truck. In this case the GVW of the truck is 60 tons, so the 35 to 70 range applies. On that line, go across to the column corresponding to the speed of interest, which is 25 mph. Read the estimated stopping distance as 226 feet.

Since in this example the available sight distance of 180 feet is clearly less than the stopping distance, there may be a potential hazard at the posted speed for the condition when a coefficient of friction of 0.3 applies. Use this type of analysis to help identify situations where a potentially hazardous condition may exist. Note that in estimating the stopping distance as indicated above, it is assumed that the brakes are maintained and used as intended by the manufacturer and the effect of brake fade, or the loss of brake effectiveness due to heat buildup, is <u>not</u> taken into account.

Following Distance

Stopping distance is related to safe following distance. If a vehicle follows another vehicle too closely, an accident can occur if the driver in the trailing vehicle doesn't react as fast as the lead driver to an emergency-stop situation, or if the trailing vehicle cannot stop as effectively as the lead vehicle. For these reasons, vehicles should follow one another at a distance that provides a cushion or margin for error.

Coal: Section 77.1607 requires, in part, that (a) vehicles follow at a safe distance, and (c) operating speeds be consistent with conditions of traffic and the type of equipment used.

Metal/Nonmetal:
Section 56/57.9101 requires, in part, that operating speeds be consistent with traffic and the type of equipment used.

As vehicle speeds increases, the following distance must be lengthened to provide the necessary level of safety. Drivers should increase their following distance in any conditions where the sight distance is reduced (e.g., foggy conditions) or when road conditions may result in a longer stopping distance (e.g., wet weather). Various following-distance rules are used on mine properties:

< Some mines instruct their drivers to use a minimum following distance, such as 200 feet on level roads and 400 feet on grades. Whether these following distances are safe at a particular operation depends on the vehicle operating speeds, payloads, and the road conditions.

< Another approach is to instruct drivers to follow the vehicle in front by at least a set time, such as 4 seconds. For speeds of 10, 20, and 30 mph, the 4-second rule results in following distances of only 59, 117, and 176 feet, respectively. These values leave little cushion or margin for error in some situations.

< Even at speeds of less than 10 mph, a common recommendation is that a distance of at least two vehicle lengths be maintained between vehicles.

Since the driver in the trailing vehicle may not realize that a lead vehicle is coming to an emergency stop, one approach is to set the minimum safe following distance based on the trailing vehicle's stopping distance. With this approach, the stopping distance values given in Tables 4 through 11 can be used as a basis for establishing safe following distances. A mine operator should consider the speeds on both level roads and grades, and establish following distance rules that will provide for safe distances in all situations.

Brakes and Stopping Distance

The information on stopping distance contained in this handbook assumes that the vehicle's brakes are maintained, adjusted, and operated as intended by the manufacturer. And the effect on stopping distance of brake "fade," where the effectiveness of the brakes is diminished due to heat buildup, is <u>not</u> taken into account. Regulations dealing with brakes are indicated below.

Coal: Section 77.404 requires, in part, that any type of mobile equipment be maintained in safe operating condition and that equipment in unsafe condition be removed from service immediately.

Section 77.1605(b) requires, in part, that mobile equipment be equipped with adequate brakes.

Section 77.1606 requires, in part, that: (a) mobile haulage equipment be inspected by a competent person before such equipment is placed in operation; and (c) equipment defects affecting safety be corrected before the equipment is used.

Metal/Nonmetal:

Section 56/57.14100 requires, in part, that: (a) self-propelled mobile equipment to be used during a shift be inspected by the equipment operator before being placed in operation on that shift; (b) defects on any equipment that affect safety be corrected in a timely manner to prevent the creation of a hazard to persons; and (c) when defects make continued operation hazardous to persons, the defective items including self-propelled mobile equipment be taken out of service until the defects are corrected.

Section 56/57.14101 requires, in part, that: (a)(1) self-propelled equipment be equipped with a service brake system capable of stopping and holding the equipment with its typical load on the maximum grade it travels; (a)(3) all braking systems installed on the equipment be maintained in functional condition; and (b) service brake tests be conducted on surface-operated equipment when the inspector has reason to believe that the service brakes do not function as required.

<u>Stopping Distance - Summary of What You Can Do</u>

< Where there is concern for whether a vehicle would be able to stop in time to avoid an accident, determine the available sight distance and compare it to the estimated stopping distance.

< To estimate the stopping distance, estimate the available friction coefficient (or deceleration rate) for the conditions. A coefficient of 0.30 is generally a reasonable average value for the friction achievable by the brakes of loaded trucks. Use this value unless a lower value would apply because of the road conditions, or more specific information is available. See Table 2 for friction coefficients applicable to various road conditions.

< For a range of values of grade, friction, and speed, Tables 4 through 11 can be used to estimate the stopping distance. Be sure to note the conditions that apply in the use of these tables. To estimate the stopping distance for other conditions, see Part D of the Appendix.

< Where vehicles appear to be following one another too closely, you can use the stopping distance estimates for guidance on the distance that should be maintained between vehicles.

CHAPTER 4 - GRADES

The steepness or grade of a roadway can have a significant effect on the driver's ability to control a vehicle. Two important aspects are:

1. the grade needs to be compatible with the braking capabilities of the equipment; and
2. the grade will affect a vehicle's stopping distance.

Determining the Grade of a Road

The steepness of a roadway is normally expressed as **"percent grade."** Information in equipment operator manuals about braking capabilities, for example, is normally given in terms of the grade in percent. The grade in percent is determined by dividing the road's vertical rise by its horizontal run and multiplying this value by 100. An easier way to remember this is that **the grade, in percent, is equal to the number of feet that the road rises (vertically) over a horizontal distance of 100 feet.** For example, a road that rises 9 feet over a horizontal distance of 100 feet is a 9 percent grade. Percent grade is illustrated in Figure 2.

The steepness or grade of a road can be measured using an Abney level. The simplest way to measure the grade with an Abney level is to go to the top of the hill, to a point where you can look down the grade directly along the surface of the road. From this point, site through the Abney level along the surface of the road while adjusting the leveling bubble. When the bubble is level, the scale on the instrument will indicate the steepness of the grade.

Abney levels are available with a scale that reads the grade directly in percent. Other Abney levels may have a scale that gives the angle of the grade in degrees. If the steepness of a grade is measured in degrees, see Appendix B for a table that converts degrees to percent.

The grade of a roadway can be determined if the road is shown on an accurate topographic map. In this case the change in elevation along the road (rise) can be determined from the change in contours, and the corresponding horizontal distance (run) can be scaled off the map. The grade in percent is then the indicated rise divided by the measured run, multiplied by 100.

The grade should be determined over a portion of the road where the grade is constant. Where the steepness of the road varies, the grades should be determined for different segments.

Grade and Equipment Compatibility

The grade or steepness of a road is an area where you must have **compatibility between road conditions and equipment capability.** A critical safety concern is that the brakes can handle the downgrades without leading to loss of control of the vehicle. Different equipment, having different performance characteristics, will use the haul roads. The roads must be designed to accommodate the equipment with the least, or the most critical, braking capability, which is usually the large haul trucks.

Brakes slow a vehicle by converting the kinetic energy of the moving vehicle into heat energy. Under normal conditions this heat is dissipated into the air. The concern on steeper grades is whether the equipment can be controlled without causing more heat than the system can dissipate and a loss of the effectiveness of the braking system. Figure 3, for example, shows how the retarder performance information for a truck might typically be presented. This type of chart shows, for a given truck weight and percent grade, what gear the vehicle should be in and what speed the retarder can safely handle without exceeding its designed capacity. The values will vary model to model. This information is provided by the truck manufacturer and is usually found in the operator's manual. Retarder performance charts such as the one shown in Figure 3 can be confusing, and the information can be shown in different ways by different manufacturers. It is best to check with the manufacturer if you have any uncertainty about how to interpret a retarder chart.

In using a chart such as shown in Figure 3, the effective grade going downhill is the actual grade minus the rolling resistance of the road surface itself. This rolling resistance will vary with road conditions. Typical values of rolling resistance are given in Table 3. However, since the rolling resistance of a road will tend to vary, and in order to provide a margin of safety, it is prudent to consider a minimum rolling resistance, or no rolling resistance, in determining what grade a particular truck can handle.

For the truck whose retarder performance is indicated in Figure 3, following the directions shown on the figure, you can find that, when loaded at its gross vehicle weight (GVW), the truck's speed while descending a 10 percent (effective) grade should not exceed about 8 mph.

Trucks are equipped with retarders to provide a way to control the speed of the truck on downgrades without having to use the service brakes. In situations where the capacity of the retarder is exceeded, the truck could still be controlled using the service brakes. But service brakes are not intended to be routinely used to control speed on downgrades; and if used in this way, excessive heat will be generated which will increase wear on the brakes and could reduce the effectiveness of the brakes if required in an emergency.

Drivers should be familiar with information on the braking capabilities of the trucks they operate. The people who lay out the roads have to take it into account in determining what grades can be safely used. Some manufacturers put a decal in the cab giving guidance on maximum speeds for a given grade for that particular truck. An example is shown below. This is a good safety practice and should be encouraged. This in-truck information should be supplemented by placing signs on significant grades indicating the steepness of the grade.

Truck Model XXXX - Retarder Performance Guideline		
Steepness of Downgrade, Percent	Speed not to be exceeded, mph	
	Loaded (at GVW)	Empty
4	22	27
6	20	25
8	18	24
10	15	23
12	12	22
Reduce speed further, as necessary, under adverse conditions (Note: This is an example only; data will vary depending on truck model.)		

Note that in using retarder charts the weight of the truck is an important factor. Overloading a truck will decrease the speed the retarder can handle. Overloading also can result in a combination of grade and truck weight that exceeds the retarder capabilities.

Typical mining trucks are designed to meet the requirements of the standard braking test of the Society of Automotive Engineers (SAE, J1473). This standard test requires that the loaded vehicle be brought to a stop from a speed of 30 mph on a hard and dry road surface which is at an 8 to 10% downgrade. To pass the test, the truck must stop within a distance of 350 feet.

Some state regulations limit the maximum grades on haul roads. Typically the maximum overall grade is restricted to 10%, with grades to 15% permitted only for short distances.

Operators need to be cautious of using equipment on steep grades. On any grade over 10%, it is especially important that the operator's manual be checked to ensure that the equipment can be safely operated and to be aware of what precautions need to be taken.

Coal: Section 77.1607(b) requires that mobile equipment operators have full control of the equipment while in motion; (c) requires that equipment operating speeds be prudent and consistent with conditions of roadway, grades, clearance, visibility, traffic, and the type of equipment used.

Metal/Nonmetal:

Section 56/57.9101 requires that mobile equipment operators maintain control of the equipment while it is in motion; and that operating speeds be consistent with conditions of roadway, track, grades, clearance, visibility, traffic, and the type of equipment used.

Effect of Grade on Stopping Distance

On a downgrade, all other conditions being equal, the stopping distance will be greater than on level ground. See the stopping distance estimates in Tables 4 through 11, where the effect of different grades on stopping distance is shown. For particular conditions, the effect of a downgrade on stopping distance can be estimated as shown by Equation 3 in Appendix D. On an upgrade the stopping distance will be shorter than on level ground.

Grade Situations to Avoid

Mine operators should avoid haul road alignments that result in a sharp curve near the top of a grade. Such a curve is difficult to perceive at night, when headlights would tend to shine up into the darkness. If this situation cannot be avoided, measures should be taken to define the curve, such as through the use of reflective markers.

Another situation that should be avoided is the placement of a sharp curve near the bottom of a grade. Here, a vehicle may tend to pick up momentum, making it more difficult to maintain control around the curve. If this situation cannot be avoided, a safe speed for descending the grade should be posted and adequate restraining measures, such as large berms or a runaway ramp, should be used as a precaution.

Grades - Summary of What You Can Do

< Determine the percent grade of a haul road by measuring with an Abney level, or by obtaining the rise and run of the road from an accurate topographic map. **Grades over 10% are of special concern.**

< Check that the mine operator has verified that the equipment can safely handle the grades.

< Check that the mine operator has considered the braking capabilities of the equipment in establishing speed limits for downgrades, that is, that the speed limits keep the vehicle within its retarder performance capabilities.

< Emphasize to mine operators that brake/retarder performance depends not only on the steepness of the grade, but also on the vehicle's weight, so that it is important that trucks not be overloaded.

< Check that drivers have access to operator manuals, and that driver training includes grade-gear-speed relationships for the vehicles.

< Encourage mine operators to place signs in the cabs indicating, for each particular truck, the speeds that should not be exceeded on various grades. This should be combined with placing signs to indicate the grade of steep portions of the haul road.

CHAPTER 5 - SPEED LIMITS

Speed limits should be established based on the layout and condition of the roads and the capabilities of the equipment using the roads. For a given segment of a road, the speed limit should be the speed at which, under normal conditions, sight distances are adequate, the curves can be safely negotiated, and downgrades can be traveled without exceeding the braking capabilities of the equipment. Additionally, the speed should be consistent with the width and smoothness of the road, so that the driver can operate the vehicle with a reasonable margin for error and a reasonable level of comfort and control.

Lower speed limits should be posted on segments of road that routinely require slower speeds for safe operation, such as where the sight distance is limited or the road is narrow. Speeds need to be reduced where the road narrows to allow the driver to more accurately position the vehicle. Lower speed limits should also be used in congested areas because of the limited field of vision from haulage equipment.

When driving conditions are less than ideal, such as during inclement weather, drivers must lower their operating speed an appropriate amount to compensate for reduced visibility and/or traction. Operating speeds need to be reduced when visibility is limited, because the driver needs to maintain the ability to bring the vehicle to a stop within the available sight distance. The speed needs to be reduced when traction is poor, because the braking distance is increased and the ability to steer the vehicle around curves is impaired. Lower speeds may also apply at night when the sight distance is limited to the area illuminated by the headlights and when driver reaction time may be increased because perceptions are not as sharp.

Speeds must also be consistent with the following distances that are used. At higher speeds, more distance must be maintained between vehicles to allow the driver of a trailing vehicle adequate time to stop in an emergency without hitting the vehicle in front of them. The subject of safe following distance was discussed in Chapter 3, “Stopping Distance.”

