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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Release:
_9-388_
Date:
10/21/11_

MANUAL TRANSMITTAL SHEET

Subject

9113 – 1 – Roads Design Handbook

1. Explanation of Materials Transmitted:

This is an update of current manual and handbook on Roads; with the creation of Handbook 2 for Condition Assessment Protocols. Attached is the Manual Section Handbook 1 only, per Directives instructions. The Manual Section 9113 and Handbook 2 are under separate clearance sheets for each.

2. Reports Required: None.

3. Material Superceded: The material superseded by this Handbook Release is listed under "REMOVE" below.

4. Filing Instructions:

REMOVE	INSERT
9113- 1 – Road Design (Rel. 9-218)	9113 – 1- Roads Design Electronic Version
(Total: 10 sheets)	(Total: 33 sheets)

/s/ Jeanine Velasco
Assistant Director, Business and Fiscal Resources

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.1 Design.

.11 Surveys and Investigations. The type, accuracy requirements, and intensity of surveys and materials investigations are determined by the functional classification of the proposed road, land ownership, and the type of construction. Surveys and investigations supply data to the designer; therefore, the designer must work closely with the survey crew and soils/materials (geotechnical) investigation crews to assure that the required data is obtained. The designer directs the centerline survey and the location of soils/materials investigations by flagging on-the-ground locations or by plotting the proposed design alignment on large-scale topographic maps or aerial photos.

A. Aerial Surveys. Road projects of larger scope should consider use of an aerial survey. Precision, as indicated by the industry standard, should be reviewed to assure appropriate level of detail.

B. Ground Surveys. Ground surveys for road design are governed by the following guidelines:

1. Permission to Survey. The Bureau is required to obtain permission to survey or to investigate materials on lands not owned by the United States Government or not controlled by the Bureau of Land Management. Notify permittees and lessees whose operations might be affected by, or which could affect, survey or investigation work. Contact the field specialist and furnish information as necessary to obtain timely required permission or easements, or to notify concerned parties. Entry to commence such work occurs after the field specialist has notified the designer that permission has been received and/or notices have been sent.

2. Precision of Surveys. The accuracy requirements of road surveys, as shown in Illustration 1– Precision Requirements for Road Surveys must meet the following precision classes:

a. Collector Roads. Traverses, level circuits, and cross sections require precision class B.

b. Local Roads. Traverses not requiring easements are done to precision class C; easements require precision class B. Level circuits require precision class C, and cross sections require precision class D.

c. Resource Roads. Traverses not requiring easements are to precision class E; easements require precision class B. Level circuits require precision class E, and cross sections require precision class F.

3. Stationing. Stations are set continuously along centerline surveys at maximum 100-foot intervals, at all tangent and curve control points, at all fence or utility crossings, and at all breaks in ground profile where the centerline ground varies more than 1foot vertically from a straight line connecting the above points, and at all other points defined by industry

standard. Stations should also be set along curves at a maximum of 100 feet.

4. Topographic Survey. Survey existing built features (buildings, fences, utilities, existing road, etc.) and natural features (rock outcrops, streams, swamps, lakes, trees, and cacti to be preserved, etc.) that require special design considerations or that may affect construction operations. Show these features on the construction drawings.

5. Section Corner and Boundary Ties. All road centerline traverse surveys must be tied to the Public Land survey system, using the same precision required for the traverse. Ties should be made each time the centerline traverse crosses a section line or boundary line (ownership, withdrawal, reservation, etc.). If the traverse is within one section, a tie should be made near each end of the centerline traverse.

6. Establishing Bearings. Show all bearings for roadway centerlines.

7. Bridges and Major Culverts. See Manual Section 9112 – Bridges and Major Culverts.

8. Survey Notes. Survey notes are to be kept in a bound book or as typical for industry standard.

C. Soil Surveys and Material Site Investigation. Soils surveys and material site investigations furnish necessary information on the types of soils and physical limits of the various soils or materials that will be encountered on a project. The extent of survey and sampling and testing work required depends on the type and size of the project and the character of the soils.

1. Soil Surveys. Roads being designed for heavy loads, high volumes, or paving require more thorough and accurate sampling and testing to determine structural values. Extensive testing is advisable for projects with large earthwork volumes. The soil type and classification is determined through a detailed geotechnical report provided by a licensed geotechnical engineering firm. A soil survey includes a soils profile made along the proposed centerline. Establish a trial profile grade line and conduct an investigation to determine the soil horizons and limits by examining exposed soils, and using auger borings or test holes at sufficiently close intervals and of sufficient depth to identify changes in soil types. Use American Association of State Highway and Transportation Officials (AASHTO) classification, sampling, and testing procedures for road soil surveys. Visual classification is sufficient for lower standard roads that will not carry heavy loadings. Visual soil investigations and classifications should be done through use of the Unified Soil Classification System and in Illustration 2– Characteristics of Unified Soil Classification System Pertinent to Roads.

2. Materials Site Investigations. Designated materials sites are sampled and tested to determine if the volume and character of the material is adequate and if the material can meet the required specifications. Use AASHTO sampling and testing procedures for material site investigations.

3. Commercial Material Sources. Manufactured aggregates, ready-mix concrete, and other materials may be available from commercial sources. Sampling and testing for design purposes is unnecessary if the supplier furnishes required information and certification.

.12 Design Guidelines. Bureau roads are designed and constructed primarily to support the protection, development, use, and administration of public lands and resources with minimum impact on the environment. Bureau roads must ensure the safety of the user, but should respect the natural setting of the area. Designers of Bureau roads must be sensitive to national policy emphasizing safety, esthetics, protection and preservation of historic and cultural values, visual resource management objectives, and accessibility for the physically challenged. Designers of Bureau roads must incorporate these considerations in their designs.

A. Design Speed. Design speed determines the maximum degree of road curvature and minimum safe stopping, meeting, passing, or intersection sight distances. The design speed selected should be consistent with the anticipated speed users will drive on the constructed road. For example, in flat, open terrain where relatively straight alignment may induce drivers to travel relatively fast, low design speeds are unsafe.

1. Maximum Degree of Curvature. The maximum degree of curvature is determined by design speed, surface type, and the maximum superelevation rate. Using the maximum superelevation rate chosen by the designer see .12D – Superelevation of Curves, and the surface type of the proposed road, the maximum allowable curvature for various design speeds is determined using the rates shown in Illustration 3– Maximum Curvature and Recommended Superelevation Rates.

2. Sight Distances. Sight distances are those lengths of road the driver must be able to see to execute safely various vehicle operations. Sight distance requirements affect vertical curvature and may affect horizontal alignment by requiring easier curves to avoid sight obstructions due to terrain, vegetation, or built features. The designer may be required to adjust the horizontal or vertical curvature, the typical cross section, or to remove vegetation or built features to attain the required sight distances. Sight distance calculations are based on an eye height of 3.75 feet, and object height of 0.5 feet, and an opposing vehicle height of 4.50 feet. Driver perception and reaction time of 2.5 seconds is used. Since braking distance is related to surface type and weather conditions, it would be difficult to cover all foreseeable combinations of situations. Refer to Illustrations 4 through 8 for design guidance.

B. Horizontal Alignment. Alignment for higher standard roads should be as direct as possible with few curves and more than minimum sight distances. Coordinate horizontal alignment with vertical alignment to ensure user safety and comfort. Lower standard road designs should maintain a high quality alignment, but cost consideration may require that values normally required for higher standard road designs be lessened for construction economy. Accepted practices for good alignment design include the following:

1. Terrain. Fit the terrain.

2. Curve Length. Avoid short curves that provide the illusion of an angle. In open areas with long sight distances, the minimum curve length should be 500 feet for a 5 degree central angle. Where sight distance is limited, choose curves that appear to flow rather than curves that appear abrupt.

3. Reverse Curves. Avoid reverse curves separated by a short tangent. Where terrain dictates reverse curves, a tangent between curves of sufficient length to provide superelevation runoff without overlap is required.

4. Broken Back Curves. Broken back curves (two curves in same direction separated by a short tangent) should not be used. Substitute a longer curve or a compound curve.

5. Compound Curves. Compound curves may be used to fit the alignment closer to the natural contour, or to avoid the use of broken back curves. Compound curves should be limited to three separate curves, with the center curve being the sharpest, but not over 50% sharper than adjacent curves.

6. Alignment. Consistent alignment is safer and is more esthetically pleasing. Sharp curves at the end of long tangents, or a sharp curve among easy curves is hazardous. Where a sharp curve must be used, it should be approached by transitional, successively sharper curves from both directions to eliminate a sudden, unexpected, change for the driver.

