MONTANA
ROAD DESIGN MANUAL

MONTANA DEPARTMENT
OF TRANSPORTATION

PREFACE

The *Montana Road Design Manual* has been developed to provide uniform design practices for Department and consultant personnel preparing contract plans for Department projects. The roadway designer should attempt to meet all criteria presented in the *Manual*. However, the *Manual* should not be considered a "standard" which must be met regardless of impacts.

The *Manual* presents most of the information normally required in the design of a roadway project; however, it is impossible to address every situation which the road designer will encounter. Therefore, designers must exercise good judgment on individual projects and, frequently, they must be innovative in their approach to roadway design. This may require, for example, additional research into the highway literature.

The *Montana Road Design Manual* was developed by the MDT Road Design Section with assistance from the engineering consulting firm of Roy Jorgensen Associates, Inc. The *Manual* Review Committee consisted of:

Dave Johnson	Montana Department of Transportation
Ron Williams	Montana Department of Transportation
Paul Ferry (Project Coordinator)	Montana Department of Transportation
Brian Vieth	Montana Department of Transportation
Kerry Robertson	Montana Department of Transportation
Jay Ramlo	Montana Department of Transportation
Ken Shearin	Roy Jorgensen Associates, Inc.
Craig Birkholz	Roy Jorgensen Associates, Inc.

ROAD DESIGN MANUAL

(Revision Process)

All revisions to the *Montana Road Design Manual* will be submitted and reviewed according to the following process:

Revision and Review

1. All proposed revisions should be submitted to the Road Design Engineer. The Revision Request Form (next page) should be used for the submittal.

2. A four-person Review Committee, selected by the Road Design Engineer, will meet every three months, or as necessary, to review the proposed changes.

3. The Committee will submit their recommendations and will meet with the Road Design Engineer and the Preconstruction Engineer to determine if the proposed revisions should be incorporated into the *Manual*.

4. If the revisions represent a policy change, the revisions will be presented to the District Engineers for comment.

5. If the *Manual* will be revised as recommended, a memo describing the revision will be distributed by the Road Design Engineer. The revised pages of the *Manual* will be attached to the memo and will be sent to all *Manual* holders.

Review Committee

The Review Committee will consist of four members. One member will be replaced each year; therefore, no one will serve on the Committee for more than four consecutive years. Individuals may serve on the Committee more than once.

In addition to the review of proposed revisions, the Committee will be responsible for the following:

1. providing all updates for the *Road Design Manual*,

2. maintaining a comprehensive list of all *Manual* holders, and

3. maintaining a library of all revisions to the *Manual* in chronological order.

ROAD DESIGN MANUAL

(Revision Request)

Identification

Date Submitted:____

Section To Be Revised:____________________________________

Section Title:____

Page Number(s):____

Description of Revision

List other sections of the *Manual* that would be affected by the revision:

A.

B.

C.

List the *MDT Detailed Drawings* that would be affected by the revision:

A.

B.

C.

Justification For The Revision

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18 October 2016

MONTANA DEPARTMENT OF
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Chapter One
ROAD DESIGN PROCESS

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Chapter One
ROAD DESIGN PROCESS
Introduction

Chapter One documents the basic approach used by MDT in its road design process and the computer based management system (OPX2) that is utilized to monitor that process. This chapter summarizes the road design activities that occur in the development of a "typical" project. This is followed by a brief description of each activity within the network. In their use of Chapter One, the users should consider the following:

1.1 Flowcharts

Flowchart. The flowchart presents a network which graphically illustrates the sequence of activities that occur in the development of typical projects. The following flowcharts are:

Road Design Projects

- Road Design Urban & Rural Reconstruction, Urban & Rural New Construction
- Road Design Urban & Rural Resurface
- Road Design Resurface and Widen
- Road Design Urban & Rural Safety and Spot Improvement
- Bridge Replacement - Road Design
- Pavement Preservation

Bridge Projects

- Bridge Replacement

Traffic Projects

- Traffic Safety Design

Environmental Projects

- Environmental In-House Mitigation Design

Flowcharts may be obtained from Engineering Information Management Section. An evaluation of the scope of the proposed work is necessary to determine the correct flowchart for a specific project. The Road Design Section will usually not have project management responsibility for Bridge, Traffic or Environmental projects. Common exceptions are where traffic safety projects are designed in the Road Design Section and where bridges will be replaced with culverts.

1. Precedence Activity Network. The network of the road design process is a precedence activity network. An "activity" occurs when a significant, discrete event occurs and/or when the responsibility for the project (activity) is transferred from one unit to another. The "precedence" nature of the network implies that an activity cannot occur until all activities preceding that one have been completed. However, the user must be aware that some flexibility is necessary to apply this network to the various types of road design projects.

2. Project Application. The flowchart represents an approximate road design process for a relatively complicated project. Not every activity will be applicable to every project; i.e., some activities will represent "zero" time on relatively minor projects. In addition, some major projects are more complex than illustrated in the network. However, the user should find that projects which are developed according to this process will have fewer management problems.

   The references to flowcharts and activity descriptions assume a project designed in-house. The process for a consultant-designed project will be similar, except that communication lines exist between MDT and the consultant for MDT review and approval.

3. Lines of Communication. The rigid application of the flowchart would lead to predetermined, precise points at which communication occurs between units. This is neither realistic nor desirable. Communication between units must be continuous. The use of OPX2 does not preclude face-to-face communication. Rather its aim is creating the forum that will encourage it. Hopefully this will result in fewer problems and fewer "surprises" in the road design process.

4. Road Design Emphasis. The objective of the flowchart is to illustrate the interrelationship of activities necessary for the development of a project. The activities on the main stem of the flow chart are the critical path for the shortest project completion time. Other project development elements may become part of the critical path if they are not completed in a timely manner. The user is

referred to the Project Management System manual for detailed descriptions of the activities for other project development elements.

5. Other *Manual* Chapters. The *Montana Road Design Manual* contains several other chapters which provide complementary information to Chapter One. The designer should review these chapters for more information on the road design process. In particular, Chapter One should be used in combination with Chapter Two "Road Design Coordination" and Chapter Four "Plan Preparation," which describes the specific content of individual plan sheets.

1.2 Engineering Management Process

The Engineering Information Management Section (EIMS) monitors, maintains and updates the OPX2 program which is used to schedule project tasks and monitor preconstruction manpower needs. EIMS is also available to provide technical assistance to managers in statusing their projects.

1. Project Design Managers. Project Design Managers (PDM) are assigned the responsibility to monitor the design of Highway Projects from inception until they are let to contract.

2. Functional Managers. Functional Managers (FM) are assigned the everyday responsibility of completing the project tasks set forth in the OPX2 program schedule.

PDM's and FM's reside primarily in the Highways Bureau, Bridge Bureau, Environmental Bureau, Traffic and Safety Bureau, and District offices. In the Road Design Section the Project Design Manager, acts as both PDM and FM, although Engineering Specialists and Design Supervisors may also be employed as FM’s.

1. Preliminary Field Review. Design of projects cannot proceed until the appropriate engineering staff completes a Preliminary Field Review (PFR) and sends a copy to EIMS. Using the PFR as a guide, EIMS creates new projects in OPX2 assigning a template for standardized project types, a temporary project manager, and ready date. The project then shows up on the PDM’s list of new projects within OPX2.

2. Project Tasks. The OPX2 program compiles a customized list of tasks and an anticipated man-hour schedule for each project. These tasks must be performed before the submittal of the final plan package to the Contract Plans Bureau.

3. Submittal to FM for Overrides. The PDM reviews the project header information and schedule. If any further changes are needed he/she notifies EIMS. Once

project modifications are completed, the PDM pronounces the project ready to proceed through the override process.

4. Override Process. The FM approves or reworks the tasks using the override process. The override process is performed by adjusting the duration and man-hours as dictated by the proposed scope of the project using tools in OPX2.

5. Release of the Project for Design. The FM submits the overrides into OPX2, and after a review of the overrides, the PM releases the approved project schedule back to the FM who manages the project tasks assigned to his/her unit. The FM then is charged with regularly reporting the status of said tasks to the OPX2 system and thus to the PDM.

1.3 Road Design Activities

The following are brief summaries of the tasks that are involved in the activities. The activities are listed in the order in which they occur in the project development. With the exception of Activity 216 and 222 the progression of the activities follow the numerical order. Go to the Engineering Information Services website for complete activity descriptions.

200 Preliminary Field Review Report

This activity involves the following

- Gathering and reviewing background information such as traffic and accident data, preliminary hydraulics information, aerial photos and as-built plans

- Conducting a field review of the project with the appropriate people in attendance (e.g. personnel from various engineering disciplines, environmental, maintenance and district construction)

- Writing and distributing a report summarizing the proposed project scope, feasible alternatives, engineering decisions, level of environmental involvement, R/W and utility issues, public involvement process and other miscellaneous issues that need to be addressed during the project development.

250 Prepare PFR/SOW Report

This activity combines the tasks of Activity 200 and 214, because projects of this nature have extremely limited potential for change. It includes a field review and a distribution for approval and comments. This activity also includes the submittal of a checklist for the statewide programmatic categorical exclusion if it is appropriate for the project.

This activity is used only for pavement preservation projects and other projects of restricted scope.

202 Draft News Release

This activity provides the initial public notification that a project is being initiated. The news release outlines the general project scope and begins the public input process.

205 Prepare for Public Involvement

This activity involves preparing the information including any visual displays to be presented at a public meeting. It also includes requesting that the Public Involvement Officer schedule a public meeting.

210 Distribute Survey Information and Request Design Input

This activity acts as a notification that the survey information is available so that formal design can begin. Design input is also requested from various units on specific issues identified at the Preliminary Field Review.

212 Preliminary Plan Preparation

For this activity the designer develops the following:

- Title Sheet
- Notes sheet
- Control Diagram
- Typical Sections
- Preliminary plan and profile sheets
- Preliminary cross sections

For projects where the alignment is not fixed, preliminary horizontal and vertical alignments are provided so that other sections can begin their preliminary design and environmental analysis.

216 Establish Alignment & Grade

This activity involves establishing the final horizontal and vertical alignments. After this activity is completed, the adjustments to the vertical alignment should be slight. The alignments may be adjusted to address drainage, environmental, geotechnical, utility or R/W issues. It may also be adjusted to optimize earthwork.

This activity also involves finalizing the surfacing section. The subsurface information should be reviewed to determine if it adequately describes the subgrade material for the designed alignment.

This activity should address all key design issues and entails extensive coordination with other units. Preliminary plans with surfacing, grading and major drainage features are distributed and the opportunity for a field review is provided. After the changes from the field review are incorporated into the design a reporting documenting the decisions is distributed for comment.

On the more complex projects where the alignment is predetermined due to site constraints (e.g. urban reconstruction), this activity is still crucial for resolving key design issues.

214 Prepare Scope of Work Report

This activity involves the preparation and distribution of a report that describes in detail the scope of the project. The report establishes the final scope of the project and essentially directs the future development of the project. It includes the decisions and the reasons for the decisions on all major design and construction issues. It also describes environmental commitments, responses to public input and required design exceptions.

The report is distributed to the Maintenance and Planning Divisions, Construction, the Bridge, Traffic, Right-of-Way, Environmental and Materials Bureaus and the District for concurrence. It is also distributed to the FHWA for their concurrence on projects where they have full oversight.

222 Approve Scope of Work

This activity consists of the addressing comments to the scope of Work Report and resolving all scope-related issues that may not have the concurrence of all appropriate parties. The Chief Engineer approves the final report

218 Prepare Plans for Plan-in-Hand

This activity involves the detailed design of all features on the project. It includes the calculation of plan quantities for all items, the preparation of design details, a detailed cost estimate and draft special provisions. When this activity is completed the preliminary plans should be essentially finished and ready for a Plan-in-Hand review.

220 Plan-in-Hand Inspection

This activity consists of the distribution of the preliminary plan package and a sheet-by-sheet review of the plans, cost estimate and special provisions. The office review is typically followed by a field review. All items discussed at the office and field review are documented in a Plan-in-Hand Report, which is distributed for comment.

The recommendations contained in the report are used by the design personnel to revise the plans, special provisions and cost estimate.

224 Provide Construction Limits to R/W Bureau

This activity consists of finalizing the construction limits and all other items that affect the right-of-way such as approach locations and construction permits. The designer furnishes this informant to the Right-of-Way Bureau to assist in the completion of the R/W plans.

228 Design Miscellaneous Features

This activity consists of finalizing all elements of the design. These include design details, changes discussed at the Plan-in-Hand, revisions to special provisions and the completion of any items necessary for the environmental permit submittals.

230 Final Plan Review

This activity involves the distribution of the completed plan package for review by the appropriate parties, especially District construction personnel. Although this activity is typically a mail-out of the plan package with comments submitted to the Project Design Manager, a formal review may be scheduled if there are key unresolved items or if major changes occurred at the Plan-in-Hand. The review should address any conflicts between the plans, special provisions and cost estimate. The final plan review should significantly reduce the number of changes that occur when the blue sheet plans are distributed by the Contract Plans Bureau.

A Final Plan Review Report is prepared documenting all decisions, revisions and comments.

236 Final Plan Updates and Revisions

The designer makes all changes resulting from the Final Plan Review. The designer or Design Supervisor performs a final review of the plans. The designer then submits the plan package to the Checker.

240 Check Plans

The checker ensures that the plans package conforms to the Scope of Work Report and the decisions that are documented in subsequent reports. The checker also ensures conformance with current standards, department policy and design practices. The plans package is also checked in detail for accuracy, completeness and consistency. The checker verifies that all corrections and changes are made by the designer.

245 Transmit to Contract Plans

Upon completion of the checking process the checker will submit the final plans package in an electronic format to the Contract Plans Bureau.

The following activities apply to the development of wetland mitigation sites. Since the tasks associated with these activities are subject to change refer to the Engineering Information Management Section website for full activity descriptions.

242 Road Design Site Evaluation

244 Design Conceptual Plan

246 Final Mitigation Plan Development

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Chapter Two
ROAD DESIGN COORDINATION

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Chapter Two
ROAD DESIGN COORDINATION

During the development of a road design project, the road designer must coordinate with many units internal and external to the Road Design Section. Chapter One presented a synopsis of the Project Management System (OPX2) in which the progress of transportation projects are tracked from inception to design to construction. Chapter Two outlines the Highways and Engineering Division and discusses the project development sequence including the responsibilities of the road designer to coordinate specific activities between Road Design and other units. Together, the two chapters will provide an understanding of the necessary interaction among the various units in project development

2.1 INTERNAL MDT UNITS

This section discusses the specific coordination responsibilities between the road designer and other MDT units. Figure 2.1A presents an organizational chart for the Highways and Engineering Division of the Montana Department of Transportation.

2.1.1 PRECONSTRUCTION

The Preconstruction Program is comprised of the Highways, Traffic and Safety, Environmental Services, Right-of-Way, Consultant Design, and Bridge bureaus; and the Engineering Information Management Section.

2.1.1.1 Highways Bureau

The Highways Bureau is comprised of the Hydraulics, Photogrammetry and Mapping, and Road Design Sections. The Highways Bureau handles technical activities on highways from the time a project is programmed until the start of actual construction.

2.1.1.2 Hydraulics Section

The Hydraulics Section is responsible for hydrologic and hydraulic analyses for both roadway drainage appurtenances and bridge waterway openings. The following summarizes the coordination between the Road Design Section and Hydraulics Section:

1. Culverts. For all box culverts and all pipe culverts with diameters greater than 24” (600 mm), the Hydraulics Section will perform all work on the culvert design. This includes:

    a. hydrological analysis to calculate design flow rate based on the drainage basin characteristics;

    b. hydraulic analysis to select culvert dimensions and layout (e.g., longitudinal slope);

    c. selection of culvert material (e.g., reinforced concrete, corrugated metal);

    d. structural/service life design of the culvert; and

    e. end treatments.

    The road designer is responsible for the design of minimum-sized pipes [24 “ (600 mm)]. These may be judged to be adequate based on input from the District maintenance personnel that an existing 24” (600 mm) pipe culvert has performed adequately. However, the Hydraulics Section will provide assistance as required to support the decision to use a 24” (600 mm) culvert.

2. Storm Drainage Trunk Line. The road designer will present the proposed roadway design to the Hydraulics Section documenting, for example, pavement widths, cross slopes, longitudinal grades, location of intersecting roads and approaches, etc. Based on this information, the Hydraulics Section is responsible for all work related to the design of a closed drainage system. This includes:

    a. flow calculations in the system,
    b. pipe size and material (including optional material),
    c. spacing of inlets,
    d. pipe slopes, and
    e. outfall location and design.

The road designer will determine the exact location of inlets to ensure that the inlets are located at low spots and to avoid conflicts with utilities, curb ramps, etc. The road designer will also calculate the quantities for the storm drain facility.

3. Irrigation/Sprinkler Systems. The Hydraulics Section is responsible for all designs related to an irrigation system (e.g., siphon details) for pipes larger than 18” (450 mm) in diameter and for the design of sprinkler systems. The road designer is responsible for relocating minor irrigation lateral ditches outside of the R/W. The Hydraulics Section will assist the road designer as required during the design of these minor irrigation facilities.

4. Roadside Ditches. The road designer determines the dimensions of the roadside ditch based on the criteria presented in Chapters Eleven and Twelve of the *Road Design Manual*. Typically, no analysis is performed to determine hydraulic capacity. However, where determined necessary, the Hydraulics Section will evaluate the potential for erosion in the ditch and, if needed, recommend a permanent protective lining.

5. FEMA Regulations. The Hydraulics Section is responsible for determining that the project design is consistent with regulations promulgated by the Federal Emergency Management Agency (e.g., development within regulatory flood plains).

6. Curb Ramps. To meet the requirements of the *Americans with Disabilities Act*, a project may require the installation of curb ramps which may, in turn, interfere with an existing curb inlet. In this case, the road designer and Hydraulics Section will work together to resolve the conflict.

7. Documentation. The following will apply to roadway drainage appurtenances:

    a. The Hydraulics Section will submit the necessary information documenting its recommendations for the roadway drainage design.

    b. The road designer will incorporate all details into the road design plans and cross sections.

The road designer will calculate all quantities for the roadway drainage appurtenances.

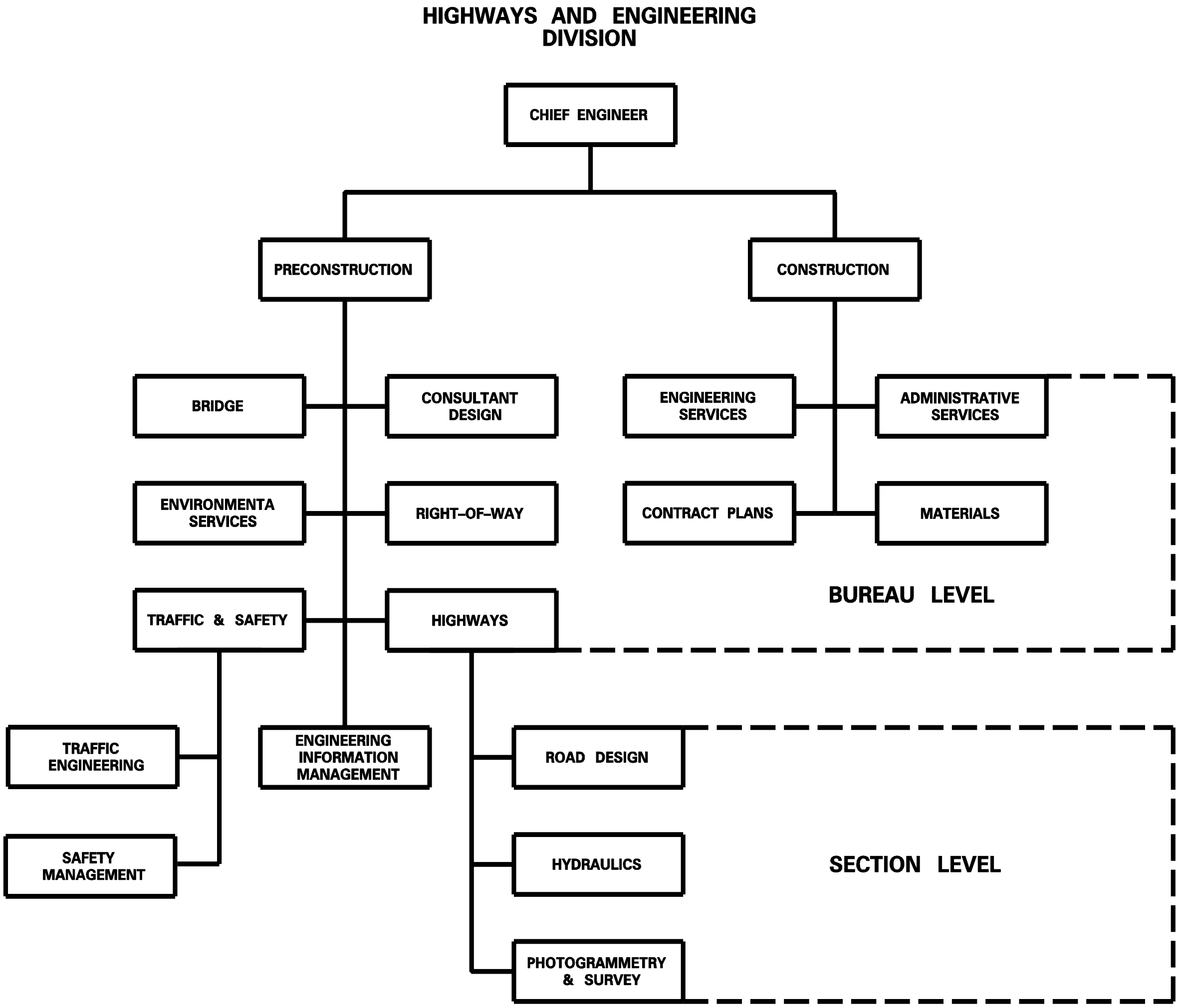
HIGHWAYS AND ENGINEERING DIVISION
CHIEF ENGINEER
PRECONSTRUCTION
CONSTRUCTION
BRIDGE
CONSULTANT DESIGN
ENGINEERING SERVICES
ADMINISTRATIVE SERVICES
ENVIRONMENTA SERVICES
RIGHT-OF-WAY
CONTRACT PLANS
MATERIALS
BUREAU LEVEL
TRAFFIC & SAFETY
HIGHWAYS
TRAFFIC ENGINEERING
ENGINEERING INFORMATION MANAGEMENT
ROAD DESIGN
SAFETY MANAGEMENT
HYDRAULICS
SECTION LEVEL
PHOTOGRAMMETRY & SURVEY

Figure 2.1A

2.1.1.3 Photogrammetry and Survey Section

The Photogrammetry and Survey Section is responsible for conducting aerial and field surveys, in coordination with the District Office, for all Department projects. The following summarizes the coordination with the Road Design Section:

1. Field Surveys. The decision that a field survey is needed is made at the Preliminary Field Review. The survey is then conducted by the District survey crews. The Survey Section checks the survey for accuracy and completeness. For data collector surveys, the information will be submitted in a MicroStation design file with a DGN extension. The road designer and surveyor will coordinate to finalize the DGN file and create the Digital Terrain Model file. The surveyor will place the file on the network, notify the road designer, and the road designer will notify the appropriate personnel that the survey information is available. For manually conducted surveys, the designer will be responsible for plotting the survey data using the Department’s CADD system. In addition to the field notes, the designer should obtain a copy of the as-built plans (if available) for informational purposes. The as-built plans can be obtained at the MDT Central Office in Helena.

2. Aerial Surveys. The decision that an aerial survey is needed is made at the Preliminary Field Review. The Photogrammetry and Survey Section plots the necessary flight lines and requests that targets be provided. A District survey crew will conduct the control survey and will provide any needed additional survey information. The Photogrammetry and Survey Section will prepare a strip map and a digital terrain model of the project. The road designer will strip cross sections from the DTM as needed.

3. Control Diagram. The Photogrammetry and Survey Section checks the control survey data and then plots the control diagram. The road designer will retrieve the control plot and coordinates table for inclusion in the plans.

2.1.1.4 Traffic and Safety Bureau

The Traffic and Safety Bureau is responsible for managing and coordinating highway safety programs and for providing management, design and technical support with respect to traffic engineering within the department. The Bureau is responsible for developing and reviewing plans and specifications for highway safety projects including signing, geometric features, pavement marking, lighting, signals and hazard elimination.

2.1.1.5 Traffic Engineering Section

The Traffic Engineering Section is responsible for all capital improvement projects for which the Section serves as the lead unit, and the Section provides a variety of traffic engineering services to other Department units (e.g., traffic control devices, highway capacity analyses, traffic engineering studies). The following describes the road designer's coordination with the Traffic Engineering Section.

1. Traffic Control Devices. The Traffic Engineering Section is responsible for the selection, design and placement of all permanent traffic control devices within the project limits. This includes traffic signals, signs, pavement markings and highway lighting. The Section is also responsible for the structural design of supports for small signs, traffic signals and highway lighting appurtenances.

   The Traffic Engineering Section will prepare the permanent traffic control plans. The road designer will review the traffic control plans for any potential conflicts with the roadway design. For example, the road designer will coordinate with the Traffic Engineering Section to ensure that the curb ramp locations do not interfere with the traffic control devices and that they are compatible with the pavement markings. The Traffic Engineering Section will also provide quantities for the pavement markings, which the road designer will incorporate into the summaries. The plans, quantities and special provisions for the remaining permanent traffic control devices will be submitted directly to the Contract Plans Bureau.

   When railroad crossings are located within the project limits, coordination between the road designer, the Traffic Engineering Section and the Utilities Section will be necessary to ensure that an agreement with the railroad company for signing/signalization at the crossing is secured.

2. Geometrics. The following summarizes the coordination between the Traffic Engineering Section and road designer for the geometric design of a roadway:

   a. Highway Capacity. The Traffic Engineering Section performs all needed highway capacity analyses for the project. This includes, for example, the warrants and limits of truck climbing lanes. The Traffic Engineering Section incorporates the results of its analyses into the design of intersections. The road designer incorporates the results into the design of other highway elements (e.g., number of lanes).

   b. Intersections At-Grade. The Traffic Engineering Section performs all work on the geometric design of major intersections at-grade. The Section prepares all necessary detail sheets to clearly identify all geometric features. The road designer will place these in the final plans and will calculate all roadway quantities for intersection work. The Traffic Engineering Section will revise the details as needed.

c. Interchanges. The Traffic Engineering Section determines the interchange type and basic geometric configuration, and the road designer prepares the detailed design of the interchange. Note that, for most interchange projects, the Road Design Section will be the lead.

d. Medians. The Traffic Engineering Section is responsible for selecting the median type and for determining the basic geometric dimensions of the median (e.g., width, location of openings, width of openings). The road designer prepares the detailed design of the median.

e. Other Geometric Design Features. The Traffic Engineering Section will review and comment on the other proposed geometric design features (e.g., horizontal and vertical alignment).

3. Traffic Engineering Investigations. The Road Design Section is responsible for reviewing the project to determine if any traffic engineering investigations are needed (e.g., speed studies, school zone studies). The Traffic Investigations Unit will collect and analyze the necessary data, review warrants and prepare a report on the findings. This investigation will include a review of potential conflicts with other projects.

2.1.1.6 Safety Management Section

The Safety Management Section is responsible for reviewing the crash history on projects. The review should identify correlations between crash characteristics and existing roadway features and should identify any crash cluster areas. The Section will provide the road designer with the crash data, collision diagrams and statistical trends for use in project design. The Safety Management Section is also responsible for reviewing the preliminary plans and providing comments on features which would improve the safety of the traveling public and the safety needs of special user groups.

2.1.1.7 Environmental Services Bureau

The Environmental Services Bureau is responsible for a variety of activities related to environmental impacts and procedures. This includes air, noise and water quality analyses; biological, archeological and historical impacts; preparation of environmental documents for MDT projects; evaluation and mitigation of hazardous waste sites; and the public's involvement with the environmental document. The following summarizes the coordination between the Road Design Section and the Environmental Services Bureau:

1. Permits/Approvals: The road designer provides Environmental Services with the project information needed for securing several environmental permits/approvals (when needed):

    a. Section 402, Temporary Erosion Control permit (from the Montana Department of Environmental Quality or the Federal EPA);

    b. U.S. Army Corps of Engineers Section 404/Section 10 permit(s);

    c. U.S. Fish and Wildlife, U.S. Forest Service, Bureau of Land Management approvals; and

    d. any applicable regional, tribal and State permits (see Comments #9 and #11).

    Environmental Services coordinates with the applicable Federal or State agency and processes the permit information and gains agency approval. Environmental Services notifies the Road Design Section when the permit or approval is received.

2. NEPA/MEPA Requirements. The Road Design Section works with Environmental Services to ensure that the project meets the Department's environmental and public input criteria pursuant to the National Environmental Policy Act and the Montana Environmental Policy Act. This includes project documentation (i.e., categorical exclusion, EA, EIS), water quality impacts, biological impacts, historical impacts, archeological impacts, and the need for public hearings. In general, Environmental Services makes its determination of impacts based on input from the Road Design Section.

3. Section 4(f). A Section 4(f) approval is required if a project will impact publicly owned land (e.g., public park, recreational area, wildlife/waterfowl refuge). An approval will be granted only if there is no feasible and prudent alternative. Where a Section 4(f) approval is required, the road designer will provide the necessary project information to Environmental Services, who will secure the approval.

4. Section 6(f). Federal law places restrictions on the use of land acquired with funds authorized by the Land and Water Conservation Act of 1965 as administered by the U.S. Department of Interior (Section 6(f) of the LWCF). Where a Section 6(f) approval is required, the road designer will provide the necessary project information to Environmental Services, who will secure the approval.

5. Mitigation Features. Environmental Services and Road Design Section work together on the plan for mitigation of environmental impacts.

6. Early Coordination. Environmental Services determines the need for early coordination on environmental issues with other State, Federal and public entities and makes all direct contacts, with input from the Road Design Section.

7. Hazardous Wastes. Environmental Services identifies all hazardous waste sites and determines any needed mitigation measures. Environmental Services will coordinate the mitigation if it will be performed before letting the construction project to contract. They will provide the Road Design Section with any necessary provisions, and the road designer is responsible for incorporating these into the construction plans and specifications, if the hazardous waste removal or site mitigation will be accomplished by the road contractor.

8. Erosion Control During Construction. The road designer is responsible for providing the Environmental Services Bureau with construction plans showing the as-designed contours. The Environmental Services Bureau will then develop a plan for temporary erosion control during construction. The road designer may be requested to place the BMP symbols on the erosion control plans. The Environmental Services Bureau will secure approval from the Montana Department of Health and Environmental Sciences or Federal EPA.

9. Montana Department of Fish, Wildlife and Parks (MDFWP). The need for coordination with the MDFWP will be determined by Environmental Services on a project-by-project basis. If needed, the road designer will provide a set of plans to Environmental Services, who will submit them to MDFWP as part of the Stream Protection Act 124 notification. Environmental Services will coordinate with the MDFWP to secure approval and notify the Road Design Section when approval is received.

10. Section 106. For all Federally funded projects, MDT must identify archeological and historic sites in the vicinity of the project. The identified sites must be evaluated to determine if they are eligible for the National Register of Historic Places (NRHP). MDT submits recommendations for eligibility to the State

Historic Preservation Officer (SHPO) for its concurrence. If a site is considered eligible for the NRHP and if the project will impact the site, the Department is mandated to mitigate the adverse effects. Mitigation is accomplished through written agreements among MDT, the Advisory Council on Historic Preservation and the Montana SHPO. A project cannot proceed unless the MDT's NRHP determination and any necessary mitigation measures are approved by SHPO.

11. Wetland Mitigation. For wetland mitigation sites, Environmental Services will determine the location of the site, review the hydrology with the Hydraulics Section to ensure an adequate water supply, and provide a conceptual plan of the site. The road designer is responsible for the preparation of plans, cross sections and summaries of quantities and for providing any special provisions that apply to construction items.

2.1.1.8 Right-of-Way Bureau

The Right-of-Way Bureau is responsible for all activities related to the legal right-of-way for the State highway system. This includes appraisals, acquisitions, relocation, property management and agreements with utility companies and railroad companies. The following summarizes the coordination between the Road Design Section and Right-of-Way Bureau:

1. Coordination. The Road Design Section provides R/W with the needed design information to determine the right-of-way, utilities and railroad impacts.

2. Plan Preparation. The road designer provides the R/W Bureau with a strip map and preliminary construction limits. The R/W Bureau is responsible for determining the R/W design, and the Bureau prepares a separate set of right-of-way plans for each project where right-of-way impacts exist. The road designer should notify R/W Design when the following changes are made after Alignment and Grade:

    a. Changes are made to the const. limits due to grade changes, back slopes or fill slopes.

    b. New pipes added or old pipes removed.

    c. Any changes to the horizontal or vertical alignment.

    d. Any changes to irrigation or drainage facilities.

    e. When final const. limits are complete.

  f. If a project has been put on hold for some reason.

  g. Change in Scope.

  h. Determination that additional wetlands are needed.

  i. Approach Changes

  j. Changes to Riprap (especially at pipe ends)

3. Acquisition. The R/W Bureau performs all right-of-way work and procures all takings and easements needed for the project. The Bureau notifies the Road Design Section of any design considerations resulting from negotiations with the property owners, and the Bureau will provide copies of signed agreements.

4. Utility Coordination. After the Alignment Review, the Road Design Section will notify the Utilities Section and will provide the R/W Plans Section with a set of plans with the existing utilities and conflicts plotted as determined from the survey. The road designer will list the utility conflicts by station and offset from centerline and place the utilities on the cross sections. The R/W Plans Section will prepare the Utility Plans and submit these to the Utilities Section. Based on the Scope of Work Report and the initial utility plans, the Utilities Section will work with any impacted utility companies and municipalities to implement the utility process. This process may include the following:

   a. Plan Preparation. The utility companies are responsible for preparing all utility adjustment/relocation plans, based on the initial utility plans. The plans will be developed according to the criteria in the *Montana Utility Accommodation Policy*.

   b. Funding. Depending on the right-of-way ownership for existing and proposed utility locations, highway funds may be eligible for utility adjustment/relocation required by the highway project. The utilities pay for all betterments.

   c. Agreements. The Utilities Section will prepare a Utility Agreement for each affected utility and will work with the utility companies to gain their input and approval.

5. Railroad Coordination. Based on the Alignment Review, the Utilities Section will work with any impacted railroad companies, the Road Design Section and other

Department units to implement the railroad coordination process. For road projects, this process may include the following:

a. The Utilities Section will prepare the Railroad Agreements and work with the railroad companies to gain their input and approval.

b. For any work at the crossing itself (e.g., replacing the railroad crossing surface, improving drainage), the railroad company will advise the Department of its requirements to be incorporated into the plans.

c. For any active traffic control devices (e.g., flashing lights, automatic gates), the Utilities Section will verify the warrants for these devices. The Road Design Section will design the crossing in coordination with the railroad company. The Traffic Engineering Section will recommend locations of the railroad signals or recommend protection if they must be located within the clear zone. The railroad companies will perform the design work and construction of the electrical components of the active traffic control devices.

d. The Road Design Section is responsible for the detailed design of the roadway approaching the crossing.

2.1.1.9 Consultant Design Bureau

The Department may use a consultant for a road design project. When a consultant is used, the Consultant Design Bureau is the primary contact with the consultant. The Highways Bureau will provide technical support on the project and review the plans prepared by the consultant.

2.1.1.10 Bridge Bureau

The Bridge Bureau is responsible for the structural design of all bridges [longer than 20' (6 m)] and concrete retaining walls on State-maintained highways. The following describes the coordination between the Road Design Section and Bridge Bureau:

1. Roadway Geometrics. The road designer provides the Bridge Bureau with preliminary horizontal and vertical alignments. The bridge designer determines a preliminary structure length and depth of superstructure, and the bridge designer provides approximate bridge end elevations. The road designer modifies the alignment as necessary, based on the preliminary grade recommendations from

the bridge designer. The Bridge Bureau reviews and comments on the proposed roadway geometrics.

The Bridge Bureau determines the bridge width according to criteria in the *Montana Structures Manual*. The proposed bridge width will not be less than the roadway width summarized in the Geometric Design Tables in Chapter Twelve.

2. Approach Roadway. Even where only minor roadway work is necessary at, for example, a bridge replacement, the Road Design Section is responsible for all roadway work.

3. Roadside Safety Appurtenances. The Bridge Bureau will select the type and design of the bridge rail. The road designer will determine the design of the approaching guardrail transition into the bridge rail.

4. Sidewalks. Sidewalk requirements on bridges will be determined jointly by the Bridge Bureau, the Road Design Section and the District.

5. Traffic Control Plan (TCP). The road designer is typically responsible for developing a strategy for the maintenance and protection of traffic during construction across any bridges within the project limits. This may include, for example, providing one lane of traffic across a two-lane, two-way bridge, providing a detour around the bridge or, on a multilane facility, providing a crossover between the two roadways. The Bridge Bureau assists in the development of the proposed TCP. The Bridge Bureau may prepare additional TCP requirements.

   The Bridge Bureau will develop a traffic control requirements across the structure when part-width construction is used or when the removal of an existing structure (and the construction of the new structure) must be performed in a specific sequence.

6. Plan Preparation. The Bridge Bureau prepares all necessary structural design plan sheets and submits these to the Contract Plans Section for direct insertion into the final plan assembly.

2.1.1.11 Engineering Information Management Section

The Engineering Information Management Section monitors and updates the Preconstruction Management System, (OPX2 program) which is used to schedule projects and develop preconstruction manpower needs. Project Managers have been assigned the responsibility to monitor the design of Highway Projects from inception until they are let to contract. Functional Managers have been assigned the everyday responsibility of completing the project activities set forth in the OPX2 program schedule.

After the Preliminary Field Review Report has been transmitted for comment and the Functional Managers have submitted overrides for their activities, the Project Manager releases the approved project schedule back to the Functional Managers who manage the project activities assigned to their unit. The Functional Managers then are charged with regularly reporting the status of said activities to the OPX2 system and thus to the Project Manager. The computerized OPX2 program compiles a standardized list of activities and anticipated man-hours that must be performed before the submittal of the final plan package to the Contract Plans Section. The Project Design Manager, who acts as both the Project Manager and Functional Manager for Road Design modifies the list and required man-hours as dictated by the proposed scope of the project. The Engineering Information Management Section is charged with maintenance of the OPX2 System and is available for technical assistance to the managers in statusing their projects.

The Project Design Manager and the Design Supervisor acting as functional managers are responsible for:

1. monitoring the OPX2 program by entering completion dates into the system when activities are completed, and coordinating changes to the project schedules with other Functional Managers if additional activities or durations must be added due to a change in project scope, and

2. Providing updates to the Engineering Information Management Section on construction cost estimates.

2.1.2 <u>Tribal Coordinator</u>

The Tribal Coordinator answers to the Director’s office. Coordination with the Tribal governments is an essential element of the project development process. When a road design project is on tribal land, the road designer coordinates with the Tribal Coordinator, the District and the Tribe.

The Project Design Managers will generally be responsible for ensuring that the Tribes are receiving the appropriate reports and documentation throughout the project development process. However, this should be verified with the District Administrator, since the MDT contact with the Tribes varies with each District. The Tribal representatives who typically receive these documents are listed below:

1. TERO Director
2. Planning Director (or Transportation Planner)
3. Tribal President (or Chairman)

Once again this will vary with each Tribe. A list of the appropriate contact people should be obtained from the District Administrator or the Tribal Coordinator.

The information should be sent to each individual. Do not send it to one person and expect them to distribute it to the other Tribal representatives. We also recommend that documents be accompanied with cover letters that provide a more in-depth explanation of the information than is necessary for MDT personnel. For plans distributions it is not necessary to send plans to the Tribal Presidents. Sending them cover letters will be sufficient.

2.1.2.1 Tribal Coordination Checklist

The following is a checklist of documents and plans that should be sent to the Tribes.

Preliminary Field Review
Invitation to the field review
PFR Report
Alignment & Grade Review
Invitation to the review accompanied by plans
A & G Report
Scope of Work Report
Report distributed for comments (not signatory approval)
Final Scope of Work Report with final approval
Plan-in Hand

PIH review invitation accompanied by plans, cost estimate, special provisions. (There has been some question about whether or not we should send the cost estimates to the Tribes. This issue should be resolved with the individual District Administrator.)

1. PIH Review Report. It may not be necessary to send the PIH Report to the Tribes. The need will be determined on a project-by-project basis.

2. Final Plan Review. If a field review will be conducted, an invitation, plans and the report should be sent to the Tribes. If the FPR is just a send-out of plans for review, it will not be necessary to send anything to the Tribes.

3. Blue Sheets. Contact the Contract Plans Bureau to determine if plans need to be sent to the tribal representatives.

4. Comments to reports. – Comments should be sent to the Tribes only if they affect previous decisions, are major changes or affect tribal property. The decision to send these memos should be made on a case-by-case basis and should generally be discussed with the District Administrator.

2.1.3 Construction

The Construction Program in the Central Office in coordination with the District Offices is comprised of the Construction Engineering Services Bureau, the Construction Administration Services Bureau, Materials Bureau and the Contract Plans Bureau, and is responsible for all construction activities on all State-administered projects.

2.1.3.1 Construction Administration Services Bureau

The Construction Administration Services Bureau is responsible for planning and administering construction program operations and contract administration activities including developing and implementing new standards and methods as well as administering current projects, and ensuring that projects in development reflect the most recent standards for administration purposes. The bureau also directs the development and administration of construction and contract administration computer programs and automated systems, and manages the Department's general Construction staffing and equipment budgets, as well as the Construction Administration Services Bureau's budget, policies, and equipment.

The road designer’s coordination with the Construction Administration Services Bureau is generally indirect. The Construction Administration Services Bureau provides updates to the Standard Specifications, the Supplemental Specifications, Standard Special Provisions and Detailed Drawings.

2.1.2.2 Construction Engineering Services Bureau

The Construction Engineering Services Bureau is responsible for issuing direction on technical construction issues, general construction issue resolution, construction oversight and uniformity, construction project reviews, implementation and follow-up of constructability and post construction review findings, change order discussions, value engineering proposal investigation and recommendations, non-uniformity complaint resolution and implementation of new construction processes, procedures and specifications. The following summarizes the coordination between the Road Design Section and the Construction Engineering Services Bureau.

The Construction Engineering Services Bureau will conduct constructability reviews on projects at various milestones during the project development process. They will also conduct Value Analyses of selected projects. These activities will require close coordination between the road designer and the Construction Engineering Services Bureau personnel.

The Construction Engineering Services Bureau receives copies of the Preliminary Field Review Report, Alignment Review Report, Scope of Work Report and the Plan-in-Hand Report. In addition, they receive the preliminary plans, which are distributed for the plan-in-hand review, and the final plan review. The Construction Engineering Services Bureau will review the plans and provide recommendations for changes to the Road Design Section.

The road designer is responsible for developing the initial proposal for the maintenance and protection of traffic through the construction zone, including the sequence of construction operations and the need for any detours. The Construction Engineering Services Bureau and District construction personnel will review and revise the road designer's proposed strategy, and the Road Design Section is responsible for placing the necessary information into the final contract document.

2.1.2.3 Materials Bureau

The Materials Bureau is responsible for testing and certifying all materials used on Department projects. This includes geotechnical analyses and materials for pavements and structures. Normally, the District materials personnel perform the field sampling. The following summarizes the coordination between the Road Design Section and Materials Bureau:

1. Geotechnical. The Geotechnical Section prepares a Geotechnical Report for roadway projects when deemed necessary. The Report presents the soil and rock types, bearing capacities, slope stability, rock cut recommendations, muck excavation, subdrainage needs, erosion control strategies, etc. Road Design comments on the Geotechnical Report and works with the Geotechnical Section to resolve any conflicts. The road designer incorporates the geotechnical recommendations into the road design plans.

2. Pavement Design. The Materials Bureau recommends alternative pavement types (concrete or bituminous) and surfacing treatments (e.g., recycling, crack and seat) and designs the pavement structure. The road designer coordinates with the District to determine the most appropriate surfacing section and incorporates the final pavement design into the road design plans.

3. Walls. Where needed, the Geotechnical Section is responsible for preparing the design of retaining walls, reinforced earth walls, bin walls and gabions. The road designer incorporates this information into the road design plans.

New Materials/Experimental Items. The Materials Bureau determines the need for any new materials and/or experimental items in the project, and it develops the specifications and special provisions for the items. The road designer incorporates this information into the final contract document.

2.1.2.4 Contract Plans Bureau

After the road design plans have been finalized, the Project Design Manager will transmit the entire project package to the Contract Plans Bureau for final processing. The package will include the following items:

1. final, original construction plans,
2. road design cost estimate, and
3. any Special Provisions.

The Contract Plans Bureau will review the final construction plans and distribute the plans for review by other MDT sections. The Project Design Manager will review the comments and suggestions and determine if changes or corrections are warranted. The Project Design Manager will be responsible for incorporating any appropriate revisions into the plans resulting from this review.

2.2 OTHER COOPERATING INTERNAL MDT UNITS

2.2.1 Rail, Transit and Planning Division

The Rail, Transit and Planning Division is responsible for all MDT planning functions including developing the Department's program of projects, performing initial planning studies and coordinating with the Metropolitan Planning Organizations (e.g., on the Transportation Improvement Program). The following describes the coordination between the Road Design Section and the Rail, Transit and Planning Division:

1. Traffic Data. The road designer requests traffic data for projects. The Rail, Transit and Planning Division obtains the data which includes average annual daily traffic, design hourly volume, percentage of trucks, and the daily equivalent single-axle loads (ESAL). The data should also include any major changes in traffic volumes within the project limits. The Division also provides the traffic volumes of the various directional movements at intersections as required.

2. Programming. The Rail, Transit and Planning Division provides the Road Design Section with the necessary programming papers to initiate the road design project. The Road Design Section submits the following to the Rail, Transit and Planning Division:

   a. the Preliminary Field Review Report, and
   b. the Project Scope of Work Report.

2.2.2 Public Affairs

The Public Affairs Unit is the primary focal point for all contact with the general public. This includes preparing news releases of upcoming MDT work and coordinating the presentation of public hearings and informal public meetings. On road design projects, the Road Design Section coordinates with the Public Affairs Unit on any public contacts.

2.2.3 MDT District Offices

The Department's five District Offices (Missoula, Butte, Great Falls, Glendive and Billings) provide the field services needed within each geographic area. Their responsibilities include maintenance of the State highway system, construction inspection services, contacts with county and city governments, and traffic-related activities (e.g., approach permits). Specifically for preconstruction activities, the following summarizes the coordination between the Road Design Section and District Offices:

1. Design. Some road design projects are assigned to Project Design Managers in the District Offices. This work is coordinated with the Project Design Managers in the Central Office who is responsible for projects in that District.

2. Coordination. In general, for all projects designed in Helena, the Central Office will maintain a steady contact with the District Office. The District Office, for example, will be invited to all field reviews and will receive all project-related correspondence.

3. Aerial Survey. When an aerial survey is conducted, the District Office is responsible for the control traverse and "pick-up" field survey to locate items which may be missed by the aerial survey (e.g., underground utilities). For projects designed in the Central Office, the District conveys this information to the Road Design Section for plotting.

4. Soils. The District Office is responsible for all soils surveys. Its report is submitted to the Materials Services Section in the Central Office. The District Office will also provide recommendations for shrink/swell factors for project soils.

5. Informal Public Meetings. The District Office, in coordination with the Area Project Supervisor, is responsible for scheduling and conducting informal public meetings.

6. Construction Cost Estimate. The District Office will provide the Central Office with unit prices to assist in the preparation of the construction cost estimate.

7. Temporary Traffic Control. District personnel review the proposed temporary traffic control plan and modify it as needed. The District also provides a quantity estimate for traffic control units required for the project.

2.2.4 Motor Carrier Services

Motor Carrier Services is responsible for monitoring and regulating truck traffic within the State of Montana. If it initiates work for a new weigh station or an existing weigh station, the Road Design Section is responsible for the design of the weigh station. The road designer should contact Motor Carrier Services whenever a weigh station or portable scale site is located within the project limits.

2.2.5 Legal Services

Legal Services is responsible for providing all legal counsel required by MDT (e.g., interpretation of State laws on highway work). In its administration of road design projects, the Road Design Section is responsible for preparing and processing, where applicable, agreements with other entities. Once prepared, Legal Services reviews, comments on and approves the text of the proposed Agreement.

Legal Services is also responsible for resolving R/W parcels that are in condemnation. When a parcel is in condemnation the road designer must not to provide the landowner with any additional design features or concessions without involving the staff attorney. The attorney is typically negotiating with the landowner and changes without the attorney's approval can cause problems.

When any information is provided to Legal Services, include the name of a contact person (generally the Project Design Manager), so that Leal Services will know who should be contacted for additional information or who to respond to.

2.2.6 Human Resources

The Road Design Section coordinates with the Human Resources, Civil Rights Bureau, to ensure compliance with the *Americans with Disabilities Act*. The Civil Rights Bureau will, for example, provide interpretations on the intent and application of the Act.

2.3 EXTERNAL UNITS

This Section discusses the specific coordination activities between the Road Design Section and selected major units external to MDT.

2.3.1 Federal Agencies

2.3.1.1 Federal Highway Administration

The Federal Highway Administration (FHWA) administers the Federal-aid program which funds eligible highway improvements nationwide. Their basic responsibility is to ensure that the State DOT's comply with all applicable Federal laws in their expenditure of Federal funds and to ensure that the State DOT's meet the applicable engineering requirements for their proposed highway projects. FHWA maintains a Division Office within each State, and this is the primary point of contact for a State DOT. Section 8.7 describes FHWA’s involvement in project development.

2.3.1.2 United States Forest Service (USFS)

The USFS is responsible for the management of all national forests. The USFS and the MDT currently have a Memorandum of Understanding (MOU) and approved procedures that describe the coordination between the two agencies for the planning and the development of projects having USFS involvement. If a proposed road design project will impact a national forest, the Road Design Section must coordinate the project development with the USFS. The USFS will, for example, be invited to any field reviews and receive copies of major project reports (e.g., Scope of Work Report). In some cases, project actions will require USFS approval (e.g., right-of-way acquisition).

2.3.1.3 U.S. Postal Service (USPS)

Coordination with the USPS may be necessary to determine location of mail delivery points and mailbox turnouts and to ensure that crash-tested mailboxes are installed on the project. The District will contact the USPS for all projects designed by MDT. The consultant will be responsible for projects designed by consultants.

2.3.1.4 Federal Aviation Administration (FAA)

Coordination may be necessary with the FAA when road projects are located in the vicinity of airports. The anticipated development of the airport and existing traffic patterns which involve the airport should be considered during the design process.

2.3.1.5 National Park Service (NPS)

Coordination with the NPS will be necessary where road projects are in the vicinity of land under the jurisdiction of the NPS. Although the Department has no formal agreement with the NPS, the level of involvement on projects will be similar to that between the MDT and the USFS.

2.3.2 State Agencies

2.3.2.1 Department of Fish, Wildlife and Parks (FWP)

Coordination with the FWP will be necessary where a proposed project is in the vicinity of land under the jurisdiction of the FWP. Although the Department has no formal agreement with the FWP, the level of involvement on road design projects will be similar to that between the MDT and the USFS.

2.3.2.2 Other State Agencies

The Road Design Section coordinates with other State agencies on an as-needed basis.

2.3.3 Local Governments

The following describes the coordination between the Road Design Section and local governments:

1. Design. The Road Design Section solicits input from the local government on road design projects in that locality and, in general, keeps the local governments up-to-date on any current or planned activities. For example, the decision on whether to provide open or closed drainage on an urban street is heavily influenced by input from the locality. In addition, larger municipalities may have their own design criteria, which must be considered during the design process.

2. Coordination. The Road Design Section typically invites the local government to any field reviews and provides the local government with copies of major project reports (e.g., Scope of Work Report).

3. Assistance. The Road Design Section provides technical assistance to the city and county governments, upon request. Road Design responds to any verbal or written inquiries from local governments on road design issues.

4. Information From Locals. Where applicable, the Road Design Section will need to obtain information from local governments.

5. Agreements. All projects within the limits of an incorporated city or town require a City/Town Agreement. This agreement is typically prepared near the end of the project development process. Memorandums of Understanding (MOU) are also need for projects that involve major improvements. MOU's should generally be prepared prior to the plan-in-hand. The Project Design Manager should coordinate with the District to determine who will prepare the agreements. All agreements must be sent to Legal Services for their review and approval prior to sending them to the local government.

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Three

ADMINISTRATIVE POLOCIES AND PROCEDURES

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Chapter Three
ADMINISTRATIVE POLICIES AND PROCEDURES

This Chapter discusses several items related to the operational practices for the Department's Road Design Section. It contains information on the preparation of in-house project reports, outside correspondence, memoranda, meetings and project work types.

3.1 PROJECT REPORTS

This section provides information on how to prepare the Department's project reports including the Preliminary Field Review Report, Alignment Review Report, Scope of Work Report, Plan-in-Hand Report and Final Plan Review Report. When used as described, this information will provide consistent, accurate and appropriate project reports.

3.1.1 Preliminary Field Review Report

3.1.1.1 General

A preliminary field review is conducted after a project is nominated to determine major design features, project-related issues and potential problems. Representatives attending the review are summarized in Section 3.1.1.2. The Preliminary Field Review (PFR) Report provides written documentation of all major determinations made during the preliminary field review meeting. It should list the major project design features and provide a general overview of proposed major improvements for the highway. The following procedures will apply:

1. Preparation. The Project Design Manager or designee, is responsible for the preparation of the PFR Report. Organize the Report using the format discussed in Section 3.1.1.2.

2. Signature. The PFR Report is prepared for the Road Design Engineer's review and the Highways Engineer’s signature.

3. Approval. The Road Design Engineer will forward the PFR Report to the Highways Engineer for his approval and signature.

4. Distribution. After the Highways Engineer has approved the Report, copies of the PFR Report will typically be distributed to the preconstruction project file and

to the following individuals (note that this is a standardized list – other people may receive copies as needed);

a. Preconstruction Engineer,
b. District Administrator,
c. Rail, Transit and Planning Division Administrator,
d. Maintenance Division Administrator
e. Motor Carrier Services Administrator
f. All Engineering Bureau Chiefs,
  (1) Highways Engineer
    - Highways Design Engineer
    - Road Design Engineer
    - Hydraulics Engineer
    - Photogrammetry
  (2) Construction (2 copies)
  (3) Bridge
  (4) Right-of-Way
    - Utilities
    - Access Management
  (5) Engineering Oversight
  (6) Traffic and Safety
    - Safety Management
  (7) Materials
    - Geotechnical
    - Pavement Engineer
  (8) Consultant Design
  (9) Environmental Services
    - Engineering Section Supervisor
    - Biologist
g. Fiscal Planning
h. Engineering Management
i. all other parties involved in the field review,
  (1) City/County Officials
j. any other individuals or units deemed appropriate.
  (1) Secondary Roads
  (2) Tribal Affairs Coordinator (as appropriate),
  (3) ADA Coordinator,
  (4) Bicycle and Pedestrian Coordinator
  (5) FHWA (NHS projects)

5. Comments. All parties receiving a copy of the PFR Report are requested to provide comments on the Report within two weeks of the distribution date.

Concurrence of the Report will be assumed if no comments are received within three days of the date specified.

If comments are submitted that substantially alter the proposed design features or raise additional issues, a revised Preliminary Field Review Report should be distributed for additional comment. The report should consist of only the sections affected by the changes. It does not need to include all of the background information contained in the original report.

3.1.1.2 Format/Content

In general, prepare the Preliminary Field Review (PFR) Report in the order and format discussed below. This will provide a uniform presentation for all Department PFR Reports and will ensure that all appropriate information will be addressed. Not all of the subject areas listed below will be required for every PFR Report, and adjustments will need to be made to the Report as deemed necessary. The level of coverage for each item will also vary from project-to-project. Although in-depth coverage of the individual design details is usually not included in this Report, sufficient detail still must be provided to allow the reader to fully understand the proposed project.

The following provides the topic areas, in order, that should be addressed in the PFR Report:

1. Introduction. The introduction should include the date of the field review and provide a list of individuals who attended the review. The listing should also include the individual's title, organization and office location. Depending on the project, representatives at a field review may include:

    a. the Project Design Manager
    b. the District Administrator,
    c. the Division Maintenance Chief,
    d. the Engineering Services Engineer/Supervisor,
    e. a representative from the Consultant Design Section,
    f. a representative from the Hydraulics Section,
    g. a representative from the Bridge Bureau,
    h. a representative from the Environmental Services,
    i. a representative from the Right-of-Way Bureau,
    j. a representative from the Geotechnical Section,
    k. a representative from the Civil Rights Bureau (ADA Coordinator),

l. the Tribal Affairs Coordinator,
m. a representative from the District Construction Office,
n. a representative from FHWA (if applicable),
o. local officials (if deemed appropriate), and
p. others as deemed appropriate.

6. Proposed Scope of Work. This section should provide a very brief description of the proposed scope of work for the project and/or the project intent. For example, "The proposed project has been nominated to provide an overlay and roadside safety enhancements." Also include a brief discussion explaining the reason(s) why the proposed scope of work was selected.

   If it is determined that an outside consultant should be considered for the design of the project, provide a division of expected responsibilities between MDT and the consultant.

7. Project Location and Limits. Some of the descriptions that may be used to briefly describe the project location include:

   a. county name;
   b. city/town name;
   c. Indian reservation;
   d. route number;
   e. functional classification;
   f. reference points*;
   g. project length;
   h. crossing routes and/or local streets;
   i. distances from major bridges on the route;
   j. distance and direction from nearby towns/cities;
   k. as-built project numbers;
   l. adjacent project numbers; and
   m. direction of the proposed project.

   * Where the stationing proceeds in the opposite direction from the reference points (e.g., stationing increases from south to north while the reference points increase from north to south), note this in the Report.

8. Physical Characteristics. A brief description of the project's physical characteristics may include a discussion of the following:

    a. year when the existing road/bridge was built or reconstructed and when it was last overlaid or rehabilitated;
    b. pavement width and number of lanes;
    c. surface types and thicknesses;
    d. number and thickness of previous overlays;
    e. the Pavement Management System's pavement condition and treatment recommendations;
    f. general terrain of the area;
    g. rural or urban location;
    h. general description of the existing horizontal and vertical alignment, including all features which do not meet the proposed design criteria;
    i. number of locations where the existing grade exceeds the proposed design maximum;
    j. maximum gradient on the project;
    k. general description of the existing fill and cut slopes, including slope rates, fill heights and cut depths;
    l. lengths and widths of existing bridges;
    m. any other unique physical characteristics related to the project; and
    n. special features within the project limits (e.g., National Forest, State Parks, etc.).

9. Traffic Data. The traffic data listed in the PFR Report should include the following:

    a. current AADT,
    b. letting date AADT,
    c. design year AADT,
    d. DHV,
    e. percent of trucks,
    f. the expected daily 18,000 lb (8165 kg) Equivalent Single Axle Load (ESAL), and

   g. basis of projected traffic growth.

10. <u>Accident Analysis</u>. This section should briefly summarize the following crash history data:

    a. number of crashes;
    b. types of crashes;
    c. overall crash and severity rates for the project location;
    d. average statewide crash and severity rates for similar routes, if available;
    e. a description of how the project compares to the statewide averages; and
    f. a listing of locations with an unexpectedly high number of crashes and a brief description of why a higher than normal number of crashes may be occurring and proposed countermeasures to be investigated.
    g. other remarks furnished by Safety Management regarding the crash history of the project.

11. <u>Major Design Features</u>. The PFR Report should provide a general discussion for each of the following design features, if pertinent:

    a. Design Speed. This section should provide the expected design speed for the project. If more than one design speed is selected for the project, then clearly identify the termini for each design speed selected. For existing facilities, also identify the existing posted speed limit.
    b. Horizontal Alignment. Identify all the major horizontal features for the proposed project, including all features which may not meet the proposed design criteria. The discussion should also indicate the roadway alignment that can be reasonably obtained and possible methods for improving the horizontal alignment. The utilization of a new alignment, offset and parallel to the existing alignment, should be discussed for all reconstruction projects.
    c. Vertical Alignment. Provide a general description for all the major vertical alignment features on the proposed project. This discussion may identify any grades which exceed the design criteria, the vertical alignment that can be reasonably obtained and possible methods for improving the vertical alignment.
    d. Typical Sections and Surfacing. Provide a discussion for the proposed typical section(s) of the project. This includes the final overall roadway width, travel lane widths, shoulder widths, two-way left-turn lanes, medians, side slopes, sidewalks, etc. Include separate descriptions where

there are significant changes in the typical section (e.g., changes in lane widths). Provide a description of the type of surfacing/surfacing treatment that will be used on the project

e. Geotechnical Considerations. This section should provide a brief listing of the major geotechnical considerations and techniques that may be required to construct the project (e.g., slope stability options).

f. Hydraulics. If the Location Hydraulics Study Report is attached, this section of the PFR Report will only need to list the major hydraulic features of the project (e.g., bridge replacement, culvert replacements greater than 84 in). If the Location Hydraulics Study Report is not attached, provide a discussion for the major hydraulic design elements on the project (e.g., pipe replacement, irrigation facilities, flooding or overtopping issues).

g. Bridges. If there are bridges on the project, include a description of the proposed work to be performed on each bridge. The description should also discuss the need for sidewalks, bicycle paths, utilities or any special features that may be included on the bridge. This section should also address any structural removals.

h. Traffic. Provide a brief discussion for each intersection which has been proposed for major revisions (e.g., adding turning lanes, changing an existing "Y" intersection to a "T"). In addition, this section should address all major traffic control devices that may be used within the project (e.g., traffic signals, highway lighting, major signs).

i. Pedestrian/Bicycle/ADA. Discuss impacts to existing facilities. Discuss implementation of new ADA features. Where there are no existing pedestrian or bicycle facilities and if there is evidence of use, include a proposal for their accommodation.

j. Miscellaneous Features. This section should provide a discussion for all major design elements which are not identified in one of the above design areas. Miscellaneous features may include guardrail, mailbox turnouts, on-street parking, accessibility requirements, retaining walls, fencing, etc.

k. Context Sensitive Design Issues. Discuss any issues which may be context sensitive and potential solutions. These are issues that may affect the development of the project and are not strictly transportation related. They may include environmental, cultural and social issues

12. <u>Other Projects</u>. This section should identify all other projects that are currently under construction or will be in the near future that may affect this project.

13. Location Hydraulics Study Report. If available, attach the Location Hydraulics Study Report to the PFR Report. The Location Hydraulics Study Report will be prepared by the Hydraulics Section.

14. Design Exceptions. If known at this stage, list all proposed design exceptions with a brief discussion of why an exception is considered necessary.

15. Right-of-Way. Briefly describe the existing and proposed right-of-way widths. Note if the project will use minimum or standard Right-of Way widths. Include separate descriptions where the existing or proposed right-of-way is significantly different between various typical sections. If known, provide a listing of the major right-of-way acquisitions (e.g., taking of commercial property). In addition, identify the proposed access control classification for the highway.

16. Access Control. The current access control classification for the highway should be identified and discuss if the access control will be modified on the project.

17. Utilities/Railroads. Include a listing of known utility and/or railroad companies that may be affected by the project. Also describe any railroad crossing and the type of signing/signalization. For utilities, note their location and how they may affect the project.

18. Survey. Address the need for a survey and the recommended survey methodology. Provide recommended target dates for the survey completion. This section should also discuss the need for other survey types (e.g., soil survey, S.U.E.).

19. Public Involvement. This section should discuss the type of public involvement required. (See Public Involvement Handbook) This may include meetings with local officials, an early public involvement meeting and/or a formal public hearing. Also include the proposed approach for distributing project information to the public.

20. Environmental Considerations. List the level of Environmental Document proposed by Environmental Services. Identify any major environmental concerns on the project (e.g., hazardous waste, waterways, wetlands, archaeological/cultural sites). List all proposed measures that should be evaluated to avoid and minimize impacts to wetlands. The need for obtaining a consultant to prepare the environmental documents should also be addressed.

21. Traffic Control. Identify the proposed traffic control procedure planned for the construction zone (e.g., detours, lane closures, shifting traffic, crossovers).

22. Project Management. State which office will be responsible for the plans and identify the Project Manager.

23. Ready Date. Include the ready date in the Report. The project ready date is typically three months prior to the letting date. The proposed letting date can be obtained from the Engineering Information Management Section.

1. Preliminary Cost Estimate. Include the estimated cost that has been programmed to construct the project. Also show this estimate using a cost per mile (kilometer) basis. The cost estimate should be adjusted using an inflation factor based on the project's anticipated letting date. (Use 3% inflation factor) The construction engineering (CE) cost should be listed separately. The report should also note whether or not the CE cost is included in the total construction cost. See Chapter 7 for more information on cost estimates. Use the following format for showing the cost estimate in the report:

Cost Estimate

New Structure	$132,000
Remove Structure	$ 10,000
Road Work	$ 82,000
Traffic Control - Detour	$ 77,000
Subtotal	$301,000
Mobilization (12%)*	$ 36,000
Subtotal	**$337,000**
Contingencies (10%)*	$ 34,000
Subtotal	$371,000
Inflation (3% per year x 3 years)	$ 34,000
Total CN:	**$405,000**
CE (15%)*	**$ 61,000**

*See Figure 7.2A for suggested rates, coordinate with Bridge Bureau as appropriate (match the numbers they feel are appropriate), and use judgment based on the level of design completed so far.

Board of Review (pre-letting) suggested rates:

24. Site Map. Project location site map should be attached.

25. Preliminary Field Review Work Sheet. The Preliminary Field Review Work Sheet should be used as a checklist to identify issues that should be addressed during the Preliminary Field Review. All information noted on the work sheet should be

discussed in the PFR Report. It is not necessary to attach the Preliminary Field Review Work Sheet to the PFR Report, however it may be attached to summarize the data contained in the PFR Report. A blank Preliminary Field Review Work Sheet form is provided at the end of Section 3.1.

3.1.2 Alignment and Grade Review Report

3.1.2.1 General

The Alignment and Grade Review (AGR) Report provides written documentation of the horizontal and vertical alignment determinations made during preliminary design and the alignment review meeting. The alignment review meeting is typically only held where major changes to the alignment are proposed. However, a review should also be conducted at this stage in the project's development if significant design issues need to be addressed, even if the alignment and grade will not be altered by the project. The proposed alignment should be submitted to the District Administrator or District Engineering Services Supervisor for review. The need for a field review of the proposed alignment will be determined by the Project Design Manager on a project-by-project basis.

1. Preparation. The Project Design Manager is responsible for the Draft AGR Report, but the designer is typically assigned to prepare the Report. Organize the Report using the format discussed in Section 3.1.2.2.

2. Approval. The designer will submit the Draft AGR Report to the Project Design Manager for review. The Project Design Manager will in turn submit it to the Road Design Engineer who will forward it to the Highways Engineer for his approval. The Project Design Manager will attach the plans as appropriate and distribute the Draft AGR Report for comment.

3. Distribution. Copies of the Draft AGR Report, plans and cross sections will typically be distributed for comment to the following individuals:

    a. District Administrator, (w/1 set const.)
    b. Road Design Engineer,
    c. Rail, Transit and Planning Division Administrator,
    d. Highways Design Engineer
    e. Bureau Chiefs,
        (1) Highways
        (2) Environmental Services (w/3 sets const., 1-X-Sections)
        (3) R/W, (w/1 set const., X-Sections)

    (4) Bridge (w/1 set const.)
    (5) Construction, (w/1 set const.)
    (6) Traffic and Safety, (w/1 set const.)
    (7) Materials, (w/1 set const.)
f. Geotechnical, (w/1 set const., X-Sections)
g. Hydraulics, (w/1 set const., X-Sections)
h. Utilities, (w/1 set const., X-Sections)
i. Traffic Engineer, (w/1 set const.)
j. Project Design Manager, (w/1 set const., X-Sections)
k. District Construction Engineer, (w/1 set const., X-Sections)
l. District Engineering Services, (w/1 set const., X-Sections)
m. District/Division Maintenance, (w/1 set const.)
n. District R/W Supervisor, (w/1 set const., X-Sections)
o. any other individuals or units deemed appropriate.
    (1) FHWA(HOP-MT) (NHS) (w/1 set const.)
    (2) City Officials, (w/1 set const.)
    (3) County Officials, (w/1 set const.)
p. Highways File

4. Summary. After a two week review by the distribution, the comments will be summarized by the Project Design Manager and the summary along with copies of the comments will be submitted to the Highways Engineer for his approval of the Alignment and Grade:

3.1.2.2 Format/Content

In general, prepare the Alignment and Grade Review (AGR) Report in the sequence and format discussed below. This will provide a uniform presentation for all Department AGR Reports and will ensure that all appropriate information will be addressed. Not all subject areas need to be covered in every AGR Report, there will not always be a field review, and adjustments will need to be made as deemed necessary.

In lieu of a field review for projects in which the alignment is not appreciably changed or controversial, the plan package may be distributed as shown in (3. Distribution) above and comments solicited and summarized for the approval of the Highways Engineer. The level of coverage for each item may also vary from project-to-project. Although an in-depth coverage of the design details is usually not provided in this report, provide sufficient detail to allow the reader to fully understand the proposed project.

The sample format can be found on the Road Design share drive. The preparer should note that the heading will need to be completely filled out, including the project number, project name, control number and project work type number.

The following provides the topic areas, in order, that should be addressed in the Draft AGR Report:

1. Introduction. The introduction should include the date of the field review and a list of those who attended the review, if one was held, including the individual's title, organization and office location. Typical representatives at an alignment field review may include:

    a. the Project Design Manager.
    b. the District Administrator;
    c. the Engineering Services Supervisor;
    d. the Design Supervisor;
    e. other design personnel who may be involved with the project;
    f. the Consultant, for consultant-designed projects;
    g. FHWA (NHS – full oversight projects);
    h. local officials (if deemed appropriate); and
    i. others as deemed appropriate.

    If no field review was held, begin the report with the Scope of Work.

2. Scope of Work. Provide a brief description of the proposed scope of work. For example, "The proposed scope of work for this project is to completely reconstruct the existing roadway." The discussion should also include the selected design speed for project.

3. Project Location and Limits. Some of the descriptions that may be used to briefly describe the project location and limits include:

    a. county name,
    b. city/town name,
    c. Indian reservation,
    d. route number,
    e. functional classification,
    f. reference points,

   g. project length,
   h. crossing routes and/or local streets,
   i. distances from major bridges on the route,
   j. distance and direction from nearby towns/cities,
   k. as-built project numbers,
   l. adjacent project numbers, and
   m. direction of proposed project.

5. Physical Characteristics. This section does not need to be included in the report unless the following elements affect the selection of the alignment, grade and surfacing section:

   a. general terrain of the area;
   b. rural or urban location;
   c. pavement width and number of lanes;
   d. surface types and thickness;
   e. generalized descriptions of the horizontal and vertical alignment;
   f. generalized descriptions of the existing fill and cut slopes, fill heights and cut depths;
   g. lengths and widths of existing bridges; and
   h. any other unique physical characteristic related to the project.

6. Horizontal Alignment. One of the primary purposes of the AGR Report is to identify the proposed horizontal alignment features on the project. Therefore, this section should provide more detail than other sections of the Report. The horizontal alignment elements that should be discussed in detail include:

   a. the relationship of the proposed alignment to the existing alignment,
   b. curve radii,
   c. alignment shifts, and any other major features affected by the horizontal alignment.

   The discussion should list the various horizontal alignment design features using the appropriate stations and a brief discussion. For example:

Station 1+20 to 1+75	The alignment will be shifted to the right by 10 m by using a 500 m radius curve. The new alignment will

	allow the construction of a wider roadway template without having the fill slopes encroach into the river channel on the left.
Station 1+75 to 3+00	This tangent section is approximately 10 m right of the existing alignment to avoid a conflict with the overhead power line which is parallel to the roadway on the left.

7. Vertical Alignment. Discussion of the vertical alignment is also a primary objective of the AGR Report. Therefore, the discussion should be similar to that shown for horizontal alignment in Comment #5. Some of the vertical alignment elements that should be discussed include:

   a. raising or lowering of the existing vertical alignment,
   b. an identification of the maximum grades
   c. proposed steepening or flattening of existing grades,
   d. general vertical curvature requirements,
   e. depth of special subgrade excavations,
   f. grade controls (e.g. existing bridges, railroad crossings)
   g. relationship to the horizontal alignment, and
   h. any other major features affected by the vertical alignment.

8. Surfacing and Typical Section. Briefly summarize the pavement recommendations developed by the Pavement Analysis Section, including any surfacing and/or subgrade recommendations. Specify the finished top width or widths that will result from the proposed work. The finished width is particularly critical when overlaying segments of roadway having marginal widths. The discussion should also include the recommended cross slopes and side slopes for the project. Separate discussions may be required if there are significant changes in the typical section such as auxiliary lanes or if there is a need for an additional soil survey.

9. Grading. This section should provide any information on how grading may affect the horizontal and vertical alignment. Some of the factors that may be addressed include:

   a. type of excavation,
   b. special soil considerations which may require shifting the alignment, and

   c. proposed balance points.

10. Hydraulics. Provide a discussion on how the hydraulic design may affect the roadway alignment. This includes:

    a. major hydraulic structures (e.g., bridges over waterways, large culverts, irrigation channels);
    b. waterway impacts and proposed channel changes;
    c. flooding potential; and
    d. permit needs for alignment revisions.

11. Bridges. If there is a bridge within the project limits, address how the bridge will impact the roadway alignment (e.g., increasing the curve radii so that the horizontal curvature is continuous across the bridge, bridge end elevations as vertical control points). The Bridge Bureau should be consulted when placing a horizontal or vertical curve alignment on bridges so that curve control points can be coordinated with structural design.

12. Traffic. Identify any revisions to the roadway alignment required to provide proper intersection alignment and profile designs, or how the alignment may impact existing traffic control devices.

13. Miscellaneous. Address any miscellaneous items relative to the design which have not been previously discussed (e.g. fencing, turn-outs, guardrail).

14. Design Exceptions. If known at this stage, discuss the need for any proposed horizontal and vertical alignment design exceptions.

15. Right-of-Way. The right-of-way discussion should address how the proposed roadway alignment will affect the existing and proposed right-of-way limits. Note if project will use minimum or standard Right-of Way widths.

16. Utilities/Railroads. Provide a discussion on how the proposed alignment will affect known utilities and/or railroads.

17. Environmental Considerations. The report should address all major environmental concerns that are affected by the roadway alignment. The report should summarize the measures taken to avoid and minimize impacts to wetlands. Also discuss where and why avoidance or minimization is not feasible. Identify the depth of environmental study required for the project (e.g., categorical exclusion, environmental assessment, environmental impact statement).

18. Traffic Control. Discuss how the proposed roadway alignment will impact the proposed traffic control strategy during construction (e.g., detours, crossovers).

19. Public Involvement. If held, briefly summarize the results of the public informational meeting. Also document the need for any further public involvement (e.g., the need for a public hearing).

20. Cost Estimate. Update the PFR cost estimate using the process described in Chapter 7.

21. Ready Date. Provide the ready date shown in the Project Management System.

3.1.3 Scope of Work Report

3.1.3.1 General

The Scope of Work (SOW) Report identifies the major design features of the subject project and provides an overview of the project improvements. The project design will proceed as described in the Report unless opposition is expressed within the specified comment period. Any disagreement in the scope of the project must be resolved prior to the final approval by the Chief Engineer of the Engineering Division. Consequently, it is essential that the Scope of Work Report be written as soon as the appropriate data is available.

Projects of very limited scope often have a combined Preliminary Field Review/Scope of Work Report (PFR/SOW). These reports follow the format for the SW report. They are distributed for comment and approval following the same procedure as the SW report.

Most projects of limited scope meet the criteria for the Statewide Programmatic Categorical Exclusion. Since the SOW report cannot be finalized until the environmental document is approved, the combined PFR/SOW report must be submitted to Environmental Services with a checklist for the Statewide Programmatic Categorical Exclusion. If the Statewide Programmatic Categorical Exclusion does not apply the final approval of the PFR/SOW report will be delayed until the project specific environmental document is approved

The designer should use the following procedure to prepare the SOW Report and to obtain management approval of the report:

1. The Project Design Manager who is responsible for the preparation of the SOW Report, will typically designate the designer to prepare the preliminary draft of the Report and all appropriate distribution memorandums.

2. The Project Design Manager will review the report, make all necessary changes and forward it to the Road Design Engineer.

3. The Road Design Engineer will initial the SOW Report Memorandum and forward it to the Highways Engineer.

4. Once concurrence has been received from the Bureau Chiefs and the FHWA*, if applicable, the Project Design Engineer or designee, will prepare another memorandum requesting the Chief Engineer's approval for the SOW Report. This memorandum is prepared for the Highways Engineer's signature. It should include the comments received and their proposed disposition. A sample memorandum used for requesting approval from the Chief Engineer, Engineering Division can be found on the share drive. After approval, copies of the SOW Report will typically be distributed as follows:

Preconstruction Engineer
Highways Engineer
Highways Design Engineer
Hydraulics Engineer
Safety Mgmt. Engineer
Materials Engineer
Geotechnical Engineer
Environmental Services Chief
Engr. Mgmt. Supervisor
Traffic Engineer
Access Management Engineer
Fiscal Programming Supervisor
District Maintenance Chief
Project Manager
City/County Officials

District Administrator.
Utilities Supervisor
Right-of-Way Chief
Program & Policy Analysis Administrator
Road Design Engineer
Construction Administrator
Bridge Engineer
Traffic & Safety Engineer
Maintenance Administrator
Bicycles & Pedestrians Coordinator
Project Design Manager
District Construction Engineer
District Engineering Services Supervisor
FHWA (HOP-MT)(NHS)
Highways File

*The FHWA will provide concurrence only on NHS projects with an estimated cost of $3 million or more, and on Interstate projects with an estimated cost of $1 million or more for reconstruction and $3 million or more for pavement preservation

3.1.3.2 Format/Content

In general, prepare the Scope of Work (SOW) Report in the sequence and format discussed below. This will provide a uniform presentation for all Department SOW Reports and will ensure that all necessary design elements are addressed. Not all subject areas will be covered in every SOW Report, and adjustments will be added as necessary. The level of coverage for each item may also vary from project-to-project. Although an in-depth discussion for each design element is usually not provided in this

Report, sufficient detail must be provided to allow the reader to fully understand the proposed project. On non-reconstruction projects (e.g. Overlay, Widening etc.) where no changes to the Alignment and Grade are proposed, a combination Alignment Review/Scope of Work Report may be distributed along with plan sheets where the main thrust of the Alignment Review is a discussion of the Typical Section for the project. The following declaration should be presented on the cover sheet of the report:

"No Alignment and Grade Report will be forthcoming due to the fact that no "new" alignment and grade will be designed; however, comments regarding typical section or geometric designs shown in the plans distributed with this report are solicited".

The following provides the topic areas, in order, that should be addressed in the SW Report:

1. Proposed Scope of Work. This section should provide a very brief description of the proposed scope of work for the project. For example, "The proposed scope of work for the subject project is to provide a 0.50 ft. overlay and roadside safety enhancements." This section should also include a brief discussion of why the proposed scope of work was selected.

2. Project Location and Limits. The following descriptions may be used to briefly describe the project location and limits:

   a. county name;
   b. city/town name;
   c. Indian reservation;
   d. route number;
   e. functional classification;
   f. reference points;
   g. crossing routes and/or major local streets/interchanges;
   h. project length;
   i. distances from major bridges on the route;
   j. distance and direction from nearby towns/cities;
   k. as-built project numbers;
   l. adjacent project numbers; and
   m. direction of proposed project.

Note - Where the stationing proceeds in the opposite direction from the reference points (e.g., stationing increases from south to north while the reference points increase from north to south), note this in the report.

3. Physical Characteristics. A brief description of the project's physical characteristics may include a discussion of the following:

   a. year when the existing road/bridge was built or reconstructed and when it was last overlaid or rehabilitated;
   b. pavement width and number of lanes;
   c. existing surface types and thicknesses;
   d. number and thickness of overlays;
   e. general terrain of the area;
   f. rural or urban location;
   g. general description of the existing horizontal and vertical alignment, including all features which do not meet the Department criteria;
   h. number of locations where the existing grade exceeds the applicable maximum;
   i. maximum gradient on the project;
   j. general description of the existing fill and cut slopes, including slope rates, fill heights and cut depths;
   k. lengths and widths of existing bridges; and
   l. any other unique physical characteristics related to the project.

4. Traffic Data. The traffic data in the Report should include the following:

   a. current AADT,
   b. letting date AADT,
   c. design year AADT,
   d. DHV,
   e. number and percent of trucks,
   f. the expected daily 18,000 lb (8165 kg) ESAL, and
   g. basis of projected traffic growth.

5. Accident Analysis. This section should briefly summarize the following crash history data:

a. number of crashes;

b. types of crashes;

c. listing of locations with an unexpectedly high number of crashes;

d. overall crash and severity rates for the project location;

e. statewide average crash and severity rates for similar routes, if available;

f. a description of how the project compares to the statewide averages; and

g. a brief description of why higher than normal number of crashes may be occurring and proposed countermeasures.

h. other remarks furnished by Safety Management regarding the crash history of the project.

6. Major Design Features. The SOW Report should provide a general discussion for each of the following design features. This discussion should also include any approved design exceptions for that design element. Prepare each topic area based on the station sequencing. Although each major design element is provided its own section, the designer should address how the element will interact with other design elements. The SW Report should discuss the following topics:

a. Design Speed. This section should present the expected design speed for the project. If more than one design speed is selected for the project, clearly identify the termini for each design speed selected. Also indicate the posted speed limit. If a speed zone study is recommended, it should also be noted.

b. Horizontal Alignment. Provide a brief discussion of the major horizontal features for the proposed project (e.g. “The project includes 5 horizontal curves with radii from 1500 ft to 4200 ft. Spirals will be used where required.”), including all features which will not meet the applicable design criteria. The discussion should also include the maximum design criteria that can be reasonably obtained and the proposed methods for improving the horizontal alignment.

c. Vertical Alignment. Include a brief description for all the major vertical alignment features on the proposed project (e.g. “The project includes 5 crest and 6 sag vertical curves all of which provide the SSD for a 60 mph design speed. The maximum grade on the project is 3.5%”). This discussion should identify the maximum design criteria that can be reasonably obtained and the proposed methods for improving the vertical alignment. If truck-climbing lanes are warranted, their location and extent should be described.

A more detailed discussion should be provided when design features cannot meet the design criteria for the project. The discussion should include the reasons why it is impractical to meet the design criteria and also demonstrate that safety is still sufficiently addressed.

d. Typical Sections. This section should briefly describe the major cross section elements. These include roadway widths, travel lane widths, shoulder widths, two-way left turn lanes, medians, sidewalks, etc. Provide separate descriptions where there are major changes in the typical section. A detailed description of the finished top width or widths and surfacing inslopes that will result from the proposed work are particularly critical when overlaying segments of roadway having marginal widths.

e. Surface Design. The pavement design discussion may include a summary of the soils report, including the results from the pavement samples taken on existing highways; the proposed pavement design, including pavement type and thickness; milling depths and widths; recycling considerations; etc.

f. Grading. This section should discuss the general grading on the project. This may include a discussion on balance points, special excavation, features that may affect grading operations (bridges communities), the need for large amounts of borrow, special soil considerations, shrink/swell factors, etc.

g. Slope Design. Describe the proposed slope design for the project in this section. Typical slope discussions may include slope flattening for guardrail, slope flattening for removal of guardrail, use of a barn roof section, steep side slopes, rock cuts, transverse median slopes, non-standard slope rates, etc.

h. Geotechnical Considerations. This section should identify the major geotechnical features and problems on the project and any planned techniques that will be used to address these concerns.

i. Hydraulics. This section should provide a brief summary of the hydraulic issues and the proposed treatment for the hydraulic design elements on the project. These may include bridge replacements over water, culvert replacements, closed drainage systems, irrigation facilities, special roadway designs within flood limits, construction requirements for replacement of structures in live streams, etc.

j. Bridges. If there are bridges on the project, provide a description of the proposed work on the bridge for each bridge. The description should also discuss the need for sidewalks, bicycle paths, utilities or any special features that may be included on the bridge. This section should also address any removal and salvage requirements of existing structures.

k. Safety Enhancements. This section should describe the proposed approach for major safety enhancements. These include the flattening of slopes, removing guardrail, replacing existing guardrail, adding new guardrail, using impact attenuators, using special culvert end treatments, etc. This section should also address any recommendations provided by the Safety Management Section.

l. Context Sensitive Design. Discuss any issues which may be context sensitive and the solutions that will be incorporated into the project. These are issues that may affect the development of the project and are not strictly transportation related. They may include environmental, cultural and social issues. It should also be noted which issues were resolved through the public involvement process.

m. Traffic. Provide a brief discussion for each intersection which has proposed major revisions (e.g., adding turn lanes, converting an existing "Y" intersection to a "T"). This section should also address the traffic control devices that will be required for the project including traffic signals, highway lighting, signing (new or reused), standard or special pavement markings, islands, etc.

n. Pedestrian/Bicycle/ADA. Discuss impacts to existing facilities. Discuss implementation of new ADA features. Where there are no existing pedestrian or bicycle facilities and if there is evidence of use, include a proposal for their accommodation.

o. Miscellaneous Features. Include a general discussion for all major design elements which are not identified in one of the above design areas. Miscellaneous features may include rumble strips, mailbox turnouts, on-street parking, accessibility requirements, fencing, unusual seeding and sodding requirements, etc.

7. Design Exceptions. This section should identify any required and approved design exceptions for the project. The design exceptions should also be noted in the individual design areas listed previously in Item #6.

8. Right-of-Way. Briefly describe the existing and proposed right-of-way width requirements. Note if project will use minimum or standard Right-of Way widths.

Provide separate descriptions where the existing or proposed right-of-way is significantly different between various typical sections. Also document any major right-of-way acquisitions (e.g., taking of commercial property).

9. Access Control. The current access control classification for the highway should be identified and discuss if the access control will be modified on the project.

10. Utilities/Railroads. The report should describe any potential problems relative to utilities and/or railroads. The discussion should also describe what has already been accomplished for utility and railroad companies.

11. Environmental Considerations. The environmental document must be approved prior to completing the SOW report. Include the date and conditions of approval. Summarize any environmental commitments and concerns identified in the document. This section should also provide brief descriptions of any environmental, cultural avoidance and mitigation measures taken as well as treatment of hazardous waste sites.

12. Other Projects. Discuss the resolution of any project conflicts identified in the Preliminary Field Review and/or Alignment Review Reports and determine if the projects can be combined for bid letting.

13. Traffic Control. Provide a discussion on the proposed traffic control strategy planned for the construction zone. This may include the need for detours, lane closures, traffic shifts, crossovers, etc.

14. Public Involvement. This section should summarize the public involvement process used for the project. It should note what has been done to date, what public involvement still needs to be accomplished and any concerns raised during the public involvement meeting. The proposed disposition of each concern should also be included.

    This section should also note any required agreements with Tribes and local governments.

15. Cost Estimate. This section should provide the latest cost estimate available for the project. The designer may be required to prepare a detailed estimate for this Report. Adjust the estimate for inflation and indicate the inflation factor used. List the construction engineering cost separately. For urban projects, discuss the city’s cost participation for such items as storm drains, manholes and water valves. Use the following format for showing the cost estimate in the report:

Cost Estimate

New Structure	$132,000
Remove Structure	$ 10,000
Road Work	$ 82,000
Traffic Control - Detour	$ 77,000
Subtotal	$301,000
Mobilization (12%)*	$ 36,000
Subtotal	**$337,000**
Contingencies (10%)*	$ 34,000
Subtotal	$371,000
Inflation (3% per year x 3 years)	$ 34,000
Total CN:	**$405,000**
CE (15%)*	**$ 61,000**

*See Figure 7.2A for suggested rates, coordinate with Bridge Bureau as appropriate (match the numbers they feel are appropriate), and use judgment based on the level of design completed so far.

16. Ready Date. Include the proposed ready date in the Report. The project ready date is typically three months prior to the letting date.

17. Site Map. Project location site map should be attached.

3.1.4 Plan-in-Hand Report

3.1.4.1 General

The plan-in-hand review is an in-depth review of all items contained in the project plans and draft special provisions. It typically consists of a sheet-by-sheet office review of the plans followed by a field review. The Project Design Manager is responsible for scheduling the plan-in-hand review. The Plan-in-Hand (PIH) Report provides a written documentation of all decisions made during the plan-in-hand office and field review meetings. The PIH Report addresses the concerns and questions raised by the review team and their proposed disposition. Use the following procedures to prepare the PIH Report:

1. Preparation. The designer is responsible for the preparation of the PIH Report. The Project Design Manager will review the Report, make all necessary changes and forward it to the Road Design Engineer.

2. Approval. The Road Design Engineer will sign and forward the Report to the Highways Engineer for approval.

3. Format. The preferred heading and approval memorandum format the designer should use when preparing the PIH Report can be found on the share drive.

4. Distribution. After approval by the Highways Engineer, copies of the PIH Report will typically be distributed to the Highways project file and to the following individuals:

   a. all applicable Bureau Chiefs,
   b. Highways Design Engineer,
   c. District Administrator,
   d. Rail, Transit and Planning Division Administrator,
   e. all parties involved in the field review,
   f. any other individuals or sections deemed appropriate, and
   g. FHWA for projects that have FHWA oversight.

All parties receiving a copy of the PIH Report are requested to provide comments on the Report. Concurrence of the Report will be assumed if no comments are received by the specified date.

5. Conducting the Review. Prior to beginning the review the design project manager should summarize the scope of the project and the major issues that need to be addressed at the PIH. Depending on the scope of the project, the major issues that need to be discussed may include the following:

   a. Sequence of operations

   b. Constructability

      1) If the R-value is low, i.e. 15 or less, or A-4 through A-7 material, or soil survey shows existing moisture contents above optimum moisture, look closely at the constructability of the section and brainstorm for ideas that could improve the construction process.

      2) Will the existing sequence support construction activities and operations?

3) If the grade will require removal of the existing mat on the PTW, determine if the material under the mat will support construction equipment.

c. Maintenance of traffic, detours and traffic control plan issues**.** A traffic control plan or concept should be developed to determine major issues especially on urban projects.

d. Grading. This may include balanced grading versus waste and borrow, special borrow, selective grading and subexcavation. Determine if the mass diagram is an accurate representation of how the grading will be performed.

e. Surfacing. Discuss the use of RAP, leveling/isolation lifts, whether or not to use different grades of oil, alternate surfacing sections, use of millings

f. Geotechnical issues. Discuss foundations, digouts and slope stability. Determine if there is enough or representative cores and soils analysis.

g. Major drainage structures. This may include optional vs. alternate bid items, coating requirements, channel changes, detour crossings, and riprap layout

h. Irrigation facilities. Consider timing restrictions. Will the irrigation have the potential for saturation of subgrade, other construction related issues. Can modifications to the irrigation be done by paying the landowner to do it (cost to cure)

i. Storm Drains. Discuss the location and capacity of inlets. Are the gutter grades adequate

j. Utilities. Avoid and minimize impacts where practical

k. R/W issues. Discuss properties to avoid, approach locations and grades

l. Environmental items. This may include a discussion of commitments made in the environmental document, wetland impacts, fish and wildlife passage, cultural sites and potential for encountering hazardous waste sites.

m. Structures & bridges. Are there any concerns with the connections, including guardrail, concrete rails, approaches, etc.

For the above items the question that needs to be asked most frequently is, "do the plans and special provisions describe and address these items accurately".