Coal: Section 77.1600 (b) requires, in part, that traffic rules be standardized at each mine and posted. Section 77.1607 (c) requires that equipment operating speeds be prudent and consistent with conditions of the roadway, grades, clearance, visibility, traffic, and the type of equipment used.

Metal/Nonmetal:

Section 56/57.9100(a) requires, in part, that rules governing speed be established and followed at each mine.

Section 56/57.9101 requires that equipment operators maintain control of equipment while it is in motion, and that operating speeds be consistent with conditions of roadways, tracks, grades, clearance, visibility, traffic, and the type of equipment used.

Checking the Speed of a Vehicle

If there is a question as to whether vehicles are exceeding the speed limit, or exceeding the safe speed on a downgrade, you can check the speed by timing a vehicle over a known travel distance. In the area where you want to check the speed, measure or pace off a known distance along the road. Place a mark at the edge of the lane at the beginning and end of the distance. Using a stop watch, measure the time it takes for the vehicle to travel from one mark to the other. The average speed of the vehicle, in miles per hour, is equal to the distance in feet divided by the time in seconds, multiplied by 0.68. Speed determinations should normally be based on several measurements.

Tables 12 and 13 show the speed of a vehicle based on the number of seconds that it takes to travel 100 or 200 feet. Use the longer distance when practical, as it will generally result in a more accurate speed measurement.

Speed on Downgrades

The speed limit posted on downgrades should take into account the braking capabilities of the equipment. See the discussion on retarders in the section on "Grade and Equipment Compatibility" in Chapter 4. In laying out a grade, the mine operator needs to make sure that the combination of speed limit and grade steepness is within the retarder performance capability of the equipment. Furthermore, speed limits need to be reduced in advance of a downgrade to account for the lag time involved before retarders are engaged. Vehicle operator manuals should be consulted to determine retarder lag time requirements.

Speed Around a Curve

A vehicle traveling around a curve is held on the curved path by the friction between the tires and the road surface and, if the curve is banked, by the inward tilt of the vehicle. If the friction and banking forces are exceeded, the vehicle will slide or have a tendency to overturn as it rounds the curve.

The higher the speed and weight of the vehicle, and the sharper the curve, the greater the chances of sliding or overturning. So for a given speed, there is a limit to the sharpness of a curve that can be safely negotiated.

The sharpness of a curve can be indicated by its radius. That is, the curve is approximated as a portion of a circle. A sharp curve would correspond to a portion of a circle with a small radius, while a gentle curve would correspond to a large radius. See Part C of the Appendix for information on how the radius of a curve can be determined.

Table 14 gives, for some speed and road conditions, the minimum curve radius that can be handled without exceeding the friction and banking forces. The friction values shown in the table are values typically used in road design. The “Cross-slope” column represents how much the road surface is banked or sloped. Based on Table 14, for a speed of 20 mph and a friction coefficient of 0.17, a curve that’s not banked should have a radius of at least 160 feet. Note that on mine roads, the available side friction may be less, which would mean that either lower speeds or larger radius curves would be required. Note also that the amount that curves are banked must be limited in areas subject to snow and ice to avoid situations where slow traveling vehicles would tend to slide to the inside of the curve.

Another consideration for the speed around curves is the effect on the vehicle’s tires. The use of lower speeds around curves will reduce stress in the tires, help avoid tire ply separation, and lead to increased tire life.

If you notice that vehicles seem to be having trouble negotiating a certain curve, or if you are concerned about the safety of a curve, the above information can be used to get an idea of whether the speed may be too great for the curve conditions. Where a problem is indicated, the possible remedies are to reduce the speed around the curve, or alter the curve by making the curve more gradual, that is, increasing the radius of the curve.

Speed Limits - Summary of what you can do

- In any area where sight distance is restricted, check that equipment traveling at the posted speed limit would be able to stop within the available sight distance.
- Check whether the minimum following distances that are used on the property appear appropriate for the speed limits and grades.
- On downgrades, check that the mine operator has considered the retarder performance information for the equipment that will use the grades, and that the speed limits have been selected to keep the equipment operating within the capabilities of their braking systems.
- On curves, the speed must be limited, as explained above, to allow adequate traction.
- Where sight distance, the grade, or a curve, does not govern the safe speed, consider the following factors in judging whether the speed limit is appropriate:
    - -the width of the roadway,
    - -the smoothness of the roadway,
    - -the presence of other slower-moving traffic, and
    - -the minimum following-distance that is maintained between vehicles.

  Where these conditions are less than ideal, the mine operator should reduce the speed limit to compensate.
- Finally, emphasize to drivers that the speed limit only applies under ideal driving conditions, and that they are responsible for reducing their speed to a safe level when road, weather, or traffic conditions are less than ideal.

CHAPTER 6 - HAUL ROAD WIDTH

Haulage roads should be designed with ample width to promote safe operation. The large size of haulage equipment requires that even the best operators be provided with a margin for error. A narrow roadway will increase the chances of collision with other vehicles, cause the occurrence of other hazardous situations such as inadvertently contacting a berm or roadside ditch, and generally place drivers in a more stressful driving environment.

The width of a haul road should be based on the widest vehicle in use. To allow for the perception difficulties created by larger vehicles, the space provided for side clearance should increase with increasing vehicle size. **A good safety practice with mining equipment is that each lane of travel should provide clearance, on both sides, equal to one-half the width of the widest vehicle in use.** This means that for two lanes of traffic, a haulage road should be at least 3.5 times the width of the widest vehicle using the road. With 18-foot wide trucks, for example, the road should be 63 feet wide for two-way traffic (i.e., 3.5 x 18 = 63). Figure 4 shows the recommended roadway widths for equipment of different widths. Note that on a single lane road, an additional roadway width of at least 4 feet should be provided, so that if a vehicle broke down other equipment would be able to safely go around it.

An important point is that the roadway widths indicated above consider the width of the travel area only. So this width should be provided in addition to the space needed for berms, or for a ditch along the road. It is important that berms be founded on a sound base, even with the roadway, and not partially founded on the outslope. In situations where it is not possible to provide the full, ideal road width, warning signs should be provided and slower speeds should be used.

Coal: Section 77.1600(c) requires, in part, that where side clearances on any haulage road are hazardous, such areas be conspicuously marked and warning devices installed when necessary to ensure the safety of the workers.

Metal/Nonmetal:

Section 56/57.9100(b) requires that signs or signals be placed at appropriate locations at each mine to warn of hazardous conditions.

Section 56/57.9306 requires that where restricted clearance creates a hazard to persons on mobile equipment, warning devices be installed in advance of the restricted area and the restricted area be marked.

Haul Road Width Around Curves

Haulage roads should be widened around curves. It is more difficult to drive a large vehicle on the intended line around a curve, so an additional margin for error should be provided for the driver. Also, since the rear tires don't track on the same radius as the front tires, a vehicle is effectively wider going around a curve than it is when going straight. This effect is most pronounced when articulated units are in use. On mild curves, a slight widening is sufficient, while on switchbacks and sharp curves, significant widening is needed. Table 15 provides guidance on how much haul roads should be widened around curves.

Haul Road Width - Summary of What You Can Do

Where there is concern for adequate roadway width, measure the available road width or estimate it by pacing. Compare the width with the recommended values shown in Figure 4. Check that roads are widened around curves. Encourage mine operators to use the recommended widths; and if the width is less than recommended, measures such as reduced speed limits and the placement of warning signs to alert drivers, should be taken.

CHAPTER 7 - ROAD SURFACE CONDITIONS

The materials that make up the road surface and road base need to serve two functions: 1) provide adequate traction; and 2) provide support for the traffic without excessive sinking-in or rutting.

Function No. 1 - Traction

The forces required to accelerate, turn, or stop a vehicle are developed by the friction generated between the tires and the road surface. The amount of friction available varies with different road surfaces and is indicated by a friction coefficient, which is a measure of how well the tire grips the road surface. The friction coefficient indicates how much of the total weight of the vehicle can be generated as a force between the tire and the road surface. The higher this force, the better the grip on the road, and the more control the driver has in climbing, steering, and stopping.

Table 2 shows some typical friction coefficients for a variety of road surfaces. Notice the significant differences, with values varying from concrete (0.9) down to ice, which can be practically zero. The value of 0.9 for rubber tires on concrete means that 90% of the weight on a tire is available as braking force (presuming that the brake components themselves can provide this much braking force). This braking force is reduced to half this much on wet clay, to 20% on snow, and to less than 10% on ice.

These different values show why it is so important that drivers adjust their speed to suit the road conditions. All other factors being equal, it will take a longer distance to stop when the traction values are low. If the friction coefficient is reduced by half, once the brakes are applied the stopping distance is doubled. Friction values also affect steering ability. When traction is low, the defensive driving measure is to reduce speed.

Remember that the road surface coefficients given in Table 2 are the maximum values for the conditions indicated. Maximum tire grip occurs when the tire is still rolling and just before the tire would lockup and slide. Once a tire locks up and goes into a skid, the available friction is reduced. This reduction can be as much as 50% under poor road conditions. This is why antilock brakes are of such benefit. They help prevent tires from locking up, so the available friction stays at the higher values. **Remember that the brakes stop the wheel, but it's the grip between tire and road surface that stops the vehicle.**

The discussion above shows why a road surface of gravel or crushed stone is preferred for mine haul roads. While some other materials provide better traction when dry, a gravel road surface offers good traction values in both dry and wet conditions.

Coal: Section 77.1607 required, in part, that (b) mobile equipment operators have full control of the equipment while in motion; and (c) equipment operating speeds be prudent and consistent with conditions of the roadway and the type of equipment used.

Metal/Nonmetal:
Section 56/57.9101 requires that equipment operators maintain control of equipment while it is in motion, and that operating speeds be consistent with conditions of roadways and the type of equipment used.

Function No. 2 - Support

Rutting of a soft road surface can create a safety hazard by affecting a driver's ability to control the vehicle and by subjecting the driver to rough or jarring conditions. Rutting occurs when tires sink into the road surface because the road material doesn't offer adequate support. Fine-grained soils, even when well-compacted, may not support the tire loads imposed by large haulage trucks, especially during wet conditions. To prevent or minimize rutting of the road surface, a road base material with sufficient strength to support the tire loadings needs to be provided. A layer of gravel or crushed stone, for example, has higher bearing strength and will distribute the tire loadings over a larger area. The use of a layer of geotextile can assist in providing a road base that will better support the tire loadings.

In general, when well-constructed and properly maintained, gravel or crushed stone offers a roadway that, in a variety of weather conditions, resists deformation and provides a relatively high coefficient of friction. Where road base material has inadequate support strength, a great deal of maintenance work will be necessary to keep the road in good condition.

Metal/Nonmetal: Section 56/57.9104 requires, in part, that railroad crossings be planked or filled between the rails.

Road Surface Conditions - Summary of What You Can Do

Where you notice problems with rutting, or with traction on grades or around curves, note the type of roadbed and road surface material. Encourage operators to construct roads using durable gravels that will provide the best traction and support in all weather conditions. A well-maintained all-weather road improves both the safety and the efficiency of a mining operation. If traction or roughness problems are not solved by improving the road material, then equipment operators must slow down to compensate.

CHAPTER 8 - ROADSIDE BERMS AND GUARDRAILS

Roadside berms are a common safety feature along elevated roadways. However, the capability of berms may be misunderstood, and it's dangerous if they give equipment operators a false sense of security.

Berms should be considered mainly to:

- give the driver a visual indication of the location of the roadway edge;
- provide a sensation of contact to the driver if they accidentally contact the berm;
- provide restraint to the vehicle to give the operator the opportunity to regain control and keep the vehicle from leaving the roadway; and
- keep a vehicle back from the edge of the slope by a distance equal to at least the width of the berm.

Coal: Section 77.2(d) defines a "berm" as a pile or mound of material capable of restraining a vehicle.

Section 77.1605(k) requires that berms or guards be provided on the outer bank of elevated roadways.

The "Coal General Inspection Procedures Handbook" (Chapter 3, Section II, Part L) contains "Procedures for Determining if Berms or Guards are required on Elevated Roadways in Accordance with 30 CFR 77.1605(k)." This information is reproduced in Appendix E of this handbook, which also includes the berm-related information contained in the Program Policy Manual. Numerous coal mines have been granted petitions for modification of 77.1605(k). The provisions of these documents should be reviewed in the mine file book prior to an inspection.

Metal/Nonmetal:

Section 56/57.9000 defines a "berm" as a pile or mound of material along an elevated roadway capable of moderating or limiting the force of a vehicle in order to impede the vehicle's passage over the bank of the roadway.

Section 56/ 57.9300 requires that (a) berms or guardrails be provided and maintained on the banks of roadways where a drop-off exists of sufficient grade or depth to cause a vehicle to overturn or endanger persons in equipment; and (b) berms or guardrails be at least mid-axle height of the largest self-propelled mobile equipment which usually travels the roadway.

Section 56/57.9300(d) gives the conditions under which berms are not required on roadways which are infrequently traveled and which are used only by service or maintenance vehicles.

Earthen Berms

To serve the four functions indicated above, earthen berms must be **at least** as high as the mid-axle height of the largest piece of equipment that uses the roadway. While the adequacy of a berm is normally judged based on its height, mine operators should realize that the effectiveness of a berm also depends on its width, or thickness, and its firmness.

One way for an earthen, roadside berm to provide restraint is for the berm to deflect the tire, and re-direct the vehicle back onto the road. To do this, the berm material must be firm, and the inside slope of the berm must be steep. If a berm is too loose, it will provide little restraint and the vehicle may easily plow straight through it. If a berm is firm, but is not steep on the roadway side, the vehicle could ride up and over it.

Berms constructed of broken rock will normally offer restraint due to the interlocking and frictional resistance of the rock pieces. A berm that is constructed of loose, fine-grained material will offer less restraint. If berms are constructed using only fine-grained material, the berm material should be compacted to compensate, and/or larger berms should be constructed.

Berms can be built by packing the berm material, such as by using the bucket of a loader, and then steepening the inside by cutting along the berm. However, when the inside slope of a berm is cut to steepen it, operators should ensure that a sufficient amount of berm material is initially placed so that the berm will still have an adequate base width after it is cut. The base width should be at least the width that an axle-height berm would have, if both the inside and outside slopes were at the material's angle of repose.