C. Vertical Alignment. Controls on vertical alignment include maximum grade requirements for the applicable road standard see Manual Section 9113 - .23 Geometric Standards and the vertical curve length requirements for minimum sight distances.

1. Vertical Curves. Vertical curves must be long enough to provide minimum stopping sight distance throughout the road length and to provide a road that is safe, comfortable, pleasing in appearance, and adequately drained. Vertical curves longer than required for minimum sight distance should be used to reduce earthwork volume or to provide a better visual appearance.

a. Stopping Sight Distance (SSD). Minimum stopping sight distance must be met for the entire length of all roads. Refer to Illustrations 5 – 7 for design guidance.

b. Passing Sight Distance (PSD). Minimum passing sight distance should be met at regular intervals on two-lane roads. Higher-volume roads require more frequent passing opportunities than lower-volume roads. Construction costs are a major factor in determining passing sight distance needs.

c. Meeting Sight Distance (MSD). Minimum meeting sight distance must be met over the entire length of all single-lane road sections. Meeting sight distance is calculated as the sum of the opposing stopping sight distances. Distance adjustment for grades may be ignored since such adjustments tend to cancel one another. Vertical curves provide safe stopping sight distances. See Illustration 8 – Crest Vertical Curves Based on Minimum Meeting Sight Distance (Single Lane Roads Only) for determining crest vertical curve lengths. However, safe meeting sight distance may require that lateral clearance on the inside of horizontal curves be lengthened, or that a double-lane section be used and the lateral clearance provide minimum stopping sight distance.

2. Recommended Practices. Recommended practices for providing a desirable vertical alignment are as follows:

a. Coordinate vertical alignment and horizontal alignment to ensure a smooth flowing, safe, comfortable, and esthetically pleasing road.

b. Provide a grade requiring minimum earthwork. This limits costs, reduces erosion, and is more environmentally acceptable.

c. Provide a smooth vertical alignment with gradual changes consistent with class of road and character of terrain. Avoid an alignment with abrupt transitions.

d. Avoid grades less than 0.5 percent due to difficulty in providing drainage of side ditches.

e. Reduce grades around sharp curves, at intersections, at turnouts, and at turnarounds.

f. Avoid roller coaster and hidden-dip grades, even though they may reduce earthwork quantities (not applicable for very low cost roads). They will cause uncomfortable and possibly dangerous conditions for drivers.

g. When possible, avoid locating a vertical curve within a horizontal curve.

D. Superelevation of Curves. The selection of a maximum superelevation rate should depend on several factors: frequency and amount of ice and snow; amount and type of roadside development; and number of slow-moving vehicles. Illustration 9 – Minimum Superelevation Runoff Lengths provides recommended maximum superelevation rates for various design speeds. The minimum superelevation rate for any curve is not less than the normal crown rate for adjacent tangent sections. Superelevation is required on all roads with a design speed of 20 mph or greater. See Illustration 9 – Minimum Superelevation Runoff Lengths for runoff lengths for various superelevation rates and design speeds. One-third of this runoff occurs on the curve and two-thirds on the tangent. Increase runoff lengths where necessary to provide for better drainage or esthetics.

E. Cross Section Elements. The designer must determine the typical cross section(s). Changes in terrain, materials, visual resources, and vegetation may justify changing the typical cross section. Elements of the cross section include subgrade width, roadway crown or cross slope, side ditches, cut and fill slopes, widenings, and turnouts.

1. Subgrade Width. The subgrade width normally is equal to the traveled way width plus twice the taper width of surfacing materials. For an earthen road, the traveled way width is equal to the subgrade width. Extra widening for shoulder area may be provided where estimated ADT is over 400, or where special considerations justify a shoulder area. The taper of the surfacing material on surfaced roads provides a "usable" shoulder area if the tapered slope is 4:1 or flatter. The taper slope ratio should be approximately the same as the slope ratio selected for the flattest fills or side ditch inslope, but should never be steeper than 3:1. A taper slope ratio flatter than 4:1 may be provided if justified, but it should not be common practice. Select the total subgrade width to the nearest even 2 feet. Considerations for designing the subgrade width include the following:

a. Changes in subgrade soil support values may require a change of the surfacing thickness, resulting in a change in taper and subgrade width.

b. Using curbs may affect subgrade width.

c. In areas with steep side slopes, the typical section may be narrowed by reducing the side ditch or by forming the side ditch in the surfacing course. This may be done only if the surfacing material can be protected from saturation and if the ditch shape and dimensions are such that user safety is not compromised.

2. Road Crown. The road should be crowned to ensure proper drainage. All double-lane roads except insloped or outsloped roads must have a centerline or shoulderline crown. See .12E3 – Insloped or Outsloped Roads. Place shoulderline crowns with the downstream shoulder highest in order to prevent erosion of fills. Recommended slopes are as follows:

Earth Surface .03-.05 ft./ft.

Aggregate Surface .02-.04 ft./ft.

Paved Surface .02-.03 ft./ft.

3. Insloped or Outsloped Roads. A local road with a design speed of 20 mph or less may be insloped or outsloped for sections where the grade does not exceed 6%. (An insloped or outsloped road is a road without side ditches and superelevated curves.) Insloping or outsloping roads are not recommended unless the subgrade materials are resistant to erosion and traffic volume is extremely low. The slope across the roadway is the same as for normal crowns See .12E2 – Road Crown.

4. Cut and Fill Slopes. Cut and fill slopes provide: a structurally stable road, a safe recovery area for errant vehicles, minimum erosion susceptibility, and maximum revegetation possibility. Slopes steeper than 2:1 in level and rolling terrain or 1 1/2:1 in mountainous terrain must not be used, except as stated below. If the steepest allowable slopes do not intersect with the natural terrain within a reasonable distance, make adjustments in the alignment and/or grade, or provide retaining walls. Fills with heights less than the depth of the side ditch are designed and staked as a cut section to ensure

continuity of the side ditch.

a. The following slopes are suggested for use on Bureau roads. Where rock excavation is encountered, cut slopes may be steeper since weathered slopes should remain stable. Cut slopes may be steeper than recommended to reduce resource, environmental, or visual impacts; however, the angle of repose of the exposed material must not be exceeded.

b. Fill widening must be a minimum of 2 feet where the slope is 2:1 or steeper. Fill widening must be integrated with the normal embankment. Widening for curves and/or guardrails is determined independently of fill widening, and does not supersede fill widening requirements. See .12E9 – Curve and Guardrail Widening. Fill widening does not require widening of surfacing courses.

RECOMMENDED EARTH SLOPES
FOR BUREAU ROADS

Height of Cut or Fill (in Feet)	Level and Rolling Terrain	Mountainous Terrain
0-4	4:1	3:1
4-10	3:1	2:1
Over 10	2:1	1 ½:1[1]

[1]In clayey or silty soils subject to erosion, maximum slope should be limited to 2:1 or less, depending on stability of the soils.

c. Slopes can be sculptured to provide a more natural appearance. Sculpturing is recommended for major roads through areas of high visual quality. Consult with visual management specialist on the advisability of slope sculpturing. Sculpturing methods include:

(1) Flattening slope at cut-to-fill transitions;

(2) Laying back cutslopes where a cut intersects a natural drainage to provide a more natural appearance;

(3) Accenting natural ridges intersected by cuts with a steeper cut slope and wider rounding of intersection;

(4) Creating diversity in long cuts by flattening slopes to create false draws;

(5) Providing benches in rock cuts to accent natural strata;

(6) Leaving planting pockets in rock slopes;

(7) Leaving non-hazardous rock outcroppings to add variety; and

(8) Varying slopes to save specimen trees, rock outcrops, or other items of visual interest, provided they do not constitute a roadside hazard.

d. The intersection of cut and fill slopes with natural ground should be rounded to improve integration with the natural topography. Slopes are normally rounded for approximately 5 feet on each side of the intersection between the construction slope and natural ground.

e. Slope treatments include revegetation and other landscaping techniques used to stabilize slopes and retard erosion. Use serrated slopes, topsoil, mulch, and jute matting if local conditions justify them. Revegetation with native grass and wildflower species is preferred. Other landscape treatments such as tree and shrub plantings or selected thinning of adjacent vegetation can mitigate the impact of the construction in areas of high visual quality. The degree of treatment is scaled to the location and purpose of the road. Landscape treatments should be coordinated with a landscape architect.