6. The following practices should be utilized to achieve an effective plan review:

   a. Prior to distributing PIH prints, the design team should perform a 3-sheet review to make sure the information in the summaries, plan & profile sheets and the x-sections match.

   b. Prior to distributing PIH prints, the design team should ensure that the method of measurement and basis of payment in the special provisions and specifications correspond to the items in the summaries and on the cost estimate.

   c. Emphasize that people who receive the PIH prints need to review the plans, x-sections and special provisions before the PIH meeting

   d. Bring a list of specific questions to the PIH

   e. Reviewers can provide the designer written comments or redlined plans at the PIH. The review team could then elect to discuss specific items rather than going through each comment at the PIH review. Focus on project construction rather than on minor details.

   f. Provide a full set of plans for PIH. This means getting plans, special provisions, and cost estimate information from all the contributing areas (R/W. Environmental, Bridge, Signing, Electrical).

   g. Emphasize that special provisions and costs estimates need adequate discussion at the PIH

7. After the PIH the following tasks must be performed:

   a. Write a report that accurately documents the decision that were made and the changes that resulted from the PIH review. This includes documenting why various recommendations were rejected.

   b. Make the appropriate changes to the plans and special provisions. Design project managers must ensure that functional managers make the changes to the sections of the plans package that are their responsibility (e.g. road plans and signing plans on a BR project). However, the functional managers and designers are also accountable for developing accurate plans and special provisions and making the PIH changes.

c. Coordinate with other disciplines as needed to provide a complete and accurate plans package. Emphasis should be placed on contacting areas affected by the PIH changes.

d. Address unresolved issues through an issue resolution process, i.e. elevate issues through the chain-of-command as necessary.

e. Share and distribute any "lessons learned" from the project

3.1.4.2 Format/Content

When preparing the PIH Report, the designer should consider the following:

1. Combine all office and field review comments into one Report.

2. Combine and present all comments from the office and field reviews in the order in which they appear in the plan sheets. Also present the comments for the plan and profile sheets according to increasing stations down the proposed centerline of the project.

3. The first part of the PIH Report should provide all general comments on the project.

4. Identify all comments by sheet number and station location. If appropriate, provide the distance from the proposed centerline.

5. The resolution should briefly summarize the problem, question or request raised during the review meeting and state how the designer intends to address the comment.

6. Where practical, identify the individual making the comment.

7. Include all revisions to the special provisions in the PIH Report with a brief discussion of the reason for the revisions.

8. Include an updated cost estimate for the project. The estimate should incorporate the latest unit prices provided by the District. Forward a copy of the estimate to the Engineering Management Unit and Fiscal Planning. If the

estimate differs substantially from previous estimates, include the reasons for the change in project costs.

3.1.5 Final Plan Review Report

The final plan review is an in-depth review of the final project plans and special provisions. Generally, it will consist of individual plan reviews by everyone on the distribution. Formal plan reviews or field reviews will be scheduled only for very specific circumstances. The reviewers' comments will be submitted to the designer within a specified time period. The Final Plan Review (FPR) Report presents the designer's proposed disposition of the reviewers' comments. At this stage of the project, comments should only be related to the completeness and accuracy of plans.

Responsibilities, approvals, format and distribution of the FPR Report will typically follow the same procedures as described in Section 3.1.4 for the Plan-in-Hand Report.

Montana Department of Transportation
Preliminary Field Review Work Sheet

Project No.______________________________ Project Name__________________________
Date of Review__________________________ Design Assignment______________________
Proposed Ready Date_____________________ Project Work Type______________________

PROJECT LOCATION
County__________________________________ Route Name____________________________

“AS-BUILT” PROJECTS FROM TO
Identification Number Station (Reference Point) Station (Reference Point)
____
____
____
____
____

Begin Station___________________________ End Station___________________________
Begin Reference Point___________________ End Reference Point____________________
Length: Urban___________________, Rural___________________, Total___________________
Speed Zones____
____
____
Last Major Work_________________________ Improved______________________________

ROADWAY FUNCTIONAL CLASSIFICATION
Type:__________________________________ (See Chapter Eight for selection criteria.)

ACCIDENT DATA
Accident Rate___________________ Avg. Accident Rate – Statewide:______________________
Severity Rate___________________ Avg. Accident Rate – Statewide:______________________
Clusters____

EXISTING GEOMETRIC DESIGN
Type of Surface____
Existing Surface Width____
____
Horizontal Curves that do not meet MDT criteria__________________________________
“As-Built” P.I. Station (Reference Point) Curve Direction
____
____
____
Crest Curves that do not meet MDT criteria______________________________________
____
____

Sag Curves that do not meet MDT criteria

Grades that do not meet MDT criteria

Maximum Grade
Existing Fill Slopes
"As-Built"
Fill Height
Slope
Existing Cut Slopes
"As-Built"
Cut Depth
Slope
Proposed Work (Type of Project)

Route Segment Plan Pavement Width Standard Width

TRAFFIC DATA

Present AADT DHV Future AADT/year
Rural Functional Classification
Other

ATTENDED BY

ROADSIDE HAZARDS (Mailboxes, Utilities, Trees, Rocks, Signs, Culvert Ends, etc.)

Montana Department of Transportation
Preliminary Field Review Work Sheet

FIELD REVIEW RECOMMENDATION

Design Speed__________________________ Terrain________________________________

Finished Surface Width____

Finish Roadway Width____

Pedestrian Features____

Curb & Gutter____

Overlay Thickness____

Back Slope____

Inslope____

Truck Climbing Lane____

Adjustments (Drains, Valves, etc.)____

Cold Milling____

Guardrail (New, Upgrade, Structure, etc.)____

Special Considerations____

SURVEY

Aerial Mapping______________ Full Survey______________ Partial Survey_____________

Cross Sections____

Pipes: Condition________________; Soil Tests_______________________________________

R-Value______________________________ Corings_______________________________

Materials____

Digouts____

Hydraulic Survey____

Target Date of Survey Completion____

Other Items____

RIGHT-OF-WAY

Existing R/W Width____

New R/W (Incl. Possible Permits)____

Limited Access____

Railroad Requirements____

Define – “Clear Zone Width”____

Stockpasses:

"As-Built"	Station	(Reference Point)	Type	Remarks

UTILITIES

Telephone____

Power Poles____

Railroad Conflicts____

Sewer & Water Conflicts____

Other____

M.O.U. with City____

ENVIRONMENTAL ISSUES

Environmental Document Type (will be determined by Environmental Services)______________

4(f) Lands____

6(f) Lands____

Wetlands____

Possible Hazardous Waste Sites____

Cultural Survey Required____

Historic Bridges____

Other (Prairie Dogs, Protected Streams, Landmarks, etc.)________________________________

PUBLIC HEARINGS

Formal_____________ Informational_____________ News Release_____________

Montana Department of Transportation
Preliminary Field Review Work Sheet

TRAFFIC ITEMS
Signing (Upgraded to MUTCD Criteria)______________________________
Lighting, Intersections, Noise, etc.______________________________

GEOMETRIC DESIGN EXCEPTION
Grade______________________ Fill/Cut Slopes______________________
Width______________________ Design Speed______________________
Vertical Curves______________________ Clear Zones______________________
Horizontal Alignment______________________________
Other______________________________

HYDRAULIC INFORMATION
Channel Changes (Station)______________________________
Structures (“As-Built”, Station, Reference Point, Type, Replace, Name of Drainage, Detour)
Pipes Over 84” (2100 mm)______________________________
Other (Backwater, Debris, etc.)______________________________

Administer of the Floodplain (county and/or incorporated community)

Materials and Geotechnical Considerations

3.2 CORRESPONDENCE

3.2.1 In-house Memoranda

3.2.1.1 General

Memoranda are used by MDT to provide written, interdepartmental information between the various Bureaus, Sections, Districts, etc. They are used to distribute project reports, process approval requests, request project information, submit project information, distribute policies and for informational purposes. Each Bureau and Section has established its own policies for circulating incoming mail. In general for the Road Design Section, the Highways Engineer's staff will review incoming memoranda to determine who needs additional copies.

3.2.1.2 Signatures

For outgoing memoranda, the Highways Bureau has established the following signature requirements:

9. All memoranda containing substantive materials for distribution outside of the Highways Bureau and for Bureau-wide general information will require the Highways Engineer's signature.
10. All memoranda containing substantive materials for distribution outside of the Section, but within the Bureau, and for Section-wide general information will require the Section Head's Signature.
11. All general project correspondence, including those to the Districts, project information requests, and general day-to-day forms, may be signed by the Project Design Manager.
12. All correspondence originating in the Districts will be signed by the District Administrator.

3.2.1.3 Distribution

The Highways Bureau has established the following procedure for distribution of outgoing memoranda:

1. Project Information Submitted to Others. Memoranda providing project information to the Districts, other Bureaus or Sections should also include a copy to the following:

   a. Highways Engineer,
   b. Highways Design Engineer,
   c. Road Design Engineer,
   d. District Administrator,
   e. the Highways project file, and
   f. others as needed.

2. <u>Project Information Requests</u>. Memoranda requesting project information from the Districts, other Bureaus or Sections should also include a copy to the following:

   a. Road Design Engineer,
   b. District Administrator,
   c. the Highways project file, and
   d. others as needed.

3. <u>District Correspondence</u>. All correspondence sent to the District will be addressed to the District Administrator.

4. <u>General Information</u>. Distribution and copies of other memoranda types will be determined on a case-by-case basis.

3.2.2 <u>Outside Correspondence</u>

3.2.2.1 General

In general, prepare all written materials for sources outside of the Department on MDT letterhead. Letters for the Governor's signature will be on the Governor's letterhead.

The writer must exercise common sense when preparing outside correspondence to match the reader's understanding. Department letters will often be written to individuals without a transportation background; therefore, the letter should use terminology which is understandable to the general public. In contrast, letters and surveys to AASHTO, FHWA, TRB, etc., should use standard highway engineering terminology.

3.2.2.2 Signatures

In general, all letters will be forwarded though the chain of command to the individual signing the correspondence. The following presents the Department's policy for the signing of all out-going letters:

5. Letters to U.S. Congressmen, the Governor and legislators will be signed by the Director.

6. Letters responding to citizen inquiries will be signed by the Preconstruction Engineer or a higher level, depending on who initially received the letter.

7. Letters which provide substantive information to towns, counties or local officials should be signed by the Preconstruction Engineer. Routine project information sent to towns, counties or local officials may be signed by the Section Supervisor

8. Information requested by the news media should be signed by the Preconstruction Engineer or a higher level. General news releases may be signed by the Section Supervisor.

9. Information to Federal and State agencies, AASHTO, TRB, other State DOT's, etc., should be signed by the Highways Engineer.

Project information submitted to consultants, contractors, suppliers, etc., should be signed by the Section Supervisor.

3.3 MEETINGS

Good communication is a necessity. It is imperative that all meetings be well planned, attended by the proper individuals, and the information disseminated to the affected people in a timely manner. The following provides additional information for project and staff meetings in the Road Design Section.

3.3.1 Project Review Meetings

During project design, there are typically several meetings to allow others to review the project design. MDT formal review meetings include the Preliminary Field Review, the Alignment & Grade Review, the Plan-in-Hand Review and the Final Plan Review. In addition, informal meetings are often initiated to gather or disseminate information between the affected parties.

In general, the Project Design Manager will be responsible for arranging the meeting, determining the location, leading the meeting and documenting the concerns and decisions made during the meeting. Section 3.1 provides the procedures for reporting the results of major project meetings. For informal meetings, a memorandum documenting the decisions made during the meeting should be submitted to those involved with copies distributed to the project file and other individuals as deemed necessary.

3.3.2 Staff Meetings

Staff meetings are held to disseminate design and administrative information, discuss design problems, discuss policy changes and discuss personnel concerns. Staff meetings are typically held monthly. These meetings are typically attended by the Road Design Engineer, Project Design Managers, Design Supervisors and others as needed.

Individuals who have questions, concerns or ideas that may need to be addressed during the staff meeting should first discuss, or submit in writing, their ideas to the Project Design Manager. If deemed appropriate for the Road Design Section staff meeting, the interested party or the Project Design Manager will request, in writing at least one week in advance of the meeting, that the Road Design Engineer add the item to the next monthly meeting agenda. The Road Design Engineer will provide a written agenda to the Project Design Managers and Design Supervisors approximately two days prior to the meeting. This will allow all attendees time to review the agenda and properly prepare any responses before attending the meeting.

3.4 PROJECT WORK TYPE CODES

All project documents are required to provide the project work type number in the subject portion of a memorandum. Figure 3.4A provides a listing of the standardized project work type codes used by the Department. The applicable project work type number will be determined during the Preliminary Field Review. It may be revised for the Scope of Work Report.

The Engineering Management Unit will use the Preliminary Field Review and Scope of Work Reports to input the project work type number into the Department's Project Master File. Changes to the project work type after the Scope of Work Report has been approved must be agreed upon by the Engineering Management Unit and Fiscal Programming Unit. If there are any questions concerning assigning or changing project work type number, contact the Engineering Management Unit.

Number	Description
Roadway	
110	New Construction
111	New Construction – Facilities
120	Relocation
130	Reconstruction – With Added Capacity
140	Reconstruction – Without Added Capacity
141	Reconstruction – Remove and Replace Culverts
150	Major Rehabilitation – w/added capacity
151	Major Rehabilitation – w/o added capacity
160	Minor Rehabilitation
170	Restoration and Rehabilitation – PCCP
172	Restoration and Rehabilitation – Facilities
180	Resurfacing – Asphalt (Thin Lift ≤ 0.20 ft.) (including Safety Improvements)
181	Resurfacing – Asphalt (Thin Lift ≤ 0.20 ft) (Scheduled maintenance)
182	Resurfacing – PCCP
183	Resurfacing – Seal & Cover
184	Resurfacing – Gravel
185	Resurfacing – Crack Sealing
Bridges	
210	New Bridge
220	Bridge Replacement with added capacity
221	Bridge Replacement with no added capacity
222	Bridge Replacement with a culvert with no added capacity
223	Bridge Replacement with Culvert while adding capacity.
230	Bridge Rehabilitation with added capacity
231	Major Bridge Rehabilitation without added capacity
232	Minor Bridge Rehabilitation
Safety	
310	Roadway & Roadside Safety Improvements
311	Railroad/Highway Crossing Safety Improvements
312	Structure Safety
313	Pedestrian and Bicycle Safety
Traffic Operation & Control Systems	
410	Traffic Signals and Lighting

Number	Description
411	Signing, Pavement Markings, Chevrons, etc.
412	Miscellaneous Electronic Monitoring or Information Services
Environmental	
510	Environmental
520	Landscaping, Beautification
Miscellaneous	
610	Maintenance Stockpiles
620	Bicycle and Pedestrian Facilities
630	CTEP – Monitoring and Inspection
640	Bridge Maintenance Safety Inspection
650	Miscellaneous Study Programs
660	Historic Preservation

PROJECT WORK TYPE CODES

Figure 3.4A

18 October 2016

MONTANA DEPARTMENT OF

TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Four
PLAN PREPARATION

Table of Contents

Table of Contents
(Continued)

Chapter Four
PLAN PREPARATION

Other chapters in the *MDT Road Design Manual* provide the designer with uniform criteria and procedures for the geometric design of a highway facility. These designs must be incorporated into the roadway plans so that they can be clearly understood by contractors, material suppliers, and Department personnel assigned to supervise and inspect the construction of the project. To ensure a consistent interpretation of the contract plans, individual sheets should have a standard format and content, and the sequence of plan assembly should generally be the same. To provide this consistency, this chapter provides guidelines for the uniform preparation of contract plans including recommended plan sequence, drafting guidelines, plan sheet content and sample plan sheets.

4.1 GENERAL INFORMATION

4.1.1 Working Sheets

The Department currently uses the following paper sizes during project development:

1. <u>22” x 34” (559 mm x 864 mm) (D)</u>. This paper size is considered to be “full-size”. It is seldom used for the majority of projects. Where deemed necessary for projects with extensive detail on the plan and profile sheets, this size may be used for preliminary design reviews and final plans. Provide a border around the sheet with a 2” (51 mm) left-binding margin and ½” (13 mm) right, top and bottom margins.

2. <u>11” x 17” (279 mm x 432 mm) (B)</u>. This paper size is the half-size of the "D" paper and is typically used for preliminary draft reviews, requests for permits and bid advertising. This plan sheet is a half scale of the final plan size in Comment #1. This sheet size may also be used for plotting cross sections on the laser plotter.

3. <u>8½” x 11” (216 mm x 279 mm) (A)</u>. This paper size is used for Pavement Preservation projects. These project types typically contain a minimal amount of design information and, therefore, the smaller sheet sizes are used. If the project contains significant amounts of information, use one of the larger sheet sizes instead.

For the preliminary design stage and for the final design stage of CADD-prepared plans, print all sheets on white paper and use the "B" (A3 metric) paper size. Cross section sheets will be on "B" paper size. Prior to letting, the CPB (Contract Plans Book) will be submitted electronically to the Contract Plans Bureau. Full-size plans and cross sections will be provided when requested.

4.1.2 Construction Plan Sheet Organization

4.1.2.1 Plan Sequence

To provide consistency from project to project, assemble the construction plan sheets in the sequence below. Note that not all plans will have all the sheets and that several sheets can be combined together (e.g., Table of Contents, Notes). If several sheets are combined, the sequence below still should be followed; that is, they should be listed in order from left to right on the sheet. The recommended plan sequence is as follows:

1. Title Sheet
2. Table of Contents
3. Notes
4. Linear and Level Data
5. Control Diagram and Abstract Table
6. Typical Sections
7. Summaries
8. Hydraulic Data Summary
9. Detail Sheets:
    a. drainage details (including storm drains);

    b. special maintenance and protection of traffic through construction zone plans;

    c. miscellaneous details (including details for major approaches, interchanges, connections to existing pavement, etc);

    d. mass diagram. (not included in final construction plans)

10. Plan and Profile Sheets
11. Sanitary Sewer Plans (if not included in Detail Sheets)
12. Water Plans (if not included in Detail Sheets)
13. Signing Plans:

    a. Summary Signing and Delineation Quantities Sheet

- b. Sign Location and Specifications Sheet
- c. Signing Detail Sheets
- d. Plan Sheets

14. Electrical Plans:

    a. Electrical Quantity Summary Sheet
    b. Electrical Detail Sheets
    c. Plan Sheets

15. Bridge Plans:

    a. Title/Quantity Sheet
    b. General Layout of Structure Sheet
    c. Footing Plan Sheet
    d. Bent/Pier Sheet
    e. Erection Plan Sheet
    f. Slab Detail Sheet
    g. Beam/Girder Sheet
    h. Detail Sheets
    i. Standard Sheets

16. Cross Sections:

    a. mainline (including detours)
    b. approach cross sections
    c. misc. cross section items (berms, ditches, bikepaths, etc.)
    d. Skewed culverts (cross section shown along the skew of the culvert)

4.1.2.2 Sheet Numbering

The title sheet will be considered as page one, but it will not be numbered. Number all other sheets sequentially with the sheet numbers in the upper right-hand corner.

Number road plans with separate, sequential whole numbers. Number cross-section sheets with separate, sequential whole numbers beginning with #1. Sanitary sewer, water, signing, electrical and bridge plans will be numbered separately within each group beginning with #1 and will have the following letter prefixes:

1. Sanitary Sewer Plans — SS*
2. Water Plans — WS*
3. Signing Plans — S

4. Electrical Plans — E
5. Bridge Plans — B

* The Sanitary Sewer and Water Plans will only be designated by the SS and WS prefixes for new installations or extensive modifications to existing systems. The details for minor modifications or additions to existing systems will typically be included in the road plans without a prefix designation. The determination to separate the sanitary sewer and water line details from the road plan details will be made at the Plan-in-Hand.

4.1.3 MDT Detailed Drawings

The *MDT Detailed Drawings* provide information on design elements that are consistent from project to project (e.g., guardrail). They are included in the contract. Section 6.1.4 provides additional information on *MDT Detailed Drawings*.

4.1.4 Temporary Detours and Median Crossovers

The need for separate maintenance of traffic through construction zone plans will vary from project to project. For crossovers or temporary detours, show the plan and profile views, detour typical section and items of work included in the lump sum on a detail sheet.

Typically, a lump-sum bid item should be used for median crossovers and to construct, maintain and remove detours. Section 5.5.1 provides additional information on lump-sum bid items.

4.2 DESIGN AND DRAFTING GUIDELINES

Project drafting will be done with the use of CADD. The following sections provide information on the general design and drafting criteria used by the Department.

4.2.1 Computerized Design

Computers have significantly changed the Department's mode of preparation for its highway plans. Computer-aided drafting and design packages have both simplified and complicated the designer's plan production procedures. Computers have assumed the tedious tasks of drawing cross sections, plotting mass diagrams, calculating grading quantities, etc. They also allow the designer the freedom to develop and evaluate alternatives. On the other hand, they require the designer to be well versed in how to use complex hardware and software. This Section briefly discusses the computer hardware and software MDT uses to prepare its construction plans and MDT’s CADD file management.

4.2.1.1 Computer Hardware

1. Equipment. The Department is presently using MicroStation as its computer-aided drafting and design (CADD) package. MicroStation is used with Windows-based PC’s. All PC's are connected to file server computers in the Central and District Offices.

   For information on how to purchase, upgrade, replace, maintain or repair CADD workstations or PC's, the designer should contact the Department's CADD Coordinator in the Central Office.

2. Network. All MDT PC's have been networked or interconnected to the Central and District Offices file server computers. The information on District file server computers are downloaded to the Central Office file server computer on a daily basis. This allows designers across the State to access the same information regardless of their location or which machine they are using. To accomplish this, all project files must be saved on the Central or District Office file server computer. The designer is required to download the project files from the file server to their PC at the beginning of each work session. At the end of each work session, the designer is required to upload all project files back to the Central or District Office file server computer.

The Information Services Division is responsible for backing up all files on the file server computer and for maintaining the network system. The designer is responsible for maintaining the files within the Document Management System (DMS).

4.2.1.2 Computer Software

All users outside of the Department network should consult with the MDT CADD Coordinator to determine which version(s) of the software programs are acceptable to the Department. All consultants submitting CADD contract plans to the Department must use the same version as the Department. The Department uses the following design software packages:

1. MicroStation. MDT has selected MicroStation for its Department-wide computer-aided drafting and design software package, which is used for the drafting of most contract plans. Using MicroStation's levels and reference files allows various users within the Department to work on the same set of plans without interfering with each other's design work (e.g., Right-of-Way, Electrical). By integrating or linking MicroStation with other software packages (e.g., GEOPAK, databases), the designer can use the computer to perform the actual design and layout of a project.

   MicroStation is a complex program with many features. If problems or questions occur when using the software, the user should first contact the Lead CADD Operator within each MDT unit or the CADD Coordinator for information on how to use the software.

2. GEOPAK. GEOPAK is a comprehensive, proprietary roadway design package that works as an interactive program within MicroStation. GEOPAK allows the designer to lay out design centerlines and profiles, calculate superelevation, generate cross sections, compute quantities, generate mass diagrams, complete plan labeling, etc. By providing GEOPAK with the minimum/maximum design criteria and other design control points, the designer can command the software to generate all line work for plan views, profiles and cross sections. GEOPAK can also be used to produce 3D model images of the design. Although GEOPAK can generate most roadway quantities, special care must be devoted to the design to ensure that the appropriate symbols, cells and MDT rounding criteria are used.

For more information on GEOPAK, the designer should review the *MDT GEOPAK User's Manual* or contact the Lead CADD Operator in each MDT unit, the MDT CADD Coordinator or the manufacturer.

4.2.2 General Drafting Guidelines

The following provides general guidelines for the plotting of survey data and design details on the plan sheets:

1. Scales. Use the following drawing scales when developing a set of construction plans:

   a. Title Sheet. The layout map should use a 1:60 000 scale. Layout maps for urban areas may use a larger scale for better clarity.

   b. Plan and Profile Sheets. Typically, a scale of 1":100' (1:1000) should be used for the plan view. For urban and/or small projects, a 1":50' (1:500) scale may be used. For the profile view, the horizontal scale will be the same as the plan view. The vertical scale will be a 1:10 proportion of the horizontal scale.

   c. Typical Sections. Typical section figures will generally be drawn using a 1:50 scale for both horizontal and vertical dimensions. A 1:100 scale may be used for wide typical sections (e.g., 4-lane highways).

   d. Detail Sheets. Detail sheets will vary according to the element shown. For special intersection or approach drawings, a plan view scale of 1:250 should generally be used. Where necessary to show more detail, scales of 1:200 or 1:100 may be used.

   e. Cross Sections. Cross section scales will typically be prepared using a 1:100 scale. A 1:200 scale may be used where a greater cross section width or height is required. The vertical scale should always be a 1:1 proportion of the horizontal scale.

2. Abbreviations. Figure 4.2A presents a listing of the common abbreviations that should be used where it is necessary to abbreviate elements within the set of plans.

3. Stationing. English stations of 100 ft are used by MDT. Show each station as a half tic mark and denote every tenth station with a full tic mark. Metric stations of

100 m are used by MDT. Show half tic marks at 20 m intervals and full tic mark at 100m intervals.

4. Cross Sections. The line work for cross sections will be drawn with GEOPAK or other Department approved software. The topography will typically be CADD drafted onto the cross sections using MicroStation or GEOPAK

5. Sheet Breaks. For English units each plan sheet should typically show 3000 ft of the project location with no overlap between sheets. For metric units each plan sheet should typically show 700 m of the project location with no overlap.

6. North Arrow. The North arrow on finished plans should be uniform within each set of plans. The standard North arrow CADD cell will be used.

7. Project Block. For English all sheets, should have a standard block in the lower right-hand corner indicating the State, project number and sheet number. For Metric all sheets, except the title sheet, should have a standard block in the upper right-hand corner indicating the State, project number and sheet number.

8. Combination Scale Factor (CSF). For Us Customary projects using state plane coordinates system the CSF will be placed in the project block at the bottom of all plan sheets. For Metric projects using the state plane coordinate system the CSF will be placed under the project block of the plan & profile sheet, on the control traverse diagram, and under the letting date on the title sheet.

&	And
@	At
AB.	Abrupt
A.C.	Aluminum Cap/Asphalt Cement
ADD. EXC.	Additional Excavation
A.A.D.T.	Annual Average Daily Traffic
A.D.T.	Average Daily Traffic
ADJ.	Adjusted
AGG.	Aggregate
AH.	Ahead
APP.	Approach
APPL.	Application
APPROX.	Approximate
ASPH.	Asphalt
ASTM	American Society for Testing & Materials
AVE.	Avenue
AVG.	Average
AZ.	Azimuth
BBLS.	Barrels
B.C.	Brass Cap
B.C.R.	Begin Curb Return
BEG.	Begin
B.E.	Bridge End
BIT.	Bituminous or Bitumen
BK.	Back or Bank
BLDG.	Building
BLK.	Block
B.L.M.	U.S. Bureau of Land Management
BLVD.	Boulevard
B.M.	Bench Mark
BNDRY.	Boundary
BOT.	Bottom
BR.	Bridge
B.R.	Base of Rail
BRG.	Bearing
B.S.	Backsight
B.S.T.	Bituminous Surface Treatment
B.W.FE.	Barbed Wire Fence
C	Cut
C&G.	Curb & Gutter
C/A	Control of Access
C/L	Centerline
CALC.	Calculated
C.A.P.	Corrugated Aluminum Pipe
CATV	Cable TV
CB.	Curb
C.B.	Catch Basin
C.B.W.	Concrete Block Wall
C.C.	Closing Corner
CDTN.	Condition
CEM.	Cement
CH.	Channel or Chain
CH.CH.	Channel Change
CHD.	Chord
CHIS. "x"	Chiseled Cross
C.I.	Curb Inlet
CIR.	Circle
CL.	Class or Clearance
CL-1.2F,1.5F	Chain Link Fence (w/height)
C.M.P.	Corrugated Metal Pipe
C.N.	Concrete Nail
CO.	County or Company
C.O.	Clean Out
COMP.	Compaction
CONC.	Concrete
COND.(TEL.)	Conduit (specify type)
CONN.	Connection
CONST.	Construction
CONST. PMT.	Construction Permit
COR.	Corner
CORR.	Corrected
COV.	Cover
C.P.	Catch Point
CR.	Crushed or Creek
CRS.	Course
C.S.	Curve to Spiral
C.S.F.	Combination Scale Factor
C.S.P.	Corrugated Steel Pipe
C.S.P.A.	Corrugated Steel Pipe Arch
CT.	Court
C.T.B.	Cement Treated Base
CTR.	Center
CULV.	Culvert
D	Distribution of Traffic
DBL.	Double
D.D.	Down Drain
DE	Difference in Elevation
DEFL.	Deflection

PLAN ABBREVIATIONS

Figure 4.2A

DESC.	Description
DEST.	Destroyed
DET.	Detour/Detail
DETC.	Detector
D.H.	Drill Hole
D.H.V.	Design Hourly Volume
D.I.	Drop Inlet
DIA.	Diameter
DIST.	Distance or District
DN.	Down
DP.	Deep
DR.	Drain or Drive
DT.	Ditch
DWG.	Drawing
DY.	Daylight
E	East/External Distance
EASE.	Easement
E.B.	Eastbound
E.C.R.	End Curb Return
E.D.M.	Electronic Distance Measurement or Measurer
E.G.	Edge of Gutter
ELEV. or EL.	Elevation
ELONG.	Elongated
ELY.	Easterly
EMB.	Embankment
EMUL.	Emulsified
E.O.	Edge of Oil
E.P.	Edge of Pavement
EQ.	Equation
E_S	External Distance
E.S.	Edge of Shoulder
E.T.W.	Edge of Traveled Way
EW.	End Wall
EX.	Existing
EXC.	Excavation
EXT.	Extension
EXWY.	Expressway
F.	Fill
F.A.	Federal Aid
F.C.	Flood Control
FD.	Found
FDN.	Foundation
FE.	Fence
FERT.	Fertilizer
F.E.T.S.	Flared End Terminal Section
F.G.	Finished Grade
F.G.S.	Finished Grade Stake
F.H.	Fire Hydrant
FIN.	Finish
FL.	Flush
F.L.	Flow Line
F.P.	Fence Post
FR.	Frontage
FR. RD.	Frontage Road
F.S.	Foresight
FTG.	Footing
FUT.	Future
FWY.	Freeway
G	Grading
g	Gram
GALV.	Galvanized
GAR.	Garage
GEOD.	Geodetic
G.L.	Gas Line
G.L.O.	General Land Office
G.P.S.	Global Positioning System
G.R.	Guardrail
GR.	Grade
GRD.	Grid
GRND.	Ground
GR.SEP.	Grade Separation
G.S.	Gravel Surfacing
G.S.P.	Galvanized Steel Pipe
GTR.	Gutter
G.V.	Gas Valve
ha	Hectare
H&T	Hub & Tack
HDWL.	Headwall
HG.	Headgate
H.I.	Height of Instrument
HO.	House
HOR.	Horizontal
H.P.	Hinge Point
HT.	Height
HWY.	Highway
H.W.	High Water
I	Interstate
I.C.	Incidental Construction
I.D.	Inside Diameter

PLAN ABBREVIATIONS

(Continued)

Figure 4.2A

I.E.	Invert Elevation
INC.	Incorporated
INCL.	Included
INSTR.	Instrument
INT.	Intersection
INTCH.	Interchange
INV.	Invert
I.P.	Iron Pin
IRR.	Irrigation
JCT.	Junction
J.P.	Joint Use Pole
kg	Kilogram
km	Kilometer
L	Length of Curve, Liter
L.C.	Long Chord
L_C	Length of Circular Curve
L.D.	Loop Detector
LENG.	Length - Lengthen
LN.	Lane
L.S.	Land Surveyor
L_S	Length of Spiral
LT.	Left
m	Meter
mm	Millimeter
m^2	Square Meter
m^3	Cubic Meter
mm^2	Square Millimeter
MATL.	Material
MAX.	Maximum
M.C.	Medium Curing
MEAS.	Measured
MED.	Median
MH.	Manhole
MIN.	Minimum, Mineral or Minute
MISC.	Miscellaneous
MKR.	Marker
M.L.	Mainline
MNCPL.	Municipal
M.O.	Mid Ordinate
MON.	Monument
M.P.C.	Mid-Point of Curve
N	North
N.B.	Northbound
N.C.	Normal Crown
N.E.	Northeast
N.G.	Natural Gas
N.G.S.	National Geodetic Survey
NL.	Nail
NLY.	Northerly
NO. or #	Number
N.W.	Northwest
N.W.EL.	Normal Water Elevation
O. or O/S	Offset
O.C.	On Centers or Overhead Crossing
O.D.	Outside Diameter
O.G.	Old Ground or Original Ground
OH.	Overhang or Overhead
O'PASS	Overpass
P	Power Cable or Pipe
P. or PG.	Page
PAVT.	Pavement
P.B.	Pull Box
P.C.	Point of Curve (Beginning)
P.O.C.	Point on Curve
P.C.C.	Point of Compound Curve or Portland Cement Concrete
P.C.S.	Project Control System
P.E.	Preliminary Engineering
PEN.	Penetration
PERF.	Perforated
P.I.	Point of Intersection
P.L.	Property Line
PL.	Place or Plate
PLAS.	Plastic
P.M.	Principal Meridian or Punch Mark
P.M.B.	Plant Mix Base
P.M.P.	Perforated Metal Pipe
P.M.S.	Plant Mix Surfacing
P.O.L.	Point on Line
P.O.V.C.	Point on Vertical Curve
PP.	Pages
P.P.	Power Pole
PREST.	Prestressed
PROC.	Processing
PROJ.	Project or Projected
PROT.	Protect, Protector or Protection
P.O.S.	Point on Spiral
P.O.S.T.	Point on Semi-Tangent
P.O.T.	Point on Tangent

PLAN ABBREVIATIONS

(Continued)

Figure 4.2A

PT.	Point
P.T.	Point of Tangent (End of Curve)
P.T.W.	Present Traveled Way
PVC.	Polyvinyl Chloride
PVT.	Private
PWR.	Power (Lines)
Q	Peak Discharge (Water)
R	Range, Radius, Rise
REC.	Record
RC	Spiral Curve Radius
R.C.	Rapid Curing
R.C.B.	Reinforced Concrete Box
R.C.P.	Reinforced Concrete Pipe
R.C.P.A.	Reinforced Concrete Pipe Arch
RD.	Road
RDL.	Radial
RDWY.	Roadway
REF.	Reference
REINF.	Reinforcement
RET.W.	Retaining Wall
RIV.	River
R.M.	Reference Monument
R.P.	Reference Point, Radius Point
R.R.	Railroad
RT.	Right or Route
RTE.	Route
R/W	Right of Way
RY.	Railway
S	Rate of Full Superelevation, Slope in m per m, Span or South
SA.	Satellite (for traverse use)
SAN. SEW.	Sanitary Sewer
S.B.	Southbound
S C	Slow Curing
S.C.	Spiral to Curve
SCH.	Schedule
SDWK.	Sidewalk
S.E.	Southeast
SEC.	Section or Second
S.G.	Subgrade
SH.	Shoulder
SHT.	Sheet
SIP.	Siphon

S.L.D.	Sea Level Datum
SLOT. DR.	Slotted Drain
SLP.STK.	Slope Stake
SLY.	Southerly
S.P.	Stand Pipe or State Plane
SPEC. PROV.	Special Provision
S.P.H.P.	Steel Pipe, High Pressure
SPK.	Spike
S.S.	Emulsified Asphalt
S.S.P.P.	Structural Steel Plate Pipe
S.S.P.P.A.C.	Structural Steel Plate Pipe Arch Culvert
S.T.	Spiral to Tangent
ST.	Street
STA.	Station
STD.	Standard
STD. SPEC.	Standard Specifications
STK.	Staked or Stake
STL.	Steel
STM.	Storm Drain
STPD.	Stamped
STR.	Structure
SUBD.	Subdivision
SUBGR.	Subgrade
SURF.	Surface or Surfacing
SURV.	Survey
S.W.	Southwest or Sidewalk
T	Township, Tangent Length or Percent Trucks Metric Ton
TAN.	Tangent
T.B.C.	Top Back of Curb
T.B.M.	Temporary Bench Mark
TBR.	Timber
TEL.	Telephone
TEL.C.	Telephone Cable
TELG.	Telegraph
TEL.P.	Telephone Pole
TEMP.	Temperature/Temporary
THK.	Thickness
TK.	Tack
TOPOG.	Topographic
T.P.	Turning Point
TR.	Tract
TRANS.	Transmission Line or Transition

PLAN ABBREVIATIONS

(Continued)

Figure 4.2A

TRAV.	Traverse
TRIA.	Triangulation
TRW	Top of Retaining wall
T_S	Length of Tangent (Curve with Spirals)
T.S.	Tangent to Spiral
T.T.	Transmission Tower
TYP.	Typical
U	Unit
U.G.	Underground
UNCL.	Unclassified
U'PASS	Underpass
U.S.C. & G.S.	U.S. Coast & Geodetic Survey
U.S.C.E.	U.S. Corps of Engineers
U.S.F.S.	U.S. Forest Service
U.S.G.S.	U.S. Geological Survey
U.S.P.L.S.	U.S. Public Land Survey
V	Design Speed or Velocity
V.A.B.M.	Vertical Angle Bench Mark
V.C.	Vertical Curve
V.C.CORR.	Vertical Curve Offset Correction
V.C.M.	Vertical Control Monument
V.C.P.	Vitrified Clay Pipe
VEH.	Vehicular
VERT. or VT.	Vertical
VIT.	Vitrified
V.P.	Vent Pipe
V.P.C.	Vertical Point of Curve
V.P.I.	Vertical Point of Intersection
V.P.T.	Vertical Point of Tangency
W	West
W/	With
W.B.	Westbound
W.C.	Witness Corner
W.L.	Water Line
WLY.	Westerly
W/O	Without
W.P.	Wing Point
W.S.	Water Service or Warped or Variable Slope
W.T.	Water Table
WT.	Weight
W.V.	Water Valve
W.W.	Wing Wall or Woven Wire
XING.	Crossing
XSEC.	Cross Section

PLAN ABBREVIATIONS

(Continued)

Figure 4.2A

4.2.3 Plotting Survey Data

For surveys conducted by aerial survey, the Photogrammetry and Survey Section will be responsible for plotting the survey data. For data collector surveys, the surveyor will provide a 3D MicroStation file with graphical triangles for the road designer to create a Digital Terrain Model and a 2D MicroStation file with the topographic information to be used as a base map. For manually conducted surveys, the designer or consultant will be responsible for plotting the survey data using the Department or approved compatible CADD system. In addition to the field notes, the designer should obtain a copy of the as-built plans (if available) for informational purposes. The as-built plans may be obtained at the MDT Central Office in Helena.

The *MDT Survey Manual* provides the Department's criteria for plotting the survey field notes. In general, plot the survey 700 ft (200 m) beyond the proposed project limits.

For project surveys, an established point is typically assigned a set of coordinate values and the coordinates for all other points are calculated from these assumed values. Global Positioning System (GPS) surveys utilize the NAD 83 State Plane Coordinate Systems. Coordinates should be provided at all major control points on the linear and level data sheet; for additional information, see Section 4.3.4.

4.2.4 CADD Drafting

To help in providing consistency from project-to-project and among designers, the following sections provide Department guidelines for the drafting of construction plan sheets using MicroStation. For specific drafting standards and detailed procedures, the designer should review the *MDT CADD Standards Manual*. Copies of this document are provided to each design crew, or it can be obtained from the CADD Coordinator or viewed on the MDT internet website.

4.2.4.1 File Setup

Each project is saved in its own subdirectory on the Department's central computer. The project subdirectory is named using the Uniform project number provided for each of the Department units involved with the project (e.g., Road Design, Right-of-Way, Survey) under the project directory. The *MDT CADD Standards Manual* provides the subdirectory names that will be used for each of these Department units, as well as the standard file naming convention.

The Department uses a standard file format for the placement of individual plan sheets in the files. For more information on these formats, see the *MDT CADD Standards Manual* or contact either the section lead CADD operator or the CADD coordinator.

4.2.4.2 Reference Files

Reference files allow the various users to integrate several files together from several sources and to view the result from all the files in one view. The project strip map is an example of a reference file that is used by the various designers to develop the project (e.g., Right-of-Way, Traffic, Road Design, Hydraulics). Reference files allow the designers to see how their design will interact with the various other units' designs. Although reference files allow designers to review other units' files, the designer is unable to make changes to these files. The designers can only make changes to their own files. It should be noted that, where appropriate, the designer can copy elements from the reference file to their own file.

Separate reference files have been developed containing sheet borders for the following plan sheets:

1. Title/Summaries,
2. Typical Sections,
3. Detail Sheets, and
4. Plan and Profiles.

The designer will create the plan and profile sheet by referencing the strip map for the applicable Section (e.g., Photogrammetry, R/W, Traffic). For more information on reference files, the designer should review the *MDT CADD Standards Manual* or contact their section lead CADD operator or the CADD Coordinator.

4.2.4.3 Cell Libraries

For plan consistency, the Department has developed a set of symbols that should always be used to indicate certain elements. For symbol uniformity and ease of drafting, these symbols have been incorporated into the Department's CADD cell libraries.

Cell libraries are developed to allow the CADD user to call up a symbol, figure, form, etc., without having to redraw the figure each time. The *MDT CADD Standards Manual* lists the cell libraries that are available for the designer's use.

To obtain a copy of these cell libraries, MDT employees should contact the CADD Coordinator or their section's lead CADD operator. Outside consultants should request a copy of the cell libraries from the Consultant Design Bureau or download them from the Department’s Internet web site.

4.2.4.4 Drafting Levels

MicroStation allows the user to select a variety of different levels to input data. The *MDT CADD Standards Manual* provides guidelines for what information should be provided on each level. Because units other than the Road Design Section utilize the information contained on the various levels, placement of data on the correct level is essential. Presenting the project data on different levels allows the user to see or print only the desired data by turning on or off the various levels.

4.3 PLAN SHEET CONTENT

Prepare the construction plans as simply as practical. Avoid the use of duplicate data and unnecessary cross references. *MDT CADD Standards Manual* provides model drawings for various plan sheets. The following sections provide additional information on what should be included within each sheet. Section 4.2.4 provides information on text sizes, font types, symbols, cell libraries and drafting levels that should be used for each plan sheet.

4.3.1 Title Sheet

The Title Sheet is the front cover for a set of plans. It identifies the project type, project location and other pertinent project information. Pre-drafted title sheets are available as reference files. Pre-drafted sheets provide the State map and blocks for design data, project approvals, related projects and associated project agreement numbers. Also shown is the Department name and standard data for scales and project length.

The Title Sheet should contain the following information:

1. State Map. A state map in the upper left-hand corner of the sheet should show the general location of the project in relation to other roads within the State. An arrow labeled "THIS PROJECT" will indicate the project location.

2. Title Information. Show the project title information in the top center of the sheet in the following order:

    a. Montana Department of Transportation.

    b. Project construction number as provided by the Fiscal Programming Section. Figure 4.3A defines the project number codes.

    c. Project descriptions as provided in the Engineering Management System Report.

    d. Project name. The project name must match the name on the project's programming document.

    e. Access control note, if applicable.

    f. County name.

Project NH1-9(23)565
NH-Funding Designation (see table below)
1 - Route Number
9 - County Designation along the route (west to east, south to north)
23 - Agreement Number
565 - Reference Point on the Route

Federal-Aid Program	Project Prefix
Interstate Program:	
Interstate – Maintenance	IM
National Highway System:	
National Highway	NH
Surface Transportation Program:	
Secondary	STPS
Urban	M, STPU
Primary (minor arterial)	STPP
State Flexible (State Highway)	STPX
Rail/HWY Crossing - Hazard Elimination	STPRR
Rail/HWY Crossing - Protective Devices	STPRP
Hazard Elimination	STPHS
Transportation Enhancements	STPE
Bridge Program:	
Bridge Replacement & Rehabilitation - 20% (Optional)	BR & BH
Bridge Replacement & Rehabilitation – 15% (Off-System)	BR & BH
Bridge Replacement & Rehabilitation – 65% (On-System)	BR & BH
Congestion Mitigation & Air Quality Improvement Program:	
Congestion Mitigation & Air Quality	CM
SPR/PL Program:	
HWY Planning & Research	SPR
Research, Development & Technology Transfer	SPR
Metropolitan Planning	PL
Innovation Projects:	
DPI Projects (Shiloh & Missoula Interchange)	DPI
Demonstration Projects:	HDP
Discretionary Funds:	
Public Lands	PLH
Forest Highway	FH
State-Aid Program	**Project Prefix**
National Highway System:	
National Highway (less Interstate)	SFCN
National Highway (Interstate)	SFCI
State Primary	SFCP
State Secondary	SFCS
State Urban	SFCU
State Highway (State maintained)	SFCX

PROJECT CODE DEFINITION
Figure 4.3A

3. Project Length. Show the net contract length of the project to the nearest tenth of a mile (kilometer) immediately below the title information.

4. Scales. Show scales of plan and profile sheets, cross sections and reduced sheets immediately below the project length.

5. Surfacing Source. Just to the right of the scales, indicate whether or not the surfacing source is contractor furnished for the project.

6. Design Data. Include project design data in a block in the upper right-hand corner. For those projects having two or more road segments with different design data, prepare separate design data blocks for each segment.

7. Letting Date. The letting date recorded in the upper right-hand corner will represent the actual letting date, not the proposed letting date.

8. Combination Scale Factor (CSF). Show the CSF(s) for the project just below the letting date

9. Layout Map. The layout map is located at the bottom center of the Title Sheet. Reference the layout map from the county maps directory —\\Astro\Maps. Urban and county maps are MicroStation design files. Urban Maps have a URB extension and County maps have a CNT extension. The designer should only show the area necessary for the project. The map should not remain referenced to the Title Sheet file, as it is too large a file. Copy the portion of the map that shows the project onto the Title Sheet. The standard scale for rural layout maps is 1:60 000 and should be used wherever practical. Layout maps for urban-area work should show enlarged views of the urban areas affected.

   The layout map should clearly show the following:

   a. the location of the project roadway in relation to true north, nearby townships, ranges, section numbers along the route, existing roads, county, towns, major drainage features, State-optioned borrow and surfacing sources, railroads and buildings;

   b. the beginning and ending stations of the project and project number;

      1) Station limits of connection if beyond beginning of project and end of project.

   c. the numbers and stations of as-built projects onto which the project is tied;

    1) Identify units as English or Metric.

d. Beginning and ending reference posts;

e. names of interchanges;

f. signed route numbers for U.S., State and local highways;

g. enlarged maps of cities and towns where construction is scheduled through those areas;

h. the name of the Indian reservation, when any portion of the project is located within the boundaries of a reservation;

i. separation structures and bridges on the project. A single station number, based on mainline stationing, will represent the approximate center of each structure. Data will indicate the length of each structure, whether it is an overpass or underpass in relation to the main line and whether it will be constructed under this contract;

j. do not show non-optioned surfacing or borrow pits on the layout map or elsewhere on the Title Sheet; and

k. for an index to the map symbols, reference the MDT CADD Standards Manual.

10. Related Projects. Provide a block for related projects in the lower left-hand corner of the sheet. Data for "Related Projects" include contract units not covered by the contract plans and project numbers financially related to the main project (e.g., projects constructed in stages or units, projects tied for letting).

11. Associated Project Agreement Numbers. Show associated project agreement numbers for right-of-way, incidental construction (utilities), preliminary engineering and uniform project control number under the related project box.

12. Project Approval Block. A project approval block will be shown in the lower right-hand corner of the sheet. The approval box should include:

    a. the contract plan approval date;
    b. the Director's name;
    c. the Highways Engineer's signature;
    d. the Highways Engineer's or the Consultant Engineer’s (in responsible charge of the project) professional registration symbol; and

e. where appropriate, the FHWA Division Administrator's approval.

4.3.2 Table of Contents Sheet

Include a table of contents in each set of construction plans. One sheet is generally used solely for the table of contents, although notes may be placed on the same sheet if sufficient room is available. Each group of information must be clearly labeled "TABLE OF CONTENTS," "NOTES" and "LINEAR AND LEVEL DATA" and be placed in order from left to right, respectively.

The table of contents will indicate the major groups of sheets and those subgroups necessary to facilitate locating each item in the plans. Section 4.1.2 provides the proper order for listing, numbering and prefixing the plan sheets.

4.3.3 Notes Sheet

Include a notes sheet in each set of plans. One sheet is generally used solely for notes, except where the notes can be readily placed on the same sheet with the table of contents.

Notes sheets will provide general information necessary for plan users to obtain a complete understanding of the plans. Notes should not be used where subjects are addressed in the Standard or Supplemental Specifications or Special Provisions. Examples of information that may be addressed include:

1. descriptions of items to be removed by non-contractor personnel;
2. instructions for the contractor regarding items not to be disturbed, clearing and grubbing and digout areas;
3. descriptions of work items absorbed in the cost of bid items;
4. basis for plan quantities of surfacing materials;
5. instructions for interpreting the plans;
6. a skew diagram, if applicable; and
7. Backslope rounding detail

The sample note sheet in Section 4.4 provides a sample listing of notes that are commonly included in a set of plans.

4.3.4 Linear and Level Data Sheet

Include a linear and level data sheet within each set of construction plans. Generally, only use one sheet for linear and level data, except where it can be readily placed on the same sheet with the table of contents and notes. Linear and level data sheets will show a summary of project lengths, a tabulation of bench mark data, the sources of bearing and level data, and centerline coordinate table. The linear and level data sheet should contain the following information:

1. Project Lengths. Summarize project lengths by showing roadway lengths, bridge lengths and total lengths for each of the following:

   a. each route,
   b. 2-lane sections,
   c. 4-lane sections,
   d. *other multi-lane sections (including climbing and passing lanes)
   e. sections financed separately,
   f. sections in different counties, and
   g. **areas not included in the contract within the project limits.

   *This does not include auxiliary lanes such as turn bays

   **This does not apply to projects that include spot improvements at a number of sites (e.g. guardrail upgrades on multiple routes).

   When there is a transition from a segment with fewer lanes to a segment with more lanes, the length of the transitions are included in the segment with narrower lanes (e.g. for a transition from a 2-lane to a 4-lane section, the length of the transition is included in the length of the 2-lane segment).

   Connections that are located outside of the project limits are not included in the linear data.

   Bridge lengths should be provided for any work performed on a bridge including overlays and guardrail upgrades. Bridge lengths are measured from the centerline of bearing to the centerline of bearing of the end bents. Formats of length summaries should clearly identify the sections for which individual lengths are shown (e.g., 2-lane/4-lane, funding type). Calculate the lengths in feet (meters) to two decimal places (i.e., 0.01 ft or 0.01 m). See Section 4.4 for a sample of a linear and level data sheet.

2. Bench Mark Table. For projects having control, the z-coordinates of the control points can be used as the vertical control. Where these coordinates are

available, the bench mark table is not required. Bench mark tabulations should show the station, location, description and elevation of each bench mark. Show bench mark locations referenced to the mainline first, followed by bench marks referenced to other lines in the order they appear along the mainline.

Clearly identify the road or line to which a group of bench marks is referenced. Tabulate each group of bench marks in the order of increasing stations. Show elevations in feet to two decimal places; i.e. 0.01. (Show elevations in meters to three decimal places; i.e., 0.001 m).

3. Bearing Source. State the source used to take the bearings (e.g., previous surveys, adjacent projects, solar observations).

4. Level Datum Source. A detailed description will be provided to identify the level datum source. The description should include the bench mark location, elevation, number and any other pertinent information.

5. Centerline Coordinate Table. The coordinate table should show the station, description, east or X coordinate, north or Y coordinate, and any appropriate remarks. Show the coordinates to four decimal places (i.e., 0.0001 ft or 0.0001 m). Coordinates are typically provided for:

    a. the project's beginning and ending points of the mainline including connections, side roads, or any other splits described in Comment #1;

    b. PC;

    c. PI;

    d. PT;

    e. TS;

    f. SC;

    g. CS;

    h. ST; and

    i. station equation points.

4.3.5 Control Diagram

The control diagram is used to establish a permanent, recoverable horizontal and vertical control system for highway design and construction. All topographic features, section corners, controlling property corners, geological data, hydrological data, existing right-of-way and miscellaneous design information are tied to the control traverse. The control will also be used to layout the design centerline and right-of-way. During construction, if a control point is destroyed or becomes unusable, a new control point can be set using the control diagram. See sample plan sheets, Section 4.4 and use the following guidelines to plot the control diagram:

1. Scale. The diagram will generally be drawn using an appropriate scale. However, the scale may need to be changed so that the diagram will fit onto one sheet.

2. Segments. The diagram can be broken into segments on the sheet to allow for a better fit.

3. Combination Scale Factor . Include the combination scale factor on the diagram for all projects that use the state plane coordinate system.

4. Identification Number. Show the control point identification number next to the control point.

5. Congested Areas. In congested areas where the control points plot close together, provide a detail, which does not need to be to scale, to show the relative positions and lines of sight.

6. Symbol. Plot control points using the standard CADD cell.

7. Abstract. The control diagram will require an abstract summarizing the important aspects of the survey control points. If practical, the abstract should be placed on the same sheet as the diagram. The abstract may be placed on a separate sheet or may be incorporated onto the linear and level data sheet. The abstract should contain:

    a. the point identification number,

    b. the easting or x coordinate, round to four decimal places (i.e.,0.0001 ft or m)

    c. the northing or y coordinate, round to four decimal places (i.e.,0.0001 ft or m)

d. the point elevation or z coordinate, round to two decimal places for US Customary and three decimal places for Metric(i.e.,0.01 ft or 0.001 m) and

e. a description on how to find or reach the control point.

4.3.6 Typical Sections

One or more typical sections are required for each set of plans. Typical sections are used to illustrate the cross section for a roadway section, the basis for surfacing quantities, roadway widths for tangent and superelevated sections, and cut and fill slope rates. Provide a separate typical section for each of the following situations:

1. tangent sections;
2. superelevated sections;
3. where there are changes to the pavement structure;
4. where there are changes from a curbed section to a non-curbed section or vice versus;
5. side approaches and roads which have a significant length of reconstruction;
6. cross section changes (e.g., shoulder additions, median changes);
7. where the bridge width differs from the roadway provide a typical section matching the bridge roadway width from the end of the bridge to the end of the longest run of guardrail.

Changes in pavement width are generally shown on separate typical sections. For extremely localized changes in pavement width (e.g., turnouts, chain-up areas), the change may be shown on a detail with the additional quantities included in the appropriate frames. Separate typical sections are recommended when transitioning from a reconstructed or new section to an existing section or connection to PTW to ensure that adequate taper rates are provided. The need for a separate typical section for connections will be determined on a case-by-case basis. The widths of the design and existing typical sections should at least be noted in the “Remarks” column of the Additional Surfacing summary

Prepare typical sections using the following guidelines:

1. <u>Orientation</u>. Orient all typical sections horizontally (landscaped) on the sheet.

2. Scale. Draw typical sections using a scale of 1:50, both horizontally and vertically. A different scale may be used for wide typical sections (e.g., 4-lane highways).

3. Order. Show the mainline typical sections first, followed by the other sections in the order they appear in increasing stations along the mainline.

4. Titles. Number each typical section sequentially as they occur in the plan and profile sheets. The first typical section on a project should be No. 1, the second No. 2, etc. Also include the name of the road to which the typical section applies directly below the typical section number.

5. Frontage/Access Roads. Reference the beginning and/or end of frontage and access roads with respect to the mainline stationing.

6. Station Limits. List the station limits for which the typical section applies in the upper right-hand corner of each typical section. Station limits should also be included for bridge ends. The limits should extend from centerline of bearing to centerline of bearing for each bridge. Transitions from one typical section to another should be stated next to the station limits (e.g, TRANS. TYP. 3 TO TYP. 4). Include the transition note on the preceding typical section. Transition call outs are generally required at all typical section changes. Where transitioning from a tangent section to a superelevated section, the transition stationing begins at the beginning of the tangent runout and ends where full superelevation is achieved, not at the PC, PT, TS, ST, etc. The station limits for superelevated sections should be followed by the appropriate superelevation and direction of curve (e.g., 7% RT).

7. Cross Section. The typical section cross-section view should show the following elements:

    a. the grading template, including non-standard slope designs;

    b. profile grade line reference;

    c. surfacing templates for immediate and future development;

    d. types of surfacing and thicknesses shown to the nearest 0.05 feet (5 mm).

    e. dimensions from which cuts and fills are staked; and

    f. slopes and dimensions necessary to define the typical section. Use dimensions instead of slopes wherever the typical section can be defined with dimensions. Cross slopes should typically be shown to the nearest percent (i.e., 1%). Show subgrade widths the nearest foot and finished top widths to the nearest 0.1 foot (in meters to one decimal place; i.e., 0.1 m), and intermediate pavement widths to the nearest tenth of a foot; i.e. 0.1’ (hundredth of a meter; i.e., 0.01 m).

8. Slope Table. Include fill and back slope slopes tables where back or fill slopes are presented as variable on the typical section.

9. Quantities Frame. Show the quantities of surfacing materials represented by the typical section underneath the typical section figure. Superelevated sections which have the same basic quantities may reference the appropriate tangent typical section. Section 5.4.2 provides the rounding criteria that should be used in the quantity frame.

10. Width Table. A width table showing the roadway widths should be provided for each superelevation rate for a given typical section. Where only one superelevation rate occurs for a typical section, show the dimensions in the same manner as for a tangent typical section. Figure 4.3B illustrates a sample width table.

% SUPER	ENGLISH WIDTH TABLE (ft)						
	A	B	C	A’	B’	C’	D’
5	18.6	19.9	26.0	17.4	18.2	23.0	3.0
7	19.2	20.7	26.0	17.2	17.9	22.0	4.0

% SUPER	METRIC WIDTH TABLE (m)						
	A	B	C	A’	B’	C’	D’
5	5.57	6.00	7.8	5.21	5.44	6.8	1.0
7	5.73	6.25	7.8	5.19	5.40	6.7	1.1

Note: Non-primed letters are for the dimensions left of the design centerline and primed letters are for those right of the design centerline.

SAMPLE WIDTH TABLE
Figure 4.3B
(Refer to sample drawing 4.4G, Typical Section 2)

11. Notes. The R-values of the subgrade material, which are the basis for surfacing design, will be shown on the typical section. Design and construction notes that are only pertinent to the specific typical section may also be included on the typical section.

12. Special Borrow. When special borrow is provided in the surfacing recommendations from the Surfacing Design Section, it can be designed into the typical section as an additional lift of material or it can be designed as the top component of the subgrade. When special borrow is designed into the typical section, the subgrade shown on the cross sections is located at the bottom of the special borrow.

    When special borrow is designed as the top 2’ (0.6 m) of the subgrade as part of the surfacing recommendations it should be shown as a cross-hatched area on the cross sections. However it is not shown in the profile view. In cut sections where the subgrade inslope is 6:1, the inslope must be extended to 14 ft (4.1 m) to ensure that the bottom of the special borrow is above the ditch. The following options need to be evaluated for the treatment of the flat-bottom ditch:

    1) Provide the entire 10’ (3 m) flat-bottom ditch

    2) Reduce the ditch width to 6’ (1.9 m) so that the hinge point of the back slope is in the same place as it would be for the standard cut section.

    When a 4:1 subgrade inslope is used (low-volume secondary routes), the special borrow will not extend beyond the 10’ (3 m) inslope and no adjustment is necessary.

    When the special borrow is included in the subgrade to address site-specific subsurface conditions, it should be shown in a detail and as a cross-hatched area on the cross sections and the profile.

    The project team including representatives from District Construction, Environmental Services and the Surfacing Design Section, should decide how the special borrow will be designed as soon as the surfacing recommendations are submitted. This decision should be documented in the Alignment and Grade Report.

    If the special borrow is added later to address a site condition discovered after the surfacing is designed, it should treated as part of the subgrade and should be shown as described above.

13. CADD Cells. Standard CADD cells are available for the slope table, the quantities frame, the width table and other typical section elements.

14. CADD Drafting. The MDT CADD Standards Manual provides drafting and dimensioning guidelines for typical sections.

4.3.7 Summary Sheets

One or more summary sheets will typically be included in each set of construction plans. Summary sheets will show all quantities of work and materials required by the plans. No other data will be shown on the summary sheets. Chapter Five presents the guidelines for developing plan quantities. Prepare the summary sheets according to the following guidelines:

1. CADD Cells. Figure 4.3C provides a listing of the typical summary frames and the corresponding CADD cell name for each summary frame. Additional frames may be required for specialty items. Their use will be determined on a project-by-project basis.

2. Frame Adjustments. The summary frames may need to be adjusted for the project. The frames should include three blank lines between the last quantity and the total. Additional lines may be required for large projects. When developing new summary frames, start with an existing cell and use the format shown in sample plans sheets in Section 4.4. Blank-out or remove columns within the frame that are not used to eliminate possible confusion.

3. Stationing. Stationing within each summary frame should be sequential wherever practical. Figure 4.3C provides the recommended station listing procedure that should be used within each frame.

4. Rounding. Chapter Five presents the rounding procedure that should be used within each summary frame.

5. Placement. Place quantities so that they are right justified under the description of the item, and align all other numbers so that all numbers in an individual column have the same place value. For English units use commas to separate 3-digit groups (e.g. 1,000). For metric units use spaces in place of commas. A period (.) will be used to signify the decimal point. Place a zero in front of the decimal point for numbers less than one.

Frame	Cell Names	Sample Sheet Figure	Stationing Listing Requirements* Description
Additional Grading (Unclassified Exc.)	ADDEX	Fig 4.4K-1	Begin and end station (or each location.)
Grading (Unclassified Exc.)	GRADEX	Fig 4.4K-1	Stations from balance point to balance point.
Subexcavation (Unclassified Exc.)	SUBEX	Fig 4.4K-1	Begin and end station of each location.
Additional Grading(Embankment-in-Place)	ADDEM	Fig 4.4K-2	Begin and end station (or each location.)
Grading (Embankment-in-Place)	GRADEM	Fig 4.4K-2	Begin and end station (or each location.)
Subexcavation (Embankment-in-Place)	SUBEM	Fig 4.4K-2	Begin and end station of each location.
Additional Surfacing	ADSURF	Fig 4.4K-3	Begin and end station (or each location.)
"	"	Fig 4.4K-4	"
"	"	Fig 4.4K-5	"
Surfacing	SURF	Fig 4.4K-3	Begin and end station of applicable typical section.
"	"	Fig 4.4K-4	"
"	"	Fig 4.4K-5	"
Bituminous Pavement Removal	BITPAV	Fig 4.4K-6	Begin and end station of each location.
Cattle Guard	CATGRD	Fig 4.4K-6	Each location station.
Clearing and Grubbing	CLEAR	Fig 4.4K-6	Begin and end station of each location.
Cold Milling	COLDML	Fig 4.4K-6	Begin and end station of each location.
Concrete Drainage Chutes	CONCDR	Fig 4.4K-6	Each location station.
Concrete Lined Ditch	CONCLD	Fig 4.4K-6	Begin and end station of each location.
Channel Restoration and Fish Passage	CHANREST	Fig 4.4K-6	Begin and end station (or each location.)
Culvert Frame - Optional	CULVOP	Fig 4.4K-7	Each location station.
Approach Pipe	APPIPE	Fig 4.4K-8	Each location station.
Culvert Frame - No Options	CULVNO	Fig 4.4K-8	Each location station.
Culvert Summary Recap	CULVRE	Fig 4.4K-9	Total for whole project (no stationing).
Curb	CURB	Fig 4.4K-9	Begin and end station of the B.C.R.
Detour (Construct, Maintain & Remove)	DETOUR	Fig 4.4K-9	Begin and end station of each location.
Ductile Iron Fittings	DUCTIRON	Fig 4.4K-9	Total for whole project (no stationing).
Digout Excavation	DIGOUT	Fig 4.4K-10	Begin and end station of each location.
Embankment Protectors	EMPRO	Fig 4.4K-10	Begin and end station of each location.
Equipment	EQUIP	Fig 4.4K-10	Begin and end station of each location.
Fencing	FENCE	Fig 4.4K-10	Begin and end station of each type.
Finish Grade Control	FGC	Fig 4.4K-10	Begin and end station of each location.
Gabions	GABIANS	Fig 4.4K-10	Begin and end station of each location.
Edge Drain	EDGEDR	Fig 4.4K-10	Begin and end station of each location.
Concrete Barrier Rail	CONCMR	Fig 4.4K-11	Begin and end station of each location.
Guardrail	GRDRAL	Fig 4.4K-11	Begin and end station of each location.
Irrigation Structures	IRRSTR	Fig 4.4K-12	Each location station.
Mailboxes	MAILFR	Fig 4.4K-12	Each location station.
Manholes in Place	MANHOL	Fig 4.4K-12	Each location station.
Median Concrete Curb	MEDCB	Fig 4.4K-12	Begin and end station of each location.

**See Chapter Five for additional information on how to determine quantities.*

SUMMARY FRAMES

Figure 4.3C

Frame	Cell Names	Sample Sheet Figure	Stationing Listing Requirements* Description
Median Crossover	MEDCO	Fig 4.4K-12	Begin and end station of each location.
Temporary Guardrail	TEMPGR	Fig 4.4K-12	Begin and end station of each location.
Median Inlets	MEDI	Fig 4.4K-13	Each location station.
Muck Excavation	MUCKEX	Fig 4.4K-13	Begin and end station of each location.
Obliterate Roadway	OBLIT	Fig 4.4K-13	Begin and end station of each location.
Pavement Markings	PAVEMK	Fig 4.4K-13	Total for whole project (no stationing).
Plant Mix Lined Ditch	PMLIDI	Fig 4.4K-13	Begin and end station of each location.
Pulverization	PULV	Fig 4.4K-13	Begin and end station of each location.
Random Riprap	RANRAP	Fig 4.4K-13	Begin and end station (or each location.)
Remove Structure	REMSTR	Fig 4.4K-13	Center location station.
Miscellaneous Items	MISC	Fig 4.4K-13	Begin and end station (or each location.)
Revegetation	REVEG	Fig 4.4K-14	Begin and end station of each location.
Road Leveler Operations	RLEVOP	Fig 4.4K-14	Begin and end station of each location.
Rumble Strips	RUMSTR	Fig 4.4K-14	Begin and end station of each location.
Sidewalk	SIDWLK	Fig 4.4K-14	Begin and end station of the B.C.R.
Special Borrow	SPBRW	Fig 4.4K-14	Begin and end station of each location.
Select Backfill	SELBACK	Fig 4.4K-14	Begin and end station of each location.
Riprap Revegetation	RIPREVEG	Fig 4.4K-14	Each location station.
Stockpass	STKPS	Fig 4.4K-15	Each location station.
Storm Drain	STORM	Fig 4.4K-15	Begin and end station of each location.
Topsoil & Seeding	TOPSO	Fig 4.4K-15	Approximately every 10 stations.
Underdrain	UNDR	Fig 4.4K-16	Begin and end station of each location.
Waterline	WATER	Fig 4.4K-16	Each location station.
Wetland Site	WETLAND	Fig 4.4K-16	Begin and end station of each location.
Water Valve Boxes	WTRADJ	Fig 4.4K-16	Each location station.

**See Chapter Five for additional information on how to determine quantities.*

SUMMARY FRAMES (Continued)
Figure 4.3C

6. Separate Frames. Separate frames may be required for the same items when more than one funding is utilized on a project. For more information on when separate frames should be used, see Chapter Five.

4.3.8 **Hydraulic Data Summary Sheet**

The hydraulic data sheet contains the information on culvert sizes ≥ 30” (≥ 750 mm in diameter or equivalent arch size), bridges, longitudinal encroachments, flood data and other necessary hydraulic data. When optional culverts are used the largest option will be shown in the summary sheet. This sheet is prepared by the Hydraulics Section. The road designer is responsible for incorporating it into the plans.

4.3.9 <u>Detail Sheets</u>

4.3.9.1 General

Detail sheets are used for those items that require more specific information than can be adequately described on either the plan or the profile views of the plan and profile sheets. Detail sheets are used to show:

1. drainage details (including storm drains);
2. special maintenance and protection of traffic through construction zone plans;
3. miscellaneous details (including details for major approaches, intersections, interchanges, connections to existing pavement, etc);
4. contour grading plans;
5. standard details; and
6. mass diagrams. (not included in final construction plans)

Clearly label each detail in the title box in the lower right-hand corner of the space allotted to the detail. In the title box, show the name of the detail, the station(s) to where it applies and the scales to which it is drawn, if appropriate.

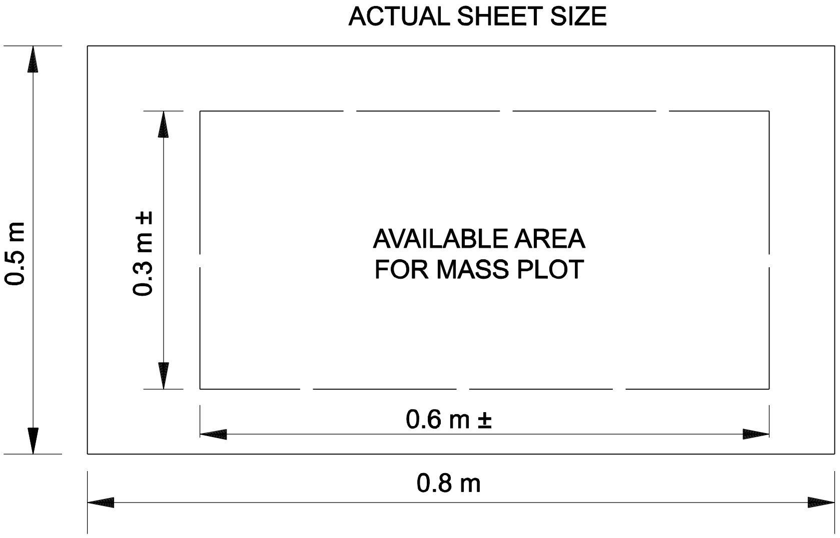
A mass diagram detail sheet is included in the preliminary plans for projects utilizing unclassified excavation. Mass diagrams are typically not required for embankment-in-place projects or urban projects. The mass diagram provides a capsule view of the earthwork quantities and how they could be moved. See Section 5.2.5 for more information on mass diagrams. Scale the mass diagram so that it can be placed onto one page. Figure 4.3D illustrates how to scale the mass diagram to fit onto one page. Where practical, the mass diagram should be continuous with no breaks. The mass diagram should contain the following information:

1. begin and end stations with the project number;
2. mass curve and balance line;
3. balance point station, to the nearest meter;
4. volumes of unclassified excavation, embankment +, and haul between balance points;

5. borrow or excess volumes, if applicable;
6. shrink/swell factor;
7. a note stating "Haul shown for information only"; and
8. a scale for horizontal and vertical units, see Figure 4.3D.

Section 5.2.5 provides additional information on how to use a mass diagram.

Plan views of geometric layouts are used where the mainline plan and profile sheets cannot adequately show horizontal alignment details of large or complex facilities such as major intersections. The contents of geometric layouts generally should be the same as the contents of plan views on mainline plan and profile sheets, except that the topography will not be shown and the name of the features should be clearly shown on the right side of the detail.



1. Actual length of project (m) ÷ 0.6 m = horizontal scale
2. Difference of most extreme mass ordinates (m3) ÷ 0.3 m = vertical scale

Note: Round scales to multiple of available scales on ruler (e.g., 1:100, 1:200, 1:250, 1:300, 1:400, 1:500).

* * * * * * * * * *

Example

Given: Length of project = 8825.36 m

Highest mass ordinate = +101 320 m3

Lowest mass ordinate = -74 176 m3

8825.36 ÷ 0.6 = 14 709.9 Round Y 1:15 000 horizontal scale

101 320 - (-74 176) = 175 496 ÷ 0.3 = 584 986 Round Y 1:600 000 vertical scale

* * * * * * * * * *

SCALING A MASS DIAGRAM

Figure 4.3D

4.3.9.2 Straightline Diagrams

Straightline diagrams provide only the plan view of the roadway and can be categorized into three formats. The designer should select one of the following formats depending on the work involved:

1. Straightline Sheets. These sheets are typically used for overlay projects having no R/W involvement. The horizontal alignment is represented by straight lines. Curves are not depicted but curve data is provided. Two or three segments of roadway may be shown on a sheet depending on available space. Scales other than 1:1200 (1:1000 metric) may be used.

2. Plan Sheets. These sheets are typically used for widening and overlay projects requiring R/W acquisition or construction permits. These sheets should utilize a 1:1200 (1:1000 metric) scale. They are very similar to the "plan" portion of plan and profile sheets. Information which is normally included on the profile may be shown on these sheets (e.g., guardrail).

3. Detail Sheets. These sheets may be used for special cases involving extensive additional work. They will utilize the same format as the plan sheets described above, but quantities will be listed on the plan sheet for clarify.

4.3.10 Plan and Profile Sheets

The plan and profile sheets are the basic design sheets used by the designer to illustrate the horizontal and vertical alignments and to depict the construction items and the topography necessary for construction. Therefore, the designer needs to ensure that these sheets are drawn with clarity and are as simple as practical, but still provide the necessary information to construct the project.

4.3.10.1 General Guidelines

The following provides several guidelines for the preparation of the plan and profile sheets:

1. Views. The Department's practice is to provide the plan and profile on the same sheet. The plan view is shown in the upper half of the sheet with the corresponding profile view shown directly below it.

2. Sequence of Sheets. Show the mainline plan and profile sheets first, in the order of increasing stations. Project stationing typically increases from south to north and west to east. Do not interrupt the continuous stationing of the mainline plan and profile sheets with the insertion of plan and profile sheets for other facilities (e.g., side roads, frontage roads, railroads). Insert these additional plan and profile sheets after the mainline sheets in the order they appear along the mainline.

3. Labeling. Clearly label all additional plan and profile sheets on the right side so that the plan user can readily determine what plan and profile is being shown.

4. Sheet Overlap. There should be no sheet overlap between successive sheets (i.e., use match marks). Generally, lay out the sheets so that approximately 3000 ft (700 m) of the project is shown on each sheet. However, this may be adjusted as needed on a sheet-by-sheet basis.

5. Note Orientation. In general, write all notes and dimensions horizontally from left to right, except for the following:

    a. Plan Views. Pipe, irrigation facilities, bridges and storm drain installation notes are placed vertically at the bottom of the plan view. Stationing, at 1000’ (100 m) intervals, is placed radially approximately 4” (100 mm) above the centerline. Curve data is placed radially on the inside of the curve. The curve station callouts should be placed on the left side of the leader, because R/W data is always placed on the right side of the leader.

Place curve controls, equations and angle points at right angles to the centerline.

b. Profile Views. Write equations diagonally. Full stations and elevations of VPI, pipe stations, begin/end stations and bridge end stations should be written vertically. Place any notes above the profile.

c. Special Considerations. Where limited space for notes and dimensions makes horizontal placement detrimental to the readability of the plans, they may be placed vertically or below the profile.

d. See sample plan sheets for additional information.

6. Use of Notes. Notes on plan sheets should be brief, clear and consistent. Indicate any installations and removals by station and provide a brief description. Do not include detailed descriptions on the plan and profile sheets. These should be placed on the Note Sheet. Typical notes for some common items are shown in Figure 4.3E.

7. Drafting Details. Figure 4.2A provides the recommended abbreviations that should be used. Section 4.2 also provides additional drafting details that should be reviewed when preparing plan and profile sheets.

ITEM	TYPICAL NOTE	
	English	Metric
New culvert (optional)	65 + 00 NEW 24” DR	65 + 00 NEW 600 mm DR
New culvert (non-optional)	65 + 00 NEW 24” CSP.DR.	65 + 00 NEW 600 mm CSP.DR.
Existing culvert to be removed	70 + 30 610 24’ C.M.P. IN-PLACE REMOVE	70 + 30 610 mm C.M.P. IN-PLACE REMOVE
New approach	75 + 20 PUBLIC APP. RT.	75 + 20 PUBLIC APP. RT.
New riprap	92 + 35 to 93 + 80 CL.2 RIPRAP RT.	92 + 35 to 93 + 80 CL.2 RIPRAP RT.
Subexcavation	82 + 00 to 83 + 30 SUBEXC.	82 + 00 to 83 + 30 SUBEXC.

TYPICAL PLAN AND PROFILE NOTES

Figure 4.3E

4.3.10.2 Approaches

Correct approach designations are required for R/W purposes. However, during design it may be difficult to determine the appropriate designation (e.g., private or farm field). Designers should use their best judgment to designate approaches during design. When R/W agreements become available, the designer should check the agreements to ensure that the appropriate approach designations are provided in the plans. The following defines the various approaches.

1. Public Approaches. Public approaches are connections to and/or from a highway, street, road, alley, etc., or dedicated public right-of-way.

2. Private Approaches. Private approaches are permanent entrances to and/or from a commercial, industrial or residential property.

3. Farm Field Approaches. Farm field approaches are revocable entrances to and/or from a field.

When designating approaches, the designer should consider the following:

1. Limited Access Control Projects. R/W will provide the designer with the "Limited Access Control Recommendations," which provides the designations for all approaches within Limited Access Control. Listed below are the appropriate approach designations to be used with the station and location (LT or RT) for call out on plan sheets and cross sections:

   Public APP.
   Private APP.
   *Private APP. (future)
   Private APP. (joint)
   *Private APP. (future-joint)
   Farm Field APP. (revocable)

   *Future approaches will be called out, but not drawn on the construction plans or cross sections nor the quantities computed.

   Example:

   200 + 50
   FARM FIELD APP. LT.

2. Regulated Access Projects. R/W will not provide the designer with recommendations of designation for approaches. The designer will make this

determination from "existing use" or R/W agreements, if applicable. Listed below are the appropriate approach designations to be used with the station and location (LT or RT) for callouts on plan sheets and cross sections:

PUBLIC APP.
PRIVATE APP.
PRIVATE APP. (JOINT)
FARM FIELD APP.

Example:

100+20
PRIVATE APP. LT.

3. <u>Widths</u>. Approach widths other than 24’(7.2 m) should be noted on the plan sheets and cross sections. For urban projects, show all approach widths.

Example:

20+00 *FARM FIELD APP. LT.* *32’ TOP*	*20+00* *FARM FIELD APP. LT.* *9.6 m TOP*

4.3.10.3 Preliminary Plans

There are several items that are only shown on the preliminary design plans. Do not include these items in the final plans. The information that may be shown in the preliminary plans includes:

1. <u>Utilities Conflicts</u>. In general, utility plans are the responsibility of the Utility Section. Where utility items exist within the project construction limits, the road designer should denote on the construction plans provided to the R/W Bureau the following information:

    a. Above Ground Utilities. Existing above ground utilities such as power poles, telephone pedestals, gas and water valves, fire hydrants, etc., located within proposed construction limits should be circled and labeled with a station and distance from the design centerline.

    b. Underground Utilities. Existing underground utilities located longitudinally and within the proposed construction limits do not have to be circled but should be called out as a conflict (from-to station of the conflict) and shown on the plans.

c. Utility Hazards. Telephone and power poles, which include guy wires, located within the clear zone as defined in Section 14.2 should be labeled "Clear Zone" and circled with a station and distance from the design centerline. Telephone pedestals 6” x 6” (150 mm x 150 mm) or less are not considered obstacles unless they are supported by a vertical pole larger than 5” (125 mm) in diameter or a post larger than 4” X 4” (100 mm x 100 mm).

2. <u>Plan View</u>. Show construction limits on the preliminary plans. Where deemed necessary, contour lines and the control traverse may also be shown on preliminary plans.

3. <u>Profile View</u>. Subbase conditions are generally noted on the final plans. Soils information may be eliminated from the final plans if the profile view becomes too cluttered. The decision to eliminate the soils information from the final plans should be made at the plan-in-hand.

4.3.10.4 Plan View

The following presents the recommended guidelines for preparing the plan view:

1. <u>Centerlines</u>. The centerline preferably should be called the "design centerline." The terms "staked centerline" or "projected centerline" may only be used where a centerline is survey and staked in the field as part of the engineering survey.

2. <u>Horizontal Alignment Data</u>. Chapter Nine presents the criteria for horizontal alignment. Show the horizontal alignment data in the plans as follows:

a. Horizontal Curve Data. Place horizontal curve data, including superelevation, inside the curves to which they apply. When a curve extends onto multiple sheets, show the curve data on the sheet where the PI is located. Figure 4.3F presents the order and rounding accuracy that should be used to present the curve data.

SPIRAL CURVE DATA	SIMPLE CURVE DATA	ACCURACY
Δ	Δ	01° 01’ 01”
RC (existing)	RC (existing)	0.01 ft (0.001 m)
RC (new)	RC (new)	10 ft (5 m)

L_S		0.01 ft (0.01 m)
Θ_S		01° 01’ 01”
Δ_S		01° 01’ 01”
Ts	T	0.01 ft 0.01 m
Lc	L	0.01 ft 0.01 m
Es	E	0.01 ft 0.01 m
S	S	1%

HORIZONTAL CURVE DATA
(Plan Sheets)

Figure 4.3F

b. Curve Points. Show perpendicular lines from the design centerline for all curve points. Indicate the curve notation (e.g., PC, PT, SC, TS) and station, to the nearest hundredth of a foot (meter) (i.e., 0 + 00.01) along the perpendicular line. Include the PI station with the curve data.

c. Bearings. Write bearing notations below the line to which they apply. Note the bearing in degrees, minutes, or seconds, rounded to the nearest second (i.e., 01° 01’ 01”).

d. Offsets. Where a conventional survey is used, note the offsets between the construction and survey centerlines at the beginning and end points where they are parallel to each other.

e. Equations. Equations are used to correct a discrepancy in stationing that may occur along the centerline. Show them perpendicular to the design centerline similar to that discussed in Comment "b" above. For more information on equations see Section 9.6.6.

3. Topography. The topography shown should include all utilities, irrigation and drainage facilities, buildings and other items pertinent to construction. In general, show existing elements as solid lines and proposed elements in dashed lines. (Existing utilities are shown using the appropriate line code). Include the North arrow, along with the township and range, on all plan sheets and ensure that it is consistent from sheet to sheet. Also list the section with the North arrow unless section corners or section lines are shown on the sheet.

4. Items to be Removed or Abandoned. Show all items within the right-of-way limits that will be removed or abandoned in place. Clearly note those items which will be removed by non-contractor personnel.

5. Urban Roadway Widths. Roadway widths should be indicated on the Typical Sections and should not be provided on the plan sheets. However, where a typical section is not provided (e.g., for public approaches), show the roadway width on the plan view measured from the back-of-curb to back-of-curb.

6. Station Call Outs. Provide station call outs at the following locations:

   a. beginning and ending points of the project;

   b. 10 station increments – English (100 m station increments – metric);

   c. horizontal curve points;

   d. beginning and ending points of tapers, including the distance and direction from the design centerline;

   e. construction permit locations and right-of-way breaks;

   f. curb openings, including the distance and direction from the design centerline;

   g. curb ramp locations, including the direction from the design centerline;

   h. drainage crossings, inlets, grates, manholes, water valve boxes, sewer crossings, etc., and where applicable, the distance and direction from the design centerline;

   i. utility crossings;

   j. side street intersections;

   k. monument boxes, including the distance and direction from the design centerline;

   l. section line ties, right-of-way takes, etc., including the distance and direction from the design centerline;

   m. funding limits (e.g., county line, urban to rural change, 2-lane to 4-lane change, reservation boundary); and

   n. other locations where deemed appropriate.

7. Drainage. Show all drainage structures in the plan view including culverts, bridges, storm drainage systems, etc. Sanitary sewers and water mains should

be considered as utilities; these are described in Comment #8 below. The following presents several guidelines for placing drainage structures on the plan view:

a. Culverts. For culverts or cross drains note the station location, the pipe size and flow direction. Round pipe skew angle to the nearest degree. For new installations, unless directed otherwise by the Hydraulics Section, the culvert material type will be at the contractor's discretion and should not be noted on the plans. Note the material type when it is specified by the Hydraulics Section and for existing culverts to remain in place or to be lengthened,.

b. Bridges. Bridges should be shown on the plan sheet with centerline station locations of the removed bridge and the new bridge. General bridge details are shown in the profile view. Detailed design information will be provided in the bridge plans.

c. Storm Drains. Storm drainage systems or closed drainage systems are provided on the plan view using the line symbols as shown in the MDT CADD Standards Manual. Include the pipe size and type next to the topography symbol. Note all inlet, outlets and manholes and list them according to work description (e.g., NEW MANHOLES, RESET INLETS, PLUG AND ABANDON EXISTING MANHOLES). The listing should include the station location and the distance and direction from the design centerline.

8. Utilities. Where overhead utilities cross the centerline, include notes to indicate the design centerline station, the type of utility, the number of wires and the clearance above the existing ground. Where underground utilities cross the centerline, include notes to indicate the design centerline station, the type of utility, and the size and depths of the utility below the existing ground. If these elevations are not known they should be called out as “depth unknown” or “clearance unknown”.

Provide a listing of the valve boxes or utilities manholes shown in the plan view on each plan sheet. Organize this listing according to the type of work (e.g., ADJUST MANHOLES IN PLACE). Under each heading, the listing should include the station location and the distance and direction from the design centerline.

9. Right-of-Way. The right-of-way plans designer will:

   a. show the right-of-way limits on the plan view;

   b. note any breaks in the right-of-way alignments by the design centerline station and offset distances;

   c. show any easements, construction permits and control of access limits, as applicable; and

   d. clearly label each line where the control of access limits do not coincide with the right-of-way limits.

The bearings of the section lines, township lines and range lines crossing the design centerline should be clearly shown as should the station at the point of intersection. Do not use angle call outs.

The road designer will label section lines with the appropriate section numbers. If section lines are not present, show the section number below the North arrow.

10. Guardrail. Show the locations for new and existing guardrail on the plan view.

11. Curb Openings (Laydowns). Where applicable, provide a note on each plan sheet listing the stations, widths and direction from the design centerline for each curb opening located on the sheet.

12. Curb Ramps. Where applicable, provide a note on each plan sheet listing the stations, distance and direction from the design centerline for each curb ramp located on the sheet. Most curb ramps will require additional details.

13. Monument Boxes. Where applicable, provide a note on each plan sheet listing the stations, distance and direction from the design centerline for each monument box located on the sheet.

14. Wetlands. Delineate wetland and wetland impacts. Identify the delineated wetlands with a one-directional cross hatching and areas with wetland impacts with a two-directional cross hatching.

15. Core Logs. Place the appropriate symbol to indicate the core log location on the plan sheet.

4.3.10.5 Profile View

The following presents the recommended guidelines for preparing the profile view:

1. Existing Ground Line. Show the existing ground line along the design centerline for each profile view as a solid line. See the MDT CADD Standards Manual for the applicable line weights.

2. Vertical Alignment Data. Chapter Ten presents the criteria for vertical alignment. The vertical alignment data should be shown in the plans as follows:

    a. Profile Grade Line. The profile grade line represents the elevation of the top of the finished surfacing at the location shown on the typical section. In superelevated sections, when the typical section defines the profile grade point less normal crown, the profile grade line represents the theoretical elevation of centerline at normal crown.

    b. Vertical Curve Notations. Depict the V.P.C. and V.P.T. with small circles on the profile grade line. The small circle for the V.P.I. should be shown with short segments of the vertical tangents. Note the V.P.I. station (to the nearest tenth of a foot – 0+00.1 (hundredth of a meter — 0 + 00.01) and elevation (to the nearest tenth of a foot – 0.1 (hundredth of a meter — 0.01 m) on the profile view. Place V.P.I. notes vertically above the profile for crest curves and below the profile for sag curves. Do not record the V.P.C. and V.P.T. stations and notations on the profile view.

    c. Vertical Curve Lengths. Round the vertical curve calculations determined from Chapter Ten to at least the next highest 50 ft (20 m) increment for new vertical alignments and to the nearest 0.1 ft (0.01 m) when matching the existing alignment. Write vertical curve lengths horizontally above the profile for sag curves and below the profile for crest curves.

    d. Tangent Grades. Show tangent grades to the thousandth of a percent (i.e., 0.001%). Show positive grades with the "+" prefix and negative grades with the "-" prefix. A "+" prefix indicates that the grade is ascending ahead on stationing.

    e. Transition Grades. Sections using transition grades should be noted as “Transition Grade”.

3. Curb and Gutter Profiles. Where curbing is provided, a supplemental profile will be required, showing the profile at the top back of curb regardless of whether or not the curb grade is parallel to the centerline grade. Provide a gap in the profile

for each curb cut. The criteria presented in Comment #2 also applies to curb profiles. Show the existing ground line on each profile. Show the left-curb profile on the top of the profile view and the right-curb profile on the bottom.

4. Curbing/Sidewalks. Where curbing and/or sidewalks are provided, draw a straight, horizontal line on the bottom portion of the profile view from radius point to radius point for each curb and/or sidewalk location, including median curbs. Show curbing and sidewalks for the left side on the top, those in the median in the middle and those on the right side on the bottom. Record the sidewalk information including type, location and radii on the top of the line. Curb information including type, location and radii are provided below the line. Breaks are provided for all curb cuts. Measure all dimensions for curbs from the back of the curb and not the face of curb. See the sample plan sheets in Section 4.4 for additional note designations.

5. Subexcavation. Show subexcavation as a crosshatched area under the profile grade line. The designer should note that the subexcavation should be shown to the top of the subgrade and not to the profile grade line. Each subexcavation location should note the station locations. Show the width and depth of subexcavation on a detail sheet.

6. Drainage Structures. Show mainline cross drainage structures as solid ovals on the profile view and provide a plus station callout (e.g. for a pipe located at 20+35 show +35 at the pipe symbol in the profile view). Longitudinal drainage structures are generally not shown unless there may be a potential conflict with utilities, other drainage structures, etc. Where conflicts may occur, provide a supplemental profile; see Comment #9. Show bridges as a cross-hatched area equal to the length and depth of the superstructure. Also show the riprap at bridge ends.

7. Guardrail. Show new guardrail locations on the profile view as straight, horizontal lines. Provide separate lines for each side of the road. Write the guardrail type above the line. Existing guardrail to be removed will be described in a note on the profile view; see the sample plan sheets in Section 4.4.

8. Vertical Clearances. Show the vertical clearances for all overhead structures on the profile view. Record the minimum clearance distance to the nearest tenth of a foot – 0.1 (hundredth of a meter - 0.01 m).

9. Supplemental Profiles Sheets. Supplemental profile sheets may be provided after the plan and profile sheets to illustrate special drainage structures and roadside ditches.

10. Core Logs. Show the elevation view of the core log to scale with the thickness and soils classification of each soil placed at the correct elevation. Place the station, offset and core identification number at the bottom of the core.

4.3.11 Cross Sections

Cross sections provide a graphical representation of the proposed roadway as compared to the existing ground line. The following sections present the general guidelines for developing cross section sheets.

4.3.11.1 Computer Generated

In general, GEOPAK will generate the line work for the cross sections. The designer should review the user's manuals for GEOPAK to determine how to generate the cross sections. In addition, the designer should consider the following:

1. Orientation. Preferably, draw the cross section horizontally (landscaped) on the sheet. This is the default direction assumed by the computer. If determined to be practical, the cross sections may be drawn vertically (portrait). Show the cross sections from the bottom of page to the top according to increasing stations.

2. Spacing. The computer default spacing between cross sections is approximately 4" (100 mm) apart. However, the designer should ensure that there is no overlap of the individual cross section figures, especially in areas of large cuts or fills. Align individual cross sections on a page vertically with the design centerline, or staked line where applicable.

3. Intervals. In rural areas, plot the cross sections at 50' (15 m) intervals. For urban areas, plot them at 25' (10 m) intervals. Plot additional cross sections at major grade breaks, all pipe crossings, all approach centerlines, all curve control points (TS, SC, CS, ST), all typical section transition points and other locations as deemed necessary. Plot additional cross sections at all superelevation control points for both simple and spiral curves (refer to Figure 9.3E).

4. Order. Show the mainline cross sections first, in increasing stations. Individual cross sections of approaches will generally not be shown, except in cases where major construction is conducted for a significant distance along the approach. For skewed culverts, cross sections taken along the skew of the culverts may also be included. Where cross sections for side roads, frontage roads, ramps, skewed culverts, etc., are provided, place them after the mainline cross section in

the order they appear along the mainline. Clearly label each special cross section sheet to allow the user to identify the location of the cross sections.

5. Generated Data. The following cross section information will typically be plotted by GEOPAK:

   a. existing ground line;

   b. proposed top of subgrade line (the finish top surfacing may be shown);

   c. design centerline location (staked line if applicable);

   d. station locations;

   e. top of subgrade elevations, placed vertically, to the nearest hundredth of a foot (meter);

   f. groundline elevations along the design centerline or staked line, if applicable (these points should be written diagonally);

   g. roadway slopes for both right and left of the design centerline and offset from staked line, if applicable;

   h. the actual amount of excavation or embankment between stations (no shrink or swell factors are applied), in cubic meters (excavation values are shown on the left and embankment values shown on the right); and

   i. right-of-way limits.

6. Additional Details. The project number, street name or other special cross section identification must be placed as additional drafting details.

4.3.11.2 Additional Plotting Details

Once GEOPAK generates the cross section, the designer may be required to plot the following elements on the cross sections:

1. Drainage. Drainage elements are commonly plotted separately on the cross sections. Section 4.3.11.3 provides additional information on how to present the drainage structures on the cross sections.