A berm can also impede the passage of a vehicle by a combination of the tire sinking into and raising up as it climbs the berm material and the vehicle getting bogged down as it plows through the berm material. But to effectively impede a vehicle in this way, a berm generally needs to be larger than axle-height. In general, the finer the material used, and the less effort that is made in compacting and shaping a berm, the larger the berm should be to provide similar restraint.

Equipment operators should know that due to the large size and weight of mine equipment, the typical axle-height berms cannot be relied on, by themselves, to completely stop a vehicle except at low speeds. Berms much larger than axle-height would be required to completely restrain a vehicle for the full range of possible conditions of speed and impact. For example, a U. S. Bureau of Mines study (1982) concluded that to act as a restraint system, earthen berms would need to be constructed to a **height of three times the axle-height for vehicles under 85 tons and four times the axle-height for vehicles over 85 tons**. This is based on a vehicle contacting the berm at 30 mph at a 30 degree angle of contact.

The amount of restraint offered by a berm depends on the conditions under which the vehicle impacts it. The greater the vehicle speed, or the more head-on the vehicle contacts the berm, the larger the berm must be. For this reason, larger than typical berms should be used in areas where it is reasonable to expect more adverse conditions, such as where equipment would have more speed or would contact the berm more head-on. An example would be where there is a curve at the bottom of a grade. In such cases, berm size should be increased.

Roads need to be made wide enough so that berms are constructed on a firm foundation that is even with the roadway. If the road width is inadequate and a portion of the berm extends over the hillside, the berm will be more likely to give way when hit and offer little restraint.

Another important consideration with earthen berms is that they are properly maintained. Berms tend to deteriorate over time. The size of a berm may be reduced by the action of rain and wind, by erosion, by material sloughing off the sides or settling, or by the berm being contacted by mine equipment. Sometimes the slope of the outer bank becomes unstable and slope movement undercuts the berm. Berms should be checked regularly; and if any of these factors have reduced the effectiveness of a berm, corrective action should be taken.

Operators should realize that effective berms will easily pay for themselves if they prevent, or lessen the severity of, even one accident.

Boulder Berms

Sometimes a continuous row of boulders is used to form a berm. When a piece of equipment contacts a boulder berm, the restraint comes from the frictional forces involved in sliding the boulder ahead of the vehicle. So, to be effective, the boulders cannot be placed right at the edge of the drop off. There has to be a distance available for the vehicle to push the boulders. This distance will depend on the size of the boulders and the size and speed of the truck. To account for this distance, additional road width is required.

Guardrails

If guardrails are used instead of berms, they should be capable of serving the same functions of:

< providing a visual indicator of the location of the edge of the road;

< giving a sensation of contact to the driver if the guardrail is accidentally contacted; and

< restraining or impeding the vehicle's passage over the edge.

Considering the large size and mass of haulage trucks, to serve these purposes on mine roads, guardrails generally need to be higher and stronger than the guardrails typically used on public roads. The Program Policy Manual, Volume V, Part 77 indicates that "Where guardrails are used in lieu of berms, they shall be of substantial construction." See Appendix E in this handbook for additional information on guardrails in the Program Policy Manual (Part 77) and the "Coal General Inspection Procedures Handbook," PH95-V-1.

Concerns with guardrails are that the posts are embedded deep enough to provide adequate resistance and that the posts and horizontal guide members are strong enough to restrain or impede the passage of the vehicle. Reference Number 3 can be consulted for more specific information on the design of guardrails for mine haulage roads.

Berms - Summary of What You Can Do

- Emphasize to mine operators that to serve their function, earthen berms need to be **at least** mid-axle height, of firm construction, and steep-sided on the roadway side.
- Encourage the use of larger berms, especially in areas where vehicles may have more speed and in areas where there may be a greater chance of a vehicle going out of control, such as around curves or on steep grades..
- Remind mine operators that, where only finer-grained material is used in berm construction, and efforts are not made to compact and shape the berms, larger berms should be used to compensate.
- Be alert to how well the berms are maintained, and whether erosion, or sloughing of the slope, has undercut or otherwise made a berm inadequate.
- Check that boulder berms are placed back from the edge of the drop-off.

CHAPTER 9 - TRAFFIC RULES AND SIGNS

The orderly and predictable flow of traffic on mine property depends on the vehicle operators' having a clear understanding of the traffic rules, and especially the right-of-way practices, used on the property. This can be achieved through driver training and the effective use of signs.

Coal: Section 77.1600 requires, in part, that (a) only authorized persons be permitted on haulage roads; (b) traffic rules, signals, and warning signs be standardized at each mine and posted; and (c) areas of haulage roads be conspicuously marked where clearance presents a hazard.

Section 77.1708 requires that each mine operator establish and maintain a program of instruction on the safety regulations and procedures to be followed at the mine, and that the safety regulations and procedures be published, posted and distributed to each employee.

Section 77.1709 requires that new employees be indoctrinated in safety rules and safe work procedures, and that inexperienced employees not be assigned to work duties until they have been trained thoroughly in safe work procedures related to the assigned work duties.

Metal/Nonmetal:

Section 56/57.9100 (a) and (b) require that rules governing speed, right-of-way, direction of movement, and the use of headlights to assure appropriate visibility be established and followed; and that signs or signals that warn of hazardous conditions be placed at appropriate locations.

Section 56/57.9104 requires that designated railroad crossings be posted with warning signs or signals or be guarded when trains are passing.

Section 56/57.9306 requires, in part, that areas be conspicuously marked where restricted clearance creates a hazard to persons on mobile equipment.

Section 56/57.18006 require that new employees be indoctrinated in safety rules and safe work procedures.

Section 56/57.20011 require that areas be barricaded where safety hazards exist that are not immediately obvious to employees, or warning signs be posted at all approaches. Warning signs are to be readily visible, legible and display the nature of the hazard and any protective action required.

Right-of-Way Rules

A mine needs clearly established rules for right-of-way, but these rules may vary at different operations. Uncertainty about who has the right-of-way can lead to accidents. Generally, loaded haulage trucks are considered to have the right-of-way; followed by empty haulage trucks, and finally other service and passenger vehicles. In cases of similar vehicle types, the downgrade traffic would have the right-of-way, or the vehicle arriving first would have the right-of-way. But in some situations, such as at an intersection, the truck to the left, because it has a blind spot to the right, is considered to have the right-of-way. Since these rules can sometimes be in conflict, it is important that each mine establish right-of-way rules and priorities for their specific conditions, train their drivers about them, and provide signs in any areas where application of the right-of-way rules would either differ from normal traffic conventions or otherwise be uncertain. Drivers should be taught to yield anytime there is uncertainty about the right-of-way. The mine operator must consider that the question of who has the right-of-way must be clear, even to persons who only infrequently travel the mine's roads.

Traffic Signs

Traffic control signs, such as stop and yield signs, are important to ensure the orderly, predictable movement of vehicles and in making clear who has the right-of-way. Other signs, such as for speed limits, are important in providing the information, warning, and guidance that a driver needs to safely travel the property. These are especially important in warning drivers where special precautions must be taken, such as at a narrow point in the roadway, or where an unusual traffic pattern is used, such as driving to the left. On steeper grades, especially any grade at or over 10%, mine operators should be encouraged to install signs which indicate the percent grade. This information helps a driver select the appropriate gear and speed so that the grade can be safely negotiated.

To be effective, signs should:

- fulfill a need;
- command attention;
- have a clear, simple message; and
- be properly located to give drivers the information prior to when they need it.

Operators should regularly review the adequacy of their signs. Care should be taken to ensure that signs do not become blocked by vegetation or become illegible from dirt or deterioration. As new mining areas are developed, additional signs may be needed. In evaluating the adequacy of signs, they should be considered from the viewpoint of a first-time visitor on the property, such as a sales person or a contractor.

Pay special attention to any areas where public roads intersect mine roads. Other drivers may not be familiar with the operation of mining equipment, the mine's traffic patterns, and equipment blind spots. Ensure that the traffic and warning signs that are provided in these areas are adequate.

Driving on the Left Side

Reasons that an operation may drive on the left side of the road include:

< In some situations, driving left reduces the problems that drivers have with the blind spot to the right of the truck. In approaching a dump point, for example, driving left gives the driver the benefit of being in a better position to examine the dump area during the approach and to judge where to turn and position the truck.

< On roads with a drop-off on one side, driving on the left side may be used so that loaded trucks can travel in the inside lane, staying away from the outer edge. Or to put the driver in the outside lane in a better position to judge the edge location.

< In driving left, truck cabs are positioned to the outside, so that if two trucks traveling in opposite directions were to collide, the contact would not occur on the drivers' sides of the vehicles.

Signs are especially important where driving on the left side is used. If driving on the left side is done on the entire property, signs need to be placed at all points where vehicles can enter the mine property and in various areas around the property to act as reminders. Of particular concern in this regard are persons who may be infrequent visitors, or first-time visitors, on the mine property. Consider, for example, whether a visitor who has spent a few hours in the mine office or maintenance shop would be reminded to "drive left" when leaving those areas.

Some operations "drive left" only on portions of the property, such as at dump sites. In these cases adequate signs must be provided: to alert drivers that the traffic pattern will change ahead; to clearly indicate exactly where the traffic pattern changes from driving right to driving left; to remind drivers of the prevailing traffic pattern; and to indicate exactly where the pattern changes back to right-side driving.

Safety at Railroad Crossings

Railroad crossings along haul roads can be potentially hazardous locations. On public roads, each year there are over 1000 accidents and around 500 fatalities as a result of trains colliding with cars and trucks at crossings. Mine operators should make sure that crossings are adequately marked and that sufficient sight distance for looking both ways down the tracks is provided. Mine operators should also avoid situations, such as road intersections near railroad crossings, where equipment crossing the tracks could get backed up and either overhang or be trapped on the tracks.

Some common safety precautions that equipment operators should be aware of include the following:

< Expect a train on a track at any time. Trains do not run on set schedules.
< Never race a train to the crossing. It's easy to misjudge a train's speed and distance. If in doubt, stop and wait.
< Never drive around a lowered gate.

< Don’t shift gears while crossing tracks.

< Be careful not to get trapped on the tracks. Make sure that there is room to completely cross the tracks before proceeding.

< Be aware that trains cannot stop quickly. A freight train can take over half a mile to stop from a speed of 30 miles per hour.

Hazard Training

Check that the hazard training given at the mine adequately covers the haul road hazards and any traffic rules, such as driving on the left side, which are particular to the mine property. Talk to the individual responsible for providing hazard training to ensure that they are familiar with the hazards associated with the haul roads.

Understanding the traffic patterns and right-of-way rules is especially important for contract truckers or others who may not be familiar with the property. Also, these drivers may not be used to driving on mine roads, which can be a lot steeper and may provide less traction than public roads. The mine’s hazard training should emphasize to these drivers the importance of controlling their speed, and making sure they are in the proper gear, so they can maintain control while descending grades or going around curves on mine property.

You should also determine whether the traffic rules and signs identifying hazards along the haul roads reinforce the hazard training given for the mine. It cannot be overemphasized that hazard training has to be mine specific and that the training should be re-enforced with traffic rules being posted and hazardous conditions being identified by warning signs.

Traffic Rules and Signs - Summary of What You Can Do

< Be alert to areas where traffic rules may be unclear, especially with respect to who has the right-of-way.

< Try to view the roads through the eyes of a new equipment operator or a visitor who is unfamiliar with the property.

< Where traffic rules or signs are unclear, or seem inappropriate, take appropriate action to remedy the situation.

< For more information on traffic signs, consult MSHA’s booklet entitled “Guidelines for Traffic Control at Surface Mines and Installations,” 1997.

< Observe equipment where it crosses railroad tracks. Be alert to whether the sight distance down the tracks is adequate and watch for situations where equipment would tend to stop on the tracks.

< Check that the hazard training adequately alerts drivers to any unusual traffic patterns, rules, or conditions on the property.

CHAPTER 10 - DRAINAGE PROVISIONS

Poor drainage control jeopardizes the safety of a haul road by allowing:

< muddy and slick road surface material;
< erosion to cause washouts and rutting;
< standing water to soak and soften the road base; and
< fill sections and slopes to become saturated and unstable.

Coal: Section 77.1608(a) requires, in part, that haulage roads be kept reasonably free of water, debris, and spillage.

Metal/Nonmetal:

Section 56/57.9300 (c) indicates that berms may have openings to the extent necessary for roadway drainage.

Section 56/57.9313 requires that water, debris, or spilled material on roadways which creates hazards to the operation of mobile equipment be removed.

Proper drainage is normally provided by the use of:

< **Cross-slope.** To promote drainage, either the road surface should be sloped from one side to the other, or the road should be crowned, or raised, in the center. A cross-slope of 2 to 4 % is normally recommended. (When ice or mud are constant problems, excessive cross-slope can cause slow moving vehicles to slide sideways, so a minimum value should be used.) Note that a cross-slope value of about 4 percent is also a typical value used to bank a curve. Openings should be left in berms to the extent necessary to prevent drainage from collecting on the roadway.

< **Free-draining road materials.** Allow water on the road surface to drain down and out.

< **Roadside ditches.** Collect drainage from the road surface and intercept runoff from adjacent hillsides, keeping it off the road surface.

< **Culverts.** Carry runoff under the road surface to a drainage course.

Be sure that there is adequate erosion protection at the discharge end of a culvert. Otherwise the area may erode and eventually affect the road surface.

Drainage Provisions - Summary of What You Can Do

- Be alert to roadway areas where storm runoff either accumulates or causes erosion.
- While it is raining, or right after it rains, is a good time to check that drainage ditches and pipes are working properly. Also check for erosion problems at pipe outlets. Where drainage problems present a hazard, take appropriate action to have the situation corrected.
- If you notice that the drivers seem to have trouble on a particular curve, check how the curve is banked. Make sure that the curve is not banked the wrong way, i.e., sloping to the outside of the curve. This can occur, for example, if crowning is carried around the curve.

CHAPTER 11 - SLOPE HAZARDS ABOVE AND BELOW ROADS

Haulage road hazards can be created due to instability of material either above or below the road. The concern from above is for rockfalls or slides of material onto the road which could endanger passing equipment. From below there is concern, especially when haul roads are constructed on fill areas, that the ground will not be stable or have sufficient strength to support the traffic weight.

Coal: Section 77.1000 requires, in part, that operators establish and follow a ground control plan for the safe control of highwalls, pits, and spoil banks, that will ensure safe working conditions.