5. Daylight Sections. Daylighting of cuts is recommended if the disturbed slope area is not excessive. To daylight a slope, use a ratio of approximately 100:1 beginning at the bottom of the side ditch.

6. Side Ditches. Side Ditches (borrow ditches) are adjacent to and parallel with the roadway shoulder. They also collect the runoff from the roadway from adjacent upstream areas if no intercept ditch is provided above the cut slope. The shape and dimensions of the ditch are selected to carry adequately the anticipated runoff from a major storm without saturation of subgrade or surfacing material. As it must be safe for errant vehicles, the ditch is wider for higher design speeds and has an inslope (the slope between the subgrade shoulder and the ditch bottom) of the same ratio as the flattest fill slope. Flat bottom ditches are recommended for higher speed roads, and slope slightly away from the traveled way. A minimum longitudinal gradient of 0.5 percent ensures good drainage. Vary ditch sections as required to satisfy differing conditions.

7. Turnouts. Turnouts are provided on single-lane roads for passing opposing traffic. Turnouts normally are spaced at a maximum distance of 1,000 feet. For higher volume or higher speed roads, a maximum distance of 700 feet is recommended. Locate turnouts where needed and where most economical. On haul roads, try to locate turnouts on the right side of the "empty" direction. The most economical locations for turnouts are usually on the low side in cuts, high side in fills, or at the transition between cuts and fills. Recommended turnout dimensions are 100 feet long with 50 foot transitions, but these may be changed to fit terrain. Width should be 10 feet. Eight foot width may be sufficient for longer turnouts. As vehicles generally come to a stop or are traveling at low speed at turnouts, the slope of the turnout may be less than the superelevation of the adjacent traveled way on curve sections.

a. Turnouts can provide a second lane to satisfy safe meeting sight distance requirements around blind curves; however, the design must still provide for safe stopping sight distance. The minimum width of turnouts should be at least 10 feet, with additional width recommended for roads serving oversized vehicles. The cross slope of the turnout is the same as the adjacent traveled way cross slope. Satisfying meeting sight distance requirements by providing lateral clearance or by flattening curves is preferable to using blind-curve turnouts. Widening of the traveled way with long turnouts encourages higher speeds and increases hazard.

b. Long turnouts are acceptable for double-lane roads with high traffic volumes and a mix of fast and slow-moving vehicles. They allow passing on uphill grades. Safe passing sight distance is not required if lane markings or signing prevent opposing traffic from entering the passing lane.

c. Turnarounds are provided as needed on single lane roads. Turnaround dimensions must be adequate to allow the average vehicle using the road to turn around with minimum maneuvering.

8. Vertical and Horizontal Clearance. A minimum vertical clearance of 16 feet must be provided. This applies to all obstructions within the 16 feet. Clearances on already existing roads of less than 14 feet must be properly signed. See Manual Section 9130 – Sign Manual. A minimum horizontal clearance of 4 feet from the edge of traveled way is recommended. A runoff distance that is safe, negotiable by errant vehicles, and free of hazards located adjacent to the edge of the traveled way is recommended. If safe runoff distances for roads with design speeds of 30 mph and above cannot be provided, seriously consider installing guardrails or other protective devices, particularly when the road is used by the general public.

9. Curve and Guardrail Widening. Curve, guardrail, and fill widening requirements are independent of one another, but widening for any cause is integrated with normal pavement structure construction operations. See .12E1 – Subgrade Width.

a. Guidelines for determining curve widening are given in AASHTO "A Policy on Geometric Design of Highways and Streets" and Attachment 1. Curve widening is generally placed on the inside of a curve, with the transition generally occurring at the same location as the superelevation transition.

b. A 2-foot widening of the pavement structure, in addition to any necessary fill or curve widening, is required wherever a guardrail is to be placed. Length of transition for guardrail widening is governed by visual acceptability and State requirements.

F. Earthwork Design. BLM encourages balanced earthwork design. Waste or borrow is discouraged unless material characteristics require it. Adjust alignment, gradient, or slopes to eliminate need for waste or borrow, or utilize retaining walls, cribs, typical section adjustments, etc., to provide a balanced design. Side-cast waste is environmentally unacceptable. Any waste and borrow areas must be located out of view of the constructed roadway and in environmentally acceptable locations. Embankments should be constructed with the addition of suitable moisture to obtain density. Compact the top foot of material beneath the pavement surface to a minimum of 95 percent maximum density as determined by AASHTO T-99 – “Moisture-Density Relations of Soils Using a 5.5-lb Rammer and a 12-in. Drop.”

G. Pavement Structures, Sections, and Compaction. Selection of materials typically used and available for construction in each state is recommended. BLM encourages the use of Federal Highway Administration's “Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects.” In addition, individual state Highway and Bridge Manuals and Specifications, distributed by that specific State Department of Transportation and/or Highways can be used to select appropriate materials, gradation, and compaction. See Illustrations 11 through 14 for typical sections and templates.

H. Drainage Elements. Proper drainage is critical in road design. Protection of the road, adjacent upstream land, and downstream lands depend upon proper drainage design. This requires knowledge of both hydrology and hydraulics.

1. Bridges and Major Culverts. Design must conform to Manual Section 9112 – Bridges and Major Culverts.

2. Drainage Culverts. Culverts are used for all minor drainage crossings, unless debris problems or unusually low volume justify the use of a ford. The ford must be safe and environmentally compatible. Very low volume resource roads that are outsloped or insloped are usually the only type that may utilize fords.

a. Culverts are to be designed using the appropriate hydraulic design procedures. Refer to AASHTO “Highway Drainage Guidelines” and State highway agencies for guidance. In addition, other publications are available from FHWA. Use any of the standard hydrologic and hydraulic design methods, but use a second method as a check to ensure that the solution is adequate but not extravagant. Special consideration may be necessary for debris passage.

b. The type of culvert is specified in the design. If possible, specify alternate acceptable culvert materials.

c. An 18-inch diameter or equivalent size is the smallest culvert normally used. Smaller sizes are difficult to clean and maintain.

d. Minimum recommended cover over a culvert is 12 inches or one-half the diameter, whichever is greater. Compliance with manufacturer’s recommendations for cover over various culvert materials is necessary.

e. Culverts carrying runoff from one side of the road to the other between natural drainages are spaced as shown in Illustration 10 – Spacing for Drainage Laterals, unless local experience dictates otherwise.

f. The inlet and outlet treatments of culverts include drop inlets, downspouts, energy dissipaters, flared ends, headwalls, riprap, paving, and beveled ends. Choose an end treatment that ensures that the culvert is properly protected, erosion is retarded, and the protrusion of the culvert is not a hazard to errant vehicles.

g. Culverts in small drainages should generally be aligned with the natural channel and with a gradient that maintains the natural drainage velocity so sedimentation or erosion is not increased. Culverts used as laterals are skewed to form an entrance angle of 45 to 60 degrees with the side ditch, and have a gradient equal to or slightly greater than the approach ditch gradient.

h. Culverts may be protected from debris by deflectors, racks, cribs, raisers, basins, spillways, or other controls. Incorporate debris protection as necessary.

i. Culverts must be designed for minimum impact on aquatic life. Open bottom shapes should be used if it is necessary to maintain the character of the streambed. If a closed bottom shape is used, install the culvert so the gradient does not exceed one-half percent, placing the invert at least 6 inches below the natural streambed, and fill the bottom with rock and gravel to simulate natural streambed characteristics. Any construction in fish-bearing streams must be accomplished during the time of year when the least aquatic environmental impact will occur.

3. Ditches and Channels.

a. Intercept ditches are used to intercept and carry sheet runoff to natural drainages before it can reach the roadway. A gradient of about 0.5 percent is recommended. Design intercept ditches to intercept and concentrate sheet runoff so the ditch does not erode.

b. Natural channels must be avoided when possible. If channel changes must be made, maintain the natural stream depth, width, general flow conditions, and characteristics as closely as possible. Use appropriate protective devices, such as gabions, deflectors, and plantings. Vegetation near banks can provide natural sediment filters, shade, and shadows. Vegetation on slopes adjacent to channels reduces erosion and provides a natural sediment filter.

4. Fords and Dips. Fords and dips may be used if they are not a hazard to traffic. Design fords and dips to provide safe stopping sight distance. The roadway must be stable and self cleaning. Place signs and flow depth markers to protect users.

5. Subsurface Drainage. Subsurface drainage is required to prevent failures due to excess moisture in the pavement structure beneath the surface course. Selection of appropriate material to allow water to drain is necessary. Intercept or drain water with subdrains if necessary. Prevent runoff from saturating the material by providing proper drainage away from the pavement structure.