2. Utilities. Plot both overhead and underground utilities on the cross section.

In general all underground utilities can be generated on the cross sections using Geopak. Additional plotting may be required for all utility crossings. Also if available include in the note the following additional information for various utilities:

a) Gas meter – pipe diameter
b) Gas valve – type (above or below ground) and pipe diameter
c) Guy pole – type (anchor, push or other)
d) Manholes – description (electric, storm, sewer or other), type (cone, straight, or other), depth and diameter
e) Pedestal base – type (electric, telephone or other) and size
f) Power pole – type (wood, steel, laminated or other), pole number and underground drop if any
g) Power pedestal – type (pole or ground mount) and box number
h) Telephone pole – type (wood, steel, laminated or other), pole number and underground drop if any
i) Telephone pedestal – type (pole or ground mount) and box number
j) Water meter – pipe diameter
k) Water valve – type (above or below ground) and pipe diameter
l) Tower – type (communication, electrical or other)
m) Misc. valves – type (above or below ground) and pipe diameter

Overhead utility crossings – Place appropriate line between the cross sections that graphically represents the utility crossing station. Place a note near the centerline of the crossing stating the station, type of crossing (power, telephone), clearance to lowest wire and total number of wires.

Underground utility crossings – Place appropriate line between the cross sections that graphically represents the utility crossing station. Place a note near the centerline of the crossing stating the station, type of crossing gas, telephone, sanitary sewer etc. the depth of the utility and the diameter of pipe if known.

3. Grading Notes. Show subexcavation locations on the cross sections. Note the total volume amounts on the cross sections. Show special borrow on the typical section if it is provided in the surfacing recommendations from the Pavement Analysis Section. If it is added later to address a site condition discovered after the surfacing is designed, only show it on the cross sections.

Additional grading notes may be added to the cross sections to give direction to the contractor (e.g., GRADE TO DRAIN).

4. Structures. Depict buildings, bridges or other structures affected by construction on the cross section sheets.

5. Right-of-way. In general, right-of-way limits will be generated on the cross section by the computer. However, problems may arise on projects with variable right-of-way widths. Under these circumstances the right-of-way limits may need to be plotted on the cross sections separately. Construction permits and easements will generally need to be plotted on the cross sections separately.

6. Ditch Blocks. Label ditch blocks at the closest adjacent cross section of the mainline and note them in the following manner:

26+10
DT. BLK. LT.
20 cu. yds. EMB.+

4.3.11.3 Drainage Structures

The following presents guidelines for showing drainage structures on cross sections:

1. Culverts. Provide individual cross sections for each pipe location. Culverts must be fully described on cross section sheets. Each description should include a drawing and a note or "call out." The sample cross section sheets in Section 4.4 illustrate the procedures for noting culverts on the cross section. In addition, the designer should consider the following.

   a. Mainline Culverts Without Skews. Each culvert drawing should show the lines representing the top of the pipe, the flowline of the pipe, bedding and the appropriate end treatment.

   b. Mainline Culverts With Skews. Skewed mainline culverts should only be shown skewed if the skew angle is greater than 5°. Large skews may require the use of two cross sections, one for the inlet and one for the outlet. Each drawing should show the lines representing the top of the pipe, the flowline of the pipe, bedding and the appropriate end treatment. The skew line is centered on a grid line which represents the centerline station of the pipe. The skew line is extended left and right of this point at the appropriate skew angle to a line perpendicular to the culvert end drawn on the cross section. Note the centerline station, skew angle, and inlet and outlet stations on the skew line. In addition, show the true angle of skew so that the pipe lengths can be scaled from the skew line. Where skewed pipe cross sections are provided, placing the skew line on the cross sections is not necessary.

c. Approach Pipes. The cross section figures in Section 4.4 illustrate the correct procedure for noting a sample approach pipe application.

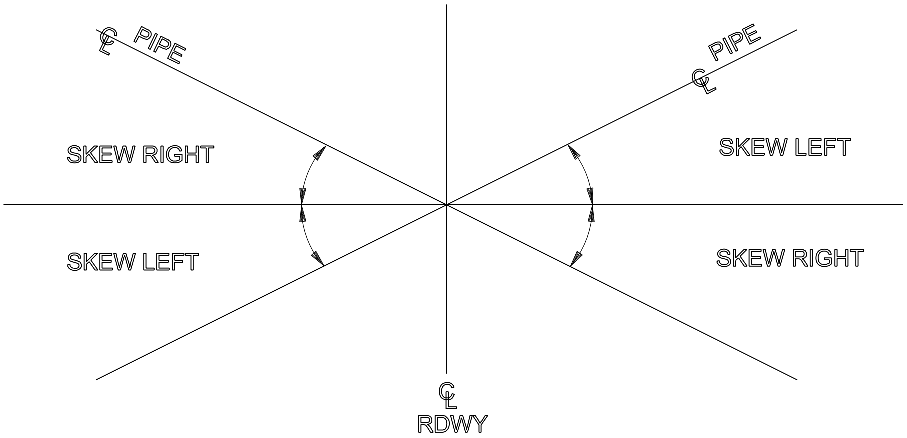
d. Notes. Culvert drawings should be supplemented with notes containing the following data, as appropriate:

1) station location of culvert at the design centerline;

2) description of pipe, including material type (if no option), length, inside diameter, or rise and span;

3) amount of skew in degrees, measured right or left as shown in Figure 4.3G;

4) description of end treatment;



SKEW MEASUREMENTS

Figure 4.3G

5) height of cover, measured from the top of the pipe to the top of the lowest point on the finished grade;

6) cubic meters of culvert excavation;

7) quantity of bedding material;

8) quantity of concrete;

9) quantity of culvert riprap for edge protection; and/or

10) quantity of foundation material and geotextile.

2. Drop Inlets and Storm Drain. Drop inlets and storm drains should be detailed on the cross sections unless a separate detail sheet is included in the plans.

3. Drain Ditches. Inlet and outlet drain ditches should be drawn on the cross sections, and should be described by notation wherever they are used. Each note should indicate the station location, the cubic meters of additional excavation, whether it is an inlet ditch or an outlet ditch and whether it is left or right of the mainline. A typical note is shown below:

73 + 50
OUTLET DT. LT.
20 c.y. ADD. EXC.

4. Irrigation Facilities. All irrigation facilities should be shown on the cross section by the designer. However, they will be designed and detailed by the Hydraulics Section. A typical note on the cross section for irrigation facilities is shown below:

71 + 75
NEW 24” x 126 ’ SIPHON
SKEW 20° RT.
1.6 C.Y. CL. DD CONC. (INLET & OUTLET HEADWALLS)
1.4’ COVER
80 C.Y. CULV. EXC.
SEE DETAIL SHEET

5. SSPPC Installations. Structural steel plate pipe arch culverts will be shown on the cross sections. However, they will be designed and detailed by the Hydraulics Section. A typical note for large culverts is shown below:

200 + 00
NEW 60” x 120’ SSPPC DRAIN, 0.138” THK.
SKEW 30° LT

2:1 STEP BEVELED END LT. AND RT
5.9 C.Y. CLASS DD CONC. CUTOFF WALLS LT. AND RT.
4.4 C.Y. CLASS DD CONC. EDGE PROTECTION - INLET
30.6 C.Y. CLASS I CULVERT RIPRAP - OUTLET
141 C.Y. BEDDING MATERIAL
10.4' COVER
130 C.Y. CULVERT EXC.

4.3.12 Erosion Control Plan

The designer will submit a set of construction plans showing designed finished grade contours to the Environmental Services Bureau for projects requiring a Department of Environmental Quality "General Discharge Permit for Stormwater Associated with Construction Activity." These plans will be submitted when the final construction limits are sent to the R/W Bureau. The Environmental Services Bureau will place the erosion control plan's best management practices (BMP) to be used at each site on these plan sheets that correspond to stationing of the construction plans. The Road Design Section will perform the Cadd drafting to include the BMPs on the erosion control plans and return them to the Environmental Services Bureau for their final review. The designer will revise the erosion control plans as recommended and return them to the Environmental Services Bureau The final erosion control plan and documentation will be submitted by the Environmental Services Bureau to the Department of Environmental Quality.

4.4 SAMPLE PLAN SHEETS

To assist the designer in developing a set of plans, this section provides several sample plan sheets. Although these plan sheets present a major portion of the information required on plan sheets, the designer may need to make adjustments to match field conditions for each individual project. Figure 4.4A provides a list of the plan sheets illustrated in this Section.

PLAN SHEET	FIGURE #
Title Sheet	Figure 4.4B
Table of Contents	Figure 4.4C
Notes	Figure 4.4D
Linear and Level Data	Figure 4.4E
Control Traverse Diagram with Abstract Table	
Typical Sections	
- rural reconstruction project	Figure 4.4G
- rural reconstruction with rumble strips	Figure 4.4H
- urban reconstruction project	Figure 4.4I
- cement treated base	Figure 4.4J
Summaries	Figure 4.4K-1 — K-10
Hydraulic Data	Figure 4.4L
Details - Mass Diagram	Figure 4.4M-1 — M-7
Plan and Profile	
- rural reconstruction project	Figure 4.4N
- urban reconstruction project	Figure 4.4O
- bridge replacement project	Figure 4.4P
- line diagrams with R/W involvement	Figure 4.4Q
- straight-line diagram for overlays	Figure 4.4R
Cross Sections	
- with pipes	Figure 4.4S-1 — S-5
- with topography	Figure 4.4T-1 & T-2

SAMPLE PLAN SHEET SUMMARY

Figure 4.4A

18 October 2016

MONTANA DEPARTMENT OF
TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Five
QUANTITY SUMMARIES

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Chapter Five
QUANTITY SUMMARIES

In addition to preparing clear and concise construction plans, as described in Chapter Four, the designer needs to compile an accurate estimate of the project construction quantities. This information leads directly to the Engineer's Estimate, which combines the computed quantities of work and the estimated unit bid prices. An accurate estimate of quantities is critical to prospective contractors interested in submitting a bid on the project. Chapter Five presents detailed information on estimating quantities for highway construction projects.

5.1 GENERAL

5.1.1 Guidelines for Preparing Quantity Summaries

When preparing quantity summaries, the designer should consider the following guidelines:

1. Specifications. Cross check all items against the *Standard Specifications,* the *Supplemental Specifications* and special provisions to ensure that the appropriate pay items, methods of measurement and basis of payment are used.

2. Computations. For the preliminary summaries, prepare a separate computation sheet for each item used on the project. Include all computation sheets in the project work file.

3. Rounding. The quantity of any item provided in the summaries should match exactly with the figure provided on the computation sheets. Note any required rounding of raw estimates on the computation sheets. Unless stated otherwise, do not round the calculations until the value is incorporated into the summary frames.

4. Significant Digits. Perform quantity calculations with careful regard to the implied correspondence between the accuracy of the data and the given number of digits. In all calculations, the number of significant digits retained should be such that accuracy is neither sacrificed nor exaggerated. Use the following rules to determine the appropriate number of significant digits:

    a. Number of Digits. Any digit that is necessary to define the specific value or quantity is considered significant. When measured to the nearest 1 ft (m), a distance may be recorded as 157 ft (m); this number has three significant digits. If the measurement had been made to the nearest 0.1 ft (0.1 m), the distance may have been 157.2 ft (m); this number has four significant digits.

Zero may be used to indicate either a specific value, like any other digit, or a number's order of magnitude. The area of PCCP (Portland Cement Concrete Pavement) shown on a set of plans, rounded to thousands, was 120 000 $ft^2(m^{2)}$. The three left-hand digits of this number are significant; each measures a value. The three right-hand digits are zeros which merely indicate the order of magnitude of the number rounded to the nearest thousand. The identification of significant digits is only possible through knowledge of the circumstances. For example, the number 1000 may be rounded from 965, in which case only one zero is significant, or it may be rounded from 999.7, in which case all three zeros are significant.

b. Addition and Subtraction. When adding and subtracting quantities, do not express the answer's significant digits any further to the right than occurs in the least precise number. The following illustrates this rule:

Consider the addition of three numbers drawn from three sources, the first of which reported data in millions, the second in thousands, and the third in units:

$$\begin{array}{r} 163\ 000\ 000 \\ 217\ 885\ 000 \\ \underline{+\quad 95\ 432\ 768} \\ 476\ 317\ 768 \end{array}$$

The total should be rounded to 476 000 000.

c. Multiplication and Division. Do not express the product or quotient of multiplication and division calculations with any more significant digits than are used in the calculations. The following illustrates this rule:

Multiplication:

113.2 x 1.43 = 161.876, round to 161.9

Division:

113.2 ÷ 1.43 = 79.16, round to 79.2

5. <u>Quantity Splits</u>. Some projects will require quantity splits for work conducted under various financing arrangements. The quantities for district-wide pavement marking projects do not need to be split. Determine the need to separate project quantities into funding categories during the Preliminary Field Review.

Two types of project splits are utilized: a hard split, which is a detailed separation of quantities, and a soft split, which splits the quantities using a ratio based on the major cost items on a project.

Hard splits are required when the following circumstances occur:

a. A portion of the project is inside a Reservation boundary

b. Different funding sources are utilized (e.g. safety funds included in a larger project)

c. The project has local government involvement/funding

d. The project is located in more than one financial district

For projects requiring hard splits, organize the summary frames to readily identify each division subtotal and the total of all divisions. Show subtotals in the summaries for all hard splits. Provide station callouts on the plan sheets at the locations of the hard splits.

Soft splits are utilized when the following circumstances occur:

a. Portions of the project are in different counties

b. The project is inside and outside of a urbanized boundary

c. The functional classification of the route changes within the project limits

Quantity subtotals are not required for soft splits and no changes to the plans are necessary. A ratio for the soft split will be provided to Fiscal Programming for their use in determining the actual costs for the various splits.

To determine the ratio for a soft split, calculate the cost of major items on a project. These typically include surfacing (plant mix and base), grading (including unclassified borrow), major structures (bridges, retaining walls), lump sum items, mobilization and traffic control. The ratio is then determined based on the cost in each portion of the project.

Example: Project Length = 10 miles: 8 miles in County A, 2 miles in County B. The dollar amounts shown for County A & B were obtained from the plans summaries

Item	$ Amount in County A	$ Amount in County B
Unclassified Excavation	$1,100,000	$400,000
Crushed Aggregate Course	400,000	100,000
Plant Mix Surfacing	480,000	120,000
PG 64-28 & CRS-2P	460,000	115,000
Bridge Removal		50,000
Detour		75,000
TOTALS =	$ 2,440,000	$ 860,000

The ratio = $\frac{2,440,000}{3,300,000}$ to $\frac{860,000}{3,300,000}$ ~ 0.74 to 0.26 or 74% to 26%

For this example the quantity split would be 74% for County A and 26% for County B.

Show all splits if more than one split applies to a project.

6. Preliminary Cost Estimate. Use only the total values from the summary frames to develop the Preliminary Cost Estimate. All items described in the plans that are to be included in the cost estimate must be shown in the summaries. Chapter Seven provides the Department criteria for preparing construction cost estimates. The Preliminary Cost Estimate is utilized by the Board of Review and the Contract Plans Section in their preparation of the final Engineer's Estimate.

5.1.2 Computer Estimates

For most projects, use the computer to develop the quantity estimates for earthwork and other similar items. All other elements are typically calculated manually. For small projects, it may be more efficient to manually calculate all quantities, including earthwork.

The designer should review the instruction manuals for GEOPAK to determine how to properly use the software for estimating purposes. GEOPAK can generate most, but not all, project quantities. Give special consideration to how the design is prepared on the computer (e.g., cell names, levels, processing procedures) to allow the software to determine the quantities. Contact the MDT CADD Coordinator or the section lead CADD operator for additional assistance with GEOPAK.

5.1.3 Units of Measurement

Report quantity estimates in summary frames for all contract bid items consistent with the terms and units of measurement presented in the *Standard Specifications*. Figure 5.1A illustrates typical rounding criteria that should be used for each frame on the Summary Sheets. Note that certain elements (e.g., pipe lengths, guardrail) are rounded based on standard manufacturer sizes. Unless stated elsewhere in this Chapter, round quantities consistent with the criteria presented in Figure 5.1A.

5.1.4 Item Codes

Each item used for measurement and payment in construction is identified by a 9-digit number with a title and description. These numbers are used by the Department's Construction Management System for tracking the project through construction. Note that the first three digits of the item number are coordinated with the *Standard Specifications*. For example, Item #606010030 “Guard Rail-Steel” is referenced to Section 606 “Guardrail, Median Barrier Rail and Guide Post” of the *Standard Specifications*.

The Contract Plans Section is responsible for numbering and naming the various items used in construction. Contact the Contract Plans Section or the Contractors System link on the MDT web site to obtain a copy of the official item list. Only use the official name and description in contract plans. Submit all proposed changes or additions to this list to the Contract Plans Section.

Item	Measured Unit	Rounding Criteria
GRADING FRAME		
Unclassified Excavation Embankment + Embankment in Place Borrow Roadway Compaction	cubic yard, cy cubic meter, m^3	1
ADDITIONAL GRADING FRAME		
Excavation Embankment + Embankment in Place Additional Excavation Additional Embankment in Place	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
SUBEXCAVATION FRAME		
Subexcavation Special Borrow	cubic yard, cy cubic meter, m^3	1
DIGOUTS FRAME		
Digout Excavation Special Borrow	cubic yard, cy cubic meter, m^3	1
MUCK EXCAVATION FRAME		
Muck Excavation Special Borrow	cubic yard, cy cubic meter, m^3	1
CLEARING and GRUBBING FRAME		
Clearing and Grubbing	Acre (hectare, ha)	0.1
REMOVE STRUCTURES FRAME		
Structures	Lump Sum	1
OBLITERATE ROADWAY FRAME		
Stations	number of 100 ft (m) stations	1
EQUIPMENT and ROAD LEVELER OPERATIONS FRAME		
Dozer Motor Grader Road Leveler	Hour, hr	1
DETOUR FRAME		
Construct, Maintain and Remove	Lump Sum	1

SUMMARY FRAMES ROUNDING CRITERIA

Figure 5.1A

Item	Measured Unit	Rounding Criteria
CULVERT FRAME (Option, No Option and Approach)		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Relay Pipe	foot, ft (meter, m)	2 (0.5)
Culvert Excavation (for estimating purposes – not a pay item)	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1
Class "DD" Concrete Culvert Riprap	cubic yard, cy cubic meter, m^3	0.1
Height of Cover Remove Culvert	Foot, ft (meter, m)	0.1
Geotextile	square yard, sy (meter, $m^{2)}$	1
CULVERT SUMMARY RECAP FRAME		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Relay Pipe	feet,ft (meters, m)	2 (0.5)
Clean Culvert	Foot, ft (meter, m)	1
Remove Culvert	Foot, ft (meter, m)	0.1
Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1
Class "DD" Concrete Culvert Riprap	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Geotextile	square yard, sy (square meter, $m^{2)}$	1
STOCK PASS FRAME		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Plant Mix Surfacing	Ton (Metric ton, MT)	1
Crushed Top Surfacing Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
Asphalt Cement	Ton (metric ton, t)	0.1
Culvert Excavation (for estimating purposes – not a pay it em)	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Class "DD" Concrete Culvert Riprap	cubic yard, cy cubic meter, m^3	0.1
Geotextile	square yard, sy square meter, m^2	1
Height of Cover	foot, ft (meter, m)	0.1
UNDERDRAIN FRAME		
Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Filter Material	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Geotextile	square yard, sy (square meter, $m^{2)}$	1
Plastic Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
STORM DRAINS and DRAINAGE STRUCTURES FRAME		
Pipe Lengths Slotted Drain	0.1 foot increment, ft 0.1 meter increment, m	0.1 0.1
Manholes Tee Sections Drop Inlets Curb Inlets Irrigation Turnouts Adjustments	each, ea	1
Bedding Material	cubic yard, cy (cubic meter, $m^{3)}$	1
Class "DD" Concrete	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Trench Excavation (not a pay item) Culvert Excavation (not a pay item)	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Height of Cover	Foot, ft (Meter, m)	0.1
WATER VALVE BOXES FRAME		
Water Valve Box - Adjust to Grade	each, ea	1

* Where existing stationing is utilized, the dimensions may only be available to the nearest 0.1 meters.

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
EMBANKMENT PROTECTORS FRAME		
Embankment Protector – 12” (300 mm)	2 foot increment, ft 0.5 meter increment, m	2 0.5
Bituminous Curbing	foot, ft (meter, m)	0.1
Bank Protection	cubic yard, cy (cubic meter, $m^{3)}$	0.1
MANHOLE FRAMES		
Manhole - Adjust to Grade	each, ea	1
SURFACING and ADDITIONAL SURFACING FRAMES		
Distance *	Foot, ft (meter, m)	0.01
Hydrated Lime Plant Mix Surfacing Blotter	ton (metric ton, MT)	1
Cover Material	square yard, sy square meter, m^2	1
Traffic Gravel	cubic yard, cy (cubic meter, $m^{3)}$	1
Asphalt Cement Prime Dust Palliative Seal Curing Seal Portland Cement Fly Ash	ton, (metric ton, MT)	0.1
Crushed Top Surfacing Crushed Base Course Crushed Aggregate Course	cubic yard, cy or ton cubic meter, m^3 or metric ton, t	1
Tack and Aggregate Tack	gallon, gal (liter, L)	1
Cement Treated Base (preferred)	cubic yard, cy (cubic meter, m)	1
Cement Treated Base Cement Treated Pulverized Base Portland Cement Concrete Pavement	square yard, sy square meter, m^2	1
COLD MILLING FRAME		
Cold Milling	square yard, sy square meter, m^2	1

* Where existing stationing is utilized, the dimensions may only be available to the nearest 0.1’ (0.1 m).

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
FINISH GRADE CONTROL FRAME		
Course Foot (Kilometer)	foot, ft (kilometer, km)	50 feet 0.01 km
BITUMINOUS PAVEMENT REMOVAL and IN-PLACE ASPHALT PAVEMENT RECYCLING FRAMES		
Bituminous Pavement Removal Recycle Asphalt Pavement (in-place)	square yard, sy square meter, m^2	1
Recycle Agent	gallon, gal (liter, L)	1
NEW SIDEWALKFRAME		
4” (100 mm) Concrete Sidewalk 6” (150 mm) Concrete Sidewalk	square yard, sy square meter, m^2	0.1
Width	foot, ft (meter, m)	0.1
NEW CONCRETE CURB and GUTTER FRAME		
Curb and Gutter Cut-off Curb Median Curb	foot, ft meter, m	0.1
NEW MAILBOX FRAME		
Mailbox	each, ea	1
TOPSOIL FRAME & SEEDING FRAME		
Salvaging and Placing	cubic yard, cy cubic meter, m^3	1
Seed Fertilizer Condition Seedbed Mulch Revegetation	acre hectare, ha	0.1
Revegetation	Lump sum (less than 1 acre or ha)	
RANDOM RIPRAP FRAME		
Riprap	cubic yard, cy (cubic meter, m$^{3)}$	0.1
Geotextile	sq yard, sy (sq meter, m$^{2)}$	1
Revegetation	sq yard, sy (sq meter, m$^{2)}$	1
CONCRETE DRAINAGE CHUTES FRAME		
Class “AC-DC” Concrete Bank Protection	cubic yard, cy cubic meter, m^3	0.1

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
GUARDRAIL FRAME		
New Metal Guardrail Intersecting Roadway Terminal Section	12.5’ increment, ft 3.81 meter increment, m	12.5 3.81
Box Beam Guardrail	18 foot increment, ft 5.49 meter increment, m	18 5.49
Remove Guardrail Cable Guardrail	Foot, ft meter, m	0.1 0.01
Bridge Approach Section	unit	1
Optional Terminal Section Optional Box Beam Terminal Section Box Beam Terminal Section Type 2 One-Way Departure Terminal Section Cable Guardrail Terminal Section	each, ea	1
MEDIAN CONCRETE CURB FRAME		
Concrete Sidewalk (4” or 100 mm)	square yard, sy square meter, m^2	0.1
Median Curb Remove and Reset	foot, ft meter, m	0.1
FENCING FRAME		
Fence Types Temporary Fence	foot, ft (0.1 meter, m)	1’ (0.1 m)
Panels Deadman	each, ea	1
Gates	2 foot increment, ft 0.6 meter increment, m	2 0.6
CATTLE GUARD FRAME		
New Reset Remove	each, ea	1
PAVEMENT MARKING FRAME		
Paint Words and Symbols, Epoxy	gallon, gal (liter, L)	1

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
Plastic Pavement Striping	foot, ft (meter, m)	1
Words and Symbols, Plastic	square foot, sq ft square meter, m^2	0.1
Temporary Pavement Markings Epoxy Pavement Marking	mile, mi (kilometer, km)	0.1
SURVEY MONUMENTS and BOXES FRAME		
Location	each, ea	1
CONCRETE BARRIER RAIL FRAME		
Concrete Barrier Rail	Each(10’ or 3.05 m increment)	1
Impact Attenuator	each, ea.	1
PLANT-MIX LINED DITCH FRAME		
Plant-Mix Lined Ditch	foot, ft (meter, m)	0.1
RUMBLE STRIPS FRAME		
Rumble Strip	mile, mi (kilometer, km)	0.1
IRRIGATION STRUCTURES FRAME		
Class “DD” Concrete Riprap	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Concrete Ditch Liner	Foot, ft (meter, m)	0.1
Geotextile	square yard, sy square meter, m^2	1
Headgate Canal Gate Remove Irrigation Structure Check/Turnout	each, ea	1

SUMMARY FRAMES ROUNDING CRITERIA
(Continue)

Figure 5.1A

5.2 EARTHWORK COMPUTATIONS

5.2.1 Computer Computations

As stated in Section 5.1.2, most highway mainline earthwork computations are determined using the computer. Earthwork quantities for small projects, approaches, side roads, ditches and additional grading features may need to be calculated manually (see Section 5.2.2). For the computer to calculate the mainline earthwork quantities, the following information is required:

1. horizontal and vertical roadway alignments;
2. typical sections;
3. terrain data;
4. shrink and swell factors;
5. cut and fill slope rates; and
6. identification of sections not to be included (e.g., bridge sections).

The computer will provide a listing of the quantities for each station. Present these amounts on the cross sections as described in Section 4.3.11. The quantities presented in the Grading Frame are based on the stations between balance points. For information on determining balance points, see Section 5.2.4.

When using computer programs, see the instructional manuals to determine the appropriate procedures for calculating earthwork quantities.

5.2.2 Manual Computations

The following presents procedures for determining earthwork quantities manually:

1. <u>Computation Sheets</u>. Figures 5.2A through 5.2D illustrate a sample problem for manually calculating earthwork quantities on the Department's computation sheet. A blank computation sheet is provided at the end of this section. Note that the example illustrated in Figure 5.2A through 5.2D includes rock excavation which requires a swell factor to be applied to the excavated material. See Section 5.2.6 for guidance on shrink/swell factors with excavations. Complete the first five columns of the sheet (i.e., grades, vertical curve data, grade elevations, stations and distance between stations) during the process of computing grades. The remaining columns are used for documenting cross-section areas, volumes between cross sections, shrink and swell factors and mass curve data used for plotting the mass diagram. Projects requiring a mass diagram typically should be prepared using the computer. Compute quantity sections for each terrain station.

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION ______ SHEET ___ OF ___ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE FEET				VOLUME IN CUBIC YARDS									
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA			
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M	
			0+00		0		0										0	
				65.62		4306		323	5233			393			4840			
			0+65.62		4306		323										+4840	
				65.61		9419		1399	11444			1700			9744			
			1+31.23		5113		1076										+14584	
				65.62		7373		13132	8960			15958				6998		
			1+96.85		2260		12056										+7586	
				65.62		2260		24327	2746			29562				26816		2+15.41
			2+62.47		0		12271										-19230	
				65.61		538		21313	654			25895				25241		
			3+28.08		538		9042										-44471	
				65.62		1238		14532	1504			17659				16155		3+87.14
			3+93.70		700		5490										-60626	
				65.62		1884		7750	2289			9418				7129		
			4+59.32		1184		2260										-67755	
				55.77		2314		3337	2390			3445				1055		
			5+15.09		1130		1076										-68810	
				75.46		2529		1076	3534			1504			2030			59128 cyds HAULED BACK
			5+90.55		1399		0										-66780	
				65.62		6297		0	7652			0			7652			
			6+56.17		4898		0										-59128	
				131.23		17815		0	43294	20 %	51953	0		*127139	51953			
			7+87.40		12917		0										-7175	
				131.24		26049		323	63309		75971	785			75186			7+99.92
			9+18.64		13132		323										+68011	
				98.42		17761		1184	32371			2158			30213			
			10+17.06		4629		861										+98224	
				32.81		6136		2045	3728			1243			2485			
			10+49.87		1507		1184										+100709	
				65.62		1615		3337	1963			4055				2092		68011cyds HAULED AHEAD
			11+15.49		108		2153										+98617	
				65.61		216		4844	262			5885				5623		
			11+81.10		108		2691										+92994	
				65.42		2261		4898	2739			5934				3195		
			12+46.72		2153		2207										+89799	
				65.67		4952		4037	6022			4909			1113			
			13+12.39		2799		1830										+90912	
				163.99		5705		6674	17325			20268				2943		14+69.82
			14+76.38		2906		4844										+87969	
				164.04		2906		11625	8828			35314				26486		
			16+40.42		0		6781										+61483	
				164.04		0		12163	0			36948				36948		
			18+04.46		0		5382										+24535	
				164.04		0		14316	0			43489				43489		18+97.01
			19+68.50		0		8934										-18954	

* SUM OF ADJUSTED ROCK EXCAVATION

EXAMPLE EARTHWORK COMPUTATION SHEET
(First Run)

Figure 5.2A (US Customary)

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30%
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
1ST RUN-20% SWELL APPLIED FROM STA. 2+00 TO STA. 2+80 ONLY

PROJECT NO. EXAMPLE LOCATION ______ SHEET____OF____SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

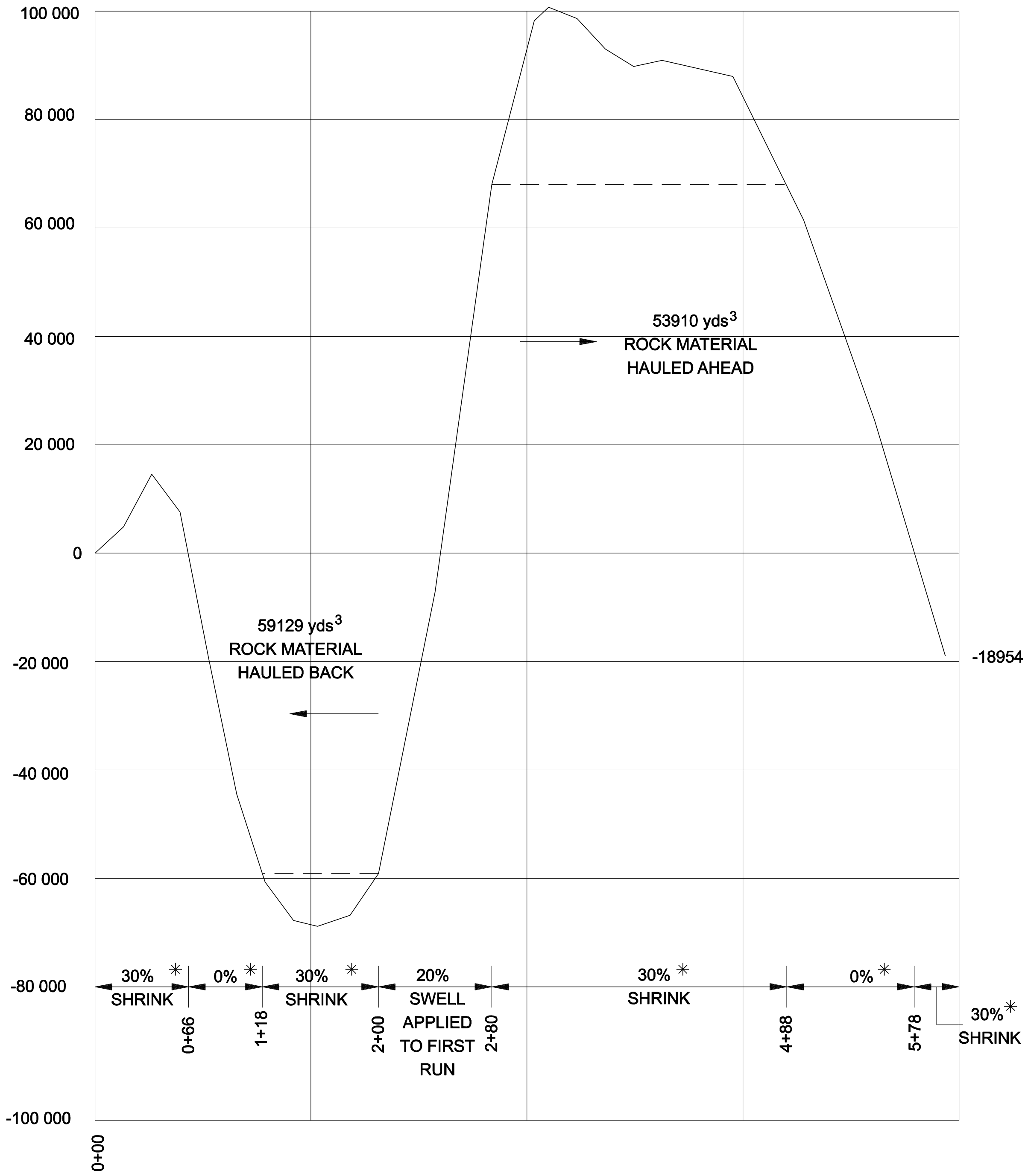
GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL -	M
			0+00		0		0										0
				20		400		30	4000			300			3700		
			+20		400		30										+3700
				20		875		130	8750			1300			7450		
			+40		475		100										+11 150
				20		685		1220	6850			12 200				5350	
			+60		210		1120										+5800
				20		210		2260	2100			22 600				20 500	
			+80		0		1140										-14 700
				20		50		1980	500			19 800				19 300	
			1+00		50		840										-34 000
				20		115		1350	1150			13 500				12 350	
			+20		65		510										-46 350
				20		175		720	1750			7200				5450	
			+40		110		210										-51 800
				17		215		310	1828			2635				807	
			+57		105		100										-52 607
				23		235		100	2703			1150			1553		
			+80		130		0										-51 054
				20		585		0	5850			0			5850		
			2+00		455		0										-45 204
				40		1655		0	33 100	20%	39 720	0		*97 200	39 720		
			+40		1200		0										-5484
				40		2420		30	48 400		58 080	600			57 480		
			+80		1220		30										+51 996
				30		1650		110	24 750			1650			23 100		
			3+10		430		80										+75 096
				10		570		190	2850			950			1900		
			+20		140		110										+76 996
				20		150		310	1500			3100				1600	
			+40		10		200										+75 396
				20		20		450	200			4500				4300	
			+60		10		250										+71 096
				20		210		455	2100			4550				2450	
			+80		200		205										+68 646
				20		460		375	4600			3750			850		
			4+00		260		170										+69 496
				50		530		620	13 250			15 500				2250	
			+50		270		450										+67 246
				50		270		1080	6750			27 000				20 250	
			5+00		0		630										+46 996
				50		0		1130	0			28 250				28 250	
			+50		0		500										+18 746
				50		0		1330	0			33 250				33 250	
			6+00		0		830										-14 504

0+66
1+18
45 204 m^3 HAULED BACK
2+44
51 996 m^3 HAULED AHEAD
4+88
5+78

* SUM OF ADJUSTED ROCK EXCAVATION

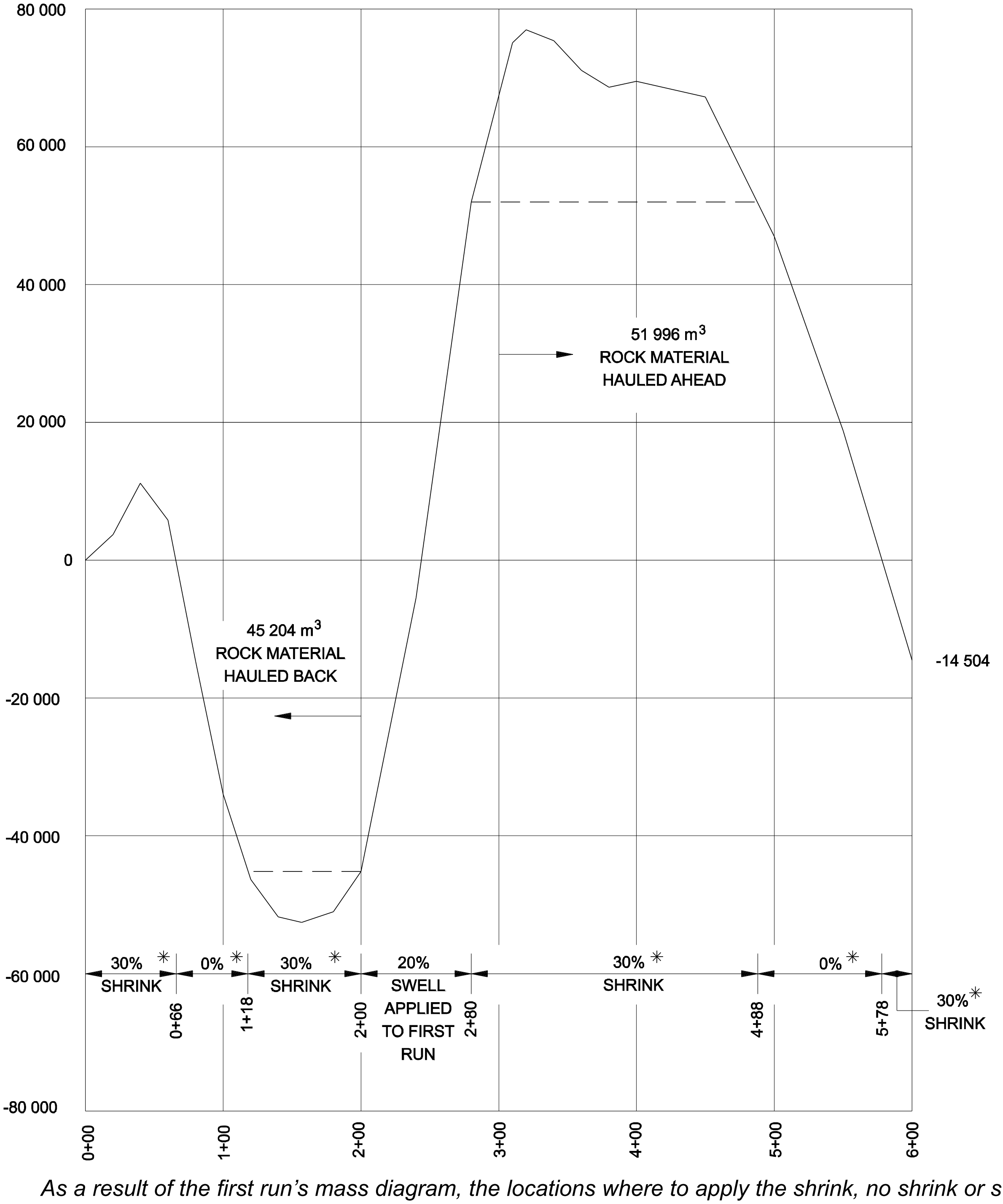
EXAMPLE EARTHWORK COMPUTATION SHEET
(First Run)

Figure 5.2A (Metric)



* As a result of the first run's mass diagram, the locations where to apply the shrink, no shrink or swell factors can be determined. Apply all shrink and swell factors to the second run.

MASS DIAGRAM
(First Run: With Only Swell Factor Applied)
Figure 5.2B (US Customary)



* *As a result of the first run's mass diagram, the locations where to apply the shrink, no shrink or swell factors can be determined. Apply all shrink and swell factors to the second run.*

MASS DIAGRAM
(First Run: With Only Swell Factor Applied)

Figure 5.2B (Metric)

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION ______ SHEET ____ OF ____ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE FEET				VOLUME IN CUBIC YARDS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M
			0+00		0		0										0
				65.62		4306		323	5233			393	30%	511	4722		
			0+65.62		4306		323										+4722
				65.61		9419		1399	11444			1700		2210	9234		
			1+31.23		5113		1076										+13956
				65.62		7373		13132	8960			15958		20745		11785	
			1+96.85		2260		12056										+2171
				65.62		2260		24327	2746			29562	0%	11529 20693		29476	
			2+62.47		0		12271										-27305
				65.61		538		21313	654			25895		25895		25241	
			3+28.08		538		9042										-52546
				65.62		1238		14532	1504			17659		15893 2296		16685	
			3+93.70		700		5490										-69231
				65.62		1884		7750	2289			9418	30%	12243		9954	
			4+59.32		1184		2260										-79185
				55.77		2314		3336	2390			3445		4479		2089	
			5+15.09		1130		1076										-81274
				75.46		2529		1076	3534			1504		1955	1579		
			5+90.55		1399		0										-79695
				65.62		6297		0	7652			0		0	7652		
			6+56.17		4898		0										-72043
				131.23		17815		0	43294	20%	51952	0	0%	0	51952		
			7+87.40		12917		0										-20091
				131.24		26049		323	63309		75971	785		785	75186		
			9+18.64		13132		323										+55095
				98.42		17761		1184	32371			2158	30%	2805	29566		
			10+17.06		4629		861										+84661
				32.81		6136		2045	3728			1243		1616	2112		
			10+49.87		1507		1184										+86773
				65.62		1615		3337	1963			4055		5272		3309	
			11+15.49		108		2153										+83464
				65.61		216		4844	262			5885		7651		7389	
			11+81.10		108		2691										+76075
				65.42		2261		4898	2739			5934		7714		4975	
			12+46.72		2153		2207										+71100
				65.62		4952		4037	6018			4906		6378		360	
			13+12.34		2799		1830										+70740
				164.04		5705		6674	17331			20274		26356		9023	
			14+76.38		2906		4844										+61717
				164.04		2906		11625	8828			35314		34889 8476		34537	
			16+40.42		0		6781										+27180
				164.04		0		12165	0			36955	0%	36955		36955	
			18+04.46		0		5382										+9768
				164.04		0		14316	0			43489		24356 24872		49228	
			19+68.50		0		8934										-59003
													30%				

2+01.68
8+22.47
17+61.09

EXAMPLE EARTHWORK COMPUTATION SHEET
(Second Run)

Figure 5.2C (US Customary)

EARTHWORK COMPUTATIONS

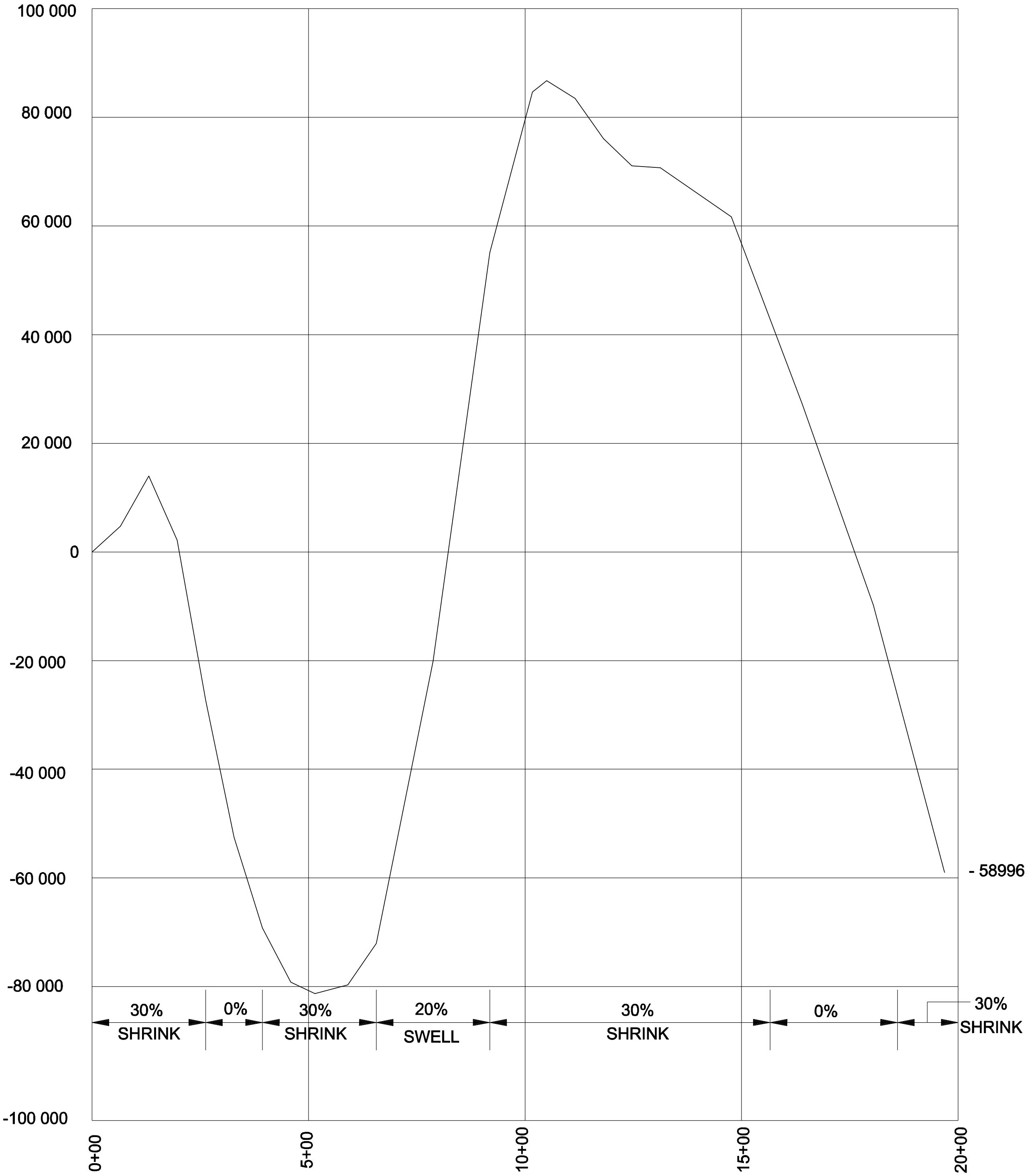
EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION ______ SHEET ______ OF ______ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS									
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA			
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M	
			0+00		0		0										0	
				20		400		30	4000			300	30%	390	3610			
			+20		400		30										+3610	
				20		875		130	8750			1300		1690	7060			
			+40		475		100										+10 670	
				20		685		1220	6850			12 200		15 860		9010		
			+60		210		1120										+1660	
				20		210		2260	2100			22 600	0%	8814 15 820		22 534		0+61
			+80		0		1140										-20 874	
				20		50		1980	500			19 800		19 800		19 300		
			1+00		50		840										-40 174	
				20		115		1350	1150			13 500		12 150 1755		12 755		
			+20		65		510										-52 929	
				20		175		720	1750			7200	30%	9360		7610		
			+40		110		210										-60 539	
				17		215		310	1828			2635		3426		1598		
			+57		105		100										-62 137	
				23		235		100	2703			1150		1495	1208			
			+80		130		0										-60 929	
				20		585		0	5850			0		0	5850			
			2+00		455		0										-55 079	
				40		1655		0	33 100	20%	39 720	0	0%	0	39 720			
			+40		1200		0										-15 359	
				40		2420		30	48 400		58 080	600		600	57 480			2+51
			+80		1220		30										+42 121	
				30		1650		110	24 750			1650	30%	2145	22 605			
			3+10		430		80										+64 726	
				10		570		190	2850			950		1235	1615			
			+20		140		110										+66 341	
				20		150		310	1500			3100		4030		2530		
			+40		10		200										+63 811	
				20		20		450	200			4500		5850		5650		
			+60		10		250										+58 161	
				20		210		455	2100			4550		5915		3815		
			+80		200		205										+54 346	
				20		460		375	4600			3750		4875		275		
			4+00		260		170										+54 071	
				50		530		620	13 250			15 500		20 150		6900		
			+50		270		450										+47 171	
				50		270		1080	6750			27 000		26 676 6480		26 406		
			5+00		0		630										+20 765	
				50		0		1130	0			28 250	0%	28 250		28 250		
			+50		0		500										-7485	
				50		0		1330	0			33 250		18 620 19 019		37 639		5+37
			6+00		0		830										-45 124	
													30%					

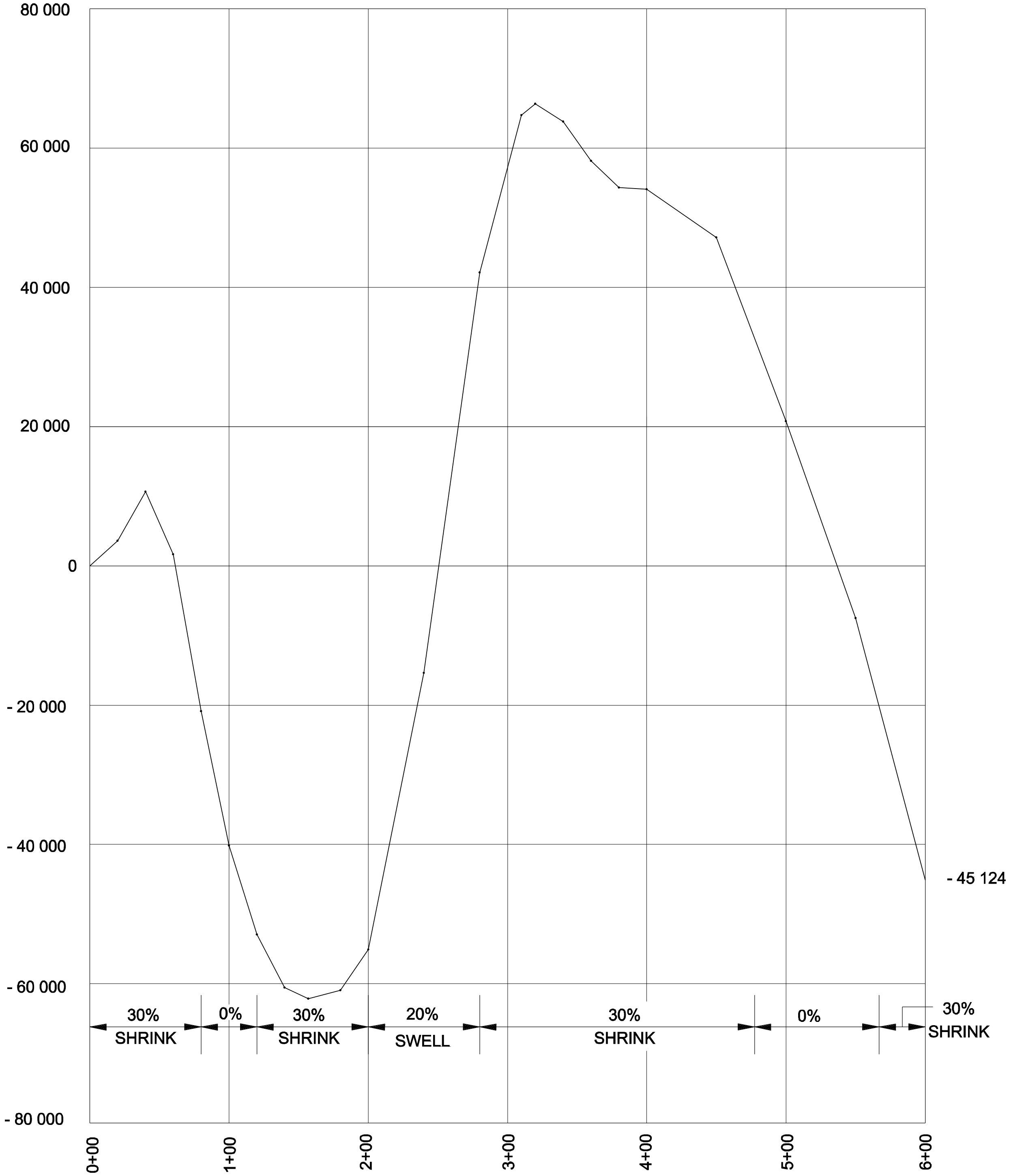
EXAMPLE EARTHWORK COMPUTATION SHEET
(Second Run)

Figure 5.2C (Metric)



MASS DIAGRAM
(Second Run: With All Shrink and Swell Factors Applied)

Figure 5.2D (US Customary)



MASS DIAGRAM
(Second Run: With All Shrink and Swell Factors Applied)

Figure 5.2D (Metric)

2. Area Definitions. The end areas that are used to compute the quantities are defined by the ground lines and typical section template (see Figure 5.2E). Where special borrow is required, compute fill areas to the bottom of the special borrow as shown in Illustration (B) of Figure 5.2E. Determine the area of cut and fill for each cross section using CADD. Record the cut and fill areas for each cross section in the "AREA" column of the Computation Sheet. The "DOUBLE AREA" column shows the sum of adjacent cross-section areas.

3. Volume Computations. Determine volumes for excavation and embankment using the average-end-area formula:

US Customary

$$V = \frac{A_1 + A_2}{2} x \frac{D}{27}$$

Metric

$$V = \frac{A_1 + A_2}{2} xD \qquad \text{(Equation 5.2-1)}$$

Where:

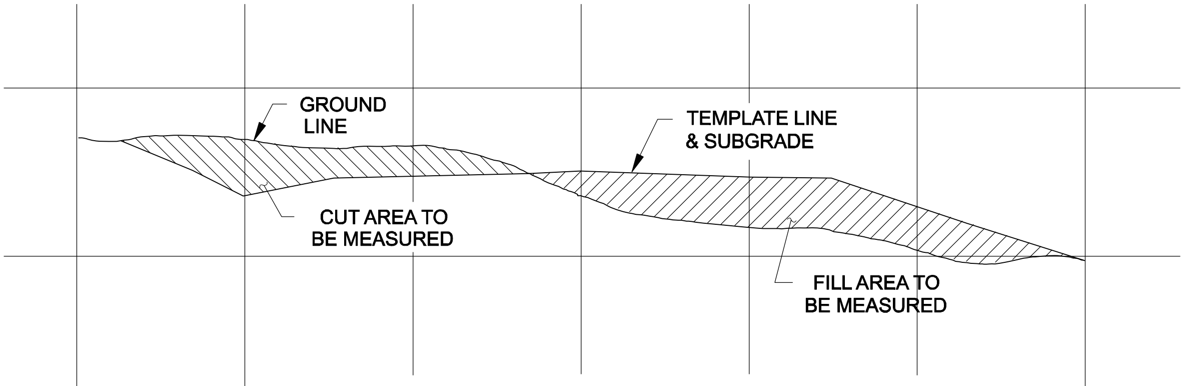
V = volume, yd^3 (m^3)

$A_1 + A_2$ = sum of cut or fill end areas of adjacent sections (Double Area), ft^2 (m^2)

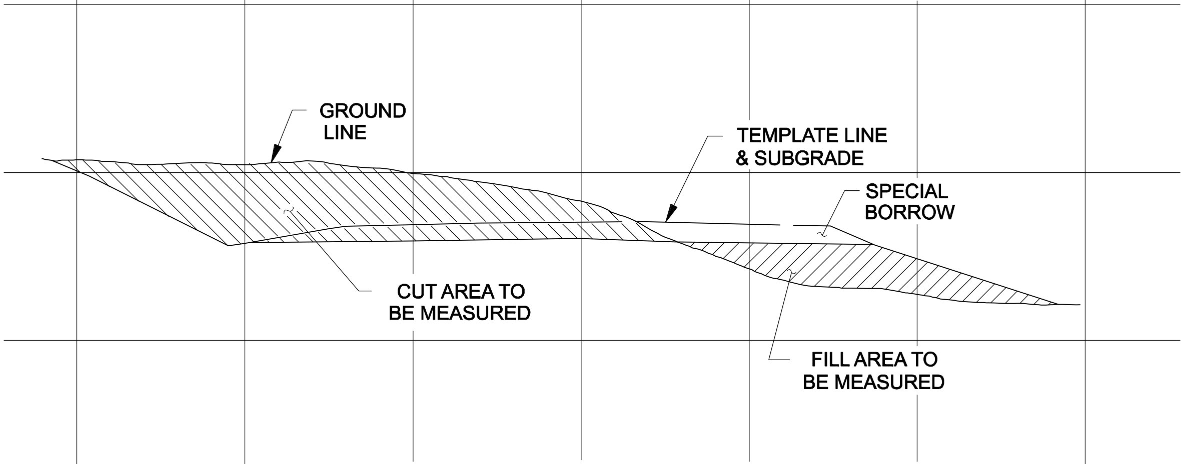
D = distance between sections, ft (m)

Record these values in the appropriate excavation or embankment "ACTUAL" columns on the Computation Sheet. The "EMB +" column provides the embankment quantity multiplied by the appropriate shrink factor(s). Enter the difference between the "EMB +" and "ACTUAL" Excavation columns in either the "CUT +" or "FILL -" columns for Mass Curve Data. If the "EMB +" is greater than the "ACTUAL" excavation volume, enter the difference in the "FILL -" column. If the "ACTUAL" excavation volume is greater than the "EMB +" volume, enter the difference in the "CUT +" column. The "ADJ. EXC." column is the excavation column multiplied by the appropriate swell factor(s). Enter the difference between the "ADJ. EXC." and the "ACTUAL" embankment in the Mass Curve Data in either the "CUT +" column, if excavation is greater, or in the "FILL -" column, if embankment is greater.

The shrink and swell factor used should be recorded on the computation sheet. Total volumes for the sheet should be shown on the bottom of each Computation Sheet.



(A) SECTION WITHOUT SPECIAL BORROW



(B) SECTION WITH SPECIAL BORROW

AREA DEFINITIONS

Figure 5.2E

5.2.3 Shrink and Swell Factors

Adjust excavation and/or embankment quantities, calculated either manually or by the computer, by the appropriate shrink and/or swell factor(s). The use of more than one factor for a project is often necessary to describe the characteristics of the excavated material. However, do not apply both shrink and swell factors to the same material. The factors used in the calculations will depend on the soil type, quantity to be moved and judgment. The applicable factors to be used in the calculations are provided by the District. Also present these factors on the mass diagram.

5.2.4 Balancing

For most large projects, it is highly desirable to provide an earthwork balance for the project (i.e., excavation equals adjusted embankment quantities). However, due to the degree of accuracy of shrink/swell factors and the nature of grading work, do not make an extensive effort to produce an exact zero earthwork balance. Typically, a project is considered balanced if the borrow/excess quantity is within 3% of the total excavation quantity. If the earthwork is balanced within 3%, show the borrow or excess quantity with an asterisk (*) and a note stating "Not a bid item - for informational purposes only." A small amount of excess is preferred over a small amount of borrow on a project because, in most cases, a disposal site for a small excess quantity can be easily found. A small amount of borrow will likely be bid at an inflated price. Unbalanced projects will require the contractor to haul extra material (e.g., borrow) or remove excess material (e.g., excavation) from the project, which will typically increase construction costs. Balancing within the project limits can be accomplished by revising the profile grade line, revising cut and fill slopes, daylighting sections, revising ditch profiles, etc. To determine if balancing is appropriate for a project, consider the following guidelines:

1. New Construction/Reconstruction Projects. Make every reasonable effort to balance the project.

2. Overlay and Widening Projects. Determine the need for balancing the project on a project-by-project basis.

3. Other Projects. For urban projects, interchange projects and pavement preservation projects, it is generally impractical to provide a balanced grading design. Therefore, it will not be necessary to balance earthwork quantities on these project types.

It is generally not cost effective to balance a project over long distances. On long projects, provide several intermediate balance points. Preferably, the distance between balance points should not exceed 2 miles (3 km). Hauling material across bridges to achieve a balance is undesirable.

5.2.5 Mass Diagram

On projects where the grading is bid as unclassified excavation, prepare a mass diagram to illustrate how the project will be balanced.

To better understand the application of a mass diagram, consider the following guidelines:

1. Curve. The mass diagram curve illustrates a cumulative, algebraic summation of the excavation and embankment quantities, typically from the start of the project. A rising curve in the direction of summation indicates excavation exceeds embankment, and a falling curve indicates embankment exceeds excavation. Inflection points (i.e., curve crests and sags) represent points where the net earthwork changes from a cut to a fill or vice versa. The horizontal distance on the mass diagram represents the horizontal distance on the ground in stations. The vertical distance represents the net accumulation of earthwork volume in cubic meters.

2. Balance Line. The balance line is any horizontal line which intersects the mass summary curve in at least two places. This indicates that the excavation and embankment quantities are balanced between the two intersecting points. These intersection points are called balance points. For most projects, the balance line is typically started at zero at the beginning of the project.

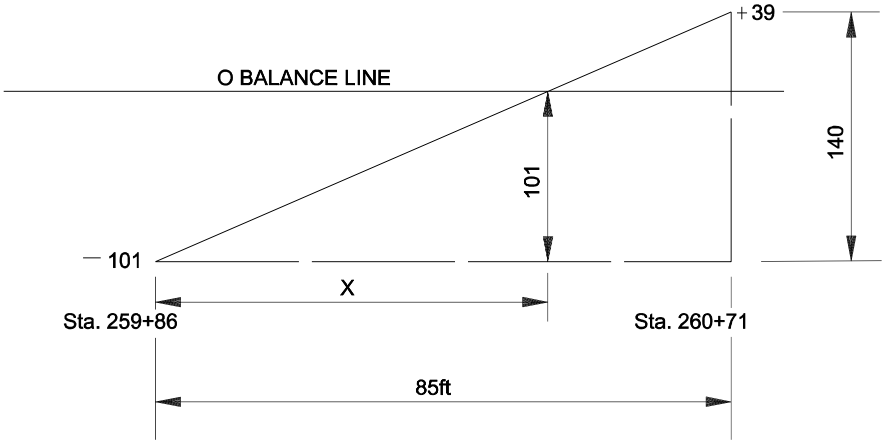
3. Balance Points. Once the grades have been finalized and the earthwork has been balanced, compute the balance points and the earthwork quantities for summarization. It is not necessary to compute earthwork quantities for each balance point. Several small balance points may be combined within distances of approximately 1000’ (300 m). Where a balance point falls between the stations listed on the computation sheet, compute the stationing using a straight-line interpolation; see Example 5.2-1. Round the stationing to the nearest meter.

4. Borrow/Excess. As stated in Section 5.2.4, long distances between balance points or over bridges are generally not cost effective. Also, it may be necessary to adjust the balance line at funding divisions to indicate the amount of material moved for the particular section. To balance a section, the balance line may need to be adjusted up or down. Downward adjustments in the balance line indicate the need for borrow, and upward adjustments indicate excess material. Note the amount of borrow or excess next to the vertical balance line. The location of the borrow pit or waste disposal location will typically be determined by the contractor.

* * * * * * * * *

Example 5.2-1

Given:



Problem: Find the stationing of the balance point between stations 259+86 and 260+71.

Solution: Use straight-line interpolation.

Stationing of Balance Point = 259+86 Plus " X " feet

$$X = \frac{101}{140} x85\,ft$$

$$X = 61\,ft$$

(round to the nearest foot)

Stationing of Balance Point = 259+86 + 61 = 260+47

* * * * * * * * * *

5. Haul. Calculate the amount of haul by determining the volume of material that will be moved from the center of the excavation to the center of the embankment between two balance points. Haul is typically calculated for informational purposes and is not a bid item. To compute haul, calculate the unit haul Mile Yards per Square Inch (m^3 • km) represented by one grid unit and divide by the actual area Square Inches (m^2) of the grid unit. This produces a ratio of unit haul per unit area Cubic Yards x Mile Yards/Square Inches (m^3 • km/m^2) at the specified scale. Multiply this ratio by the mass area Square Inches (m^2) to produce the haul Cubic Yards x Miles (m^3 • km) for that mass area as shown in Equation 5.2-1.

$$\text{Mile Yards/Square Inch (MY/IN}^2\text{)} = \frac{\text{Station/Inch x Cubic Yards/Inch}}{52.8}$$

US Customary

$$Haul = \left[\left(\frac{H.G.V.\,x\,V.G.V.}{52.8}\right) \div G.A.\right] x\ M.A.$$

Metric

$$Haul = \left[\left(\frac{H.G.V.\,x\,V.G.V.}{1000}\right) \div G.A.\right] x\ M.A.$$

(Equation 5.2-1)

Where:

$Haul$ = the amount of material moved, yds^3 • mile (m^3 • km)

$H.G.V.$ = horizontal grid value on horizontal axis of each unit of grid, Inch (m)

$V.G.V.$ = vertical grid value on vertical axis of each unit of grid, yd s^2 (m^3)

$G.A.$ = measured area of one grid unit, inch^2 (m^2)

$M.A.$ = measured area bounded by mass curve and balance line between balance points, inch^2 (m^2)

6. Quantities. Show the amount of excavation, embankment and haul on the mass diagram between each set of balance points. Also present the excavation and embankment quantities in the Grading Frame on the Summary Sheet.

5.2.6 Unclassified Excavation

The following presents the procedures for recording unclassified excavation quantities on the Grading and Additional Grading Frames:

1. Shrink/Swell Factors. Use the following procedures to adjust the excavation and embankment quantities by the appropriate shrink or swell factors:

    a. Soil. Adjust the actual embankment volumes by the appropriate shrink factor and show the results in the “EMB+” column on the Grading Frame.

    b. Rock. Depicting the adjusted excavation (swelled) volumes for rock in the mass curve provides a truer representation of the distribution of grading quantities. Computing earthwork quantities for projects having rock (swell factors) typically requires two earthwork runs. The first run is used to determine the quantity of rock excavation and the locations for applying shrink factors to embankments. For this first run, apply the appropriate swell factor to the actual excavation within the station limits of designated rock cut only. Do not apply a shrink factor to the remainder of the project. Produce a preliminary mass diagram from the first run.

From the mass diagram, determine the direction the rock material will be hauled and the locations to apply the appropriate shrink factor. In the areas where rock material will be used to construct the embankment, the actual volumes are not adjusted.

The second run will have both factors, swell in the rock cut areas and shrink in the areas of embankments not being constructed with rock. See Figures 5.2A through 5.2D for example computations and mass diagrams of rock excavation.

Output from the second run is shown in the Grading Frame. Show both the actual unclassified excavation and the adjusted unclassified excavation quantities on the Grading Frame. The total actual unclassified excavation is used for bidding purposes. The adjusted unclassified excavation is used to determine the excess or borrow quantities.

2. Additional Grading. Additional grading is the excavation and embankment required for constructing the items of work in addition to the mainline roadway template required for the project. Embankment quantities should always be included in the roadway quantities. Excavation quantities fall into two categories as follows:

    a. Suitable Material. If the material is suitable, include the quantity in the mainline roadway quantities. Material is considered suitable if it consists of an acceptable soil type and the quantity is large enough to make handling practical. Examples include approaches, widening, slope flattening, etc.

    b. Unsuitable Material. If the material is unsuitable, designate the quantity as an “ADD. EXC.” item but do not include this item in the mainline roadway quantities. Material is considered unsuitable if it consists of unacceptable soil types and/or quantities too small to make handling practical. Examples include material near inlet and outlet ditches, existing ditches graded to drain, etc.

Do not use the additional excavation item (i.e., “ADD. EXC.”) as a catch-all for late entries. This practice is a carryover from when earthwork quantities and the mass diagram were produced by hand. Revisions at that time were very time consuming. With computers and CADD, revisions to grading quantities and the mass diagram can be performed in a relatively short period of time. Items with significant volumes that are added late in the design phase require inclusion in both the mainline roadway quantities and the mass diagram to reflect the changes such quantities have on balances, haul, volumes, etc.

3. Topsoil Replacement. Topsoil replacement is the volume of embankment required to fill the void left after the topsoil has been removed. This quantity mathematically re-establishes the ground line to its original state prior to topsoil removal. Adjust topsoil replacement quantities by employing the same shrink factor used for mainline grading quantities in the area that the topsoil was removed. Include topsoil replacement in the roadway quantities for all projects. This results in representing topsoil replacement as an embankment or borrow quantity. Show the project total for topsoil replacement as an “EMB+” quantity in the “INCLUDED IN ROADWAY” column of the Additional Grading Frame.

4. Subexcavation. On reconstruction projects, subexcavation is generally a specified depth of excavation below subgrade in existing fill or natural ground. Always specify subexcavation depth from the top of the subgrade elevation unless an unusual circumstance justifies another reference. Typically, this material can be excavated using the equipment and procedures normally used for unclassified excavation. If the material is unstable, the subexcavation also includes the disposal of the material. Material is considered unstable if it contains saturated soils, mixtures of soils, and/or organic matter that is unsuitable for foundation material. Examples of unstable material include swelling clays or silty soils having low support value or subject to frost heaving.

   An unclassified excavation quantity is used to remove subexcavated material and either place it in embankments or dispose of it. If the material may be used for embankments, include the quantities in the earthwork run and denote the quantities shown in the Subexcavation Frame with an asterisk (“*”) and a note stating “Included in roadway quantities.” Record these same quantities in the “INCLUDED IN ROADWAY QUANTITIES — EXCAVATION” column of the Additional Grading Frame. If the material is to be disposed, record the quantity in the “UNCL. EXC.” column of the Subexcavation Frame only. This quantity should not be included in the Additional Grading Frame or the earthwork run.

5. Subexcavation Replacement. If subexcavation is not replaced with special material, include the adjusted quantities in the earthwork run and show these quantities in the “INCLUDED IN ROADWAY” column of the Additional Grading Frame. If a special material is provided, show the actual quantity as special borrow in the Subexcavation Frame.

6. Roadbed Compaction. Roadbed compaction is usually not a bid item, unless otherwise determined during the plan review process. It is utilized to ensure proper embankment construction. The roadbed compaction quantity is the total volume (cubic yd or m^3) of all embankment material (e.g., roadway, approaches, berms) plus a volume determined from the project length, the subgrade width and an 8” (0.2 m) compacted depth either of natural ground, in fill sections, or of

subgrade in cut sections. If required as a bid item, calculate roadbed compaction as follows:

US Customary	Metric
$C = \underline{(W \times L \times D/12)/27} + EMB+$	$C = (W \times L \times D) + EMB+$

Where:

W = Width of subgrade, ft (m)

L = Length of project, ft (m)

D = Compacted depth = 8” (0.2 m)

C = Roadbed compaction, cubic yd (m^3)

EMB+ = Adjusted quantity of material placed in the roadway, cubic yd (m^3). If the subgrade width varies, compute quantities for each width. Show the total quantity on the Grading Frame.

5.2.7 Embankment-in-Place Projects

Only use the embankment-in-place item on projects with embankment quantities less than 25,000 cubic yd (20 000 m^3) and where embankment exceeds excavation. For all other projects, designate the grading quantities as unclassified excavation. The following presents the procedures for recording the embankment-in-place quantities in the Grading and Additional Grading Frames:

1. Shrink/Swell Factors. Do not adjust the excavation or embankment quantities with shrink or swell factors.

2. Additional Grading Frame. Show both the embankment and excavation of suitable material quantities in the Additional Grading Frame. Suitable material is defined in Section 5.2.6, Item 2. Add the totals from the Additional Grading Frame to the Grading Frame.

3. Minor Excavation. Additional grading items consisting of small excavation quantities and/or excavation of unsuitable material will be paid as embankment in place. Unsuitable material is defined in Section 5.2.6, Item 2. Show these excavation quantities in the “ADD. EMB. IN PLACE” column of the Additional Grading frame and total. This quantity is not used to determine the amount of borrow required for the project.

4. Topsoil Replacement. Show the project total for topsoil replacement as an "EMB. IN PLACE" quantity in the Grading Frame. However, it should not be adjusted for shrinkage.

5. Subexcavation. An embankment-in-place quantity reflects the removal of subexcavated material that is either placed in embankments or disposed of. Show the quantity as a line item in the Grading Frame. Denote the total of the Subexcavation Frame with an asterisk ("*") and a note stating "Included in the Grading Frame."

6. Subexcavation Replacement. If subexcavation is not replaced with special material, an embankment-in-place quantity is required to replace the subexcavated material. Denote the total of the Subexcavation Frame with an asterisk ("*") and a note stating "Included in the Grading Frame," and show the quantity as a line item in the Grading Frame. If a special material is required, show the actual quantity as a special borrow item in the Subexcavation Frame.

7. Mass Diagram. A mass diagram is not required for embankment-in-place projects.

8. Roadbed Compaction. Roadbed compaction is not a bid item for embankment-in-place projects.

5.2.8 Miscellaneous Considerations

In addition to the above, consider the following when determining earthwork quantities:

1. Street Excavation. Street excavation is typically used on urban projects and consists of the excavation and removal of all material within the specified template. Street excavation should be utilized when the designer anticipates that material is present that is not normally encountered in typical unclassified excavation (e.g. abandoned pipe, old foundations).

2. Digout Excavation. The District Office and the Geotechnical Section are responsible for determining the need for and location of digouts. The designer is responsible for incorporating their recommendations onto the plans. The excavation and disposal of existing surfacing and subgrade is measured and paid for by the cubic yard (cubic meter) of "Digout Excavation." If a special material is required for a fill portion of the digout replacement, it is measured and paid for as special borrow or as special backfill as specified by the Geotechnical Section and shown in the Digout Frame. If it is not replaced with special material, the fill is paid for as follows:

a. Unclassified Excavation Projects. For unclassified excavation projects, the replacement fill is entered as EMB+ quantity in the earthwork run and is not measured for payment. The digout replacement quantities should be shown in the Additional Grading Frame. Denote the “DIGOUT REPLACEMENT” column in the Digout Frame with an asterisk (“*”) and a note stating “Included in the roadway quantities.”

b. Embankment-in-Place Projects. For embankment-in-place projects, the replacement fill is paid for as embankment-in-place. Add a line item to the Grading Frame, and denote the DIGOUT REPLACEMENT column of the Digout Frame with an asterisk (“*”) and a note stating “Included in the Grading Frame.”

Surfacing is normally replaced with new surfacing material. Include these quantities in the Additional Surfacing Frame. Note that digouts are not provided on new construction/reconstruction projects. For these projects, the removal of unsuitable material below subgrade (i.e., in cut sections) and natural ground (i.e., in embankment sections) is paid for as either unclassified excavation or muck excavation, depending on the material and equipment used. Where digouts are required, include a detail showing all removal and replacement thicknesses in the plans.

3. Muck Excavation. Muck excavation is both the removal and disposal of unstable material below either the subgrade elevation, in cut sections, or the natural ground line, in embankment sections. Specify muck excavation if the unstable material cannot be excavated using the same equipment and methods as for unclassified excavation.

4. Unclassified Channel Excavation. Unclassified channel excavation is the excavation and disposal of all material for either the construction of new water courses and channels or the modification (e.g., widening, deepening, straightening) of existing channels. Unclassified channel excavation is typically specified when the excavated material is not used to construct roadway embankments.

5. Unclassified Borrow. Unclassified borrow for embankment construction is contractor furnished material excavated from outside the right-of-way or construction easement areas. Sources for this material must be approved by the Department and meet current environmental and cultural resource preservation regulations. Note that construction permits requested solely for the purpose of obtaining material to construct embankments are of questionable legality. Therefore, slope flattening beyond the right-of-way limit is not an acceptable practice for balancing a project. Show the amount of unclassified borrow in the

Grading Frame and mass diagram. It should be noted that the unclassified borrow is assumed to have the same shrink/swell factor and structural value as the unclassified excavation on the project. If the designer believes that the values for the unclassified borrow will differ significantly from the unclassified excavation, these values should be reviewed at the Alignment & Grade Review or the PIH.

6. Special Borrow. Special borrow for embankment construction is material that has a specific minimum R-value or soils-class designation. Typically, special borrow is contractor furnished material excavated from a Department-approved source outside the right-of-way or construction easement areas. Use the following guidelines where special borrow is required:

    a. Reducing Surfacing Section Thickness. To reduce a surfacing section's depth and cost, its design may be based on a minimum R-value, for the top 2' (0.6 m) of subgrade, that is higher than that of readily available material. This practice frequently requires the use of special borrow. In this case, for the top 2' (0.6 m) of subgrade, calculate the quantity of special borrow required from a Department-approved source rather than relying on a special provision to specify the material's minimum R-value or soils-class designation. The use of a special provision, in this case, generally results in a cost increase and requires the contractor to selectively grade the project to meet the requirements. Without specific guidance, the contractor will estimate the quantity and source of the special borrow material, and any uncertainties will tend to produce overly conservative estimates and higher bid prices from the contractor. If special borrow is recommended to reduce surfacing section thickness, the special borrow may be treated as either part of the surfacing section or included in the subgrade. Refer to Section 4.3.6 for guidance as to how the special borrow should be shown. Where special borrow that is used to reduce the surfacing section is included in the subgrade, it should not be shown in the profile view. For both methods of special borrow placement, ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the special borrow.

    b. Unsuitable Material Replacement. If special borrow is recommended to replace unsuitable material, do not consider it as part of the surfacing section. Designate the excavation required to remove unsuitable material below the surfacing subgrade as subexcavation. The subexcavation limits, depth and replacement material (i.e., special borrow) will be shown in a detail. The location and depth of special borrow will be designated by crosshatched areas on the profile and cross sections. The roadway template shown on the cross sections will be at the bottom of the surfacing section. Ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the surfacing section; however, do not include special borrow for subexcavation in the grading quantities or mass diagram. In addition, do not include subexcavation material in the grading quantities or mass diagram if disposed outside the roadway template.

Where special borrow is specified, verify the material's availability and cost effectiveness. The required material may not be available in close proximity to the project or may be too costly or difficult to obtain from landowners. If an excessive price for special borrow is anticipated, it may be cost effective to redesign the roadway typical section. Discuss these issues during the Plan-In-Hand meetings with District Construction, Materials and Right-of-Way personnel. The designer should also discuss with District Construction how special borrow will be measured. Special borrow is typically measured in place and no shrink factor is applied. However, district personnel may elect to measure special borrow at the source (borrow site). A shrinkage factor needs to be applied to the material when it will be measured at the pit.

7. <u>Approach Grading</u>. The approach grading will be paid the same as the mainline grading. Approach fills will utilize 6:1 slopes within the clear zone, regardless of fill height. This does not apply where the approach is shielded with guardrail. See the MDT Detailed Drawings for cut and fill slopes beyond the clear zone. The fill slopes on public approaches will at least match the existing slopes. Compute earthwork quantities for approaches consistent with Figure 5.2F. Figure 5.2G presents the end areas for standard approaches with a 34' (10.6 m) subgrade width. The procedure for using Figure 5.2F is as follows:

    a. Scale the horizontal distance from the intersection of the mainline surfacing inslope and approach subgrade ① to each break in ground line ②, ④, ⑥ and ⑦ and approach grade, clear zone ③ and cut/fill transition point ⑤ and ⑧. This distance is entered in the "STATION" column of the Earthwork Computations Form.

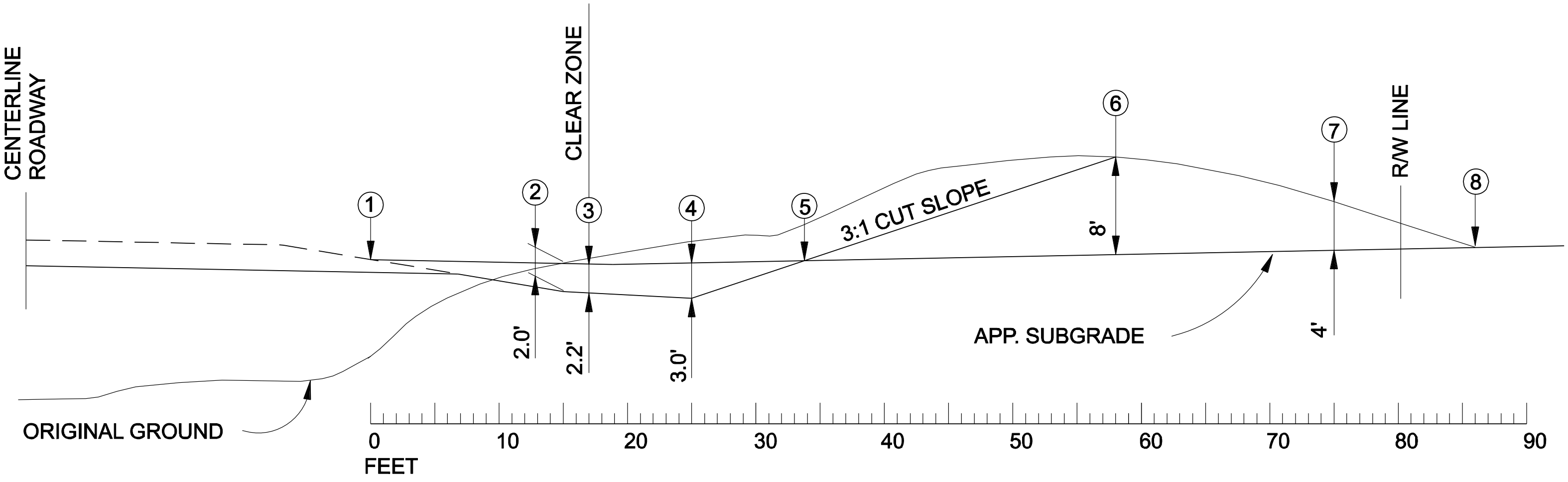
    b. Scale the vertical distance at each point determined in Step #1.

    c. Use the vertical distance to select the area from the appropriate "END AREAS FOR APPROACHES" tables in Figure 5.2G. Enter this area in the "CUT AREA" or "FILL AREA" column of the Earthwork Computations Form.

    d. Complete the Earthwork Computations Form as described in Section 5.2.2.

For approaches involving a significant realignment (e.g., button hook approaches) or change in grade, more detailed earthwork calculations may be necessary. Details that include a plan and profile should be provided for public approaches. For private or farm field approaches, show the horizontal alignment with the appropriate curve radii on the plan sheet. Also provide a profile of the approach on a detail sheet.

8. Slope Flattening Behind Guardrail. Additional embankment material and/or surfacing material is required for slope flattening behind guardrail. See the *MDT Detailed Drawings* for configuration of slope flattening. Use aggregate surfacing material for material placed above subgrade. Depending on the quantity involved, use either embankment or aggregate material for material placed below the subgrade.

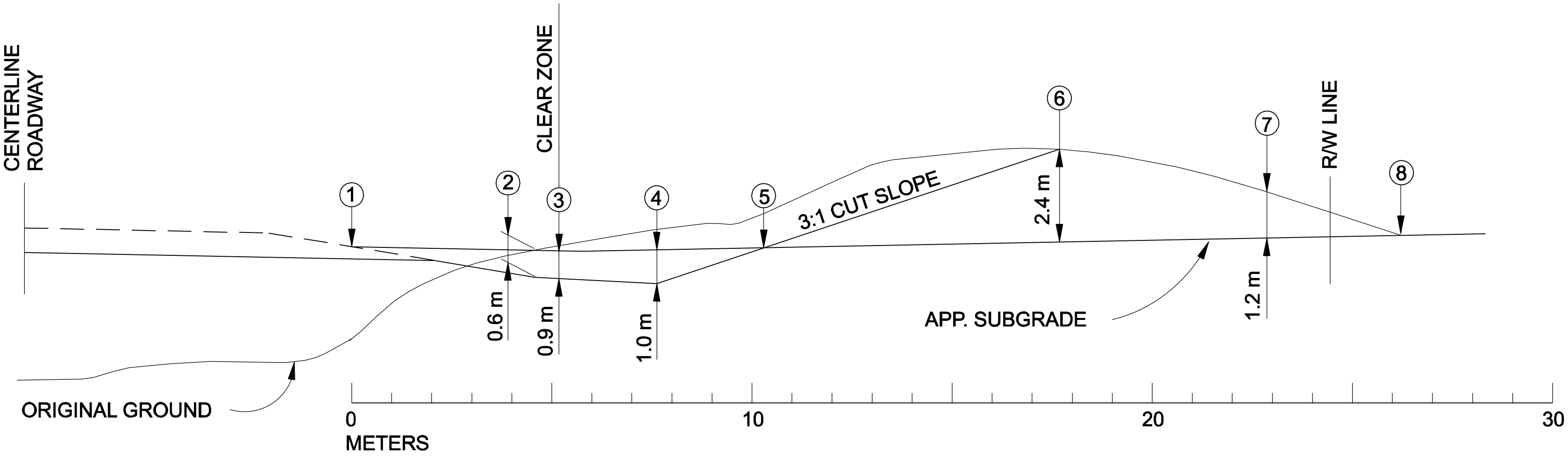


AREA VALUES FROM "END AREAS FOR APPROACHES" TABLES

STATION	DIST. (ft)	AREA IN SQUARE FT				VOLUME IN CUBIC YARDS					
		CUT		FILL		EXCAVATION			EMBANKMENT		
		AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +
① 0+00.00		0		0						35%	
	15		0		77	0			21		29
② 0+15.00		0		77							
	1.8		0		220	0			7		10
③ 0+16.8		0		143							
	8.2		0		308	0			47		63
④ 0+25.0		0		165							
	8.8		0		165	0			27		36
⑤ 0+33.8		0		0							
	24.2		528		0	237			0		0
⑥ 0+58.0		528		0							
	17.0		825		0	260			0		0
⑦ 0+75.0		297		0							
	11.0		297		0	61			0		0
⑧ 0+86.0		0		0							
				TOTAL		558					138

EARTHWORK FOR APPROACHES

Figure 5.2F (US CUSTOMARY)



AREA VALUES FROM "END AREAS FOR APPROACHES" TABLES

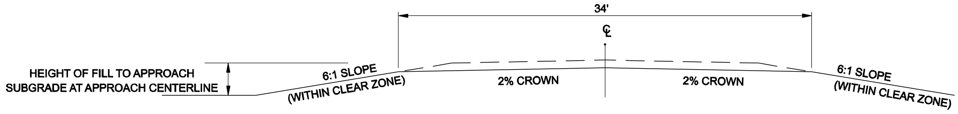
STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS					
		CUT		FILL		EXCAVATION			EMBANKMENT		
		AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +
① 0+00.00		0		0							
	4.63		0		7	0			16	35%	22
② 0+04.63		0		7							
	0.55		0		20	0			6		7
③ 0+05.18		0		13							
	2.44		0		28	0			34		46
④ 0+07.62		0		15							
	2.68		0		15	0			20		27
⑤ 0+10.30		0		0							
	7.38		48		0	177			0		0
⑥ 0+17.68		48		0							
	5.18		75		0	194			0		0
⑦ 0+22.86		27		0							
	3.34		27		0	45			0		0
⑧ 0+26.20		0		0							
				TOTAL		416					102

EARTHWORK FOR APPROACHES

Figure 5.2F (METRIC)

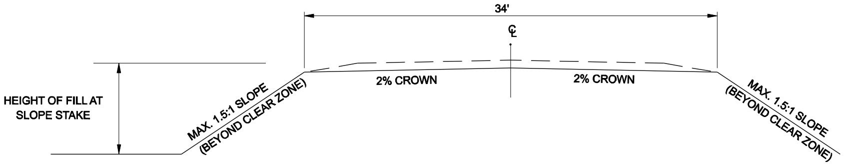
END AREAS FOR APPROACHES - WITHIN THE CLEAR ZONE

6:1 FILL SLOPE		6:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
FT	FT^2	FT	FT^2
0.5	11	5.5	341
1.0	31	6.0	390
1.5	53	6.5	443
2.0	79	7.0	498
2.5	107	7.5	557
3.0	139	8.0	618
3.5	173	8.5	683
4.0	211	9.0	750
4.5	251	9.5	821
5.0	295	10.0	894



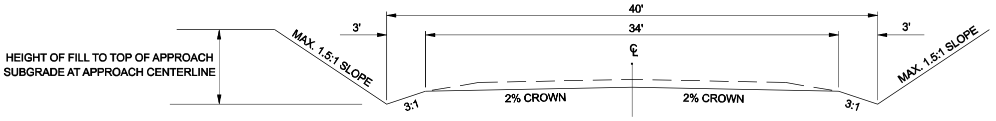
END AREAS FOR FILL APPROACHES - BEYOND THE CLEAR ZONE

4:1 FILL SLOPE		4:1 FILL SLOPE		2:1 FILL SLOPE		2:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2
0.5	11	5.5	288	10.5	558	15.5	981	20.5	1301	25.5	1811
1.0	30	6.0	326	11.0	595	16.0	1029	21.0	1348	26.0	1866
1.5	51	6.5	367	11.5	634	16.5	1078	21.5	1397	26.5	1922
2.0	73	7.0	410	12.0	674	17.0	1127	22.0	1446	27.0	1978
2.5	98	7.5	454	12.5	715	17.5	1178	22.5	1496	27.5	2036
3.0	125	8.0	501	13.0	757	1830	1230	23.0	1546	28.0	2094
3.5	153	8.5	550	13.5	800	18.5	1283	23.5	1598	28.5	2153
4.0	184	9.0	600	14.0	843	19.0	1337	24.0	1650	29.0	2212
4.5	216	9.5	653	14.5	888	19.5	1391	24.5	1703	29.5	2273
5.0	251	10.0	707	15.0	934	20.0	1447	25.0	1756	30.0	2334



END AREAS FOR CUT APPROACHES - BEYOND THE CLEAR ZONE

4:1 FILL SLOPE		2:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE	
DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA
FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2	FT	FT^2
0.5	44	5.5	324	10.5	640	15.5	1056	20.5	1546	25.5	2111
1.0	73	6.0	359	11.0	679	16.0	1102	21.0	1599	26.0	2172
1.5	103	6.5	394	11.5	718	16.5	1148	21.5	1653	26.5	2233
2.0	135	7.0	430	12.0	758	17.0	1195	22.0	1708	27.0	2296
2.5	170	7.5	467	12.5	798	17.5	1243	22.5	1763	27.5	2358
3.0	206	8.0	505	13.0	839	1830	1292	23.0	1819	28.0	2422
3.5	245	8.5	544	13.5	881	18.5	1341	23.5	1876	28.5	2486
4.0	285	9.0	585	14.0	924	19.0	1391	24.0	1934	29.0	2552
4.5	327	9.5	626	14.5	967	19.5	1442	24.5	1992	29.5	2617
5.0	372	10.0	668	15.0	1011	20.0	1494	25.0	2051	30.0	2684

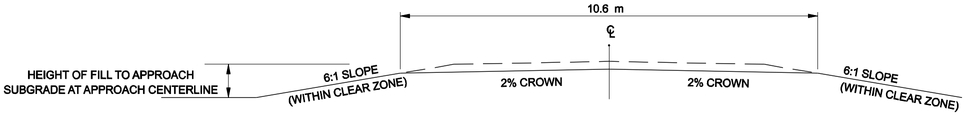


APPROACH GRADING QUANTITIES
Figure 5.2G (US CUSTOMARY)

END AREAS FOR APPROACHES - WITHIN THE CLEAR ZONE

6:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
0.2	2
0.4	4
0.6	7
0.8	11
1.0	15
1.2	19
1.4	24
1.6	30
1.8	36
2.0	42

6:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
2.2	49
2.4	56
2.6	64
2.8	73
3.0	81



END AREAS FOR FILL APPROACHES - BEYOND THE CLEAR ZONE

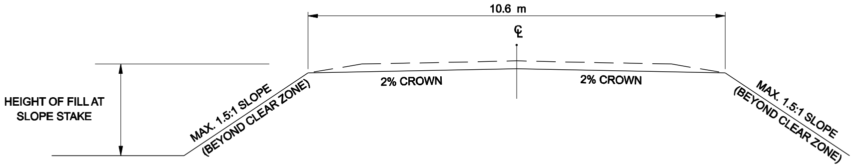
4:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
0.2	2
0.4	4
0.6	7
0.8	10
1.0	13
1.2	17
1.4	21
1.6	25
1.8	30
2.0	35

4:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
2.2	40
2.4	46
2.6	52
2.8	58
3.0	65
2:1 3.2	53
3.4	57
3.6	62
3.8	67
4.0	72

2:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
4.2	77
4.4	83
4.6	89
4.8	94
5.0	100
5.2	106
5.4	113
5.6	119
5.8	126
6.0	133

1.5:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
6.2	121
6.4	127
6.6	133
6.8	139
7.0	145
7.2	151
7.4	158
7.6	164
7.8	171
8.0	177

1.5:1 FILL SLOPE	
HEIGHT OF FILL	AREA
m	m²
8.2	185
8.4	192
8.6	199
8.8	206
9.0	213
9.2	221
9.4	229
9.6	236
9.8	244
10.0	252



END AREAS FOR CUT APPROACHES - BEYOND THE CLEAR ZONE

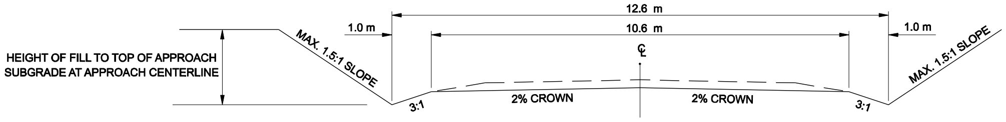
4:1 CUT SLOPE	
DEPTH OF CUT	AREA
m	m²
0.2	5
0.4	9
0.6	13
0.8	17
1.0	22
1.2	27
1.4	32
2:1 1.6	30
1.8	34
2.0	38

2:1 CUT SLOPE	
DEPTH OF CUT	AREA
m	m²
2.2	43
2.4	47
2.6	52
2.8	57
3.0	63
1.5:1 3.2	61
3.4	66
3.6	71
3.8	76
4.0	81

1.5:1 CUT SLOPE	
DEPTH OF CUT	AREA
m	m²
4.2	86
4.4	92
4.6	97
4.8	103
5.0	108
5.2	114
5.4	120
5.6	126
5.8	133
6.0	139

1.5:1 CUT SLOPE	
DEPTH OF CUT	AREA
m	m²
6.2	145
6.4	152
6.6	159
6.8	165
7.0	172
7.2	179
7.4	187
7.6	194
7.8	201
8.0	209

1.5:1 CUT SLOPE	
DEPTH OF CUT	AREA
m	m²
8.2	216
8.4	224
8.6	232
8.8	240
9.0	248
9.2	256
9.4	265
9.6	273
9.8	282
10.0	291



APPROACH GRADING QUANTITIES

Figure 5.2G (METRIC)

EARTHWORK COMPUTATIONS

PROJECT NO. ______________________ LOCATION ______________________ SHEET _____ OF _____ SHEETS

DESIGNER ______________________ DESIGN DATE __________ CHECK DATE __________

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M

EARTHWORK COMPUTATIONS

PROJECT NO. ____________ LOCATION ____________ SHEET ______ OF ______ SHEETS

DESIGNER ____________ DESIGN DATE ____________ CHECK DATE ____________

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M

5.3 DRAINAGE COMPUTATIONS

Chapter Seventeen presents the criteria for determining quantities for pipes, culverts, culvert ends, bedding material, riprap, irrigation facilities, storm drains and other drainage items. In addition, the designer should note the following:

1. Pipe Sizes. The following will apply:

    a. New. Pipe sizes for new installations are hard converted (e.g., a 914 mm CSP is noted as a 900 mm CSP). See Chapter Seventeen for the applicable US Customary and metric pipe sizes.

    b. Existing. When converting from US Customary to metric dimensions for existing pipe installations, soft convert and round the pipe diameter to the nearest millimeter. For example, a 36” CSP is converted to 914.4 mm and rounded to 914 mm.