Section 77.1001 requires, in part, that loose hazardous material be stripped a safe distance from the top of highwalls and loose unconsolidated material be sloped to the angle of repose, or barriers or other devices be provided to afford equivalent protection.

Section 77.1004 requires, in part, that (a) highwalls, banks, benches, and terrain sloping into the working areas shall be examined after every rain, freeze, or thaw before persons work in such areas; and (b) overhanging highwalls and banks be taken down and other unsafe ground conditions corrected promptly, or the area posted.

Section 77.1005(a) requires, in part, that hazardous areas be scaled before any other work is performed in the hazardous area.

Section 77.1006(a) requires that persons, other than those necessary to correct unsafe conditions, not work near or under dangerous highwalls or banks.

Metal/Nonmetal:

Section 56.3130 requires, in part, that mining methods be used that maintain wall, bank, and slope stability in places where persons work or travel.

Section 56.3131 requires, in part, that loose or unconsolidated material be sloped to the angle of repose, or stripped back for at least 10 feet from the top of the pit or quarry wall, in places where persons work or travel in performing their assigned tasks; and that other conditions at or near the perimeter of the quarry wall which create a fall-of-material hazard to persons be corrected.

Section 56/57.3200 requires that ground conditions that create a hazard to persons be taken down or supported before other work or travel is permitted in the affected area. Until corrective work is completed, that area is to be posted with a warning against entry and, when left unattended. a barrier is to be installed to impede unauthorized entry.

Section 56/57.3401 requires, in part, that persons experienced in examining for loose ground examine conditions in areas prior to work commencing, after blasting, and as ground conditions warrant during the work shift. Highwalls and banks adjoining travelways are to be examined weekly or more often if changing ground conditions warrant.

Rockfalls: Haul roads often run along highwalls where there is concern for a rockfall hazard. Rock slopes tend to become less stable over time due to factors such as weathering, freeze-thaw cycles, and the effects of water. They should be regularly checked for overhangs, open joints, or other evidence of unstable rock. Unstable material must be either removed or supported, or the area barricaded so that equipment operators are not exposed to a potential rockfall.

If barricading is used, a judgment must be made about how high and how far out from the wall the barricade must be to prevent passing traffic from being exposed to the hazard. If an earthen berm is used as a barricade, it has the advantage of restraining fallen material by offering a barrier and by providing material that will absorb and dissipate some of the energy. How far a piece of falling rock will come out from a wall depends mainly on the steepness of the wall and the presence and condition of any benches. With a vertical wall, a rockfall would tend to end up near the base of the wall. However, with a sloping wall, or a wall with benches that have accumulations of material on them, the falling material will tend to bounce and be propelled farther out from the base of the wall.

To restrain rockfall material, both the height of the barricade and its distance out from the wall must be considered. For guidance, a rule-of-thumb that is sometimes used is that a barricade be placed a distance out from the wall of 15 feet, or one-fourth of the wall height, whichever value is greater. The height of a barricade should be at least 4 feet; and where the highwall height exceeds 60 feet, barricades should be at least 6 feet high. Reference Number 10 provides more details.

Fill Slopes: Fills should be constructed in compacted, horizontal layers. If the material is end-dumped, it will have a greater tendency to become unstable when it becomes wet or saturated. Also, the area near the edge of an end-dumped fill may not provide adequate support for haulage equipment. When fill is placed on an existing slope, the layers should be tied-in by first removing vegetation and cutting horizontal benches into the existing slope material. Any springs or seepage areas should be collected in a drain to prevent the fill from becoming saturated. Erosion of fill slopes should be repaired before the condition threatens the safety of the haul road.

<u>Slope Stability Hazards - Summary of What You Can Do</u>

< Be alert to pieces of rock that have fallen on the roadways and other indications, such as open joints, that the ground above the road may be hazardous. Unstable material needs to be removed or supported, or the area barricaded.

< Note that rock faces with southern exposures are subject to more freeze/thaw cycles and may produce more rockfalls.

< Watch for signs, such as tension cracks or settling, that the ground <u>below</u> the road may be unstable. Slopes may become unstable as they absorb rainfall, become eroded, or are loaded by the weight of heavy equipment.

< Pay special attention to the stability of any area where water is seeping out of a slope - the presence of water tends to make slopes less stable.

CHAPTER 12 - HAZARDS FROM OVERHEAD POWER LINES

A potential hazard that should be considered on haul roads is the presence of overhead power lines. In locating power lines and haulage roads, mine operators need to consider the danger of equipment contacting or coming too close to an energized conductor. Power line clearance is especially a concern regarding the raised beds of haulage trucks and the use of draglines, cranes, or other equipment where the reach can be extended.

Coal: Section 77.807-1 requires that high-voltage power lines located above haulageways be installed to provide the minimum clearance specified in the National Electrical Safety Code, with no high-voltage power lines being installed less than 15 feet above the ground.

Section 77.807-2 requires that the booms and masts of equipment not be operated within 10 feet of an energized overhead power line. Where the voltage is 69,000 volts or more, the minimum distance from the boom or mast is required to be as follows:

Nominal power line voltage (in 1000 volts)	Minimum clearance distance, in ft.
69 to 114	12
115 to 229	15
230 to 344	20
345 to 499	25
500 or over	35

Section 77.807-3 requires that when the clearances specified in 77.807-2 would not be met for any part of any equipment, the power lines are to be deenergized or other precautions taken.

Metal and Nonmetal:

Section 56/57.12045 requires that overhead high-potential power lines be installed as specified by the National Electrical Code.

Section 56/57.12071 requires that when equipment must be moved or operated near energizied high-voltage powerlines and the clearance is less than 10 feet, the lines be deenergized or other precautionary measures taken.

The clearance values specified in Section 77.807-2 of the Coal regulations are based on the National Electrical Safety Code (NESC). The Metal/Nonmetal regulation refers to the National Electrical Code, but this code refers to the NESC. So the clearance values specified in Section 77.807-2 should be used to determine adequate clearance from overhead power lines at any type of mine.

Pay special attention to the presence of power lines around dump points, where truck beds would be raised. Where haulage trucks pass under power lines, a sound precaution for mine operators to take would be to suspend the power lines high enough that the minimum clearances are provided above the raised-bed height of the haulage trucks used at the mine.

CHAPTER 13 - ROAD MAINTENANCE

Even with the best haul roads, a regular road maintenance effort is necessary for safety and efficiency. Dust, spillage, ruts, and other poor surface conditions will occur on any road surface, and if left uncorrected will lead to more serious problems. Without proper maintenance, a minor problem which at first only reduces the efficiency of the haulage operations (increased cycle times; equipment damage) can then lead to injuries, such as "jarring-type" injuries to equipment operators, and finally may lead to a serious accident if the deteriorated road condition causes loss of control of a vehicle.

Besides keeping haul roads safe, maintenance efforts will normally pay for themselves in reduced operating costs. Road conditions, for example, have a significant effect on the life of tires, which represent a major operating cost.

Coal: Section 77.1607(i) requires that dust control measures be taken where dust significantly reduces visibility of equipment operators.

Section 77.1608 (a) requires, in part, that haulage roads be kept reasonably free of water, debris, and spillage.

Metal/Nonmetal:

Section 56/57.9202 requires, in part, that mobile haulage equipment be loaded to minimize spillage where a hazard to persons could be created.

Section 56/57.9313 requires that water, debris, or spilled material on roadways which creates hazards to the operation of mobile equipment be removed.

Section 56/57.9315 requires, in part, that dust be controlled on haulage roads where hazards to persons would be created as a result of impaired visibility.

Section 56/57.18002(a) requires, in part, that a competent person designated by the operator examine each working place at least once each shift for conditions which may adversely affect safety or health; and that the operator promptly initiate appropriate action to correct such conditions.

Road maintenance should emphasize **preventive** measures. These include:

- periodically checking drainage provisions and ensuring that roadside ditches and culverts are effective in minimizing the effects of water on the road surface and foundation;
- taking measures to prevent trucks from being overloaded, which leads to spillage on the roadway;
- controlling dust so that visibility is not significantly reduced;
- promptly removing spills or other loose material from the road;
- maintaining the berms and escape ramps;

- periodically regrading road surfaces to remove small ruts and potholes before they cause serious problems; and
- training drivers to immediately report hazardous road conditions to their supervisor.

Concerning dust control measures, note that water applied to roads to control dust also reduces the traction available on the road surface. Where watering could present traction problems, such as on a grade or around a curve, a good practice is to water alternating segments of the road in each lane. This results in a checkered pattern of watered and un-watered areas. In this way, dust is controlled while still allowing for segments of more effective traction for braking, steering, and climbing. The water truck can then treat the un-watered areas on the next pass.

Road Maintenance - Summary of What You Can Do

- Reinforce to mine operators that well-maintained haulage roads improve not only the safety, but also the efficiency, of haulage operations.
- Check that the roads are maintained consistent with the conditions under which they are used. For example, if the roads are rough, make sure that the speeds that are used are low enough that equipment operators are not in danger of losing control of the vehicle or subjected to jarring type injuries.

CHAPTER 14 - RUNAWAY-VEHICLE PROVISIONS

Safety features can be incorporated into haulage road design to guard against the consequences of runaway vehicles. As previously discussed, typical edge-of-road berms should not be relied on, by themselves, to stop a large haul truck. However, there are other methods such as the use of escape ramps which can bring a runaway vehicle to a safe stop and prevent an accident. While the regulations do not specifically require provisions to control runaways, good practice dictates that where a reasonable potential for runaways exists, measures to control them should be provided. Provisions to control runaways should be considered, for example, in the following instances:

< where the grade is steep, such as grades over 10%;
< where older equipment is in use;
< where the road conditions call for vehicles to be operated near the limit of their capabilities; or,
< where a runaway accident has occurred, or experience has shown that there is a problem keeping vehicles under control.

Two methods to provide restraint for runaway vehicles are <u>center berms</u> and <u>escape ramps</u>.

<u>Center or Median Berms</u>

Some mining companies have had success controlling runaways by using a **berm of loose fine material** placed in the middle of the haul road, i.e., between lanes, at crucial points along the haul road. If the brakes fail, the **driver aligns the vehicle** so that it **straddles the berm**. By having to plow through the top of the berm material, and by the drag resistance of the material along the bottom of the truck, the berm is intended to bring the truck to a stop.

The height and length of a center berm depend on the size of equipment using the road. See Figure 5 and reference 3 for guidance on how high and how long the berms should be.

Some points to remember about center berms are:

< to be used effectively, the drivers must be trained in their use;
< the location and spacing of the berms is important as a berm must be available before the truck picks up too much momentum;
< the berm should be constructed of fine, loose material to minimize damage to the truck; and
< since they are in the middle of the road, a wider road is required.

Escape Ramps

Escape ramps are another possible way to intercept and control runaways. They bring a vehicle to a stop by some combination of:

< having it **bog down in loose, high rolling-resistance material;**
< directing the vehicle to a ramp that is going up hill (see Figure No. 6); or
< straddling a berm of loose material on the ramp, like the safety center berm idea.

The required length of a ramp depends on the entry speed of the vehicle, the rolling resistance provided by the ramp material, and the grade of the ramp. See Table 16 for guidance on the required length of a ramp. References 3 and 4 should be consulted for more detailed information. Table 16 is based on a ramp with a rolling resistance of 200 pounds per ton of vehicle weight, which is equivalent to the resistance provided by a loose sand. Note that Table 16 indicates that if the entry speed was only 40 mph, even for an escape ramp at a 10% adverse grade, the ramp would need to be 267 feet long. Since a vehicle could be trying to enter the ramp at a high rate of speed, the alignment of the ramp is important and a gradual curve is required.

The material that works best to bog down a vehicle is a layer of gravel made up of loose, rounded, half-inch size particles. The layer should be at least 3 feet thick. Any loose material that offers high rolling resistance could be used, but a material that has a lot of fines in it will tend to pack and not offer high rolling resistance.

Besides escape ramps, another technique that has worked at some mines is to construct a “drag berm” along the ditch side of a steep roadway. This method has been used where other methods were not considered practical because of topographic constraints. Loose piles of material are placed on the ditch side of the road at various locations along the grade. A pipe is installed underneath the piles to maintain drainage. The idea is that if a driver loses the brakes, he would straddle one of these piles, or drag along them.

For any type of runaway truck provision, it’s important that signs be provided so that a driver is alerted or reminded well in advance of the features location.

Runaway Vehicle Provisions - Summary of What You Can Do

Where operations have steep grades, ask the mine operator to consider how many hauls will be made down those grades over the life of the haul roads. Ask the operator to consider that if a vehicle goes out of control while descending a grade, a serious accident will likely occur. Discuss the benefits of providing a method to control runaways. Such a measure provides a margin of safety for drivers in the form of relatively inexpensive safety insurance. If an escape ramp or berm controls just one runaway vehicle, it will be well worth the time and effort needed to install it.

REFERENCES

For more detailed information you should consult these references:

1. Design of Surface Mine Haulage Roads - A Manual, IC 8758, U.S. Bureau of Mines (USBM), 1977.

2. Surface Mine Haulage Road Design Study, USBM Contract J0225037, Skelly and Loy, 1976.

3. Haulroad Berm and Guardrail Design Study and Demonstration, USBM Contract H0282028, OFR 188-82; Strecklein, G.L. and Labra, J., 1981.