I. Cattleguards. Cattleguards are placed normal to the roadway centerline on the finished roadway grade. If the road will be surfaced in the future, place the cattleguard at the final design elevation, with a 50-foot temporary ramp on each side to provide a smooth crossing. Use Bureau standard designs for all cattleguards. Cattleguard widths and design loads must meet requirements of Manual Section 9113-.25 – Structure Widths.

J. Signs and Markers. Each road design must include provisions for traffic control signing. Signs and markers must be in place prior to opening the road to traffic. These must meet the requirements of Manual Section 9130 – Sign Manual and the Federal Highway Administration's (FHWA) “Manual on Uniform Traffic Control Devices.” Roads open to traffic during construction must be signed in accordance with the FHWA's “Manual on Uniform Traffic Control Devices.”

.13 Specifications, Drawings and Cost Estimates. Specifications and construction drawings must describe the location, design, and work to be accomplished in sufficient detail to ensure the project is constructed according to the designer's intent and that materials and methods of construction meet or exceed the quality required by the design standards.

A. Specifications. BLM uses the current edition of the FHWA's “Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects” for construction of roads and bridges, with amendment by the designer as needed. Coordination with State standard specifications is also recommended. In addition, CSI specifications are also acceptable.

B. Drawings. Drawings are prepared according to Manual Section 9102 – Facility Design, regardless of type of funds used for project construction. See Manual Section 9112 – Bridges and Major Culverts for bridge and major culvert drawings.

C. Cost Estimates. Prepare cost estimates in accordance with Manual Section 9102 – Facility Design, regardless of type of funds used for project construction. Cost allowances for timber sale roads are prepared in accordance with appropriate cost schedules.

.14 Permits. Permits may be required whenever a Bureau road intersects with a Federal-Aid, county, or municipal highway. US Army Corps of Engineers Section 404 Clean Water Act permits may be required for stream crossings or construction in streambeds. Determine permit requirements and secure any needed permits in a timely manner in order to prevent construction delays. Permits that contain provisions affecting construction methods or schedules must be addressed in the plans and specifications.

.2 Construction. See Manual Section 9103 – Facility Construction. Construction stakes are placed as precisely as required for the design survey. See .11B2 – Precision of Surveys.

ITEMS	A	B	C	D	E	F
TRAVERSES						
Minimum linear closure	1/5000	1/3000	1/1000	1/600	1/300	1/100
Distance accuracy	1/7500	1/4500	1/1500	1/900	1/450	1/150
Angular accuracy *(use least value)*	1/7500. 30 sec. x √N¹ or 8.0 sec. per station. 2 sets, direct and reverse. 20 sec. rejection limit.	1/4500. 1 min. x √N¹ or 15 sec. per station. 1 set, direct and reverse. 1 min. rejection limit.	1/500. 90 sec. x √N¹ or 20 sec. per station.	1/900. If forward and backward bearings of tangents differ by more than 30 min. bearings must be computed as deflection angle traverse.	1/450. If forward and backward bearings of tangents differ by more than 1 deg., bearings must be computed as defection angle traverse.	1/150
LEVEL CIRCUITS						
Vertical error of closure on bench mark *(use least value)*	0.05√M² or 0.0015 foot per station in level circuit.	0.1 √M² or 0.0025 foot per station in level circuit.	0.25 √M² or 0.005 foot per station in level circuit.	1.0 √M² or 0.02 foot per station in level circuit.	2.0 √M² or 0.04 foot per station in level circuit.	4.0 √M² or 0.1 foot per station in level circuit.
CROSS SECTIONS						
Allowable deviation of the line projection from a true perpendicular to tangents and a true bisector of angle points.	±2º	±2º	±3º	±3º	±4º	±4º
Topography measurements must be taken so that variations in ground from a straight line connecting the cross section points will not exceed:	1.5'	1.5'	2.0'	2.0'	2.5'	3.0'
Horizontal and vertical accuracy, in feet, or percentage of horizontal distance measured from traverse line, which-ever is greater.	0.1' to 0.5%	0.1' to 0.5%	0.2' to 1.0%	0.2' to 1.5%	0.3' to 2.0%	0.4' to 3.0%
SLOPE STAKES, REFERENCES, AND CLEARING LIMIT STAKES						
Horizontal and vertical accuracy, in feet, or percentage of horizontal distance measured from centerline or reference stake, whichever is greater.						
a. Slope reference stakes and slope stakes.	0.1'	0.1' to 0.5%	0.2' to 1.0%	0.2' to 1.5%	0.2' to 1.5%	0.3' to 2.0%
b. Clearing limits.	1.0'	1.0'	1.0'	1.5'	1.5'	2.0'

Derived from information included in BLM "Manual of Surveying Instructions, 1973."

ILLUSTRATION 1 – PRECISION REQUIREMENTS
FOR ROAD SURVEYS

Major Divisions (1)	(2)	Letter (3)		Symbol: Hatching (4)	Symbol: Color (5)	Name (6)	Value as Foundation When Not Subject to Frost Action (7)	Value as Base Directly Under Bituminous Pavement (8)	Potential Frost Action (9)	Compressibility and Expansion (10)	Drainage Characteristics (11)	Compaction Equipment (12)	Unit Dry Weight (lbs.per.cu.ft.) (13)	Field CBR (14)	Subgrade Modules, k, (lbs.per.cu.ft.) (15)
Coarse-grained Soils	Gravel and Gravelly Soils	GW			Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Good	None to Very Slight	Almost None	Excellent	Crawler-type Tractor, Rubber-tired Equipment, Steel-wheeled Roller	125-140	60-80	300 or More
		GP			Red	Poorly-graded gravels or gravel-sand mixtures, little or no fines	Good to Excellent	Poor to Fair	None to Very Slight	Almost None	Excellent	Crawler-type Tractor, Rubber-tired Equipment, Steel-wheeled Roller	110-130	25-60	300 or More
		GM	d		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to Excellent	Fair to Good	Slight to Medium	Very Slight	Fair to Poor	Rubber-tired Equipment, Sheepsfoot Roller, Close Control of Moisture	130-145	40-80	300 or More
		GM	u		Yellow		Good	Poor	Slight to Medium	Slight	Poor to Practically Impervious	Rubber-tired Equipment, Sheepsfoot Roller	120-140	20-40	200-300
		GC			Yellow	Clayey gravels, gravel-sand-clay mixtures	Good	Poor	Slight to Medium	Slight	Poor to Practically Impervious	Rubber-tired Equipment, Sheepsfoot Roller	120-140	20-40	200-300
		SW			Red	Well-graded sands or gravelly sands, little or no fines	Good	Poor	None to very Slight	Almost None	Excellent	Crawler-type Tractor, Rubber-tired Equipment	110-130	20-40	200-300
		SP			Red	Poorly graded sands or gravelly sands, little or no fines	Fair to Poor	Poor to Not Suitable	None to very Slight	Almost None	Excellent	Rubber-tired Equipment, Sheepsfoot Roller	120-135	10-25	200-300
		SM	d		Yellow	Silty sands, sand-silt mixtures	Good	Poor	Slight to High	Very Slight	Fair to Poor	Crawler-type Tractor, Rubber-tired Equipment	105-130	20-40	200-300
		SM	u		Yellow		Fair to Poor	Not Suitable	Slight to High	Slight to Medium	Poor to Practically Impervious	Rubber-tired Equipment, Sheepsfoot Roller	105-130	10-20	200-300
Fine-grained Soils	Sand and Sandy Soils	SC			Green	Clayey sands, sand-clay mixtures	Fair to Poor	Not Suitable	Slight to High	Slight to Medium	Poor to Practically Impervious	Rubber-tired Equipment, Sheepsfoot Roller, Close Control of Moisture	100-130	10-20	200-300
		ML			Green	Inorganic Silts and Very Fine Sands, Rock Flour Silty or Clayey Fine Sands, or Clayey Silts with Slight Plasticity	Fair to Poor	Not Suitable	Medium to Very High	Slight to Medium	Fair to Poor	Rubber-tired Equipment, Sheepsfoot Roller, Close Control of Moisture	100-125	5-15	100-200
		CL			Green	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays	Fair to Poor	Not Suitable	Medium to Very High	Medium	Practically Impervious	Rubber-tired Equipment, Sheepsfoot Roller	100-125	5-15	100-200
		OL			Blue	Organic Silts and Organic Silt Clays of Low Plasticity	Poor	Not Suitable	Medium to Very High	Medium to High	Poor	Rubber-tired Equipment, Sheepsfoot Roller	90-105	4-8	100-200
		MH			Blue	Inorganic Silts, Micaceous or Diatomaceous Fine Sandy or Silty Soils, Elastic Soils	Poor	Not Suitable	Medium to Very High	High	Fair to Poor	Sheepsfoot Roller	80-100	4-8	100-200
		CH			Blue	Inorganic Clays or High Plasticity, Fat Clays	Poor to Very Poor	Not Suitable	Medium	High	Practically Impervious	Sheepsfoot Roller	90-110	3-5	50-100
		OH			Blue	Organic Clays of Medium to High Plasticity, Organic Silts	Poor to Very Poor	Not Suitable	Medium	High	Practically Impervious	Sheepsfoot Roller	80-105	3-5	50-100
Highly Organic Soils		Pt			Orange	Peat and Other Highly Organic Soils	Not Suitable	Not Suitable	Slight	Very High	Fair to Poor	Compaction Not Practical			

Notes:

1. Column 3: Division of GM and SM groups into subdivisions of "d" and "u" are for roads only; subdivision is on basis of Atterburg Limits: suffix "d" (e.g. GMd) will be used when the liquid limit is 28 or less and the plasticity index is 5 or less: the suffix "u" will be used when the liquid limit is greater than 28.