       When converting from metric to US Customary dimensions for existing pipe installations it should be noted that metric steel pipe is the actual metric dimension while reinforced concrete pipe is a hard-converted US Customary dimension (i.e. a 900 mm CSP has an inside diameter = 900 mm while a 900 mm RCP has an inside diameter = 914 mm). Consequently, for existing metric CSP, soft convert and round the pipe size to the nearest 0.1”. For example, a 900 mm CSP is converted to 35.43” and rounded to 35.4” and a 900 mm RCP is converted directly to 36”.

2. Rounding. Round pipe lengths up to the nearest 2-foot (0.5 m) increment. Culvert excavation quantities should be rounded in 5 cubic yd (m^3) increments, with a minimum quantity of 5 cubic yd (m^3). Report pipe locations to the nearest whole foot (meter) station.

3. Optional Pipe. On all projects where optional material for mainline culverts is appropriate, specify concrete, steel and aluminum options for each culvert installation, unless otherwise recommended for an individual installation. Plastic options may be included for approach pipes. Where optional pipe material is used, list the approach pipes in a separate summary. Indicate the size and thickness or class of each pipe indicated, including the type of coating required. Irrigation or siphon should be noted, if applicable. Specify the standard corrugation sizes for steel and aluminum pipes and note any exceptions. For each option, compute and report separate quantities for bedding, foundation material, concrete, riprap and geotextile material. Information on culvert size and any special requirements for thickness, class and/or corrugation size will be

furnished by the Hydraulics Section for any culvert larger than 24” (600 mm) on the mainline and 18” (450 mm) on the approaches.

4. <u>End Sections</u>. List the appropriate end section only if a new one is required. If the end section is left in place or relayed, leave the “End Section” column in the Culvert Summary blank.

5. <u>Basic Bid</u>. When concrete is an option, the basic bid culvert is always concrete pipe. Therefore, the size, quantity, length, etc., for the culvert is the same as that for concrete pipe, even though these characteristics may differ for pipe options (e.g., metal pipe). If concrete pipe is not an option, the basic bid item for culvert is the quantity of steel pipe. If only one type of culvert is specified, the basic bid item is the quantity of that particular pipe.

6. <u>Culvert Recap Frame</u>. Summarize the basic bid items of the Culvert Summary Frame in the Culvert Recap Frame and present the total length of each pipe size and the total quantities for bedding material, concrete, foundation material, relay pipe, geotextile, remove pipe and riprap. List irrigation pipe and siphons separately from drainage pipe in the recap. Reference the pipe material, if only one culvert option is specified.

7. <u>Non-Optional Pipe</u>. On projects where optional culvert material is inappropriate (i.e., the type of material is specified), the Culvert Frame (No Option) may be used. Use this frame only if pipe options are not given on the project (e.g., an overlay and widening project where existing culverts are only being lengthened). If both optional and non-optional pipes exist in the project, use the Culvert Frame (Option).

8. <u>Storm Drains</u>. For most projects, the option bid provision will not apply to storm drain installations. Storm drain designs will be prepared by the Hydraulics Section. Except for minor installations, use the Storm Drain Frame to record quantities for storm drain culverts and appurtenant items. Where options are proposed, the Hydraulics Section will provide the recommendations for storm drain installation. Include this information in the summaries and indicate the optional sizes and material types. Where optional materials are specified, determine the basic bid item in the same manner as for culverts.

9. <u>Water Mains</u>. Present water mains in a separate frame from storm drains because they are normally funded separately and include items not applicable to storm drains.

10. <u>Existing Culverts</u>. List the size, length and type of pipe for all culverts to be removed. Designate existing pipe size with the culvert’s true cross-sectional dimensions (e.g., 24” CSP = 610 mm CSP). Culvert removal will be paid by the

linear foot (meter) pipe removed regardless of pipe size. Relaying of culverts is measured and paid per length of culvert. Include the necessary excavation to remove the culvert prior to relaying for information purposes only. Lengthening existing culverts is measured and paid per length of new pipe including associated excavation. See Sections 17.1.11, 17.1.12 and 17.7.1 for criteria on culvert excavation and extension.

11. Culvert Excavation. Culvert excavation is not measured for payment. The quantity of culvert excavation is shown for informational purposes. This work consists of excavation for culvert placement, removal or other installations as shown on the plans. It includes foundation preparation, backfilling and disposal of excavated material. For culvert excavation, use the volume bounded by the bottom elevation of the **bottom of the culvert**, the vertical planes 1’ (0.3 m) outside the inside wall of the pipe, and the vertical planes 1’ (0.3 m) beyond the neat line of the end of the pipe or to the width of the bedding/foundation material, whichever is greater. The cost of culvert excavation is included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert removal, culvert bedding and special foundations is included in the unit prices bid for those items.

12. Trench Excavation. Trench excavation is not measured for payment. The quantity of trench excavation is shown for informational purposes. Trench excavation is typically specified where vertical trench walls are necessary and the trench width is provided. Calculate the quantity of trench excavation in the same manner as described in Item 10 for culvert excavation. However, for the side walls of the trench, use the vertical planes 1.5’ (0.5 m) outside the pipe’s inside wall or to the width **and depth of the bedding/foundation material, whichever is greater.** The cost of trench excavation is included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert bedding and special foundations is included in the unit prices bid for those items

13. Riprap. The Hydraulics Section will specify both the use and dimensions of riprap for permanent erosion control in conjunction with pipe installations. Where excavation is required for riprap placement, the cost of excavation is included in the unit price bid for riprap. For riprap installations at bridges, the specifications, quantities and design data are furnished by the Bridge Bureau.

14. Clean Culverts. The FHWA has determined that there will be no federal participation on projects for cleaning culverts less than or equal to 48". Federal participation for culverts > 48" will be determined on a case-by-case basis. This also applies to off-system projects, even though MDT is not responsible for maintenance.

Consequently, do not include culvert cleaning on projects unless FHWA has determined that participation is appropriate or unless the Department has agreed to use state funds for culvert cleaning.

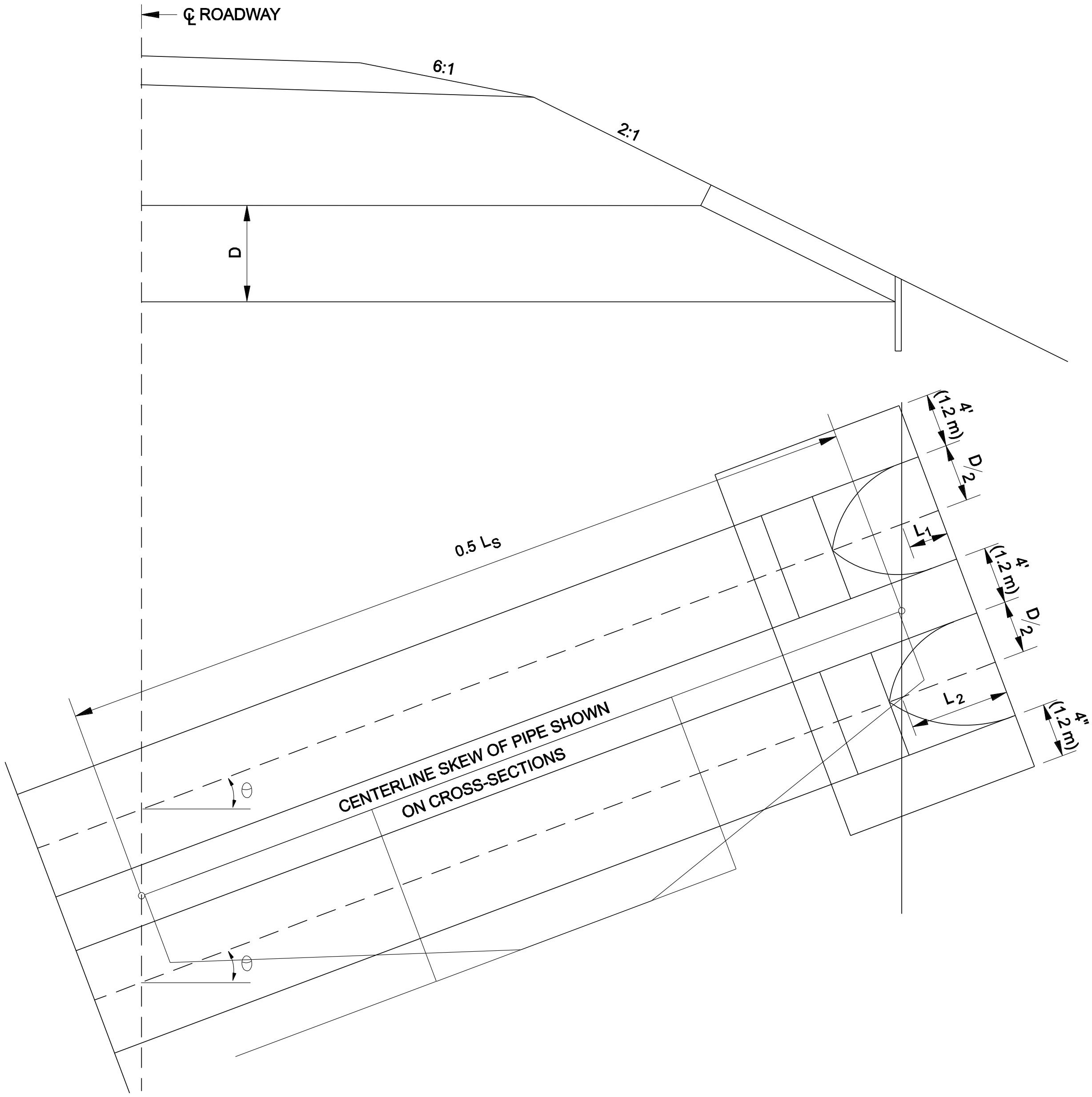
15. Pipe Length. Draw cross drains to scale at the proper flowline on the nearest template cross section. See Chapter Seventeen and the MDT Detailed Drawings for end section criteria and dimensions. If the installation is perpendicular or skewed less than 5°, then the pipe length may be scaled directly from the cross sections. Also consider the following:

    a. Do not bid FETS (Flared End Terminal Section) and RACETS (Road Approach Culvert End Treatment Section) separately. Include them in the length of pipe.

    b. Where beveled ends are used, measure the pipe length along the pipe flowline.

If the pipe is skewed more than 5°, scale its length along the skewed line (see Section 4.3.11.3).

No additional pipe length is required where skew beveled end sections are provided on a skewed pipe. However, if end sections are perpendicular to the centerline of the skewed pipe, additional pipe length is required; see L_1 and L_2 in Figure 5.3A. Calculate the total pipe length using the following equations:



SKEWED PIPE MEASUREMENTS

Figure 5.3A

a. Single Installation (see Figure 5.3A):

$$L_1 = (D + 2.4)\tan\theta$$

$$L = L_1 + L_S$$

Where:

L = total length of pipe, ft (m)
L_S = length of pipe measured on skew, ft (m)
L_1 = additional distance for both ends due to skew, ft (m)
D = diameter of pipe, ft (m)
θ = angle of skew, degrees

b. Double Installation (see Figure 5.3A):

$$L = (L_1 + L_2) + 2L_S$$

$$(L_1 + L_2) = (4D + 24)\tan\theta$$

Where:

$L_1 + L_2$ = additional distance for both ends of both pipes due to the skew

16. End Treatments. Quantities for cutoff walls, concrete edge protection and riprap for each pipe size are presented in the MDT Detailed Drawings. Adjust end treatment quantities for skew beveled end sections as follows:

$$T = \frac{Q}{\cos\theta}$$

Where:

T = adjusted quantity, cubic yd (m$^{3)}$
Q = quantity from MDT Detailed Drawings
$\cos\theta$ = angle of skew, degrees

5.4 ROADWAY COMPUTATIONS

The Pavement Analysis Section is responsible for determining the type of finished surface, pavement material type and various course thicknesses. The designer is responsible for recording this information on the construction plans and calculating the roadway quantities. Use the criteria and procedures presented in this Section to prepare the typical sections and quantities. The basis for roadway quantities is presented on the Notes Sheet.

5.4.1 Typical Section Geometrics

The following sections present recommended procedures for determining the horizontal dimensions of various surface courses. These horizontal dimensions are used for developing the surfacing quantities and for field construction staking. Surfacing thicknesses are identified on the typical sections in 0.05’ (5 mm) increments. Convert metric dimensions to meters before performing width and quantity calculations.

5.4.1.1 Symmetrical Sections

The most commonly used typical section is the 2-lane highway on a tangent alignment with normal cross slopes. In this typical Section, the dimensions of the subgrade width and intermediate surfacing courses are symmetrical about the centerline. The finished roadway width will be determined according to the criteria in Chapter Twelve or as determined during the Preliminary Field Review.

The first step is to establish the width of subgrade using the following equation:

$$W_S = W_f + \left(\frac{tZ}{1 - CZ} \right) \quad \text{(Equation 5.4-1)}$$

where:

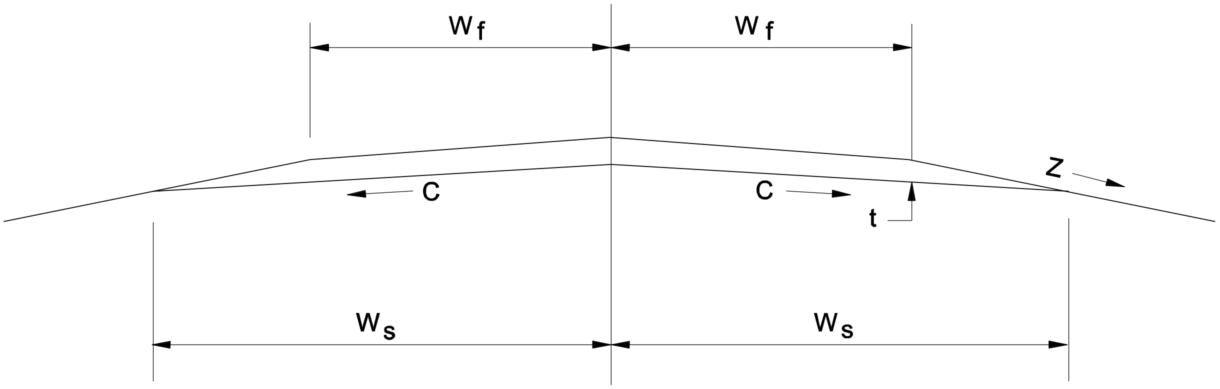
W_S = half width of subgrade, ft (m)

W_f = half width of finished grade, ft (m)

t = total surfacing thickness at finished shoulder, ft (m)

Z = numerator of side slope ratio (e.g., Z = "6" for a 6:1 side slope)

C = crown (e.g., 0.02 for 2% cross slope)



Because of the rounding process, the side slope through the surfacing courses will not be exactly 6:1, but the difference is negligible.

* * * * * * * * * *

Example 5.4-1	US Customary			Metric		
Given:	W_f	=	20’	W_f	=	6.0 m
	t	=	1.80’	t	=	0.55 m
	Z	=	6:1	Z	=	6:1
	C	=	0.02	C	=	0.02

Problem: Determine width of subgrade.

Solution: Use Equation 5.4-1 and solve for W_s.

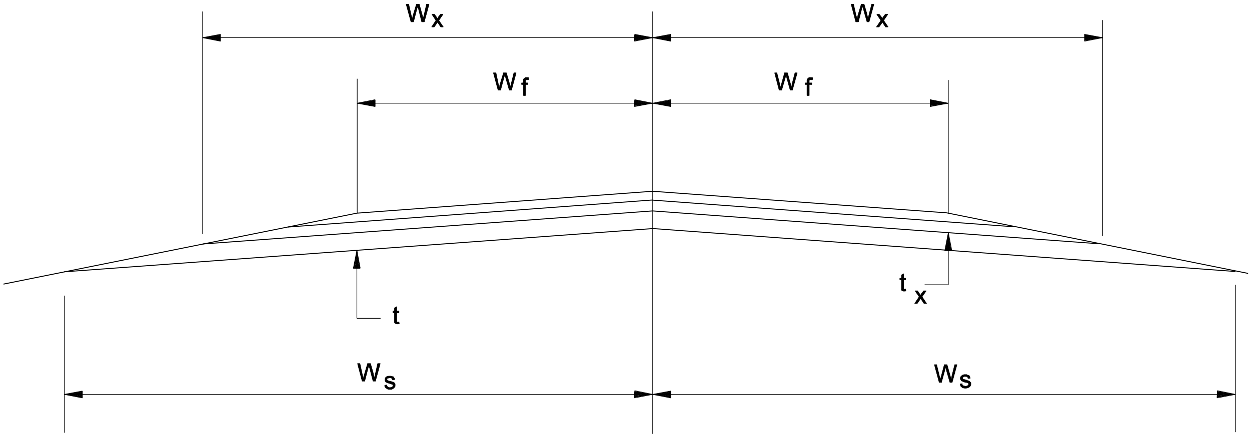
US Customary	Metric
$W_S = \frac{(1.8)(6)}{1-(0.02)(6)} + 20$	$W_S = 6.0 + \frac{0.55x6}{1-0.02x6}$
$W_S = 20 + 12.27 = 32.27'$	$W_S = 6.0 + 3.75 = 9.75\,m$
$W_S = 32.0$ (Rounded to nearest foot)	$W_S = 9.8\,m$ (Rounded to nearest 0.1 m)

* * * * * * * * * *

The second step is to establish the width of the intermediate surfacing courses. Compute each horizontal course dimension proportionately to its thickness. The width at the top of any surfacing course is determined by the following equation:

$$W_X = W_f + \left[\frac{(W_S - W_f)}{t}\right] t_X$$ (Equation 5.4-2)

where:
w_X = top width of intermediate surfacing course, ft(m)
w_f = half width of finished grade, ft(m)
w_S = half width of subgrade, ft(m)
t = total surfacing thickness at finished shoulder, ft(m)
t_X = cumulative thickness of courses above w_X at finished shoulder, ft(m)



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<u>Example 5.4-2</u> US Customary Metric

	US Customary	Metric
Given:	t_X = 0.80’	t_X = 0.25 m

Problem: Using the values given in Example 5.4-1, determine the intermediate surfacing course width.

Solution: Use Equation 5.4-2 and solve for w_X

US Customary

$$W_X = 20 + \left[\frac{(32-20)}{1.8}\right]0.80$$

$$W_X = 20 + 5.333 = 25.333'$$

$W_X = 25.3'$ (Rounded to nearest 0.1’)

Metric

$$W_X = 6.0 + \left[\frac{(9.8-6.0)}{0.55}\right]0.25$$

$$W_X = 6.0 + 1.727 = 7.727\,m$$

$W_X = 7.73\,m$ (Rounded to nearest 0.01 m)

* * * * * * * * * *

5.4.1.2 Unsymmetrical Sections

Where sections are not symmetrical about the centerline, compute and record the widths to the left and right of centerline separately. Unsymmetrical sections exist with each superelevated section and with divided highways where inside and outside shoulders have different widths. The widths for unsymmetrical sections are determined as follows:

1. <u>Superelevated Sections</u>. To compute subgrade widths for superelevated sections, use the following equations:

<u>Low Side</u>

$$W_{sl} = W_f + \frac{tZ}{1-CZ} \qquad \text{(Equation 5.4-3)}$$

<u>High Side</u>

$$W_{sh} = W_f + \frac{tZ}{1+SZ} \qquad \text{(Equation 5.4-4)}$$

where:

W_{sl} = width from centerline to edge of subgrade on low side of superelevation, ft (m)

W_{sh} = width from centerline to edge of subgrade on high side of superelevation, ft (m)

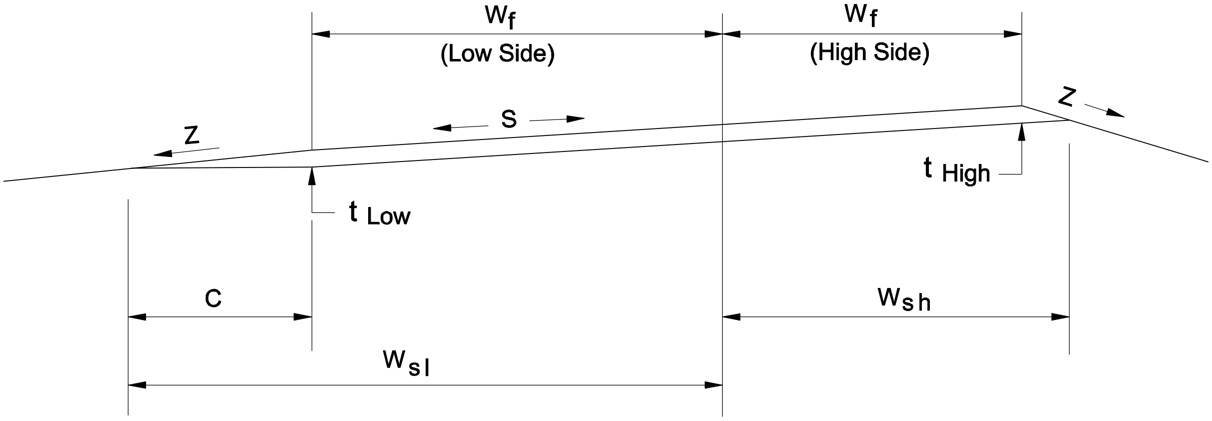
W_f = width of finished grade low or high side, ft (m)

t = total thickness of surfacing at finished shoulder, ft (m)

S = slope of superelevation (%)

Z = numerator of side slope ratio (e.g., Z = "6" for a 6:1 side slope)

C = cross slope of tangent typical



Round each computed value for W_{sl} and W_{sh} to the nearest 1' (0.1 m).

2. Divided Highways. For both tangent and curve sections of divided highways, compute the subgrade widths left and right of centerline as follows:

Tangent

$$W_S(\text{median}) = W_f(\text{median}) + \frac{tZ}{1 - CZ}$$ (Equation 5.4-5)

$$W_S(\text{outside}) = W_f(\text{outside}) + \frac{tZ}{1 - CZ}$$ (Equation 5.4-6)

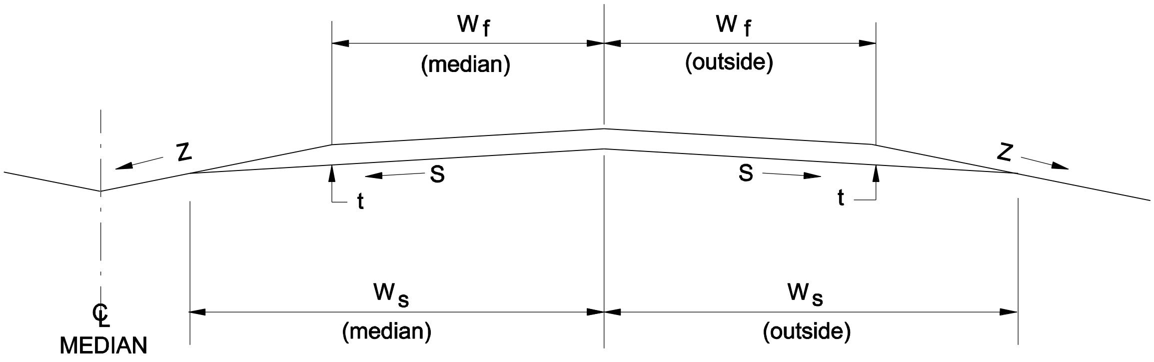
Curve

$$W_S(\textit{median high side}) = W_f(\textit{median}) + \frac{tZ}{1 + SZ}$$ (Equation 5.4-7)

$W_S(\text{outside low side}) =$ same as tangent typical section width

$$W_S(\text{outside high side}) = W_f(\text{outside}) + \frac{tZ}{1 + SZ}$$ (Equation 5.4-8)

$W_S(\text{median low side}) =$ same as tangent typical section width



Round the computed W_s (outside) to the nearest 1’ (0.1 m). Where the median is uniformly controlled, round the computed W_s (median) to the nearest 0.1’ (0.01 m). In the case of divided independent roadways, round both W_s (outside) and W_s (median) to the nearest 1’ (0.1 m).

3. Intermediate (High Side). Compute the widths of intermediate surfacing courses for unsymmetrical sections on the high side in the same manner as for symmetrical sections (i.e., proportionately to the thicknesses), except that the width should be computed and recorded separately for each side of the centerline and rounded to the nearest 0.1’ (0.01 m).

4. Intermediate (Low Side). The following example illustrates the procedure that should be used to determine the horizontal distances for the intermediate surface courses on the low side of superelevated curves:

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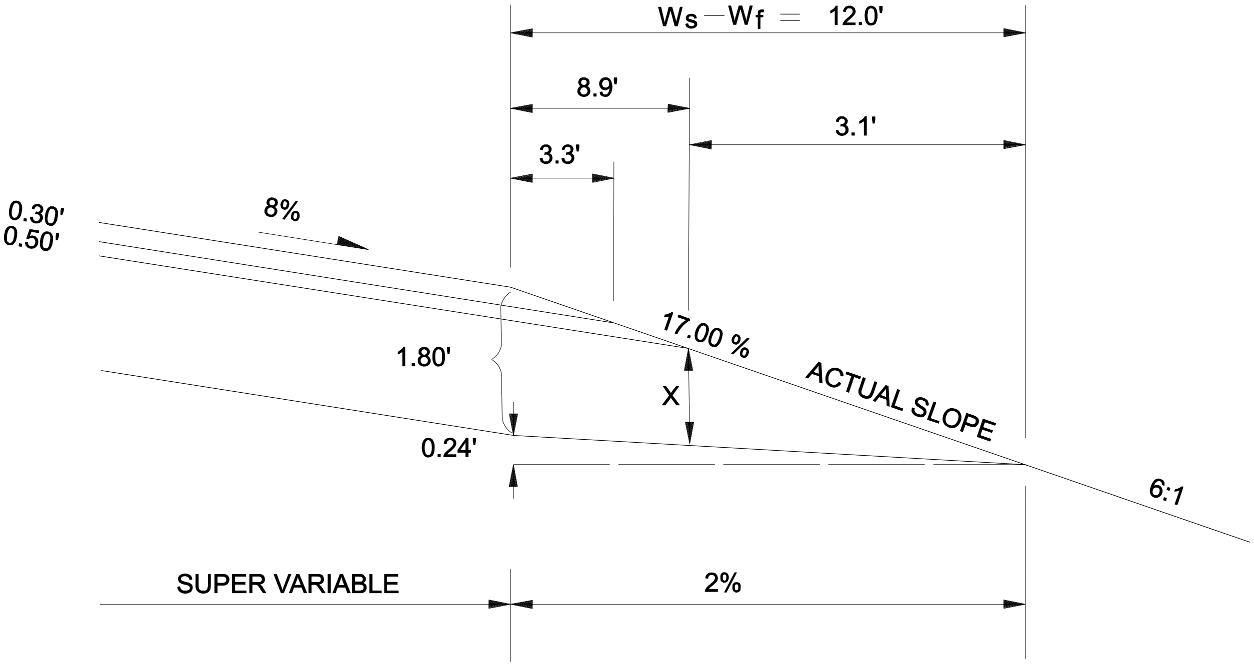
Example 5.4-3 (US Customary)



Given: t = 1.80’
t_{x1} = 0.30’
t_{x2} = 0.50’
W_S = 32.0’
W_f = 20.0’
Superelevation rate = 8%
Subgrade shoulder slope = 2%

Problem: Determine the horizontal distances for the intermediate lifts.

Solution:

1. Determine the actual slope rate.

   Subgrade shoulder width = W_S - W_f = 12.0’
   Rise of subgrade = (12.0) (0.02) = 0.24’
   Total depth = 0.24 + 1.80 = 2.04’
   Actual slope = 2.04 / 12 = 0.1700 or 17.00% (Rounded to the nearest 0.01%)

2. Determine horizontal distance for intermediate lifts.

Slope difference = (17.00 - 8.00)/100 = 0.0900

t_{x1} / slope difference = 0.30 / 0.0900 = 3.33’ ~3.3’

(t_{x1} + t_{x2}) / slope difference = 0.80/0.0900 = 8.89’ ~ 8.9’

3. Determine "x" for aggregate test (see figure above).

Slope difference = (17.00 – 2.00)/100 = 0.1500
Subbase width = 12 – 8.9 = 3.1’
x = (3.1)(0.1500) = 0.4650’

= 5.6’

Note: "x" must be at least 1.5 times the size of the aggregate. If "x" is less than 1.5 times the size of the aggregate in the first lift, then the first lift is applied parallel to the subgrade (normal crown). Subsequent lifts are applied at the superelevation rate unless "x" is less than 1.5 times the size of the aggregate for a given lift.

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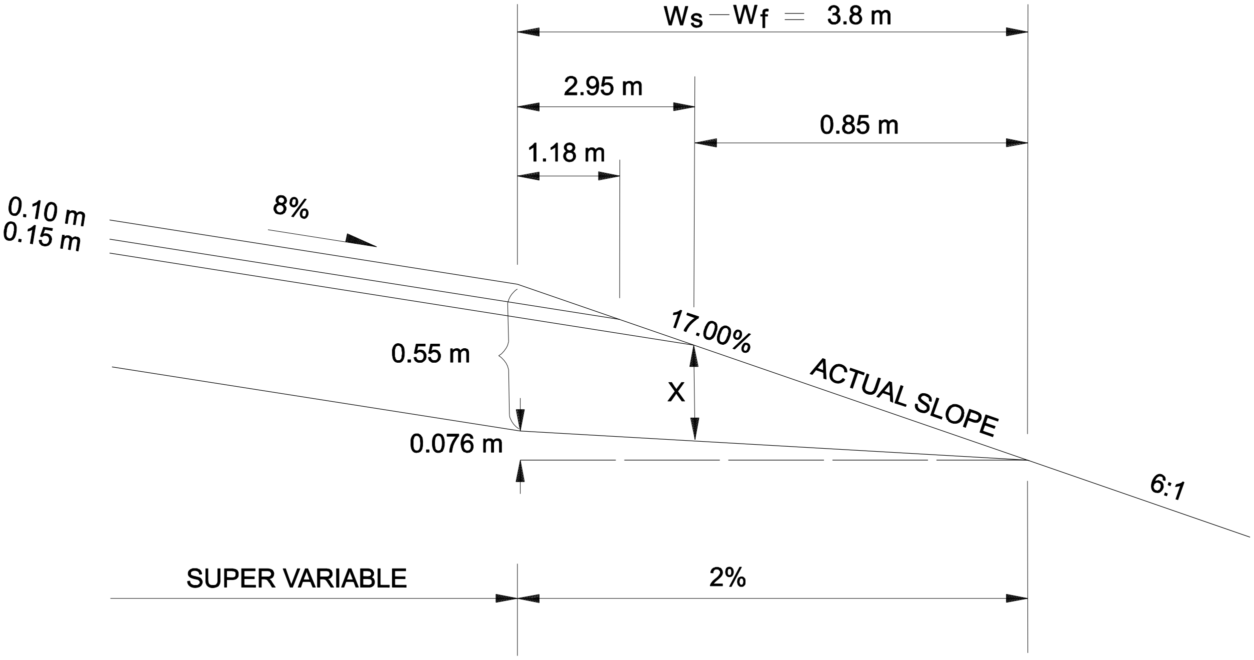
Example 5.4-3 (Metric)



Given: t = 0.55 m

t_{x1} = 0.10 m
t_{x2} = 0.15 m
W_S = 9.8 m
W_f = 6.0 m
Superelevation rate = 8%
Subgrade shoulder slope = 2%

Problem: Determine the horizontal distances for the intermediate lifts.

Solution:

4. Determine the actual slope rate.

Subgrade shoulder width = W_S - W_f = 9.8 - 6.0 = 3.8 m
Rise of subgrade = 3.8 m x 0.02 = 0.076 m
Total depth = 0.076 + 0.55 = 0.626 m
Actual slope = 0.626/3.8 = 0.1647 or 16.47% (Rounded to the nearest 0.01%)

5. Determine horizontal distance for intermediate lifts.

Slope difference = 16.47 - 8.00 = 8.47%
t_{x1} / slope difference = 0.10/0.0847 = 1.18 m
(t_{x1} + t_{x2}) / slope difference = 0.25/0.0847 = 2.95 m

6. Determine "x" for aggregate test (see figure above).

Slope difference = 16.47 - 2.00 = 14.47%
Subbase width = 3.8 - 2.95 = 0.85 m
x = 0.85 x 0.1447 = 0.123 m

Note: "x" must be at least 1.5 times the size of the aggregate. If "x" is less than 1.5 times the size of the aggregate in the first lift, then the first lift is applied parallel to the subgrade (normal crown). Subsequent lifts are applied at the superelevation rate unless "x" is less than 1.5 times the size of the aggregate for a given lift.

* * * * * * * * * *

5.4.2 Typical Section Quantities

For each typical section, determine the quantities per station for each type of surfacing material. These quantities will be used to compute the total surfacing quantities for the entire project. Use the procedures in the following sections to determine surfacing quantities and follow the rounding criteria as directed before proceeding to the next step.

5.4.2.1 Typical Sections

Provide a quantities frame for each tangent typical section. Use these frame values to estimate the surfacing quantities for each applicable section. Tangent typical sections are also used to calculate the quantities for superelevated sections that have the same finished top widths and surfacing depths. Use the criteria presented in Section 5.4.1 and Figure 5.4A to round each item in the Quantities Frame.

For widening projects, calculate the gravel quantities as though the existing surfacing is cut on a 3:1 slope from the finished surface to the top of the subgrade at a given distance from the centerline of the roadway. On the typical section, and the cross sections show the dashed slope (3:1±) and label it “Construction Slope.” The new gravel surfacing will be keyed into the existing surfacing according to the Standard Specifications.

US Customary

QUANTITIES									
Units	AGGREGATE			Units	BITUMINOUS MATERIAL			Agg. Treatment	
	Cover	Plant Mix	Crushed Agg. Course**		Asphalt Cement	Seal	Tack	Dust Palliative	Agg. Tack
Area ft^2	—	0.01	0.01	yd^2/Sta.	—	1	1	1	1
yd^3/Sta.	—	0.1	0.1	tons/Sta.	0.01	0.01	—	0.01	—
tons/Sta.	—	0.1	*0.1	Gal/Sta.	—	—	1	—	1
Yds^2/Sta	1	—	—	—	—	—	—	—	—

*The basis of payment for these items is typically paid for at the unit price bid per cubic yard.

Metric

QUANTITIES									
AGGREGATE				BITUMINOUS MATERIAL					
Units	Cover	Plant Mix	Crushed Agg. Course**	Units	Asphalt Cement	Seal	Tack	Dust Palliative	Agg. Tack
m^2	—	0.001	0.001	m^2/Sta.	—	1	1	1	1
m^3/Sta.	—	0.1	0.1	t/Sta.	0.01	0.01	—	0.01	—
t/Sta.	—	0.1	*0.1	L/Sta.	—	—	1	—	1
m^2/Sta	1	—	—	—	—	—	—	—	—

*The basis of payment for these items is typically paid for at the unit price bid per cubic meter.

** Crushed Base Course or Crushed Top Surfacing may be specified for gravel roads.

QUANTITIES FRAME ROUNDING CRITERIA
(Typical Section)

Figure 5.4A

US Customary

QUANTITIES														
AGGREGATE						Units	BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT	
UNITS	Cover	Plant Mix	Cr. Agg. Course	Cement Treated Base	Blotter		Asphalt Cement	Seal	Tack	Curing Seal	Portland Cement	Fly Ash	Dust Palliative	Agg. Tack
AREA(ft^2)	—	0.01	0.01	0.01	—	yd^2/Sta	—	1	1	1	—	—	1	1
yd^3/Sta.	—	0.1	0.1	0.1		Tons/Sta	0.01	0.01	—	0.01	0.01	0.01	0.01	—
Tons/Sta	—	0.1	0.1*	0.1	0.1	Gal/Sta	—	—	1	—	—	—	—	1
yds^2/Sta	1	—	—	—	—	—	—	—	—	—	—	—	—	—

Metric

QUANTITIES														
AGGREGATE						Units	BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT	
UNITS	Cover	Plant Mix	Cr. Agg. Course	Cement Treated Base	Blotter		Asphalt Cement	Seal	Tack	Curing Seal	Portland Cement	Fly Ash	Dust Palliative	Agg. Tack
m^2	—	0.001	0.001	0.001	—	m^2	—	1	1	1	—	—	1	1
m^3/Sta	—	0.1	0.1	0.1	—	t/Sta	0.01	0.01	—	0.01	0.01	0.01	0.01	—
t/Sta	-	0.1	0.1*	0.1	0.1	L/Sta	—	—	1	—	—	—	—	1
m^2/Sta	1	-	-	-	-	-	-	-	-	--	-	-	-	-

* The Basis of payment for these items is typically paid for at the unit price bid per cubic yard (meter).

QUANTITIES FRAME ROUNDING CRITERIA
CEMENT TREATED BASE
(Typical Section)

Figure 5.4A

5.4.2.2 Aggregate Quantities

Determine the aggregate quantities in the Quantities Frame for each typical section by using the following guidelines:

1. Aggregate Quantities. Use the following steps to determine aggregate quantities:

   a. Compute the cross-sectional end areas for each course. Round and record the computed end areas to the nearest 0.01 ft^2 (0.001 m^2). Use the rounded answer in Step 1b.

US Customary	**Metric**
End Area (ft^2) = average width x thickness	End Area (m^2) = average width x thickness

   b. Compute the cubic yards per station for each course level. Round the answer to the nearest 0.1 yd^3 (0.1 m^3).

US Customary	**Metric**
yd^3/Sta. = [End Area (ft^2) x 100]/ 27	m^3/Sta. = End Area (m^2) x 100 m

   Use the rounded answer in Step c. only if the aggregate is paid for by the cubic yard (cubic meter). If the aggregate is paid for by the ton, proceed to Step d.

   c. Compute the tons per station. Unless otherwise directed, use an aggregate mass density of 3700 lb (cu yd 2200 kg/m^3). Round the answer to the nearest 0.1 t.

US Customary	**Metric**
$t/Sta. = \frac{yd^3/Sta. \text{ x } 3700 \text{ lbs per cy}}{2000 \text{ lbs/ton}}$	t/Sta. = m^3/Sta. x 2.2 t/m^3

   d. Record the computed aggregate quantities in the "Crushed Aggregate Course " column of the Quantities Frame using the criteria illustrated in Figure 5.4A.

2. Plant-Mix Aggregate Quantities. Use the following steps to determine plant-mix quantities:

   a. Compute the cross-sectional end areas. If the plant-mix course has uniform thickness, use the same procedure as for other aggregate courses. However, if the shoulder cross slopes are steepened, special computations must be made to accommodate the variable thicknesses.

Round and record the end areas to the nearest 0.01 ft^2 (0.001 m^2) and use the rounded answer in Step 2b.

b. Compute the cubic yards (meters) per station for the plant mix. Round the answer to the nearest 0.1 yd^3 (0.1 m^3) and use the rounded answer in Step 2c.

US Customary	**Metric**
yd^3/Sta. = End Area (ft^2) x 100 ft/27	m^3/Sta. = End Area (m^2) x 100 m

c. Compute the tons per station. Unless otherwise directed, use a mass density of 3855 lb/yd^3 (2287 kg/m^3). If alternate aggregate types are used in the project, ensure that the appropriate mass density of the aggregate type is used. Round the answer to the nearest 0.1 t.

US Customary	**Metric**
t/Sta. = yd^3/Sta. x (3855/2000) t/yd^3	t/Sta. = m^3/Sta. x 2.287 t/m^3

d. Record the plant-mix aggregate quantities in the "Plant Mix" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

e. The plant mix surfacing type is selected mainly on the quantity of plant mix used on the project. The total quantity may need to be considered if projects are tied for letting. The designer should also consider the use of Grade S on smaller projects where the daily ESALs > 300. Use the following guidelines to determine the type of plant mix on projects:

US Customary

Quantity	Plant Mix Type	Lift Thickness
>2,000 t*		
	**½” Grade S	less than 0.15’
	¾” Grade S	0.15’ or greater
<2,000 t	Grade D Commercial	
	Grade B, special cases	

Metric

Quantity	Plant Mix Type	Lift Thickness
>2,000 MT*		
	**12.5 mm Grade S	less than 45 mm
	19 mm Grade S	45 mm or greater
<2,000 MT	Grade D Commercial	
	Grade B, special cases	

*When the quantity of plant mix is between 2,000 and 20,0000 tons a non-volumetric Grade S plant mix will be used . The non-volumetric Grade S will be designated by adding NV to the plant mix heading in the Surfacing and Additional Surfacing summaries.

** Use ½” (12.5 mm) aggregate only when the overlay thickness is less than 0.15’ (45 mm) and **all** of the following conditions are met:

a. The existing surface has an average rut depth of 0.20” (5 mm) or less,

b. The existing surface has an average ride value of 80 in/mile or less

c. An isolation lift is required on the project.

Use Grade B (PMS) on bike paths or other features that will not be chip sealed. Grade B should only be used when the quantities exceed 500 tons and the feature is not subject to heavy vehicle loading.

Do not use Grade C mix. Use Grade D Commercial where Grade C (PMS) was traditionally used. For Grade D Commercial, do not include a separate pay item for asphalt cement, fillers, hydrated lime, additives, dust palliative, aggregate tack, and tack for either mix. However show these quantities for informational proposes only.

f. Reclaimed Asphalt Pavement (RAP). Do not use RAP for any Grade S plant mix. Where RAP will be used, specify a Grade D RAP plant mix in the bottom lift and Grade S in the top lift. Specify a 50% RAP for the lower lifts of hot plant recycle plant-mix surfacing. A 50% RAP mix allows the use of a 30% to 50% range for reclaimed asphalt pavement. A 50% RAP mix is permitted for ramps on Interstate projects. The unit weight of the RAP is equal to the unit weight of new plant mix (3855 lb/cu yd or 2287 kg/m^3).

3. Grade S Plant Mix (Superpave). Grade S plant mix is a unique aggregate mixture that is designed for the available aggregate on each project. It is not based on gradations, but is tested for compliance with specified properties. Reclaimed Asphalt Pavement (RAP) cannot be used for Grade S plant mix.

4. Leveling & Isolation Lifts. Leveling quantities should not exceed 25% of the mainline quantity for a planned overlay. If more than 25% is required, the project is probably not a good candidate for a single-lift overlay.

   When a plant mix overlay is placed on a surface that has been crack sealed, the heat from the plant mix overlay causes the sealant to expand resulting in a bump in the riding surface. We have determined that placing an extremely thin lift of plant mix prior to placing the primary overlay will reduce the effects of the sealant on the riding surface. This application is called an isolation lift.

   The decision to use an isolation lift will be made at the Preliminary Field Review. The use of isolation lifts generally applies to pavement preservation projects, although they could be used on designed overlay projects with plant mix thicknesses less than 0.30’. Isolation lifts are not needed on projects that include milling of the travel lanes. We recommend that milling be considered as an option for treating surfaces that have extensive crack sealing.

   To ensure that adequate surfacing is provided in the plans, a minimum 0.22' overlay thickness will be required whenever an isolation lift is needed with the exception discussed on the previous page for ½” aggregate. The isolation lift is placed with a paver or other approved method to a minimum thickness of 0.07 feet and is limited to the travel lanes. Leveling used to correct distortion in the road’s surface may be placed in conjunction with the isolation lift, but this will depend on the project specific characteristics of the road surface.

   The quantity for the isolation lift is included in the overall lift thickness (i.e. a 0.22’ overlay will be shown in the typical section even though the 0.07’ isolation layer will be placed in a separate operation). Leveling used to correct distortion in the road’s surface will continue to be shown as a separate quantity in the Additional Surfacing summary.

5. Aggregate Cover Material. For seal coat operations calculate the square yards (square meters) per station and round to the nearest 1 square yard (1 square meter). Record this value in the "Cover" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

The cover material should be designated as Cover – Type I and Cover – Type II, which correspond to Grade 4A and Grade 2A aggregate respectively. Cover Type I will be used for all rural projects. Cover – Type II will be used in areas where a combination of stop/start, turning movements and higher ADT are a concern (i.e. major intersections, urban projects, interchanges). Both types of cover material could potentially be used on a project that includes both rural and urban segments. The decision to use two types of cover material on the same project -will be made by the District Construction Engineer and documented in the Scope of Work Report.

The same seal oil will be used for both types of cover material (typically CRS-2P), and the same application rate will be used.

6. Blotter. Where the cement-treated base will carry traffic during construction, use blotter material to cover the curing seal at a rate of 1.7 lbs/ft^2 (8.2 kg/m^2). To determine the quantity of blotter needed calculate the area of the CTB surface in square feet. Do not apply blotter to aggregate tack.

7. Cement-Treated Surfacing. Use the following guidelines to estimate cement-treated surfacing quantities:

   Cement-Treated Base Aggregate. Cement is added to the Cement-Treated Base (CTB) to increase the structural strength of the surfacing. The greater strength allows the use of thinner aggregate sections. The minimum thickness for CTB is 8” (200 mm). Cement-Treated Base typically extends 1.0’ (0.3 m) beyond the outside edges of the travel lanes and then on a 1:1 slope to the top of the subgrade. Estimate the cubic yards (meters) of Cement Treated Base using the average of its top and bottom width times the depth and record the computed area in the “CEMENT TREATED BASE” column of the Quantities Frame. Unless otherwise directed use an aggregate mass density of 3620 lbs per cubic yard (2148 kg per cubic meter) for CTB. Record the computed quantities in the “CEMENT TREATED BASE AGGREGATE” column of the Quantities Frame using the same rounding criteria shown in Figure 5.4A for Crushed Aggregate Course. Estimate the quantity of the cement using 5% of the computed mass of the CTB and record this amount in the “Cement” column of the Quantities Frame using the same rounding criteria shown in Figure 5.4A for Asphalt Cement. The cement is added to the CTB during the pug-milling of the aggregate. 4% Cement and 1% Fly Ash can be used in place of 5% cement.

   Cement-Treated Pulverized Base. A cement-treated pulverized base also increases the strength of the surfacing. The existing paved surface is pulverized and mixed with the existing base aggregate prior to application of the cement. The cement is added and mixed into the pulverized surface. Estimate the square meters of Cement-Treated Pulverized Base and record the total in the “CEMENT TREATED PULVERIZED BASE” column of the Quantities Frame. The depth of pulverization and the percentage of cement will be provided by the Materials Bureau. The quantity of cement will be calculated using the specified percentage and a mass density of 3620 lbs per cubic yard (2148 kg per cubic meter) for the entire pulverized section. A different mass density will not be used for the pulverized plant mix. Record the computed quantity in the “CEMENT” column of the Quantities Frame.

The Surfacing Design Section will determine the need for cement-treated and cement-stabilized bases. However, a CTB alternate should be evaluated whenever the depth of the crushed aggregate course exceeds 1.30’ (400 mm).

5.4.2.3 Bituminous Material Quantities

For estimating purposes, assume the bituminous material has a mass density of 8.5 lbs/gal (1.02 kg/L). Use the following guidelines to determine the bituminous material quantities in the Quantities Frame for each typical section:

1. Performance Graded Asphalt Cement. All grades of asphalt cement will be referred to as Performance Graded Asphalt Binders (PGAB). The PGAB will be followed by two numbers (e.g., PG 64-28). The first number is an indicator of rut resistance and the second number is an indicator of its resistance to thermal cracking at temperature extremes.

   Separate columns should be provided where more than one PGAB is used on a project.

   Where Grade S aggregate is used, estimate the quantity of asphalt cement at 5.4% for ¾” (19mm) and 5.8% for ½” (12.5mm) of the computed mass of the plant mix and round to the nearest 0.01 t/Sta. For all other aggregates and each grade of asphalt cement, including PGAB, estimate the quantity at 6.0% of the computed mass of the plant mix and round to the nearest 0.01 t/Sta. Record this value in the bituminous material "Asphalt Cement" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A

   Where Recycled Asphalt Pavement (RAP) is used, the quantity of asphalt cement is based on the percentage of RAP used in the surfacing.

   a. For 10% RAP, estimate the quantity of asphalt cement at 5.0% of the computed mass of the plant mix.

   b. For 25% RAP, estimate the quantity of asphalt cement at 4.5% of the computed mass of the plant mix.

c. For 40% RAP, estimate the quantity of asphalt cement at 3.6% of the computed mass of the plant mix.

d. For 50% RAP, estimate the quantity of asphalt cement at 3.0% of the computed mass of the plant mix.

Record this value in the bituminous material “Asphalt Cement” column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

2. Dust Pallative. Estimate dust palliative at an application rate of 0.3 gal/sq yd (1.4 L/m^2) of surface area of the top aggregate course. For computational purposes, also convert this value to (metric) tons per station assuming a unit weight of 10.8 lbs/gal (1.3 kg/L). Record both the surface area and tons per station in the bituminous material "Dust Palliative" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A

3. Tack Oil & Aggregate Tack Oil. Tack oil is no longer paid separately. Its cost is included in the cost of plant mix. A quantity will still be shown in the plans for estimating purposes. Estimate tack oil at a rate of 0.025 gal/sq yd (0.12 L/m^2) between the lifts of plant-mix material and between the plant-mix surfacing and the bituminous-stabilized base courses. Tack oil may also be applied between CTB and the plant mix surface. Although not accurate, it is acceptable to use the area at the bottom of the plant mix to estimate tack oil quantities. Record the quantities in the bituminous material "Tack" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Tack oil quantities are presented in gallons (liters).

   Aggregate Tack Oil is measured and paid separately. Apply aggregate tack at a rate of 0.05 gal/sq yd (0.23 L/m^2) between the crushed aggregate course and the first lift of plant mix. When a plant mix overlay is placed on top of PCCP apply aggregate tack on top of PCCP at a rate of 0.05 gal/sq yd (0.23 L/m^2). Record the quantities in the bituminous material "Aggregate Tack" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Tack oil quantities are presented in gallons (liters).

4. Fog Seal. Do not calculate a quantity of fog seal to be applied to the finished surface of the plant-mix surfacing including rumble strip applications unless it is specifically requested by the District. Document the request in the appropriate

report. If fog seal is requested, estimate fog seal quantities at an undiluted rate of 0.05 gal/yd^2 (0.20 L/m^2) of surface area of the plant-mix finished surface. Record the quantities in the bituminous material "FOG SEAL" column of the Quantities Frame using the rounding criteria for tack illustrated in Figure 5.4A. On the project estimate, include the fog seal quantity in the total quantity for SS-1.

5. Seal Oil. Estimate seal oil at a rate of 0.40 gal/yd^2 (1.8 L/m^2) of surface area of the plant-mix finished surface or the surface area of the top aggregate course where a double bituminous surface treatment is applied. For computational purposes, also convert this value to tons per station assuming an application rate of 0.0017 tons/yd^2 (for metric tons the conversion is 0.001 836 t/m2). Record both the surface area and the number of tons per station in the bituminous material "SEAL" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Seal and cover is typically applied to mainline travel lanes and shoulders only. Discuss the need to apply seal and cover to approaches, turnouts, etc., during the Plan-In-Hand. Typically, the Department uses cover material Grade 2A (Type II) or Grade 4A (Type I) with CRS-2P Seal.

6. Double Bituminous Surface Treatment. Use the following application rates to estimate double bituminous surface treatment quantities:

   a. Aggregate (first application) — 27.8 lb/yd^2 – ¾" stone (16.25 kg/m^2 -19 mm stone)
   b. Aggregate (second application) — 22.8 lbs/yd^2 – ½" stone (13.55 kg/m^2 - 13 mm stone)
   c. Bituminous material (first application) — 0.41 gal/yd^2 (2.05 L/m^2)
   d. Bituminous material (second application) — 0.36 gal/yd^2 (1.80 L/m$^{2)}$

7. Curing Seal. Use the following guidelines to estimate the curing seal for Cement-Treated Surfacing:

   A curing seal is typically placed on top of the CTB. Estimate curing seal at the application rate of 0.2 gal/yd^2 (0.9 L/m^2). CRS-2 oil is typically used for the curing seal. Record both the surface area and the number of tons per station in the "CURING SEAL" column of the Quantities Frame. Use the above estimating values unless otherwise specified by the Materials Bureau. Curing seal is applied to the top of the Cement-Treated Pulverized Base at the same rate as it is applied to CTB.

5.4.2.4 Portland Cement Concrete Pavement (PCCP)

Quantities

PCCP is measured by the square meter and rounded to the nearest 0.1 sq yd (0.1 m^2). Fillets for widened sections or at drainage structures and similar locations placed monolithic with the pavement are measured as pavement. Areas constructed other than as pavement are deducted from the pavement area (e.g. gutter pan). Do not make any deductions for any fixtures located within the pavement limits that have a surface area of 1.0 sq yd (0.8 m^2) or less.

Where PCCP is specified, include the necessary details in the plans for the various types of joints and joint locations or patterns. See Section on joint details.

PCCP Types

The following are the two basic categories of PCCP:

1. Plain Jointed Pavement. This PCCP has transverse joints without dowel bars. Load transfer across the joint is developed by aggregate interlock. Aggregate interlock relies on the interaction between aggregate particles at the irregular crack face that forms below the saw cut. The Department does not recommend the use of plain jointed pavement for new construction.

   Applications for plain jointed PCCP are where:

   a. truck traffic volumes are less than 80 trucks per day per lane, and

   b. slab lengths are shorter than or equal to 15’ (4.5 m).

   Figure 5.4B provides the suggested joint spacings for plain jointed pavements based on various thicknesses.

US Customary

Pavement Thickness	Maximum Joint Spacing
5” 6” 7” ≥ 8”	10’ – 12.5’ 12’ – 15’ 14’ – 15’ 15’

Metric

Pavement Thickness	Maximum Joint Spacing

125 mm 150 mm 175 mm ≥200 mm	3.0 m - 3.8 m 3.7 m - 4.5 m 4.3 m - 4.5 m 4.5 m

JOINT SPACING FOR PLAIN JOINTED PAVEMENT

Figure 5.4B

For highway applications, use skewed randomly spaced joints to reduce harmonic induced ride quality problems caused by faulting. The random spacing should be specified at 12', 15', 14', 13' (3.6 m, 4.5 m, 4.3 m, 4.0 m) and repeated. The skew should be 10º skewed counterclockwise to the direction of traffic movement.

2. Reinforced Jointed Pavement. This PCCP has transverse joints with dowel bars. Dowel bars are round, smooth steel bars placed across transverse joints to transfer loads without restricting horizontal joint movement due to thermal and moisture contractions and expansions. Dowel bars also keep slabs in horizontal and vertical alignment and reduce deflections and stresses due to traffic loads.

   Applications for reinforced jointed PCCP are where:

   a. required slab thickness is 6" (150 mm) or greater,
   b. truck traffic volumes are greater than 80 trucks per day per lane, and
   c. slab lengths are longer than 20' (6.0 m).

   For reinforced jointed pavements, maximum joint spacing is 30' (9.0 m).

Dowel sizes for reinforced jointed pavements and construction joints are shown in Figure 5.4C.

Slab Depth (inches)	Dowel Diameter	Dowel Embedment (inches)	Total Dowel Length (inches)
6	3/4"	5"	14"
6.5	7/8"	5"	14"
7	1"	6"	16"
7.5	1 1/8"	7"	16"
≥ 8"	1 1/4"	8"	17"

Slab Depth (mm)	Dowel Diameter (mm)	Dowel Embedment (mm)	Total Dowel Length (mm)
150	20	125	360
165	22	125	360
180	25	150	400
190	28	180	400
200	32	200	430

Notes:

1. *All dowels are spaced at 12” (300 mm) centers.*
2. *Embedment is on each side of the joint.*
3. *Total dowel length has allowances for joint openings and minor errors in placement.*
4. *On transverse joints, dowels are placed parallel to the profile grade and parallel to the direction of travel.*

DOWEL SIZES FOR REINFORCED JOINTED PAVEMENTS

Figure 5.4C

Joint Details

There are four general classifications of joints for PCCP. Joint types and their functions are discussed below:

1. Transverse Joints. Transverse joints are placed perpendicular to the roadway’s centerline. These joints primarily control the natural transverse cracking due to contraction in the PCCP. Proper transverse joint design for both plain and reinforced pavements will specify the joint interval that will control cracks and provide adequate load transfer across joints.

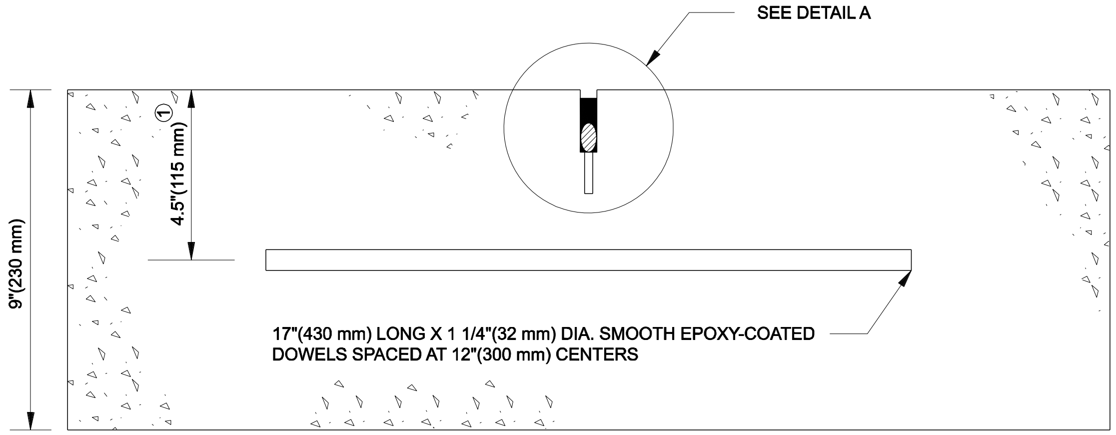
   Joint formation as shown in Figure 5.4D is achieved with an initial saw cut to a depth of at least 25% of the slab thickness and having a minimum width of 1/8” (3 mm). For pavements on stabilized subbases (plant mix base, cement-treated base), the initial saw cut depth should be increased to 33% of the slab thickness. See the manufacturer’s specifications for sealant reservoir dimensions. Figure 5.4D also shows a typical sealant reservoir.

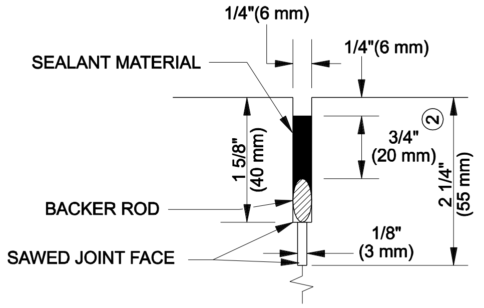
2. Construction Joints. These joints are placed at planned interruptions (e.g., at the end of each day’s paving, at intersections, where unplanned interruptions suspend operations for an extended period of time). Wherever practical, install the joints shown in Figure 5.4E at the location of a planned joint. These are butt-type joints that need dowels because there is no aggregate interlock to provide

load transfer. Dowel size and spacing are the same as shown in Figure 5.4C. To perform properly, the dowel ends extending through the butt joint must be lubricated before paving is resumed. If an unplanned construction joint occurs in the middle two-thirds of the normal joint interval, use a keyed joint as shown in Figure 5.4E with tiebars instead of dowels.

3. Longitudinal Joints. Longitudinal joints are placed parallel to the roadway's centerline. These joints primarily control longitudinal cracking developed from the combined effects of load and restrained warping after pavements are subjected to traffic. On 2-lane and multilane roadway pavements, a spacing of 10' (3.0 m) to 13' (4.0 m) serves the dual purpose of crack control and lane delineation.

   The longitudinal construction joint shown in Figure 5.4F is used for one lane-at-a-time construction. This includes adjacent lanes, shoulders, and curb and gutters. This joint may or may not be keyed depending on the slab thickness, lateral restraint and traffic volumes. The longitudinal contraction joint shown in Figure 5.4G is used where two or more lanes are paved at a time. With slipform paving 2-, 3- or 4-lane pavements can be placed in one pass. These joints depend on the tiebar to maintain aggregate interlock, structural capacity and serviceability.





DETAIL A

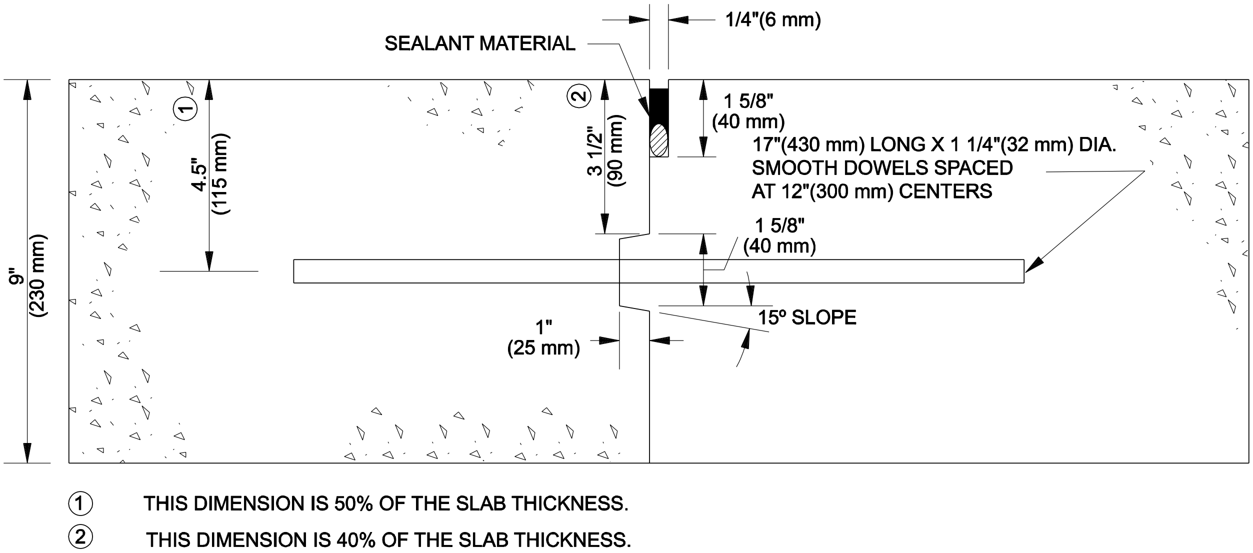
SAWED TRANSVERSE OR LONGITUDINAL
JOINT WITH HOT POURED SEALANT

① THIS DIMENSION IS 50% OF THE SLAB THICKNESS.

② THIS DIMENSION IS 25% OF THE SLAB THICKNESS.

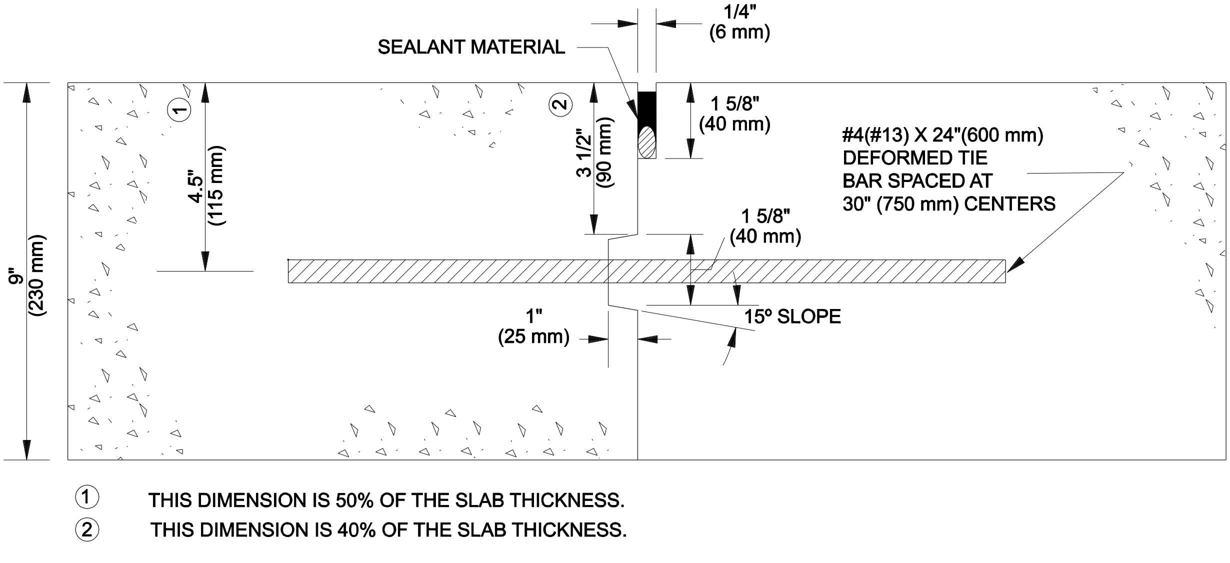
TRANSVERSE CONTRACTION JOINT

Figure 5.4D



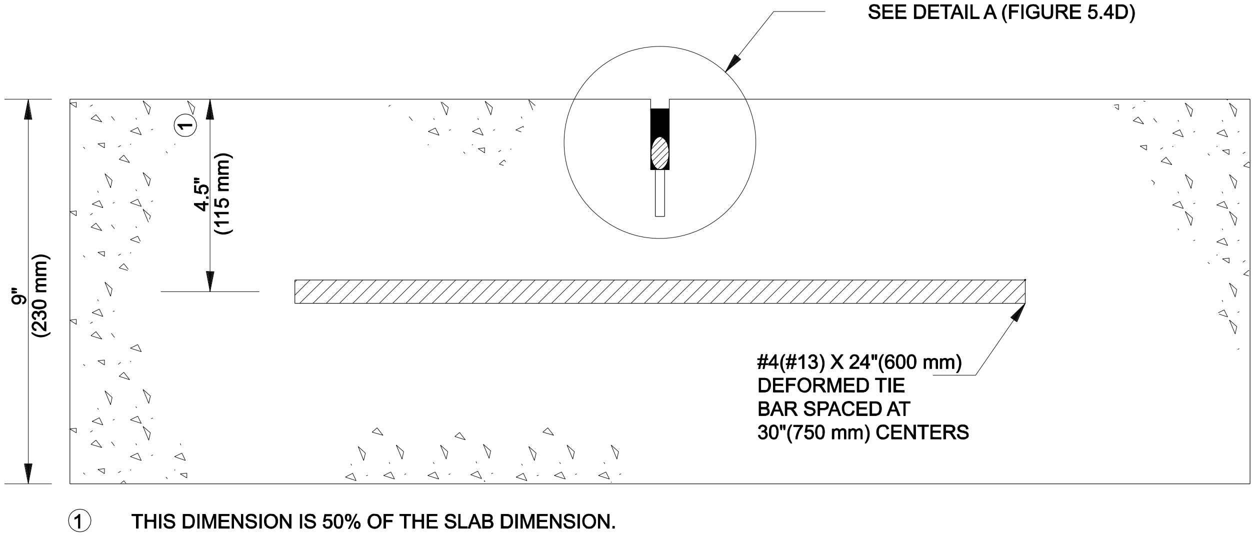
TRANSVERSE CONSTRUCTION JOINT

Figure 5.4E



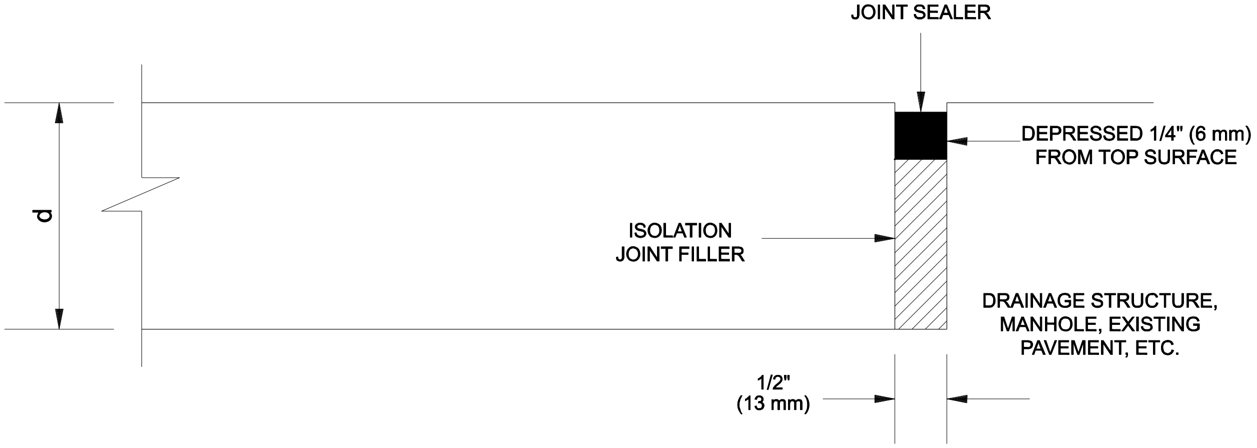
LONGITUDINAL CONSTRUCTION JOINT

Figure 5.4F



LONGITUDINAL CONTRACTION JOINT

Figure 5.4G



NON-DOWELED ISOLATION JOINT

Figure 5.4H

In urban areas, where the pavement is laterally restrained by the backfill behind the curbs, there is no need to tie longitudinal joints with deformed tiebars. However, on roadways not restrained from lateral movement, tiebars must be placed at mid-depth of the slab to prevent the joint from opening due to the contraction of the concrete slabs. Typically, #4 (#13) deformed tiebars by 24” at 30” (600 mm at 750 mm) spacings are used. Do not place tiebars within 15” (380 mm) of transverse joints or they may interfere with the joint movement. Do not coat tiebars with grease, oil or other material that prevents bonding to the concrete.

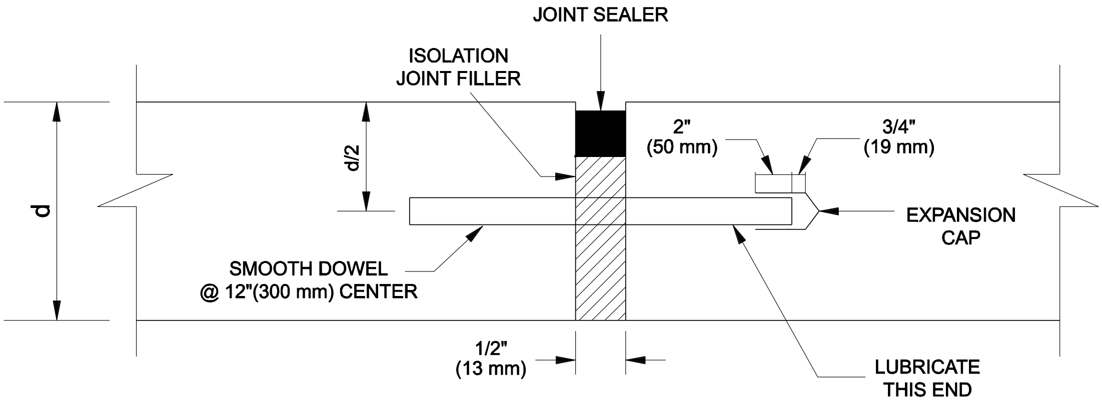
4. Isolation Joints. Isolation joints are placed around in-pavement structures (e.g., drainage inlets, manholes, lighting structures). These joints primarily lessen compressive stresses that develop between the pavement and a structure or between two pavement sections. See Figure 5.4H for a typical isolation joint.

   Isolation joints used at structures (e.g., bridges) should have dowels to provide load transfer and increase pavement performance. See Figure 5.4I for detail of doweled isolation joints.

Jointing Layout

A well designed jointing layout can eliminate unsightly random cracking, can enhance the appearance of the pavement and can provide years of low maintenance service. The following recommendations will help in the design of a proper jointing system.

1. Avoid odd-shaped slabs.
2. Maximum transverse joint spacing for plain jointed pavement should either be 24 or 30 times the slab thickness or 15’ (4.5 m), whichever is less; or 30’ (9.0 m) or less for reinforced jointed pavements.
3. Longitudinal joint spacing should not exceed 12.5’ (3.8 m).
4. Keep slabs as square as practical. Long narrow slabs tend to crack more than square ones.
5. All transverse contraction joints must be continuous through the curb and have a depth equal to 25% to 33% of the pavement thickness depending on the subbase type.
6. In isolation joints, the filler must be full depth and extend through the curb.



DOWELED ISOLATION JOINT

Figure 5.4I

7. If there is no curb, tie longitudinal joints with deformed tiebars.

8. Offsets at radius points should be at least 1.5’ (0.5 m) wide. Avoid joint intersection angles less than 60°.

9. Minor adjustments in joint location made by shifting or skewing to meet inlets and manholes will improve pavement performance.

10. Where the pavement area has drainage structures, place the joints to meet these structure, if practical.

A typical joint layout detail is shown in Figure 5.4J.

5.4.3 Surfacing Quantities (Summary Sheet)

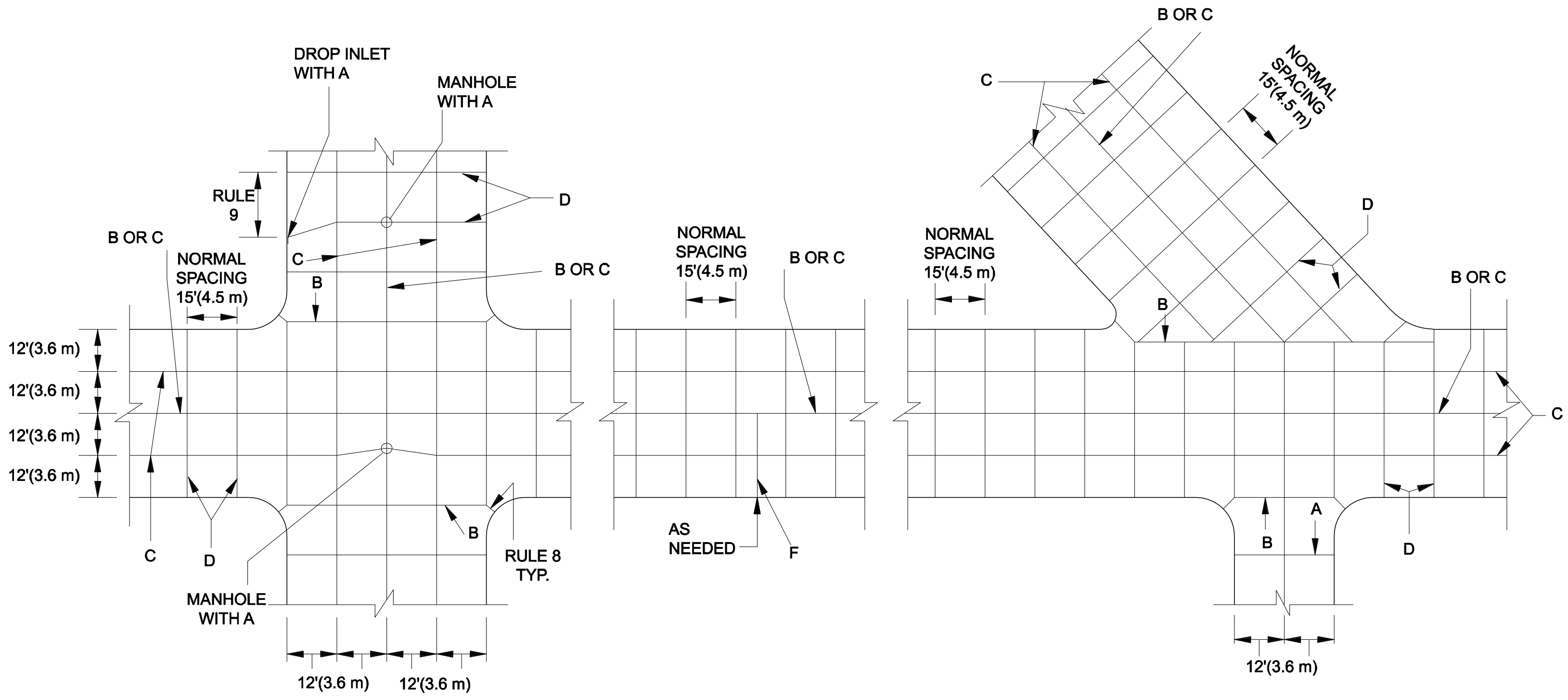
When calculating the quantities for the Surfacing and Additional Surfacing Frame on the Summary Sheets, consider the following guidelines:

1. Typical Section Quantities. For each typical section that has a Surfacing Quantity frame, multiply the quantities by the net number of stations, round the result according to the criteria presented in Figure 5.1A and record the values in the Surfacing Frame. Do not include bridge lengths, as measured from the bridge end bents’ centerline-of-bearing to centerline-of-bearing, in the net length. Provide a separate line in the Surfacing Frame each time the typical section used to calculate quantities changes. Quantities between the transition of two typical sections should also be recorded on a separate line. Estimate transition quantities by multiplying the transition length, in stations (Sta.), by the average quantity of surfacing in the two typical sections.

2. Bridges. Any surfacing of bridges must be approved by the Bridge Bureau. The thickness of plant mix material allowed on bridge decks is based on the structural capacity of the bridge.

3. Hydrated Lime. Typically, hydrated lime is used to treat plant-mix surfacing materials, including RAP. Estimate the quantity of hydrated lime at 1.4% of the mass of plant mix, round to the nearest (metric) ton and record the total in the Surfacing Frame on the Summary Sheets.

4. Additional Surfacing Frame. Use the Additional Surfacing Frame to record the surfacing quantities for approaches, connections to PTW, pavement tapers, etc. The quantity totals from the Additional Surfacing Frame are recorded on the bottom of the Surfacing Frame and added to the Surfacing Frame totals.



A. Isolation joints
B. Longitudinal construction joints
C. Longitudinal contraction joints
D. Transverse contraction joints
E. Planned transverse construction joint
F. Emergency transverse construction joint

PAVEMENT JOINT DETAILS

Figure 5.4J

5. Approach Surfacing Quantities. Chapter Thirteen presents the Department criteria for approaches. Figure 5.4K provides the typical surfacing quantities for approaches. In addition, the designer should consider the following guidelines:

    a. New Construction or Reconstruction Projects. Pave public and private approaches to the right-of-way line. Farm field approaches will be surfaced with gravel to the right-of-way line and will receive a 12’ (3.6 m) plant-mix strip adjacent to the roadway. The decision whether to seal and cover approaches will be determined at the Plan-in-Hand.

    b. Overlay and Overlay/Widening Projects. All public approaches will be overlaid to the right-of-way line. On all paved private approaches and all farm field approaches having a paved width of 12’ (3.6 m), provide a 3’ (1 m) plant-mix strip. This strip serves as a transition and reduces the edge-breaking potential of the new pavement.

    c. High-Volume Approaches. Approaches with high volumes of traffic, particularly truck traffic, may require special designs. The surfacing design and layout should be discussed with the Surfacing Design Section and the Geometric Design Section during the development of the project.

    d. Frame Listing. Total the surfacing required for each type of approach and record each total separately in the Additional Surfacing Frame (i.e., all public approaches = 1 item, all private approaches = 1 item, all farm field approaches = 1 item). Approaches that require a lengthy or different surfacing section also should be recorded separately in the Additional Surfacing Frame.

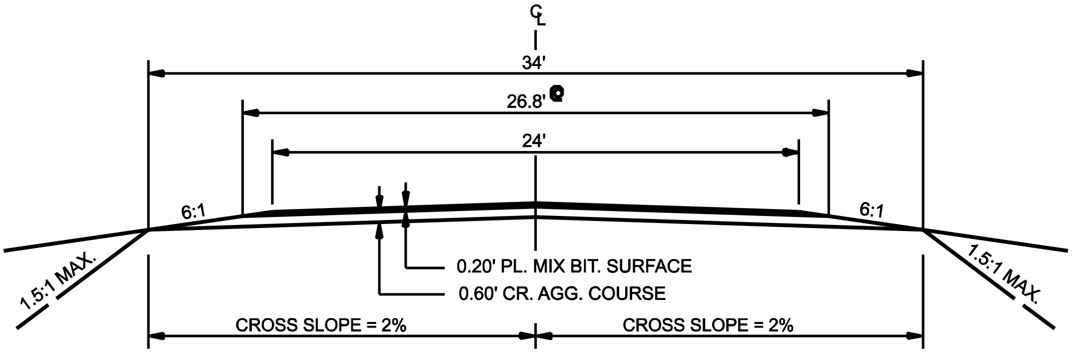
5.4.4 Miscellaneous Roadway Quantities

5.4.4.1 Pavement Markings

The Traffic Engineering Section is responsible for determining both interim and final pavement marking quantities. The designer is responsible for recording each in the Pavement Marking Frame on the Summary Sheet. Round all markings according to the criteria presented in Figure 5.1A.

The designer is responsible for determining the quantities required for temporary pavement markings. Estimate the quantities for each of the following paving operations:

1. Each lift of pavement – for estimating purposes lift thicknesses are between 0.15’ (45 mm) and 0.20’ (60 mm) inclusive



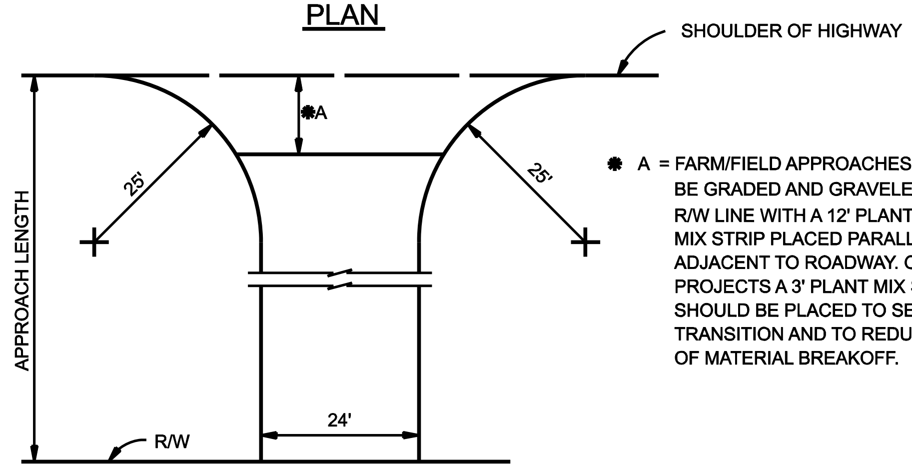
QUANTITIES PER APPROACH (INCL. WYES - 25' RADIUS)

SURFACING TREATMENT	AGGREGATE		BITUM. MAT'L.			AGGREGATE TREATMENT	
	TONS	yd^3	TONS			TON DUST PALLIATIVE	GALLONS AGGREGATE TACK
	PL.MIX BIT.SURF.	CR. AGG. COURSE	ASPHALT CEMENT				
			6.0%	5.8%	5.4%		
OVERLAY PROJECTS - 3.0' PL.MIX STRIP	2.3		0.14	0.13	0.12		
1ST 25' W/ 12' PL. MIX STRIP	8.1	21.6	0.49	0.47	0.44	0.09	2.9
1ST 25' PL. MIX SURFACED	13.8	21.6	0.83	0.80	0.75	0.18	5.6
EACH ADDITIONAL FOOT	0.4	0.7	0.02	0.02	0.02	0.01	0.2

BASIS OF QUANTITIES

COMP. WT. OF PL. MIX BIT. SURF. = 3855 lbs/yd^3
PL. MIX BIT. MAT'L. = 6.0% OF COMP PLANT MIX BIT. SURF. (GRADE D)
PL. MIX BIT. MAT'L. = 5.8% OF COMP PLANT MIX BIT. SURF. (GRADE S 1/2")
PL. MIX BIT. MAT'L. = 5.4% OF COMP PLANT MIX BIT. SURF. (GRADE S 3/4")
Ⓠ DUST PALLIATIVE = 0.3 gal/yd^2 (FOR PUBLIC APP'S ONLY)
Ⓠ AGGREGATE TACK = 0.05 gal/yd^2 (FOR PUBLIC APP'S ONLY)

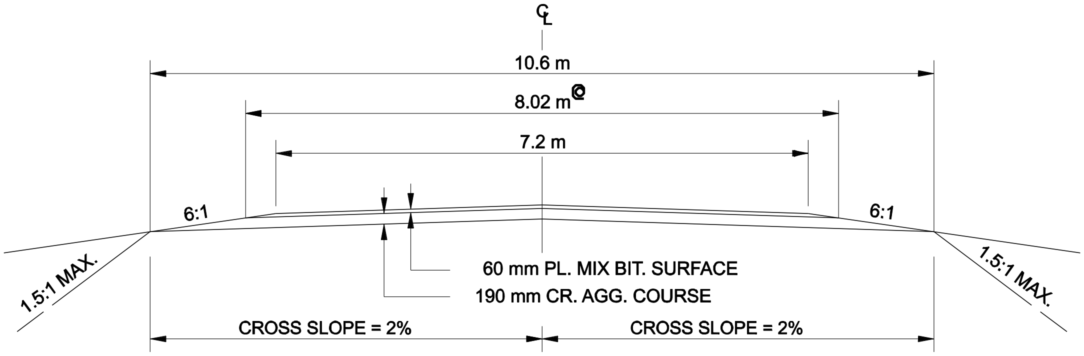
PLAN



✱ A = FARM/FIELD APPROACHES SHOULD BE GRADED AND GRAVELED TO R/W LINE WITH A 12' PLANT MIX STRIP PLACED PARALLEL AND ADJACENT TO ROADWAY. ON OVERLAY PROJECTS A 3' PLANT MIX STRIP SHOULD BE PLACED TO SERVE AS A TRANSITION AND TO REDUCE EDGE OF MATERIAL BREAKOFF.

ESTIMATED QUANTITIES FOR APPROACH SURFACING

Figure 5.4K (US Customary)



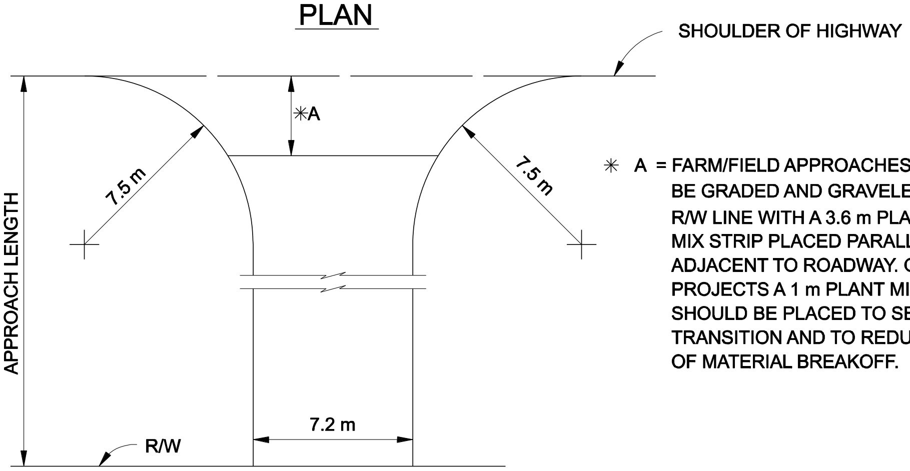
QUANTITIES PER APPROACH (INCL. WYES - 7.5 m RADIUS)

SURFACING TREATMENT	AGGREGATE		BITUM. MAT'L.			AGGREGATE TREATMENT	
	TONS	m^3	TONS			TON DUST PALLIATIVE	LITERS AGGREGATE TACK
	PL.MIX BIT.SURF.	CR. AGG. COURSE	ASPHALT CEMENT				
			6.0%	5.8%	5.4%		
OVERLAY PROJECTS - 1.0 m PL.MIX STRIP	2.4		0.14	0.14	0.13		
1ST 7.5 m W/ 3.6 m PL. MIX STRIP	6.6	17.1	0.40	0.38	0.36	0.09	11
1ST 7.5 m PL. MIX SURFACED	11.2	17.1	0.67	0.65	0.60	0.15	20
EACH ADDITIONAL METER	1.0	1.8	0.06	0.06	0.05	0.01	2

BASIS OF QUANTITIES

COMP. WT. OF PL. MIX BIT. SURF. = 2287 kg/m^3
PL. MIX BIT. MAT'L. = 6.0% OF COMP PLANT MIX BIT. SURF. (GRADE D)
PL. MIX BIT. MAT'L. = 5.8% OF COMP PLANT MIX BIT. SURF. (GRADE S 1/2")
PL. MIX BIT. MAT'L. = 5.4% OF COMP PLANT MIX BIT. SURF. (GRADE S 3/4")
@ DUST PALLIATIVE = 1.4 L/m^2 (FOR PUBLIC APP'S ONLY)
@ AGGREGATE TACK = 0.23 L/m^2 (FOR PUBLIC APP'S ONLY)

PLAN



✳ A = FARM/FIELD APPROACHES SHOULD BE GRADED AND GRAVELED TO R/W LINE WITH A 3.6 m PLANT MIX STRIP PLACED PARALLEL AND ADJACENT TO ROADWAY. ON OVERLAY PROJECTS A 1 m PLANT MIX STRIP SHOULD BE PLACED TO SERVE AS A TRANSITION AND TO REDUCE EDGE OF MATERIAL BREAKOFF.

ESTIMATED QUANTITIES FOR APPROACH SURFACING

Figure 5.4K (Metric)

2. A milled surface

3. isolations lifts

An additional quantity of temporary pavement markings may also be required for the existing pavement. The need for additional quantities will be determined by District Construction personnel. Temporary pavement markings are not needed for normal leveling. Compute the quantities for temporary pavement markings for each 2-lane mile (kilometer) of the project and round the result to the nearest 0.1 mile (0.1 km) as illustrated in Figure 5.1A.

5.4.4.2 Guardrail

Chapter Fourteen presents the Department's criteria for guardrail placement. Station limits for guardrail will include the terminal sections and bridge approach sections. Guardrail quantity calculations should reflect the following information:

1. W-Beam Guardrail Quantities. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 12.50' (3.81 m).

2. Cable Guardrail Quantities. Compute the length of need and round up to the next highest multiple post spacing. Post spacing on tangents and curves with radii greater than 720' (220 m) is 16' (4.88 m). Post spacing on curves with a radii less than 720' (220 m) and greater than or equal to 440' (135 m) is 12' (3.66 m). Do not install cable guardrail on the outside of curves with radii less than 440' (135 m) or on the inside of any curve.