4. Truck Escape Ramps - Synthesis of Highway Practice 178, Witheford, David, Transportation Research Board, May 1992.

5. Haulroad Sign Design Study and Demonstration, USBM Contract HO282028, OFR 189-82, Mak, King, 1981.

6. Highway Engineering, Oglesby and Hicks, Fourth Edition, 1982.

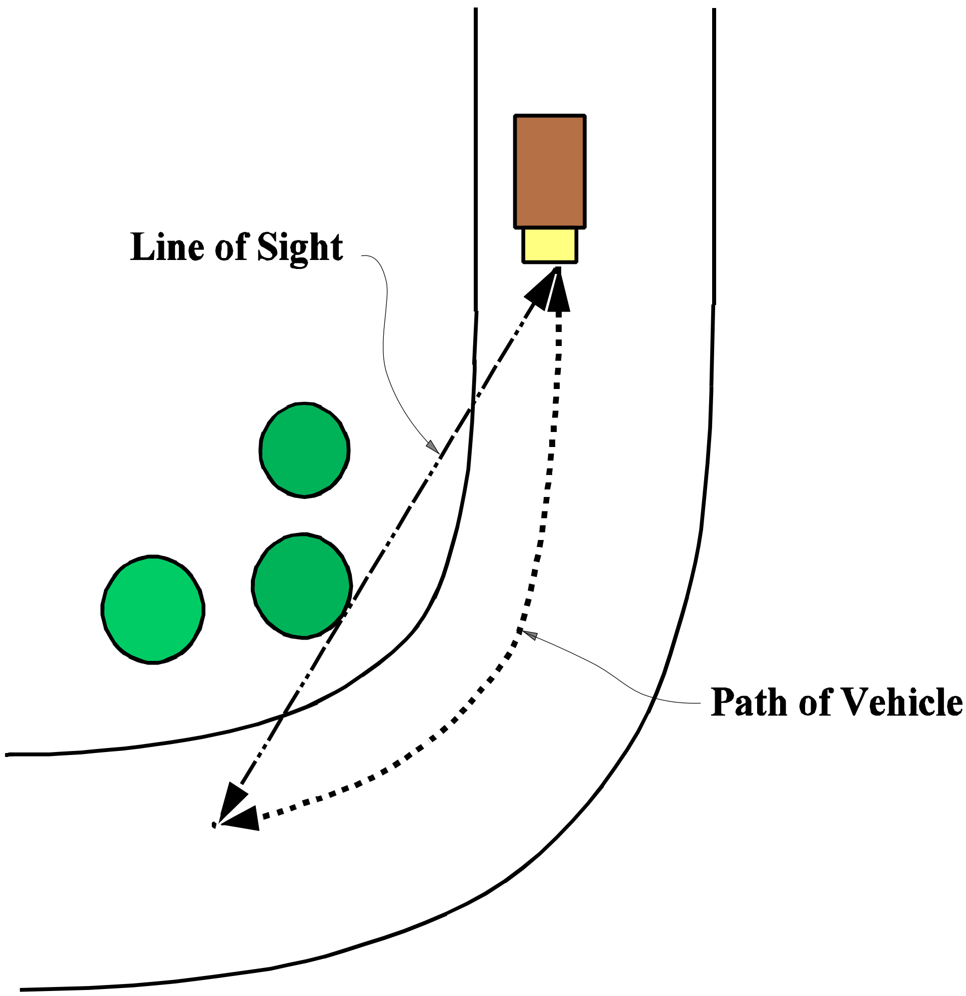
7. Principles of Highway Engineering and Traffic Analysis, Mannering and Kilareski, 1990.

8. A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, DC, 1984.

9. The Traffic Accident Investigation Manual, J.S. Baker and L.B. Fricke, Northwestern University Traffic Institute, Ninth Edition, 1986.

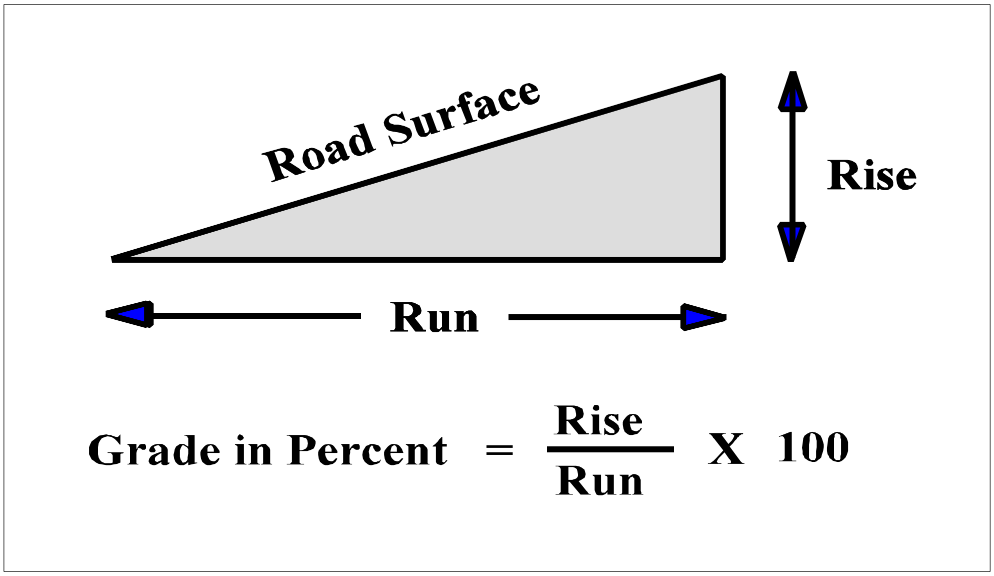
10. Evaluation of Rockfall and Its Control, Ritchie, A.M., Highway Research Record, Number 17, 1963.

(Note: These references are available through the Technical Information Center and Library at the National Mine Health and Safety Academy. The Technical Information Center and Library can be contacted at 304-256-3266.)



Note that the available stopping distance, or the "sight distance," is measured along the path of the vehicle.

Figure 1 - Sight Distance



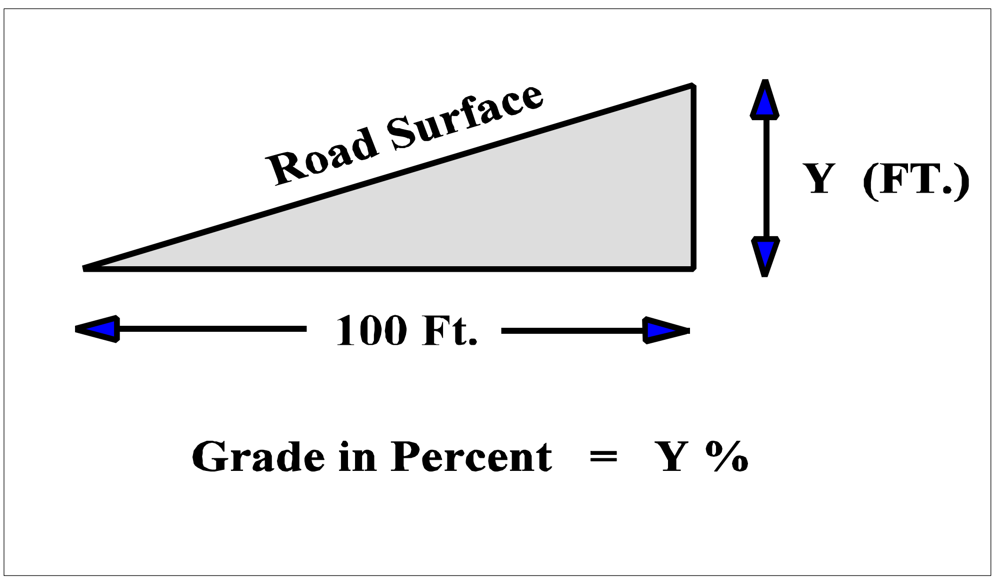
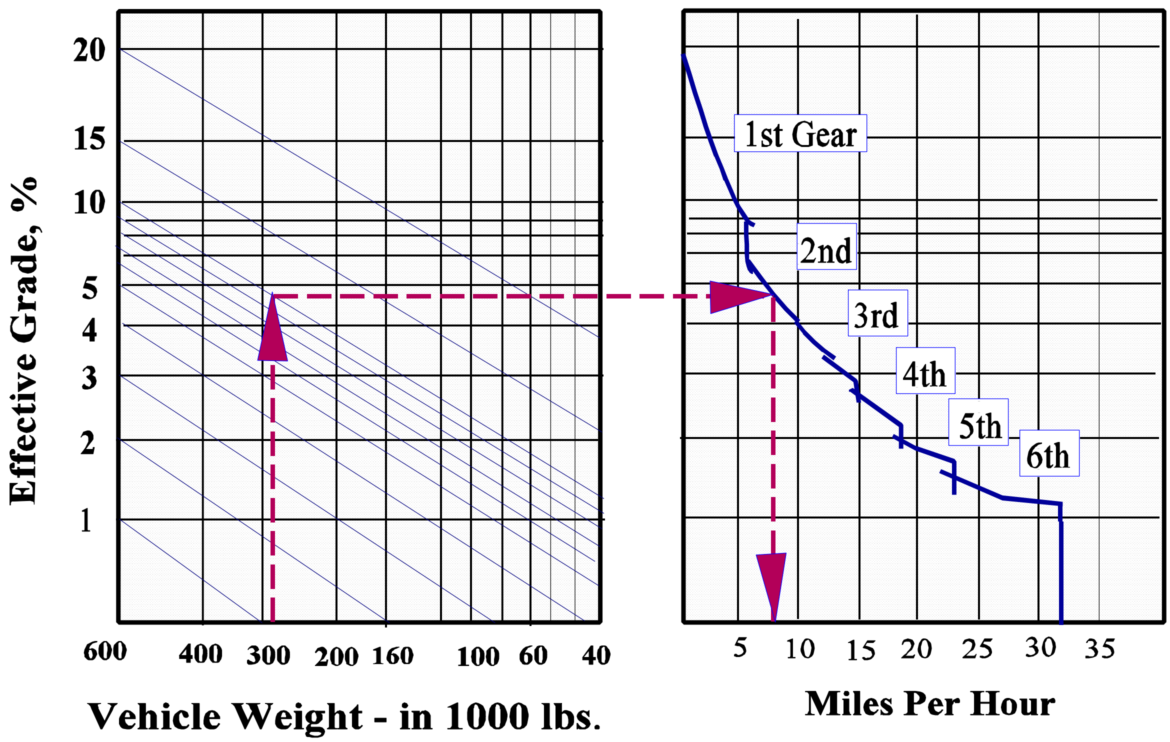


Figure 2 - Grade in Percent



To use this chart:

1. Find the vehicle weight on the horizontal scale of the graph on the left side.
2. Read up from this point to intersect the slanted line corresponding to the effective grade.
3. From this point, read across to the right to intersect the curve on the right-side graph.
4. From this point, read down to the vehicle speed, in miles per hour, that should not be exceeded to stay within the vehicle's retarder performance envelope.

EXAMPLE: For the truck that this retarder chart applies to, as shown by the arrows, at the truck's rated gross vehicle weight (GVW) of 290,000 pounds a speed of 8 mph should not be exceeded on a 10% grade.

Note: This chart is an example that is presented for illustrative purposes only. Retarder performance information varies by truck model and can be presented in different ways. If you are uncertain about how to use a retarder performance chart, contact the truck manufacturer for assistance.

Figure 3 - Example of Retarder Performance Chart

Vehicle Width, feet	1 Lane	2 Lanes	3 Lanes	4 Lanes
8	16	28	40	52
9	18	31.5	45	58.5
10	20	35	50	65
11	22	38.5	55	71.5
12	24	42	60	78
13	26	45.5	65	84.5
14	28	49	70	91
15	30	52.5	75	97.5
16	32	56	80	
17	34	59.5	85	110.5
18	36	63	90	117
19	38	66.5	95	123.5
20	40	70	100	130
21	42	73.5	105	136.5
22	44	77	110	143
23	46	80.5	115	149.5
24	48	84	120	156
25	50	87.5	125	162.5
26	52	91	130	169
27	54	94.5	135	175.5

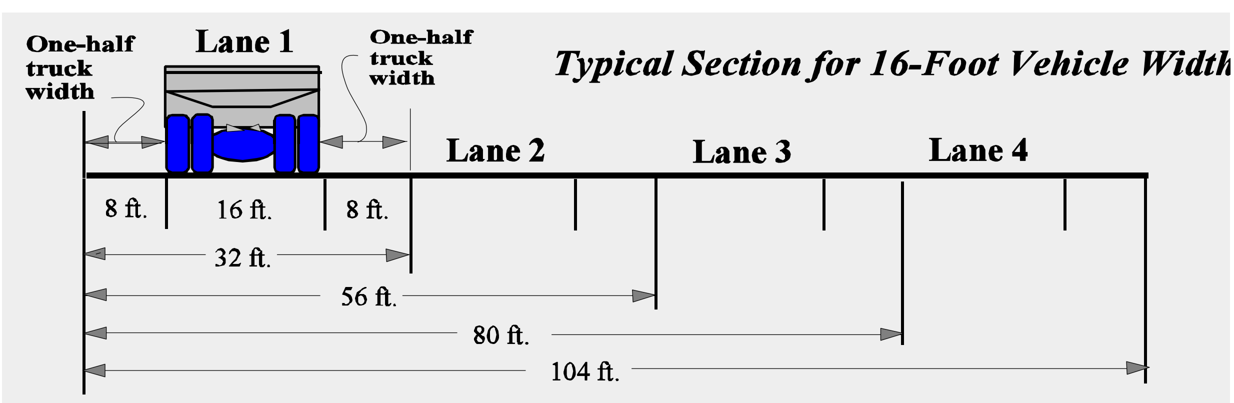
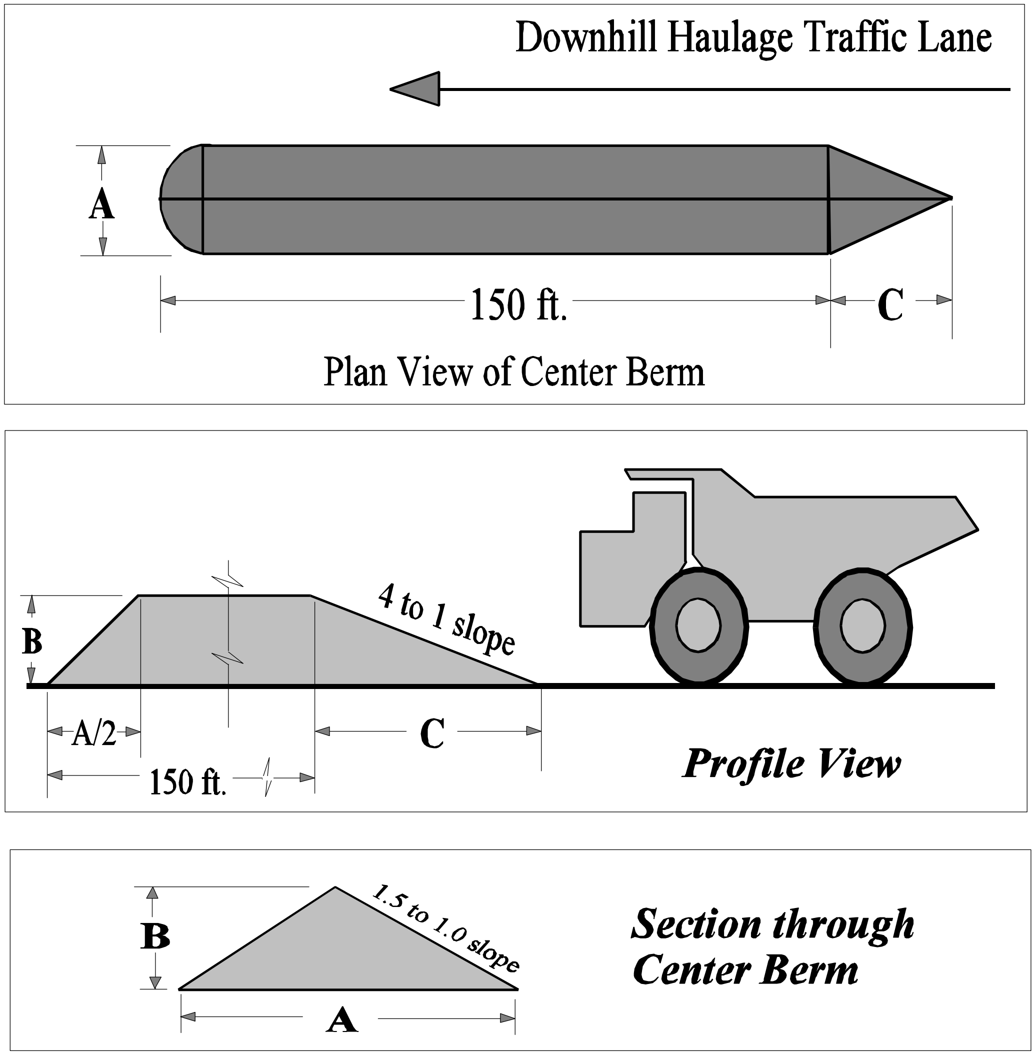
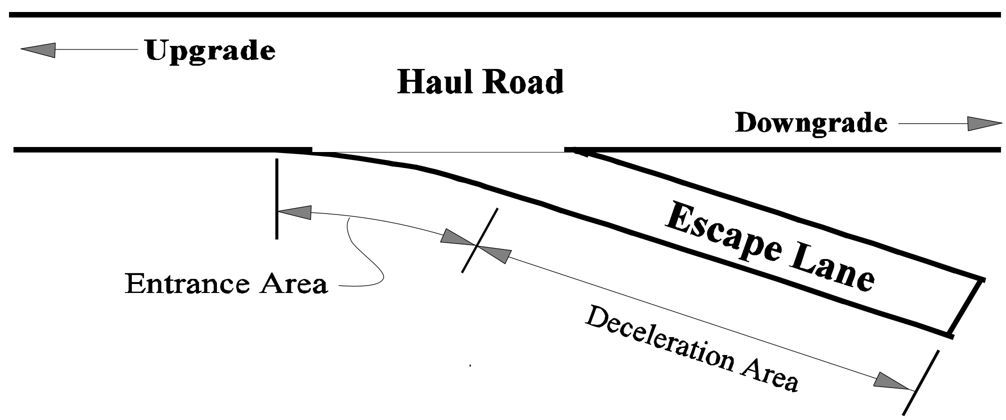