2. Column 7: Values are for subgades and base courses except for base course directly under bituminous pavement.

3. Column 8: The term "excellent" has been reserved for base materials consisting of high-quality processed crushed stone.

4. Column 13: The equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift as properly controlled. In some instances, several types of equipment are listed because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.

4. a. Processed base materials and other angular materials. Steel-wheeled rollers are recommended for hard angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials subject to degradation.

4. b. Finishing. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.

5. Column 13: Unit dry weights are for compacted soils at optimum moisture content for modified AASHTO compactive effort.

The Unified Soil Classification System, Appendix B, Army Engineer Waterways Experiment Station, Vicksburg, MS, May 1967.

ILLUSTRATION 2 – CHARACTERISTICS OF UNIFIED SOIL CLASSIFICATION SYSTEM PERTINENT TO ROADS

MAXIMUM DEGREE OF CURVE (MINIMUM RADIUS) FOR
VARIOUS SURFACE TYPES, DESIGN SPEEDS, AND
MAXIMUM SUPERELEVATION RATES

SURFACE TYPE	DESIGN SPEED (MPH)	SIDE-FRICTION FACTOR	MAXIMUM SUPELEVATION RATE (%)				
			2	4	6	8	10
PAVED	10	.16	115°(50')	115°(50')	115°(50')		
	15	.16	73°(79')	77°(74')	81°(71')		
	20	.16	38°(150')	44°(130')	48°(120')		
	30	.16		18°(320')	21°(270')	23°(250')	
	40	.15		10°(500')	11°(510')	12°(480')	13°(430')
	50	.14		6°(930')	7°(830')	8°(760')	8°(690')
UNPAVED	10	.12	115°(50')	115°(50')	115°(50')		
	15	.12	52°(110')	61°(94')	70°(82')		
	20	.10	26°(220')	30°(190')	34°(165')		
	30	.09		12°(460')	14°(385')	15°(350')	
	40	.09		7°(820')	8°(720')	9°(630')	10°(560')
	50	.10		4°(1400')	5°(1200')	6°(1000')	6°(930')

Notes:

1. Values have been rounded to nearest even degrees and to two significant figures for radii.
2. Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 3 – MAXIMUM CURVATURE AND RECOMMENDED SUPERELEVATION RATES

WET PAVEMENT – MINIMUM STOPPING SIGHT DISTANCES					
DESIGN SPEED (MPH)	ROAD GRADE (%)				
	+16 TO +10	+10 TO +3	+3 TO -3	-3 TO -10	-10 TO -16
10	45	50	50	50	55
15	75	75	80	85	90
20	115	120	125	135	150
30	180	190	200	225	240
40	235	260	275	325	375
50		320	350	450	

WET PAVEMENT – MINIMUM INTERSECTION SIGHT DISTANCE						
DESIGN SPEED (MPH) OF MAJOR ROAD	10	15	20	30	40	50
MINIMUM INTERSECTION SITE DISTANCE (FT)	100	150	200	300	400	500

MINIMUM PASSING SIGHT DISTANCE						
DESIGN SPEED (MPH)	10	15	20	30	40	50
MINIMUM PASSING SITE DISTANCE (FT)	500	700	850	1100	1500	1800

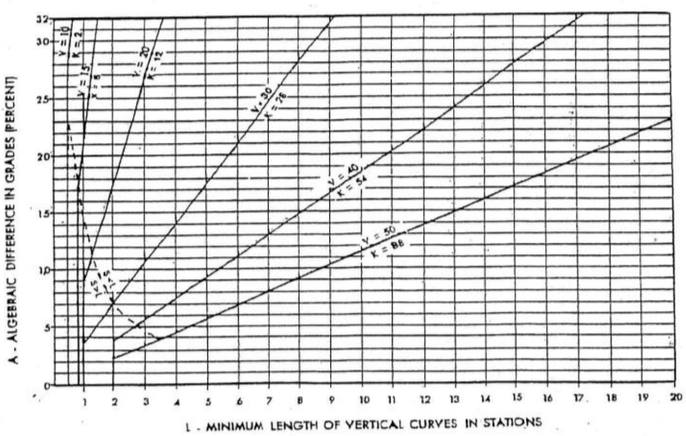
MINIMUM MEETING SIGHT DISTANCE				
DESIGN SPEED (MPH)	10	15	20	30
MINIMUM MEETING SITE DISTANCE (FT)	100	160	250	400

Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 4 – MINIMUM SIGHT DISTANCE

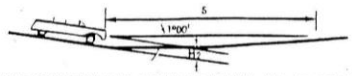
Height of Eye, (H_1), is 3.75' Above Roadway
Height of Object, (H_2), is 0.50' Above Roadway

L=LENGTH OF VERTICAL CURVE IN FEET A=ALGEBRAIC DIFFERENCE IN GRADE(%) S=SIGHT DISTANCE IN FEET	DESIGN SPEED M.P.H. (V)	MINIMUM SIGHT DISTANCE, (S) REQUIRED, IN FEET	K=RATE OF VERTICAL CURVATURE, LENGTH PER PERCENT OF A	MINIMUM LENGTH OF VERTICAL CURVE WHEN S>L
$L = \frac{AS^2}{200(\sqrt{H_1}+\sqrt{H_2})^2}$ WHEN S<L	10	50	2	50
	15	80	3	80
$S = 37.4\sqrt{L/A}$	20		12	100
$K = \frac{L}{A}$ or $L = KA$ Rounded for Design	30	200	28	100
	40	275	54	200
	50	350	88	200



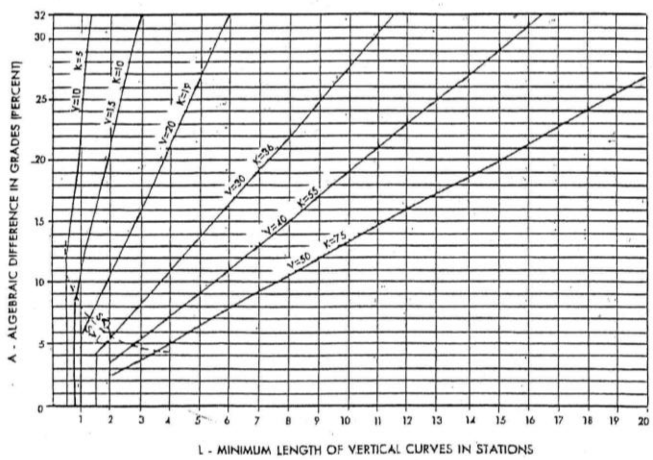
Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 5 – CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE



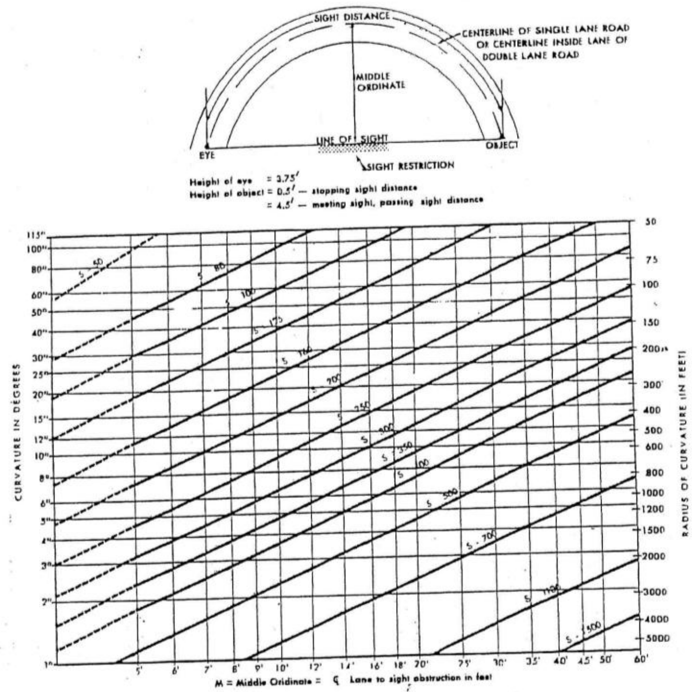
HEIGHT OF HEADLAMP ABOVE ROADWAY (H_2), IS 2.00 FEET

L=LENGTH OF VERTICAL CURVE IN FEET A=ALGEBRAIC DIFFERENCE IN GRADE(%) S=SIGHT DISTANCE IN FEET	DESIGN SPEED M.P.H. (V)	MINIMUM SIGHT DISTANCE (S) REQUIRED, IN FEET	K=RATE OF VERTICAL CURVATURE LENGTH PER PERCENT OF A	MINIMUM LENGTH OF VERTICAL CURVE WHEN S>L
$L = \frac{AS^2}{200 H_2 + 3.5S}$ When S<L	10	50	5	50
	15	80	10	80
	20	125	19	100
$K = \frac{L}{A}$ OR $L = KA$ Rounded for Design	30	200	36	150
	40	275	55	200
	50	350	75	200



Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 6 – SAG VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

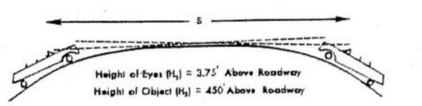


INSTRUCTIONS: Single lane road — determine minimum meeting sight distance required (See Illustration 3) and select combination of horizontal curve and middle ordinate that intersect at or below the respective diagonal sight distance line on the chart. If combination is not feasible, provide turnout throughout length of curve and check to see that required stopping sight distance (See Illustration 3) is provided, and if not, adjust curvature and/or middle ordinate as required.

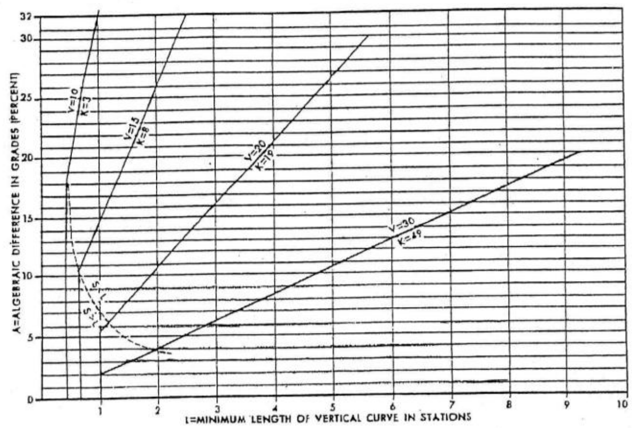
Double lane road — Determine minimum stopping sight distance required (See Illustration 3) and select combination of horizontal curve and middle ordinate that intersect at or below the respective diagonal sight distance line on chart. Use similar method to determine if minimum passing sight distance (See Illustration 3) is provided. Make adjustments in curvature and/or middle ordinate if minimum passing sight distance is desired.

Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 7 – SIGHT DISTANCES PROVIDED BY VARIABLE LATERAL CLEARANCE AND CURVE COMBINATIONS



L=LENGTH OF VERTICAL CURVE IN FEET A=ALGEBRAIC DIFFERENCE IN GRADE (%) S=SIGHT DISTANCE IN FEET	DESIGN SPEED M.P.H. (V)	MINIMUM SIGHT DISTANCE, (S) REQUIRED, IN FEET	K=RATE OF VERTICAL CURVATURE LENGTH PER PERCENT OF A	MINIMUM LENGTH CURVE WHEN S>L
$L = \frac{AS^2}{200(\sqrt{H_1}+\sqrt{H_2})^2}$ WHEN S<L	10	100	3	50
	15	160	8	80
$K = \frac{L}{A}$ or $L = KA$ — Rounded for Design	20	250	19	100
	30	400	49	100



Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

ILLUSTRATION 8 – CREST VERTICAL CURVES BASED ON MINIMUM MEETING SIGHT DISTANCE
(Single Lane Roads Only)

SUPERELEVATION RATE (%)	DESIGN SPEED (MPH)					
	10	15	20	30	40	50
2	24	27	30	36	42	48
3	36	41	45	54	63	72
4	48	54	60	72	84	96
5	60	68	70	90	105	120
6	72	82	95	108	126	144
7				126	147	168
8				144	168	192
9				162	189	216
10				180	210	240

NOTES:

1. Use 0.75 of values shown for single lane roads with centerline crowns.
2. Use values shown for double lane roads and shoulder crowned single lane roads.
3. Derived from AASHTO “A Policy on Geometric Design for Highways and Streets, 2004.”

ILLUSTRATION 9 – MINIMUM SUPERELEVATION RUNOFF LENGTHS

Recommended Spacing for Lateral Drainage Culverts in Various Soil Types*

Soil Types	Erosion Index 10	20	30	40	50	60	70	80	90	100
Silty sands, sand-silt mixtures, inorganic silts and very fine sands, silty or clayey fine sands	x	x								
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts, organic silts or organic silty clays or low plasticity, inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			x	x						
Organic clays of medium to high plasticity, organic silts, inorganic clays of high plasticity, fat clays, clayey sands, sand-clay mixtures, silty-gravels, gravel-sand-silt mixtures					x	x				
Clayey gravels, gravel-sand-clay mixtures							x			
Clean sands or clean gravelly sands								x	x	
Clean gravels or sand-gravel mixtures										x

* Unified Soil Classification

Recommended Spacing (ft)

Gradient (%)	Erosion Index 10	20	30	40	50	60	70	80	90	100
2	900	1225								
3	600	815	1070	1205						
4	450	610	800	905	1015					
5	360	490	640	725	810	865	1000			
6	300	410	535	605	675	720	835	1010		
7	255	350	455	515	580	620	715	865	1030	1210
8	225	305	400	450	505	540	625	755	900	1055
9	200	270	355	400	450	480	555	670	800	940
10	180	245	320	360	405	435	500	605	720	845
11	165	220	290	330	370	395	455	550	655	770
12	150	205	265	305	340	360	415	505	600	705
13	140	190	245	280	310	335	385	465	555	650
14	130	175	230	260	290	310	355	430	515	605
15	120	165	215	240	270	300	335	405	480	565
16	115	20	200	225	255	280	310	380	450	530

Note: This table is based on rainfall intensities of 1 to 2 inches per hour following a 15 minute period with an expected interval reoccurance of 25 years. For areas having intensities other than 1 to 2 inches per hour, divide values in the table as follows:

Rainfall Intensity	Divisor
2-3 inches per hour	1.50
3-4 inches per hour	1.75
4-5 inches per hour	2.00
Less than 1 inch per hour	Whatever the intensity (.75, .85, etc.)

Derived from AASHTO "A Policy on Geometric Design of Highways and Streets, 2004."