3. Box Beam Guardrail Quantities. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 18.0' (5.49 m).

4. Concrete Barrier Rail. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 10' (3.05 m). Concrete barrier rail is paid at the unit price bid for each 10' (3.05 m) increment.

5. Raise Guardrail. Use the pay item "Raise Guardrail" to adjust existing rail to provide 21.625"±3" (550 mm ±75 mm) of distance from the center of the rail to the top of the pavement. Compute and round the quantity up to the nearest 12.5' (3.81 m).

6. Remove Guardrail. Compute and round the quantity up to the nearest 12.5' (3.81 m).

7. Reset Guardrail. Reset Guardrail is not a separate pay item. Provide a quantity of remove guardrail and a quantity of new guardrail for this item of work.

Compute and round these quantities up to the nearest 12.5’ (3.81 m). The contractor is allowed to use any approved salvaged materials in new installations.

8. Bridge Approaches. Bridge approach sections are included in the station limits but are bid as a separate unit and, therefore, are not included in the length of rail. Ensure the type of bridge approach section specified matches the bridge rail. See the *MDT Detailed Drawings* for the application of each type of bridge approach section. Box beam guardrail can only be connected to Wyoming Bridge Rail. Designer must contact Bridge Bureau.

9. Terminal Sections:

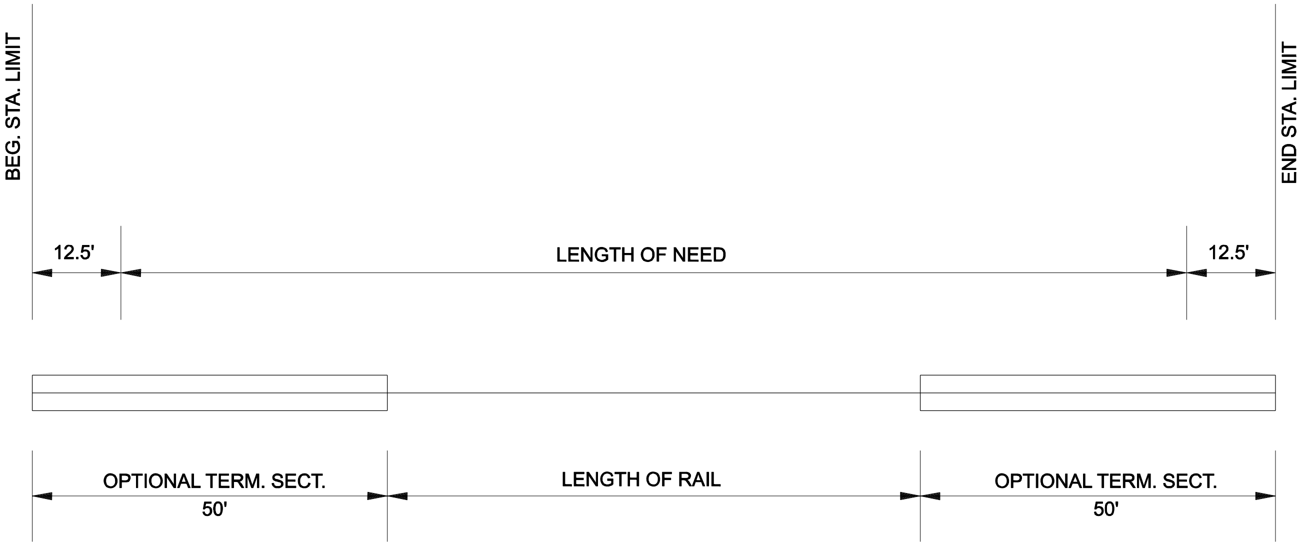
    a. W-Beam Guardrail. The optional terminal section and one-way departure terminal section are included in the station limits but are separate bid items; therefore, it is not included in the length of rail. See Figure 5.4L for computing guardrail lengths with Optional Terminal Sections.

    b. Cable Guardrail. Note that an additional 42’ (12.80 m) of cable guardrail is required on each end beyond the length of need. This additional 42’ (12.80 m) terminal section is measured separately for bidding purposes. Also, note that the maximum run of cable guardrail is 2000’ (609.4 m); see the *MDT Detailed Drawings*. Therefore, with a long run of cable guardrail, there may be several terminal sections. See Figure 5.4M for computing length of cable guardrail.

    c. Box Beam Guardrail. The WY-BET terminal section and terminal section 2 are included in the station limits but are separate bid items; therefore, they are not included in the length of rail. See Figure 5.4N for computing length of box beam guardrail.

10. End Anchors. End anchors are not bid separately, but are included in the cost of the terminal section.

11. Intersecting Roadway Terminal Section. For intersecting roadway terminal section (IRT), the length of rail is bid separately from the guardrail. The station limits of the IRT should extend from the guardrail connection to the end of the IRT. Because the IRT is installed on a radius, the station limits do not reflect the length of the IRT rail. See the *MDT Detailed Drawings* for the selection of radii that will result in 12.5’ (3.81 m) increments of rail. See Figure 5.4O for computing guardrail lengths with intersecting roadway terminal sections. Do not use intersecting roadway terminal sections with box beam rail.



Steps:

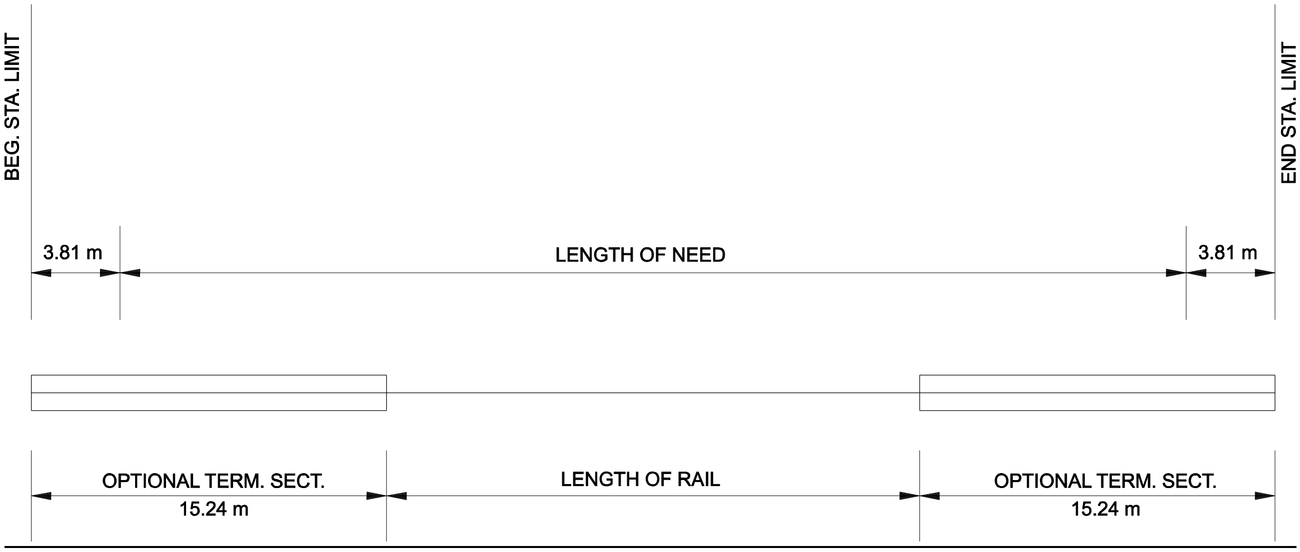
1. Compute length of need rounded to a multiple of 12.5’.
2. Add 12.5’ to each end of length of need to establish beginning and ending stations.
3. The difference between beginning and ending stations minus (2 x 50.0’) = length of rail.

Example: Guardrail is warranted between Stations 9 + 90 and 15 + 00

4. (15 + 00 - 9 + 90) ÷ 12.5 = 40.8 Rnd ⇒ 41
5. 41 x 12.5 = 512.5’ Length of Need
6. 9 + 90 - 12.5 = 9 + 77.5 Beginning Station
7. 9 + 77.5 + 512.5 + (2)(12.5) = 15 + 15.00 Ending Station
8. 15 + 15.00 - 9 + 77.5 - (2)(50) = 437.5’ Length of Rail

OPTIONAL TERMINAL SECTION

Figure 5.4L (US Customary)



Steps:

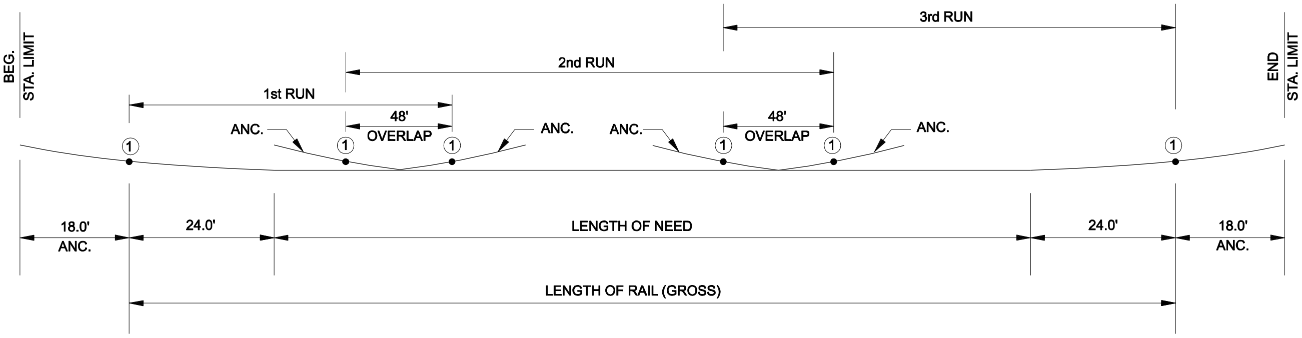
1. Compute length of need rounded to a multiple of 3.81 m.
2. Add 3.81 m to each end of length of need to establish beginning and ending stations.
3. The difference between beginning and ending stations minus (2 x 15.24 m) = length of rail.

Example: Guardrail is warranted between Stations 10 + 00 and 15 + 00

1. (15 + 00 - 10 + 00) ÷ 3.81 = 131.2 Rnd ⇒ 132
2. 132 x 3.81 = 502.92 m Length of Need
3. 10 + 00 - 3.81 = 9 + 96.19 Beginning Station
4. 9 + 96.19 + 502.92 + (2 x 3.81) = 15 + 06.73 Ending Station
5. 15 + 06.73 - 9 + 96.19 - (2 x 15.24) = 480.06 m Length of Rail

OPTIONAL TERMINAL SECTION

Figure 5.4L (Metric)



<u>Steps</u>:

1. Compute length of need rounded to a multiple of 16’.
2. *Add 42’ to each end of the needed rail length to establish the beginning and ending stations.*
3. *The difference between beginning and ending stations minus the length of anchor sections (2 x 18’) = length of rail (gross).*
4. *Length of rail (gross) ÷ 2000’ = number of runs (round up to nearest whole number).*
5. *(No. of runs - 1) x 48’ added to length of rail (gross) = total payment length of cable rail.*
6. *No. of runs x 2 = number of anchors.*

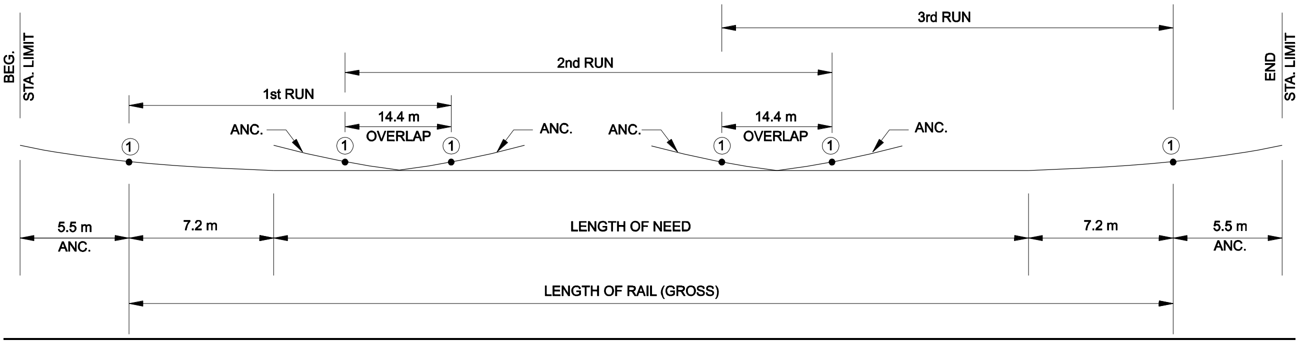
<u>Example</u>: Guardrail is warranted between Sta 20 + 00 and 55 + 00.

1. (55 + 00 - 20 + 00) ÷ 16.0 = 218.75 Rnd ⇒ 219
   (219)(16) = 3504’ Length of Need

2. 20 + 00 – 42 = 19 + 58.0 Beginning Station
   19 + 58.0 + 3504.0 + (2)(42) = 55 + 46.0 Ending Station
3. 55 + 46.0 - 19 + 58.0 - (2)(18) = 3552.0’ (gross) Length of Rail
4. 3554 ÷ 2000 = 1.78 Rnd ⇒ 2 Runs
5. (2 - 1)(48) + 3552 = 3600.0 Length of Cable Rail for Payment
6. 2 x 2 = 4 Anchors

CABLE GUARDRAIL

Figure 5.4M (US Customary)



<u>Steps</u>:

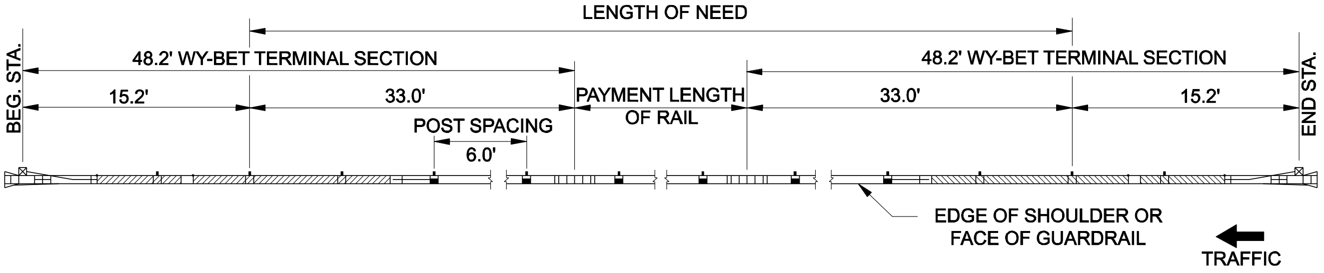
1. Compute length of need rounded to a multiple of 5.0 m.
2. *Add 12.7 m to each end of the needed rail length to establish the beginning and ending stations.*
3. *The difference between beginning and ending stations minus the length of anchor sections (2 x 5.5 m) = length of rail (gross).*
4. *Length of rail (gross) ÷ 609.4 m = number of runs (round up to nearest whole number).*
5. *(No. of runs - 1) x 14.4 m added to length of rail (gross) = total payment length of cable rail.*
6. *No. of runs x 2 = number of anchors.*

<u>Example</u>: Guardrail is warranted between Sta 20 + 00 and 35 + 00.

1. (35 + 00 - 20 + 00) ÷ 5.0 = 300.00 Rnd⇑ 300
   300 x 5.0 = 1500.0 m Length of Need
2. 20 + 00 - 12.7 = 19 + 87.3 Beginning Station
   19 + 87.3 + 1500.0 + (2 x 12.7) = 35 + 12.7 Ending Station
3. 35 + 12.7 - 19 + 87.3 - (2 x 5.5) = 1514.4 m (gross) Length of Rail
4. 1514.4 ÷ 609.4 = 2.48 Rnd⇑ 3 Runs
5. (3 - 1) x 14.4 + 1514.4 = 1543.20 m Length of Cable Rail for Payment
6. 3 x 2 = 6 Anchors

CABLE GUARDRAIL

Figure 5.4M (Metric)



Steps:

1. Compute the length of need, minus 33.0' for each terminal section, rounded to a multiple of 18.0' = payment length of box beam guardrail.
2. Add 48.2' to each end of the rounded length of need to establish the beginning and ending stations.
3. The WY-BET Terminal Section (48.2') is bid per each including the end anchor (no separate payment is made for the end anchor).

Example: Guardrail is warranted between Stations 17+50 and 32+75.

1. [(32+75 - 17+50) - (2)(33)] ÷ 18 = 81.06 Round $\Rightarrow$ 82

   (82)(18) = 1476' Payment Length of Box Beam Guardrail

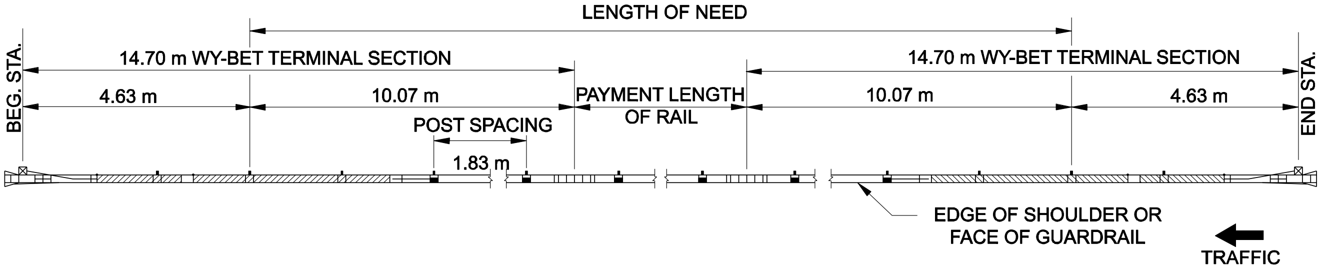
2. (17+50 + 33) – 48.2 = 17 + 34.80 Beginning Station

   1734.80 + 1476 + (2)(48.2) = 33 + 07.20 Ending Station

3. 2 WY-BET Terminal Sections

BOX BEAM GUARDRAIL

Figure 5.4N (US Customary)



<u>Steps</u>:

4. Compute the length of need, minus 10.07 m for each terminal section, rounded to a multiple of 5.49 m = payment length of box beam guardrail.
5. Add 14.70 m to each end of the rounded length of need to establish the beginning and ending stations.
6. The WY-BET Terminal Section (14.70 m) is bid per each including the end anchor (no separate payment is made for the end anchor).

<u>Example</u>: Guardrail is warranted between Stations 17+50 and 22+75.

7. [(22+75 - 17+50) - (2 x 10.07)] ÷ 5.49 = 91.96 Round ⇑ 92

   92 x 5.49 = 505.08 m Payment Length of Box Beam Guardrail

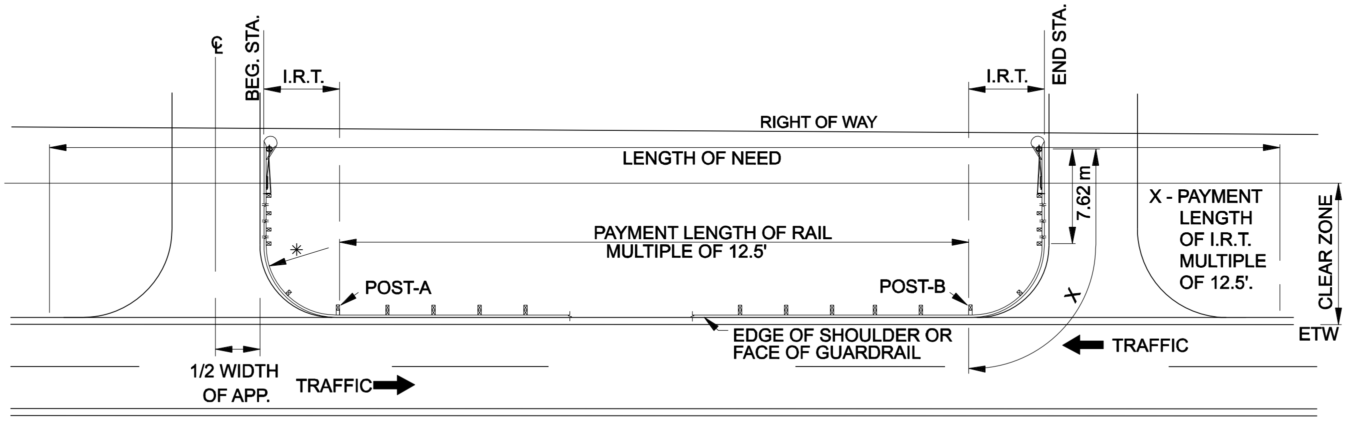
8. (17+50 + 10.07) - 14.70 = 17 + 45.37 Beginning Station

   17+45.37 + 505.08 + (2 x 14.70) = 22 + 79.85 Ending Station

9. 2 WY-BET Terminal Sections

BOX BEAM GUARDRAIL

Figure 5.4N (Metric)



*Note: The radius for any particular installation is constant. Select a radius that best fits approach radius from table.

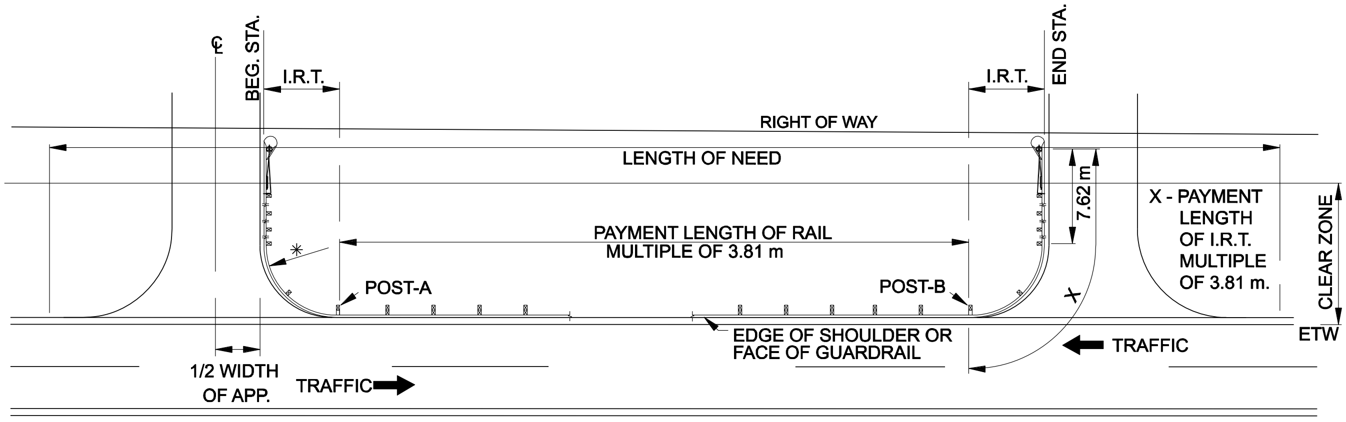
Radius	Length of Bent Rail	Total Length of I.R.T.
8’	12.5’	37.5’
16’	25’	50’
24’	37.5’	62.5’
32’	50.0’	75.0’

Note: Dynamic deflection distance for rail is 4‘.

1. Determine barrier warrants (Section 14.3).
2. Calculate advancement and departure lengths. (Section 14.4.3).
3. If approaches, turnouts or other obstacles are within the required length of guardrail, I.R.T. terminals may be used to shorten the required lengths.
4. Ensure that R/W width is sufficient (i.e., far enough from the shoulder to get the full I.R.T. installed without encroaching).
5. Determine the edge of each approach.
6. Determine the location of Post-A and Post-B.
7. Determine the best fit radius from the table, based on the difference between the edge of approach and Post-A. Repeat for Post-B.
8. Minor adjustments to the approach stationing or minor grading along the edge of the approach may be necessary to fit the I.R.T. to the approach.
9. Station of Post-A minus the radius = the beginning station of rail. Station of Post-B plus the radius = the end station of guardrail.
10. The distance between Post-A and Post-B is the payment length of guardrail.
11. The payment length for the I.R.T. is the length of bent rail plus 25’.
12. I.R.T. end anchors are not bid separately.

COMPUTATIONS OF PAY QUANTITIES FOR W-BEAM GUARDRAIL AND INTERSECTING ROADWAY TERMINAL (IRT) SECTIONS

Figure 5.4O (US Customary)



*Note: The radius for any particular installation is constant. Select a radius that best fits approach radius from table.

Radius	Length of Bent Rail	Total Length of I.R.T.
2.45 m	3.81 m	11.43 m
4.85 m	7.62 m	15.24 m
7.30 m	11.43 m	19.05 m
9.70 m	15.24 m	22.86 m

Note: Dynamic deflection distance for rail is 1.2 m.

1. Determine barrier warrants (Section 14.3).
2. Calculate advancement and departure lengths. (Section 14.4.3).
3. If approaches, turnouts or other obstacles are within the required length of guardrail, I.R.T. terminals may be used to shorten the required lengths.
4. Ensure that R/W width is sufficient (i.e., far enough from the shoulder to get the full I.R.T. installed without encroaching).
5. Determine the edge of each approach.
6. Determine the location of Post-A and Post-B.
7. Determine the best fit radius from the table, based on the difference between the edge of approach and Post-A. Repeat for Post-B.
8. Minor adjustments to the approach stationing or minor grading along the edge of the approach may be necessary to fit the I.R.T. to the approach.
9. Station of Post-A minus the radius = the beginning station of rail. Station of Post-B plus the radius = the end station of guardrail.
10. The distance between Post-A and Post-B is the payment length of guardrail.
11. The payment length for the I.R.T. is the length of bent rail plus 7.62 m.
12. I.R.T. end anchors are not bid separately.

COMPUTATIONS OF PAY QUANTITIES FOR W-BEAM GUARDRAIL AND INTERSECTING ROADWAY TERMINAL (IRT) SECTIONS

Figure 5.4O (Metric)

12. Impact Attenuators. Using the manufacturer's guidelines, determine the number of bays required based on the design speed at the site. Impact attenuators are included in the station limits of the guardrail but are a separate bid item. Attenuators are bid as a unit (i.e., each).

13. Stiffened Guardrail Sections. Compute the length of stiffened guardrail and round up to the next highest multiple of 12.5' (3.81 m). Include the length of transitions (bridge approach sections) in the length computed for stiffened guardrail. See MDT Detailed Drawings for configuration on one-way and two-way roadways.

5.4.4.3 Curb and Gutter

Section 11.2.6 provides the Department criteria for curb and gutter sections. Show the curb and gutter station limits in the Curb Frame from the beginning of one curb return to the beginning of the next curb return (BCR to BCR). Figure 13.2B illustrates the location of the BCR. In addition to the length of the curb and gutter between BCR's, the distance of the curb and gutter around the radius to the end of the curb return must also be included in the summary quantities. Radii dimensions are to the back of curb. Round the curb and gutter quantities in the Curb Frame to the nearest 0.1' (0.1 m).

5.4.4.4 Sidewalks

Section 11.2.7 provides the Department criteria for sidewalks. For each depth of sidewalk in the project, compute the sidewalk area in square yards (meters) and round to the nearest 0.1 square yard (0.1 square meter). Report the results in the Sidewalk Frame. The cost for the aggregate base is typically incorporated in the unit cost per square yard (meter) of sidewalk. For sidewalk sections under vehicular traffic (e.g., intersections with approaches and alleys), use a 6" (150 mm) sidewalk depth. For all other locations, use a 4" (100 mm) sidewalk depth. Curb ramps are included in the 4" (100 mm) sidewalk quantities and are not a separate bid item. The curbing around the curb ramp is paid for as curb and gutter and is typically included in the curb radii of curb and gutter; see Section 5.4.4.3.

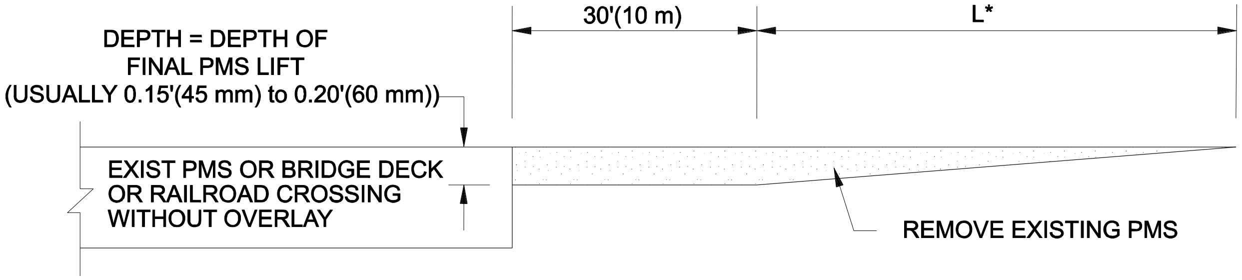
5.4.4.5 Truncated Domes

Truncated domes are a standardized detectable warning surface for sight-impaired pedestrians. The domes are installed in the sidewalk ramp adjacent to the roadway and provide a cue that the pedestrian is moving from a pedestrian area to a vehicular area. We are required to install truncated domes on all new curb ramps and any project involving alterations to existing ramps.

The truncated domes are located at the bottom of the curb ramp and extend the width of the ramp. Truncated domes will be measured and paid by the square yard (square meter). Show the quantities for truncated domes in a separate column in the Sidewalk Summary. Refer to Detailed Drawing No. 608-40 for more complete information.

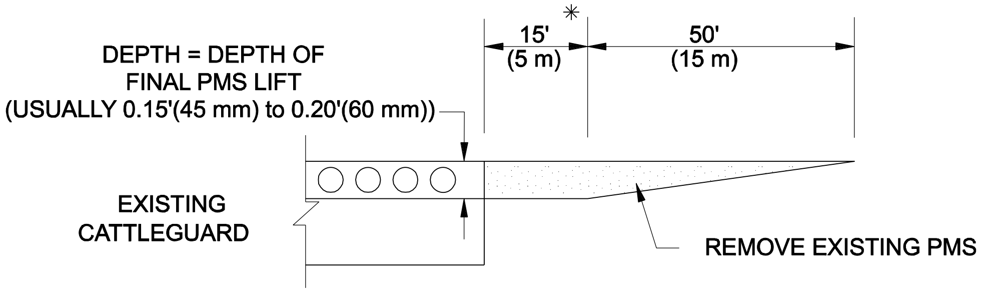
5.4.4.6 Cold Milling

Cold milling is used to remove a specified depth of pavement. Where the pavement has deteriorated, the removal of all pavement above the plane of failure may be necessary prior to placing a new overlay. For these cases, the depth of milling will be determined by the Surfacing Design Section. Cold milling is also used in conjunction with overlays to match the new surfacing elevations at bridge decks, railroad crossing, cattle guards and connections to existing pavement; see Figure 5.4P.



** For plant mix thickness ≤ 0.35’(105mm) L=200’(60m). When the plant mix thickness ≥ 0.35’(105mm) L is calculated based on 30’(10 m) of taper per 0.05’(15 mm) of plant mix thickness. For connection to PTW use only L, the 30’(10m) full depth section is not needed.*

Example: For a 0.35’ (105 mm) overlay $L = \left(\frac{0.35}{0.05}\right)(30) = 210'$ $\left(L = \left(\frac{105}{15}\right)(10) = 70\right)$



* *Add the following note to the Detail Sheet in the contract plans: “Actual removal distances to be determined during construction by the Engineer.”*

COLD MILLING TAPERS

Figure 5.4P

Typically, wherever milling is required, remove all plant-mix material from concrete bridge decks within the project limits. Otherwise, written documentation is required. See Figure 5.4P to determine the extent of milling beyond the bridge ends. If taper milling has been used to tie a previous overlay to the bridge end, L must be calculated for both overlay thicknesses. For cattle guards, the pavement is typically milled for 65’ (20 m) on either side of the structure. Review the application of this criteria during the Plan-In-Hand Field Review. Standard milling widths are 6.25’, 12.5’ and 14.0’ (1.905 m, 3.810 m and 4.267 m). Avoid using costly non-standard milling widths unless absolutely necessary. Use the bottom width of the milled surface to compute the cold milling area and round to the nearest square meter. Where milling depth tapers are needed, use the maximum width (i.e. width at the bottom of the milled surface) to calculate the cold milling area. Record the results in the Cold Milling Frame.

5.4.4.7 Pavement Pulverization

Pavement pulverization is used to produce a uniform material for the total subgrade width by mixing the existing bituminous pavement with aggregate. Specify the depth of pavement pulverization based on Surfacing Design recommendation. The depth of the pulverization is the average depth of the existing bituminous pavement (the maximum depth is typically 0.66’/200 mm). Use the bottom width of the pulverized surface base on the specified depth to compute the quantity of pavement pulverization. Calculate the area in square yards (meters) and round to the nearest square yard (meter). Record the results in the Surfacing Frame.

Achieving a blend of pulverized plant mix and untreated aggregate surfacing is important. Pulverized plant mix should comprise 60% of the mix, while the remainder should be underlying base gravel, new aggregate blended during pulverization, or a combination of the two. Aggregate added to the pulverized material for leveling is measured by the ton (metric ton). Calculate the quantity and round the results as shown in Section 5.4.2.2. Record the results in the Pulverization Frame. Provide a design profile grade where pavement pulverization is specified. The Design profile grade should be adjusted as necessary to account for leveling and swell of pulverized material.

5.4.4.8 Finish Grade Control

Record finish grade control staking quantities in the finish grade control Staking Frame on the Summary Sheets. Also consider the following:

1. Each course foot (kilometer) of finish grade control staking is based on a 2-lane roadway, including shoulders and ditches.

2. Each traffic lane, ramp, climbing lane, etc., is one-half of a course foot (kilometer) for measurement. Do not measure parking lanes, turning lanes, median lanes and chain-up areas separately from the adjacent roadway.

3. Four-lane facilities require separate measurements for each roadway.

4. Measure the subgrade and each base course of aggregate requiring finish grade control staking separately, by the course foot (kilometer), for each roadway, ramp, intersecting roadway, PTW connections, temporary detour and frontage road.

5. For facilities with aggregate surfaces, finish grade control is only provided for the subgrade if the aggregate is paid for by the (metric) ton. However, finish grade control is provided for both subgrade and aggregate surfacing if the aggregate is paid for by the cubic yard (meter). A separate course of finish grade control staking will be required where special borrow is used.

6. Take measurements along the centerline of each roadway and round to the nearest 50 feet (0.01 km).

The following example illustrates how to calculate finish grade control staking for a project.

* * * * * * * * * *

Example 5.4-4

Given: 4-lane freeway with 7 miles (km) of construction
Interchange with construction of four 0.4 mile (km) long ramps
2-lane intersecting roadway with 1 mile (1.61 km) of construction

Pavement section:

0.25’ (75 mm) Plant Mix
1.00’ (300 mm) Crushed Aggregate Course
1.25’ (375 mm) Selected Surfacing

Problem: Determine the amount of finish grade control staking required for the project.

Solution: Calculate the course mile (kilometer) of finish grade control staking for the mainline, ramps and intersecting roadway:

US Customary

2 - 7.0	mile = 36,960 rounded to 36,950 x (2) =	73,900 ft	subgrade — mainline
2 - 7.0	mile = selected surfacing — mainline	73,900 ft	
2 - 7.0	mile = crushed aggregate — mainline	73,900 ft	
2 - 0.4	mile = 2,112 rounded to 2,100 x (2) =	4,200 ft	subgrade — ramps
2 - 0.4	mile = selected surfacing — ramps	4,200 ft	
2 - 0.4	mile = crushed aggregate — ramps	4,200 ft	
1.0	mile = subgrade — intersecting road	5,300ft	
1.0	mile = selected surfacing — intersecting road	5,300 ft	
1.0	mile = crushed aggregate — intersecting road	5,300 ft	
		250,200 ft total	

Metric

14.00	km subgrade — mainline
14.00	km selected surfacing — mainline
14.00	km crushed aggregate — mainline
0.80	km subgrade — ramps
0.80	km selected surfacing — ramps
0.80	km crushed aggregate — ramps
1.61	km subgrade — intersecting road
1.61	km selected surfacing — intersecting road
1.61	km crushed aggregate — intersecting road
48.23	km total

* * * * * * * * * *

5.4.4.9 Traffic Gravel

Traffic gravel is used as temporary surfacing to carry traffic on stages of unfinished grading (i.e., cuts or fills). For the areas where the traffic cannot be maintained on the PTW or finished subgrade, determine the number of stages the cut or fill will be constructed. Compute the quantity of traffic gravel based on the following criteria:

1. 24-foot (7.2 m) minimum travel width,
2. 0.20’ (65 mm) depth of traffic gravel,
3. the length of temporary surfacing.

When specifying traffic gravel, use the type and grade of crushed aggregate course specified for the project. Verify traffic gravel quantities with district construction personnel. Traffic gravel is measured and paid by the cubic yard (cubic meter). Round the calculated quantity to the nearest cubic yard (cubic meter) and record the quantity in the “TRAFFIC GRAVEL” column of the Surfacing Frame.

5.4.4.10 Rumble Strips

See Section 11.2.2.6 for criteria for rumble strips. When calculating rumble strip quantities, consider the following guidelines:

1. Each individual line of rumble strip is measured separately for payment.
2. Deduct gaps for bridges, ramps, approaches, etc., from the length quantity for rumble strips.
3. Discontinue rumble strips on shoulders less than 6’ (1.8 m) wide if guardrail exists or is proposed.
4. Take measurements along the centerline of the roadway and round to the nearest 0.1 miles (0.1 km).
5. Record the rounded quantity in the Rumble Strips Frame.
6. On all projects that have rumble strips, calculate a quantity of fog seal to be applied to the rumble strips. Use SS-1, applied to a width of 2’ (0.6 m) at an undiluted application rate of 0.05 gal/sq yd (0.2 L/m^2). Show this quantity for informational purposes. The cost of the fog seal is included in the cost of the rumble strips

5.5 MISCELLANEOUS COMPUTATIONS

5.5.1 Lump-Sum Items

Use lump-sum bid items where the scope of work for the item is clearly defined and the amount of work has a minimal chance of changing during construction. Lump-sum should also considered where the end result is defined but there are various methods of achieving the desired results. Including an item of work in another item should only be done where the scope of work for each item is clearly defined and the chance of the quantity of either item changing is minimal. Where practical, list separately the quantities that comprise the lump-sum item of work. The list should note that the separate "quantities are for estimating purposes only." Provide a clear definition of work for each item whether it is bid by the unit, included in the cost of other items or bid lump sum. Where there is a significant chance of quantity change, the work must be bid by the unit. Where lump-sum items are used, the total quantity for the project should always equal one. If more than one item or location is included in the lump-sum show the decimal proportion of the work of each location. For example, a project which includes the removal of three structures being 30’, 30’, 60’ (10, 10, 20 meters) long the proportion would be .25, .25, .50 respectively.

5.5.2 Clearing and Grubbing

Clearing and grubbing is typically included in the construction plans and, generally, will not require a separate set of plans. Decisions related to the payment method (e.g., lump sum, absorbed in other bid items, by the acres or hectare) should be made during the Plan-in-Hand Field Review. Payments based on the number of acres (hectares) involved require the quantities to be presented on the Clearing and Grubbing Frame. Where clearing and grubbing will be included in the grading bid item -, include an appropriate note in the Notes Sheet. Clearing and grubbing may be bid either as separate bid items with different bases for payment or as a single item. If the clearing and grubbing has separate phases, the quantities for each should be shown separately in the summary and the special provisions should describe the measurement and payment for each phase. The decision on the disposition and areas of selective cutting will be made at the Plan-in-Hand Field Review. The disposition of merchantable timber should be determined during right-of-way negotiations.

5.5.3 Topsoil

In general, topsoil will be required on most projects. The designer should review the following relative to the placement of topsoil:

1. Topsoiled Areas. Provide topsoil according to the following guidelines:

   a. Topsoil will be required on all projects where the existing topsoil is disturbed. Where topsoil is impractical to salvage or is unsuitable (i.e. rock cut), eliminate the area from the topsoil salvage quantity. Also provide a special provision describing the special slope treatment to be used.

   b. Provide topsoil on all 2:1 or flatter slopes.

   c. Place topsoil on the gravel surfacing inslope to the edge of the plant mix for all projects that involve disturbance of the inslope as per the *MDT Detail Drawings*.

2. Topsoil. Assume that the existing topsoil will be salvaged and stockpiled unless otherwise noted.

3. Placement. Where required, provide topsoil to a loose depth of 4”(100 mm) from the bottom edge of the plant mix to the catch point. Slopes other than serrated slopes should be scarified and conditioned to leave a rough surface suitable to catch and hold topsoil.

4. Quantities. Use the following procedure to compute topsoil quantities and record them on the summary sheets:

   a. Topsoil quantities should be based on a 4”(100 mm) depth unless otherwise determined by topsoil survey.

   b. Show topsoil quantities, in cubic yards (meters), in 3000’ (1000 m) increments in the Topsoil and Seeding Frame.

   c. Topsoil quantities can be obtained using computer-generated data or manually calculated computation sheets.

5. Topsoil Replacement. Use the following procedure to treat topsoil replacement regardless of the quantity of topsoil on a project:

   a. Topsoil replacement = (topsoil) x (1 + project shrink factor).

   b. Include the topsoil replacement quantities in the mass diagram using 3000 ft (1000 m) increments.

   c. Include the total topsoil replacement quantity line item in the Additional Grading Frame as “EMB +” in the “included in roadway quantities” column.

5.5.4 Seeding

Where seeding is provided on a project, consider the following guidelines:

1. Seeded Areas. Provide seeding on all slopes extending from the edge of plant mix to the new right-of-way limit, except on slopes steeper than 1.5:1, areas that are predominantly rock and other locations that are difficult to grow grass.

2. Determining Quantities. The Environmental Services Bureau is responsible for determining the seed type, seeding rate, amount of fertilizer and mulch used per acre (hectare). Generally, different seeding rates will be specified for:

    a. the total area to be seeded inside the new right-of-way having 3:1 or flatter slopes (Area 1) minus the areas described below,

    b. constructed slopes steeper than 3:1 (Area 2),

    c. a strip extending from a point from the edge of the plant mix to a distance of 15’ (4.5 m) or to the edge of the surfacing inslope, whichever is greater (Area 3), and

    d. other specified areas.

    The designer will be responsible for determining the size of the area to be seeded at each rate using computer generated data or manually calculated computation sheets. The number of acres (hectares) in Area 1 that require seeding are calculated as follows:

    Area 1 = R/W - Area 2 - Area 3 - Surface Area

    Where:

    R/W = The total area inside the new right-of-way
    Surface Area = (Finished top width) x (length of project)

    No fertilizer is required for Area 3.

3. Recording Quantities. Record the seeding areas in the Topsoil and Seeding Frame. The seeding areas should be recorded as follows:

    a. Present the number of separate acres (hectares) for areas on slopes of 3:1 or flatter, areas on slopes steeper than 3:1, the 15’ (4.5 m) wide strip adjacent to the edge of pavement and for other areas defined in the seeding recommendations.

b. For Area 1 and Area 3 seeding conditions, provide areas of seed bed conditioning in hectares. Mulch, in acres (hectares), is generally provided for Area 2 conditions.

5.5.5 Fencing

Section 18.3 and the MDT Detailed Drawings present the Department criteria for the design and placement of fencing. For quantity estimating, consider the following guidelines:

1. Fence Types. Section 18.3 presents the most common fencing types used by the Department. Refer to the right-of-way agreements to determine the type of fence required. Fencing is typically measured to the nearest foot (0.1 meter). The length of fence does not include cattle guard, gates or other openings. These items are paid for separately.

2. Temporary Fencing. The length around the construction permit areas should be used to determine the quantity of temporary fence.

3. Panels. See Figure 18.3A to determine the type and number of fence panels that should be used with a run of fencing.

4. Deadman. For estimating purposes, include the following number of deadmen per kilometer of fence based on the type of terrain:

   a. flat terrain — 2 deadman per mile (1 per kilometer) of fence
   b. rolling terrain — 5 deadmen per mile (3 per kilometer) of fence
   c. rough terrain — 8 deadmen per mile (5 per kilometer) of fence

5. Gates. Most gates used by the Department should be measured in 2’ (0.6 m) increments.

6. Recording. Include all fencing quantities in the Fencing Frame. List the fence lengths for the left side of the roadway from the beginning station to ending station, and then for the right side from beginning to ending station. Terminate the stationing at each parcel (R/W Agreement), change in fence or post type, gates, cattle guards, or other openings. In general, the length of fence can be determined by subtracting stationing. Lateral fences, winged fences and sharp R/W breaks should be scaled to determine fence lengths. Also include the following information in the fencing summary:

   a. The "FENCE TYPE" column heading should include the post designation (e.g., F4M, F4W) where:

M = metal posts
W = wood posts

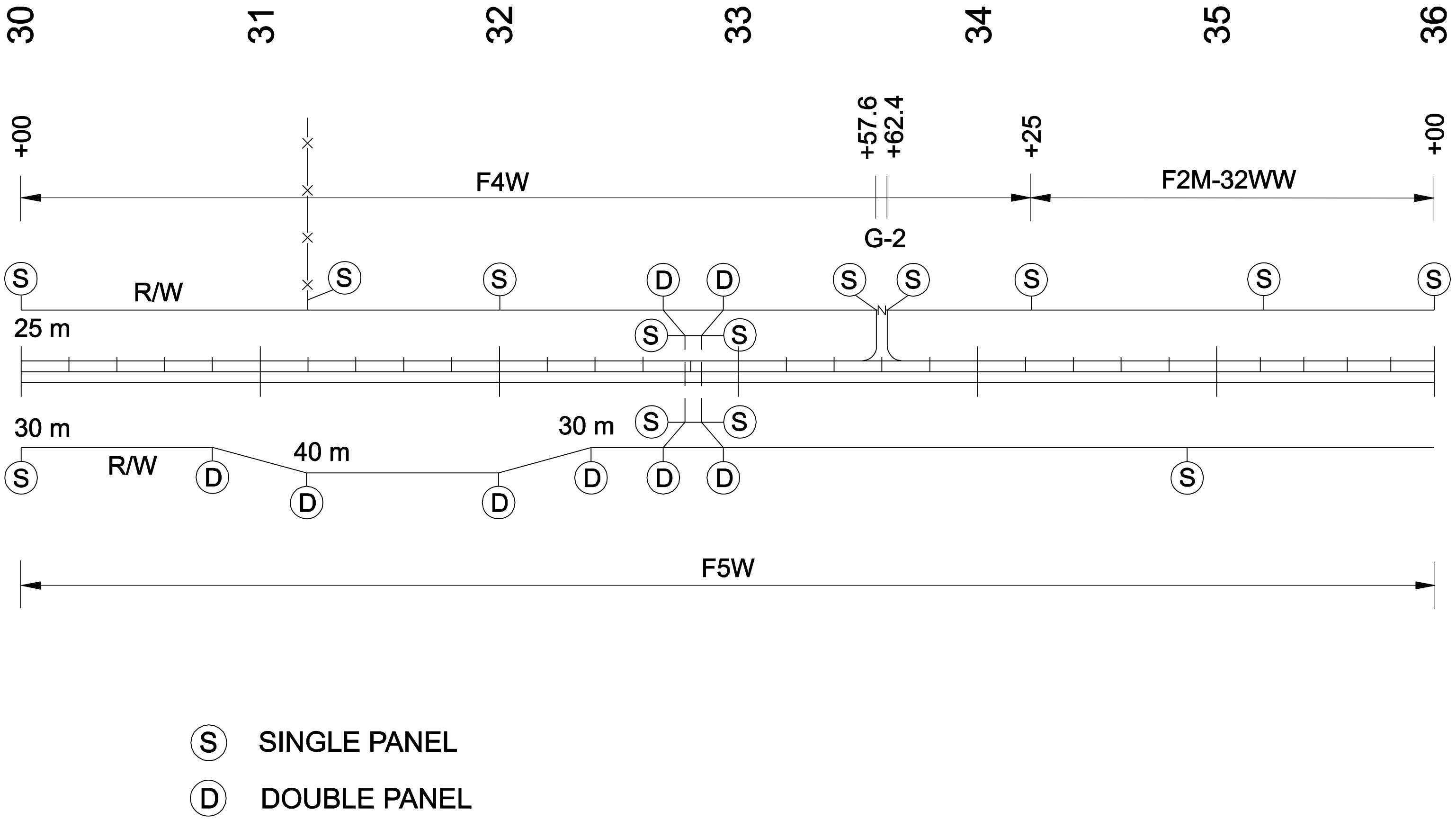
b. Call out the gates by station at each end of the gate and list them according to type.

c. Show totals only for temporary fence and deadmen.

7. Fencing Plans. If requested by the District, prepare fencing plans on a set of full size, white prints of the R/W plans. Figure 5.5B shows how the fencing plans should be prepared. Do not include the fencing plans in the contract package, but transmit them to the District at the time of the project letting.

5.5.6 Cattle Guards

Section 18.9 and the MDT Detailed Drawings present the Department criteria for the design and placement of cattle guards. For quantity measurements, note that cattle guards are available in two standard sizes: 10’ x 8’ (3.05 m x 2.44 m) and 12’ x 8’ (3.66 m x 2.44 m). For most roadways, two 12’ x 8’ (3.66 m x 2.44 m) cattle guards will provide an adequate design. In all cases, extend the cattle guard fully across the finished surface width, including finished shoulders. Itemize the number of cattle guards in the Cattle Guard Frame.



SAMPLE FENCING PLAN

Figure 5.5B

5.5.7 Concrete Slope Protection

Design concrete slope protection, used for bridge end slopes, as shown in the *MDT Detailed Drawings*. Estimate quantities of concrete slope protection in square yards (square meters) of concrete rounded to the nearest 0.1 sq yd (0.1 m^2).

5.5.8 Detours

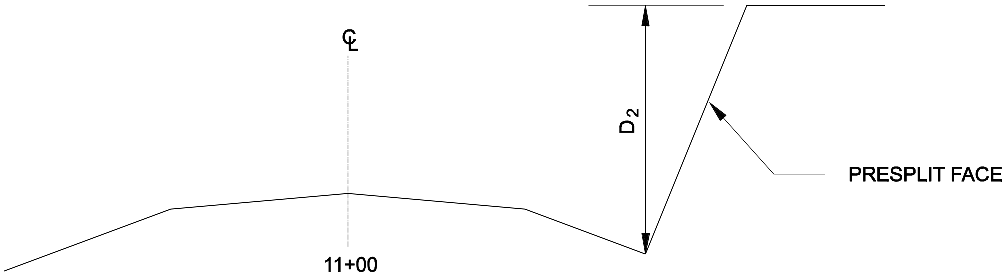
During the construction of a project, a detour often is constructed, maintained and removed. Provide sufficient details for all detours on a project. The details include the plan and profile of the detour, the typical section of the detour, the design speed of the detour and a list of the components and quantities necessary to construct the detour. The quantities are for informational purposes only. The construction, maintenance and removal of the detour will be paid as a lump-sum bid item. Section 4.4 provides an example of a detour detail. Include the detour typical section with the project typical sections.

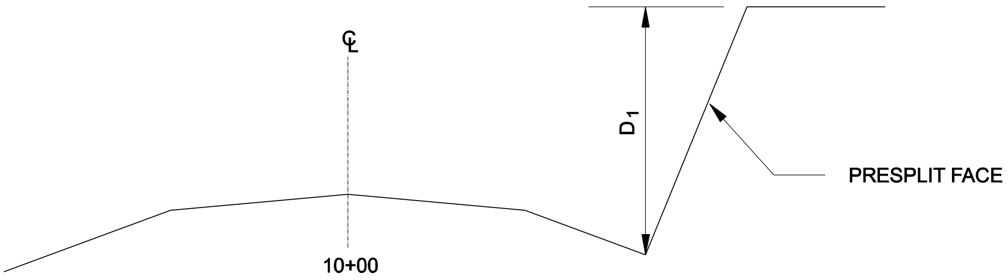
Waterway openings for detours will consist of recommendations from the Hydraulics Section for a specific drainage structure (e.g., pipes, bridge), or a statement in the special provisions that the contractor will provide an adequate waterway opening for the detour. Include the cost of any required drainage structures in the lump-sum bid for "Construct, Maintain and Remove Detour."

5.5.9 Pre-Splitting Rock Slopes

Pre-splitting rock cuts is used to produce a continuous or semi-continuous fracture between drill holes and a stable rock cut, and to eliminate overbreak in the backslope during primary blasting. Pre-splitting rock cut to a smooth plane is achieved by detonating evenly spaced holes prior to detonation of the production holes. Pre-splitting rock cuts will be recommended by the Geotechnical Section, if needed.

Drill pre-splitting holes are measured by the foot (meter) for each hole. The measurement is made from the rock surface to the roadway grade or to a predetermined bench elevation; see Figure 5.5C. A 30” (765 mm) interval is used to estimate the number of drilling pre-splitting holes. Record the computed length of holes in the Drill Pre-Splitting Holes Frame.





Calculate presplitting as follows:

$\frac{D_1 + D_2 + \dots}{N} xL = m^2$ Area of rock face (US Customary use the same equation and the answer is in square feet)

$\frac{m^2}{0.765}$ =Total length of presplitting holes US Customary equation is $ft^2/2.5$ = length

Where:

$D_1, D_2, ect. \rightarrow$ = depth of presplit on each cross section

N = number of cross sections

L = horizontal length of presplit area

PRESPLITTING ROCK SLOPES

Figure 5.5C

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Six

SPECIFICATIONS/SPECIAL PROVISIONS/DETAILED DRAWINGS

Table of Contents

Chapter Six

SPECIFICATIONS/SPECIAL PROVISIONS/ DETAILED DRAWINGS

Chapter Four presents the Department's procedures for the preparation of construction plans. In addition, contractors, material suppliers, and Department personnel assigned to supervise and inspect the construction of the project use the *Standard Specifications for Road and Bridge Construction* (Standard Specifications), Supplemental Specifications, Special Provisions and the *MDT Detailed Drawings* to assist them in the project design and construction. The *Montana Public Works Specifications* may also be utilized, particularly for urban projects and projects involving water lines and sanitary sewers. Chapter Six describes the purpose of these other documents. Chapter Six also presents the guidelines for preparing Special Provisions.

6.1 GENERAL

6.1.1 Hierarchy of Importance

The *Standard Specifications*, Supplemental Specifications, *MDT Detailed Drawings*, Special Provisions and construction plans all are essential parts of the contract. They are intended to complement each other and are used to describe and provide complete instructions for the work to be accomplished. If a discrepancy does exist between these documents, the following presents the hierarchy of importance among them:

1. Special Provisions
2. Construction plans
3. Supplemental Specifications
4. *Standard Specifications*
5. *MDT Detailed Drawings*

6.1.2 Specifications

6.1.2.1 *Standard Specifications for Road and Bridge Construction*

The *Standard Specifications for Road and Bridge Construction* (Standard Specifications) are standards adopted by the Department for work methods and materials that are used for construction. The Standard Specifications are intended for general use on all projects. They provide the Department's criteria for:

1. bidding,
2. awarding of the contract,
3. the contractor's duties,
4. controlling the material quality,
5. the contractor and the Department's legal requirements,
6. executing the contract, and
7. measuring and paying for contract items.

The *Standard Specifications* are published in book form and are typically updated and reprinted every five to seven years. Copies of the Standard Specifications can be obtained from the Contract Plans Bureau.

A Standard Specification Revision Form must be submitted for all proposed changes to the *Standard Specifications* and addressed to the Construction Administration Services Bureau for evaluation and action.

6.1.2.2 Supplemental Specifications

Supplemental Specifications are additions, deletions and/or revisions to the *Standard Specifications* that have been adopted by the Department since the last printing of the *Standard Specifications*. The intention is that they will be incorporated into the *Standard Specifications* at the next revision. As indicated in Section 6.1.1, Supplemental Specifications supersede the *Standard Specifications*. Complete sets of Supplemental Specifications are added to the contract documents for all projects and are intended for general use.

Supplemental Specifications are typically updated and reprinted in their entirety every two months. Copies of the latest versions can be obtained from the MDT Internet Web page (Contractor's System) or Contract Plans Bureau.

A Standard Specification Revision Form must be submitted for all proposed changes to the Supplemental Specifications and addressed to the Construction Administrative Services Bureau for evaluation and action.

6.1.3 Special Provisions

Special Provisions are additions or revisions to the Standard Specifications and the Supplemental Specifications setting forth conditions and requirements for a special situation on a particular project. Special Provisions are included in the contract documents for that project and are not intended for general use. Special Provisions supersede all other contract documents. The designer prepares them for inclusion into the project documents. The special provision should also include the appropriate Section number from the Standard Specifications (e.g. COLD MILLING [411]). Note that the section number is in brackets rather than parentheses. Section 6.2 discusses guidelines for preparing Special Provisions.

Standard Special Provisions are special provisions that are commonly applicable to many projects. The Contract Plans Section has compiled a list of standard special provisions for road and bridge items. This list is routinely updated and can be obtained from the Contract Plans Bureau. The designer is responsible for calling out the number and title of the standard special provisions that apply to road design items (e.g., No. 401-10 Fog Seal). Standard special provisions that require modification will have an "m" located after the date of initiation or revision. (e.g. 108-14 Sequence of Operations Revised 5-5-03 m). The designer should not send the text of the Standard Special Provision unless it contains revisions. The revisions should be highlighted. The designer must ensure that they are applicable for the particular project before their inclusion in the contract document.

6.1.4 MDT Detailed Drawings

The *MDT Detailed Drawings* provide details on various design elements that are consistent from project to project (e.g., guardrail, fencing, drainage details). They provide information on how to layout or construct the various design elements. A copy of the *MDT Detailed Drawings* is provided to the contractor upon request.

Note that the first three numbers of the detailed drawing number are coordinated with the *Standard Specifications*. For example, Detailed Drawing #606-05 "Metal Guardrail" is referenced to Section 606 "Guardrail, Median Barrier Rail and Guide Post" in the *Standard Specifications*.

Hard copies of the *MDT Detailed Drawings* can be obtained from the Contract Plans Bureau. In addition, all drawings are provided on the Department's CADD system. Users can download and review the drawings on the MDT Intranet or MDT Internet Web page (Contractor's System). However, the designer will be unable to make changes to these files. The Contract Plans Bureau will provide updated hard copy versions on an as-needed basis. All proposed changes to the *MDT Detailed Drawings* must be addressed to the Construction Administrative Services Bureau for evaluation and action.

6.2 SPECIAL PROVISION PREPARATION

Special provisions are required whenever a project contains work, material, sequence of operations, or any other requirements that are necessary for the completion of the project but are not "described completely" in the construction plans, *Standard Specifications*, Supplemental Specifications or the *MDT Detailed Drawings*. "Described completely" should be interpreted to mean that the prospective bidder will be able to clearly understand the work to be accomplished, type of materials or equipment required, construction methods or details to be used, how the item of work will be measured, and the basis of payment. The following sections provide guidelines for preparing special provisions.

6.2.1 Preparation Steps

Do not prepare special provisions using the "cut-and-paste" method. Instead, the designer should use the following steps when preparing a special provision:

1. Define Need. Review existing specifications, detailed drawings or construction plans to ensure that there is a need for the special provision. If the topic is not adequately covered in one of the other contract documents, only then should a special provision be prepared.

2. Research. Research the topic so that complete and detailed information is available before writing the special provision. This may require contacting manufacturers, contractors or suppliers for the latest information. Local conditions and problems should also be fully investigated.

3. Format. Prepare special provisions in the same manner as the *Standard Specifications*. Section 6.2.2 presents the format that should be used.

4. Type. Analyze the type of construction to be covered in the special provision to determine the type of special provision to be used. There are two basic types of special provision presentations — material or method presentation, and performance or end-result presentation. The material or method presentation describes the procedure or materials that should be used to construct the element. The performance presentation describes the end result of construction. The types of procedures and materials to achieve the end result are at the contractor's discretion. Only use one or the other form of presentation. The performance specification is preferred when applicable over the material or method specification.

5. Develop Outline. The outline should cover the basic requirements of the work to be completed or the materials to be used. It should define the essential physical characteristics of the material or work (e.g., dimensional limitations, time, strength, weight, size, shape, configuration). Organize all relevant factors under each appropriate heading.

6. Writing the Special Provision. Once the outline has been developed and all research has been completed, the first draft can then be prepared. The designer may want to review existing Special Provisions for guidance. The following presents several grammatical recommendations for preparing special provisions:

    a. Wording. Write the special provision in the active voice (sentence begins with a verb) and the imperative mood (sentence expresses a command).

       Active Voice: "Apply rubbed finish to exposed surface."

       Passive Voice: "Rubbed finish shall be applied to exposed surface."

    b. Sentences. Prepare the special provision using simple language and words. Keep words and sentences short (20 words or less), unless complexity is unavoidable.

    c. Paragraphs. Limit paragraphs to 3-4 sentences.

    d. Terminology. Words should be used consistent with the bid item and their exact meaning. Use the same word throughout; do not use synonyms. Avoid any words which have a dual meaning. Section 6.2.4 presents the recommended terminology that should be used. Omit extraneous words and phrases.

    e. Will. The term "will" is reserved to describe actions to be performed by the Department.

    f. Pronouns. Avoid the use of pronouns, even if this results in frequent repetition of nouns.

    g. Punctuation. Carefully consider punctuation using the minimum number of punctuation marks consistent with the precise meaning of the language. Ensure that there can be no doubt on the meaning of any sentence.

    h. Parentheses. Avoid the use of parentheses (). Instead, use commas or rewrite the sentence.

   i. Numbers. It is usually unnecessary to write numbers both in words and figures (e.g., “Use four (4) 1” (25 mm) bolts.”. Write numbers less than or equal to ten as words. Write numbers higher than ten numerically. When writing U.S. Customary dimensions, use fractions (e.g., ½ “, 1/8 “) and/or numerals (e.g., 0.20 ‘, 10.00 ‘, 1.7 gallons), for Metric (e.g., 5 mm, 3.0 m, 6.5 L). Do not write 2 “ x 4 “ (50 mm x 100 mm), but 2 “ by 4 “ (50 mm by 100 mm). Times and dates should be written numerically. Write fractions for metric as decimals. Decimals less than one should be proceeded by the zero e.g., 0.02 ‘(e.g., 0.02 mm).

7. Reviewing. Review previously completed paragraphs as succeeding ones take shape. Where necessary, redraft preceding paragraphs to reflect later thoughts.

   The designer should prepare and distribute the preliminary draft of the special provisions for review and comment at the Plan-in-Hand. The designer will be responsible for incorporating the reviewers' comments into the final draft. The final draft will also be distributed for comment at the final plan review.

8. The designer should coordinate with other units to ensure that special provisions are not duplicated (e.g., “Detour” or “Traffic Control and Sequence of Operations” written by both the Bridge Bureau and the Road Design Section). Where this occurs, combine the information into a single special provision that meets the needs of the project.

9. Presentation. Present special provisions as follows:

   a. Type special provisions specific to a project in Word format. Store these files in the Document Management System and include them in submittal to Contract Plans Bureau.

   b. Type standard special provisions that are modified in the Word format with the changes in bold type. When modifying a standard special provision, other than addition to active field information, delete the revision date from the title.

   c. Identify standard special provisions that are used without modification by their title and number. Identify only those special provisions that apply to road design items.

6.2.2 Format

Prepare special provisions in the active voice and in the same format as the *Standard Specifications*. The sections of the special provision that should be addressed include:

1. Description. Describe the work to be performed, with references to specifications, plans or other special provisions that further define the work. Where necessary or desirable for clarity, describe the relationship of this work item to other work items or other phases of construction.
2. Materials and/or Equipment. Designate the materials and/or equipment to be used in the work item and establish its requirements. Delineate complete specifications of the properties of each material and the method of tests. References may be made to AASHTO, ASTM or other recognized specifications.
3. Construction Details. Describe the sequence of construction operations or the desired end product. Do not mix the two types of presentations as described in Section 6.2.1. Where practical, use the performance presentation. This will permit the contractor to use improved equipment and new and advanced ideas in construction methods. Only use the presentation for the sequence of construction operations if it is critical to achieving the desired result. Specify quality control and quality assurance requirements, and specify who is responsible for testing.
4. Method of Measurement. Describe the components of the completed work item that will be measured for payment, the units of measurement and whether measured in original position, in transporting vehicles or in the completed work. Designate any modifying factors and other requirements needed to establish a definite, measured unit (e.g., disturbed or undisturbed, temperature, waste, etc.).
5. Basis of Payment. Describe the units for which payment will be made, and define the scope of work covered by such payment. Ensure consistency with the bid items.

6.2.3 Guidelines

In addition to Sections 6.2.1 and 6.2.2, the following presents several guidelines the designer should consider when developing special provisions:

1. Completeness. When developing the special provision, ensure that the essentials have been included and that each requirement is definitive and complete. The special provision should not be vague.

2. Clarity. To ensure the special provision is clearly presented, review the following:

   a. Clearly delineate the method of measurement and payment.

   b. Make a clear, concise analysis of the job requirements for general conditions, types of construction and quality of workmanship. Do not leave the bidder in doubt, as the contractor, on what will be required.

   c. Give directions, never suggestions.

   d. Never assume the engineer or contractor “knows” what is meant.

   e. Do not use phrases such as “as approved by the engineer,” “at the discretion of the engineer,” or “as directed by the engineer” in place of definite workmanship requirements. Such phrases may lead to confusion or misunderstanding. The contractor may not know what the engineer is thinking.

   f. Avoid conflicting or ambiguous requirements. Every specification should have only one meaning.

   g. Never conceal difficulties or hazards from the contractor.

3. Conciseness. Write each special provision as concise as practical. When reviewing the special provision, consider the following suggestions:

   a. Avoid duplications between the special provision and any related contract documents.

   b. Do not give reasons for a specification requirement.

   c. Do not provide additional information that is unnecessary for the preparation of bids and the accomplishment of the work.

   d. Once stated, do not repeat any instruction, requirement, direction or information given elsewhere in the contract documents.

   e. Do not include mandatory provisions that are required in general by the contract.

   f. Minimize the use of cross references.

   g. Write the specification in the positive form.

4. Correctness. To ensure that the special provision is written correctly, review the following:

   a. Where practical, independently crosscheck every factual statement.

   b. Do not include items that cannot be required or enforced.

   c. Ensure that the specification does not punish the contractor or supplier.

   d. Ensure that the specification does not unintentionally exclude an acceptable product, construction method or any equipment. If suppliers/products are specified in the provision provide at least 3 suppliers/products. Listing one supplier/product and adding “or approved equal” is not acceptable

   e. Ensure that the provision does not change the basic design of the item.

   f. Do not specify impossibilities. The practical limits of workmen and materials must be known and recognized.

   g. Specify standard sizes and patterns wherever practical.

   h. Avoid personal whims and pet requirements.

   i. Ensure that the contractor will not be held responsible for the possible inaccuracy of information furnished by the Department.

   j. Ensure that sufficient attention has been provided to assessing the durability or reliability of the material or procedure discussed. The use of permanent and recognized standards should be quoted to ensure that the specified performance or characteristics are achieved. If not, the testing criteria should be completely and accurately defined.

   k. Make a careful, critical examination of manufacturers' or trade associations' recommendations, and require supporting evidence before adopting them.

   l. Keep requirements stringent. A strong requirement can be relaxed more economically, when the need arises. Weak specifications cannot be strengthened without increasing cost and generating claims.

   m. Ensure that the provision gives directions that are consistent with the standard practice currently used by the Department.

6.2.4 Terminology

1. Abbreviations. Generally, avoid abbreviations. However, they may be used if they are defined and the definitions are consistent with the accepted meanings.

2. Amount, quantity. Use “amount” when writing about money only. When writing about measures of volume, such as m^3, liters, etc., use “quantity.”

3. And/or. Avoid using “and/or”; instead, use “and” alone, or “or” alone, or “or ... or both.” For example, “Unless otherwise specified by the plans or special provisions or both,…”.

4. Any, all. The word “any” implies a choice and may cause confusion. Use the term “all” in place of “any.” For example, “Make good all defects.”

5. As per. Do not use “as per”; instead, use “as stated,” “as shown,” “conforming to,” or other similar phrases.

6. At the contractor's expense. Do not use the phrase “at the contractor's expense”; instead use, “at no cost to the Department” or “absorbed in the cost of other contract items.”

7. Balance, remainder. Use the term “balance” when referring to money. Use “remainder” to describe something or material left over.

8. Coarse, course. Use “coarse” to describe textures and “course” for layers.

9. Conform. Use the word “conform” to refer to dimensions, sizes and fits that must be strictly adhered to (e.g., “cut bolt threads conforming to ASA Standards, Class 2 fit, coarse thread series”). Where a better product is acceptable, use the phrase “meeting the requirements of...” (e.g., aggregates meeting the specification requirements when tested in accordance with AASHTO T27.)

10. Contractor. Use the word “contractor” in place of the word “bidder” when writing special provisions for construction. Only use “bidder” for proposals.

11. Or equivalent. Use this phrase for only minor parts. The contractor may not know what is truly equivalent before awarded the contract. It is better to clearly specify those things that will be accepted as “equivalent.”

12. Proposal. Do not use the word “proposal” when the word “contract” is intended. Only use “proposal” to describe requirements during the bidding process.

13. Resisting, resistant. Do not use "corrosion-resisting," but instead use, "corrosion-resistant."

14. Said. Do not use "said pipe," "said aggregates" but instead, use "this pipe," "these aggregates."

15. Same. Do not use "same" to replace a pronoun like "it" or "them" standing alone, such as "connected to same," "specified for same," "same will be given consideration," "conforming to requirements for same." Rewrite the sentence to clearly describe what is meant.

16. Shall, will. Do not use "shall." Use "will" to describe actions performed by the Department.

17. Such. Do not end a sentence with the word "such." "Such" usually means "of this or that kind," or similar to something stated. Instead, state that which is actually meant, or name the work to be completed or rephrase the sentence.

18. Symbols. Do not use the following symbols when writing special provisions:

Symbol	Write Instead
/	per, or "a"
Xº	ºF or degree Fahrenheit
%	percent
+	plus
-	minus
x	by

19. The. Do not eliminate "the" for brevity.

20. Thoroughly. Avoid using the adverb "thoroughly," as in thoroughly wet, thoroughly dry, thoroughly clean, etc., as it is unenforceable. Preferably, state the value of the intended requirements in percent, dimensions, number of passes, etc.

18 October 2016

MONTANA DEPARTMENT OF
TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Seven

CONSTRUCTION COST ESTIMATES

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Section **Page**

Chapter Seven

CONSTRUCTION COST ESTIMATES

Chapter Five presents the Montana Department of Transportation procedures for the preparation of quantity summaries. The Department and contractors use these quantities to determine the cost for construction of the project. Chapter Seven provides information on the various pre-construction cost estimates required during project development and the procedures for developing these estimates.

7.1 PROJECT ESTIMATES

Project estimates are used by Fiscal Programming and the districts to develop the 5-year Tentative Construction Plan (TCP - Red Book) to ensure that sufficient funds are available for construction. The TCP is MDT's best estimate of when projects will be let and what the costs will be. The Engineering Division uses the TCP to prioritize project design. Accurate cost estimates ensure that designers are working on the appropriate projects. If cost estimates are too low, there won't be enough money to fund all of the designed projects. As a consequence, resources will be focused on projects that can't be let to contract until the next fiscal year. If cost estimates are too high, the TCP will under-estimate the number of projects designed for the fiscal year. This could result in hurried designs or even the loss of federal funding.

During project development, several cost estimates are prepared to determine and refine the expected project construction costs. The following presents the various cost estimates that are prepared during project development and who is responsible for preparing each estimate. Figure 7.1A provides the recommended distribution list for each of these cost estimates. The estimate is included in the distribution of the reports listed below. Figure 7.1B provides the format for showing the project estimate in the PFR, AGR and SOW reports. Detailed itemized estimates should be included in the PIH and FPR reports. Cost estimates are developed at the following project stages:

1. Project Programming/PFR. The District Office is responsible for nominating projects to be included on the Department's Program of Projects. When the District Office submits these nominations, they are also required to submit a rough cost estimate for each project. This estimate is typically revised after the Preliminary Field Review when a more detailed evaluation can be made of project issues using input from all the technical areas. Some common methods for estimating costs before quantities are available are listed below. More than one method can be used to compare for more confidence. Use the highest level of estimating possible, document all assumptions, and provide a written estimate.

a. Cost per mile. Use similar projects in region that were let in the past 6 months – year. Be sure to consider additional items and add estimated amounts appropriately. Some of the items to be considered are listed below:

    1) Guardrail
    2) ADA ramps, curb and gutter, sidewalk work
    3) Storm drain
    4) Large culverts, irrigation facilities
    5) Traffic signals, lighting
    6) Turn bays, other isolated widening
    7) Bridge work
    8) Retaining structures
    9) Wetland mitigation, wildlife crossings, wildlife fencing, etc.
    10) Constructability issues
    11) Pavement markings, signing
    12) Traffic control issues

b. Cost per square yard from the current Pavement Condition and Treatment report published by the MDT Pavement Analysis Section. Determine the project area and multiply by the appropriate cost/yd^2 taken from the cost trend table.

c. Estimated quantities – estimate quantities for the major bid items. Consider the proportion of the project that the major items comprise and increase cost accordingly. Consider additional items from list above.

d. Cost Estimation module from HEAT program – update into current bid estimate sheet. Consider additional items listed above that aren’t accounted for in module input.

e. Similar project comparison – for small, specialty projects. Compare to similar projects that were let recently and adjust for differences in project scope, regional cost variations, constructability issues, etc.

f. Contingency is an unintended or unlikely event that may occur for which project funds should be allocated, while risk is the possibility of suffering harm or loss. Contingency should be considered in quantifiable and non-quantifiable outcomes; costs can be assigned to the known issues, and contingency is assigned to the identified issues that will likely occur with unknown costs. Risks are assigned to issues that are identified that may occur or to issues that have not yet been identified. Contingency and risk depend on scope of project and known/unknown conditions. Given a thorough field review that includes consideration and discussion of the potential issues, contingency should be 10% to 25%.

2. Alignment and Grade Review/Report. The designer is responsible for determining the first detailed construction cost estimate at this stage of project development. For projects over $12 million, a cost estimate team should be convened to review the known and unknown issues and the probabilities for risk issues. Do not use the initial project estimate developed by the District Office. The major items including grading, surfacing, and large drainage facilities can be estimated more accurately. Costs for individual bid items should be adjusted based on past bid history and individual item contingency or risk. This estimate should be determined using the following:

   a. Cost estimate spreadsheet – estimate quantities for the major bid items. Major bid items are those items that make up 65% to 85% of the total project cost.
   Add costs for the items from list above that haven't yet been designed. Consider the proportion of the project that the major items comprise and increase cost accordingly. Get estimates from the other technical sections for specialty issues.

   b. Cost per mile or similar project comparison. This should be used with discretion at this stage. Cases that may require this method would include projects with alternate alignments.

   c. Contingencies depend on scope of project and known/unknown conditions: 10% - 25%

   d. Consider potential constructability issues, and the potential unknown factors that may arise.

   e. Inflation should be based on the project schedule from OPX2 and TCP: determine the realistic amount of time remaining to complete the project design and add time for letting. Take to the midpoint of construction.

   f. Specific Items. The designer should contact the Bridge Bureau to determine the estimated cost for large bridges within the project limits. These estimates are typically based on the sq. ft. (m2) of bridge surface. The Traffic Engineering Section will be responsible for providing a preliminary estimate if special elements such as signalization, extensive lighting or other permanent traffic control devices are included in the project.

g. Traffic Control should be based on similar projects in the district. Nationwide studies have found no correlation between traffic control costs and total project costs; therefore, percentage based traffic control should not be used.

Distribution	Programming Project	Alignment And Grade Review/ Report	Scope of Work Report	Plan-in-Hand Report	Final Review Report	Designer's Final Estimate
Rail, Transit and Planning Division	**X**	**X**	**X**			**X**
District Administrator(s)	**X**	**X**	**X**	**X**	**X**	**X**
Engineering Information Services Section — Engineering Division	**X**					**X**
Contract Plans Section						**X**
Secondary Roads Engineer — (STPS, SFCS Projects Only)	**X**	**X**	**X**	**X**	**X**	**X**
Urban Section — (Urban Projects Only)			**X**	**X**	**X**	**X**
Project Files	**X**	**X**	**X**	**X**	**X**	**X**
Fiscal Programming	**X**	**X**	**X**	**X**	**X**	**X**

COST ESTIMATE DISTRIBUTION
Figure 7.1A

3. Scope-of-Work Report. If a project does not have an Alignment and Grade Review, the designer will develop the first construction cost estimate which will be included in the Scope-of-Work Report. Prepare this estimate in a similar manner as discussed in Comment #2 for the Alignment and Grade Review. If an estimate was prepared for the Alignment and Grade Review, it will generally not be necessary to update the estimate for the Scope-of-Work Report.

4. Plan-in-Hand Report. The designer is responsible for updating the construction cost estimate for the Plan-in-Hand. At this stage of project development, the majority of the project quantities should be available. Section 7.2 describes the procedure that should be used to develop the cost estimate based on these project quantities. The Bridge Bureau and the Traffic Engineering Bureau will be responsible for providing the road designer with their cost estimates for bridge elements and permanent traffic control devices (e.g., signing, pavement markings, lighting, signalization), respectively. Consider potential constructability issues, and the potential unknown factors to arise. These should all be discussed in depth at the PIH review. The designer should use the following tools to accurately estimate the cost of the project:

   a. Cost estimate spreadsheet – estimate quantities for the all bid items. Include cost estimates from other design areas. Bridge costs, structural walls, landscaping and associated irrigation, signing and pavement markings, electrical items, and traffic control should be included. Discuss the cost estimate at the PIH review, spending time on the critical items and the impact of constructability issues on costs.

   b. Decision Support System (DSS)module – use the bid history to refine bid prices for regional and availability factors.

   c. Estimator can be used with discretion as a check on the cost estimate.

   d. Contingencies should be low, based on the level of known conditions: 5% - 10%

   e. Inflation should be based on the project schedule from OPX2 and TCP: determine the realistic amount of time remaining to complete the project design and take to the midpoint of construction.

   f. Traffic Control should be discussed thoroughly at the PIH review. Costs can be assigned.

5. Final Review Report. The construction cost estimate for the Final Review generally will only need to be an update of the estimate from the Plan-in-Hand.

The Bridge Bureau and the Traffic Engineering Section should provide the road designer with their updated cost estimates for bridge elements and permanent traffic control devices on the project.

6. Project Scope Changes. Whenever the scope of the project changes, the designer will be responsible for determining a new construction cost estimate. Estimates for scope of work changes are typically based on general quantities and are determined as discussed in Comment #2.

7. Final Plan Review Report. The Plan Checker will review the designer's final estimate.

8. Engineer's Estimate. The Engineer's Estimate is developed by using the final estimates from the various Sections and Bureaus involved with the project. The Contract Plans Bureau will be responsible for collecting and distributing the various units' final cost estimates to the Board of Review. The Board of Review includes representatives from the Construction Bureau, Road Design Section, Pavement Design Section and Contract Plans Bureau. The Board of Review will review and adjust the major bid item prices as deemed necessary. These items typically may include excavation, aggregate surfacing, plant mix surfacing, asphalt milling, erosion control, mobilization and miscellaneous work. The Contract Plans Bureau will review all other bid prices and prepare the Engineer's Estimate.

    Use the following format for showing the cost estimate in the report:

New Structure	$132,000
Remove Structure	$ 10,000
Road Work	$ 82,000
Traffic Control - Detour	$ 77,000
Subtotal	$301,000
Mobilization (12%)*	$ 36,000
Subtotal	**$337,000**
Contingencies (10%)*	$ 34,000
Subtotal	$371,000
Inflation (3% per year x 3 years)	$ 34,000
Total CN:	**$405,000**
CE (15%)*	**$ 61,000**

Cost Estimation Format

Figure 7.1B

7.2 ESTIMATING PROCEDURES

When preparing a detailed cost estimate for the Plan-in-Hand or later estimates, the designer should note the following:

1. Funding Splits. Some projects may have two or more funding sources. For example, where bridges comprise a substantial percentage of the total project, they may be funded separately under their own project coding. For these types of projects, separate cost estimates are required for each funding source based on the quantities within that particular funding source. The separation of quantities for funding splits will be determined during the project development.

2. Estimate Form. The Department has developed two estimating forms that the designer should use to determine the construction cost estimate — a manual form and an electronic form. Desirably, the electronic form will be used. The electronic form was developed using Excel. A copy of this program and instructions on how to use it are provided in each of the design units, or a copy can be obtained from the Road Design Section.

3. Quantities. Show all project quantity estimates on the Summary Sheets within the contract plans. Some estimate items maybe shown as information purposes only. Do not include these items in the cost estimate. Those totals from the appropriate summary frames are used in determining the cost estimate. Note that some summary frame totals are added to other frames (e.g., Additional Surfacing Frame totals are added to the Surfacing Frame). Therefore, the designer must be careful not to double count these quantities. Some items may have quantities shown in more than one frame. Combine these quantities when computing the cost estimate. See Chapter Five for information on how to develop quantity summaries.

4. Unit Prices. List the quantity items from the Summary Sheets and the appropriate average bid unit prices on the estimate form. The Contract Plans Section provides the average bid unit prices twice a year. The designer will then submit the estimate form to the District for their review. The District will incorporate their recommended unit prices on the estimate form. The District's review of similar projects should be used to aid in determining the adjusted unit prices.

5. Inflation Factors. Adjust all estimates by an annual inflation factor. Apply the inflation factor using the following formula:

Adjusted Estimate = (Estimate) x (1+i) n

Where: I = inflation factor The typical inflation factor is 3% (i = 0.03).

n = the number of years from the time the estimate is prepared to midpoint of construction (consider the potential for project design time slippage),
to the project ready date

Pavement preservation – 1 year (2 years for urban settings with ADA work)
Minor rehabilitation – 2 years
Major rehabilitation – 3-4 years
Reconstruction – 5-6 years
Bridge replacement – 4-5 years
Turn bay or spot improvement – 2-4 years

6. Quantity Descriptions. Only use the quantity description as provided in the average bid unit prices for the quantity description on the estimate form.

7. Lump-Sum Items. Desirably, do not use lump-sum items on a project. However, this is not always practical. Where necessary, only use lump-sum bid items where the scope of work for the item is clearly defined and the amount of work has a minimal chance of changing during construction. Section 5.5.1 provides additional information on how to treat lump-sum items. In determining the unit price for lump-sum items, consider the following:

   a. Mobilization. Estimate mobilization using the criteria shown in Figure 7.2A. The mobilization should be adjusted based on input from District construction personnel. The project location, structural work such as bridges and multiple sites can affect the mobilization costs.

   b. Traffic Control. A percentage is used for the preliminary estimates for traffic control until the District in the final estimate establishes quantities for units of traffic control. The final traffic control quantities provided by the District will include separate items for hours of pilot car and hours of flagging. List these items separately on the estimate sheet.

   c. Other Items. Most lump sum bid items can be divided into individual parts for estimating purposes. For example, clearing and grubbing can be divided into the number of hectares cleared or the size and number of trees to be removed. For removal of structures, the cost can be determined based on the m^2 of structures on other projects. Once the elements have been segregated, the designer uses engineering judgment to determine the appropriate cost for the lump-sum bid item on the project.

8. Contingencies and Construction Engineering. When developing the detailed cost estimate, assume a cost for construction contingencies and construction engineering. Calculate contingencies assuming a percentage of all construction items, including bridge items, traffic control devices, etc. The percentage should decrease as the project develops and the quantities become more certain. Use a 15 percent contingency for the initial estimate. Reduce this percentage for the other preliminary estimates and use a 5 percent contingency for the final estimate. Contingencies are not to be used to account for inflation.

   Calculate construction engineering based on the criteria shown in Figure 7.2A. The cost of construction engineering can be adjusted based on input from District construction personnel.

9. Approval and Distribution. The design supervisor must approve all construction cost estimates prepared by the designer. A final estimate must be included with the contract documents when the plans are forwarded to the Contract Plans Bureau. Include copies of the cost estimate to those units or individuals as shown in Figure 7.1A and to the project files.

Project Type	**Mobilization**	**Construction Engineering**
Reconstruction	8%	10%
Reconstruction (Eastern MT)	10%	10%
Single project – 2 lane overlay	15%	8%
Multiple project – 2 lane overlay	10%	8%
Interstate overlay	8%	8%
Urban reconstruction	18%	15%
Bridge and approaches	18%	15%
Signal projects	10%	10%

Mobilization and Construction Engineering
Suggested Rates
Figure 7.2A

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Eight
BASIC DESIGN CONTROLS

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Chapter Eight
BASIC DESIGN CONTROLS

Roadway design is predicated on many basic controls which establish the overall objective of the highway facility and identify the basic purpose of the highway project. Chapter Eight presents these basic controls that impact roadway design. The Chapter includes a discussion on the functional classification system, the Federal-aid system, speed, traffic volume controls, access control, sight distance and the design exception process. The application of these items to a project will impact all elements of road design.

8.1 DEFINITIONS

8.1.1 Qualifying Words

Many qualifying words are used in road design and in this *Manual*. For consistency and uniformity in the application of various design criteria, the following definitions apply:

1. Shall, require, will, must. A mandatory condition. Designers are obligated to adhere to the criteria and applications presented in this context or to perform the evaluation indicated. For the application of geometric design criteria, this *Manual* limits the use of these words.

2. Should, recommend. An advisory condition. Designers are strongly encouraged to follow the criteria and guidance presented in this context, unless there is reasonable justification not to do so.

3. May, could, can, suggest, consider. A permissive condition. Designers are allowed to apply individual judgment and discretion to the criteria when presented in this context. The decision will be based on a case-by-case assessment.

4. Desirable, preferred. An indication that the designer should make every reasonable effort to meet the criteria and that he/she should only use a "lesser" design after due consideration of the "better" design.

5. Ideal. Indicating a standard of perfection (e.g., traffic capacity under "ideal" conditions).

6. Minimum, maximum, upper, lower (limits). Representative of generally accepted limits within the design community but not necessarily suggesting that these limits are inviolable. However, where the criteria presented in this context will not be met, the designer will in many cases need approval.

7. Practical, feasible, cost-effective, reasonable. Advising the designer that the decision to apply the design criteria should be based on a subjective analysis of the anticipated benefits and costs associated with the impacts of the decision. No formal analysis (e.g., cost-effectiveness analysis) is intended, unless otherwise stated.

8. Possible. Indicating that which can be accomplished. Because of its rather restrictive implication, this word will not be used in this *Manual* for the application of geometric design criteria.

9. Significant, major. Indicating that the consequences from a given action are obvious to most observers and, in many cases, can be readily measured.

10. Insignificant, minor. Indicating that the consequences from a given action are relatively small and not an important factor in the decision-making for geometric design.

11. Standard. Indicating a design value which cannot be violated without severe consequences. This suggestion is generally inconsistent with geometric design criteria. Therefore, "standard" will not be used in this *Manual* to apply to geometric design criteria.

12. Guideline. Indicating a design value which establishes an approximate threshold which should be met if considered practical.

13. Criteria. A term typically used to apply to design values, usually with no suggestion on the criticality of the design value. Because of its basically neutral implication, this *Manual* frequently uses "criteria" to refer to the design values presented.

14. Typical. Indicating a design practice which is most often used in application and which is likely to be the "best" treatment at a given site.

15. Target. If practical, criteria the designer should be striving to meet. However, not meeting these criteria will typically not require a justification.

16. Acceptable. Design criteria which do not meet desirable values, but yet is considered to be reasonable and safe for design purposes.

17. Policy. Indicating MDT practice which the Department generally expects the designer to follow, unless otherwise justified.

8.1.2 Acronyms

The following acronyms may be used in this *Manual*:

1. AASHTO. American Association of State Highway and Transportation Officials.
2. FHWA. Federal Highway Administration.
3. HCM. *Highway Capacity Manual*.
4. ITE. Institute of Transportation Engineers.
5. ISTEA. Intermodal Surface Transportation Efficiency Act of 1991.
6. MUTCD. *Manual on Uniform Traffic Control Devices*.
7. NCHRP. National Cooperative Highway Research Program.
8. NHS. National Highway System.
9. STP. Surface Transportation Program.
10. TEA-21. Transportation Equity Act for the 21st Century.
11. TRB. Transportation Research Board.
12. USDOT. United States Department of Transportation.

8.1.3 Project Scope of Work

The project scope of work will reflect the basic intent of the highway project and will determine the overall level of highway improvement.

1. New Construction. New construction is defined as horizontal and vertical alignment on new location.

2. Reconstruction. Reconstruction is defined as work which includes one or more of the following:

   a. full-depth pavement reconstruction for more than 50% of the project length;

   b. reconstruction of the existing horizontal and vertical alignment for more than 25% of the project length; and/or

   c. the addition of through travel lanes.

3. Overlay and Widening. Overlay and widening is defined as work primarily intended to extend the service life of the existing facility by making cost-effective

improvements to upgrade the highway. It may include full-depth pavement reconstruction for up to 50% of the project length and may include horizontal and vertical alignment revisions for up to 25% of the project length. In addition, overlay and widening projects may include any number of the following spot improvements:

a. lane and shoulder widening;

b. converting an existing median to a two-way, left-turn lane (TWLTL);

c. adding a TWLTL;

d. adding a truck-climbing lane;

e. converting an uncurbed urban street into a curbed street;

f. geometric and/or roadside safety improvements;

g. drainage improvements;

h. intersection improvements (e.g., adding turn lanes, flattening turning radii, corner sight distance improvements, etc.).

i. flattening side slopes;

j. revising the location, spacing or design of existing approaches along the mainline.;

k. adding or removing parking lanes; and

l. adding sidewalks;

4. Pavement Projects. This category of projects encompasses a wide variety of surfacing treatments from preventative maintenance to major rehabilitation.

Preventative maintenance includes such treatments as crack seal, seal and cover, milling $\leq$ 0.20’, and overlays $\leq$ 0.20’ (the overlay thickness can be increased to 0.22’ if an isolation lift is need to address heavy crack sealing in the existing surfacing). Rehabilitation includes treatments ranging from designed overlays to Cement-Treated Pulverized Base. The In addition to surfacing, the following items must be considered in the development of pavement projects:

a. Environmental document
b. Guardrail treatment

c. Safety
d. Geometrics
e. Capacity

The level of involvement with these items depends on the scope of the surfacing treatment. Geometrics and capacity are only considered for rehabilitation projects. For more complete information on pavement projects refer to the Joint Agreement between FHWA and MDT titled *Guidelines for Nomination and Development of Pavement Projects*.

8.1.4 Route Segment Plan

The purpose of the Route Segment Plan is to identify and define a consistent pavement width, which will be used when reconstruction or major widening are accomplished on a portion of the route segment. The Route Segment Plan is not intended to prescribe standards for overlay and minor widening projects. It is not intended to prescribe standards for roadway cross sections or construction elements other than the pavement width itself.

8.2 HIGHWAY SYSTEMS

8.2.1 Classification Systems

The *MDT Geometric Design Standards and Route Segment Plans* were approved by the Montana Transportation Commission in 1992. They have been adopted as the design standards for the highway system. These standards correlate to the highway funding categories. Figure 8.2A coordinates the funding classification to the functional classification system. Figure 12-1 of the *Road Design Manual* provides the functional classification of State highways in Montana.

Geometric Design Standards (Funding Classification)	Functional Classification System
NH Interstate	Principal Arterial (Freeways)
NH Non-Interstate	Principal Arterial
STP Primary	Minor Arterial
STP Secondary	Major Collector
Urban	Urban

**FUNDING CLASSIFICATION VERSUS
FUNCTIONAL CLASSIFICATION**

Figure 8.2A

8.2.2 Functional Classification System

The functional classification concept is one of the most important determining factors in highway design. In this concept, highways are grouped by the character of service they provide. Functional classification recognizes that the public highway network in Montana serves two basic and often conflicting functions — travel mobility and access to property. Each highway or street will provide varying levels of access and mobility, depending upon its intended service. In the functional classification scheme, the overall objective is that the highway system, when viewed in its entirety, will yield an optimum balance between its access and mobility purposes. If this objective is achieved, the benefits to the traveling public will be maximized.

The functional classification system provides the guidelines for determining the geometric design of individual highways and streets. These guidelines equal or exceed the geometric design criteria that would be used based on the highway funding category. Once the function of the highway facility is defined, the designer can select an appropriate design speed, roadway width, roadside safety elements, amenities and other design values. The *Montana Road Design Manual* is based upon this systematic concept to determining geometric design.

The Rail, Transit and Planning Division has functionally classified all public roads and streets within Montana. For road design, it is necessary to identify the predicted functional class of the road or street for the selected design year (e.g., 20 years beyond the project completion date). The Rail, Transit and Planning Division will provide this information to the designer.