Figure 4 - Recommended Road Widths, in Feet

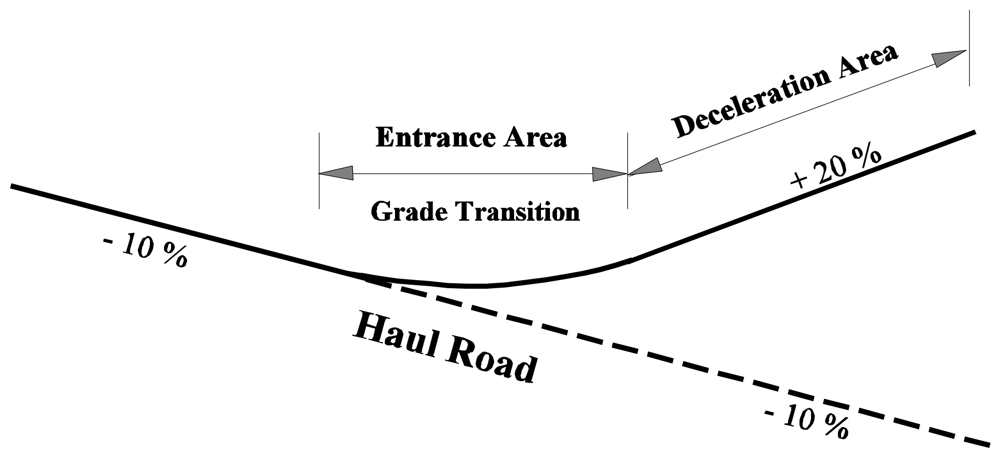


Gross Vehicle Weight, pounds	A, in feet	B, in feet	C, in feet
Less than 100,000	11 to 12	3.5 to 4	14 to 16
100,000 to 200,000	12 to 15	4 to 5	16 to 20
200,000 to 400,000	15 to 18	5 to 6	20 to 24
More than 400,000	18 to 32	6 to 11	24 to 44

Figure 5 - Guidance on Sizing of Center Berms



Plan View
Haul Road Escape Lane



Profile View
Haul Road Escape Lane

Figure 6 - Typical Escape Ramp Layout

TABLES

TABLE 1

Estimated Brake System Response Time (BSRT)
Based on Gross Vehicle Weight (GVW)

GVW, tons	1 to 18	18 to 35	35 to 70	70 to 125	125 to 200
BSRT, sec.	0.5	1.0	1.5	2.0	2.25

(Note: Values are based on the Society of Automotive Engineers (SAE) Standard J1152. These are the same values as used in Table M-1 of Sections 56/57.14101 of the regulations.)

TABLE 2

Typical Values for the Coefficient of Friction
Between Rubber Tires and Various Road Surfaces

Material	Dry	Wet
Concrete	.90	.60 - .80
Clay	.60 - .90	.10 - .30
Sand, loose	.10 - .20	.10 - .40
Quarry pit	.65	-

Material	Dry	Wet
Gravel road, firm	.50 - .80	.30 - .60
Gravel road, loose	.20 - .40	.30 - .50
Snow, packed	.10 - .40	~.00 -
Ice	~.00 -	~.00 -

TABLE 3

Typical Value for Rolling Resistance, Given in Equivalent Grade

Road Surface	Equivalent grade, %
Hard, smooth, stabilized roadway without penetration under load, watered, maintained	2
Firm, smooth surface flexing slightly under load or undulating, maintained fairly regularly, watered	3
Rutted dirt road, flexing under load, little maintenance, no watering, 1 to 2 inch tire penetration	5
Rutted dirt road, soft under travel, 4 to 5 inch tire penetration	7.5

TABLE 4
Stopping Distance Estimates in Feet on Level Road (Grade = 0 %)

Friction = 0.15 Truck GVW, tons	Truck Speed, mph 10	15	20	25	30
1 to 18	63	109	165	231	306
18 to 35	69	118	178	247	325
35 to 70	75	128	190	262	345
70 to 125	81	137	203	278	363
125 to 200	84	141	209	286	373
Over 200	87	146	215	294	382

Friction = 0.30 Truck GVW, tons	Truck Speed, mph 10	15	20	25	30
1 to 18	54	89	129	174	225
18 to 35	61	99	142	191	245
35 to 70	67	109	156	208	265
70 to 125	73	119	169	225	285
125 to 200	77	123	175	233	295
Over 200	80	128	182	241	305

Friction = 0.45 Truck GVW, tons	Truck Speed, mph 10	15	20	25	30
1 to 18	51	81	116	154	195
18 to 35	58	92	130	171	216
35 to 70	64	102	143	188	237
70 to 125	71	112	157	205	257
125 to 200	74	117	163	214	267
Over 200	77	122	170	222	277

Friction = 0.60 Truck GVW, tons	Truck Speed, mph 10	15	20	25	30
1 to 18	49	78	109	143	180
18 to 35	56	88	123	161	201
35 to 70	63	98	137	178	222
70 to 125	69	108	150	195	242
125 to 200	72	113	157	204	253
Over 200	76	118	164	212	263

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake-system-response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 5
Stopping Distance Estimates in Feet for 2 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	66	116	177	249	333
18 to 35	74	127	192	268	355
35 to 70	81	138	206	286	377
70 to 125	88	149	221	304	399
125 to 200	92	155	228	313	410
Over 200	96	160	236	323	421

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	55	91	133	180	232
18 to 35	62	102	147	198	254
35 to 70	70	113	162	216	276
70 to 125	77	124	177	235	298
125 to 200	81	130	184	244	309
Over 200	84	135	191	253	320

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	51	83	118	156	199
18 to 35	59	94	132	175	221
35 to 70	66	105	147	193	243
70 to 125	73	116	162	211	265
125 to 200	77	121	169	221	276
Over 200	81	127	176	230	287

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	50	79	110	145	182
18 to 35	57	90	125	163	204
35 to 70	64	101	140	182	226
70 to 125	72	112	154	200	248
125 to 200	75	117	162	209	259
Over 200	79	123	169	218	270

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 6
Stopping Distance Estimates in Feet for 4 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	71	126	193	274	367
18 to 35	80	139	210	295	393
35 to 70	89	152	228	317	418
70 to 125	98	165	245	338	444
125 to 200	102	172	254	349	458
Over 200	107	179	263	360	471

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	57	94	137	186	241
18 to 35	65	106	153	206	265
35 to 70	73	118	169	226	289
70 to 125	81	130	185	246	313
125 to 200	86	137	194	256	325
Over 200	90	143	202	267	337

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	52	84	120	160	203
18 to 35	60	96	135	179	226
35 to 70	68	108	151	199	250
70 to 125	76	120	167	218	273
125 to 200	81	126	175	228	285
Over 200	85	132	183	238	297

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	50	79	112	147	185
18 to 35	58	91	127	166	208
35 to 70	66	103	143	185	231
70 to 125	74	115	158	205	254
125 to 200	78	121	166	215	266
Over 200	82	127	174	225	278

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 7
Stopping Distance Estimates in Feet for 6 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	77	139	215	307	414
18 to 35	88	154	236	332	444
35 to 70	99	170	257	359	475
70 to 125	111	187	278	385	507
125 to 200	117	195	289	399	523
Over 200	123	204	300	412	539

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	58	97	142	193	251
18 to 35	67	110	159	215	277
35 to 70	77	124	177	237	304
70 to 125	86	138	195	260	330
125 to 200	91	145	205	271	344
Over 200	96	152	214	282	357

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	53	86	122	163	208
18 to 35	62	98	139	184	232
35 to 70	71	111	156	205	257
70 to 125	80	124	173	226	283
125 to 200	85	131	182	237	296
Over 200	89	138	191	248	309

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	51	80	113	149	187
18 to 35	59	93	129	169	212
35 to 70	68	105	146	189	236
70 to 125	77	118	163	210	261
125 to 200	82	125	171	221	273
Over 200	86	132	180	232	286

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 8
Stopping Distance Estimates in Feet for 8 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	86	157	247	355	481
18 to 35	100	177	272	386	519
35 to 70	114	197	299	419	558
70 to 125	129	218	326	452	597
125 to 200	137	229	340	469	617
Over 200	145	240	354	487	638

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	60	100	148	202	263
18 to 35	70	115	167	226	292
35 to 70	81	130	187	250	321
70 to 125	92	146	207	275	350
125 to 200	98	154	218	288	365
Over 200	104	163	228	301	380

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	54	87	125	167	213
18 to 35	63	101	143	189	239
35 to 70	73	115	161	211	266
70 to 125	84	130	180	234	293
125 to 200	89	137	189	246	307
Over 200	95	145	199	258	321

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	51	81	115	151	190
18 to 35	60	94	132	172	216
35 to 70	70	108	149	194	241
70 to 125	80	122	168	216	268
125 to 200	85	129	177	227	281
Over 200	90	137	186	239	295

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 9

Stopping Distance Estimates in Feet for 10 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	101	187	296	430	588
18 to 35	119	212	330	471	637
35 to 70	138	239	365	514	687
70 to 125	158	268	401	558	739
125 to 200	169	282	420	581	766
Over 200	180	298	439	604	793

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	62	105	155	212	277
18 to 35	74	121	176	238	309
35 to 70	86	138	198	266	341
70 to 125	99	156	221	294	374
125 to 200	106	166	233	308	391
Over 200	113	175	245	323	408

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	55	89	128	171	218
18 to 35	65	104	147	194	246
35 to 70	76	119	167	219	275
70 to 125	88	135	187	244	305
125 to 200	94	143	198	256	320
Over 200	100	152	208	269	335

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	52	83	116	153	194
18 to 35	62	96	134	176	220
35 to 70	72	111	153	199	247
70 to 125	83	126	173	222	275
125 to 200	89	134	183	235	290
Over 200	95	142	193	247	304

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 10
Stopping Distance Estimates in Feet for 12 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	127	240	386	566	779
18 to 35	152	276	434	624	848
35 to 70	180	315	484	685	920
70 to 125	211	357	536	749	995
125 to 200	227	378	563	781	1033
Over 200	244	401	591	815	1072

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	65	110	163	224	294
18 to 35	78	128	187	254	329
35 to 70	92	148	212	284	365
70 to 125	107	168	238	316	402
125 to 200	115	179	251	332	421
Over 200	123	190	265	349	441

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	56	91	131	175	225
18 to 35	67	107	151	201	255
35 to 70	79	124	173	227	285
70 to 125	92	141	195	254	317
125 to 200	99	151	207	268	334
Over 200	106	160	219	282	350

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	53	84	118	156	197
18 to 35	63	98	137	179	225
35 to 70	74	114	157	204	254
70 to 125	86	131	178	229	284
125 to 200	93	139	189	242	299
Over 200	99	148	200	256	314

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

TABLE 11
Stopping Distance Estimates in Feet for 14 % Downgrade

Friction = 0.15	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	187	363	595	882	1225
18 to 35	231	425	675	981	1342
35 to 70	280	492	761	1085	1464
70 to 125	333	564	851	1193	1591
125 to 200	362	602	898	1249	1657
Over 200	392	641	946	1307	1723