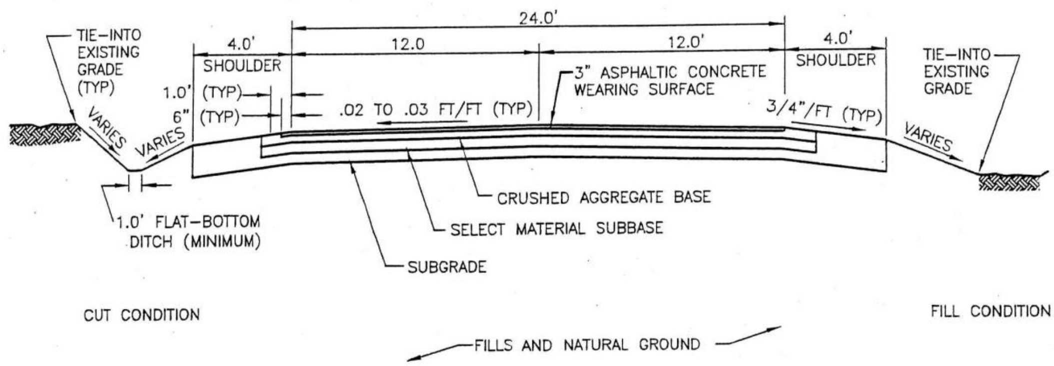
ILLUSTRATION 10 – SPACING FOR DRAINAGE LATERALS

SURFACE COURSE (OR WEARING COURSE)
INTERMEDIATE COURSE(S)
BASE COURSE
SUBBASE COURSE
SELECT MATERIAL
COMPACTED SUBGRADE
COMPACTED FILLS
UNCOMPACTED SUBGRADE

SUBSOIL

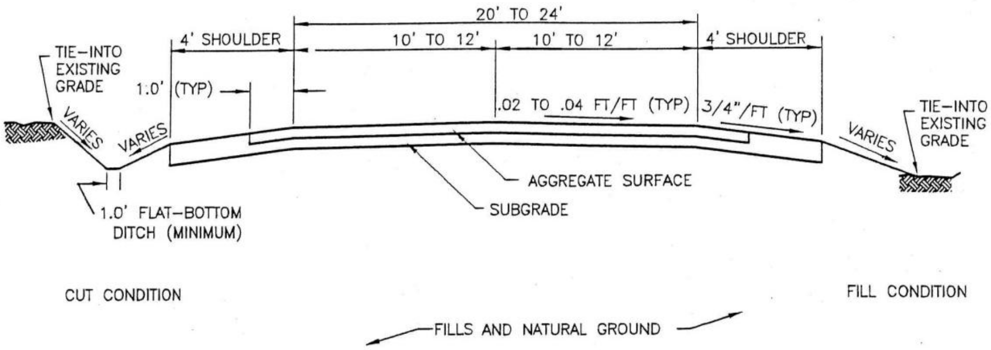
Notes:
1. The tack coat would be placed between the surface course and intermediate course(s). The prime coat would be place between the intermediate course(s) and the base course.
2. The flexible pavement structure, aggregate pavement structure, and rigid pavement structure consist of the layers from the surface course through the compacted subgrade, inclusive.
3. The word “structure” is often deleted from the phrases “flexible pavement structure,” “aggregate pavement structure,” and “rigid pavement structure.”
4. Developed by M. A. Nelson, PE, BLM, 2009.

ILLUSTRATION 11 – TYPICAL SECTION ILLUSTRATING TYPICAL PAVEMENT STRUCTURE TERMINOLOGY



Developed by M. A. Nelson, PE, BLM, 2009.

ILLUSTRATION 12
TYPICAL ROADWAY SECTION – FLEXIBLE PAVEMENT
(ASPHALTIC CONCRETE)
NOT TO SCALE

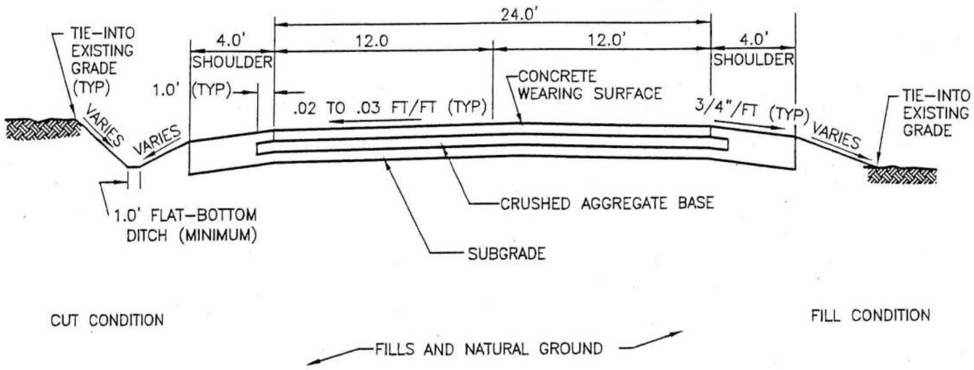


Developed by M. A. Nelson, PE, BLM, 2009.

ILLUSTRATION 13

TYPICAL ROADWAY SECTION – AGGREGATE PAVEMENT

NOT TO SCALE



Developed by M. A. Nelson, PE, BLM, 2009.

ILLUSTRATION 14
TYPICAL ROADWAY SECTION
RIGID PAVEMENT (CONCRETE)
NOT TO SCALE

ATTACHMENT 1
CURVE WIDENING

An outline of considerations and minimum lane width (MLW) equations for the determination of widening roads required on some curves to provide for off-tracking of tractor-trailer vehicles and for some light vehicle-trailer combinations are shown below. This widening is referred to as curve widening. Exhibits A and B are graphs developed from the minimum lane width equation and the vehicle configuration described.

I. CONSIDERATIONS.

A. DESIGN VEHICLE

1. GENERAL DESCRIPTION. Curve widening is considered part of the traveled way. As such, the determination of the amount of widening should consider several types of vehicles.

2. VEHICLES MOST COMMONLY CONSIDERED.

a. Tractor-trailer combinations where the fifth wheel is located directly over the drive wheels, such as a lowboy or gravel truck.

b. Tractor-trailer combinations with the towing pivot point offset to the rear of the drive wheels, such as logging trucks with "stingers" to facilitate short radius turns.

c. Tractor-trailer combinations which have two fifth wheels and accessory axles.

d. Yarders arranged in an operational mode or travel configuration.

B. TRAFFIC SERVICE LEVEL

1. GENERAL DESCRIPTION. A factor to be considered in determining the type of vehicles to design for is the traffic service level of the road to be designed. The determination of the traffic service level should be based on present and future needs of the area the road is going to service.

2. TRAFFIC SERVICE LEVEL CONSIDERATION.

a. TRAFFIC SERVICE LEVEL A. Usually Collector Roads.

CONSIDERATION – Design curve widening to accommodate the design vehicles (normally lowboy) at the design speed for each curve. Curve widening for critical vehicles should be provided if the needed width is not available. The critical vehicle should be accommodated in its normal travel configuration. Curve widening should be provided in each lane of double-lane roads.

b. TRAFFIC SERVICE LEVEL B. Usually Local Roads.

CONSIDERATION – Same as Traffic Service Level A except that curve widening for critical vehicles should be provided by use of other road elements, if planned, such as turnouts or shoulders. The critical vehicle configuration may have to be altered.

c. TRAFFIC SERVICE LEVEL C. – Usually Resource Roads.

CONSIDERATION – Curve widening should be provided only for the design vehicle. Loads carried by the critical vehicle should be off-loaded and walked to the project or transferred to vehicles capable of traversing the road. Temporary widening to permit the passage of larger vehicles may be accomplished by methods such as temporary filling of the ditch at narrow sections.

II. DETERMINATION.

A. MINIMUM LANE WIDTH

1. GENERAL DESCRIPTION – Curve widening is affected by the type of vehicle, radius of curvature, and the delta or central angle. Generally, the need for curve widening increases as the radius decreases; shorter curves require less curve widening than longer curves. It is not necessary to add curve widening to all curves; if the minimum lane width is equal to or less than the basic traveled way width no curve widening is required.

2. EQUATION. The minimum lane width, which includes two feet for tracking corrections, is given by the following equations which was developed by combining the delta or central-angle variation characteristics of trailer tractix equations with the off-tracking equations commonly used. The equation is accurate for a radius of 50 feet or greater and has been field checked.

$$MLW = 10 + \{[R - \sqrt{(R^2 - L^2)}]\,[1 - e^{(-.015\Delta R / L) + .216}]\}$$

Where:

R = Centerline radius (in feet)

E = Base for natural logarithms

Δ = Central angle (in degrees)

a. For a lowboy or standard tractor-trailer:

$$L = \sqrt{(L1^2 + L2^2 + L3^2)}$$

Where:

L1 = Wheel base of tractor (in feet)
L2 = Distance from the fifth wheel to the middle of the rear duals for the first trailer (in feet)
L3 = Distance from the fifth wheel to the middle of the rear duals for the second trailer (in feet)

b. For a "stinger" type log truck:

$$L = \sqrt{(L1^2 + L3^2 - L2^2)}$$

Where:

L1 = Wheel base of the tractor (in feet)
L2 = Length of the "stinger" measured form the middle of the tractor rear Duals to the end of the "stinger" (in feet)
L3 = Bunk to bunk distance minus the length of the "stinger" (in feet)

Exhibit A and Exhibit B were developed from these equations and can be used for common lowboy and logging truck configuration described.