8.2.2.1 Arterials

Arterial highways are characterized by a capacity to quickly move relatively large volumes of traffic and an often restricted function to serve abutting properties. The arterial system typically provides for high travel speeds and the longest trip movements. The arterial functional class is subdivided into principal and minor categories for rural and urban areas:

1. Principal Arterials. In both rural and urban areas, the principal arterials provide the highest traffic volumes and the greatest trip lengths. Principal arterials can be further subdivided into the following classifications:

    a. Freeways. The freeway, which includes Interstate highways, is the highest level of arterial. These facilities are characterized by full control of access, high design speeds, and a high level of driver comfort and safety. For these reasons, freeways are considered a special type of highway within the functional classification system, and separate geometric design criteria have been developed for these facilities. Unless otherwise noted, Interstate System projects will be designed according to freeway design criteria.

    b. (Other) Principal Arterials. These facilities may be 2 or more lanes with or without a median. In many cases, the level of geometric design is equivalent to that of freeways (e.g., 3.6 m lane widths are required on all principal arterials). Unless otherwise noted, all principal arterials will be designed according to principal arterial criteria, whether or not the facility is on the NHS.

2. Minor Arterials. In rural areas, minor arterials will provide a mix of interstate and interregional travel service. In urban areas, minor arterials may carry local bus routes and provide intra-community connections. When compared to the principal arterial system, the minor arterials accommodate shorter trip lengths and lower traffic volumes, but they provide more access to property.

8.2.2.2 Collectors

Collector routes are characterized by a roughly even distribution of their access and mobility functions. Traffic volumes will typically be somewhat lower than those of arterials. In rural areas, collectors serve intra-regional needs and provide connections to the arterial system. All cities and towns within a region will be connected. In urban areas, collectors act as intermediate links between the arterial system and points of origin and destination. Urban collectors typically penetrate residential neighborhoods and commercial/industrial areas. Local bus routes will often include collector streets.

8.2.2.3 Local Roads and Streets

All public roads and streets not classified as arterials or collectors are classified as local roads and streets. Local roads and streets are characterized by their many points of direct access to adjacent properties and their relatively minor value in accommodating mobility. Speeds and volumes are usually low and trip distances short. Through traffic is often deliberately discouraged.

8.2.3 Federal-Aid System

The Federal-aid system consists of those routes within Montana which are eligible for the categorical Federal highway funds. The Department, working with the local governments and in cooperation with FHWA, has designated the eligible routes. United States Code, Title 23, describes the applicable Federal criteria for establishing the Federal-aid system.

8.2.3.1 National Highway System

The National Highway System (NHS) is a system of those highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate highway system, logical additions to the Interstate system, selected other principal arterials, and other facilities which meet the requirements of one of the subsystems within the NHS.

To properly manage the NHS, the FHWA has mandated that each State highway agency develop and implement several management systems for those facilities on the NHS. These include management systems for pavements, bridges, traffic monitoring, congestion and safety.

8.2.3.2 Surface Transportation Program

The Surface Transportation Program (STP) is a block-grant program which provides Federal-aid funds for any public road not functionally classified as a minor rural collector or a local road or street. The STP replaced a portion of the former Federal-aid primary system and replaced all of the former Federal-aid secondary and urban systems, and it includes some collector routes which were not previously on any Federal-aid system. Collectively, these are called Federal-aid roads. In addition, bridge projects using STP funds are not restricted to Federal-aid roads but may be used on any public road. Transit capital projects are also eligible under the STP program. The basic objective of the STP is to provide Federal funds for improvements to facilities not considered to have significant national importance with a minimum of Federal requirements for funding eligibility.

8.2.3.3 Bridge Replacement and Rehabilitation Program

Because of the nationwide emphasis on bridges, the Bridge Replacement and Rehabilitation Program (BRRP) has its own separate identity within the Federal-aid program. BRRP funds are eligible for work on any bridge on a public road regardless of its functional classification.

8.2.4 National Network (for Trucks)

The Surface Transportation Assistance Act (STAA) of 1982 required that the U.S. Secretary of Transportation, in cooperation with the State highway agencies, designate a national network of highways that allow the passage of trucks of specified minimum dimensions and weight. The objective of the STAA is to promote uniformity throughout the nation for legal truck sizes and weights on a National Network. The Network includes all Interstate highways and significant portions of the former Federal-aid primary system (before the 1991 ISTEA) built to accommodate large-truck travel. In addition, the STAA requires that "reasonable access" be provided along other routes for the STAA commercial vehicles from the National Network to terminals and to facilities for food, fuel, repair and rest and, for household goods carriers, to points of loading and unloading.

In Montana, the National Network includes the Interstate highway system and all of the (former) Federal-aid primary system. The designer should note that the WB-67 (WB-20) is allowed on all public roads in the State. The WB-100 (WB-30) (triple semitrailer) is only allowed on the Interstate system and for reasonable access to the system. MDT has defined "reasonable access" as 1 mile (1.5 km) from any interchange.

8.2.5 Frontage Roads

Although frontage roads are not on the Federal-Aid system, they are the State's responsibility. They are eligible for STP funds. They are also eligible for IM or NH funds if they are adjacent to an Interstate or NH route and functional classified as a major collector or above.

Frontage roads distribute and collect traffic and as such can be an essential element of a controlled access facility. Frontage roads enhance the safety of a controlled access facility by reducing the number of interchanges needed. They may also help to segregate lower speed local traffic from higher speed through traffic. They can also be used as a backup system in case of freeway disruption.

8.3 SPEED

8.3.1 Definitions

1. Design Speed. Design speed is a selected speed used to determine the various geometric design features of the roadway. It should be logical with respect to topography, anticipated operating speeds, adjacent land use and functional classification of the roadway. The selected design speed for each project will establish criteria for several design elements including horizontal and vertical curvature, superelevation and sight distance. The speed relates to the driver's comfort and is not the speed at which a vehicle will lose control. Section 8.3.2 discusses the selection of design speed in general. Chapter Twelve presents specific design speed criteria for various conditions.

2. Low Speed. For geometric design purposes, low speed is defined as 45 mph (70 km/h) or less.

3. High Speed. For geometric design purposes, high speed is defined as greater than 45 mph (70 km/h).

4. Average Running Speed. Running speed is the average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion). The average running speed is the distance summation for all vehicles divided by the running time summation for all vehicles.

5. Average Travel Speed. Average travel speed is the distance summation for all vehicles divided by the total time summation for all vehicles, including stopped delays. (Note: Average running speed only includes the time the vehicle is in motion. Therefore, on uninterrupted flow facilities which are not congested, average running speed and average travel speed are equal.)

6. Operating Speed. Operating speed, as defined by AASHTO, is the highest overall speed at which a driver can safely travel a given highway under favorable weather conditions and prevailing traffic conditions while at no time exceeding the design speed. Therefore, for low-volume conditions, operating speed equals design speed. The designer should note that the term "operating speed" has little or no usage in geometric design.

7. 85th-Percentile Speed. The 85th-percentile speed is the speed below which 85 percent of vehicles travel on a given highway. The most common application of the value is its use as one of the factors, and usually the most important factor,

for determining the posted, legal speed limit of a highway section. In most cases, field measurements for the 85th-percentile speed will be conducted during off-peak hours when drivers are free to select their desired speed.

8. Pace. Pace is defined as that 10 mph (15 km/h) range of speeds in which the highest number of observations are recorded.

9. Posted Speed Limit. The posted speed limit is based on a traffic engineering study considering:

   a. the 85th-percentile speed;

   b. pace, the 10 mph (15 km/h) range of speeds in which the highest number observations are recorded;

   c. speed profile;

   d. *Montana Code*;

   e. type and density of roadside development;

   f. functional classification and type of area;

   g. adjacent sections;

   h. the crash experience during at least the previous year;

   i. road surface characteristics, shoulder condition, grade, alignment and sight distance; and

   j. parking practices and pedestrian activity.

For additional guidance on selecting posted speed limits, see Chapter Forty of the *Montana Traffic Engineering Manual*.

8.3.2 Design Speed Selection

The selection of a design speed for a project should consider all of the following:

1. Functional Classification. In general, the higher class facilities are designed with a higher design speed than the lower class facilities.

2. Urban/Rural. Design speeds in rural areas are generally higher than those in urban areas. This is consistent with the typically fewer constraints in rural areas (e.g., less development).

3. Terrain. The flatter the terrain, the higher the selected design speed will be. This is consistent with the typically higher construction costs associated with more rugged terrain. In certain situations, especially where a road follows a river through rugged terrain, the vertical alignment will be level. However, the flat vertical alignment is achieved through the use of smaller radii horizontal curves. The utilization of flatter horizontal curves would result in extensive grading. For these situations the lower design speed associated with more rugged terrain is appropriate.

4. Driver Expectancy. The selected design speed should be consistent with driver expectancy. The designer should consider the following when selecting a design speed:

    a. avoid major changes in the design speed throughout the project limits;

    b. where necessary, provide transitional design speeds between sections adjacent to the project;

    c. do not place minimum radius horizontal curves at the end of long tangents; and

    d. consider the expected posted speed in the selection of the design speed.

    e. balance the horizontal and vertical alignment (e.g. curvilinear alignment used with rolling grades).

    f. Evaluate the 85th percentile speed

For geometric design application, the relationship between these design elements and the selected design speed reflects general cost-effective considerations. The value of a transportation facility in carrying goods and people, is judged by its convenience and economy, which are directly related to its speed. See Chapter Twelve for specific design speed criteria.

8.4 TRAFFIC VOLUME CONTROLS

8.4.1 Definitions

1. Annual Average Daily Traffic (AADT). The total yearly traffic volume in both directions of travel divided by the number of days in a year.

2. Average Daily Traffic (ADT). The total traffic volume in both directions of travel during a time period greater than one day but less than one year divided by the number of days in that time period.

3. Capacity. The maximum number of vehicles which reasonably can be expected to traverse a point or uniform roadway section during a given time period under prevailing roadway, traffic and control conditions. The time period most often used for analysis is 15 minutes. "Capacity" corresponds to the upper boundary of LOS E.

4. Delay. The primary performance measure on interrupted flow facilities, especially at intersections. For intersections, average delay is measured and expressed in seconds per vehicle.

5. Density. The number of passenger car equivalents (PCE) occupying a given length of lane. It is usually expressed as vehicles per kilometer per lane.

6. Design Hourly Volume (DHV). The one-hour vehicular volume in both directions of travel in the design year selected for highway design. The DHV is typically the 30th highest hourly volume during the design year. Note that, for capacity analyses, the DHV is typically converted to an hourly flow rate based on the maximum 15 minute flow rate during the DHV.

7. Directional Design Hourly Volume (DDHV). The highest of two directional volumes which combine to form the DHV.

8. Directional Distribution (D). The distribution, by percent, of the traffic in each direction of travel during the DHV, ADT and/or AADT.

9. Equivalent Single-Axle Loads (ESAL's). The summation of equivalent 8165 kg single-axle loads used to convert mixed traffic to design traffic for the design period.

10. Heavy-Vehicle Adjustment Factor. A mix of vehicle types must be adjusted to an equivalent flow rate expressed in terms of passenger cars per hour per lane (see

Passenger Car Equivalent). The adjustment is made using the heavy-vehicle adjustment factor. The adjustment factor is based on the proportion of trucks, buses, and RVs in the traffic stream and on the length and severity of the upgrade or downgrade. Trucks and buses are treated identically. RVs are treated separately from trucks and buses. Data on heavy vehicles are compiled and reported by the MDT Data and Statistics Bureau.

11. Level of Service (LOS). A qualitative concept which has been developed to characterize acceptable degrees of congestion as perceived by motorists. In the *Highway Capacity Manual*, the qualitative descriptions of each level of service (A through F) have been converted into quantitative measures for the capacity analysis for each highway element, including:

    a. freeway mainline;
    b. freeway mainline/ramp junctions;
    c. freeway weaving areas;
    d. interchange ramps;
    e. 2-lane, 2-way rural highways;
    f. multi-lane rural highways;
    g. signalized intersections;
    h. unsignalized intersections; and
    i. urban and suburban arterials.

    Chapter Twelve presents guidelines for selecting the level of service for capacity analyses in road design.

12. Passenger Car Equivalent (PCE). Compared to passenger cars, heavy vehicles (trucks, buses, RVs) are slower moving and greater in length and create longer and more frequent gaps of excessive lengths in the traffic stream. PCE represents an equivalent number of passenger cars that would use the same amount of capacity as a heavy vehicle under prevailing roadway and traffic conditions and is determined by applying an adjustment factor in the analysis (see Heavy-Vehicle Adjustment Factor). This allows capacity to be estimated based on a consistent measure of flow in terms of passenger cars per hour per lane.

13. Peak-Hour Factor (PHF). A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour (typically, 15 minutes). PHF may be expressed as follows:

$$\text{PHF} = \frac{\text{Peak Hour Volume}}{4\ (\text{Peak 15-minute Volume})}$$

14. Rate of Flow. The equivalent hourly rate at which vehicles pass over a given point or section on a lane or roadway on which the volume is collected over a time interval less than one hour.

15. Service Flow Rate. The maximum hourly vehicular volume which can pass through a highway element at the selected level of service.

8.4.2 Design Year Selection

8.4.2.1 Traffic Volumes

A highway should be designed to accommodate the traffic volume expected to occur within the life of the facility under reasonable maintenance. This involves projecting the traffic conditions for a selected future year. The following will apply:

1. New Construction/Reconstruction Projects. The roadway design will be based on a 20 year projection of traffic volume. Life-cycle analysis for pavement types may exceed this period. For roads on the secondary system the selection of certain geometric features is based on the current traffic volumes.

2. Overlay and Widening Projects. When capacity and level of service are assessed, the analysis will be based on a 20 year projection of traffic. However, it is acceptable to base the design year on the design analysis period used for pavement design, with 8 years as a minimum design forecast year.

The design year is measured from the expected construction completion date. Future traffic volumes on State highways are provided by the MDT Data and Statistics Bureau.

8.4.2.2 Other Highway Elements

The following presents the recommended criteria for consideration of a design year for highway elements other than road design:

1. Bridges/Underpasses. The structural life of a bridge may be 50 years or more. For new bridges (including bridge replacements), the initial clear roadway width of the bridge or underpass will be based on the 20 year traffic volume projection beyond the construction completion date for flexible pavement designs and 30 years for concrete pavements. See the *MDT Structures Manual* for more information.

2. Right-of-Way/Grading. The designer should consider potential future right-of-way needs for a year considerably beyond that used for roadway design.

3. Drainage Design. Drainage appurtenances are designed to accommodate a flow rate based on a specific design year (or frequency of occurrence). The selected design year or frequency will be based on the functional class of the facility and the specific drainage appurtenance (e.g., culvert). New drainage facilities are designed to have a structural life of 75 years. The MDT Hydraulics Section is responsible for determining the criteria for selecting a design year for drainage.

4. Pavement Design. The pavement structure is designed to withstand the vehicular loads it will sustain during the design analysis period without falling below a selected terminal pavement serviceability. The MDT Materials Bureau is responsible for determining criteria for selecting a design year for pavement design. Preventative maintenance overlays (pavement preservation projects) are utilized to extend the life of the riding surface. They are not designed for a specific vehicular loading or analysis period.

8.4.3 Design Hourly Volume Selection

For most geometric design elements which are impacted by traffic volumes, the peaking characteristics are most significant. The highway facility should be able to accommodate the design hourly volume (adjusted for the peak-hour factor) at the selected level of service. This design hourly volume (DHV) will affect many design elements including the number of travel lanes, lane and shoulder widths and intersection geometrics.

The 30th highest hourly volume in the selected design year will typically be used to determine the DHV for design purposes.

For design analysis of intersections, the DHV of the intersecting roadways should be compared with the existing 30th highest hourly volume. An expected percent growth should be identified. If a modeled DHV is not available, existing traffic volumes should be analyzed with respect to the ability to absorb the expected growth.

8.4.4 Capacity Analyses

8.4.4.1 Objective

Design the highway mainline or intersection to accommodate the selected design hourly volume (DHV) at the selected level of service (LOS). This may involve adjusting the various highway factors which affect capacity until a design is found that will accommodate the DHV. The detailed calculations, factors and methodologies are presented in the *Highway Capacity Manual* (HCM). During the analysis, the design service volume (or flow rate) of the facility is calculated. Capacity assumes a LOS E; the design service volume is the maximum volume of traffic that a highway of designed dimensions is able to serve without the degree of congestion falling below a preselected level. This is always higher than LOS E.

For various types of highway facilities, the HCM documents the measures of effectiveness that should be used in capacity analyses to determine level of service. These measures are presented in Figure 8.4A. For each facility type, the HCM provides the analytical tools necessary to calculate the numerical value of its respective measure of effectiveness.

The following presents the simplified procedure for conducting a capacity analysis for the highway mainline:

1. Select the design year.
2. Determine the DHV.
3. Select the target level of service, see Figure 8.4B.
4. Identify and document the proposed highway geometric design (lane width, clearance to obstructions, number and width of approach lanes at intersections, etc.).
5. Using the HCM, analyze the capacity of the highway element for the proposed design:
    a. determine the maximum flow rate under ideal conditions;
    b. identify the adjustments for prevailing roadway, traffic and control conditions; and
    c. calculate the service flow rate for the selected level of service.

6. Compare the calculated service flow rate to the DHV. If the DHV is less than or equal to the service flow rate, the proposed design will meet the objectives of the capacity analysis. If the DHV exceeds the service flow rate, the proposed design will be inadequate. The various elements in the capacity analysis will help the designer assess where excess or deficient design parameters exist.

The default values in the HCM will apply unless reliable local data is available (e.g., for the peak-hour factor). Use the criteria presented in Figure 8.4B when selecting the level of service for the facility.

8.4.4.2 Responsibility

The MDT Traffic Engineering Section is responsible for performing all capacity analyses required for the project.

TYPE OF FACILITY	MEASURE OF EFFECTIVENESS
Freeways	
Basic freeway segments	Density (pce/km/ln)
Weaving areas	Density (pce/km/ln)
Ramp junctions	Flow rates (pce/h)
Multilane highways	Density (pce/km/ln) Free-flow speed (km/h)
Two-lane highways	Time delay (%)
Signalized Intersections	Average stopped delay (s/veh)
Unsignalized intersections	Average total delay (s/veh)
Arterials	Average travel speed (km/h)

MEASURES OF EFFECTIVENESS FOR LEVEL OF SERVICE

Figure 8.4A

TYPE OF FACILITY	LEVEL-OF-SERVICE CRITERIA	
Freeways (NHS — Interstate)	Rural: B	Urban: B
Principal Arterials (NHS — Non-Interstate)	Level/Rolling: B	Mountainous: C
Minor Arterials (Non-NHS — Primary)	Level/Rolling: B	Mountainous: C
Rural Collector Roads (Non-NHS — Secondary)	Desirable: B	Minimum: C
Urban Principle Arterials (NHS — Non-Interstate) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Minor Arterials (Non-NHS) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Collector Streets (Non-NHS)	Desirable: C	Minimum: D

LEVEL-OF-SERVICE CRITERIA

Figure 8.4B

8.5 ACCESS CONTROL (Definitions)

Access control is defined as the condition where the public authority fully or partially controls the right of abutting owners to have access to and from the public highway. Access control may be exercised by statute, zoning, right-of-way purchases, approach controls and permits, turning and parking regulations or geometric design (e.g., approach spacing).

The following provides definitions for the three basic types of access control:

1. Full Control (Access Controlled). Full control of access is achieved by giving priority to through traffic by providing access only at grade separation interchanges with selected public roads. No at-grade crossings or approaches are allowed. The freeway is the common term used for this type of highway. Full control of access maximizes the capacity, safety and vehicular speeds on the freeway.

2. Limited Access Control. Limited access control is an intermediate level between full control and regulated access. Priority is given to through traffic, but a few at-grade intersections and approaches may be allowed. Limited access control on a specific highway is established by passage of an Access Control Resolution by the Transportation Commission. The proper selection and spacing of at-grade intersections and service connections will provide a balance between the mobility, safety and access service of the highway.

3. Regulated Access. All highways warrant some degree of access control by permit or by design. Access is regulated through the granting of revocable permits for the construction and maintenance of approaches. If access points to other public roads and approaches are properly spaced and designed, the adverse effects on highway capacity and safety will be minimized. These points should be located where they can best suit the traffic and land-use characteristics of the highway under design. Their design should enable vehicles to enter and exit safely with a minimum of interference to through traffic.

Limited access control and regulated access is exercised by the Department on the State highway system (see the *MDT Approach Standards for Montana Highways*) and by the local jurisdiction on other facilities to determine where private interests may have access to and from the public road system.

8.6 SIGHT DISTANCE

8.6.1 Stopping Sight Distance

Stopping sight distance (SSD) is the sum of the distance traveled during a driver's perception/reaction or brake reaction time and the distance traveled while braking to a stop. To calculate SSD on level grade, the following formula is used:

SSD = Brake Reaction Distance + Braking Distance, (Figure 8.6A)

US Customary

$$SSD_{Level} = 1.47Vt + 1.075\left(\frac{V^2}{a}\right)$$

$$SSD_{Downgrades} = 1.47Vt + \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) - G\right)}$$

$$SSD_{Upgrades} = 1.47Vt + \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) + G\right)}$$

Metric

$$SSD_{Level} = 0.278Vt + 0.039\left(\frac{V^2}{a}\right)$$

$$SSD_{Downgrades} = 0.278Vt + \frac{V^2}{254\left(\left(\frac{a}{9.8}\right) - G\right)}$$

$$SSD_{Upgrades} = 0.278Vt + \frac{V^2}{254\left(\left(\frac{a}{9.8}\right) + G\right)}$$

where: SSD = stopping sight distance, ft. (m)

V = Design Speed
t = brake reaction time, 2.5 s
a = Deceleration Rate ft/s^2 , 11.2 ft/s^2 (a=3.4m/s^2)
G = Gradient ±

Figure 8.6A provides stopping sight distances for passenger cars on level grade. The designer should always attempt to meet the desirable values. Only use the minimum values where the desirable values are impractical due to natural features or existing development. When applying the SSD values, the height of eye is assumed to be 3.5 ft, (1.080 m) and the height of object 2.0 ft. (0.600 m).

Design Speed (V) (mph)	Brake Reaction Distance 1.47Vt (ft)	Braking Dist $1.075(V^2/a)$ (ft)	Calculated SSD (ft)	SSD Rounded for design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820
80	294.0	614.3	908.3	910

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 11.2 ft/s^2

Stopping Sight Distances
(Level)

Design Speed (V) (mph)	Stopping sight distances (ft)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
15	80	82	85	75	74	73
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	190	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495
65	682	728	785	612	584	561
70	771	825	891	690	658	631
75	866	927	1003	772	736	704
80	965	1035	1121	859	817	782

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 11.2 ft/s^2

STOPPING SIGHT DISTANCE
(Level Grades)
Figure 8.6A (**US Customary)**

Design Speed (V) (kph)	Brake Reaction Distance 0.278Vt (m)	Braking Dist 0.039(V^2/a) (m)	Calculated SSD (m)	SSD Rounded for design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 3.4 m/s^2

Stopping Sight Distances
(Level)

Design Speed (V) (kph)	Stopping sight distances (m)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114
90	164	174	187	140	141	136
100	194	207	223	174	167	160
110	227	243	262	203	194	186
120	263	281	304	234	223	214
130	302	323	350	267	254	243

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 3.4 m/s^2

Stopping Sight Distances
(Grades)
Figure 8.6A (Metric)

8.6.2 Passing Sight Distance

8.6.2.1 Theoretical Discussion

Passing sight distance considerations are limited to 2-lane, 2-way highways. On these facilities, vehicles may overtake slower moving vehicles, and the passing maneuver must be accomplished on a lane used by opposing traffic.

The minimum passing sight distance for 2-lane highways is determined from the sum of four distances as illustrated in Figure 8.6B. Figure 8.6C and the following provides the basic assumptions used to develop passing sight distance values for design:

1. Initial Maneuver Distance (d_1). This is the distance traveled during the perception and reaction time and during the initial acceleration to the point of encroachment on the left lane. For the initial maneuver, the overtaken vehicle is assumed to be traveling at a uniform speed, and the passing vehicle is accelerating at the rate shown in Figure 8.6C.

The average speed of the passing vehicle is assumed to be 15 km/h greater than the overtaken vehicle. Use Equation 8.6-2 to determine d_1:

US Customary Metric

$$d_1 = 1.47t_1\left(v - m + \frac{at_1}{2}\right) \qquad d_1 = \frac{t_1}{3.6}\left(v - m + \frac{at_1}{2}\right) \qquad \text{(Equation 8.6-2)}$$

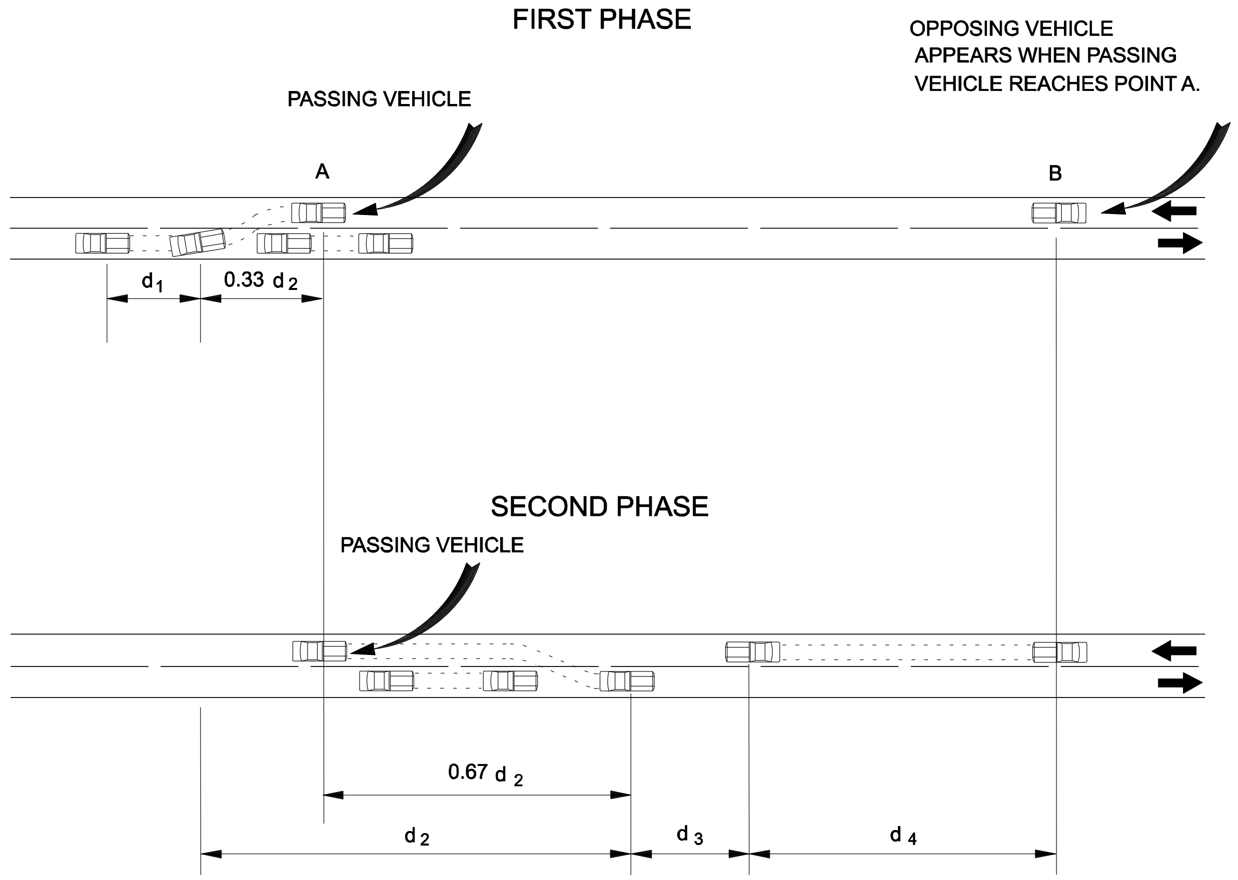
where:
t_1 = time of initial maneuver, s
a = average acceleration, mph/s (km/h/s)
v = average speed of passing vehicle, mph (km/h)
m = difference in speed of passed vehicle and passing vehicle, mph (km/h)

2. Distance of Passing Vehicle in Left Lane (d_2). This is the distance traveled by the passing vehicle while it occupies the left lane. Assumed times for when the passing vehicle occupies the left lane are shown in Figure 8.6C. Use Equation 8.6-3 to determine d_2:

US Customary Metric

$$d_2 = 1.47vt_2 \qquad d_2 = \frac{vt_2}{3.6} \qquad \textbf{(Equation 8.6-3)}$$

where:
t_2 = time passing vehicle occupies the left lane, s
v = average speed of passing vehicle, mph (km/h)



ELEMENTS OF PASSING DISTANCE
(2-Lane Highways)

Figure 8.6B

US Customary

Design Speed (mph)	Assumed Speeds		Minimum PSD for Design (ft)
	Passed Vehicle (mph)	Passing Vehicle (mph)	
30	26	36	1090
35	30	40	1280
40	34	44	1470
45	37	47	1625
50	41	51	1835
55	44	54	1885
60	47	57	2135
65	50	60	2285
70	54	64	2480
75	56	66	2580

Metric

Design Speed (km/h)	Assumed Speeds		Minimum PSD for Design (m)
	Passed Vehicle (km/h)	Passing Vehicle (km/h)	
50	44	59	350
60	51	66	400
70	59	74	490
80	65	80	550
90	73	88	615
100	79	94	675
110	85	100	750

MINIMUM PASSING SIGHT DISTANCE
(2-Lane Highways)
Figure 8.6C

3. Clearance Distance (d_3). This is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle. Based on various studies, this clearance distance at the end of the passing maneuver is assumed to be between 100’ (37 m) and 250’ (75 m).

4. Opposing Vehicle Distance (d_4). This is the distance traveled by an opposing vehicle during the time the passing vehicle occupies the left lane. As shown in Figure 8.6B, the opposing vehicle appears after approximately one-third of the passing maneuver (d_2) has been accomplished. The opposing vehicle is assumed to be traveling at the same speed as the passing vehicle. Therefore, d_4 = 0.67 d_2.

8.6.2.2 Application

Figure 8.6C provides the minimum passing sight distance for design on 2-lane, 2-way highways. These distances allow the passing vehicle to safely complete the passing maneuver. These values should not be confused with the values presented in the *MUTCD* for the placement of no-passing zone stripes, which are based on different operational assumptions (i.e., distance for the passing vehicle to abort the passing maneuver). The designer should also realize that the highway capacity adjustment in the *Highway Capacity Manual* for 2-lane, 2-way highways is based on the *MUTCD* criteria for marking no-passing zones. It is not based on the percent of passing sight distance from the AASHTO *A Policy on Geometric Design of Highways and Streets* and shown in Figure 8.6C.

On rural reconstruction projects, the designer should attempt to provide passing sight distance over as much of the highway length as practical. It will generally not be cost effective, however, to make significant improvements to the horizontal and vertical alignment solely to increase the available passing sight distance. When determining the percent of passing sight distance, consider the following factors:

1. traffic volumes,
2. truck volumes, and
3. safety.

Passing sight distance is measured from a 3.5’ (1.08 m) height of eye to a 3.5’ (1.08 m) height of object. The 3.5’ (1.08 m) height of object allows 0.8’ (225 mm) of a typical passenger car to be seen by the opposing driver:

8.6.3 Passing Lanes

Passing lanes are defined as a short added lane provided in one or both directions of travel on a 2-lane, 2-way highway to improve passing opportunities. They may present a relatively low-cost improvement for traffic operations by breaking up traffic platoons and reducing delay on facilities with inadequate passing opportunities. Truck-climbing lanes are one type of passing lane used on steep grades to provide passenger cars with an opportunity to pass slow-moving trucks. The criteria for and design of truck-climbing lanes are discussed in Chapters Twenty-six and Thirty of the *Traffic Engineering Manual*.

Passing lanes other than truck-climbing lanes may be necessary on 2-lane facilities where the desired level of service cannot be obtained. Passing lanes also may be determined to be necessary based on an engineering study that includes judgment, operational experience and a capacity analysis. The use of a passing lane will be determined on a case-by-case basis. The Traffic Engineering Section is responsible for conducting the study to justify the need for passing lanes. For more information on passing lane guidance, see the FHWA publication *Low Cost Methods for Improving Traffic Operations on Two-Lane Roads*, Report No. FHWA-IP-87-2. The Report discusses the following for passing lanes:

1. their location and configuration,
2. their length and spacing,
3. geometrics,
4. signing and pavement marking, and
5. operational and safety effectiveness.

The Report also presents approximate adjustments which may be made to the highway capacity methodology in Chapter Eight of the *Highway Capacity Manual* to estimate the level-of-service benefits from adding passing lanes to 2-way facilities.

8.7 FHWA INVOLVEMENT

FHWA will be involved in project development as follows:

1. Preliminary Field Review. FHWA should be invited to preliminary field reviews. The Highways Engineer, or designee, will sign all reports regardless of the system except where the Bridge Bureau or the Traffic & Safety Bureau is the lead. FHWA will receive copies of all Preliminary Field Review reports.

2. Scope of Work Reports. FHWA will be included in the distribution for concurrence and recommendations on all Scope of Work reports for projects on the National Highway System (NHS) that meet the following criteria:

    a. All projects on the non-Interstate NHS costing $3 million or more

    b. All reconstruction projects on the Interstate system costing $1 million or more, and all pavement preservation and rehabilitation projects on the Interstate system costing $3 million or more.

    FHWA will receive copies of the Scope of Work reports for lower cost projects on the NHS and all projects in the Surface Transportation Program.

3. Design Exceptions. FHWA will sign design exceptions for all Federal-aid projects on the NHS that meet the criteria in 2. a. & b. MDT will approve design exceptions internally on other projects with a copy sent to FHWA for informational purposes.

4. Plan Reviews. FHWA will receive all NHS road plans, estimates and special provisions, as well as any other plans with unusual or innovative features for Plan-in-Hands. For STP projects, FHWA will receive a copy of the cover letter indicating the date and location of the Plan-in-Hand.

5. Plan-in-Hand Reports. The Preconstruction Engineer, or designee, will sign all Plan-in-Hand reports except where the Bridge Bureau is the lead. FHWA will only receive Plan-in-Hand reports for NHS projects.

6. PS&E Approval. FHWA will give formal PS&E approval for all NHS projects. PS&E approval for STP projects will be done internally.

7. Concurrence in Award. FHWA will concur in award on all NHS contracts.

8.8 ADHERENCE TO GEOMETRIC DESIGN CRITERIA

The *Montana Road Design Manual* presents numerous criteria on road design for application on individual road design projects. In general, the designer is responsible for making every reasonable effort to meet these criteria in the project design. However, this will not always be practical. This Section discusses the Department's procedures for identifying, justifying and processing exceptions to the geometric design criteria in the *Road Design Manual*.

8.8.1 Department Intent

The general intent of the Montana Department of Transportation is that all road design criteria in this *Manual* should be met and, wherever practical, the proposed design should exceed the minimum criteria. Where a range of values is presented, the designer should make every reasonable effort to provide a design which equals or exceeds the upper value. This is intended to ensure that the Department will provide a highway system that meets the transportation needs of the State and provides a reasonable level of safety, comfort and convenience for the traveling public. However, recognizing that this will not always be practical, the Department has established a process to identify, evaluate and approve exceptions to geometric design criteria.

8.8.2 Design Exceptions

8.8.2.1 General

This Section presents those design elements which require a design exception when the proposed design does not meet the applicable criteria. The "controlling" design criteria are highway elements that are judged to be the most critical indicators of a highway's overall safety and serviceability.

Because the 10 km/h incremental value for design speeds does not directly equate to the 10 mph increment, situations may arise where the metric value is less than the US Customary value. FHWA has determined that designs which were acceptable under the metric system will not be considered substandard under the US Customary system if the differences are strictly the result of hard conversion. Consequently, for these situations no design exception is required.

Design exceptions are not required for substandard design elements for preventative maintenance projects. However these elements must be documented in the scope of Work Report. For major and minor rehabilitation projects design exceptions are required for specific elements under certain conditions. Refer to the *Guidelines for Nomination and Development of Pavement Projects* for more detailed information.

8.8.2.2 Design Elements

The designer must seek a MDT/FHWA design exception when the proposed design includes any of the following elements which do not meet MDT criteria:

1. design speeds;
2. horizontal alignment elements:
    a. minimum radii,
    b. warrants for spiral curves, and
    c. sight distance at curves based on desirable SSD*;
3. vertical alignment elements:
    a. crest and sag vertical curves based on desirable SSD*,
    b. maximum grades, and
    c. vertical clearances;
4. lane and shoulder widths for:
    a. through travel lanes,
    b. auxiliary lanes, and
    c. ramps;
5. bridge widths;
6. superelevation rates;
7. cross slopes on travel lanes;
8. cut and fill slopes;
9. roadside clear zones, including the adjustment for horizontal curves;
10. horizontal clearances to obstructions on curbed facilities (obstructions with 2’ (0.5 m) of curb);
11. intersection sight distances.

8.8.2.3 Design Element Documentation

The following design elements do not require design exceptions. However, they must be documented in the Scope of Work Report.

1. Superelevation transition lengths
2. Unshielded obstacles within the clear zone and shielded obstacles outside the clear zone
3. A minimum 2’ (0.6 m) offset between the face of the roadside barrier and the edge of the traveled way
4. Guardrail details (e.g. post spacing)
5. Raised medians less than 20’ (6 m) wide

8.8.3 Project Application

8.8.3.1 MDT

The MDT design exception process applies to all capital improvement projects under the jurisdiction of the Department with the following exceptions:

1. State and Federally-funded pavement preservation projects,
2. projects on routes where the intent is to maintain the existing level of development (black routes),
3. projects on off-system roads, and/or
4. safety projects.

For all of the projects listed above, except the State-funded pavement preservation projects, the elements that do not comply with the MDT design criteria will be described in the Scope of Work report. The discussion should provide documentation for the justification of the design exceptions.

8.8.3.2 FHWA

As noted in Section 8.7, requests for design exceptions will be submitted to FHWA for all projects on the NHS that meet the criteria for oversight (All projects on the non-

Interstate NHS costing $3 million or more, all reconstruction projects on the Interstate system costing $1 million or more, and all pavement preservation and rehabilitation projects on the Interstate system costing $3 million or more). The request for design exceptions will be submitted internally to MDT for all projects in the STP. The MDT criteria will be utilized by both entities in the evaluation of the design elements.

8.8.4 Documentation

The type and detail of the documentation needed to justify a design exception will be determined on a case-by-case basis. The following lists potential items which may be addressed in the documentation for a specific design exception:

1. crash data,
2. environmental impacts,
3. right-of-way impacts,
4. construction costs, and
5. serviceability impacts (e.g., traffic level of service).

8.8.5 Procedures

The following procedure will be used to process a proposed design exception:

1. Project Design Manager. The Project Design Manager will assemble the package for the design exception request. The package will be submitted to the Highways Engineer through the Road Design Engineer.

2. Highways Engineer. The Highways Engineer will review the design exception package and, if in agreement, will sign the request. This will complete the internal MDT process. In rare cases where the Highways Engineer believes necessary, the design exception request may be submitted to the Chief Engineer for action.

   If FHWA approval is needed, the Highways Engineer will submit the package to the FHWA Division Office.

3. FHWA. On applicable projects, the FHWA will review the design exception request and, if in agreement, will sign the request and return the package to the Highways Engineer.

4. Design Exception Denial. If the Highways Engineer and/or FHWA has denied the design exception request, the Project Design Manager will use the following steps:

    a. The Project Design Manager will first try to meet MDT criteria.

    b. If the MDT design criteria cannot be met, the Project Design Manager will develop alternatives and submit documentation to the Road Design Engineer.

    c. The Road Design Engineer will meet with the Highways Engineer and the Project Design Manager, discuss the issues and decide if a new design exception submittal is needed or if the issue can be resolved.

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Nine
HORIZONTAL ALIGNMENT

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Chapter Nine
HORIZONTAL ALIGNMENT

The horizontal alignment of a highway facility will have a significant impact on vehicular operation and construction costs. Chapter Nine presents the Department's criteria for horizontal alignment elements, including minimum radii, usage of horizontal curve types, superelevation rates and development, sight distance around horizontal curves and mathematical details for computing horizontal curves.

9.1 GENERAL CONTROLS

The design of horizontal alignment involves, to a large extent, complying with specific limiting criteria. These include minimum radii, superelevation rates and sight distance. In addition, the designer should adhere to general design principles and controls which will determine the overall safety of the facility and will enhance the aesthetic appearance of the highway. These general controls include:

1. <u>Consistency</u>. Alignment should be consistent. Avoid sharp curves at the ends of long tangents and sudden changes from gentle to sharply curving alignment.

2. <u>Directional</u>. Alignment should be as directional as practical and consistent with physical and economic constraints. On divided highways a flowing line that conforms generally to the natural contours is preferable to one with long tangents that slash through the terrain. Directional alignment can be achieved by using the smallest practical central angles.

3. <u>Use of Minimum Radii</u>. The use of minimum radii should be avoided if practical.

4. <u>High Fills</u>. Avoid sharp curves on long, high fills. Under these conditions, it is difficult for drivers to perceive the extent of horizontal curvature.

5. <u>Alignment Reversals</u>. Avoid abrupt reversals in alignment ("S" or reverse curves). Provide a sufficient tangent distance between the curves to ensure proper superelevation transitions for both curves.

6. <u>Broken-Back Curvature</u>. Avoid where practical. This arrangement is not aesthetically pleasing, violates driver expectancy and creates undesirable superelevation development requirements.

7. <u>Compound Curves</u>. Avoid the use of compound curves on highway mainline. These may "fool" the driver when judging the sharpness of a horizontal curve.

8. Coordination with Natural/Man-Made Features. The horizontal alignment should be properly coordinated with the natural topography, available right-of-way, utilities, roadside development and natural/man-made drainage patterns.

9. Environmental Impacts. Horizontal alignment should be properly coordinated with environmental features to reduce or avoid impacts where practical (e.g., encroachment onto wetlands).

10. Intersections. Horizontal alignment through intersections may present special problems (e.g., intersection sight distance, superelevation development). See Chapter Twenty-eight in the *Montana Traffic Engineering Manual* for the design of intersections at-grade.

11. Coordination with Vertical Alignment. Chapter Ten discusses general design principles for the coordination between horizontal and vertical alignment.

12. Visibility. Design the roadway so that the driver has a clear view of the alignment

13. Coordination with existing PTW. . Horizontal alignment should be properly coordinated with the PTW at the project limits to provide a smooth transition on to and off of the project.

9.2 HORIZONTAL CURVES

9.2.1 Definitions

1. Simple Curves. These are continuous arcs of constant radius which achieve the necessary highway deflection without an entering or exiting transition.

2. Compound Curves. These are a series of two or more horizontal curves with deflections in the same direction immediately adjacent to each other.

3. Spiral Curves. These are curvature arrangements used to transition between a tangent section and a simple curve, which are consistent with the transitional characteristics of vehicular turning paths. When moving from the tangent to the simple curve, the sharpness of the spiral curve gradually increases from a radius of infinity to the radius of the simple curve.

4. Reverse Curves. These are two simple curves with deflections in opposite directions, which are joined by a common point or a relatively short tangent distance.

5. Broken-Back Curves. Broken-back curves are two closely spaced horizontal curves with deflections in the same direction and a short intervening tangent.

9.2.2 Selection of Curve Type

The following presents MDT practice for the selection of the type of horizontal curve based on the type of facility:

1. Rural State Highways and High-Speed (V > 45mph(70 km/h)) Urban Roadways. Based on the curve radii, the following will apply:

   a. R ≤ 3820’(1165 m) — use a spiral curve.

   b. R > 3820’(1165 m) — use a simple curve.

Compound curves are not allowed on these facilities, except in transitional areas.

2. Low-Speed (V ≤ 45mph(70 km/h)) Urban Roadways/Non-State Highways.

   Typically, simple curves will be used on low-speed urban roadways and non-State highways. In urban areas, if necessary, it is acceptable to use compound curves on the mainline to:

a. avoid obstructions,
b. avoid right-of-way problems, and/or
c. fit the existing topography.

Where used, compound curves on mainline should be designed such that the radius of the flatter curve is no more than 1.5 times the radius of the sharper curve (i.e., $R_1 \leq 1.5 R_2$, where R_1 is the flatter curve).

9.2.3 Calculation of Curve Radius

9.2.3.1 Basic Curve Equation

The point-mass formula is used to define vehicular operation around a curve. Where the curve is expressed using its radius, the basic equation for a simple curve is:

$$R = \frac{V^2}{15(e+f)} \qquad \text{US Customary (Equation 9.2-1)}$$

where:

R = radius of curve, ft
e = superelevation rate, decimal
f = side-friction factor, decimal
V = vehicular speed, mph

$$R = \frac{V^2}{127(e+f)} \qquad \text{Metric (Equation 9.2-1)}$$

where:

R = radius of curve, m
e = superelevation rate, decimal
f = side-friction factor, decimal
V = vehicular speed, km/h

9.2.3.2 General Theory

Establishing horizontal curvature criteria requires a selection of the theoretical basis for the various factors in the basic curve equation. These include the selection of maximum side-friction factors (f) and the distribution method between side friction and superelevation. For highway mainlines, the theoretical basis will be one of the following:

1. Open-Roadway Conditions. The theoretical basis for horizontal curvature assuming open-roadway conditions includes:

    a. relatively low maximum side-friction factors (i.e., a relatively small level of driver discomfort); and

    b. the use of AASHTO Method 5 to distribute side friction and superelevation.

    AASHTO Method 5 distributes side friction and superelevation such that each element is used simultaneously to offset the outward pull of the vehicle traveling around the curve.

    Open-roadway conditions apply to all rural facilities and to all high-speed urban facilities; i.e., where the design speed (V) > 45mph(70 km/h).

2. Low-Speed Urban Streets. The theoretical basis for horizontal curvature assuming low-speed urban street conditions includes:

    a. relatively high maximum side-friction factors to reflect a higher level of driver acceptance of discomfort; and

    b. the use of AASHTO Method 2 to distribute side friction and superelevation.

    AASHTO Method 2 distributes side friction and superelevation such that side friction alone is used, up to f_{max}, to offset the outward pull of the vehicle traveling around the curve. Only then is superelevation introduced.

    Low-speed urban streets are defined as streets within an urban or urbanized area where the design speed (V) ≤ 45mph(70 km/h). Designers should check local design criteria for off-system facilities.

9.2.4 Minimum Radii

Figures 9.2A and 9.2B present the minimum radii (R_{min}) for open-roadway facilities and low-speed urban streets. To define R_{min}, a maximum superelevation rate (e_{max}) must be selected. See Section 9.3 for MDT criteria for e_{max}. It should be noted that the metric values are compatible with the 2001 AASHTO Greenbook. This was done to provide consistency in the completion of projects where the design has been started in the metric format.

9.2.5 Selection of Curve Radius

Where practical, the designer will select curve radii from among the radii listed in Figure 9.2C for mainline on open roadways. This will provide uniformity in project design. At individual curves, however, it may be necessary to select radii intermittent between those in the figure, rounded to the next highest 10'(5 m) increment. Curve radii on low-speed urban streets will be selected on a case-by-case basis.

US Customary

Design Speed, V (mph)	e_{max}	f_{max}	Minimum Radii, R_{min} (ft)
20	8.0%	0.27	80
25	8.0%	0.23	140
30	8.0%	0.20	220
35	8.0%	0.18	320
40	8.0%	0.16	450
45	8.0%	0.15	590
50	8.0%	0.14	760
55	8.0%	0.13	960
60	8.0%	0.12	1200
70	8.0%	0.10	1820

Note: R_{min} is based on Equation 9.2-1 rounded up to the nearest 10 ft increment.

Metric

Design Speed, V (km/h)	e_{max}	f_{max}	Minimum Radii, R_{min} (m)
30	8.0%	0.17	30
40	8.0%	0.17	50
50	8.0%	0.16	85
60	8.0%	0.15	125
70	8.0%	0.14	175
80	8.0%	0.14	230
90	8.0%	0.13	305
100	8.0%	0.12	395
110	8.0%	0.11	500

Note: R_{min} is based on Equation 9.2-1 rounded up to the nearest 5 m increment.

MINIMUM RADII
(Open-Roadway Conditions)

Figure 9.2A

US Customary

Design Speed, V (mph)	e_{max}	f_{max}	Minimum Radii, R_{min} (ft)
20	4.0%	0.27	86
25	4.0%	0.23	154
30	4.0%	0.20	250
35	4.0%	0.18	371
40	4.0%	0.16	533
45	4.0%	0.15	711

Note: Rmin is based on Equation 9.2-1 rounded up to the nearest 1 ft increment.

Metric

Design Speed, V (km/h)	e_{max}	f_{max}	Minimum Radii, R_{min} (m)
30	4.0%	0.312	20
40	4.0%	0.252	45
50	4.0%	0.214	80
60	4.0%	0.186	125
70	4.0%	0.163	190

Note: Rmin is based on Equation 9.2-1 rounded up to the nearest 5 m increment.

MINIMUM RADII

(Low-Speed Urban Streets (V) ≤ 45 mph(70 km/h))

Figure 9.2B

Select curve radii from the following	
23000’ (7000 m) 11500’ (3500 m) 7700’ (2350 m) 5700’ (1750 m) 3800’ (1150 m) 3000’ (900 m) 2300’ (700 m) 2000’ (600 m) 1650’ (500 m)	1500’ (450 m) 1150’ (350 m) 1000’ (300 m) 800’ (250 m) 700’ (220 m) 600’ (190 m) 550’ (170 m) 520’ (160 m) 500’ (150 m)

Relationship of Degree of curvature to radius			
Radius in Ft	Deg of Curve	Radius in Ft	Deg of Curve
22920	0°15'	1433	4°00'
11460	0°30'	1146	5°00'
7640	0°45'	955	6°00'
5730	1°00'	819	7°00'
3820	1°30'	716	8°00'
2865	2°00'	637	9°00'
2292	2°30'	573	10°00'
1910	3°00'	521	11°00'
1637	3°30'	478	12°00'

SELECTION OF CURVE RADII
(Open Roadways)

Figure 9.2C

9.2.6 Maximum Deflection Without Curve

It may be appropriate to design a facility without a horizontal curve where small deflection angles (Δ) are present. As a guide, the designer may retain deflection angles of about 1° or less (urban) and 0.5° or less (rural) for the highway mainline. In these cases, the absence of a horizontal curve will not likely affect driver response or aesthetics.

For highway mainline at urban intersections, higher deflection angles may be acceptable based on an evaluation of the design speed, traffic volumes, functional class, existing/future signalization, etc.

9.2.7 Minimum Length of Curve

Short horizontal curves may provide the driver with the appearance of a kink in the alignment. To improve the aesthetics of the highway, the designer should lengthen short curves, if practical, even if not necessary for engineering reasons. The following guidance should be used to establish minimum curve lengths for deflection angles (Δ) of 5° or less:

1. Open Roadways. For open roadways, use the following criteria that results in the greatest curve length:
    a. The minimum radius that results in a normal crown cross slope.
    b. The length of curve in feet or meters = 15V, where V is the design speed in mph or 3V, where V is the design speed in km/h. Double this length for controlled access facilities.
    c. A 500’(150 m) length of curve for a 5-degree deflection add 100’(30m) for each 1-degree decrease in the central angle.

   If this criteria cannot be met, the designer should document this in the Alignment Review Report.

2. Urban. The minimum length of curves on low-speed urban streets will be determined on a case-by-case basis.

9.2.8 Computation

Section 9.6 presents the applicable mathematical details for the computation of horizontal curves.

9.3 SUPERELEVATION (OPEN-ROADWAY CONDITIONS)

9.3.1 Definitions

1. Superelevation. Superelevation is the amount of cross slope or "bank" provided on a horizontal curve to help counterbalance the outward pull of a vehicle traversing the curve.

2. Maximum Superelevation (e_{max}). The maximum rate of superelevation (e_{max}) is an overall superelevation control used on a specific facility. Its selection depends on several factors including overall climatic conditions, terrain conditions, type of facility and type of area (rural or urban).

3. Superelevation Transition Length. The superelevation transition length is the distance required to transition the roadway from a normal crown section to full superelevation. Superelevation transition length is the sum of the tangent runout (TR) and superelevation runoff (L) distances:

   a. Tangent Runout (TR). Tangent runout is the distance needed to transition the roadway from a normal crown section to a point where the adverse cross slope of the outside lane or lanes is removed (i.e., the outside lane(s) is level).

   b. Superelevation Runoff (L). Superelevation runoff is the distance needed to transition the cross slope from the end of the tangent runout (adverse cross slope removed) to a section that is sloped at the design superelevation rate.

4. Axis of Rotation. The superelevation axis of rotation is the line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile throughout the curve.

5. Superelevation Rollover. Superelevation rollover is the algebraic difference (A) between the superelevated traveled way slope and shoulder slope on the outside of a horizontal curve.

6. Relative Longitudinal Slope. The relative longitudinal slope is the difference between the centerline grade and the grade of the edge of traveled way.

7. Open Roadways. Open roadways are all rural facilities regardless of design speed and all urban facilities with a design speed greater than 45mph(70 km/h).

8. Low-Speed Urban Streets. These are all streets within urbanized and small urban areas with a design speed of 45 mph(70 km/h) or less.

9.3.2 Maximum Superelevation Rate

The selection of a maximum rate of superelevation (e_{max}) depends upon several factors. These include urban/rural location, type of facility and prevalent climatic conditions within Montana. For open-roadway conditions, MDT has adopted the following for the selection of e_{max}:

1. Rural Facilities. An e_{max} = 8.0% is used on all rural facilities for all design speeds.

2. Urban Facilities (V > 45 mph(70 km/h)). An e_{max} = 8.0% is used on all urban facilities where the design speed (V) is greater than 45 mph(70 km/h).

9.3.3 Superelevation Rates

Based on the selection of e_{max} and the use of AASHTO Method 5 to distribute e and f, the following figures allow the designer to select the superelevation rate for combinations of curve radii (R) and design speed (V) and to select the minimum length of transition:

1. Figure 9.3A applies to 2-lane, 2-way highways where e_{max} = 8.0%.

2. Figure 9.3B applies to 4-lane divided and undivided facilities where e_{max} = 8.0%.

Note that superelevation rates are a controlling criteria. The designer must seek a design exception for any proposed rate which does not meet the criteria in Figures 9.3A and 9.3B. See Section 8.8 for Department procedures on design exceptions.

e	V = 30 mph			V = 35 mph			V = 40 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 4000	0	0	R ≥ 5000	0	0	R ≥ 6000	0	0
2.0%	4000 > R ≥ 2370	36	36	5000 > R ≥ 3120	40	40	6000 > R ≥ 3970	42	42
3.0%	2370 > R ≥ 1480	54	36	3120 > R ≥ 1960	60	40	3970 > R ≥ 2510	63	42
4.0%	1480 > R ≥ 1030	72	36	1960 > R ≥ 1370	80	40	2510 > R ≥ 1770	84	42
5.0%	1030 > R ≥ 730	90	36	1370 > R ≥ 1000	100	40	1770 > R ≥ 1310	105	42
6.0%	730 > R ≥ 510	108	36	1000 > R ≥ 720	120	40	1310 > R ≥ 970	126	42
7.0%	510 > R ≥ 360	126	36	720 > R ≥ 520	140	40	970 > R ≥ 720	147	42
8.0%	360 > R ≥ 220	144	36	520 > R ≥ 320	160	40	7200 > R ≥ 450	168	42
	R_{min} = 220 ft			R_{min} = 320 ft			R_{min} = 450 ft		

e	V = 45 mph			V = 50 mph			V = 55 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 7000	0	0	R ≥ 9000	0	0	R ≥ 10000	0	0
2.0%	7000 > R ≥ 4930	44	44	9000 > R ≥ 5990	48	48	10000 > R ≥ 7150	52	52
3.0%	4930 > R ≥ 3130	66	44	5990 > R ≥ 3820	72	48	7150 > R ≥ 4580	78	52
4.0%	3130 > R ≥ 2220	88	44	3820 > R ≥ 2720	96	48	4580 > R ≥ 3270	104	52
5.0%	2220 > R ≥ 1650	110	44	2720 > R ≥ 2040	120	48	3270 > R ≥ 2470	130	52
6.0%	1650 > R ≥ 1250	132	44	2040 > R ≥ 1560	144	48	2470 > R ≥ 1920	156	52
7.0%	1250 > R ≥ 940	154	44	1560 > R ≥ 1190	168	48	1920 > R ≥ 1480	182	52
8.0%	940 > R ≥ 590	176	44	1190 > R ≥ 760	192	48	1480 > R ≥ 960	208	52
	R_{min} = 590 ft			R_{min} = 760 ft			R_{min} = 960 ft		

e	V = 60 mph			V = 70 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 12000	0	0	R ≥ 15000	0	0
2.0%	12000 > R ≥ 8440	54	54	15000 > R ≥ 10700	60	60
3.0%	8440 > R ≥ 5420	81	54	10700 > R ≥ 6930	90	60
4.0%	5420 > R ≥ 3890	108	54	6930 > R ≥ 5050	120	60
5.0%	3890 > R ≥ 2960	135	54	5050 > R ≥ 3910	150	60
6.0%	2960 > R ≥ 2320	162	54	3910 > R ≥ 3150	180	60
7.0%	2320 > R ≥ 1820	189	54	3150 > R ≥ 2580	210	60
8.0%	1820 > R ≥ 1200	216	54	2580 > R ≥ 1810	240	60
	R_{min} = 1200 ft			R_{min} = 1810 ft		

e_{max} = 8.0%

Key:
R = Radius of curve, ft
V = Design speed, mph
e = Superelevation rate, %
L = Minimum length of superelevation runoff (from adverse slope removed to full super), ft
TR = Tangent runout from NC to adverse slope removed, ft
NC = Normal crown = 2.0%

Note: See Figure 9.2C for typical selection of curve radii.

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION
(Two-Lane, Two-Way Highways; Open Roadways)

Figure 9.3A (US Customary)

e	V = 50 km/h			V = 60 km/h			V = 70 km/h		
	R(m)	Trans. Length		R(m)	Trans. Length		R(m)	Trans. Length	
		L(m)	TR(m)		L(m)	TR(m)		L(m)	TR(m)
NC	R ≥ 1090	0	0	R ≥ 1495	0	0	R ≥ 1970	0	0
2.0%	1090 > R ≥ 795	30	30.00	1495 > R ≥ 1095	35	35.00	1970 > R ≥ 1445	40	40.00
3.0%	795 > R ≥ 500	30	20.00	1095 > R ≥ 700	35	23.33	1445 > R ≥ 925	40	26.67
4.0%	500 > R ≥ 350	30	15.00	700 > R ≥ 490	35	17.50	925 > R ≥ 650	40	20.00
5.0%	350 > R ≥ 260	30	12.00	490 > R ≥ 365	35	14.00	650 > R ≥ 490	40	16.00
6.0%	260 > R ≥ 190	35	11.67	365 > R ≥ 270	40	13.33	490 > R ≥ 370	40	13.33
7.0%	190 > R ≥ 135	40	11.43	270 > R ≥ 200	45	12.86	370 > R ≥ 275	50	14.29
8.0%	135 > R ≥ 80	45	11.25	200 > R ≥ 125	50	12.50	275 > R ≥ 175	55	13.75
	R_{min} = 80 m			R_{min} = 125 m			R_{min} = 175 m		

e	V = 80 km/h			V = 90 km/h			V = 100 km/h		
	R(m)	Trans. Length		R(m)	Trans. Length		R(m)	Trans. Length	
		L(m)	TR(m)		L(m)	TR(m)		L(m)	TR(m)
NC	R ≥ 2440	0	0	R ≥ 2965	0	0	R ≥ 3625	0	0
2.0%	2440 > R ≥ 1795	45	45.00	2965 > R ≥ 2185	50	55.00	3625 > R ≥ 2675	60	60.00
3.0%	1795 > R ≥ 1170	45	30.00	2185 > R ≥ 1400	50	33.33	2675 > R ≥ 1750	60	40.00
4.0%	1170 > R ≥ 825	45	22.50	1400 > R ≥ 1000	50	25.00	1750 > R ≥ 1250	60	30.00
5.0%	825 > R ≥ 620	45	18.00	1000 > R ≥ 770	50	20.00	1250 > R ≥ 950	60	24.00
6.0%	620 > R ≥ 475	45	15.00	770 > R ≥ 600	50	16.67	950 > R ≥ 750	60	20.00
7.0%	475 > R ≥ 360	55	15.71	600 > R ≥ 465	55	15.71	750 > R ≥ 590	60	17.14
8.0%	360 > R ≥ 230	60	15.00	465 > R ≥ 305	65	16.25	590 > R ≥395	65	16.25
	R_{min} = 230 m			R_{min} = 305 m			R_{min} = 395 m		

e	V = 110 km/h		
	R(m)	Trans. Length	
		L(m)	TR(m)
NC	R ≥ 4180	0	0
2.0%	4180 > R ≥ 3095	65	65.00
3.0%	3095 > R ≥ 2000	65	43.33
4.0%	2000 > R ≥ 1465	65	32.50
5.0%	1465 > R ≥ 1140	65	26.00
6.0%	1140 > R ≥ 900	65	21.67
7.0%	900 > R ≥ 735	65	18.57
8.0%	735 > R ≥ 500	70	17.50
	R_{min} = 500 m		

e_{max} = 8.0%

Key:

R = Radius of curve, m
V = Design speed, km/h
e = Superelevation rate, %
L = Minimum length of superelevation runoff (from adverse slope removed to full super), m
TR = Tangent runout from NC to adverse slope removed, m
NC = Normal crown = 2.0%

Note: See Figure 9.2C for typical selection of curve radii.

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION
(Two-Lane, Two-Way Highways; Open Roadways)

Figure 9.3A (Metric)

e	V = 30 mph			V = 35 mph			V = 40 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 4000	0	0	R ≥ 5000	0	0	R ≥ 6000	0	0
2.0%	4000 > R ≥ 2370	56	56	5000 > R ≥ 3120	58	58	6000 > R ≥ 3970	62	62
3.0%	2370 > R ≥ 1480	84	56	3120 > R ≥ 1960	87	58	3970 > R ≥ 2510	93	62
4.0%	1480 > R ≥ 1030	112	56	1960 > R ≥ 1370	116	58	2510 > R ≥ 1770	124	62
5.0%	1030 > R ≥ 730	140	56	1370 > R ≥ 1000	145	58	1770 > R ≥ 1310	155	62
6.0%	730 > R ≥ 510	168	56	1000 > R ≥ 720	174	58	1310 > R ≥ 970	186	62
7.0%	510 > R ≥ 360	196	56	720 > R ≥ 520	203	58	970 > R ≥ 720	217	62
8.0%	360 > R ≥ 220	224	56	520 > R ≥ 320	232	58	7200 > R ≥ 450	248	62
	R_{min} = 220 ft			R_{min} = 320 ft			R_{min} = 450 ft		

e	V = 45 mph			V = 50 mph			V = 55 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 7000	0	0	R ≥ 9000	0	0	R ≥ 10000	0	0
2.0%	7000 > R ≥ 4930	68	68	9000 > R ≥ 5990	72	72	10000 > R ≥ 7150	78	78
3.0%	4930 > R ≥ 3130	102	68	5990 > R ≥ 3820	108	72	7150 > R ≥ 4580	117	78
4.0%	3130 > R ≥ 2220	136	68	3820 > R ≥ 2720	144	72	4580 > R ≥ 3270	156	78
5.0%	2220 > R ≥ 1650	170	68	2720 > R ≥ 2040	180	72	3270 > R ≥ 2470	195	78
6.0%	1650 > R ≥ 1250	204	68	2040 > R ≥ 1560	216	72	2470 > R ≥ 1920	234	78
7.0%	1250 > R ≥ 940	238	68	1560 > R ≥ 1190	252	72	1920 > R ≥ 1480	273	78
8.0%	940 > R ≥ 590	272	68	1190 > R ≥ 760	288	72	1480 > R ≥ 960	312	78
	R_{min} = 590 ft			R_{min} = 760 ft			R_{min} = 960 ft		

e	V = 60 mph			V = 70 mph		
	R(ft)	Trans. Length		R(ft)	Trans. Length	
		L(ft)	TR(ft)		L(ft)	TR(ft)
NC	R ≥ 12000	0	0	R ≥ 16000	0	0
2.0%	12000 > R ≥ 8440	80	80	16000 > R ≥ 10700	90	90
3.0%	8440 > R ≥ 5420	120	80	10700 > R ≥ 6930	135	90
4.0%	5420 > R ≥ 3890	160	80	6930 > R ≥ 5050	180	90
5.0%	3890 > R ≥ 2960	200	80	5050 > R ≥ 3910	225	90
6.0%	2960 > R ≥ 2320	240	80	3910 > R ≥ 3150	270	90
7.0%	2320 > R ≥ 1820	280	80	3150 > R ≥ 2580	315	90
8.0%	1820 > R ≥ 1200	320	80	2580 > R ≥ 1810	360	90
	R_{min} = 1200 ft			R_{min} = 1810 ft		

e_{max} = 8.0%

Key:

R = Radius of curve, ft

V = Design speed, mph

e = Superelevation rate, %

L = Minimum length of superelevation runoff (from adverse slope removed to full super), ft

TR = Tangent runout from NC to adverse slope removed, ft

NC = Normal crown = 2.0%

Note: See Figure 9.2C for typical selection of curve radii.

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION
(Multilane Highways; Open Roadways)

Figure 9.3B (US Customary)

e	V = 50 km/h			V = 60 km/h			V = 70 km/h		
	R(m)	Trans. Length		R(m)	Trans. Length		R(m)	Trans. Length	
		L(m)	TR(m)		L(m)	TR(m)		L(m)	TR(m)
NC	R ≥ 1090	0	0	R ≥ 1495	0	0	R ≥ 1970	0	0
2.0%	1090 > R ≥ 795	30	30.00	1495 > R ≥ 1095	35	35.00	1970 > R ≥ 1445	40	40.00
3.0%	795 > R ≥ 500	30	20.00	1095 > R ≥ 700	35	23.33	1445 > R ≥ 925	40	26.67
4.0%	500 > R ≥ 350	35	17.50	700 > R ≥ 490	40	20.00	925 > R ≥ 650	40	20.00
5.0%	350 > R ≥ 260	45	18.00	490 > R ≥ 365	50	20.00	650 > R ≥ 490	50	20.00
6.0%	260 > R ≥ 190	50	16.67	365 > R ≥ 270	50	18.33	490 > R ≥ 370	60	20.00
7.0%	190 > R ≥ 135	60	17.14	270 > R ≥ 200	65	18.57	370 > R ≥ 275	70	20.00
8.0%	135 > R ≥ 80	65	16.25	200 > R ≥ 125	75	18.75	275 > R ≥ 175	80	20.00
	R_{min} = 80 m			R_{min} = 125 m			R_{min} = 175 m		

e	V = 80 km/h			V = 90 km/h			V = 100 km/h		
	R(m)	Trans. Length		R(m)	Trans. Length		R(m)	Trans. Length	
		L(m)	TR(m)		L(m)	TR(m)		L(m)	TR(m)
NC	R ≥ 2440	0	0	R ≥ 2965	0	0	R ≥ 3625	0	0
2.0%	2440 > R ≥ 1795	45	45.00	2965 > R ≥ 2185	50	50.00	3625 > R ≥ 2675	60	60.00
3.0%	1795 > R ≥ 1170	45	30.00	2185 > R ≥ 1400	50	33.33	2675 > R ≥ 1750	60	40.00
4.0%	1170 > R ≥ 825	45	22.50	1400 > R ≥ 1000	50	25.00	1750 > R ≥ 1250	60	30.00
5.0%	825 > R ≥ 620	55	22.00	1000 > R ≥ 770	60	24.00	1250 > R ≥ 950	60	24.00
6.0%	620 > R ≥ 475	65	21.67	770 > R ≥ 600	70	23.33	950 > R ≥ 750	75	25.00
7.0%	475 > R ≥ 360	80	22.86	600 > R ≥ 465	80	22.86	750 > R ≥ 590	85	24.29
8.0%	360 > R ≥ 230	90	22.50	465 > R ≥ 305	95	23.75	590 > R ≥395	100	25.00
	R_{min} = 230 m			R_{min} = 305 m			R_{min} = 395 m		

e	V = 110 km/h		
	R(m)	Trans. Length	
		L(m)	TR(m)
NC	R ≥ 4180	0	0
2.0%	4180 > R ≥ 3095	65	65.00
3.0%	3095 > R ≥ 2000	65	43.33
4.0%	2000 > R ≥ 1465	65	32.50
5.0%	1465 > R ≥ 1140	65	26.00
6.0%	1140 > R ≥ 900	80	26.67
7.0%	900 > R ≥ 735	90	25.71
8.0%	735 > R ≥ 500	105	26.25
	R_{min} = 500 m		

e_{max} = 8.0%

Key:

R = Radius of curve, m

V = Design speed, km/h

e = Superelevation rate, %

L = Minimum length of superelevation runoff (from adverse slope removed to full super), m

TR = Tangent runout from NC to adverse slope removed, m

NC = Normal crown = 2.0%

Note: See Figure 9.2C for typical selection of curve radii.

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION
(Multilane Highways; Open Roadways)

Figure 9.3B (Metric)

9.3.4 Minimum Radii Without Superelevation

A horizontal curve with a sufficiently large radius does not require superelevation, and the normal crown (NC) used on tangent sections can be maintained throughout the curve. Figures 9.3A and 9.3B indicate the threshold (or minimum) radius for a normal crown section at various design speeds. This threshold is based on a theoretical superelevation rate of +1.5%.

9.3.5 Transition Length

As defined in Section 9.3.1, the superelevation transition length is the distance required to transition the roadway from a normal crown section to the full design superelevation. The superelevation transition length is the sum of the tangent runout distance (TR) and superelevation runoff length (L).

9.3.5.1 Two-Lane Roadways

Superelevation Runoff

Figure 9.3A presents the superelevation runoff lengths for 2-lane roadways for various combinations of curve radii, design speed and superelevation rate. The lengths are calculated as follows:

US Customary	Metric	
$L = e \times W \times RS$	$L = e \times W \times RS \geq L_{min}$	(Equation 9.3-1)

where:

L = Superelevation runoff length for a 2-lane roadway, ft(m)

W = Width of travel lane (assumed to be 12'(3.6 m))

RS = Reciprocal of relative longitudinal slope between the roadway centerline and outside edge of traveled way (see Figure 9.3C)

e = Superelevation rate, decimal

L_{min} = Minimum superelevation runoff length regardless of calculated L (see Figure 9.3D), m (Metric Only)

US Customary

Design Speed (mph)	RS	Maximum Relative Longitudinal Slope, G(%)*
30	152	0.66
35	161	0.62
40	172	0.58
45	185	0.54
50	200	0.50
55	213	0.47
60	222	0.45
70	250	0.40

Metric

Design Speed (km/h)	RS	Maximum Relative Longitudinal Slope, G(%)*
50	150	0.65
60	167	0.60
70	182	0.55
80	200	0.50
90	210	0.48
100	222	0.45
110	238	0.42

* G(%) = 1/RS x 100

MAXIMUM RELATIVE LONGITUDINAL SLOPES
(Two-Lane Roadways)

Figure 9.3C

Metric Only

Design Speed(km/h)	Minimum Superelevation Runoff Lengths (m)
50	30
60	35
70	40
80	45
90	50
100	60
110	65

MINIMUM SUPERELEVATION
RUNOFF LENGTHS (L_{min})

Figure 9.3D

The calculated L values are subject to minimum lengths (L_{min}), which are based on approximately two seconds of travel time. Note that, where the calculated numbers apply, L has been rounded up to the next highest 15'(5 m) increment in Figure 9.3A.

Tangent Runout

Figure 9.3A presents the tangent runout distances based on a 2.0% normal crown for 2-lane roadways. For roadways having a normal crown other than 2%, use Equation 9.3-2 to compute the tangent runout distance. The distance is calculated as follows:

$$TR = \frac{S_{NORMAL}}{e/L} = \frac{(S_{NORMAL})(L)}{e} \qquad \text{(Equation 9.3-2)}$$

where:

TR = Tangent runout distance for a 2-lane roadway, ft(m)

S_{NORMAL} = Travel lane cross slope on tangent (typically 2.0%), decimal

e = Design superelevation rate (i.e., full superelevation for horizontal curve), decimal

L = Superelevation runoff length for a 2-lane roadway, ft(m) (Equation 9.3-1)

The values in Figure 9.3A are presented to the nearest foot (hundredth of a meter). This will ensure that the relative longitudinal gradient of the tangent runout equals that of the superelevation runoff. Multiply the value of the tangent runout from Table 9.3A by 1.5 for roadway with 3% normal crown (gravel roads).

9.3.5.2 Multilane Highways

Superelevation Runoff

The superelevation runoff distance for multilane highways is calculated by:

US Customary Metric

$L = 1.5 \text{ x } L_{\text{Two lane roadways}}$ $L = 1.5 \text{ x } e \text{ x } W \text{ x } RS \geq L_{min}$ (Equation 9.3-3)

where the terms are as defined for Equation 9.3-1 for 2-lane highways. The calculated runoff lengths for multilane facilities are approximately 1.5 times those for 2-lane facilities. The longer lengths are more appropriate for major facilities considering higher traffic volumes and the desire to provide a higher level of driver comfort.

Figure 9.3B presents the superelevation runoff distances for multilane facilities which are either the L_{min} values (Figure 9.3D) or the calculated values (Equation 9.3-3) rounded up to the next highest 15'(5 m) increment.

Tangent Runout

For multilane highways, the tangent runout distance is calculated from Equation 9.3-2, where L is the superelevation runoff distance for multilane highways and all other terms are as defined for Equation 9.3-2. Figure 9.3B presents the tangent runout distances to the nearest foot (hundredth of a meter). This will ensure that the relative longitudinal gradient of the tangent runout equals that of the superelevation runoff.

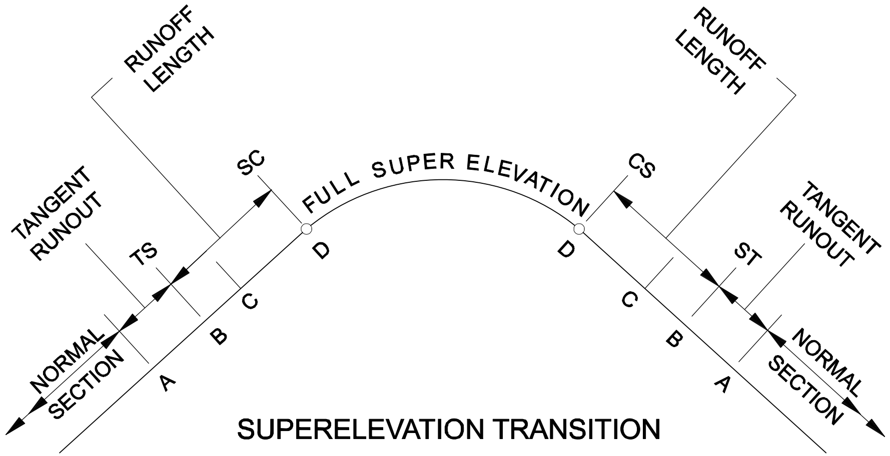
9.3.5.3 Application of Transition Length

Once the superelevation runoff and tangent runout have been calculated, the designer must determine how to fit the length in the horizontal and vertical planes. Figure 9.3E illustrates the application of the transition length in the plan view. See Section 9.3.11 for illustrations in the profile and cross section views. The following will apply:

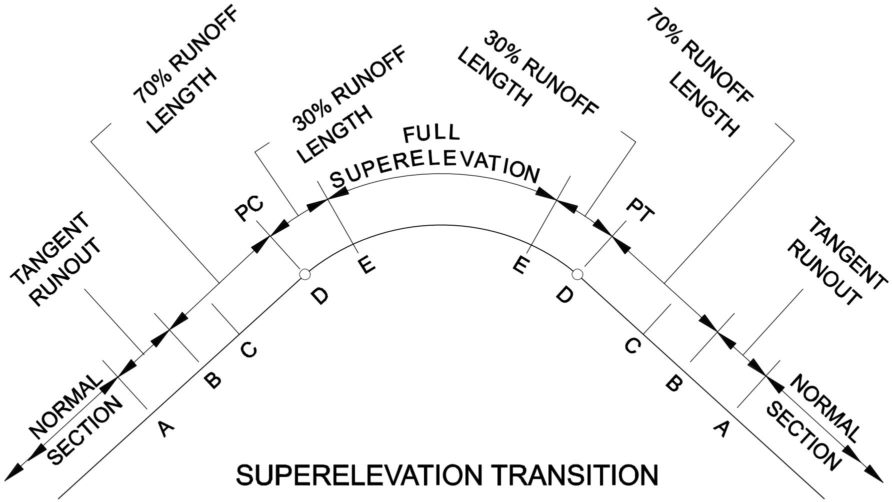
1. Spiral Curves. The tangent runout (TR) will be placed on the tangent sections immediately before and after the horizontal curve. The superelevation runoff (L) length will begin at the point of tangent to spiral (TS) and end at the point of spiral to (simple) curve (SC); i.e., the length of the spiral curve is set equal to the

superelevation runoff length. The application of L to the end of the curve will be from the CS to the ST.

2. Simple Curves. Typically, 70% of the superelevation runoff length will be placed on the tangent and 30% on the curve. For resurfacing and widening projects, it is acceptable to match the existing distribution of the superelevation runoff between the tangent and curve sections, even if 100% of the runoff length is on the tangent.



SUPERELEVATION TRANSITION
FOR SPIRAL CURVE



SUPERELEVATION TRANSITION
FOR SIMPLE CURVE

Note: See Section 9.3.11 for profile and cross section views (i.e., A, B, C, D and E) of superelevation development. C is the first (or last) point at which the cross section is at a uniform slope.

APPLICATION OF TRANSITION LENGTH
(Plan View)

Figure 9.3E

9.3.6 Axis of Rotation

The following discusses the axis of rotation for 2-lane, 2-way highways and multilane highways. Section 9.3.11 presents typical figures illustrating the application of the axis of rotation in superelevation development.

9.3.6.1 Two-Lane, Two-Way Highways

The axis of rotation will typically be about the inside edge (low side of superelevetion) of the traveled way on 2-lane, 2-way highways. This will also apply to a 2-lane highway with an auxiliary lane (e.g., a climbing lane); i.e., for a curve to the right, the axis of rotation is about the line between the climbing lane and the right travel lane.

9.3.6.2 Multilane Highways

The following will apply to the axis of rotation for multilane highways:

1. Depressed Median. The axes of rotation will be about the median side of the two inside shoulders.
2. Flush Median/Undivided Facility. The axis of rotation will be about the centerline of the entire roadway section. This also applies to highways with a concrete median barrier (CMB); i.e., the axis of rotation will be about the centerline of the CMB.
3. Raised Median. The axis of rotation will be about the centerline of the entire roadway section; i.e., the center of the raised median.

9.3.7 Shoulder Superelevation

9.3.7.1 High Side (Outside Shoulder)

On the high side of superelevated sections, the following criteria will apply to the shoulder slope:

1. Typical Application. On most horizontal curves, the high-side shoulder will be rotated concurrently with the adjacent travel lane; i.e., the shoulder and travel lane will remain in a plane section throughout the superelevated curve.
2. Exceptions. Where it is impractical to provide the typical application, the high-side shoulder may be sloped such that the algebraic difference between the shoulder and adjacent travel lane will not exceed 8% (i.e., the superelevation

rollover). This may be necessary, for example, to meet roadside development. This rollover applies to the algebraic difference in cross slopes between the travel lanes and the roadway shoulder. It also applies to lanes which diverge from the mainline, such as ramps. However, it does not apply to approaches.

9.3.7.2 Low Side (Inside Shoulder)

On the low side of a superelevated section, the typical practice is to rotate the finished shoulder concurrently with the adjacent travel lane; i.e., the inside finished shoulder and travel lane will remain in a plane section. The portion of the subgrade from a point below the finished shoulder to the subgrade shoulder point will be designed using a 2.0% slope, regardless of the superelevation rate of the traveled way. See the typical section figures in Section 11.7 for an illustration.

9.3.8 Reverse Curves

Reverse curves are two closely spaced horizontal curves with deflections in opposite directions and a short, intervening tangent. For this situation, it may not be practical to achieve a normal crown section between the two curves. A plane section continuously rotating about its axis (i.e., the two inside edges of the traveled way) can be used between the two curves, if they are sufficiently close together. The designer should adhere to the applicable superelevation development criteria (e.g., superelevation transition lengths) for each curve. The following will apply to reverse curves:

1. Normal Section. The designer should not attempt to achieve a normal tangent section between reverse curves unless the normal section can be maintained for a minimum distance of 200ft (60 m), and the superelevation transition requirements can be met for both curves.

2. Continuously Rotating Plane. If a normal section is not provided, the pavement will be continuously rotated in a plane about its axis. The minimum distance between the PT and PC of reverse simple curves will be 70% of the required runoff lengths of the two curves. See Figure 9.3L and Figure 9.3M for a schematic of a continuously rotating plane through a reverse curve. Note that, as illustrated in Figure 9.3L and Figure 9.3M, the axis of rotation switches from one inside edge of traveled way to the other inside edge at the point where the roadway becomes level.

9.3.9 Broken-Back Curves

Broken-back curves are two closely spaced horizontal curves with deflections in the same direction and a short, intervening tangent. The designer should avoid the use of broken-back curves. Where they must be used, the following will apply to superelevation:

1. Normal Section. The designer should not attempt to achieve a normal tangent section between broken-back curves unless the normal section can be maintained for a minimum distance of 200ft (60 m), and the superelevation transition requirements can be met for both curves.
2. Superelevated Section. If a normal section is not provided, the designer should provide a transitional curve-to-curve spiral or a transitional compound curve connection to accommodate the gradual change between superelevation rates.

9.3.10 Bridges

From the perspective of the roadway user, a bridge is an integral part of the roadway system and, ideally, horizontal curves and their transitions will be located irrespective of their impact on bridges. However, practical factors in bridge design and bridge construction warrant consideration in the location of horizontal curves at bridges. The following presents, in order from the most desirable to the least desirable, the application of horizontal curves to bridges:

1. The most desirable treatment is to locate the bridge and its approach slabs on a tangent section and sloped at the typical cross slope; i.e., no portion of the curve or its superelevation development will be on the bridge or bridge approach slabs.
2. If a horizontal curve is located on a bridge, any transitions should not be located on the bridge or its approach slabs. This includes both superelevation transitions and spiral transitions. This will result in a uniform cross slope (i.e., the design superelevation rate) and a constant rate of curvature throughout the length of the bridge and bridge approach slabs. This will occur at Section D in Figure 9.3F (spiral curve) and Section E in Figure 9.3G (simple curve).
3. If the superelevation transition is located on the bridge or its approach slabs, the designer should place on the roadway approach that portion of the superelevation development which transitions the roadway cross section from its normal crown to a point where the roadway slopes uniformly (i.e. there is no break in the cross slope on the bridge deck). This will occur at Section C in Figure 9.3F (spiral curve) and Section C in Figure 9.3G (simple curve). This will avoid the need to warp the crown on the bridge or the bridge approach slabs.

9.3.11 Typical Figures

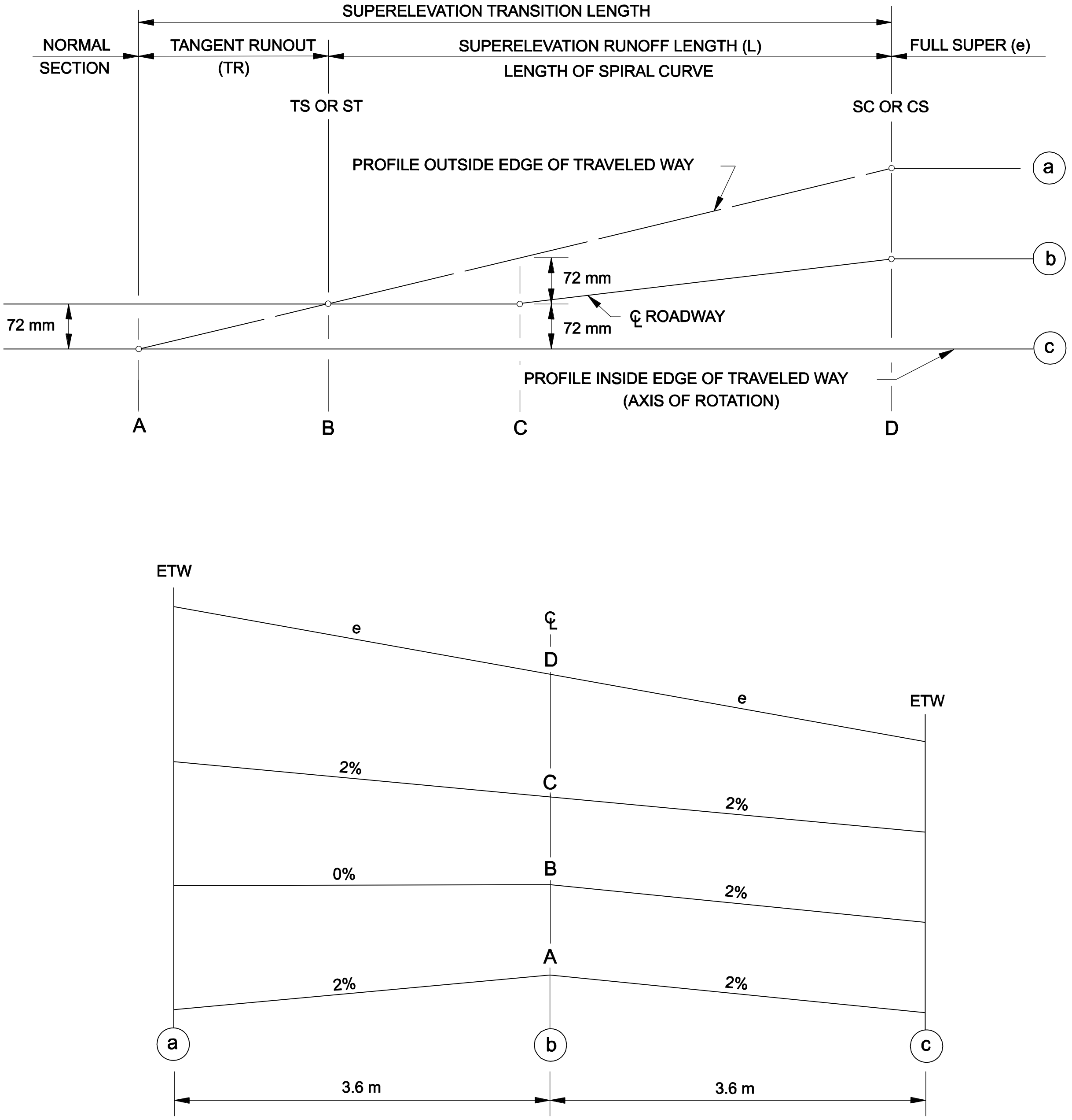
Figures 9.3F through 9.3M present typical figures for superelevation development as follows:

1. Two-Lane Facilities. Figure 9.3F (spiral curve) and Figure 9.3G (simple curve) illustrate the superelevation development with the axis of rotation about the inside edge of traveled way.

2. Multilane Divided Facilities. Figure 9.3H (spiral curve) and Figure 9.3I (simple curve) illustrate the superelevation development with the axes of rotation about the median edges of the two inside shoulders.

3. Other Facilities. Section 9.3.6 identifies several types of facilities where the axis of rotation is about the centerline of the roadway section. Figure 9.3J (spiral curve) and 9.3K (simple curve) illustrate the superelevation development with the axes of rotation about the centerline.

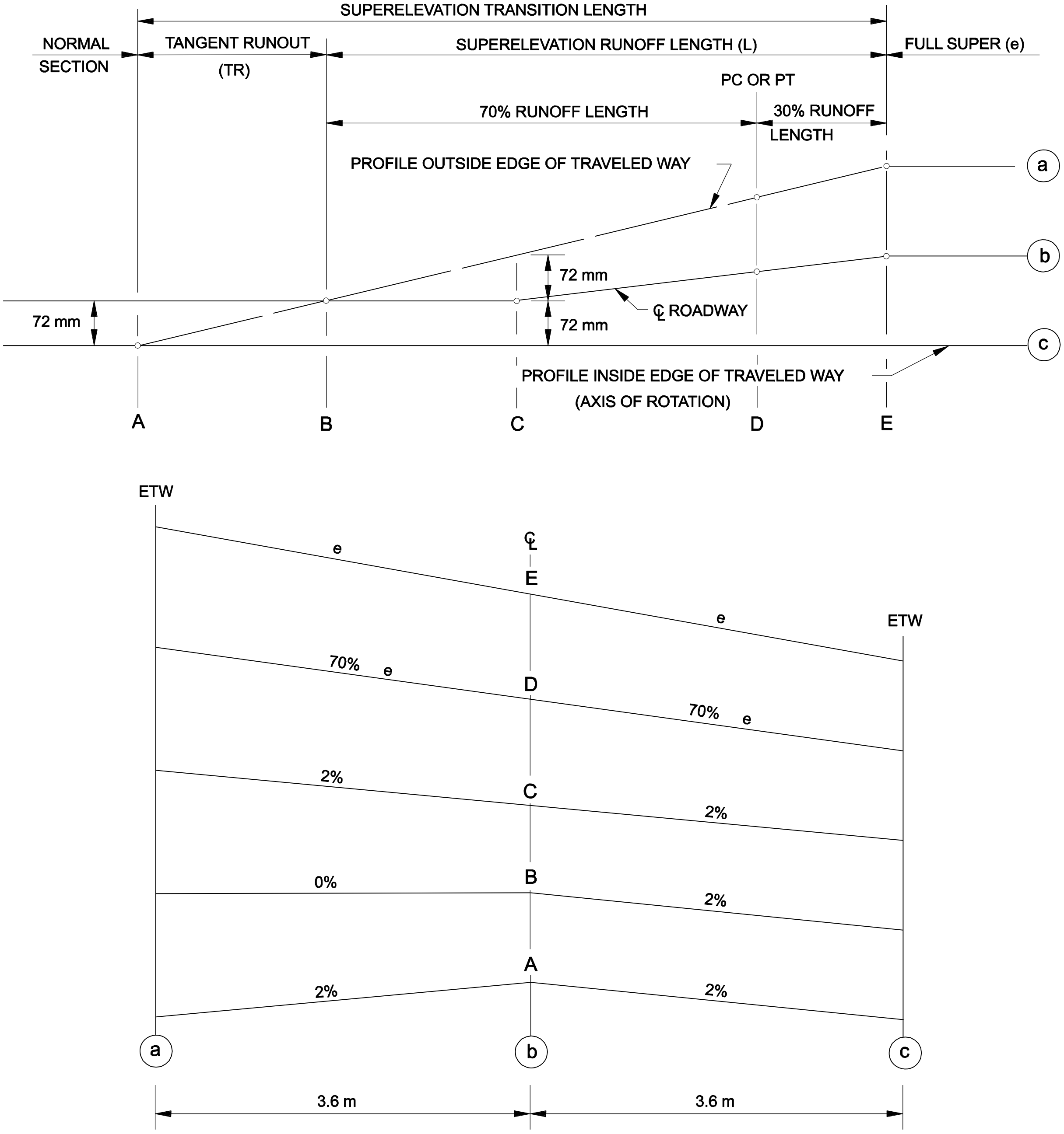
4. Reverse Curves. Figure 9.3L (simple curve) and Figure 9.3M (spiral curve) presents a schematic for superelevating reverse curves with a continuously rotating plane (i.e., no normal section).



Note: See Figure 9.3E for plan view.