Friction = 0.30	Truck Speed, mph				
Truck, GVW, tons	10	15	20	25	30
1 to 18	68	116	173	239	315
18 to 35	83	137	200	272	354
35 to 70	99	159	228	307	394
70 to 125	117	183	258	343	437
125 to 200	127	196	274	362	458
Over 200	136	209	290	381	481

Friction = 0.45	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	57	93	135	181	232
18 to 35	69	110	156	208	264
35 to 70	83	129	180	236	297
70 to 125	97	148	204	266	332
125 to 200	105	159	217	281	350
Over 200	113	169	230	296	368

Friction = 0.60	Truck Speed, mph				
Truck GVW, tons	10	15	20	25	30
1 to 18	53	85	120	159	201
18 to 35	64	101	140	183	230
35 to 70	77	117	162	209	261
70 to 125	90	135	184	237	292
125 to 200	97	145	196	251	309
Over 200	105	155	208	265	325

Conditions used in stopping distance calculations:

- **Driver perception and reaction time equals 2.5 seconds.**
- **Rolling resistance considered equivalent to 2% grade.**
- **Change in vehicle speed during brake-system-response time taken into account.**
- **Brake system response time considered to vary with gross vehicle weight as per Table 1.**
- **Brake fade not considered; if brake fade occurs, longer stopping distances would apply.**
- **Use the lowest friction value (or attainable deceleration rate) that applies. The tire/road surface friction values (Table 2) only apply when the brakes are capable of exceeding the friction at the tire/road-surface. For loaded trucks, a coefficient of 0.30 can be considered to be a reasonable value for the friction that the brakes can provide.**

Table 12 Speed Based on Time to Travel 100 Feet

No. of seconds to travel 100 ft.	8.5	7.6	6.8	6.2	5.7	5.2	4.9	4.5	4.3	4.0	3.8	3.6
Speed, mph	8	9	10	11	12	13	14	15	16	17	18	19
No. of seconds to travel 100 ft.	3.4	3.2	3.1	3.0	2.8	2.7	2.6	2.5	2.4	2.35	2.3	1.9
Speed, mph	20	21	22	23	24	25	26	27	28	29	30	35

Table 13 Speed based on Time to Travel 200 Feet

No. of seconds to travel 200 ft.	17.0	15.1	13.6	12.4	11.3	10.5	9.7	9.1	8.5	8.0	7.6	7.2
Speed, mph	8	9	10	11	12	13	14	15	16	17	18	19
No. of seconds to travel 200 ft.	6.8	6.5	6.2	5.9	5.7	5.4	5.2	5.0	4.9	4.7	4.5	3.9
Speed, mph	20	21	22	23	24	25	26	27	28	29	30	35

Table 14
Guidance on Sharpest Curve for Given Speed, Banking, and Friction

Speed, mph	Cross-slope, percent	Side friction coefficient	Minimum curve radius, feet
20	0	.17	160
20	2	.17	140
20	4	.17	130
30	0	.16	375
30	2	.16	335
30	4	.16	300

Note that the friction values shown here are those typically recommended for designing highway curves.

Table 15
Guidance on Increase of Road Widths (in Feet) at Curves on Two Lane Road

Radius on inner edge of curve, feet.	Single Unit Trucks			Articulated Trucks	
	50 to 100 tons GVW	100 to 200 tons GVW	Over 200 tons GVW	50 to 100 tons GVW	100 to 200 tons GVW
25	10	11	21	22	48
50	6	7	12	10	28
100	3	4	5	6	12
200	2	2	3	2	2

Note: Derived from information in "Surface Mine Haulage Road Design Study," 1976

Table 16
Guidance on Length (in Feet) of Escape Ramps

Uphill Grade of Escape Ramp, in Percent	Estimated Speed of Vehicle at Entrance to Escape Ramp, Miles per Hour			
	30	40	50	60
5	200	356	555	800
10	150	267	417	600
15	120	213	333	480
20	100	178	278	400

Values in this table based on a rolling resistance of 200 pounds per ton of vehicle weight. This is equivalent to a loose sand. Note that the required length of an escape ramp can be shortened by adding a center berm to the ramp.

APPENDIXES

Appendix A Conversion Between Speed in Miles Per Hour and Feet Per Second

Conversions Between Speed in Miles Per Hour and Feet Per Second

Miles Per Hour	Feet Per Second
5	7.3
10	14.7
15	22.0
20	29.3
25	36.7
30	44.0
35	51.3
40	58.7

Feet Per Second	Miles Per Hour
5	3.4
10	6.8
15	10.2
20	13.6
25	17.0
30	20.5
35	23.9
40	27.3
45	30.7
50	34.1
55	37.5
60	40.9
65	44.3

Note: **Multiply miles per hour by 1.47 to obtain feet per second.**
Multiply feet per second by 0.68 to obtain miles per hour.

Appendix B Conversion Between Grade in Percent and Grade in Degrees

Percent	Degrees
	0.6
	1.1
_	1.7
	2.3
	2.9
	3.4
	4.0
	4.6
	5.1
	5.7
12	6.8
14	8.0
16	9.1
18	10.2
20	11.3
22	12.4
24	13.5
26	14.6
28	15.6
30	16.7
32	17.7
34	18.8
36	19.8
38	20.8
40	21.8
45	24.2
50	26.6
55	28.8
60	31.0
65	33.0

Degrees	Percent
	1.8
	3.5
	5.2
	7.0
	8.8
	10.5
	12.3
	14.0
	15.8
	17.6
	19.4
	21.3
	23.1
	24.9
	26.8
	28.7
	30.6
	32.5
	34.4
	36.4
	38.4
	40.4
	42.4
	44.5
	46.6
30	57.7
35	70.0
40	83.9
45	100.0

<u>Appendix C</u> <u>Determining the Radius of a Road Curve</u>

In investigating a haul road problem, there may be times when it would be useful to determine the radius of a curve. Not all curves necessarily follow a constant radius, but in most cases it will serve the purpose of indicating the severity of a curve by approximating it as part of a circle. The shorter the radius of the curve is, the sharper the curve.

Generally it is not convenient to directly measure the radius of a curve because you would have to determine by trial and error where the center of the circle would be located. Also, there may be obstructions which prevent direct measurement. But if part of an arc is measured, the radius of the arc can be calculated. To do this you need to measure a chord and a middle ordinate, as illustrated in the top portion of Figure C-1. The chord (distance AB) is the length of a straight line from one point to another point along the curve. This can be taken across either the outside or inside curve of the roadway and can be any convenient length across a representative portion of the curve. The middle ordinate (distance CD) is then the largest distance perpendicular to the chord from the arc of the curve. If the chord is measured across the outside arc of the curve and along (or tangent to) the inside arc of the curve, as shown in the lower illustration in Figure C-1, then the middle ordinate is simply the width of the roadway.

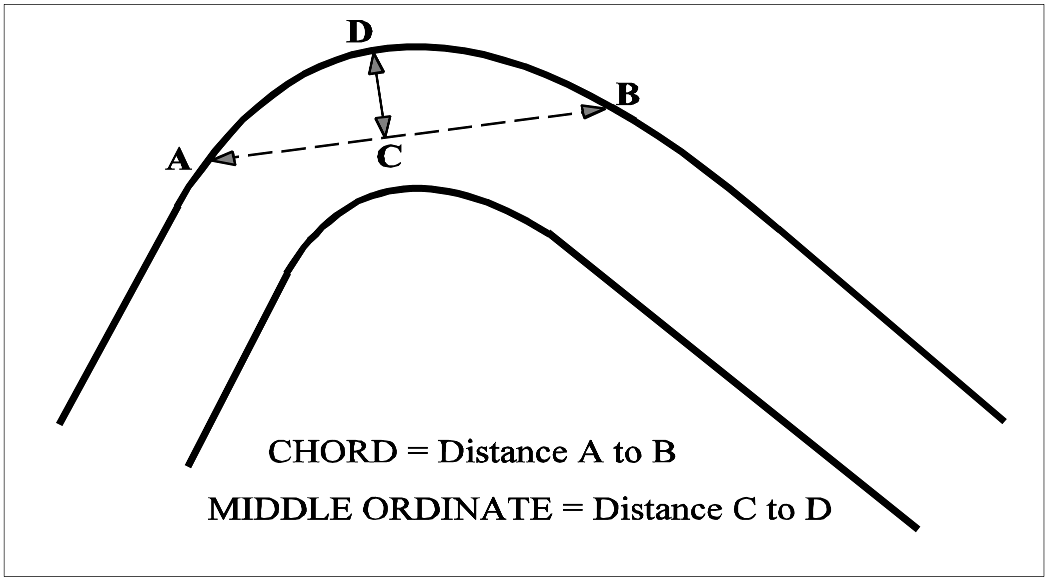
Once the chord and middle ordinate values are obtained, the radius of the curve can be calculated based on the following formula:

$$R = \frac{C^2}{8M} + \frac{M}{2}$$

where: R = radius of the curve, in feet
C = length of the chord, in feet
M = length of the middle ordinate, in feet

For example, if the chord is 600 feet long, and the middle ordinate measures 20 feet, then the radius of the arc is 2260 feet. The graph shown in Figure C-2 can be used to quickly solve the above equation. This graph is adapted from “The Traffic Accident Investigation Manual,” and has been included with the permission of the Northwestern University Traffic Institute. Use of the graph for the above example of a chord distance of 600 feet and a middle ordinate distance of 20 feet, is shown by the arrow to indicate the curve radius of 2260 feet. Note that the range of the scales in the graph in Figure C-2 can be extended by multiplying or dividing the values on the scales by 10, as was done in this example. If you do this, be sure to multiply the values ***on all three scales*** by 10.

The radius should be reported as either the inside curve, the centerline of the road, or the outside curve, whichever is measured. If one of these values is known, and the width of the roadway is known, then any of the values can be determined. That is, the radius of the outside curve is simply the radius of the inside curve plus the width of the road. In road plans, the radius of the centerline of the road is normally given.



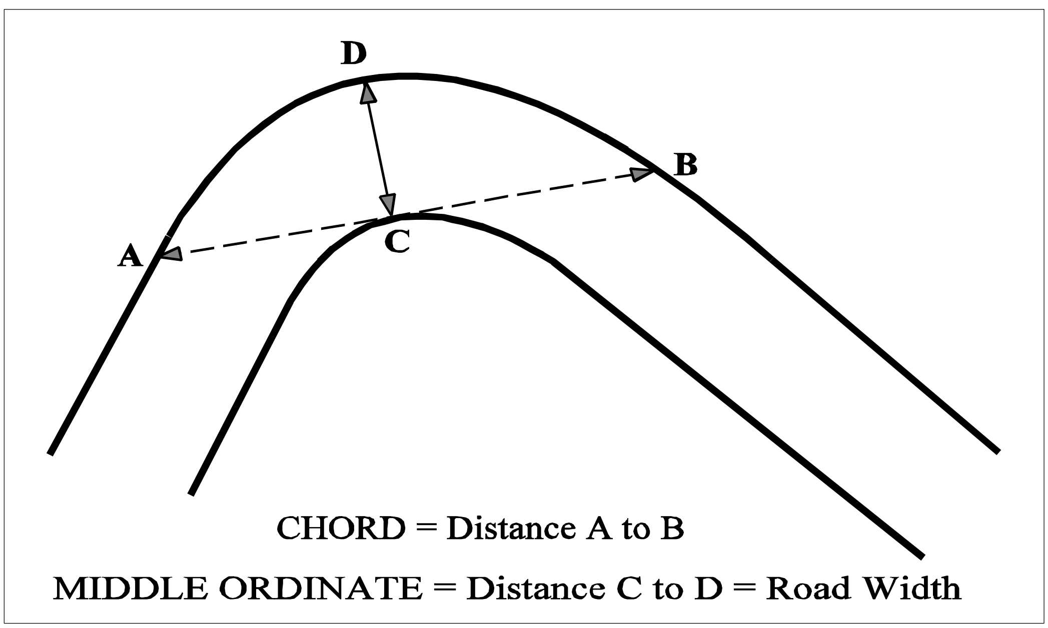
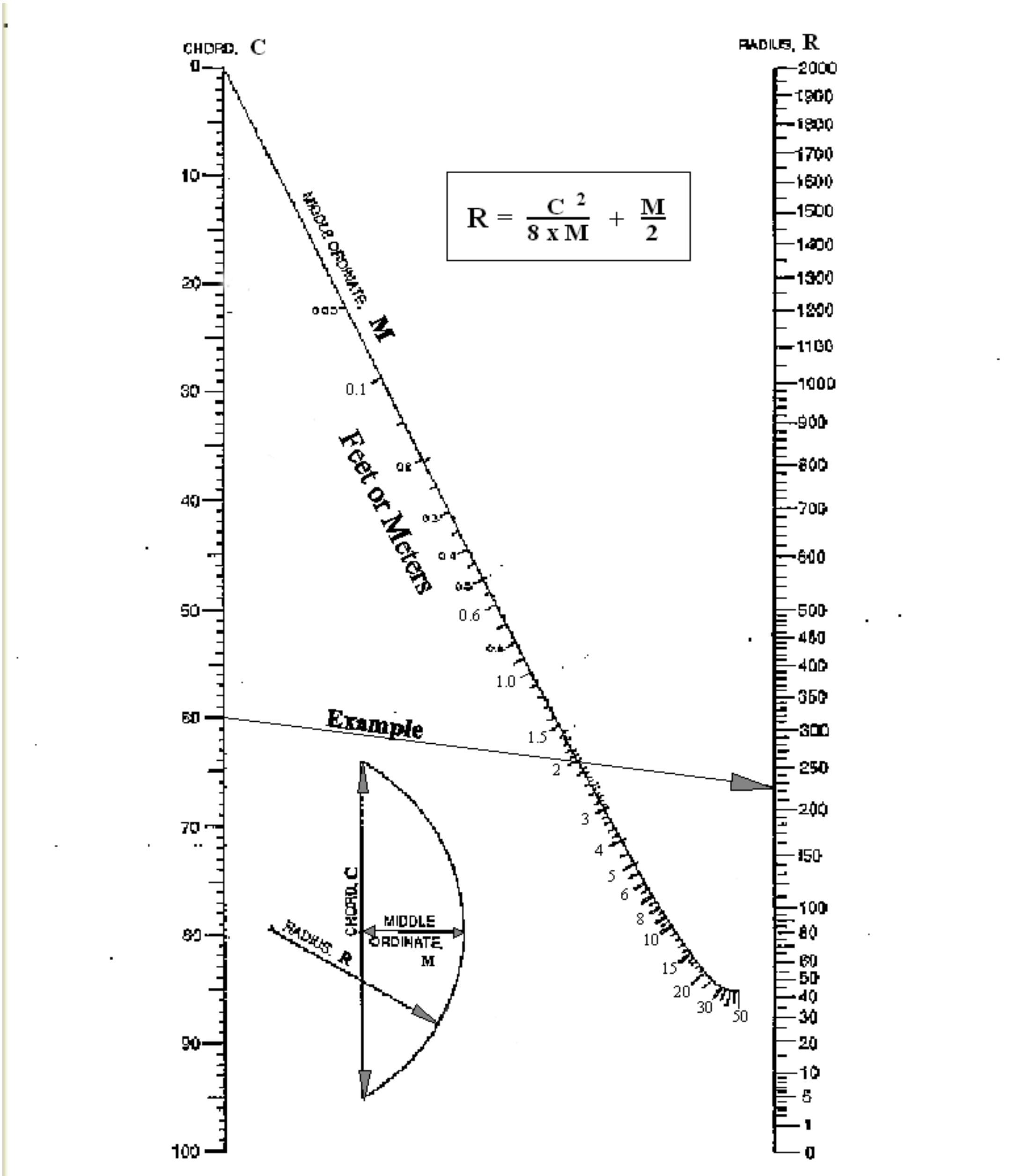


Figure C-1 Measurements to Determine the Radius of a Curve



Note: Scales are for feet or meters; to extend range, multiply or divide all scales by 10.