B. TAPER LENGTHS

1. GENERAL DESCRIPTION – Curve widening tapers should be straight lined before the point of curvature (PC) and after the point of tangency (PT) for the following lengths:

RADIUS (R) (in feet)	TAPER LENGTH (T) (in feet)
Less than 70	60
70-85	50
86-100	40
Greater then 100	30

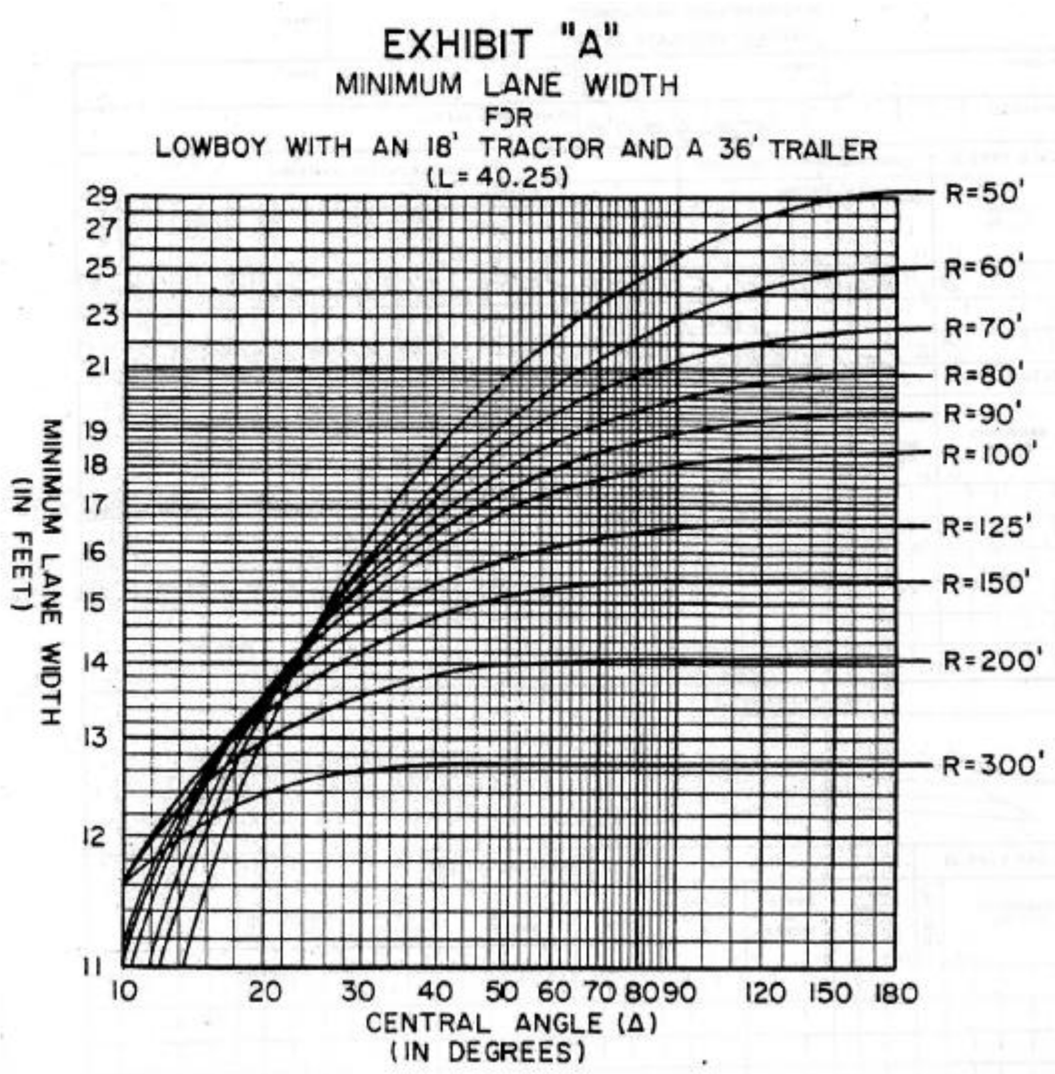


EXHIBIT "A"
MINIMUM LANE WIDTH
FOR
LOWBOY WITH AN 18' TRACTOR AND A 36' TRAILER
(L = 40.25)
MINIMUM LANE WIDTH
(IN FEET)
29
27
25
23
21
19
18
17
16
15
14
13
12
11
10
20
30
40
50
60
70
80
90
120
150
180
CENTRAL ANGLE (Δ)
(IN DEGREES)
R=50'
R=60'
R=70'
R=80'
R=90'
R=100'
R=125'
R=150'
R=200'
R=300'

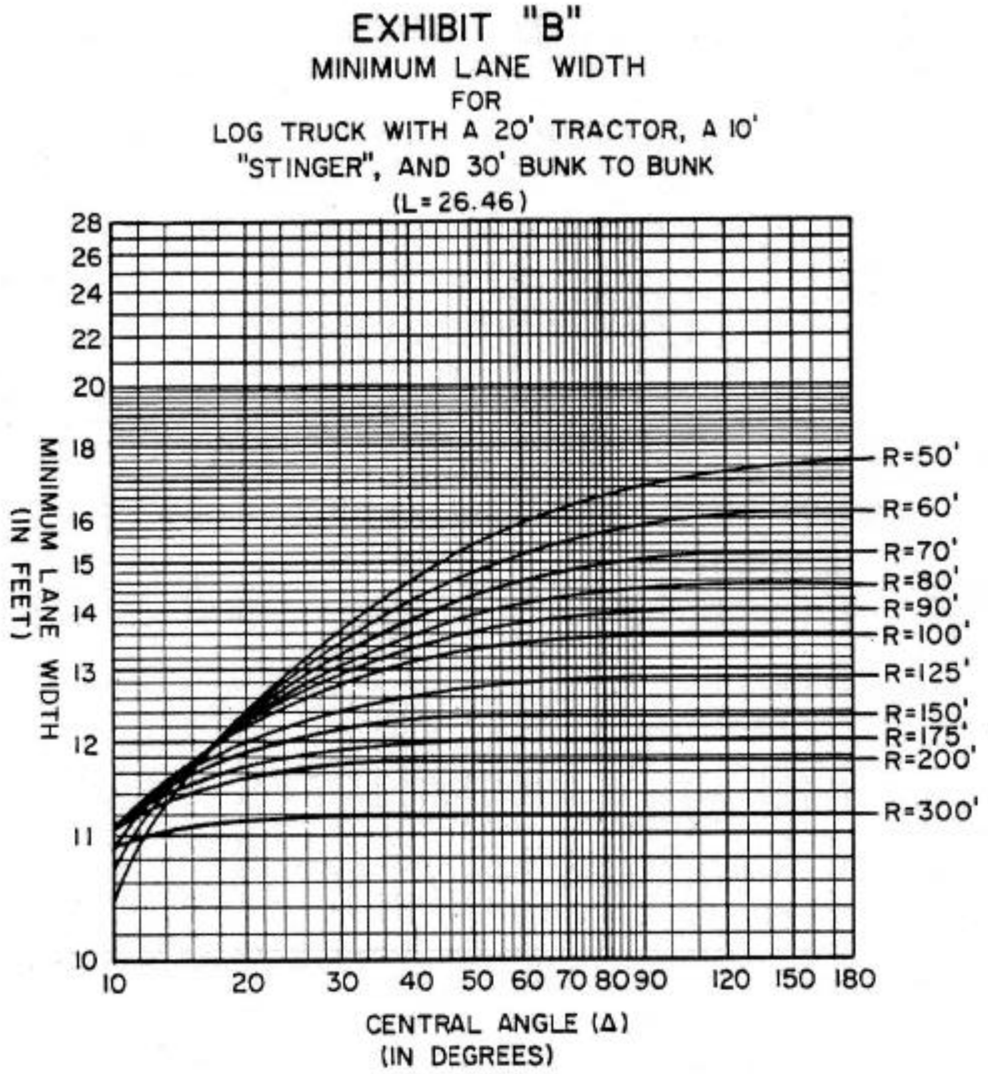


EXHIBIT "B"
MINIMUM LANE WIDTH
FOR
LOG TRUCK WITH A 20' TRACTOR, A 10'
"STINGER", AND 30' BUNK TO BUNK
(L=26.46)
MINIMUM LANE WIDTH
(IN FEET)
28
26
24
22
20
18
16
15
14
13
12
11
10
R=50'
R=60'
R=70'
R=80'
R=90'
R=100'
R=125'
R=150'
R=175'
R=200'
R=300'
10
20
30
40
50
60
70
80
90
120
150
180
CENTRAL ANGLE (Δ)
(IN DEGREES)