SUPERELEVATION OF TWO-LANE FACILITIES
(Spiral Curve)

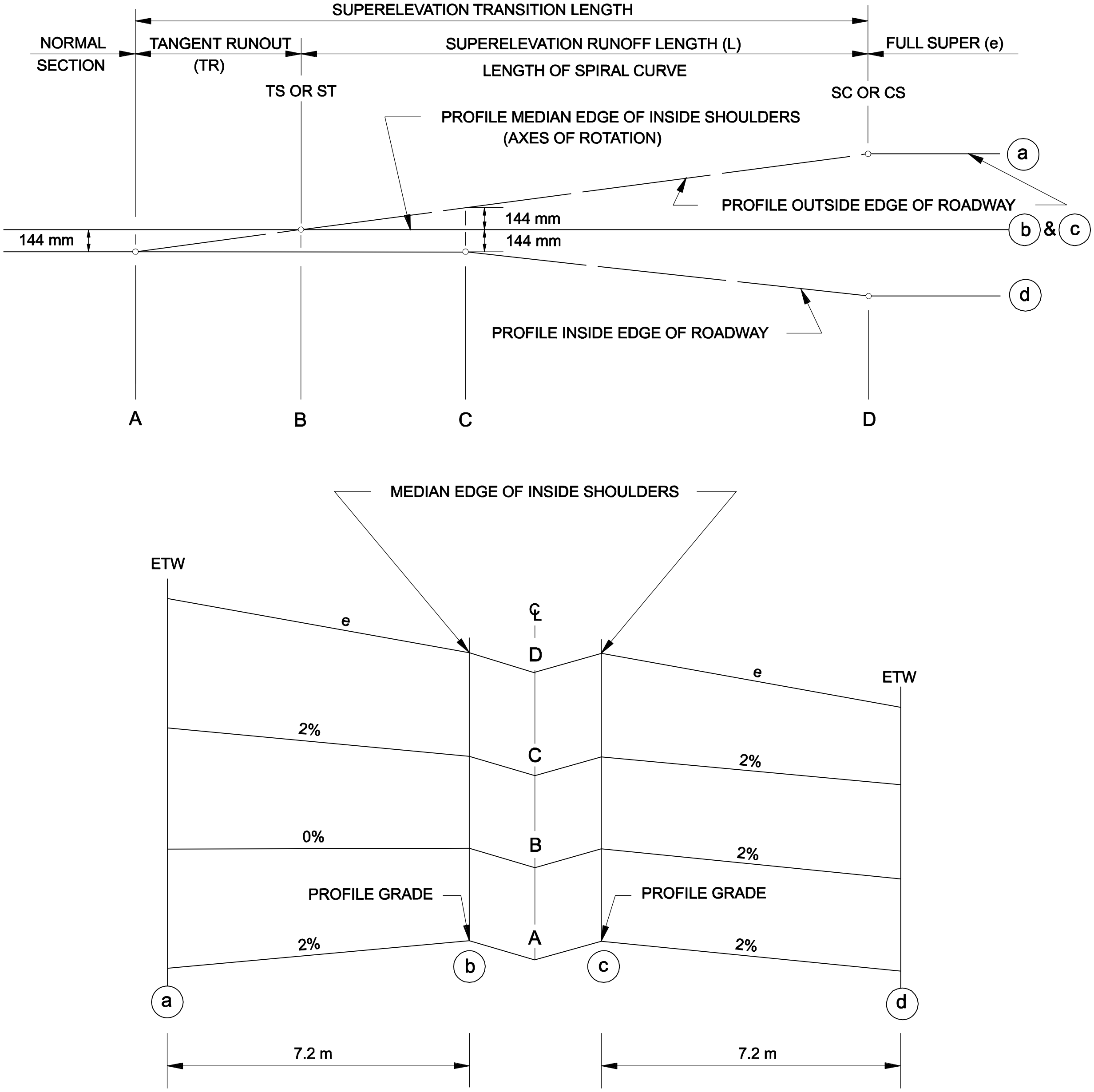
Figure 9.3F



Note: See Figure 9.3E for plan view.

SUPERELEVATION OF TWO-LANE FACILITIES (Simple Curve)

Figure 9.3G



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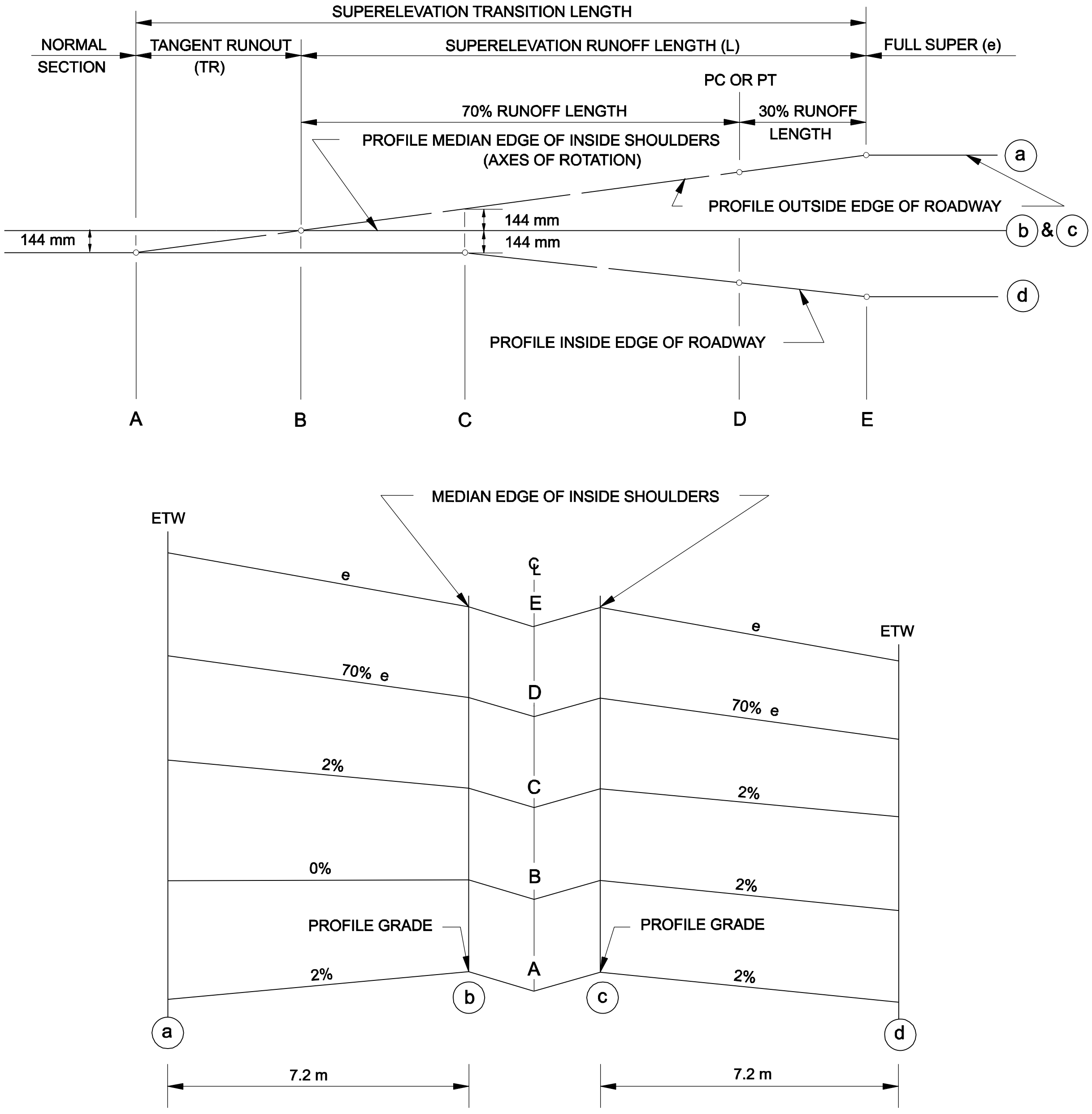
Note: See Figure 9.3E for plan view.

SUPERELEVATION OF MULTILANE DIVIDED FACILITIES
(Spiral Curve)

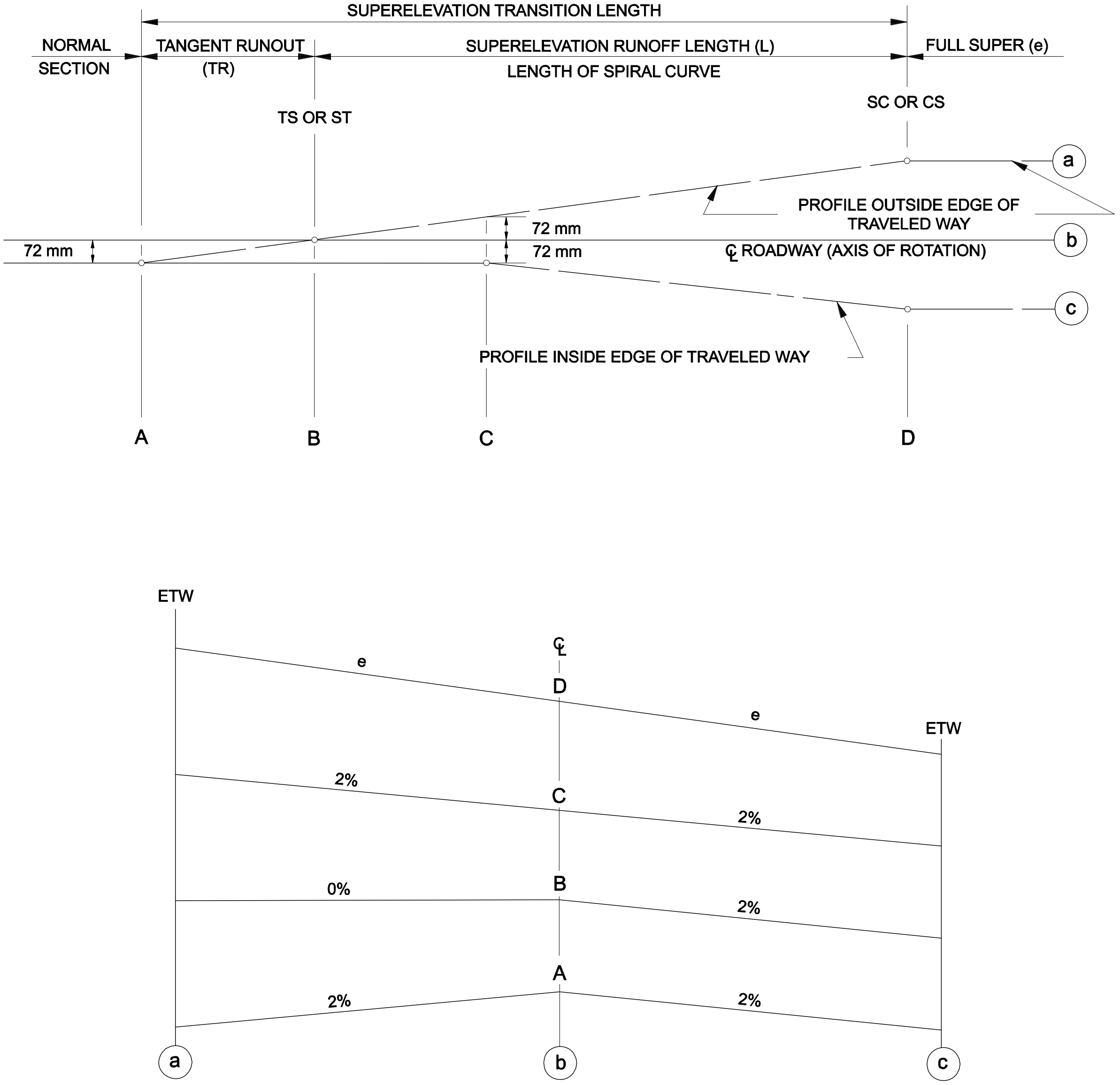
Figure 9.3H



Note: See Figure 9.3E for plan view.

SUPERELEVATION OF MULTILANE DIVIDED FACILITIES
(Simple Curve)

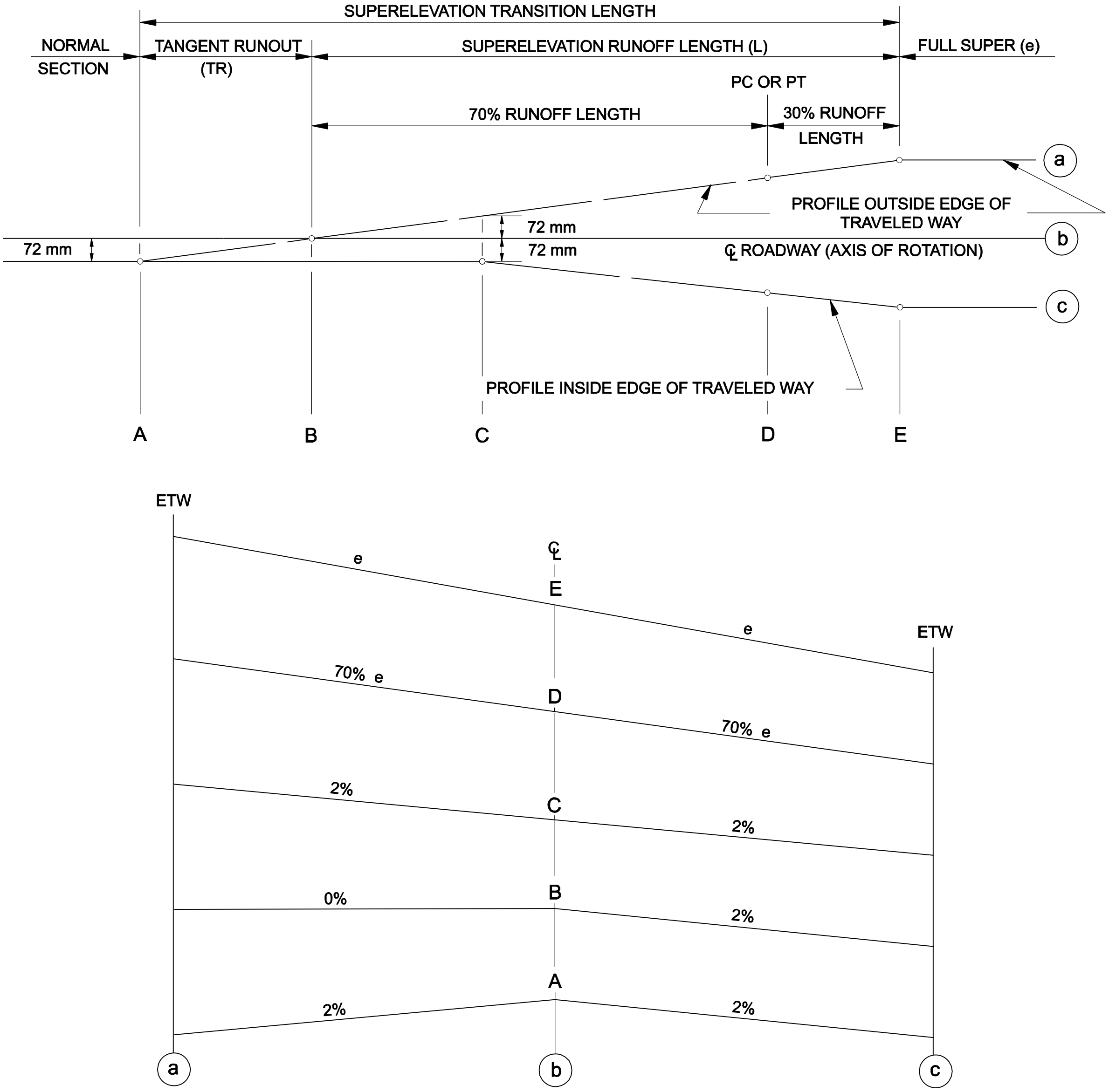
Figure 9.3I



Note: See Figure 9.3E for plan view.

AXIS OF ROTATION ABOUT CENTERLINE
(Spiral Curve)

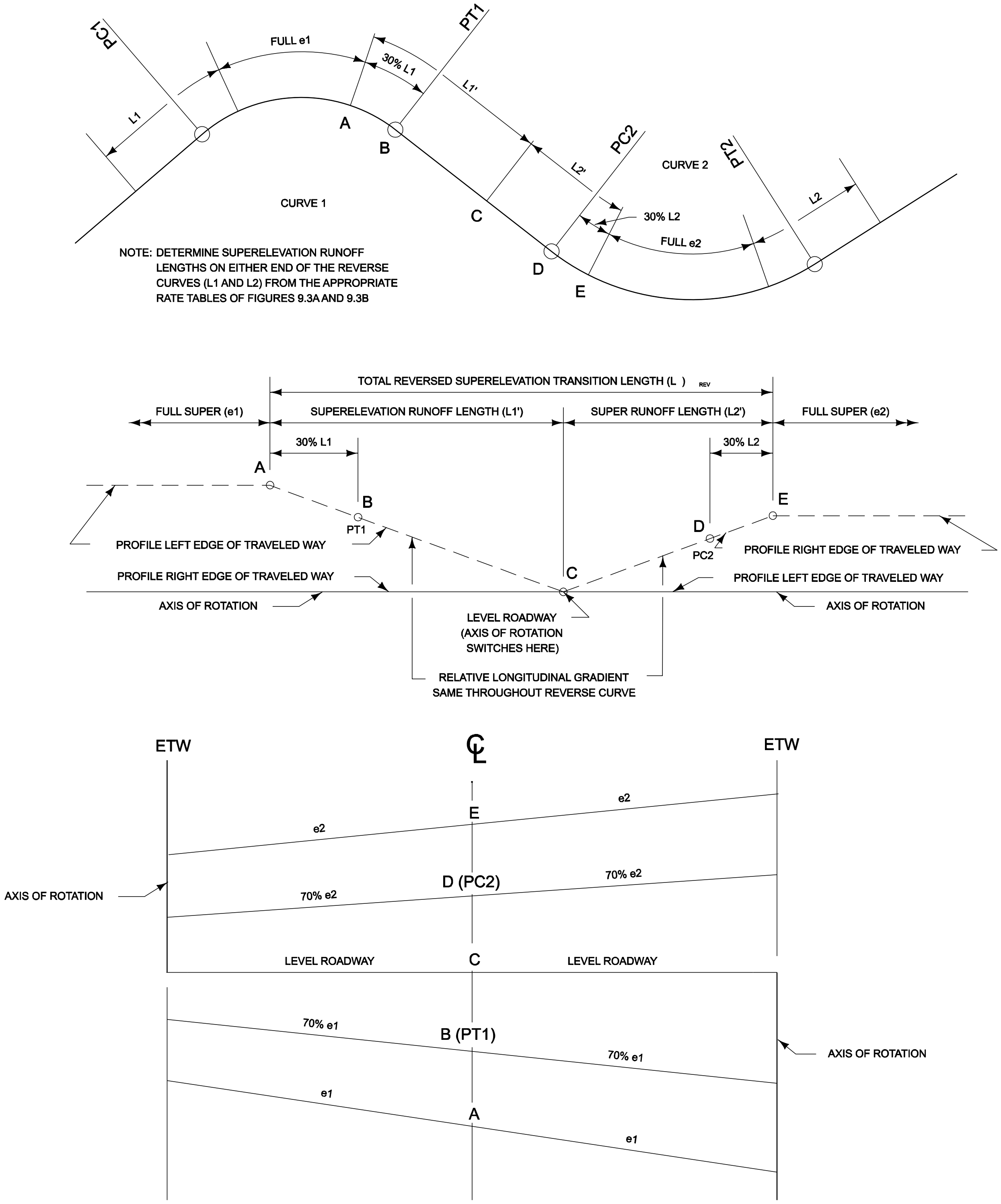
Figure 9.3J



Note: See Figure 9.3E for plan view.

AXIS OF ROTATION ABOUT CENTERLINE
(Simple Curve)

Figure 9.3K



NOTE: DETERMINE SUPERELEVATION RUNOFF LENGTHS ON EITHER END OF THE REVERSE CURVES (L1 AND L2) FROM THE APPROPRIATE RATE TABLES OF FIGURES 9.3A AND 9.3B

SUPERELEVATION OF REVERSE CURVES
(Continuously Rotating Plane)
Figure 9.3L

Example 9.3-1 Reverse Superelevation Transition (Continuous Rotating Plane)

Given: A two-lane, two-way, open roadway with a design speed of 45 mph and the following reverse curves (circular):

Curve 1	Curve 2
PI Station = 27+07.45	PI Station = 46+47.67
Δ = 73° 08’ 53” RT	Δ = 61° 14’ 40” LT
R = 1,800 feet	R = 1,050 feet
PC Station = 13+71.92	PC Station = 40+26.15
PT Station = 36+69.94	PT Station = 47+92.30

Step 1 - Determine if the curves meet the criteria for superelevation transition by the continuous rotating plane method.

From Figure 9.3A:

Curve 1 requires a 5% superelevation (e1), with 110.00 feet of Runoff (L1), and 44.00 feet of Transition Runout (TR1) for normal superelevation development.

Curve 2 requires a 7% superelevation (e2), with 154.00 feet of Runoff (L2), and 44.00 feet of Transition Runout (TR2) for normal superelevation development.

The tangent distance between the two curves is:

PC2 Sta. – PT1 Sta. = [40+26.15] – [36+69.94] = 356.21 feet

The distance outside of the curves required for normal superelevation development is 70% of the runoff + the runout distances. For these curves, normal superelevation transitions between the curves would require:

0.7*(L1 + L2) + TR1 + TR2 = 0.7*(110.00 + 154.00) + 2*44.00 = 272.80 feet

The length of normal crown between transitions is 356.21 – 272.80 = 83.41 feet. This distance is less than 200’, and the continuous rotating plane method is applicable in this situation.

Note that the minimum tangent distance between these two curves would be 70% of the two runoff distances, or 184.80 feet. Any tangent distance less than this would require either an increase in the normal transition rate or locating more of the transitions on the curves. Either option requires approval of the Highways Engineer.

Step 2 – Locate the stations of full superelevation.

For continuous rotating plane transitions, the points of full superelevation are held and the transitions are combined into a continuous transition with a constant rate of change.

Points of full super elevation are determined normally, that is 30% of the standard runoff distances onto each curve.

The point where the superelevation starts to transition from 5% RT (point A, Figure 9.3-L) is:

Station A = PT1 station – 0.3 (L1) = [36+69.94] – 0.3*(110.00) = Sta. 36+36.94

The point where the transition ends at full 7% superelevation LT (point E, Fig. 9.3-L) is:

Station E = PC2 station + 0.3(L2) = [40+26.15] + 0.3*(154.00) = Sta. 40+72.35

Step 3 – Determine the location of level roadway, where the point of rotation changes from 12' RT of centerline to 12'LT (point C, Figure 9.3-L).

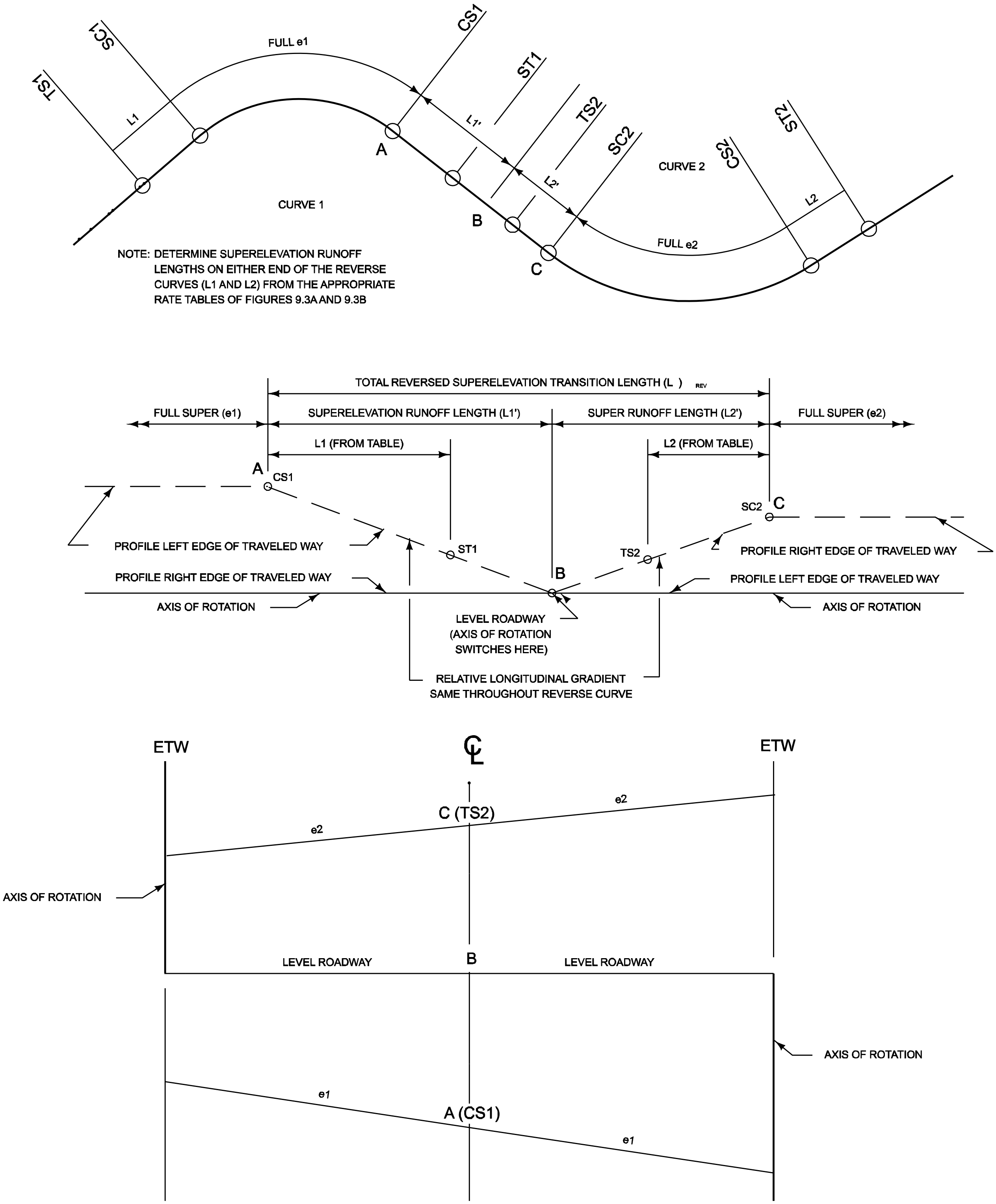
The total length of continuous superelevation transition (L_{REV}) is the distance between points A and E.

L_{REV} = Station E – Station A = [40+72.35] – [36+36.94] = 435.41 feet

The length of superelevation transition from 5% RT to level (L1') is the distance between points A and C.

L1' = $\frac{e1}{(e1+e2)} * L_{REV} = \frac{7}{(5+7)} * 435.41$ feet = 253.99 feet

Station C = Station A + L1' = [Station 36+36.94] + 253.99 = 38+90.93



NOTE: DETERMINE SUPERELEVATION RUNOFF LENGTHS ON EITHER END OF THE REVERSE CURVES (L1 AND L2) FROM THE APPROPRIATE RATE TABLES OF FIGURES 9.3A AND 9.3B

SUPERELEVATION OF REVERSE CURVES
(Continuously Rotating Plane)
Figure 9.3M

Example 9.3-2 Reverse Superelevation Transition (Continuous Rotating Plane) for curves with spiral transitions.

Given: A two-lane, two-way, open roadway with a design speed of 55 mph and the following reverse curves (w/ spiral transition):

Curve 1	Curve 2
PI Station = 314+76.54	PI Station = 326+93.50
Δ = 23° 17’ 15” LT	Δ = 21° 18’ 00” RT
R = 1,150 feet	R = 3,000 feet

Step 1 - Determine if the curves meet the criteria for superelevation transition by the continuous rotating plane method.

From Fig. 9.3A:

Curve 1 requires a 8% superelevation (e1), with 208.00 feet of Runoff and Spiral Transition (L1= L_{S1}), and 52.00 feet of Transition Runout (TR1) for normal superelevation development.

Curve 2 requires a 5% superelevation (e1), with 130.00 feet of Runoff and Spiral Transition (L1= L_{S1}), and 52.00 feet of Transition Runout (TR1) for normal superelevation development.

Using spiral calculations found in this chapter and Barnett’s *Transition Curves For Highways,* the following is calculated:

Curve 1	Curve 2
PI Station = 314+76.54	PI Station = 326+93.50
Δ = 23° 17’ 15” LT	Δ = 21° 18’ 00” RT
R = 1,150 feet	R = 3,000 feet
L_s = 208.00’	L_s = 130.00’
θ_s = 5° 10’ 54”	θ_s = 1° 14’ 29”
p = 1.5666’	p = 0.2343’
k = 103.9713’	k = 64.9988’
T_s = 341.27’	T_s = 629.19’
Δ_c = 12° 55’ 27”	Δ_c = 18° 49’ 02”
L_c = 259.40’	L_c = 985.27’
TS Station = 311+35.27	TS Station = 320+64.31
SC Station = 313+43.27	SC Station = 321+94.31
CS Station = 316+02.67	CS Station = 331+79.58
ST Station = 318+10.67	ST Station = 333+09.58

The tangent distance between the two curves is:TS2 Sta. – ST1 Sta. = [320+64.31] – [318+10.67] = 253.64 feet

The distance outside of the curves required for normal superelevation development is the sum of the Tangent Runout distances:

TR1 + TR2 = 52.00 + 52.00 = 104.00 feet

The length of normal crown between transitions is 253.67 – 104.00 = 149.64 feet. This distance is less than 200', and the continuous rotating plane method is applicable in this situation.

Note that in the case of spiral curves, there is no minimum distance between curves, since the transition from full superelevation to level roadway is accomplished within the limits of the spirals under normal conditions. Two reverse spiral curves can actually occupy the same point.

Step 2 – Locate the stations of full superelevation.

For continuous rotating plane transitions, the points of full superelevation are held and the transitions are combined into a continuous transition with a constant rate of change.

Points of full superelevation are the SC and CS of each curve, with the entire circular curve section between these points at the full superelevation. The end of full 8% LT (point A on Figure 9.3-M) is the CS of Curve 1, Station 316+02.67 and the SC of Curve 2, Station 321+94.31 is the beginning of full 5% super RT (point C on Figure 9.3-M).

Step 3 – Determine the location of level roadway, where the point of rotation changes from 12' LT of centerline to 12' RT (point B, Fig. 9.3-M).

The total length of continuous superelevation transition (L_{REV}) is the distance between points A and C.

L_{REV} = Station C – Station A = [321+94.31] – [316+02.67] = 591.64 feet

The length of superelevation transition from 8% LT to level (L1') is the distance between points A and B.

$$L1' = \frac{e2}{(e1+e2)} * L_{REV} = \frac{5}{(8+5)} * 591.64 \text{ feet} = 227.55 \text{ feet}$$

Station B = Station A + L1' = [316+02.67] + 227.55 = 318+30.22

9.4 SUPERELEVATION (LOW-SPEED URBAN STREETS)

9.4.1 General

Low-speed urban street conditions may be used for superelevating streets in urban and urbanized areas where (V) ≤ 45mph(70 km/h). On these facilities, providing superelevation at horizontal curves is frequently impractical because of roadside conditions and, in some cases, may result in undesirable operational conditions. The following lists some of the characteristics of low-speed urban streets, which often complicate superelevation development:

1. Roadside Development/Intersections/Driveways. Built-up roadside development is common adjacent to low-speed urban streets. Matching superelevated curves with many driveways, intersections, sidewalks, etc., creates considerable complications. This may also require re-grading parking lots, lawns, etc., to compensate for the higher elevation of the high side of the superelevated curve.

2. Non-Uniform Travel Speeds. On low-speed urban streets, travel speeds are often non-uniform because of frequent signalization, stop signs, vehicular conflicts, etc. It is undesirable for traffic to stop on a superelevated curve, especially when snow or ice is present.

3. Limited Right-of-Way. Superelevating curves often results in more right-of-way impacts than would otherwise be necessary. Right-of-way is often restricted along low-speed urban streets.

4. Wide Pavement Areas. Many low-speed urban streets have wide pavement areas because of high traffic volumes in built-up areas, the absence of a median and the presence of parking lanes. In general, the wider the pavement area, the more complicated will be the development of superelevation.

5. Surface Drainage. Proper pavement drainage on low-speed urban streets can be difficult even on sections with a normal crown. Superelevation introduces another complicating factor.

As discussed in Section 9.2, AASHTO Method 2 is used to distribute superelevation and side friction in determining superelevation rates for the design of horizontal curves on low-speed urban streets. In addition, relatively high side-friction factors are used. The practical impact is that superelevation is rarely warranted on these facilities.

The designer should not apply the superelevation criteria assuming low-speed urban street conditions to highway transitions between rural and urban areas, The designer should not apply the superelevation criteria even if the design speed is (V) ≤ 45mph(70 km/h). These areas should be designed assuming open-roadway conditions.

9.4.2 Superelevation Rates

Based on the selection of e_{max} = 4.0% and the use of AASHTO Method 2 to distribute e and f, Figure 9.4A allows the designer to select the superelevation rate for combinations of curve radii (R) and design speed (V). Note that superelevation rates are a controlling criteria. The designer must seek a design exception for any proposed rate which does not meet the criteria in Figure 9.4A. See Section 8.8 for Department procedures on design exceptions.

9.4.3 Minimum Radii Without Superelevation

On low-speed urban streets, horizontal curves with sufficiently large radii do not require superelevation; i.e., the normal crown section can be maintained around a curve. The threshold exists where the theoretical superelevation equals -2.0%. Figure 9.4A indicates limiting radii for normal crown (NC).

9.4.4 Transition Length

As defined in Section 9.3.1, the superelevation transition length is the distance required to transition the roadway from a normal crown section to the full design superelevation. The superelevation transition length is the sum of the tangent runout distance (TR) and superelevation runoff length (L).

9.4.4.1 Two-Lane Roadways

Superelevation Runoff

Figure 9.4A presents the superelevation runoff lengths for 2-lane roadways for various combinations of superelevation rates and design speed. The lengths are calculated as follows:

e	V = 15 mph					V = 20 mph				
	R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)		R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(ft)	TR(ft)	L(ft)	TR(ft)		L(ft)	TR(ft)	L(ft)	TR(ft)
NC	R ≥ 50	0	0	0	0	R ≥ 107	0	0	0	0
2.0%	50 > R ≥ 44	30	30	46	46	107 > R ≥ 92	32	32	50	50
3.0%	44 > R ≥ 43	45	30	69	46	92 > R ≥ 89	48	32	75	50
4.0%	43 > R ≥ 42	60	30	92	46	89 > R ≥ 86	64	32	100	50
	R_{min} = 42 ft					R_{min} = 86 ft				

e	V = 25 mph					V = 30 mph				
	R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)		R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(ft)	TR(ft)	L(ft)	L(ft)		TR(ft)	TR(ft)	L(ft)	TR(ft)
NC	R ≥ 198	0	0	0	0	R ≥ 333	0	0	0	0
2.0%	198 > R ≥ 167	34	34	52	52	333 > R ≥ 273	36	36	56	56
3.0%	167 > R ≥ 160	51	34	78	52	273 > R ≥ 261	54	36	84	56
4.0%	160 > R ≥ 154	68	34	104	52	261 > R ≥ 250	72	36	112	56
	R_{min} = 154 ft					R_{min} = 250 ft				

e	V = 35 mph					V = 40 mph				
	R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)		R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(ft)	TR(ft)	L(ft)	TR(ft)		L(ft)	TR(ft)	L(ft)	TR(ft)
NC	R ≥ 510	0	0	0	0	R ≥ 762	0	0	0	0
2.0%	510 > R ≥ 408	40	40	58	58	762 > R ≥ 593	42	42	62	62
3.0%	408 > R ≥ 389	60	40	116	58	593 > R ≥ 561	63	42	93	62
4.0%	389 > R ≥ 371	80	40	174	58	561 > R ≥ 533	84	42	124	62
	R_{min} = 371 ft					R_{min} = 533 ft				

e	V = 45 mph				
	R(ft)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(ft)	TR(ft)	L(ft)	TR(ft)
NC	R ≥ 1039	0	0	0	0
2.0%	1039 > R ≥ 794	44	44	68	68
3.0%	794 > R ≥ 750	66	44	102	68
4.0%	750 > R ≥ 711	88	44	136	68
	R_{min} = 711 ft				

e_{max} = 4.0%

Key:

R = Radius of curve, ft
V = Design speed, mph
e = Superelevation rate, %
L = Minimum length of superelevation runoff (from adverse slope removed to full super), ft
TR = Tangent runout from NC to adverse slope removed, ft
NC = Normal crown = 2.0%

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION
(Low-Speed Urban Streets)

Figure 9.4A (US Customary)

e	V = 30 km/h					V = 40 km/h				
	R(m)	Trans. Length (Two-Lane)		Trans. Length (Multilane)		R(m)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(m)	TR(m)	L(m)	TR(m)		L(m)	TR(m)	L(m)	TR(m)
NC	R ≥ 25	0	0	0	0	R ≥ 55	0	0	0	0
2.0%	25 > R ≥ 22	10	10.00	15	15.00	55 > R ≥ 47	15	15.00	15	15.00
3.0%	22 > R ≥ 21	15	10.00	20	13.33	47 > R ≥ 46	15	10.00	20	13.33
4.0%	21 > R ≥ 20	20	10.00	25	12.50	46 > R ≥ 45	20	10.00	25	12.50
	R_{min} = 20 m					R_{min} = 45 m				

e	V = 50 km/h					V = 60 km/h				
	R(m)	Trans. Length (Two-Lane)		Trans. Length (Multilane)		R(m)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(m)	TR(m)	L(m)	TR(m)		L(m)	TR(m)	L(m)	TR(m)
NC	R ≥ 104	0	0	0	0	R ≥ 178	0	0	0	0
2.0%	104 > R ≥ 86	15	15.00	15	15.00	178 > R ≥ 142	20	20.00	20	20.00
3.0%	86 > R ≥ 83	15	10.00	25	16.67	142 > R ≥ 135	20	13.33	25	16.67
4.0%	83 > R ≥ 80	20	10.00	30	15.00	135 > R ≥ 125	20	10.00	30	15.00
	R_{min} = 80 m					R_{min} = 125 m				

e	V = 70 km/h				
	R(m)	Trans. Length (Two-Lane)		Trans. Length (Multilane)	
		L(m)	TR(m)	L(m)	TR(m)
NC	R ≥ 258	0	0	0	0
2.0%	258 > R ≥ 204	20	20.00	20	20.00
3.0%	204 > R ≥ 193	20	13.33	25	16.67
4.0%	193 > R ≥ 190	25	12.50	35	17.50
	R_{min} = 190 m				

e_{max} = 4.0%

Key:
R = Radius of curve, m
V = Design speed, km/h
e = Superelevation rate, %
L = Minimum length of superelevation runoff (from adverse slope removed to full super), m
TR = Tangent runout from NC to adverse slope removed, m
NC = Normal crown = 2.0%

RATE OF SUPERELEVATION AND MINIMUM LENGTH OF TRANSITION (Low-Speed Urban Streets)

Figure 9.4A (Metric)

Metric Only

$L = e \times W \times RS \geq L_{min}$ (Equation 9.4-1)

where: Metric Section only

L = Superelevation runoff length for a 2-lane roadway, m

W = Width of travel lane (assumed to be 3.6 m)

RS = Reciprocal of relative longitudinal slope between the roadway centerline and outside edge of the traveled way (see Figure 9.4B)

e = Superelevation rate, decimal

L_{min} = Minimum superelevation runoff length regardless of calculated L (see Figure 9.4C), m (Metric Only)

The calculated L values are subject to minimum lengths (L_{min}), which are based on approximately one second of travel time. Note that, where the calculated numbers apply, L has been rounded up to the next highest 5 m increment in Figure 9.4A.

Tangent Runout

Figure 9.4A presents the tangent runout distances for 2-lane roadways. For roadways with a normal crown other than 2%, use Equation 9.4-2 to compute the tangent runout distance. The distance is calculated as follows:

$$TR = \frac{S_{NORMAL}}{e/L} = \frac{(S_{NORMAL})(L)}{e} \qquad \text{(Equation 9.4-2)}$$

where:

TR = Tangent runout distance for a 2-lane roadway, ft(m)

S_{NORMAL} = Travel lane cross slope on tangent (typically 2.0%), decimal

e = Design superelevation rate (i.e., full superelevation for horizontal curve), decimal

L = Superelevation runoff length for a 2-lane roadway, ft(m) (Equation 9.4-1)

Metric

Design Speed(km/h)	RS	Maximum Relative Longitudinal Slope, G(%)*
30	105	0.98
40	115	0.90
50	125	0.80
60	135	0.74
70	150	0.68

* G(%) = 1/RS x 100

MAXIMUM RELATIVE LONGITUDINAL SLOPES
(Low-Speed Urban Streets)

Figure 9.4B

Design Speed(km/h)	Minimum Superelevation Runoff Lengths (m)
30	10
40	15
50	15
60	20
70	20

MINIMUM SUPERELEVATION
RUNOFF LENGTHS (L_{min})
(Low-Speed Urban Streets)

Figure 9.4C (Metric Only)

The values in Figure 9.4A are presented to the nearest foot (hundredth of a meter). This will ensure that the relative longitudinal gradient of the tangent runout equals that of the superelevation runoff.

9.4.4.2 Multilane Highways

Superelevation Runoff

The superelevation runoff distance for multilane highways is calculated by:

US Customary	Metric	
$L = 1.5 \times e \times W \times RS$	$L = 1.5 \times e \times W \times RS \geq L_{min}$	(Equation 9.4-3)

where the terms are as defined for Equation 9.4-1 for 2-lane highways. The calculated runoff lengths for multilane facilities are 1.5 times those for 2-lane facilities. The longer lengths are more appropriate for major facilities considering higher traffic volumes and the desire to provide a higher level of driver comfort.

Figure 9.4A presents the superelevation runoff distances for multilane facilities which are either the L_{min} values (Figure 9.4C) or the calculated values (Equation 9.4-3) rounded up to the next highest 5 m increment.

Tangent Runout

For multilane highways, the tangent runout distance is calculated from Equation 9.4-2, where L is the superelevation runoff distance for multilane highways and all other terms are as defined for Equation 9.4-2. Figure 9.4A presents the tangent runout distances to the nearest foot (hundredth of a meter). This will ensure that the relative longitudinal gradient of the tangent runout equals that of the superelevation runoff.

9.4.4.3 Application of Transition Length

The criteria presented in Section 9.3 for open-roadway conditions will also apply to low-speed urban streets.

9.4.5 Axis of Rotation

On low-speed urban streets, the axis of rotation is typically about the centerline of the traveled way. This means, for example, if on-street parking is present on one side, the axis of rotation will not be in the center of the roadway section.

Low-speed urban streets may also present special cases because of the presence of two-way, left-turn lanes; turning lanes at intersections; etc. For these, where superelevated, the axis of rotation will be determined on a case-by-case basis.

9.4.6 Shoulder Superelevation

The criteria in Section 9.3 for open-roadway conditions will also apply to low-speed urban streets.

9.5 HORIZONTAL SIGHT DISTANCE

9.5.1 Sight Obstruction (Definition)

Sight obstructions on the inside of a horizontal curve are defined as obstacles which interfere with the line of sight on a continuous basis. These include walls, cut slopes, wooded areas, buildings and high farm crops. In general, point obstacles such as traffic signs and utility poles are not considered sight obstructions on the inside of horizontal curves. The designer must examine each curve individually to determine whether it is necessary to remove an obstruction or to adjust the horizontal alignment to obtain the required sight distance.

9.5.2 Middle Ordinate

The needed clearance on the inside of the horizontal curve is calculated as follows:

$$M = R\left(1 - COS\left(\frac{90° \cdot S}{\pi \cdot R}\right)\right) \qquad \text{(Equation 9.5-1)}$$

Where:

M = Middle ordinate, or distance from the center of the inside travel lane to the obstruction, ft (m)

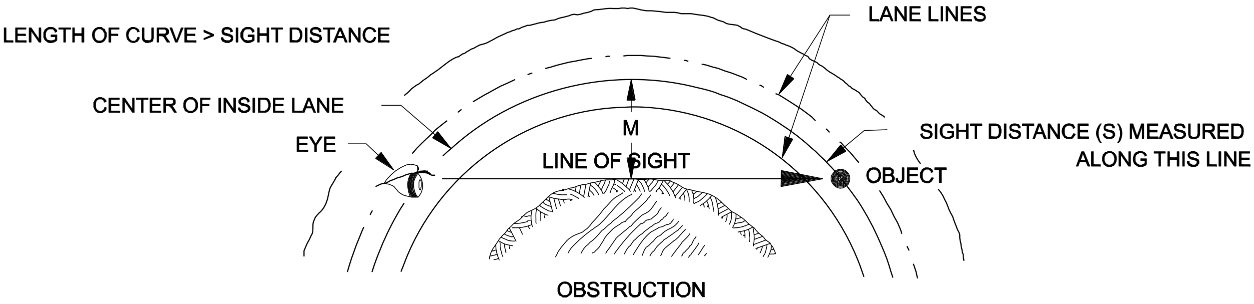
R = Radius of curve, ft (m)

S = Stopping sight distance, ft (m)

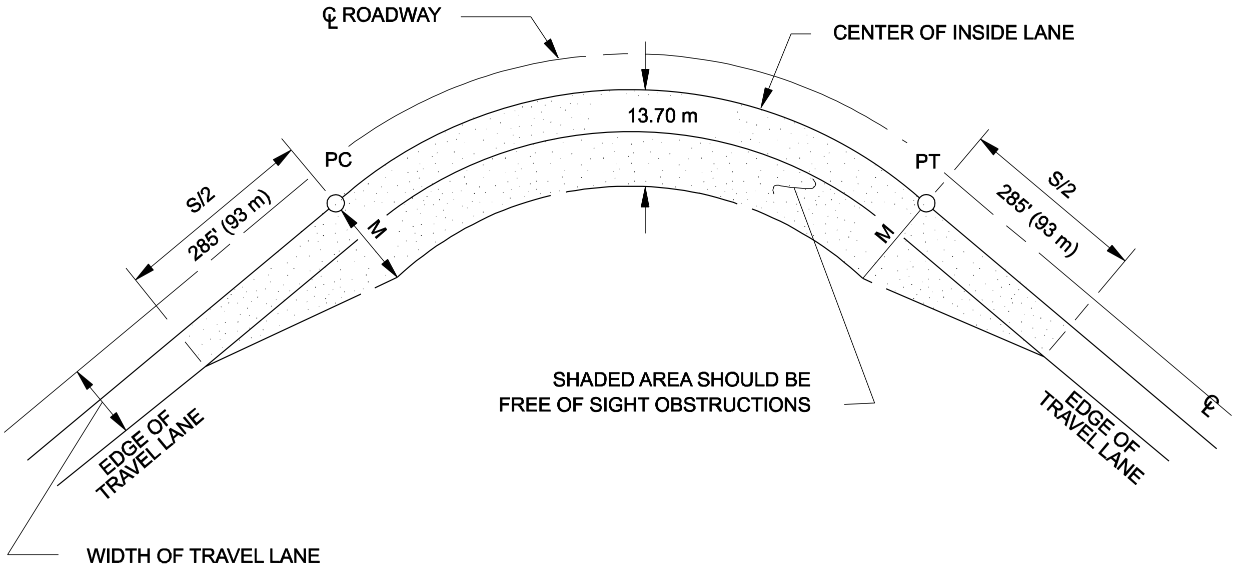
Note: The expression $\left(\frac{90° \cdot S}{\pi \cdot R}\right)$ is in degrees, not radians.

At a minimum, SSD will be available throughout the horizontal curve. Figures 9.5A and 9.5B provide the horizontal clearance criteria (i.e., the middle ordinate) for various combinations of desirable and minimum stopping sight distances and curve radii. For those selections of S which fall outside of the figures (i.e., M > 50’(16 m) and/or R < 165’(50 m)), the designer should use Equation 9.5-1 to calculate the needed clearance.

The Example on Figure 9.5C illustrates the determination of clearance requirements at a horizontal curve based on SSD.



SIGHT DISTANCE AT HORIZONTAL CURVES



Example 9.5-1 US CUSOMARY

Given: Design Speed = 60mph

R = 1400’

Problem: Determine the horizontal clearance requirements for the horizontal curve using the desirable SSD value.

Solution: Figure 8.6A yields a SSD = 570’. Using Equation 9.5-1 for horizontal clearance:

$$M = R\left(1 - \cos\left(\frac{90° \cdot S}{\pi \cdot R}\right)\right)$$

$$M = 1400\left(1 - \cos\left(\frac{(90°)(570)}{(\pi)(1400)}\right)\right) = 28.91'$$

The above figure also illustrates the horizontal clearance requirements for the entering and exiting portion of the horizontal curve.

SIGHT CLEARANCE REQUIREMENTS FOR HORIZONTAL CURVES
(Example Problem US Customary)

Example 9.5-1 METRIC

Given: Design Speed = 100 km/h

R = 400 m

Problem: Determine the horizontal clearance requirements for the horizontal curve using the desirable SSD value.

Solution: Figure 8.6A yields a SSD = 185.0 m. Using Equation 9.5-1 for horizontal clearance:

$$M = R\left(1 - \cos\left(\frac{90° \cdot S}{\pi \cdot R}\right)\right)$$

$$M = 400\left(1 - \cos\left(\frac{(90°)(185)}{(\pi)(400)}\right)\right) = 10.65\text{ m}$$

The above figure also illustrates the horizontal clearance requirements for the entering and exiting portion of the horizontal curve.

SIGHT CLEARANCE REQUIREMENTS FOR HORIZONTAL CURVES
(Example Problem Metric)

Figure 9.5B

9.5.3 Entering/Exiting Portions

The M values as calculated using Equation 9.5-1 apply between the PC and PT of the horizontal curve (or from the SC to the CS). In addition, some transition is needed on the entering and exiting portions of the curve. The designer should typically use the following steps:

Step 1: Locate the point which is on the edge of travel lane and a distance of S/2 before the PC or SC.

Step 2: Locate the point which is a distance M measured laterally from the center of the travel lane at the PC or SC.

Step 3: Connect the two points located in Step #'s 1 and 2. The area between this line and the roadway should be clear of all continuous sight obstructions.

Step 4: A symmetrical application of Step #'s 1 through 3 should be used beyond the PT or CS.

The Example on Figure 9.5B illustrates the determination of clearance requirements entering and exiting from a simple curve.

9.5.4 Application

For application, the height of eye is 3.5’(1080 mm) and the height of object is 2 ft (600 mm). Both the eye and object are assumed to be in the center of the inside travel lane. In the elevation view, the line-of-sight intercept with the obstruction is at the midpoint of the sightline and 2.75 ft (840 mm) above the road surface at the center of the inside lane.

9.5.5 Longitudinal Barriers

Longitudinal barriers (e.g., bridge rails, guardrail, CMB) can cause sight distance restrictions at horizontal curves, because barriers are placed relatively close to the traveled way (often 10’(3 m) or less) and because their height is greater than 2’(600 mm). The designer should check the line of sight over a barrier along a horizontal curve and attempt to locate the barrier such that it does not block the line of sight. The following should also be considered:

1. Superelevation. A superelevated roadway will elevate the driver eye and improve the line of sight over the barrier.

2. Vertical Curves . The line of sight over a barrier may be improved for a driver on a sag vertical curve and lessened on a crest vertical curve.

3. Barrier Height. The higher the barrier, the more obstructive it will be to the line of sight.

4. Object Height. Because of the typical heights of barriers, there may be many sites where the barrier blocks visibility to a 6”(150 mm) object but does not block

the view of a 18”(460 mm) object, the typical height of vehicular taillights. This observation provides some perspective to the potential safety problem at the site.

Each barrier location on a horizontal curve will require an individual analysis to determine its impacts on the line of sight. The designer must determine the elevation of the driver eye, the elevation of the object (2 ft (600 mm) above the pavement surface) and the elevation of the barrier where the line of sight intercepts the barrier run. If the barrier does block the line of sight to a 2 ft (600 mm) object, the designer should consider relocating the barrier or revising the horizontal alignment.

9.6 COMPUTATION OF HORIZONTAL CURVES

9.6.1 Spiral Curves

Special Note: *The computation of the spiral curve is dependent on one of two publications:*

- Transition Curves for Highways*, Public Roads Administration (Joseph Barnett)*; and
- Oregon Standard Highway Spiral*, Oregon Department of Transportation.*

The following presents typical figures for computing a spiral curve:

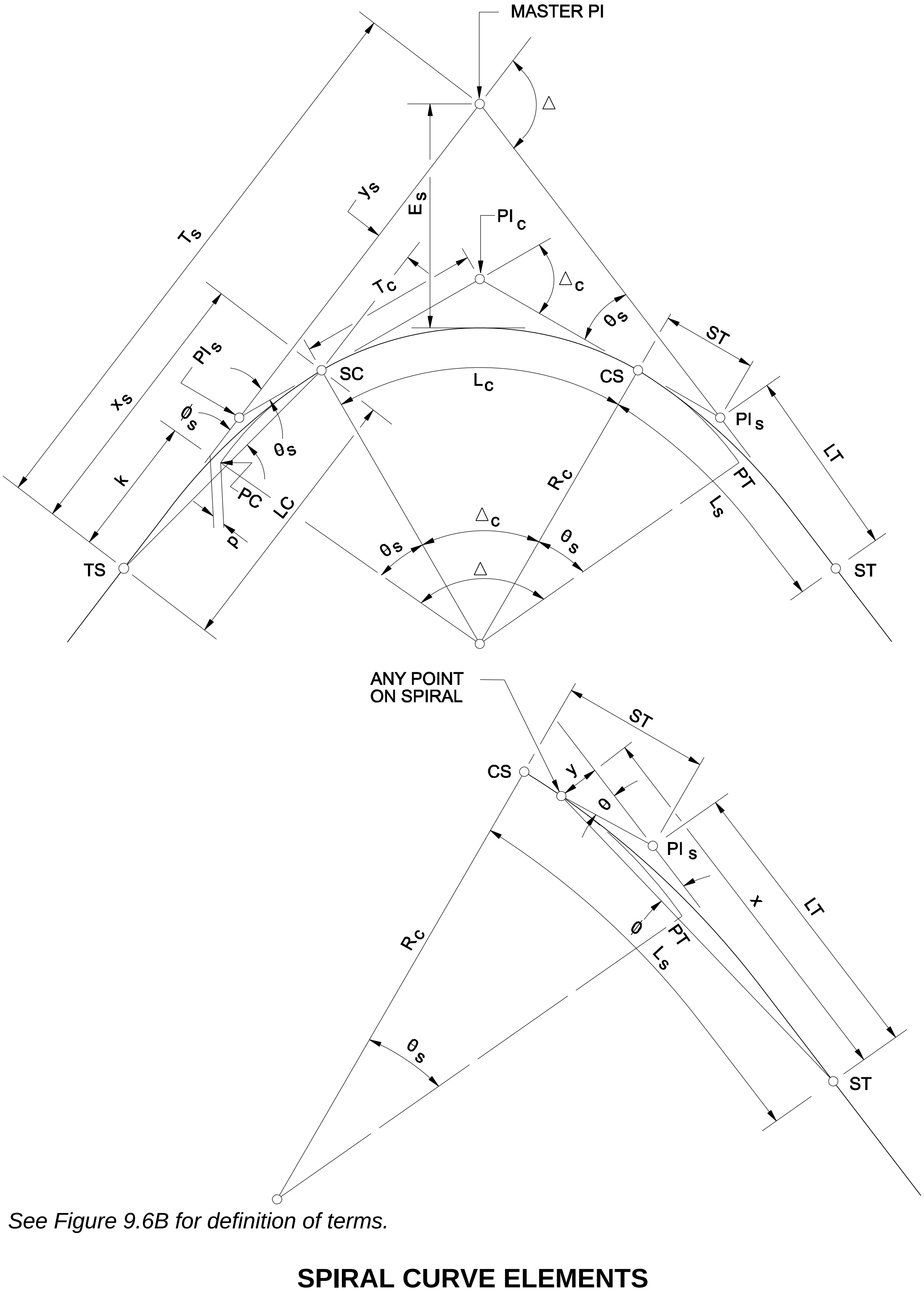
1. Figure 9.6A illustrates the key elements of a spiral curve.
2. Figure 9.6B presents definitions for the spiral curve nomenclature on Figure 9.6A.
3. Figure 9.6C presents equations for computing a spiral curve.

Typically, the known data will be the station of the Master PI, the deflection angle (Δ) and the radius of the circular curve (R_C) in feet (meters). As discussed in Section 9.3, the length of the spiral curve (L_S) will be set equal to the length of the superelevation runoff (Figures 9.3A and 9.3B). Based on the values of Δ, L_S and R_C, θ_s can be calculated as indicated in Figure 9.6C, and the p and k values can be read from Table II in *Transition Curves for Highways* by Joseph Barnett. The tangent length (T_s), the external distance (E_s) and the remaining spiral curve data can be computed as described in Figure 9.6C. Example 9.6-1 illustrates the computation of a spiral curve.

The following steps are used to determine the locations of the TS, SC, CS and ST:

1. PI station - T_s = TS station
2. TS station + Ls = SC station
3. SC station + Lc = CS station
4. CS station + Ls = ST station

Figures 9.6A, 9.6B and 9.6C are consistent with the Barnett spiral publication. It is also acceptable to use the data from the *Oregon Standard Highway Spiral* to compute a spiral curve.



Note: *See Figure 9.6B for definition of terms.*

SPIRAL CURVE ELEMENTS

Figure 9.6A

SPIRAL TRANSITION CURVE NOMENCLATURE

Master PI = Point of intersection of the main tangents.

PC = Point at which the circular curve extended becomes parallel to the line from TS to the Master PI.

PT = Point at which the circular curve extended becomes parallel to the line from ST to the Master PI.

PI_c = Point of intersection of circular curve tangents.

PI_s = Point of intersection of the main tangent and tangent of circular curve.

TS = Tangent to spiral; common point of spiral and near transition.

SC = Spiral to curve; common point of spiral and circular curve of near transition.

CS = Curve to spiral; common point of circular curve and spiral of far transition.

ST = Spiral to tangent; common point of spiral and tangent of far transition.

R_c = Radius of the circular curve (SC to CS), ft(m)

L_s = Length of spiral, ft(m)

L_c = Length of circular curve, ft(m)

T_s = Tangent distance Master PI to TS or ST, ft(m)

T_c = Tangent distance from SC or CS to PI_c, ft(m)

E_s = External distance Master PI to midpoint of circular curve, ft(m)

LT = Long tangent of spiral only, ft(m)

ST = Short tangent of spiral only, ft(m)

LC = Long chord of spiral, ft(m).

p = Offset distance from the main tangent to the PC or PT of the circular curve produced, ft(m)

k = Distance from TS to point on main tangent opposite the PC of the circular curve produced, ft(m)

Δ = Total deflection angle between main tangents of the entire curve, degrees

Δ_c = Deflection angle between tangents at the SC and the CS or the central angle of the circular curve, degrees

θ_s = Central angle between the tangent of the complete curve and the tangent at the SC; i.e., the “spiral angle,” degrees

φ_s = Spiral deflection angle from tangents at TS to SC or from ST to SC, degrees

$x_s y_s$ = Coordinates of SC from the TS or of CS from ST.

L = Length of spiral arc from the TS or ST to any point on the spiral, ft(m)

x,y = Coordinates to any point on the spiral from TS or ST.

φ = Spiral deflection angle from TS or ST to any point on spiral, degrees

θ = The central angle of spiral arc L to any point on the spiral, degrees. θ equals θ_s when L equals L_s. Note that the θ referred to in Table II of *Transition Curves for Highways* is actually θ_s.

SPIRAL CURVE NOMENCLATURE

Figure 9.6B

CURVE FUNCTIONS

1. $\theta_S = (L_s / R_C)(90/\pi)$

2. $\Delta_C = \Delta - 2\theta_S$

3. $L_C = \frac{\Delta_C}{360} 2\pi R_C$

4. $T_S = (R_C + p)\tan(\Delta/2) + k$

5. $E_S = (R_C + p)(1/\cos(\Delta/2) - 1) + p = \left[\frac{(R_C + p)}{\cos(\Delta/2)} - (R_C + p)\right] + p$

6. p and k are obtained from *Transition Curves for Highways* by Barnett.

SPIRAL FUNCTIONS

Correction for C in Formula : $\varphi = \frac{\theta}{3} - C$								
θ_S in Degrees	15	20	25	30	35	40	45	50
C in Minute	0.2	0.4	0.8	1.4	2.2	3.4	4.8	6.6

7. $\varphi(approx.) = \frac{\theta}{3}$ if $\theta_S < 15°00'$

8. $\varphi(approx.) = \frac{\theta}{3} - C$, if $\theta_S \geq 15°00'$

9. $\varphi = \frac{\theta_S}{3}\left[\frac{L}{L_S}\right]^2$

10. Exact value of φ by coordinates

$\tan\varphi = \frac{y}{x}$

11 $ST = \frac{y_S}{\sin\theta_S}$

12. $LT = x_S - \left(\frac{y_S}{\tan\theta_S}\right)$

13. $LC = \frac{x_s}{\cos\varphi_S}$

14. $x_S = LC\cos\varphi_S$

15. $y_S = LC\sin\varphi_S$

16. $\theta = \frac{L^2}{L_S{}^2}\theta_2$

17. $x = L\left(1 - \frac{\theta^2}{10} + \frac{\theta^4}{216} - \frac{\theta^6}{9360} + \frac{\theta^8}{685440}\right)^*$

18. $y = L\left(\frac{\theta}{3} + \frac{\theta^3}{42} + \frac{\theta^5}{1320} - \frac{\theta^7}{75600} + \frac{\theta^9}{6894720}\right)^*$

* θ *is in radians for equations 17 and 18 only*.

Note : These equations are based on *Transitions Curves for Highways* by Barnett.

SPIRAL CURVE FORMULAS

Figure 9.6C

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Example 9.6-1 (US Customary)

Given: Rural Two-Lane State Highway

Design Speed = 60 mph
Δ = 15°00′00″ Right
(Master) PI Station = 243+18.72
R_C = 3000 ft

Problem: If warranted, determine the curve data for the spiral curve.

Solution: The following steps apply:

Step 1: From Section 9.2.2, a spiral curve is warranted on a rural State highway where $R \leq$ 3820'. Therefore, use a spiral curve.

Step 2: The length of the spiral curve is set equal to the superelevation runoff (L_s) length. From Figure 9.3A, L_s = 135 ft for V = 60 mph and R_C = 3000 ft

Step 3: From the equations in Figure 9.6C, calculate the curve functions as follows:

1. $\theta_S = (L_s / R_C)(90/\pi) = (135/3000)(90/\pi)$

   $\theta_S = 1.28915°...$

   $\theta_S = 1°17'21"$ (rounded value)

2. $\Delta_C = \Delta - 2\theta_S = (15°0'0") - (2°34'42")$

   $\Delta_C = 12°25'18" = 12.42167°$

3. $L_C = \frac{\Delta_C}{360} 2\pi R_C = \frac{12.42}{360}(2\pi)(3000)$

   $L_C = 650.30967\, ft$

   $L_C = 650.31\, ft$ (rounded value)

4.* $T_S = (R_C + p)\tan(\Delta/2) + k$

5.* $E_S = (R_C + p)\left(\frac{1}{\cos \Delta/2} - 1\right) + p$

* For Equations 4 and 5, obtain the values for p and k from Table II of *Transition Curves for Highways*:

p =.001875 k = 0.499992

Note that these values are for a unit spiral length. To obtain the actual values for p and k, multiply by L_s,135 ft

p (0.001875) (135) = 0.253125 ft
k = (0.499992) (135) = 67.49892 ft

Therefore:

T_s = (3000 + 0.253) tan (15/2) + 67.499
T_s = 462.489801 ft
T_s = 462.49 ft (rounded value)
E_s = (3000 + 0.253) (1/cos(15/2) - 1) + 0.253
E_s = 26.1420 ft
E_s = 26.14 ft (rounded value)

Step 4: Determine the Stations for TS, SC, CS and ST:

TS Station = PI Station - T_s = 243+18.72 - 462.49 = 238+56.23
SC Station = TS Station + L_s = 238+56.23+ 135 = 239+91.23
CS Station = SC Station + L_c = 239+91.23+ 650.31 = 246+41.54
ST Station = CS Station + L_s = 246+41.54+ 135 = 247+76.54

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Example 9.6-1 (Metric)

Given: Rural Two-Lane State Highway

Design Speed = 100 km/h
$\Delta = 15°00'00''$ Right
(Master) PI Station = 43 + 16.63
R_C = 900 m

Problem: If warranted, determine the curve data for the spiral curve.

Solution: The following steps apply:

Step 1: From Section 9.2.2, a spiral curve is warranted on a rural State highway where $R \leq 1165$ m. Therefore, use a spiral curve.

Step 2: The length of the spiral curve is set equal to the superelevation runoff (L_s) length. From Figure 9.3A, L_s = 60 m for V = 100 km/h and R_C = 900 m.

Step 3: From the equations in Figure 9.6C, calculate the curve functions as follows:

1. $\theta_S = (L_s / R_C)(90/\pi) = (60/900)(90/\pi)$

   $\theta_S = 1.9098°...$

   $\theta_S = 1°54'35"$ (rounded value)

2. $\Delta_C = \Delta - 2\theta_S = (15°0'0") - (3°49'10")$

   $\Delta_C = 11°10'50" = 11.1805°$

3. $L_C = \frac{\Delta_C}{360} 2\pi R_C = \frac{11.18}{360}(2\pi)(900)$

   $L_C = 175.6237\text{m}$

   $L_C = 175.62\text{m}$ (rounded value)

4.* $T_S = (R_C + p)\tan(\Delta/2) + k$

5.* $E_S = (R_C + p)(1/\cos(\Delta/2) - 1) + p$

* For Equations 4 and 5, obtain the values for p and k from Table II of *Transition Curves for Highways*:

p = 0.00278380 k = 0.49998

Note that these values are for a unit spiral length. To obtain the actual values for p and k, multiply by L_s (60 m):

p = (0.00278380) (60) = 0.1670 m
k = (0.49998) (60) = 29.9988 m

Therefore:

T_s = (900 + 0.167) tan (15/2) + 29.9988
T_s = 148.5080 m
T_s = 148.51 m (rounded value)
E_s = (900 + 0.167) (1/cos(15/2) - 1) + 0.167
E_s = 7.9345 m
E_s = 7.93 m (rounded value)

Step 4: Determine the Stations for TS, SC, CS and ST:

TS Station = PI Station - T_s = 43 + 16.63 - 148.51 = 41 + 68.12
SC Station = TS Station + L_s = 41 + 68.12 + 60 = 42 + 28.12
CS Station = SC Station + L_c = 42 + 28.12 + 175.62 = 44 + 03.74
ST Station = CS Station + L_s = 44 + 03.74 + 60 = 44 + 63.74

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9.6.2 Simple Curves

The following presents typical figures for computing a simple curve:

1. Figure 9.6D illustrates the key elements of a simple curve.
2. Figure 9.6E presents definitions for the simple curve nomenclature on Figure 9.6D.

Typically, the known data will be the station of the PI, the deflection angle (Δ) and the radius of the simple curve (R). The remaining curve data must be computed. Example 9.6-2 illustrates a sample calculation.

* * * * * * * * * *

Example 9.6-2 (US Customary)

Given: Δ = 7°00′00″
R = 5700 ft
PI Station = 154+56.42

Problem: According to Section 9.2.2 use a simple curve when the radius is greater than 3820 ft. Assuming the use of a simple curve, determine the curve data.

Solution: Use the equations from Figure 9.6E as follows:

1. $T = R(\tan(\Delta/2)) = 5700(\tan(7/2))$
   $T = 348.6269\, ft$
   $T = 348.63\, ft$ (rounded value)
2. $L = \frac{\Delta}{360} 2\pi R = \frac{7}{360}(2\pi)(5700)$
   $L = 696.38637\, ft$
   $L = 696.39\, ft$ (rounded value)
3. $E = \frac{R}{\cos(\Delta/2)} - R = \frac{5700}{\cos(7/2)} - 5700$

   $E = 10.6515\, ft$
   $E = 10.65\, ft$ (rounded value)
4. $LC = 2R(\sin(\Delta/2)) = (2)(5700)(\sin 7/2))$
   $LC = 695.95335\, ft$
   $LC = 695.95\, ft$ (rounded value)
5. $M = R(1 - \cos(\Delta/2)) = 5700(1 - \cos(7/2))$
   $M = 10.6316\, ft$
   $M = 10.63\, ft$ (rounded value)
6. Stations are as follows:
   Station PC = Station PI - T = 154+56.42 - 348.63 = 151+07.79
   Station PT = Station PC + L = 151+07.79 + 695.95 = 158+03.74

Example 9.6-2 (Metric)

Given: Δ = 7°00′00″
R = 1300 m
PI Station = 22 + 34.58

Problem: Assuming the use of a simple curve, determine the curve data.

Solution: Use the equations from Figure 9.6E as follows:

1. $T = R(tan(\Delta / 2)) = 1300(tan(7 / 2))$
   $T = 79.5144m$
   $T = 79.51m$ (rounded value)

2. $L = \frac{\Delta}{360} 2\pi R = \frac{7}{360}(2\pi)(1300)$
   $L = 158.82496m$
   $L = 158.82m$ (rounded value)

3. $E = \frac{R}{cos(\Delta / 2)} - R = \frac{1300}{cos(7 / 2)} - 1300$
   $E = 2.4292m$
   $E = 2.43m$ (rounded value)

4. $LC = 2R(sin(\Delta / 2)) = (2)(1300)(sin 7 / 2))$
   $LC = 158.7262m$
   $LC = 158.73m$ (rounded value)

5. $M = R(1 - cos(\Delta / 2)) = 1300(1 - cos(7 / 2))$
   $M = 2.4247m$
   $M = 2.42m$ (rounded value)

6. Stations are as follows:

   Station PC = Station PI - T = 22 + 34.58 - 79.51 = 21 + 55.07
   Station PT = Station PC + L = 21 + 55.07 + 158.82 = 23 + 13.89

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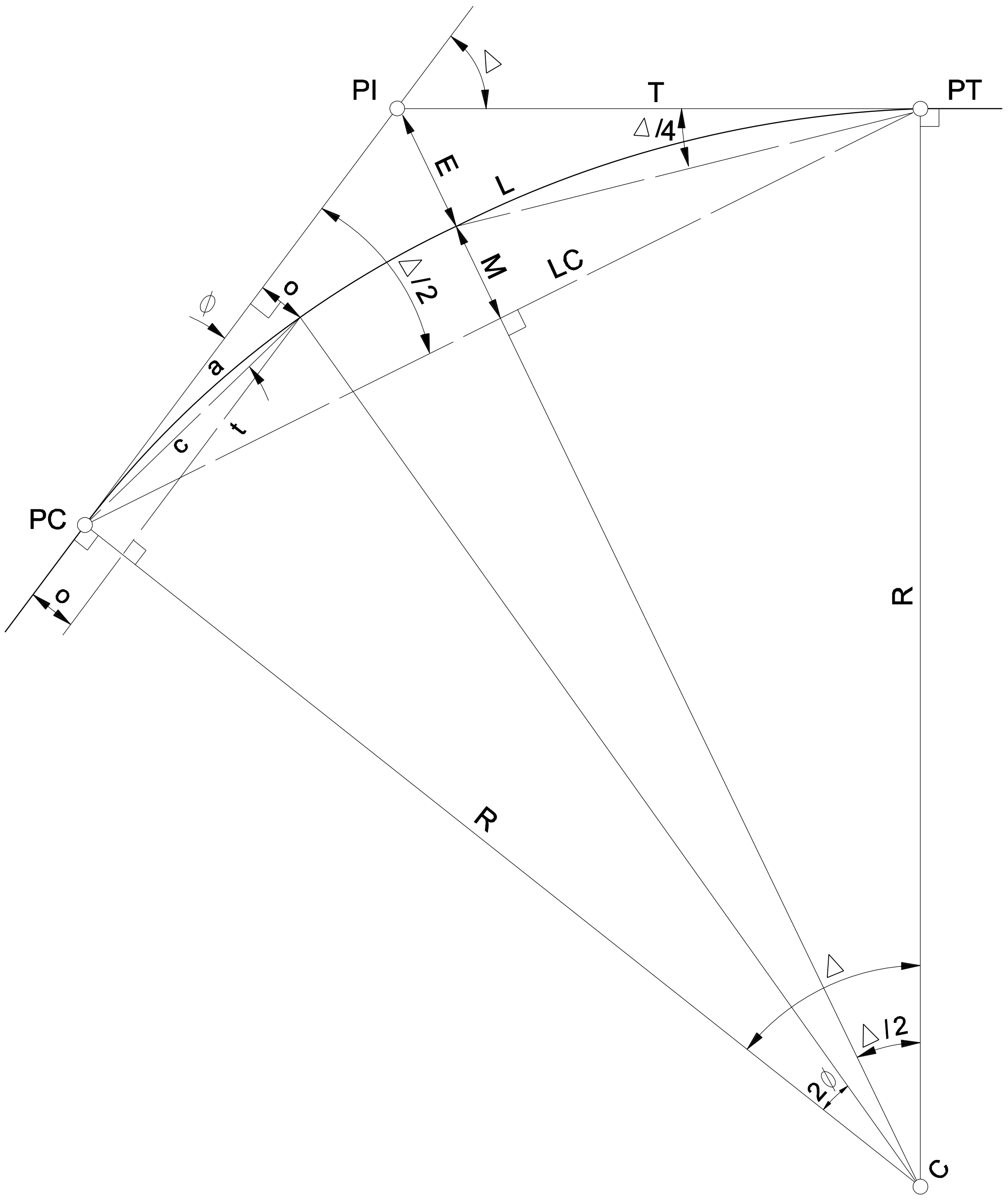


SIMPLE CURVE ELEMENTS

Figure 9.6D

CURVE SYMBOLS

Δ = Deflection angle, degrees
T = Tangent distance, ft(m). T = distance from PC to PI or distance from PI to PT
L = Length of curve, ft(m). L = distance from PC to PT along curve
R = Radius of curvature, ft(m)
E = External distance (PI to mid-point of curve), ft(m)
C = Intersection of radii at center of circular arc
LC = Length of long chord (PC to PT), ft(m)
M = Middle ordinate (mid-point of arc to mid-point of long chord), ft(m)
a = Length of arc to any point on a curve, ft(m)
c = Length of chord from PC to any point on curve, ft(m)
φ = Deflection angle from tangent to any point on curve, degrees
t = Distance along tangent from PC to any point on curve, ft(m)
o = Tangent offset to any point on curve, ft(m)

CURVE FORMULA

$$T = R(\tan(\Delta/2)) = R\,\frac{\sin(\Delta/2)}{\cos(\Delta/2)}$$

$$L = \frac{\Delta}{360}\,2\pi R$$

$$E = \frac{R}{\cos(\Delta/2)} - R = T\tan(\Delta/4)$$

$$LC = 2R(\sin(\Delta/2)) = 2T\,(\cos\Delta/2)$$

$$M = R(1 - \cos(\Delta/2)) = E\cos(\Delta/2)$$

$$a = \frac{(200\varphi)(2\pi R)}{100(360)} = \frac{(\varphi)(\pi R)}{90}$$

$$c = 2R\left(\sin\frac{(100)(360a)}{(200)(2\pi R)}\right) = 2R\,(\sin\frac{90a}{\pi R})$$

$$\varphi = \frac{90a}{(\varphi)(\pi R)}$$

$$\cos\varphi = (R - o)/2R$$

$$t = R\sin 2\varphi = (c)\cos\varphi$$

$$o = (c)\sin\varphi$$

$$o = R - \sqrt{R^2 - t^2}$$

$$o = R - (R\cos 2\varphi)$$

$$o = R(1 - \cos 2\varphi)$$

$$\pi = 3.141592654$$

CIRCULAR CURVE ABBREVIATIONS

PC = Point of Curvature (Beginning of Curve)
PT = Point of Tangency (End of Curve)
PI = Point of Intersection of Tangents
PRC = Point of Reverse Curvature
PCC = Point of Compound Curvature

LOCATING THE PC AND PT

Station PC = Station PI – T
Station PT = Station PC + L
Stations are in 100 feet (meters). For example, Sta 13+54.86 means 1354.86 feet (meters) from Sta 0+00.

SIMPLE CURVE NOMENCLATURE/FORMULAS

Figure 9.6E

9.6.3 Compound Curves

Figure 9.6F illustrates the key elements of a symmetrical, 3-centered compound curve. It also presents the equations to compute the curve elements assuming that the following are known:

1. Δ, the deflection angle;
2. p, the offset between the interior curve (extended) to a point where it becomes parallel with the tangent line;
3. R_1, the radius of the flatter entering and exiting curve; and
4. R_2, the radius of the sharper, interior curve.

Example 9.6-3 illustrates a sample computation for a 3-centered, symmetrical compound curve.

* * * * * * * * * *

Example 9.6-3 (US Customary)

Given: $\Delta = 40°$
$R_1 = 600$ ft
$R_2 = 250$ ft
p = 5 ft

Problem: Determine the curve data for the compound curve.

Solution: Use the equations from Figure 9.6F as follows:

1. $T_1 = (R_2 + p)\tan(\Delta/2) = (250 + 5)\tan(40/2)$

$T_1 = 92.81 ft$

2. $\Delta_1 = \cos^{-1}\left[\frac{R_1 - R_2 - p}{R_1 - R_2}\right] = \cos^{-1}\left[\frac{600 - 250 - 5}{600 - 250}\right]$

$\Delta_1 = 9.6963°$
$\Delta_1 = 9°41'47''$ (rounded value)

3. $T = T_1 + (R_1 - R_2)\sin\Delta_1 = 92.81 + (600 - 250)\sin(9.6963°)$
$T = 151.7591 ft$
$T = 151.76 ft$ (rounded value)

4. $T_2 = T_1 - R_2 \sin\Delta_1 = 92.81 - (250)\sin(9.6963°)$

$T_2 = 50.7036\,ft$

$T_2 = 50.70\,ft$ (rounded value)

5. $E = \dfrac{R_2 + p}{\cos(\Delta/2)} - R_2 = \dfrac{250+5}{\cos(40/2)} - 250$

$E = 21.3653\,ft$

$E = 21.37\,ft$ (rounded value)

6. $M = R_2 - (R_2\cos(\Delta/2 - \Delta_1)) = 250 - \left(250\cos\left(\dfrac{40}{2} - 9.6963\right)\right)$

$M = 4.0316\,ft$

$M = 4.03\,ft$ (rounded value)

7. $y = (R_2 + p) - R_2\cos\Delta_1 = (250+5) - (250)\cos(9.6963°)$

$y = 8.5714\,ft$

$y = 8.57\,ft$ (rounded value)

Example 9.6-3 (Metric)

Given: Δ = 90°
R_1 = 55 m
R_2 = 18 m
p = 2.5 m

Problem: Determine the curve data for the compound curve.

Solution: Use the equations from Figure 9.6F as follows:

1. $T_1 = (R_2 + p)\tan(\Delta/2) = (18 + 2.5)\tan(90/2)$

$T_1 = 20.50\text{m}$

2. $\Delta_1 = \cos^{-1}\left[\dfrac{R_1 - R_2 - p}{R_1 - R_2}\right] = \cos^{-1}\left[\dfrac{55 - 18 - 2.5}{55 - 18}\right]$

$\Delta_1 = 21.18287...°$

$\Delta_1 = 21°10'58"$ (rounded value)

3. $T = T_1 + (R_1 - R_2)\sin\Delta_1 = 20.50 + (55 - 18)\sin(21°10'58")$

$T = 33.8697...m$

$T = 33.87m$ (rounded value)

4. $T_2 = T_1 - R_2 \sin\Delta_1 = 20.50 - (18)\sin(21°10'58")$

$T_2 = 13.9958...m$

$T_2 = 14.00m$ (rounded value)

5. $$E = \frac{R_2 + p}{\cos(\Delta/2)} - R_2 = \frac{18 + 2.5}{\cos(90/2)} - 18$$

$E = 10.9913...m$

$E = 10.99m$ (rounded value)

6. $M = R_1 - [R_2 \cos(\Delta/2 - \Delta_1)] = 18 - ((18)\cos(90/2 - 21°10'58"))$

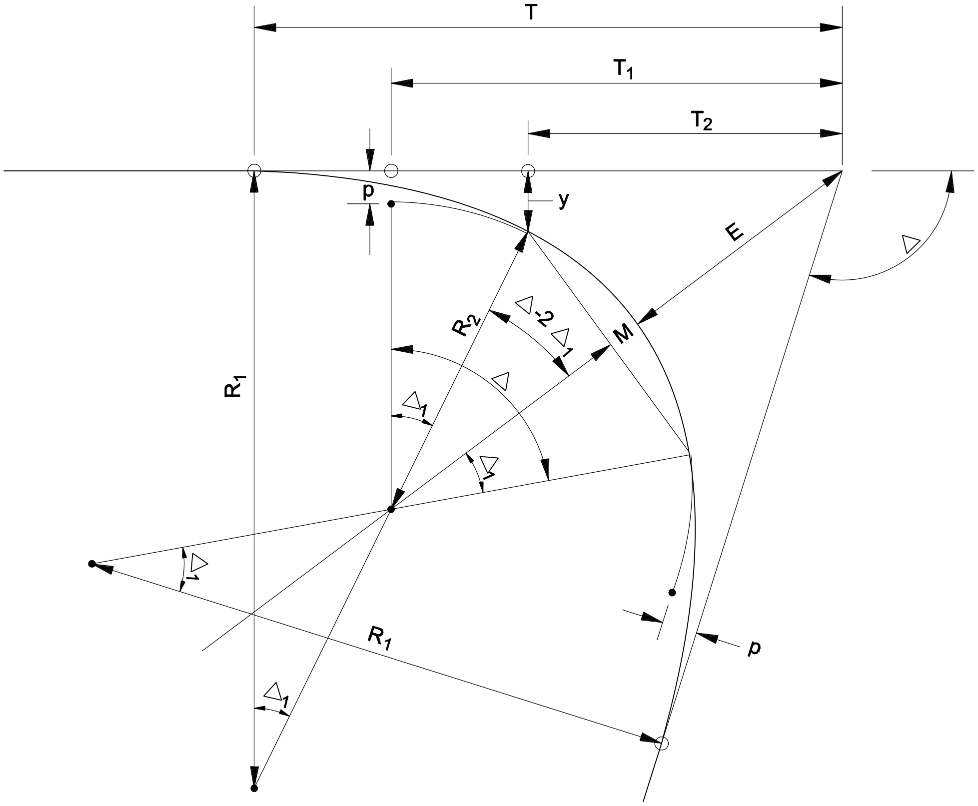
$M = 1.5329...m$

$M = 1.53m$ (rounded value)

7. $y = (R_2 + p) - R_2 \cos\Delta_1 = (18 + 2.5) - (18)\cos(21°10'58")$

$y = 3.7162...m$

$y = 3.72m$ (rounded value)



CURVE FORMULA

1. $$T_1 = (R_2 + p)\tan\frac{\Delta}{2}$$

2. $$\Delta_1 = \cos^{-1}\left[\frac{R_1 - R_2 - p}{R_1 - R_2}\right]$$

3. $$T = T_1 + (R_1 - R_2)\sin\Delta_1$$

4. $$T_2 = T_1 - R_2 \sin\Delta_1$$

5. $$E = \frac{R_2 + p}{\cos(\Delta/2)} - R_2$$

6. $$M = R_2 - \left[R_2 \cos(\Delta/2 - \Delta_1)\right]$$

7. $$y = (R_2 + p) - R_2 \cos\Delta_1$$

Note: "p" is the offset location between the interior curve (extended) to a point where it becomes parallel with the tangent line. See Figure 9.6E for other circular curve nomenclature.

COMPOUND CURVE ELEMENTS/FORMULAS

Figure 9.6F

9.6.4 Rounding of Curve Data

9.6.4.1 New Horizontal Curve

The following summarizes Department practices for presenting data for a new horizontal curve on the roadway plans:

1. Deflection Angle. These should be recorded in degrees rounded to the nearest second of a degree.
2. Linear Distances. These should be recorded in feet (meters) rounded to the nearest one hundredth of a feet (meters) (i.e., two decimal places).
3. Curve Radii. Normally, curve radii will be selected from those in Figure 9.2C. Where rounding is necessary, radii should be recorded in feet (meters) rounded to the nearest 5 feet (meters).

When using computer-generated curve data, the designer must consider the implications of rounding off the data according to the above criteria. To ensure mathematical consistency, the following procedure should be used when defining the horizontal alignment in Geopak:

Given: Horizontal alignment defined with PI coordinates from survey data or design.

Input:

1. Store given PI coordinates.
2. Inverse PI coordinates to produce distance and bearing between PIs.
3. Round distance to two places (0.01). Round bearings to nearest second (01”).
4.
    a. Define the horizontal alignment by traversing PI to PI using the rounded distance and bearing.
    b. Set station preference to two places (0.01).
    c. Set distance preference to four places (0.0001).

Output:

5.

a. Rounded bearings to nearest second (to be shown on plans).

b. Rounded control point stations to two places (to be shown on plans).

c. Adjusted control point coordinates to four places (to be shown on coordinate table).

d. Curve data to four places that must be rounded to two places before placing on plans. Round T, L and E by hand computations using the rounded D and R as shown on the plans. Minor adjustments to the control point stations may be necessary to reflect the rounded curved data.

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Example 9.6-4 (US Customary)

Given: GEOPAK SPIRAL CURVE DATA OUTPUT

Note: GEOPAK spiral curve nomenclature does not match exactly the nomenclature in Figures 25.6A through 25.6C.

```
PISCS          CG2   N 30,530.4772       E 30,526.8770        STA 202+63.64
Total Tangent        =        803.7278
Total Length         =        1,582.7160
Total Delta          =        26° 13' 01.00" (LT)
Back Tangent         =        N  72° 51' 14.00" E
Ahead Tangent        =        N  46° 38' 13.00" E
```

Spiral Back (Spiral CG2) Type 1 Spiral Element

```
Angle          2° 00' 19.27" (LT)  P      0.6125           BK     N  72° 51' 14.00" E
LS             210.0000            K      104.9957         AH     N  70° 50' 54.73" E
R              3,000.0000          LT     140.0090         Defl   0° 40' 06.40"
YS             2.4498              ST     70.0082
XS             209.9743            LC     209.9886
A              793.7254
```

Spiral Coordinates

Point	North	East	Station
TS	30,293.5306	29,758.8700	194+59.91
PI	30,334.8066	29,892.6564	195+99.92
SC	30,357.7739	29,958.7900	196+69.91
CC	33,191.7378	28,974.5904	

Circular Section Curve Data

Curve CG2

P.I. Station 202+58.66 N 30,550.9219 E 30,514.9518
Delta = 22° 12' 22.46" (LT)
Tangent = 588.7462
Length = 1,162.7160
Radius = 3,000.0000
External = 57.2246
Long Chord = 1,155.4524
Mid. Ord. = 56.1535
P.C. Station 196+69.91 N 30,357.7739 E 29,958.7900
P.T. Station 208+32.63 N 30,939.9406 E 30,956.8642
C.C. N 33,191.7378 E 28,974.5904
Back = N 70° 50' 54.73" E
Ahead = N 48° 38' 32.27" E
Chord Bear = N 59° 44' 43.50" E Circular Section

Spiral Ahead (Spiral CG2A) Type 2 Spiral Element

Angle	2° 00' 19.27" (LT)	P	0.6125	BK	N 48° 38' 32.27" E
LS	210.0000	K	104.9957	AH	N 46° 38' 13.00" E
R	3,000.0000	LT	140.0090	Defl	0° 40' 06.40"
YS	2.4498	ST	70.0082		
XS	209.9743	LC	209.9886		
A	793.7254				

Spiral Coordinates

Point	North	East	Station
CS	30,939.9406	30,956.8642	208+32.63
PI	30,986.1991	31,009.4123	209+02.64
ST	31,082.3319	31,111.2013	210+42.63
CC	33,191.7378	28,974.5904	

Problem: Re-compute curve data manually to produce rounded values to be shown on the plans.

Solution: Hold Geopak values for P.I. Station, Δ, RC and LS.

$$\theta_S = (L_s / R_c)(90/\pi) = (210/3000)(90/\pi) = 2°00'19''$$

$$\Delta_C = \Delta - 2\Theta_s = 26°13'01'' - (2)2°00'19'' = 22°12'23'' \rightarrow 22.2064°''$$

$$L_C = \left(\frac{\Delta_c}{360}\right) 2\Pi R_c = (22.2064/360)2\Pi(3000) = 1162.72\,ft$$

$$T_s = (R_c + p)\tan \Delta/2 + k$$

$$T_s = (3000 + 0.6127)\tan 26.2169/2 + 104.9958$$

$$T_s = (3000.6127)(0.2328632) + 104.9958 = 803.73\,ft$$

Use p and k found in Barnett's (p = 0.6127, k = 104.9958

202+63.64 - 803.73 =	194+59.91	TS
	+210	
	196+69.91	SC
	+1162.72	
	208+32.63	CS
	+210	
	210+42.63	ST

Note: Geopak currently does not have the capability to round curve data and at the same time produce coordinates to four places. Therefore, coordinates listed in the coordinate table for PC, PT, TS, SC, CS, ST will differ slightly from coordinates computed using the rounded curve data shown on the plans.

Example 9.6-4 (Metric)

Given: GEOPAK SPIRAL CURVE DATA OUTPUT

Note: GEOPAK spiral curve nomenclature does not match exactly the nomenclature in Figures 25.6A through 25.6C.

PISCS CG2 N30,530.4772 E30,526.8770 STA 202+63.64

Total Tangent = 239.6145

Total Length = 471.8148
Total Delta = 26°13’01.00” (LT)
Back Tangent = N 72°51’14.00” E
Ahead Tangent = N 46°38’13.00” E

Spiral Back (Spiral CG2B) Type 1 Spiral Element

Angle = 1°54’35.49” (LT)	P = 0.1667	BK = N 72°51’14.00” E
LS = 60.0000	K = 29.9989	AH = N 70°56’38.50” E
R = 900.0000	LT = 40.0023	Defl = 0°38’11.81”
YS = 0.6666	ST = 20.0021	Deg = 6°21’58.31”
XS = 59.9933	LC = 59.9970	
A = 232.3790		

Spiral Coordinates

Point	North	East	Station
TS	30,459.8366	30,297.9119	200+24.03
PI	30,471.6296	30,336.1363	200+64.03
SC	30,478.1602	30,355.0423	200+84.03
CC	31,328.8402	30,061.1998	

Circular Section Curve Data

Curve CG2

P.I. Station = 202+62.21 N30,536.3351 E30,523.4601
Delta = 22°23’50.01”(LT)
Tangent = 178.1822
Length = 351.8148
Radius = 900.0000
External = 17.4687
Long Chord = 349.5791
Mid. Ord. = 17.1361
P.C. Station 200+84.03 N30,478.1602 E30,355.0423
P.T. Station 204+35.84 N30,654.2932 E30,657.0071
C.C. N31,328.8402 E30,061.1998
Back = N 70°56’38.50” E
Ahead = N 48°32’48.49” E
Chord Bearing = N 59°44’43.50” E

Spiral Ahead (Spiral CG2A) Type 2 Spiral Element

Angle = 1°54’35.49” (LT) P = 0.1667 BK = N 48°32’48.49” E

LS = 60.0000
R = 900.0000
YS = 0.6666
XS = 59.9933
A = 232.3790

K = 29.9989
LT = 40.0023
ST = 20.0021
LC = 59.9970

AH = N46°38’13.00” E
Defl = 0°38’11.81”
Deg = 6°21’58.31”

Spiral Coordinates

Point	North	East	Station
CS	30,654.2932	30,657.0071	204+35.84
PI	30,667.5347	30,671.9986	204+55.84
ST	30,695.0011	30,701.0810	204+95.84
CC	31,328.8402	30,061.1998	

Problem: Recompute curve data manually to produce rounded values to be shown on the plans.