Example: For a chord of length, C, of 600 feet, and a Middle Ordinate, M, of 20 feet, the radius of the curve is 2260 feet.

Figure C-2 Graph for Determining the Radius of a Curve

Appendix D Stopping Distance Calculations

Stopping distance estimates are given in Tables 4 through 11 for various grades, friction coefficients (corresponding to different deceleration rates), and truck sizes. The tables are based on a driver perception and reaction time of 2.5 seconds, a rolling resistance equivalent to an adverse grade of 2%, and the brake system response times given in Table 1. To estimate the distance it will take to bring a vehicle to a stop, under other conditions, the equations used in estimating the three components of the stopping distance can be applied. They are explained below.

1. The first component of the stopping distance, D_1, is the distance that the vehicle travels during the time it takes for the driver to recognize that a stop is necessary and push on the brake pedal. This component accounts for the driver's perception and reaction time, which will vary by individual and circumstance. To allow for a variety of situations and driving abilities, an estimated perception and reaction time of 2.5 seconds, as recommended by the American Association of State Highway Officials, is used in the stopping distance tables in this handbook.

   So this component of the stopping distance is equal to (Equation 1):

$$D_1 = V_o \times DPRT$$

where: D_1 = First component of stopping distance, feet
V_o = Vehicle speed when stop is necessary, feet per second (fps)
DPRT = Driver Perception and Reaction Time, in seconds

(**Note:** Miles per hour are converted to feet per second (fps) by multiplying the miles per hour by 1.47. See Appendix A for a table of conversions.)

2. The second component of stopping distance, D_2, is the distance traveled in the time necessary for actuation of the braking system after the pedal is depressed. This lag time will vary depending on the size of the truck and the braking system. The values indicated in Table 1 are used in the stopping distance estimates provided in this handbook.

   The distance traveled during this brake lag time is equal to the average velocity (from when the brake pedal is pushed until the brakes are actually applied) times the brake-system-response-time (BSRT). During this lag time, a truck would tend to pick up speed if going downgrade, and lose speed if going level or upgrade. The speed when the brakes are actually applied can be estimated as the initial velocity plus the value of the acceleration due to gravity times the effective grade, times the brake system response time:

$$V_b = V_o + [32.2 \times g_{eff} \times BSRT]$$

where: V_b = Vehicle speed at end of brake system response time (fps)
32.2 = Acceleration due to gravity (feet per second per second)
g_{eff} = Effective grade of road, expressed as a decimal, i.e. (%grade/100); equals the actual grade minus the rolling resistance; consider downgrades as positive and upgrades as negative
BSRT = Brake system response time, in seconds (See Table 1)

Using this value for V_b, the second component of the stopping distance, in feet, is determined as shown below (Equation 2):

$$D_2 = \frac{(V_o + V_b)}{2} \times BSRT$$

3. The third component of the stopping distance, D_3, is the distance that the fully-applied brakes need to bring the vehicle to a stop. Assuming that the brakes are working properly, this distance depends on the speed of the vehicle when the brakes are applied, and on the vehicle's deceleration rate, which depends on the amount of friction available either between the brake components or between the tires and the road surface material (whichever is less governs). This component of the stopping distance can be estimated using the following equation (Equation 3):

$$D_3 = \frac{V_b^2}{64.4 \times (f - g_{eff})}$$

where: V_b = the speed of the vehicle when the brakes are applied, in feet per second. (See Part A of the Appendix to convert mph to feet per second)
f = coefficient of friction available for braking (determines the attainable deceleration rate), estimated as the lesser of the friction available either from the brake components or between the tire and road surface
64.4 = two times the acceleration of gravity, in feet per second squared
g_{eff} = effective grade of the road, in percent, divided by 100

The estimated total stopping distance is the sum of the three distances, D_1, D_2 and D_3.

It is important to note that in estimating the stopping distance, as explained above, the effect of brake "fade" is not taken into account. Brake "fade" refers to the loss of braking effectiveness that occurs from the buildup of heat in the brake components. It is a concern on long downgrades, especially for drum-type brakes, but it is unpredictable and difficult to quantify.

Also, these stopping distance estimates assume that the vehicles and the brakes are maintained, adjusted, and used as intended by the manufacturer.

EXAMPLE: On a 4 percent grade where the speed limit is posted as 25 mph, you estimate the available sight distance as 180 feet. Will a loaded truck with a gross vehicle weight (GVW) of 120,000 pounds (60 ton) have adequate sight distance when traveling this road at the posted speed limit? You estimate that a friction coefficient of 0.30 (average value typically achievable from brakes of loaded truck) would apply.

Estimate the stopping distance as follows: Estimate the driver perception and reaction time. A time of 2.5 seconds is used in this example. Estimate the brake system response time. Based on Table 1 a value of 1.5 seconds is used in this example. Estimate a value for rolling resistance, which is taken as equivalent to a 2% grade in this example. Determine from the table in Part A of the Appendix that 25 mph is equivalent to 36.7 feet per second. Express the grade and the rolling resistance as decimals, being equal to their values in percent divided by 100. Calculate the speed at the end of the brake system response time as follows:

$$V_b = V_o + [32.2 \times g_{eff} \times (BSRT)] = 36.7 + [32.2 \times (.04-.02) \times 1.5] = 37.7\ fps$$

Use the above information to calculate the three components of the stopping distance as shown below:

Equation 1	$D_1 = (36.7) \times (2.5)$	= 91.8 feet
Equation 2	$D_2 = [(36.7 + 37.7)/2] \times 1.5$	= 55.8 feet
Equation 3	$D_3 = [37.7 \times 37.7] / (64.4 \times (0.3 - (0.04-.02)))$	= 78.8 feet

The estimated total stopping distance is the sum of the three values, or 226.4 feet. Note that the same result is indicated in Table 6. Remember that this estimate applies to properly adjusted and maintained brakes with no brake “fade” taken into account.

Appendix E Coal Policy on Berms

Program Policy Manual, Volume V, Part 77, (Release V-1)

77.1605 Loading and Haulage Equipment; Installations

Paragraph (k) is applicable to all elevated roadways on mine property, including roads used to transport coal, equipment, or personnel, and regardless of the size, location, or characterization of the roadways. Berms or guards are required on all exposed banks of elevated roadways. Thus, elevated roadways with two exposed banks are required to have berms or guards on both sides.

Berms or guardrails are required along the section of an elevated roadway crossing the crest of an impounding structure when the structure has been built to its final crest elevation and when the section of road over the impounding structure is completed. However, temporary berms or guardrails are not required along the section of an elevated roadway where it crosses the working surface of the impounding structure while the site is under active construction. Placement of such temporary berms or guardrails can be detrimental to the overall, long-term integrity of the structure, since the optimum moisture content and the required compaction parameters would be adversely affected.

On elevated roadways, leading to or constructed on the inclined surfaces of the impounding structure, berms or guardrails are required to be maintained as the structure increases in height.

If active construction on an impounding structure is suspended for any reason, and the roadway has not yet achieved the final elevation in accordance with the approved construction plan, then berms or guardrails are required if the site is an elevated roadway.

The requirements of paragraph (k) apply to that part of an elevated haulage road where one bank is, or both are, unprotected by a natural barrier which will prevent vehicles or equipment from running off and rolling down the unprotected bank(s).

"Elevated roadways," as used in this requirement, are roadways of sufficient height above the adjacent terrain to create a hazard in the event that mobile equipment should run off the roadway. "Berm," as used in this Section, means a pile or mound of material at least axle high to the largest piece of equipment using such roadway and as wide at the base as the normal angle of repose provides. Where guardrails are used in lieu of berms, they shall be of substantial construction.

The width of the haulage road does not preclude the need for berms or guardrails.

Coal General Inspection Procedures Handbook, PH95-V-1, Release 3, (April 1, 1997)

<u>Procedures for Determining if Berms or Guards are required on Elevated Roadways in Accordance with 30 CFR 77.1605(k).</u> MSHA has determined that for off-highway, self-propelled mobile vehicle travel, an elevated mine roadway is that portion of the roadway where at least one embankment is not protected by a natural topographic barrier, and where a drop in grade or height can endanger an uncontrolled or sliding vehicle. Therefore a roadway on mine property is considered elevated when the embankment slope and height are equal to, or exceed, those slopes and heights shown in the chart on page 3-20 (*reproduced as Figure E-1 in this handbook).*

All elevated roadways shall be protected by adequate longitudinal guards. Such guards can be earthen berms or rock barriers, while others can be rails, cables or wire ropes attached to metal or wooden posts. These guards should be capable of moderating or limiting the force of an uncontrolled or sliding vehicle and assist the operator in regaining control.

The primary purpose for the guards is a visual warning and a physical sensation for an operator if an uncontrolled or sliding vehicle should tend to leave the roadway at a hazardous location. When these guards are present, an operator is first visually warned, and if the vehicle should drift off the roadway, there is an additional warning to redirect the vehicle and assist in regaining control.

Berms are used as primary means to guard elevated mine roadways. For acceptable berm construction results, the material should be placed on a solid road foundation and, depending on the grade of the roadway, have drainage openings at regular intervals. Nationally accepted hydraulic design precautions are to be taken to safely convey excess runoff over the embankment slope. For effective berm construction, the material should be dumped, its core densified and packed by mechanical equipment, and be at least as wide at the base as the normal angle of repose provides. It is strongly recommended that regular road maintenance include reconditioning and retention of the original configuration of the berm.

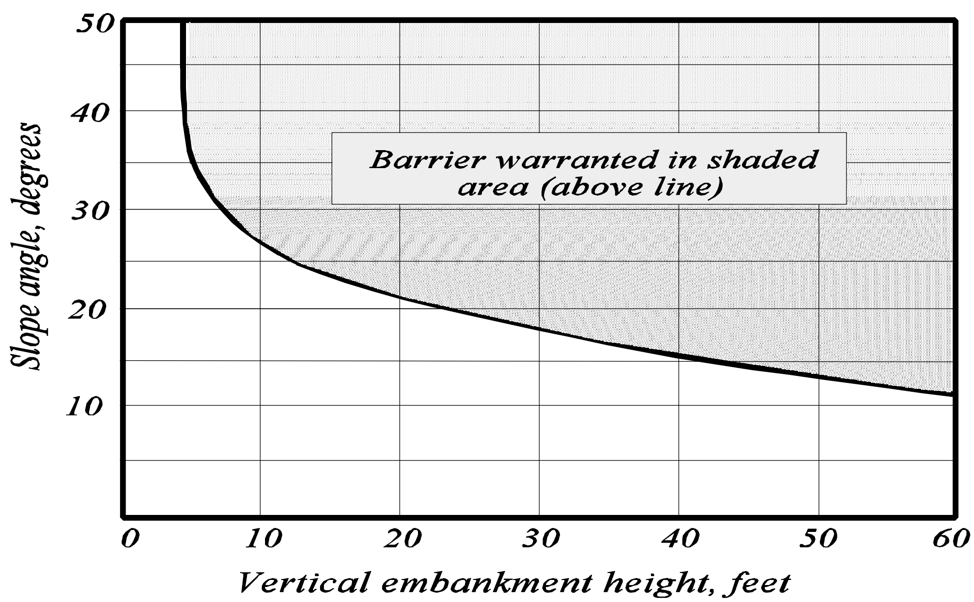
Rails, cables or wire ropes are also an acceptable means of guarding elevated roadways if the required metal or wooden posts are anchored in solid road foundation material according to nationally accepted design practices. Rock barriers are another acceptable means if they are placed on solid road foundation material according to nationally accepted design practices.

The above guards should be at least mid-axle height to the largest self-propelled mobile vehicle using the roadway. These guards will warn the operator when traveling too close to the edge of the roadway and will help deflect and redirect an uncontrolled or sliding vehicle.

A clear zone along roadways may be permitted as an alternative method to guards through a petition for modification. The District Manager should emphasize that clear zone distances in several studies were developed for highway-class vehicles by the American Association of State

Highway and Transportation Officials. Similar data for off-highway equipment is not available, and therefore a conservative extrapolation of highway-vehicle clear zone distances may provide a starting point for mine roads.

Similarly, when roadside guards cannot be constructed due to topography or other special mining conditions, an alternative method may be considered through a petition for modification. The alternative method may include reflectorized posts or signs that are tall enough and clearly visible to the operator of the largest vehicle using the roadway.



Barriers are warranted when the Slope Angle or Slope Height exceed those listed on chart.

GRADIENT	SLOPE, DEGREES	SLOPE HEIGHT, FT.	APPROX. SLOPE LENGTH, FT.
1:1	45	4	6
1.5:1	33.7	5	9
2:1	26.6	10	22
2.5:1	21.8	19	51
3:1	18.4	31	98
3.5:1	16.0	39	140
4:1	14.0	47	194
4.5:1	12.5	55	254

Figure E-1 Chart to Determine When Berms are Needed (Coal Only)