Solution: Hold Geopak values for P.I. Station, Δ, RC and LS.

$$\theta_S = \frac{90 \cdot 60}{\pi \cdot 900} = 1.90985...^\circ = 1^\circ 54'35.49'' \rightarrow 1^\circ 54'35''$$

$$\Delta_C = 26^\circ 13'01'' - (2)1^\circ 54'35'' = 26.21694^\circ - 3.81944^\circ = 22.39750^\circ = 22^\circ 23'51.0'' \rightarrow 22^\circ 23'51''$$

$$L_C = \frac{22^\circ 23'51''}{360} 2\pi 900 = 351.819 \rightarrow 351.82\text{m}$$

$$T_s = (900 + p) \tan \Delta / 2 = k$$

Use p and k found in Barnett’s (p = 0.1670, k = 29.9988)

$$T_S = (900 + .01670) \tan \frac{26^\circ 13''01''}{2} + 29.9988 = 239.61\text{m}$$

$$\begin{array}{lrl} 202+63.64 - 239.61 = & 200+24.03 & \text{TS} \\ & +60 & \\ \cline{2-2} & 200+84.03 & \text{SC} \\ & +351.82 & \\ \cline{2-2} & 204+35.85 & \text{CS} \\ & +60 & \\ \cline{2-2} & 204+95.85 & \text{ST} \end{array}$$

Note: Geopak currently does not have the capability to round curve data and at the same time produce coordinates to four places. Therefore, coordinates listed in *the coordinate table for PC, PT, TS, SC, CS, ST will differ slightly from coordinates computed using the rounded curve data shown on the plans.*

9.6.4.2 Existing Horizontal Curves

For existing US Customary horizontal curves, the Department's rounding practices for presentation on the roadway plans are:

1. Deflection Angle. These should be recorded in degrees rounded to the nearest second of a degree.
2. Linear Distances. These should be recorded in feet (meters) rounded to the nearest one hundredth of a foot (meter) (i.e., two decimal places).
3. Curve Radii. Rounding will be determined by the Project Scope of Work as follows:
    a. Overlay and Widening. Where an existing metric horizontal curve will be retained in the project, the designer will calculate the US Customary (metric) radius from the known radius and round to three decimal places. The T and L distances are then calculated based on the US Customary (metric) radius and rounded to the nearest 0.01 of a foot (meter). See Example 9.6-5.
    b. Reconstruction. Where the alignment for a reconstruction project will approximate the existing alignment, normally the curve radii will be selected from those in Figure 9.2C. Where this is not practical, the radii of the reconstructed curve may be rounded to the nearest 5 feet (meters). The T and L distances are then calculated based on the US Customary (metric) radius and rounded to the nearest 0.01 of a foot (meter). See Example 9.6-6.

* * * * * * * * * *

Example 9.6-5 (Metric to US Customary)

Given: An existing horizontal curve has the following data in Metric units:

PI Sta = 92+09.86
Δ = 12°30’
R = 1150.00 m
T = 125.95 m
L = 250.89 m

Problem: For an overlay and widening project and assuming the curve will be retained as is, determine the proper US Customary dimensions for the horizontal curve.

Solution: The US Customary data are:

PI Sta = 302+16.08
Δ = 12°30’
R = 3772.97’ (D=0°39’31”)
T = 413.22’
L = 823.13’

Example 9.6-6

Given: An existing horizontal curve has the following data in Metric units:

PI Sta = 92+9.86
Δ = 12°30’
R = 1400 m
T = 153.32 m
L = 305.43 m

Problem: For a reconstruction project and assuming the curve will be reconstructed, determine the proper metric dimensions for the horizontal curve.

Solution: The US Customary data are:

PI Sta = 302+68.57
Δ = 12°30’
R = 4595’ (D=0°48’07”)
T = 503.23’
L = 1002.47’

For existing Metric horizontal curves, the Department's rounding practices for presentation on the roadway plans are:

1. Deflection Angle. These should be recorded in degrees rounded to the nearest second of a degree.
2. Linear Distances. These should be recorded in feet (meters) rounded to the nearest one hundredth of a foot (meter) (i.e., two decimal places).

3. Curve Radii. Rounding will be determined by the Project Scope of Work as follows:

   a. Overlay and Widening. Where an existing horizontal curve will be retained in the project, the designer will calculate the metric radius from the known radius and round to three decimal places. The T and L distances are then calculated based on the metric radius and rounded to the nearest 0.01 of a meter. See Example 9.6-5.

   b. Reconstruction. Where the alignment for a reconstruction project will approximate the existing alignment, normally the curve radii will be selected from those in Figure 9.2C. Where this is not practical, the radii of the reconstructed curve may be rounded to the nearest 5 meters. The T and L distances are then calculated based on the metric radius and rounded to the nearest 0.01 of a meter. See Example 9.6-6.

* * * * * * * * * * *

Example 9.6-5 (US Customary to Metric)

Given: An existing horizontal curve has the following data in US Customary units:

PI Sta = 302+68.57
Δ = 12°30'
R = 4583.66' (D=1°15')
T = 501.99'
L = 1000.00'

Problem: For an overlay and widening project and assuming the curve will be retained as is, determine the proper metric dimensions for the horizontal curve.

Solution: The metric data are:

PI Sta = 92+9.86
Δ = 12°30'
R = 1397.010 m
T = 153.00 m
L = 304.78 m

Example 9.6-6

Given: An existing horizontal curve has the following data in US Customary units:

PI Sta = 302+68.57
Δ = 12°30'
R = 4583.66' (D=1°15')
T = 501.99'
L = 1000.00'

Problem: For a reconstruction project and assuming the curve will be reconstructed, determine the proper metric dimensions for the horizontal curve.

Solution: The metric data are:

PI Sta = 92+9.86
Δ = 12°30'
R = 1400 m
T = 153.32 m
L = 305.43 m

* * * * * * * * * *

9.6.5 Stationing and Bearings

The following will apply to projects where control points are used to establish horizontal alignment:

1. Rounding. All stationing will be rounded to the nearest hundredth of a foot (meter) (i.e., two decimal places). All bearings will be rounded to the nearest second of a degree. When rounding computer-generated bearings, the designer must ensure that the rounded numbers for bearings are mathematically consistent.

2. Coordinates. The designer will prepare a table of coordinates for the linear and level data sheet. The table will illustrate the coordinate values for all control points for either the staked centerline or control traverse survey and for the projected centerline. The control points will include the project beginning and ending points; the PC, PI and PT for simple curves; the TS, SC, (Master) PI, CS and ST for spiral curves; and all equations. All coordinates must be computed to at least five decimals and rounded in the table to the nearest four decimals.

For projects using the as-built plans as the basis of horizontal alignment (typically overlay projects), the designer will soft convert the as-built stationing to US Customary. Retain the degree of accuracy shown on the as-built plans. Also, when existing right-of-way (R/W) plans are used to describe additional R/W acquisition, the designer will ensure that the accuracy of the stationing and bearings matches that of the old R/W plans.

For projects with a new survey (typically reconstruction or major widening projects), new metric stationing should be used.

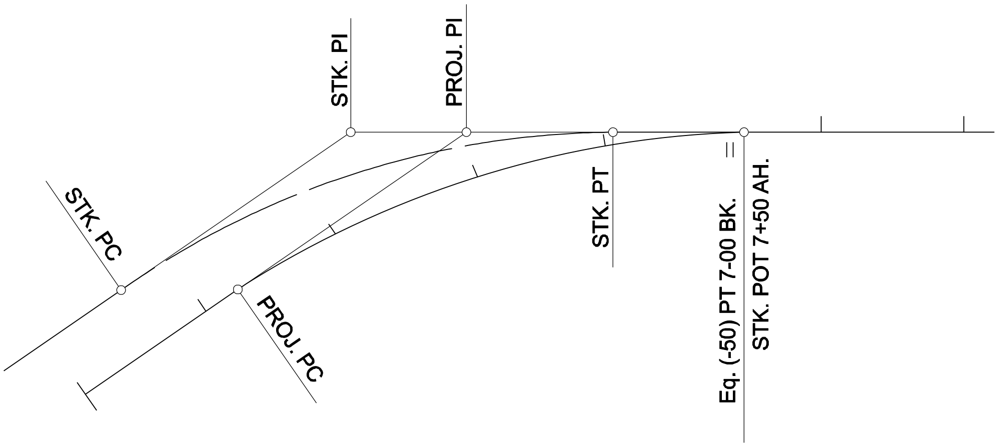
9.6.6 Equations

The following will apply to the use of equations in project stationing:

1. Purpose. An equation is used to equate two station numbers — one that is correct when measuring on the line back of the equation and one that is correct when measuring on the line ahead of the equation. Equations should be used where stationing is not continuous throughout a project.

2. Locations. Equations should be computed where design lines become coincident with staked lines. This situation is illustrated in Figure 9.6G.

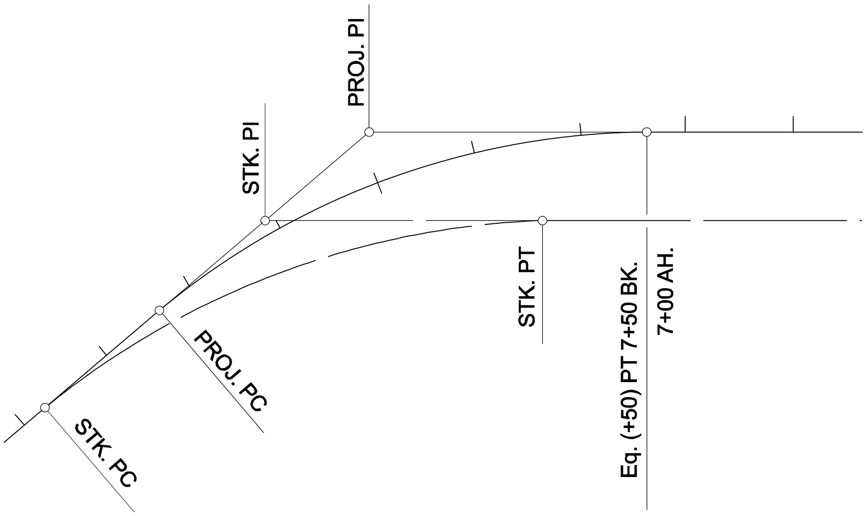
   Equations also should be computed in certain cases where design lines become parallel with staked lines. If the design line remains parallel with the staked line for a considerable distance through numerous cross sections, it is more convenient to compute an equation than to re-station the cross sections. An example of such an equation is illustrated in Figure 9.6H.



Note: If back station > ahead station, equation is (+). If back station < ahead station, equation is (-).

EQUATION WHERE DESIGN LINE BECOMES COINCIDENT

Figure 9.6G



EQUATION WHERE DESIGN LINE BECOMES PARALLEL WITH STAKED LINE

Figure 9.6H

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

CHAPTER TEN
VERTICAL ALIGNMENT

Table of Contents

Chapter Ten
VERTICAL ALIGNMENT

The highway vertical alignment plays a significant role in a highway's safety, aesthetics and project costs. Chapter Twelve "Geometric Design Tables" provides numerical criteria for various vertical alignment elements. Chapter Ten provides additional guidance on these and other vertical alignment elements, including laying out a profile grade line, maximum and minimum allowable grades, critical lengths of grade, climbing lanes, vertical curvature computations and vertical clearances.

10.1 DEFINITIONS/NOMENCLATURE

1. Bus. A heavy vehicle involved in the transport of passengers on a for-hire, charter or franchised transit basis.

2. Critical Length of Grade. The maximum length of a specific upgrade on which a loaded truck can operate without experiencing a specified reduction in speed.

3. Gradient. The rate of slope between two adjacent vertical points of intersection (VPI) expressed as a percent. The numerical value for percent of grade is the vertical rise or fall in feet (meters) for each 100’ (100 m) of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).

4. Heavy Vehicles. Any vehicle with more than four wheels touching the pavement during normal operation. Heavy vehicles collectively include trucks, recreational vehicles and buses.

5. K-Values. The horizontal distance needed to produce a 1% change in gradient.

6. Level Terrain. Level terrain is generally considered to be flat, and has minimal impact on vehicular performance. Highway sight distances are either long or could be made long without major construction expense.

7. Momentum Grade. A site where an upgrade is preceded by a downgrade, thereby allowing a truck to increase its speed on the upgrade. This increase in speeds allows the designer to use a higher speed reduction in the critical length of grade figure.

8. Mountainous Terrain. Longitudinal and transverse changes in elevation are abrupt, and benching or side hill excavation are frequently required to provide the desirable highway alignment. Mountainous terrain aggravates the performance of trucks relative to passenger cars, resulting in some trucks operating at crawl speeds.

9. Performance Curves. A set of curves which illustrate the effect grades will have on the design vehicle's acceleration and/or deceleration.

10. Profile Grade Line. A series of tangent lines connected by vertical curves. It is typically placed along the roadway centerline of undivided facilities and at the edges of the two roadways on the median side on divided facilities.

11. Recreational Vehicle. A heavy vehicle, generally operated by a private motorist, engaged in the transportation of recreational equipment or facilities; examples include campers, boat trailers, motorcycle trailers, etc.

12. Rolling Terrain. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the desirable highway alignment. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars.

13. Spline Curve. A curve, drawn using a flexible template to meet field conditions.

14. Truck. A heavy vehicle engaged primarily in the transport of goods and materials, or in the delivery of services other than public transportation. For geometric design and capacity analyses, trucks are defined as vehicles with six or more tires. Data on trucks are compiled and reported by the Transportation Planning Division.

15. VPC (Vertical Point of Curvature). The point at which a tangent grade ends and the vertical curve begins.

16. VPI (Vertical Point of Intersection). The point where the extension of two tangent grades intersect.

17. VPT (Vertical Point of Tangency). The point at which the vertical curve ends and the tangent grade begins.

10.2 DESIGN PRINCIPLES AND PROCEDURES

10.2.1 General Controls for Vertical Alignment

As discussed elsewhere in Chapter Ten, the design of vertical alignment involves, to a large extent, complying with specific limiting criteria. These include maximum and minimum grades, sight distance at vertical curves and vertical clearances. In addition, the designer should adhere to certain general design principles and controls which will determine the overall safety of the facility and will enhance the aesthetic appearance of the highway. These design principles for vertical alignment include:

1. Consistency. Use a smooth grade line with gradual changes, consistent with the type of highway and character of terrain, rather than a line with numerous breaks and short lengths of tangent grades.

2. Environmental Impacts. Vertical alignment should be properly coordinated with environmental impacts (e.g., encroachment onto wetlands). The Engineering Bureau within the Environmental Services Office is responsible for evaluating environmental impacts.

3. Long Grades. On a long ascending grade, it is preferable to place the steepest grade at the bottom and flatten the grade near the top.

4. Intersections. Maintain moderate grades through intersections to facilitate turning movements. See Chapter Thirteen for specific information on vertical alignment through intersections.

5. Roller Coaster. Avoid using a "roller-coaster" type of profile. They may be proposed in the interest of economy, but they are aesthetically undesirable and may be hazardous.

6. Broken-Back Curvature. Avoid "broken-back" grade lines (two crest or sag vertical curves separated by a 500’ (150 m) or less tangent section). One long vertical curve is more desirable.

7. Coordination with Natural/Man-Made Features. The vertical alignment should be properly coordinated with the natural topography, available right-of-way, utilities, roadside development and natural/man-made drainage patterns.

8. VPI Locations. Set VPI locations at even 50’ (10 m) stations if practical.

10.2.2 Coordination of Horizontal and Vertical Alignment

Horizontal and vertical alignment should not be designed separately, especially for projects on new alignment. Their importance demands that the designer carefully evaluate the interdependence of these two highway design features. This will enhance highway safety and improve the facility's operation. The following should be considered in the coordination of horizontal and vertical alignment:

1. Balance. Curvature and grades should be in proper balance. Maximum horizontal curvature with flat grades or flat curvature with maximum grades does not achieve this desired balance. A compromise between the two extremes produces the best design relative to safety, capacity, ease and uniformity of operations and a pleasing appearance.

2. Coordination. Vertical curvature superimposed upon horizontal curvature (i.e., vertical and horizontal P.I.'s at approximately the same stations) generally results in a more pleasing appearance and reduces the number of sight distance restrictions. Successive changes in profile not in combination with the horizontal curvature may result in a series of humps visible to the driver for some distance, which may produce an unattractive design. However, under some circumstances, superimposing the horizontal and vertical alignment must be tempered somewhat by Comment #'s 3 and 4 as follows.

3. Crest Vertical Curves. Sharp horizontal curvature should not be introduced at or near the top of pronounced crest vertical curves. This is undesirable because the driver cannot perceive the horizontal change in alignment, especially at night when headlight beams project straight ahead into space. This problem can be avoided if the horizontal curvature leads the vertical curvature or by using design values which exceed the desirable.

4. Sag Vertical Curves. Sharp horizontal curves should not be introduced at or near the low point of pronounced sag vertical curves or at the bottom of steep vertical grades. Because visibility to the road ahead is foreshortened, only flat horizontal curvature will avoid an undesirable, distorted appearance. At the bottom of long grades, vehicular speeds often are higher, particularly for trucks, and erratic operations may occur, especially at night.

5. Passing Sight Distance. In some cases, the need for frequent passing opportunities and a higher percentage of passing sight distance may supersede the desirability of combining horizontal and vertical alignment. In these cases, it may be necessary to provide long tangent sections to secure sufficient passing sight distance.

6. Intersections. At intersections, horizontal and vertical alignment should be as flat as practical to provide designs which produce sufficient sight distance and gradients for vehicles to slow or stop. See Chapter Thirteen.

7. Divided Highways. On divided facilities with wide medians, it is frequently advantageous to provide independent alignments for the two 1-way roadways. Where traffic justifies a divided facility, a superior design with minimal additional cost generally can result from the use of independent alignments.

8. Residential Areas. Design the alignment to minimize nuisance factors to neighborhoods. Minor adjustment to the horizontal or vertical alignment may increase the buffer zone between the highway and residential areas.

9. Aesthetics. Design the alignment to enhance attractive scenic views of rivers, rock formations, parks, golf courses, etc. The highway should head into rather than away from those views that are considered to be aesthetically pleasing. The highway should fall towards those features of interest at a low elevation and rise toward those features which are best seen from below or in silhouette against the sky.

10.2.3 Profile Grade Line

10.2.3.1 General

The profile grade line is perhaps the roadway geometric characteristic which has the greatest impact on a facility's costs, aesthetics, safety and operation. The profile grade is a series of tangent lines connected by parabolic vertical curves.

The designer must carefully evaluate many factors when establishing the profile grade line. These include:

1. maximum and minimum gradients;
2. sight distance criteria;
3. earthwork balance;
4. adjacent land use and values;
5. coordination with other geometric features (e.g., cross section);
6. highway safety;
7. topography/terrain;
8. right-of-way;
9. utilities;
10. truck performance;

11. highway intersections and interchanges;
12. railroad/highway crossings;
13. bridges and drainage structures;
14. high water levels;
15. drainage considerations;
16. water table elevations;
17. snow drifting;
18. types of soil;
19. urban/rural location;
20. aesthetics/landscaping;
21. construction costs.;
22. environmental impacts;
23. driver expectations;
24. airport flight paths (e.g., grades and lighting); and
25. pedestrian and handicapped accessibility.

The following sections discuss the establishment of the profile grade line in more detail.

10.2.3.2 Profile Grade Line Locations

The location of the profile grade line on the roadway cross section varies according to the highway type, whether or not the facility is divided or undivided, and the median type. The profile grade line locations are shown in the typical cross section figures provided in Section 11.7. The recommended profile grade line and axis of rotation locations for various typical sections are as follows:

1. Freeways With Depressed Median Sections (Medians 36’ (11 m) to 76’ (23 m) wide). A profile grade line is provided for each roadway, which is established on the outside edge of each median shoulder. See Figures 11.7A, 11.7B, 11.7C and 11.7D. The axes of rotation are about the profile grade lines.

2. Freeways With Depressed Median Sections (Medians 76’ (23 m) and Wider). Freeways with wide medians typically use independent alignments for both roadways. Therefore, a profile grade line is necessary for each roadway and is provided at the centerline of each roadway. See Figure 11.7E. For superelevated sections, the profile grade less normal crown is shown at the low side of the superelevation between the travel lane and shoulder on each roadway. See Figure 11.7F. The axes of rotation are about the profile grade less normal crown lines.

3. Flush Median Section (Freeways and Non-Freeways). For divided facilities with flush medians, including those with concrete median barriers, there is typically only one profile grade line at the centerline of the roadway. See Figures 11.7G, 11.7H, 11.7I and 11.7J. The axis of rotation is about the profile grade line.

4. Raised Median Section (Non-Freeways). For raised median sections, there is only one profile grade line at the centerline of the median or roadway. See Figures 11.7K and 11.7L. The axis of rotation is about the profile grade line.

5. Two-Lane Rural Highways. For 2-lane rural highways, there is typically only one profile grade line at the centerline of the roadway. See Figure 11.7M. For superelevated sections, the profile grade line less normal crown is shown at the low side between the travel lane and shoulder. See Figure 11.7N. The axis of rotation is about the profile grade less normal crown line.

6. Curbed Urban Undivided Facilities. The profile grade line will be placed at the centerline of the travelway. In addition, separate profiles at the top back of curb should be provided where necessary to ensure positive drainage and to match existing development. See Figures 11.7O and 11.7P. The axis of rotation is about the profile grade.

10.2.3.3 Urban Grade Design

Laying out profile grade lines in urban areas often is more complicated due to limited right-of-way, closely spaced intersections, the need to meet existing roadside development and accommodating drainage on curbed streets. The following provides several considerations that should be reviewed when developing a profile grade line on an urban project:

1. Vertical Curves. Long vertical curves on urban streets are generally impractical. The designer will typically need to lay out the profile grade line to meet existing conditions. Therefore, no minimum vertical curve lengths are provided for urban streets. Where practical, VPI's should be located at or near the centerlines of cross streets. Vertical curves will not be required when the algebraic difference in grades is less than 1.0%. However, the use of vertical curves should be evaluated when the algebraic difference in grades is greater than 0.5%. In addition, at signalized and stopped controlled intersections, some flattening of the approaches may be required, See Chapter Twenty-eight in the *Traffic Engineering Manual*.

2. Surface Drainage. Urban streets will often have curbs, which may complicate the layout of the profile grade to facilitate drainage. Special care should be taken to avoid flat spots where water may pond. Section 10.3.2 provides the minimum gradients for curbed streets. It will be necessary to develop separate profiles at the top of curb to promote positive drainage. Design curb elevations to permit drainage flow into the gutter and to avoid ponding of water behind the curb. At intersections, the surface drainage should preferably be intercepted upstream of the intersection. Where surface drainage is provided across intersecting streets, the drainage depression should have a minimum radius of 12' (3.6 m).

3. Spline Curves. Spline curves can be helpful in laying grades in urban areas where it is necessary to meet numerous elevation restrictions in relatively short distances. Spline curves may also be used when developing profiles for the top of curbs. The designer will need to tie these curves to the profile grade line at the beginning and end. Show elevations along spline curves at 10' (5 m) intervals.

4. Existing Roadside Development. Where roadside development is extensive and the general elevation on one side is higher than on the other, an asymmetrical section may be required. The crown point may be offset from the centerline and the total drop from crown line to gutter line will be more than normal on one side and less than normal on the other. Asymmetrical features must be clearly defined in the typical sections and shown in the cross sections. It will also be necessary to provide separate profiles at the top of curbs to match existing development. Providing an asymmetrical cross section may be preferred to reshaping existing sidewalks, parking lots, lawns, etc., to meet the revised profile.

5. Earthwork Balance. In general, balancing of earthwork is typically impractical in urban areas. An excess of excavation is preferable to the need for borrow, due to the generally higher cost of borrow in urban areas.

6. Limited Right-of-Way. Careful consideration must be given when substantially lowering or raising the profile grade line. This will often result in more right-of-way impacts (e.g., longer fill and cut slopes) where right-of-way is often restricted along urban streets.

10.2.3.4 Earthwork Balance

Where practical and where consistent with other project objectives, design the profile grade line to provide a balance of earthwork. This should not be achieved, however, at the expense of smooth grade lines and sight distance requirements at vertical curves.

Ultimately, a project-by-project assessment will determine whether a project will require borrow, excess or be balanced. For additional information on balancing earthwork, see Section 5.2.4.

10.2.3.5 Field Recommendations

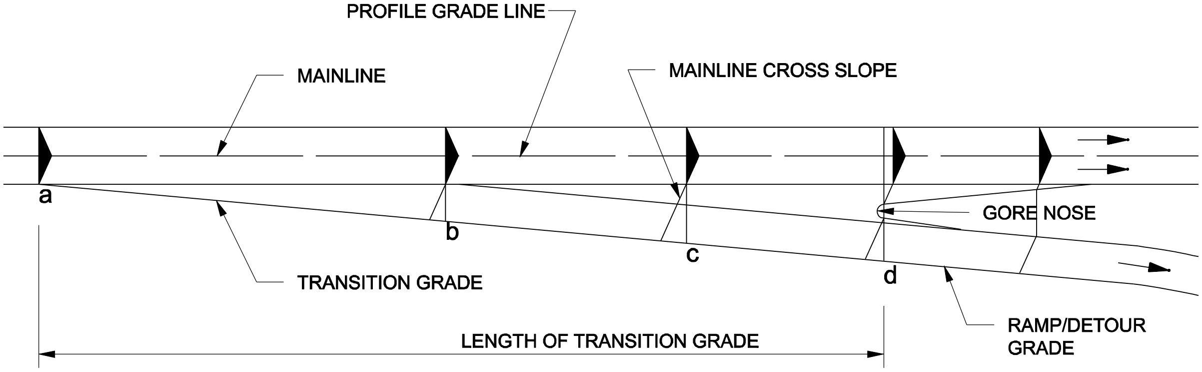
Recommendations should be made at the preliminary field review for addressing special grade controls. For example, recommendations should be provided for the profile grade line across flats, lake beds, sloughs, creek bottoms, important intersecting roads, and in front of improved property, at places subject to snow drifting and at other places requiring special attention. The designer should review and consider these recommendations when establishing the tentative profile grade line.

10.2.3.6 Ties with Existing Highways/Adjoining Projects

A smooth transition is needed between the proposed profile grade line of the project and the existing grade line of an adjacent highway section or the proposed grade line for an adjacent project. Grade lines should be reviewed for a distance of at least 2000’ (600 m) beyond the beginning and end of a project to ensure adequate sight distance. Connections should be made which are compatible with the design speed of the new project and which can be used if the adjoining road section is reconstructed.

10.2.3.7 Transition Grades

The transition grade (previously called the spline grade) is the grade line where the taper from the mainline begins for freeway ramps, turning roadways, transitions from 2-lane to 4-lane sections, detours, crossovers, etc., to the point where the ramp or roadway grade becomes independent of the mainline (i.e., at the gore nose). Figure 10.2A illustrates the location of the transition grade for ramps and detours. The transition grade is dependent on the mainline until the ramp or roadway becomes independent (i.e., the cross slope of grade lines must meet the transition grade at section "d" shown in Figure 10.2A. Site constraints may limit the ramp length such that the PC of a curve on the ramp must be located at the beginning of the independent ramp grade (d. on Figure 10.2A). For these cases, the cross slope of the ramp may vary from the cross slope of the mainline to permit a transition to the superelevation on the curve.



TRANSITION GRADE
(Ramps/Detours)

Figure 10.2A

For ramps, the transition grade should extend from the beginning of the taper from the mainline to a point where the distance between the edge of the travel lane on the mainline to the edge of the travel lane on the ramp is 8 feet (2.4 meters).

For detours, the transition grade should extend from the beginning of the taper from the mainline to a point where the distance between the edge of the travel lane on the mainline to the edge of the travel lane on the detour is 4 feet (1.2 meters). See Section 15.3 for additional information regarding transition grades for detours.

10.2.3.8 Bridges

The design of profile grade lines must be carefully coordinated with any bridges or drainage structures within the project limits. The following will apply:

1. Vertical Clearances. The criteria in Section 10.6 must be met where a new roadway and structure will be constructed over an existing roadway or where the roadway will be reconstructed under an existing bridge. When laying the preliminary grade line, an important element in determining available vertical clearance is the assumed structure depth. This will be based on the structure type, span lengths and depth/span ratio. The road designer should contact the Bridge Bureau to obtain an estimated depth of structure. If no information is available, the designer should assume a 20.0’ (6.2 m) to 22.0’ (6.5 m) distance

between the finished grade of the roadway and the finished grade of the bridge deck. For final design, the designer must coordinate with the Bridge Bureau to determine the roadway and bridge grade lines.

2. Highway Under Bridge. Where practical, the low point of a roadway sag vertical curve should not be within the shadow of the bridge. This will help minimize ice accumulations, and it will reduce the ponding of water which may weaken the earth foundation beneath the bridge. To achieve these objectives, the low point of a roadway sag should be approximately 100’ (30 m) from the bridge.

3. Bridges Over Water. Where the proposed facility will cross bodies of water, the bridge elevation must be consistent with the necessary waterway opening to meet the Department's hydraulic requirements. The road designer provides the Bridge Bureau with the preliminary grade line. The bridge designer determines minimum bridge elevations based on the hydraulic requirements. The designer must coordinate with the Hydraulics Section and Bridge Bureau to determine the final approach roadway elevation to meet the necessary bridge elevation.

4. Railroad Bridges. Any proposed facilities over railroads must meet the applicable criteria (e.g., vertical clearances, structure type and depth). The designer should contact the Bridge Bureau and the Utilities Section for more information.

5. High Embankments. The designer should consider the impacts of high embankments on structures. This will increase the span length thus increasing structure costs.

6. Low Point. It is desirable to locate the low point of a sag vertical curve off the bridge deck.

10.2.3.9 Soils

The type of earth material encountered often influences the grade line at certain locations. If rock is encountered, for example, it may be more economical to raise the grade and reduce the rock excavation. Soils which are unsatisfactory for embankment or cause a stability problem in cut areas may also be determining factors in establishing a grade line. The designer should coordinate the development of the profile grade with the Materials Bureau, which will be responsible for conducting the soils survey.

10.2.3.10 Drainage/Snow

The profile grade line should be compatible with the roadway drainage design and should minimize snow drift problems. Consider the following:

1. Culverts. The roadway elevation should provide at least the minimum cover indicated in the culvert fill height tables in Chapter Seventeen. Desirably, culverts should not extend above the top of the subgrade. Do not locate the low points of sag vertical curves directly over culverts. This is so that if flooding overtops the roadway, the chance of culverts being washed out will be minimized. See Chapter Seventeen for additional information on culvert designs.

2. Coordination with Geometrics. The profile grade line must reflect compatibility between drainage design and roadway geometrics. These include the design of sag and crest vertical curves, spacing of inlets on curbed facilities, impacts on adjacent properties, superelevated curves, intersection design elements and interchange design elements. For example, avoid placing sag vertical curves in cuts and placing long crest vertical curves on curbed pavements.

3. Snow Drifting. Where practical, the profile grade line should be at least 2’ (0.5 m) above the natural ground level on the windward side of the highway to prevent snow from drifting onto the roadway and to promote snow blowing off the roadway. See Section 11.4.2 for additional criteria to minimize snow drifting.

10.2.3.11 Erosion Control

To minimize erosion, the designer should consider the following relative to the grade line:

1. Minimize the number of deep cuts and high fill sections.

2. Conform to the contour and drainage patterns of the area.

3. Make use of natural land barriers and contours to divert runoff and confine erosion and sedimentation.

4. Minimize the amount of disturbance.

5. Make use of existing vegetation.

6. Reduce slope length and steepness and ensure that erosion is confined to the right-of-way and does not deposit sediment on or erode away adjacent land.

7. Avoid locations having high base erosion potential.

8. Avoid cut or fill sections in seepage areas.

10.2.3.12 Project Types

In addition to reconstruction projects that involve significant grade modifications, a new profile grade should be shown for pavement pulverization projects and projects that involve major surfacing rehabilitation.

It is not necessary to provide profile grades for overlays or other minor surfacing rehabilitation projects. If the need for a profile grade is in question, consult with Construction personnel.

10.3 GRADES

10.3.1 Maximum Grades

Chapter Twelve presents the Department's criteria for maximum grades based on functional classification, urban/rural location, type of terrain, and in some cases, design speed. The maximum grades should be used only where absolutely necessary. Where practical, use grades flatter than the maximum.

10.3.2 Minimum Grades

The following provides the Department's criteria for minimum grades:

1. Uncurbed Roads. Desirably, a 0.5% minimum longitudinal grade should be provided. Level longitudinal gradients may be acceptable on pavements in fills and which are adequately crowned to drain laterally. In cuts, minimum longitudinal gradients of 0.2% are acceptable.

2. Curbed Streets. The centerline profile on highways and streets with curbs should desirably have a minimum longitudinal gradient of 0.5%. Longitudinal gradients of at least 0.4% are acceptable. Because surface drainage is retained within the roadway, the longitudinal gradients must be steeper on curbed streets then uncurbed roadways to avoid ponding of water on the roadway surface.

10.3.3 Critical Length of Grade

Critical length of grade is the maximum length of a specific upgrade on which a loaded truck can operate without experiencing a specified reduction in speed. The highway gradient in combination with the length of grade will determine the truck speed reduction on upgrades. Refer to the *Traffic Engineering Manual* to determine the critical length of grade

10.4 TRUCK-CLIMBING LANES

The Traffic Engineering Section will typically determine the need for truck-climbing lanes and will provide the design details for these lanes where they are warranted. For information on truck-climbing lanes, see Chapters Twenty-six and Thirty in the *Traffic Engineering Manual*.

10.5 VERTICAL CURVES

10.5.1 Crest Vertical Curves

Crest vertical curves are in the shape of a parabola. The basic equations for determining the minimum length of a crest vertical curve are:

$$L = \frac{AS^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2}$$ (Equation 10.5-1)

$$L = KA$$ (Equation 10.5-2)

Where:

L = length of vertical curve, ft (m)
A = algebraic difference between the two tangent grades, %
S = sight distance, ft (m)
h_1 = height of eye above road surface, ft (m)
h_2 = height of object above road surface, ft (m)
K = horizontal distance needed to produce a 1% change in gradient

The length of the crest vertical curve will depend upon "A" for the specific curve and upon the selected sight distance, height of eye and height of object. The following discusses the selection of these values. For design purposes, the calculated length of curve based on the rounded K-value should be rounded up to the next highest 50’ (20 m) increment.

The principal control in the design of crest vertical curves is to ensure that, at a minimum, stopping sight distance (SSD) is available throughout the curve. Figure 10.5A presents the K-values for stopping sight distance. The following discusses the application of the K-values:

1. Passenger Cars (Level Grade). Figure 10.5A presents minimum K-values for passenger cars. These are calculated by assuming h_1 = 3.5’ (1.080 m), h_2 = 2’ (0.60 m) and S = $SSD_{minimum}$ in the basic equation for crest vertical curves (Equation 10.5-1). The minimum values represent the lowest acceptable sight distance on a facility. However, the designer should provide a design in which the K-values meet the greatest practical SSD.

US Customary

DESIGN SPEED (mph)	ROUNDED SSD FOR DESIGN[1] (ft)	CALCULATED K-VALUES[2]	K-VALUES ROUNDED FOR DESIGN[2]
		2’ Object $K = \frac{S^2}{2158}$	
20	115	6.1	7
25	155	11.1	12
30	200	18.5	19
35	250	29.0	29
40	305	43.1	44
45	360	60.1	61
50	425	83.7	84
55	495	113.5	114
60	570	150.6	151
65	645	192.8	193
70	730	246.9	247
75	820	311.6	312

Metric

DESIGN SPEED (km/h)	ROUNDED SSD FOR DESIGN[1] (m)	CALCULATED K-VALUES[2] ($K=S^2/658$)	K-VALUES ROUNDED FOR DESIGN[2]
		600 mm Object	
30	35	1.9	2
40	50	3.8	4
50	65	6.4	7
60	85	11.0	11
70	105	16.8	17
80	130	25.7	26
90	160	38.9	39
100	185	52.0	52
110	220	73.6	74
120	250	95.0	95

Notes:

1. *Stopping sight distances (SSD) are from Figure 8.6A.*

2. *K-values are calculated using rounded stopping sight distances, eye height of 3.5’ (1.080 m) and object height of 2’ (0.60 m). AASHTO K-values are based on the calculated stopping sight distance.*

K-VALUES FOR CREST VERTICAL CURVES
(Level Grades)

Figure 10.5A

2. Minimum Length. For aesthetics, the suggested minimum length of a crest vertical curve on a rural highway is 1000' (300 m). Where the algebraic difference in grades (A) is small, the calculated curve lengths may actually be zero. However, angle points are not allowed on rural highways. Therefore, the minimum length of curve is based on Equation 10.5-3.

US Customary	Metric	
$L_{\min} = 3V$	$L_{min} = 0.6\ V$	(Equation 10.5-3)

Where:

L_{min} = minimum length of vertical curve, ft (m)
V = design speed, mph (km/h)

3. Drainage. Drainage should be considered in the design of crest vertical curves where curbed sections are used. Drainage problems should not be experienced if the vertical curvature is sharp enough so that a minimum longitudinal grade of at least 0.3% is reached at a point about 50' (15 m) from either side of the apex. To ensure that this objective is achieved, the length of the vertical curve should be based upon a K-value of 167 (50) or less. For crest vertical curves on curbed sections where this K-value is exceeded, the drainage design should be more carefully evaluated near the apex.

   For uncurbed sections of highway, drainage should not be a problem at crest vertical curves. However, the adjacent roadside ditch should have minimum longitudinal gradient of 0.2% in the vicinity of the vertical curve. Grading the ditches separately from the mainline may be necessary to achieve the desired grade.

4. Passing Sight Distance. At some locations, it may be desirable to provide passing sight distance in the design of crest vertical curves. On rural reconstruction projects, the designer should attempt to provide passing sight distance over as much of the highway length as practical. It will generally not be cost effective, however, to make significant improvements to the horizontal and vertical alignment solely to increase the available passing sight distance. Section 8.6.2 discusses the application and design values for passing sight distance. These "S" values are used in the basic equations for crest vertical curves (Equations 10.5-1 and 10.5-2). The height of eye (h_1) is 3.5' (1.080 m) and the height of object (h_2) is 3.5' (1.080 m). Figure 10.5B presents the minimum K-values for determining passing sight distance.

US Customary

DESIGN SPEED (mph)	MINIMUM PASSING SIGHT DISTANCE FOR DESIGN(1) (ft)	CALCULATED K-VALUES(2) ($K=S^2/2800$)	K-VALUES ROUNDED FOR DESIGN(2)
30	1090	424.3	424
35	1280	585.1	585
45	1625	943.1	943
50	1835	1202.6	1203
55	1985	1407.2	1407
60	2135	1627.9	1628
70	2480	2196.6	2197
75	2580	2377.3	2377

Metric

DESIGN SPEED (km/h)	MINIMUM PASSING SIGHT DISTANCE FOR DESIGN(1) (m)	CALCULATED K-VALUES(2) ($K=S^2/864$)	K-VALUES ROUNDED FOR DESIGN(2)
50	345	137.8	138
60	410	194.6	195
70	485	272.3	272
80	540	337.5	338
90	615	437.8	438
100	670	519.6	520
110	730	616.8	617
120	775	695.2	695

Notes:

1. *Passing sight distances are from Figure 8.6C.*

2. *K-values are calculated using the passing sight distance, eye height of 3.5’ (1.080 m) and object height of 3.5’ (1.080 m).*

K-VALUES FOR PASSING SIGHT DISTANCE
(Crest Vertical Curves)

Figure 10.5B

10.5.2 Sag Vertical Curves

Sag vertical curves are in the shape of a parabola. Typically, they are designed to allow the vehicular headlights to illuminate the roadway surface (i.e., the height of object = 0.0' (m) for a given distance "S." These assumptions yield the following basic equations for determining the minimum length of sag vertical curves:

$$L = \frac{AS^2}{200h_3 + 3.5S} \qquad \text{(Equation 10.5-4)}$$

$$L = KA \qquad \text{(Equation 10.5-5)}$$

Where:

L = length of vertical curve, ft (m)
A = algebraic difference between the two tangent grades, %
S = sight distance, ft (m)
h_3 = height of headlights above pavement surface, ft (m)
K = horizontal distance needed to produce a 1% change in gradient

The length of the sag vertical curve will depend upon "A" for the specific curve and upon the selected sight distance and headlight height. For design purposes, the calculated length of curve based on the rounded K-value should be rounded up to the next highest 50' (20 m) increment.

The principal control in the design of sag vertical curves is to ensure that, at a minimum, stopping sight distance (SSD) is available for headlight illumination throughout the curve. The design assumes that there is a 1° upward divergence of the light beam from the longitudinal axis of the headlights. Figure 10.5C presents the K-values for stopping sight distances. The following discusses the application of the K-values:

1. Passenger Cars. Figure 10.5C presents minimum and desirable K-values for passenger cars. These are calculated by assuming h_3 = 2' (0.600 m) and S = SSD in the basic equation for sag vertical curves (Equation 10.5-4). The minimum values represent the lowest acceptable sight distance on a facility.

US Customary

DESIGN SPEED (mph)	ROUNDED SSD FOR DESIGN[1] (ft)	CALCULATED K-VALUES[2] ($K=S^2/(400+3.5(S))$)	K-VALUES ROUNDED FOR DESIGN[2]
20	115	16.5	17
25	155	25.5	26
30	200	36.4	37
35	250	49.0	49
40	305	63.4	64
45	360	78.1	79
50	425	95.7	96
55	495	114.9	115
60	570	135.7	136
65	645	156.5	157
70	730	180.3	181
75	820	205.6	206

Metric

DESIGN SPEED (km/h)	ROUNDED SSD FOR DESIGN[1] (m)	CALCULATED K-VALUES[2] ($K=S^2/(120+3.5(S))$)	K-VALUES ROUNDED FOR DESIGN[2]
30	35	5.1	6
40	50	8.5	9
50	65	12.2	13
60	85	17.3	18
70	105	22.6	23
80	130	29.4	30
90	160	37.6	38
100	185	44.6	45
110	220	54.4	55
120	250	62.8	63

Notes:

1. *Stopping sight distances (SSD) are from Figure 8.6A.*
2. *K-values calculated using rounded stopping sight distances and a headlight height (h_3) of 2’ (0.600 m). AASHTO K-values are based on the calculated stopping sight distance.*

K-VALUES FOR SAG VERTICAL CURVES

Figure 10.5C

2. Minimum Length. For most sag vertical curves, the minimum length of curve should be based on Equation 10.5-3 (i.e., L_{min} = 3V (L_{min} = 0.6V)). For aesthetics, the suggested minimum length of a sag vertical curve on a rural highway is 1000’ (300 m).

3. Drainage. Drainage should be considered in the design of sag vertical curves where curbed sections are used. Drainage problems are minimized if the sag vertical curve is sharp enough so that a minimum longitudinal grade of at least 0.3% is reached at a point about 50’ (15 m) from either side of the low point. To achieve this objective, the length of the vertical curve should be based upon a K-value of 167 (50) or less. For sag vertical curves on curbed sections where this K-value is exceeded, the drainage design should be more carefully evaluated near the low point. For example, it may be necessary to install flanking inlets on either side of the low point.

10.5.3 Vertical Curve Computations

The following will apply to the mathematical design of vertical curves:

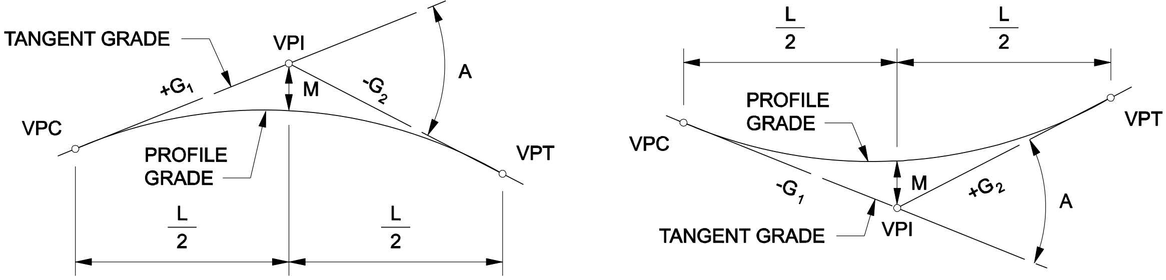
1. Definitions. Figure 10.5D presents the common terms and definitions used in vertical curve computations.

2. Measurements. All measurements for vertical curves are made on the horizontal or vertical plane, not along the profile grade. With the simple parabolic curve, the vertical offsets from the tangent vary as the square of the horizontal distance from the VPC or VPT. Elevations along the curve are calculated as proportions of the vertical offset at the point of vertical intersection (VPI). The necessary formulas for computing the vertical curve are shown in Figure 10.5E. Figure 10.5F provides an example of how to use these formulas.

3. Unsymmetrical Vertical Curve. Occasionally, it is necessary to use an unsymmetrical vertical curve to obtain clearance on a structure or to meet other field conditions. This curve is similar to the parabolic vertical curve, except the curve does not vary symmetrically about the VPI. The necessary formulas for computing the unsymmetrical vertical curve are shown in Figure 10.5G.

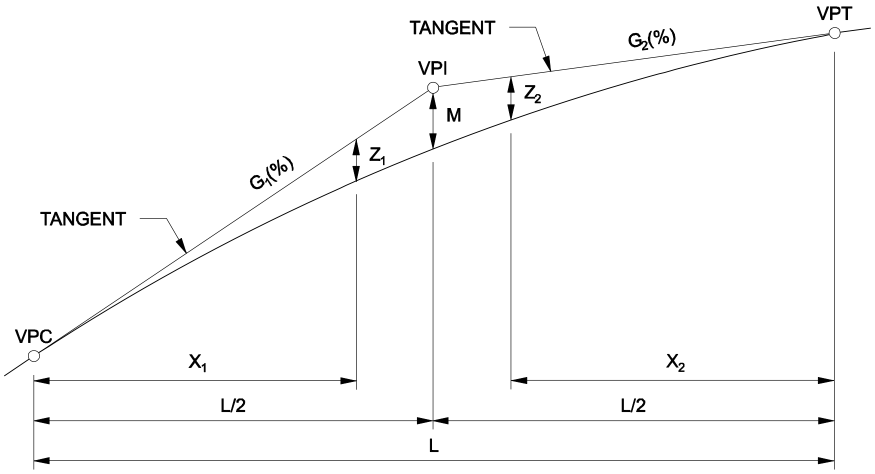
4. Vertical Curve Through Fixed Point. A vertical highway curve often must be designed to pass through an established point. For example, it may be necessary to tie into an existing transverse road or to clear existing structures. See Figure 10.5H. Figure 10.5I illustrates an example on how to use these formulas.

ELEMENT	ABBREVIATION	DEFINITION
Vertical Point of Curvature	VPC	The point at which a tangent grade ends and the vertical curve begins.
Vertical Point of Tangency	VPT	The point at which the vertical curve ends and the tangent grade begins.
Vertical Point of Intersection	VPI	The point where the extension of two tangent grades intersect.
Grade	G_1, G_2	The rate of slope between two adjacent VPI's expressed as a percent. The numerical value for percent of grade is the vertical rise or fall in feet (meters) for each 100’ (100 m) of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).
External Distance	M	The vertical distance (offset) between the VPI and the roadway surface along the vertical curve.
Algebraic Difference in Grade	A	The value of A is determined by the deflection in percent between two tangent grades (G_2 - G_1).
Length of Vertical Curve	L	The horizontal distance in feet (meters)from the VPC to the VPT.
Tangent Elevation	Tan. Elev.	The elevation on the tangent line between the VPC and VPI and the VPI and VPT.
Elevation on Vertical Curve	Curve Elev.	The elevation of the vertical curve at any given point along the curve.
Horizontal Distance	X	Horizontal distance measured from the VPC or VPT to any point on the vertical curve, in meters.
Tangent Offset	Z	Vertical distance from the tangent line to any point on the vertical curve, in feet (meters).
Low/High Point	X_T	The station at the high point for crest curves or the low point for sag curves.
Symmetrical Curve	—	The VPI is located at mid-point between VPC and VPT stationing.
Unsymmetrical Curve	—	The VPI is not located at mid-point between VPC and VPT stationing.



CREST VERTICAL CURVE SAG VERTICAL CURVE

VERTICAL CURVE DEFINITIONS
Figure 10.5D



M = External distance, ft(m)
Z = Any tangent offset, ft(m)
L = Horizontal length of vertical curve, ft(m)
X = Horizontal distance from VPC or VPT to any ordinate "Z," ft(m)
G_1 & G_2 = Rates of grade, expressed algebraically, percent

NOTE: ALL EXPRESSIONS TO BE CALCULATED ALGEBRAICALLY
(Use algebraic signs of grades; grades in percent.)

1. <u>Elevations of VPC and VPI</u>:

$$ELEV.OF\,VPC = ELEV.VPI - G_1\left(\frac{L}{200}\right) \qquad \text{(Equation 10.5-6)}$$

$$ELEV.OF\,VPT = ELEV.VPI + G_2\left(\frac{L}{200}\right) \qquad \text{(Equation 10.5-7)}$$

2. <u>For the elevation of any point "X" on the vertical curve</u>:

$$\mathrm{CURVE\,ELEV.} = \mathrm{TAN\ ELEV.} + \mathrm{Z} \qquad \text{(Equation 10.5-8)}$$

Where:

<u>Left of VPI (X_1 measured from VPC)</u>:	<u>Right of VPI (X_2 measured from VPT)</u>:
(a) $TAN.ELEV. = VPC\,ELEV. + G_1\left(\frac{X_1}{100}\right)$	(a) $TAN\ ELEV. = VPT\,ELEV. - G_2\left(\frac{X_2}{100}\right)$
(b) $Z_1 = X_1^2\,\frac{(G_2 - G_1)}{200\,L}$	(b) $Z_2 = X_2^2\,\frac{(G_2 - G_1)}{200\,L}$

3. <u>Calculating high or low point in the vertical curve</u>:

(a) To determine distance "X_T" from VPC: $X_T = \frac{L\,G_1}{G_1 - G_2}$ (Equation 10.5-9)

(b) To determine high or low point stationing: $VPC\,Sta. + X_T$ (Equation 10.5-10)

(c) To determine high or low point elevation on the vertical curve:

$$\mathrm{ELEV.}_{\mathrm{HIGH\,OR\,LOW\,POINT}} = \mathrm{ELEV\ \ VPC} - \frac{\mathrm{L\,G_1^2}}{(\mathrm{G_2 - G_1})200} \qquad \text{(Equation 10.5-11)}$$

SYMMETRICAL VERTICAL CURVE EQUATIONS

Figure 10.5E

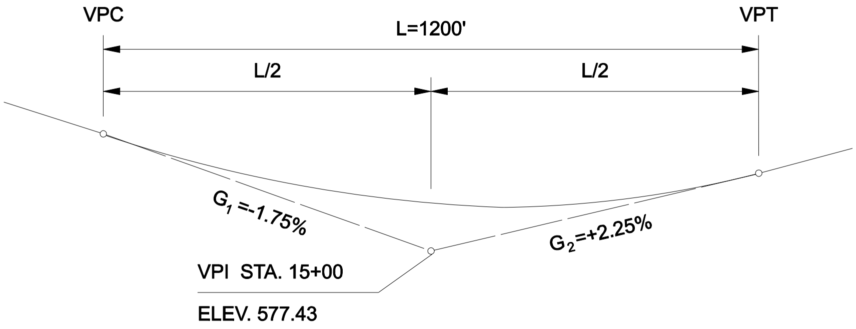
Example 10.5-1 **(US Customary)**

Given: $G_1 = -1.75\%$
$G_2 = +2.25\%$
Elev. of VPI = 577.43’
Station of VPI = 15+00
L = 1200’
Symmetrical Vertical Curve

Problem: Compute the vertical curve elevations for each 50’ station. Compute the low point elevation and stationing.

Solution:

1. Draw a diagram of the vertical curve and determine the station at the beginning (VPC) and the end (VPT) of the curve.



VPC Station = VPI Sta.- ½L = (15+00) - (6+00) = 9+00

VPT Station = VPI Sta.+ ½L = (15+00) + (6+00) = 21+00

2. Vertical curve equations:

$$CURVE\,ELEV. = TAN.ELEV. + Z$$ (Equation 10.5-8)

Where:

Left of VPI (X_1 measured from VPC):	Right of VPI (X_2 measured from VPT):
(a) $TAN\ ELEV. = VPC\,ELEV. + G_1\left(\frac{X_1}{100}\right)$	(a) $\mathrm{TAN\ ELEV.} = \mathrm{VPT\,ELEV.} - G_2\left(\frac{X_2}{100}\right)$
(b) $Z_1 = X_1^2\,\frac{(G_2 - G_1)}{200\,L}$	(b) $Z_2 = X_2^{\,2}\,\frac{(G_2 - G_1)}{200\,L}$

3. Set up a table to show the vertical curve elevations at the 50’ stations, substituting the values into the above equations.

Example 10.5-1 **(Metric)**

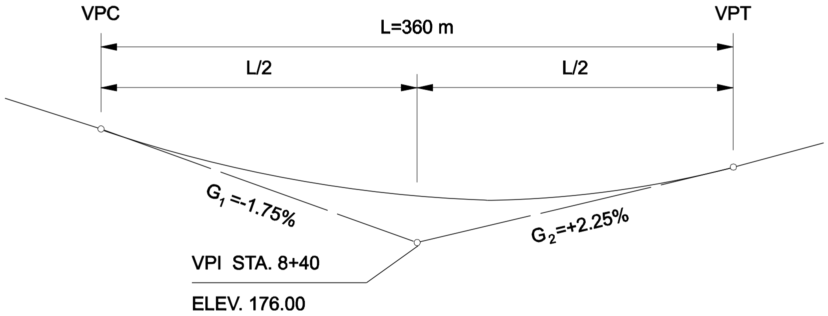
Given: $G_1 = -1.75\%$
$G_2 = +2.25\%$

Elev. of VPI = 176.00 m
Station of VPI = 8+40
L = 360 m
Symmetrical Vertical Curve

Problem: Compute the vertical curve elevations for each 20 m station. Compute the low point elevation and stationing.

Solution:

1. Draw a diagram of the vertical curve and determine the station at the beginning (VPC) and the end (VPT) of the curve.



VPC Station = VPI Sta.- ½L = (8+40) - (1+80) = 6+60

VPT Station = VPI Sta.+ ½L = (8+40) + (1+80) = 10+20

2. Vertical curve equations:

$$CURVE\,ELEV. = TAN.ELEV. + Z \qquad \text{(Equation 10.5-8)}$$

Where:

Left of VPI (X_1 measured from VPC):	Right of VPI (X_2 measured from VPT):
(a) $TAN\ ELEV. = VPC\,ELEV. + G_1\left(\frac{X_1}{100}\right)$	(a) $\text{TAN ELEV.} = \text{VPT ELEV.} - G_2\left(\frac{X_2}{100}\right)$
(b) $Z_1 = X_1^2\,\frac{(G_2 - G_1)}{200\,L}$	(b) $Z_2 = X_2^2\,\frac{(G_2 - G_1)}{200\,L}$

3. Set up a table to show the vertical curve elevations at the 20 meter stations, substituting the values into the above equations.

VERTICAL CURVE COMPUTATIONS
(Example 10.5-1)

Figure 10.5F

Example 10.5-1 **(US Customary)**

Solution: (continued)

Station	Inf.	Tangent Elevation	X	X^2	$Z=X^2/60000$	Grade Elevation
9+00	VPC	587.930	0	0	0	587.93
9+50		587.055	50	2500	0.0417	587.10
10+00		586.180	100	10000	0.1667	586.35
10+50		585.305	150	22500	0.3750	585.68
11+00		584.430	200	40000	0.6667	585.10
11+50		583.555	250	62500	1.0417	584.60
12+00		582.680	300	90000	1.5000	584.18
12+50		581.805	350	122500	2.0417	583.85
13+00		580.930	400	160000	2.6667	583.60
13+50		580.055	450	202500	3.3750	583.43
14+00		579.180	500	250000	4.1667	583.35
14+50		578.305	550	302500	5.0417	583.35
15+00	VPI	577.430	600	360000	6.0000	583.43
15+50		578.555	550	302500	6.0417	583.60
16+00		579.680	500	250000	4.1667	583.85
16+50		580.805	450	202500	3.3750	584.18
17+00		581.930	400	160000	2.6667	584.60
17+50		583.055	350	122500	2.0417	585.10
18+00		584.180	300	90000	1.5000	585.68
18+50		585.305	250	62500	1.0417	584.35
19+00		586.430	200	40000	0.6667	587.10
19+50		587.555	150	22500	0.3750	587.93
20+00		588.680	100	10000	0.1667	588.85
20+50		589.805	50	2500	0.0417	589.85
21+00	VPT	590.930	0	0	0	590.93

1. Calculate low point (Equations 10.5-9, 10.5-10 and 10.5-11):

$$X_T = \frac{LG_1}{G_1 - G_2} = \frac{1200(-1.75)}{-1.75-2.25} = \frac{-630.0}{-4.00} = 525.00\ feet\ from VPC$$

therefore, the Station at low point is:

$$VPC_{STA} + X_T = (9+00)+(5+25) = 14+25$$

elevation of low point on curve equals:

$$Elev.VPC-\frac{LG_1^2}{(G_2-G_1)200}=179.15-\frac{360(-1.75)^2}{(2.25-(-1.75))200}=179.15-1.38=177.77\ ft$$

Example 10.5-1 **(Metric)**

Solution: (continued)

Station	Inf.	Tangent Elevation	X	X^2	$Z=X^2/18000$	Grade Elevation
6+60	VPC	179.15	0	0	0.00	179.15
6+80		178.80	20	400	0.02	178.82
7+00		178.45	40	1 600	0.09	178.54
7+20		178.10	60	3 600	0.20	178.30
7+40		177.75	80	6 400	0.36	178.11
7+60		177.40	100	10 000	0.56	177.96
7+80		177.05	120	14 400	0.80	177.85
8+00		176.70	140	19 600	1.09	177.79
8+20		176.35	160	25 600	1.42	177.77
8+40	VPI	176.00	180	32 400	1.80	177.80
8+60		176.45	160	25 600	1.42	177.87
8+80		176.90	140	19 600	1.09	177.99
9+00		177.35	120	14 400	0.80	178.15
9+20		177.80	100	10 000	0.56	178.36
9+40		178.25	80	6 400	0.36	178.61
9+60		178.70	60	3 600	0.20	178.90
9+80		179.15	40	1 600	0.09	179.24
10+00		179.60	20	400	0.02	179.62
10+20	VPT	180.05	0	0	0.00	180.05

2. Calculate low point (Equations 10.5-9, 10.5-10 and 10.5-11):

$$X_T=\frac{LG_1}{G_1-G_2}=\frac{360(-1.75)}{-1.75-2.25}=\frac{-630.0}{-4.00}=157.5\ meters\ from VPC$$

therefore, the Station at low point is:

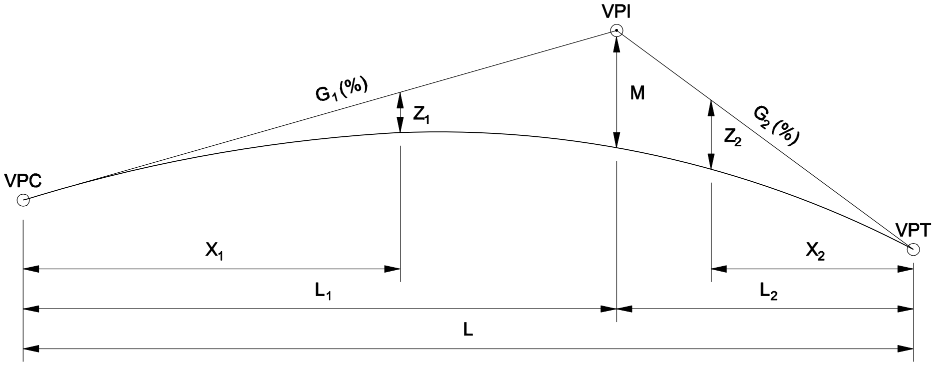
$$VPC_{STA}+X_T=(6+60)+(1+57.5)=8+17.5$$

elevation of low point on curve equals:

$$Elev.VPC-\frac{LG_1^2}{(G_2-G_1)200}=179.15-\frac{360(-1.75)^2}{(2.25-(-1.75))200}=179.15-1.38=177.77\ m$$

VERTICAL CURVE COMPUTATIONS
(Example 10.5-1)
(continued)

Figure 10.5F



M = Offset from the VPI to the curve (external distance), ft (m)

Z = Any tangent offset, ft (m)

L = Horizontal length of vertical curve, ft (m)

L_1 = Horizontal distance from VPC to VPI, ft (m)

L_2 = Horizontal distance from VPI to VPT, ft (m)

X = Horizontal distance from VPC or VPT to any ordinate "Z," ft (m)

G_1 & G_2 = Rates of grade, expressed algebraically, percent

NOTE: ALL EXPRESSIONS TO BE CALCULATED ALGEBRAICALLY
(Use algebraic signs of grades; grades in percent.)

1. Elevations of VPC and VPI:

$$ELEV.\ OF\ \ VPC = ELEV.VPI - G_1\left(\frac{L_1}{100}\right)$$ (Equation 10.5-12)

$$ELEV.\ OF\ \ VPT = ELEV.VPI + G_2\left(\frac{L_2}{100}\right)$$ (Equation 10.5-13)

2. For the elevation of any point "X" on the vertical curve:

$$CURVE\ ELEV. = TAN.ELEV. + Z$$ (Equation 10.5-14)

Where:

Left of VPI (X_1 measured from VPC):

(a) $TAN.ELEV. = VPC\ ELEV. + G_1\left(\frac{X_1}{100}\right)$

(b) $Z_1 = X_1^2\left(\frac{L_2}{L_1}\right)\left(\frac{G_2 - G_1}{200\ L}\right)$

Right of VPI (X_2 measured from VPT):

(a) $TAN.ELEV. = VPT\ ELEV. - G_2\left(\frac{X_2}{100}\right)$

(b) $Z_2 = X_2^2\left(\frac{L_1}{L_2}\right)\left(\frac{G_2 - G_1}{200\ L}\right)$

UNSYMMETRICAL VERTICAL CURVE EQUATIONS
Figure 10.5G

3. Calculating High or Low Point on Curve:

Note: Two answers will be determined by solving the equations below. Only one answer is correct. The incorrect answer is where $X_T > L_1$ on the left side of the VPI or where $X_T > L_2$ on the right side of the VPI.

a. Assume high or low point occurs left of VPI to determine the distance, X_T, from VPC:

$$X_T = \frac{L_1}{L_2}\left[\frac{G_1 L}{(G_1 - G_2)}\right] \qquad \text{(Equation 10.5-15)}$$

Note: Does $X_T > L_1$? If yes, this answer is incorrect and the high or low point is on the right side of the VPI. (Go to step d. to solve for the high or low point elevation.) If no, then this is the correct answer and proceed with steps b. and c. below.)

b. To determine high or low point stationing (where $X_T < L_1$):

$$STA_{\ HIGH\ OR\ LOW\ POINT} = VPC\ STA. + X_T \qquad \text{(Equation 10.5-16)}$$

c. To determine high or low point elevation on vertical curve (when $X_T < L_1$):

$$ELEV_{HIGH\ OR\ LOW\ POINT} = ELEV.VPC - \frac{L_1}{L_2}\left[\frac{LG_1^2}{(G_2 - G_1)200}\right] \qquad \text{(Equation 10.5-17)}$$

d. If $X_T > L_1$ from step a., the high or low point occurs right of the VPI. Determine the distance X_T from the VPT:

$$X_T = \frac{L_2}{L_1}\left[\frac{G_2 L}{(G_2 - G_1)}\right] \qquad \text{(Equation 10.5-18)}$$

e. To determine high or low point stationing:

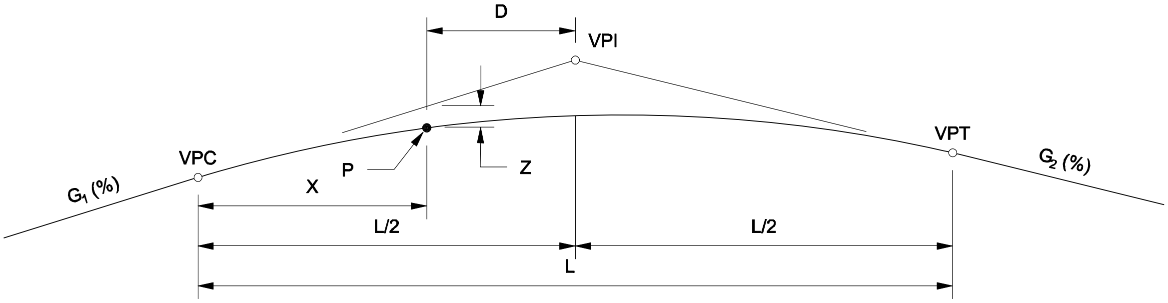
$$STA_{\ HIGH\ OR\ LOW\ POINT} = VPT\ STA. - X_T \qquad \text{(Equation 10.5-19)}$$

f. To determine high or low point elevation on the vertical curve:

$$ELEV_{HIGH\ OR\ LOW\ POINT} = ELEV.\ VPT - \frac{L_2}{L_1}\left[\frac{LG_2^2}{(G_2 - G_1)200}\right] \qquad \text{(Equation 10.5-20)}$$

UNSYMMETRICAL VERTICAL CURVE EQUATIONS (continued)

Figure 10.5G



TO PASS A SYMMETRICAL VERTICAL CURVE THROUGH A GIVEN POINT (P)

G_1 = Grade In, %

G_2 = Grade Out, %

A = Algebraic difference in grades, %

Z = Vertical curve correction at point "P", m

X = Distance from "P" to VPC, m

D = Distance from "P" to VPI, m

L = Length of vertical curve, m

Given: G_1, G_2, D

Find: Length of vertical curve

Solution:

1. Find algebraic difference in grades:

$$A = G_2 - G_1$$

2. Find vertical curve correction at Point P:

From Equation 10.5-8, (*x* measured from VPC):

$$Z = X^2\left(\frac{G_2 - G_1}{200L}\right)$$

3. From inspection of the above diagram:

$$X + D = L/2 \text{ or } L = 2(X + D) \qquad \text{(Equation 10.5-21)}$$

By substituting 2(X+D) for L, and A for (G_2-G_1) into Equation 10.5-8. Yields:

$$AX^2 + (-400Z)X + (-400DZ) = 0 \qquad \text{(Equation 10.5-22)}$$

VERTICAL CURVE COMPUTATIONS

Figure 10.5H

4. Solve for "X" given the quadratic equation:

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{400Z \pm \sqrt{160\,000Z^2 + 1600ADZ}}{2A} \qquad \text{(Equation 10.5-23)}$$

Solving for X will result in two answers. If both answers are positive, there are two solutions. If one answer is negative, it can be eliminated and only one solution exists.

5. Substitute X and D into Equation 10.5-21 and solve for L:

Note: Two positive X values, will result in two L solutions. Desirably, the longer vertical curve solution should be used provided it meets the stopping sight distance criteria (based on the selected design speed and algebraic difference in grades, see Figures 10.5A and 10.5C).

VERTICAL CURVE COMPUTATIONS
(continued)

Figure 10.5H

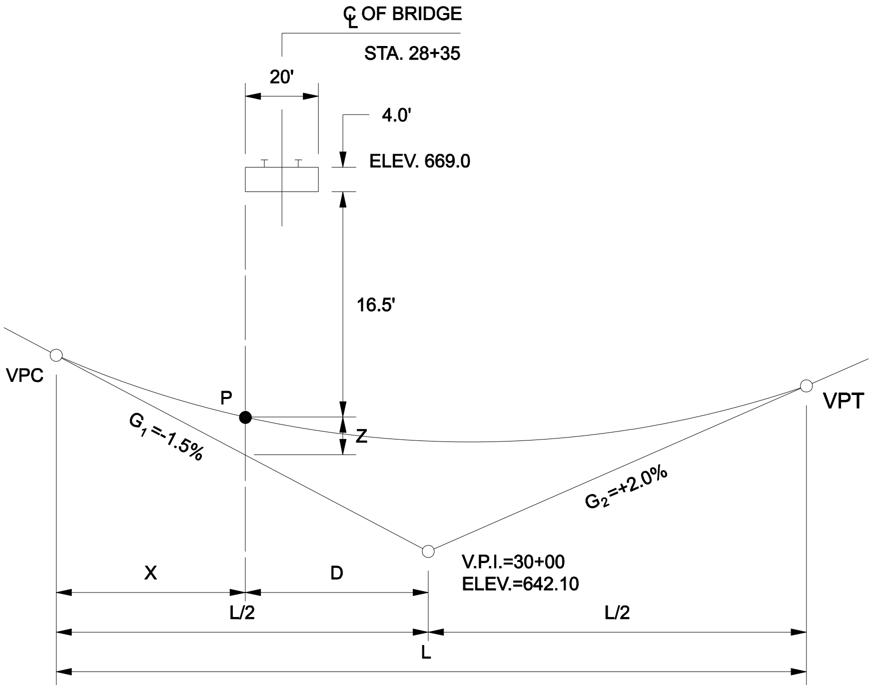
Example 10.5-2 **(US Customary)**

Given: Design Speed = 55 mph
G_1 = -1.5%
G_2 = +2.0%
A = 3.5%
VPI Station = 30+00
VPI Elevation = 642.10

Problem: At Station 28+35, the new highway must pass under the center of an existing railroad which is at elevation 669.0’ at the highway centerline. The railroad bridge that will be constructed over the highway will be 4’ in depth, 20’ in width and at right angles to the highway. What would be the length of the symmetrical vertical curve that would provide a 16.5’ clearance under the railroad bridge?

Solution:

1. Sketch the problem with known information labeled.



VERTICAL CURVE COMPUTATIONS
(Example 10.5-2)

Figure 10.5I

Example 10.5-2 (US Customary continued)

2. Determine the station where the minimum 16.5' vertical clearance will occur (Point P):

From inspection of the sketch, the critical location is on the left side of the railroad bridge. The critical station is:

$$STA.\ P = BRIDGE\ CENTERLINE\ STATION - \tfrac{1}{2}(BRIDGE\ WIDTH)$$

$$STA.\ P = STA. 28+35 - \frac{20}{2}$$

$$STA.\ P = STA. 28+25$$

3. Determine the elevation of Point P:

$$ELEV. P = ELEV. TOP\ RAILROD\ BRIDGE - BRIDGE\ DEPTH - CLEARANCE$$

$$ELEV. P = 669.00' - 4.00' - 16.50'$$

$$ELEV. P = 648.50'$$

4. Determine distance, D, from Point P to VPI:

$$D = STA.\ VPI - STA.\ P$$
$$= (30+00) - (28+25)$$
$$= 175'$$

5. Determine the tangent elevation at Point P:

$$ELEV.\ TANGENT\ AT\ P = ELEV.VPI - G_1\left(\frac{D}{100}\right)$$
$$= 642.10 - (-1.5)\left(\frac{175}{100}\right)$$
$$= 644.73'$$

6. Determine the vertical curve correction (Z) at Point P:

$$Z = ELEV.ON\ CURVE - ELEV.\ OF\ TANGENT$$
$$= 648.50' – 644.73'$$
$$= 3.77'$$

VERTICAL CURVE COMPUTATIONS
(Example 10.5-2)
(continued)
Figure 10.5I

Example 10.5-2 (US Customary continued)

7. Solve for X using Equation 10.5-23:

$$X = \frac{400Z \pm \sqrt{160\,000Z^2 + 1600ADZ}}{2A}$$

$$X = \frac{400(3.77) \pm \sqrt{160\,000(3.77)^2 + 1600(3.5)(175)(3.77)}}{2(3.5)}$$

$$X = 564.44' \qquad AND \qquad X = -133.58'\ (Disregard)$$

8. Using Equation 10.5-21, solve for L:

$$L = 2(X + D)$$

$$L = 2(564.44 + 175)$$

$$L = 1478.88'$$

9. Determine if the solution meets the desirable stopping sight distance for the 90 km/h design speed. From Figure 10.5C, the desirable K-value:

$$K = 96$$

The algebraic difference in grades:

$$A = G_2 - G_1 = (+2.0) - (-1.5) = 3.5$$

From Equation 10.5-5, the minimum length of vertical curve which meets the desirable stopping sight distance:

$$\begin{aligned} L_{MIN} &= KA \\ &= (96)3.5 \\ &= 336' \end{aligned}$$

L = 1478.88’ will provide the desirable stopping sight distance.

(Note: This would be rounded up to 1500’ for recording on the plans.)

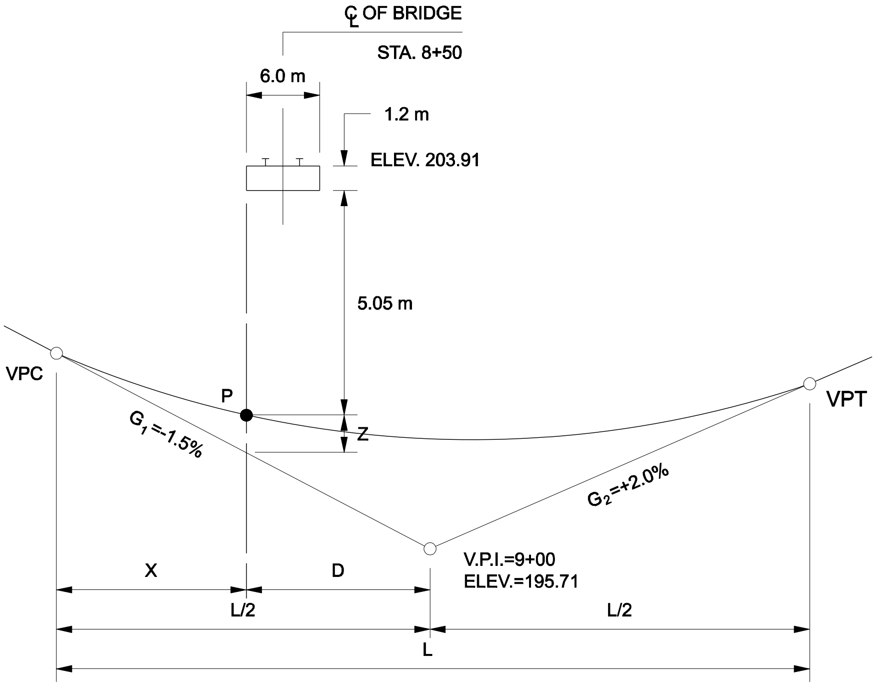
Example 10.5-2 (Metric)

Given:
Design Speed = 90 km/h
G_1 = -1.5%
G_2 = +2.0%
A = 3.5%
VPI Station = 9+00
VPI Elevation = 195.71

Problem: At Station 8+50, the new highway must pass under the center of an existing railroad which is at elevation 203.91 m at the highway centerline. The railroad bridge that will be constructed over the highway will be 1.2 m in depth, 6.0 m in width and at right angles to the highway. What would be the length of the symmetrical vertical curve that would provide a 5.05 m clearance under the railroad bridge?

Solution:

1. Sketch the problem with known information labeled.



VERTICAL CURVE COMPUTATIONS
(Example 10.5-2)

Figure 10.5I

Example 10.5-2 (Metric continued)

2. Determine the station where the minimum 5.05 m vertical clearance will occur (Point P):

   From inspection of the sketch, the critical location is on the left side of the railroad bridge. The critical station is:

$$STA.\ P = BRIDGE\ CENTERLINE\ STATION - {}^{1}\!/_{2}(BRIDGE\ WIDTH)$$
$$STA.\ P = STA. 8+50 - {}^{1}\!/_{2}(6\ m)$$
$$STA.\ P = STA. 8+47$$

3. Determine the elevation of Point P:

$$ELEV. P = ELEV. TOP\ RAILROD\ BRIDGE - BRIDGE\ DEPTH - CLEARANCE$$
$$ELEV. P = 203.91\ m - 1.20\ m - 5.05\ m$$
$$ELEV. P = 197.66\ m$$

4. Determine distance, D, from Point P to VPI:

$$\begin{aligned} D &= STA.\ VPI - STA.\ P \\ &= (9+00) - (8+47) \\ &= 53\ m \end{aligned}$$

5. Determine the tangent elevation at Point P:

$$\begin{aligned} ELEV.\ TANGENT\ AT\ P &= ELEV. VPI - G_1\left(\frac{D}{100}\right) \\ &= 195.71\ m - (-1.5)\left(\frac{53}{100}\right) \\ &= 196.51\ m \end{aligned}$$

6. Determine the vertical curve correction (Z) at Point P:

$$\begin{aligned} Z &= ELEV. ON\ CURVE - ELEV.\ OF\ TANGENT \\ &= 197.66 - 196.51 \\ &= 1.15\ m \end{aligned}$$

VERTICAL CURVE COMPUTATIONS
(Example 10.5-2)
(continued)

Figure 10.5I

Example 10.5-2 (Metric continued)

7. Solve for X using Equation 10.5-23:

$$X = \frac{400Z \pm \sqrt{160\,000Z^2 + 1600\,ADZ}}{2A}$$

$$X = \frac{400(1.15) \pm \sqrt{160\,000(1.15)^2 + 1600\,(3.5)(53)(1.15)}}{2(3.5)}$$

$$X = 171.94\ m \qquad AND \qquad X = -40.51\,m\ (Disregard)$$

8. Using Equation 10.5-21, solve for L:

$$L = 2(X + D)$$
$$L = 2(171.94 + 53)$$
$$L = 449.88\,m$$

9. Determine if the solution meets the desirable stopping sight distance for the 90 km/h design speed. From Figure 10.5C, the desirable K-value:

$$K = 41$$

The algebraic difference in grades:

$$A = G_2 - G_1 = (+2.0) - (-1.5) = 3.5$$

From Equation 10.5-5, the minimum length of vertical curve which meets the desirable stopping sight distance:

$$\begin{aligned} L_{MIN} &= KA \\ &= (41)3.5 \\ &= 143.5\,m \end{aligned}$$

L = 449.88 m will provide the desirable stopping sight distance.

(Note: This would be rounded up to 460 meters for recording on the plans.)

10.6 VERTICAL CLEARANCES

Figure 10.6A summarizes the minimum vertical clearances for various highway classifications and conditions.

Type	Minimum Clearance (m)
Freeway Under	17.0’ (5.20 m) (1)
Arterial Under	17.0’ (5.20 m) (1)
Collector Under	16.5’ (5.05 m) (1)
Roadway under Pedestrian Bridge	(2)
Roadway under Traffic Signal	17.0’ (5.35 m) (1) (3)
Railroad under Roadway (Typical)	23.29’ (7.10 m) (4)
Roadway under Sign Truss	17.0’ (5.35 m) (1)

Notes:

1. *Value allows 0.50’ (150 mm) for future resurfacing.*
2. *The vertical clearance should be the same as for the roadway under a highway bridge for that type of facility.*
3. *Distance is measured from roadway surface to the bottom of signal at the bottom of the back plate.*
4. *Contact the Utilities Section and the Bridge Bureau to determine the allowable railroad vertical clearance.*

MINIMUM VERTICAL CLEARANCES

Figure 10.6A

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Eleven
CROSS SECTION ELEMENTS

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Chapter Eleven
CROSS SECTION ELEMENTS

The highway cross section establishes the basic operational and safety features for the facility, and has a significant impact on the project cost, especially for earthwork. Most of the MDT design criteria for cross sections is contained in two chapters of the *Manual*. Chapter Twelve "Geometric Design Tables" provides numerical criteria for various cross section elements for Department projects. Chapter Eleven provides additional guidance which should be considered in the design of these cross section elements, including the roadway section, two-way left-turn lanes, curbs, sidewalks, medians, side slopes and right-of-way design. In addition, the independent design criteria of municipalities and local governments must be considered for urban projects. Chapter Eleven concludes with several typical sections for various highway types.

11.1 DEFINITIONS/NOMENCLATURE

Figures 11.1A, 11.1B and 11.1C provide the basic nomenclature for cross section elements for Interstates, rural highways and urban streets. The following definitions apply to the highway cross section:

1. Auxiliary Lane. The portion of the roadway adjoining the through traveled way for purposes supplementary to through traffic movement including parking, speed change, turning, storage for turning, weaving or truck climbing.

2. Back Slope. The side slope created by the connection of the ditch bottom, upward and outward, to the natural ground (often referred to as the cut slope).

3. Barrier Curb. A longitudinal element, typically concrete, placed at the roadway edge for delineation, to control drainage, to control access, etc. Barrier curbs may range in height between 6”(150 mm) and 12”(300 mm) with a face steeper than 1 horizontal to 3 vertical. This term has been replaced in AASHTO with the term “vertical curb”.

4. Buffer. Where used, the area or strip, also known as a boulevard, between the roadway and a sidewalk.

5. Cross Slope. The slope in the cross section view of the travel lanes, expressed as a percent based on the change in vertical compared to the change in horizontal.

6. Depressed Median. A median that is lower in elevation than the traveled way and designed to carry a certain portion of the roadway runoff.

7. Fill Slopes. Slopes extending outward and downward from the hinge point to intersect the natural ground line.

8. Flush Median. A paved median which is level with the surface of the adjacent roadway pavement.

9. Hinge Point (Freeways). The point from which the fill height and depth of cut are determined. For fills, the point is located at the intersection of the inslope extension and the fill slope. For cuts, the hinge point is located at the toe of the back slope.

10. Hinge Point (Non-Freeways). The point from which the fill height and depth of cut are determined. For fills, the point is located at the intersection of the subgrade cross slope and the fill slope for tangent sections and the low side of superelevated sections. On the high side of superelevated sections, the point is located on the fill slope at a distance from the centerline equal to the distance from the centerline to the hinge point on the tangent section. For cuts, the hinge point is located at the toe of the back slope.

11. Inslope. The side slope in a cut section created by connecting the subgrade shoulder to the ditch bottom, downward and outward.

12. Median. The portion of a divided highway separating the two traveled ways for traffic in opposite directions. The median width includes both inside shoulders.

13. Median Slope. The slope in the cross section view of a depressed median beyond the surfacing inslope, expressed as a ratio of the change in horizontal to the change in vertical.

14. Mountable Curb. A longitudinal element, typically concrete, placed at the roadway edge for delineation, to control drainage, to control access, etc. Mountable curbs typically have a height of 6”(150 mm) or less with a face no steeper than 1 horizontal to 3 vertical. This term has been replaced in AASHTO with the term “sloped curb”.

15. Paved Walkway. That portion of the highway section constructed adjacent to facilities without curb and gutter, with a minimum of 3’ (1 m) buffer area, for use by pedestrians.

16. Raised Median. A median which contains a raised portion or island within its limits.

17. Roadside. A general term denoting the area adjoining the outer edge of the roadway.

18. Roadway Section. The combination of the traveled way, both shoulders and any auxiliary lanes on the highway mainline.

19. Shelf. On curbed urban facilities without sidewalks, the relatively flat area (2% slope) located between the back of the curb and the break for the fill slope or back slope.

20. Shoulder. The portion of the roadway contiguous to the traveled way for the accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses. On sections with curb and gutter, the shoulder extends to the face of the curb.

21. Shoulder Slope. The slope in the cross section view of the shoulders, expressed as a percent.

22. Shoulder Width. The width of the shoulder measured from the edge of the traveled way to the intersection of the shoulder slope and surfacing inslope planes. On curb and gutter sections, the width of the shoulder is measured from the edge of the traveled way to a point 0.5’ (0.15 m) in front of the back of curb.

23. Sidewalk. That portion of the highway section constructed for the use of pedestrians used in combination with curb and gutter.

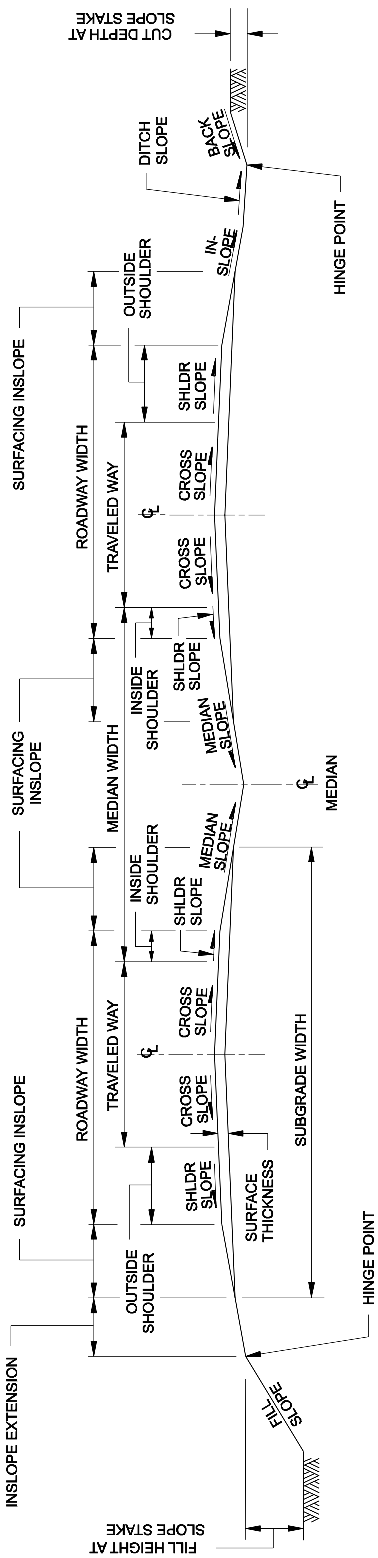
24. Slope Offset. On curbed facilities with sidewalks, the area between the back of the sidewalk and the break for the fill slope or back slope.

25. Surfacing Inslope. The slope extending from the edge of shoulder to the subgrade shoulder point, expressed as a ratio of the change in horizontal to the change in vertical.

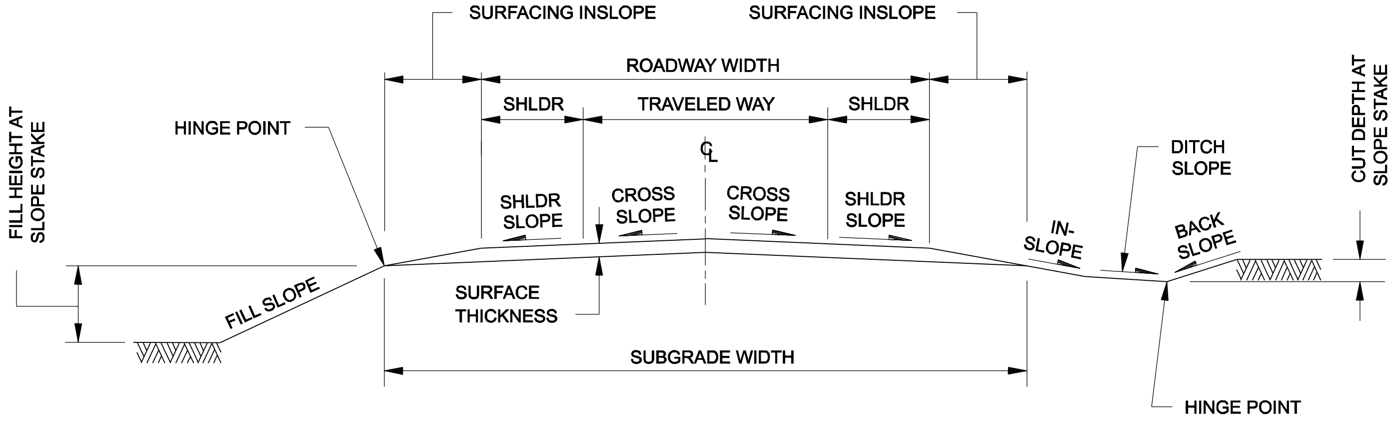
26. Toe of Slope. The intersection of the fill slope with the natural ground or the inslope with the ditch bottom.

27. Top of (Cut) Slope. The intersection of the back slope with the natural ground.

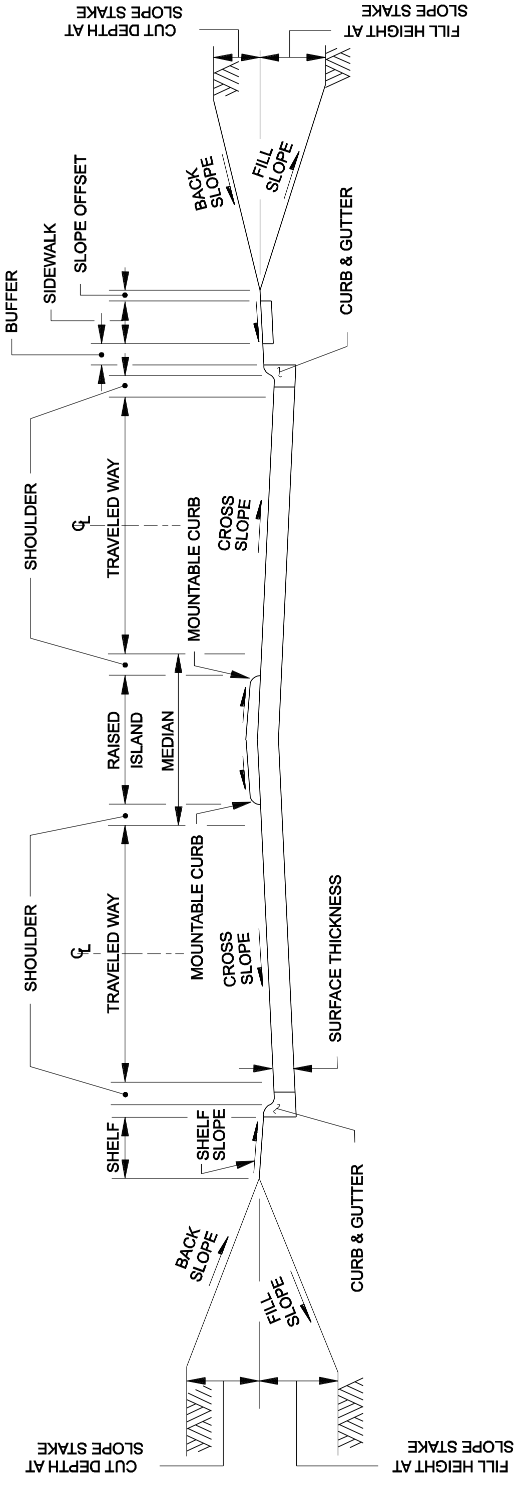
28. Traveled Way. The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.



FREEWAY NOMENCLATURE
Figure 11.1A



RURAL HIGHWAY NOMENCLATURE
(Non-Freeways)
Figure 11.1B



RURAL URBAN STREET NOMENCLATURE
Figure 11.1C

11.2 ROADWAY SECTION

11.2.1 Travel Lanes

11.2.1.1 Width

On State highways, travel lane widths are typically 12’ (3.6 m) for rural facilities. Lane widths on urban facilities may vary from 10’ (3.1 m) to 12’ (3.6m). On non-State highways, travel lane widths can vary between 10’ (3.0 m) and 12’ (3.6 m), depending upon traffic volumes, functional class and design speed. The tables in Chapter Twelve provide specific criteria for travel lane widths.

11.2.1.2 Surface Type

The following will apply to selecting the surface type for the traveled way:

1. Rural Arterials. All rural arterials will be paved.

2. Rural Collectors (State Highways). Normally, these will be paved. However, existing gravel roads may remain gravel. This decision will normally be made during the Preliminary Field Review.

3. Urban State Facilities. These will be paved.

4. Non-State Facilities. On projects where State and/or Federal funds are used on non-State facilities, the pavement surface type will normally be determined at the PFR.

11.2.1.3 Cross Slopes

Surface cross slopes are required for proper drainage of travel lanes on tangent sections. For tangent roadway sections, all pavement sections, with the exception of those having depressed medians, are crowned at the centerline of the roadway section. Sections having depressed medians are crowned at the centerlines of the individual traveled ways. The following will apply:

1. Paved (Uncurbed). The travel lane cross slope is typically 2%.

2. Curbed. On curbed facilities, the cross slope is typically 2%. Exceptions are allowed for any cross slope between 1% and 4%, depending on site conditions.

3. Gravel. The travel lane cross slope is typically 3%. At bridge ends the gravel lane cross slope must transition to match the bridge cross slopes which is generally 2%.

11.2.2 Shoulders

11.2.2.1 Functions

Shoulders serve many functions, and the wider the shoulder, the greater the benefits. Shoulder functions include:

1. providing structural support for the traveled way which prevents, for example, pavement edge dropoffs;
2. increasing highway capacity;
3. encouraging uniform travel speeds;
4. providing space for emergency and discretionary stops;
5. improving roadside safety by providing more recovery area for run-off-the-road vehicles;
6. providing a sense of openness;
7. improving sight distance around horizontal curves;
8. enhancing highway aesthetics;
9. facilitating maintenance operations;
10. providing additional lateral clearance to roadside appurtenances (e.g., guardrail, traffic signals);
11. facilitating pavement drainage;
12. providing space for pedestrian and bicycle use; and
13. providing space for bus stops.

11.2.2.2 Widths

Shoulder widths will vary according to functional classification, traffic volumes and urban/rural location. The tables in Chapter Twelve present the shoulder width criteria for the various conditions. In addition, consider the following:

1. Roadside Barriers. For roadway widths less than 28’ (8.4 m), shoulder widths should be increased to 2’ (0.6 m) when a roadside barrier is present. See Chapter Fourteen for more information on offsets to barriers.

2. Curb and Gutter. The minimum shoulder width adjacent to a curb is 2’ (0.6 m) measured from the edge of the traveled way to a point 0.5’ (0.15 m) from the back of curb.

3. Widening for Future Paving. For reconstruction and major widening projects provide 1.4’ (0.4 m) of finished top width on each side of the roadway - 2.8’ (0.8 m) total, in addition to what is required by the Route Segment Plan or Geometric Design Standards. This width is to accommodate a future 0.20’ (60 mm) overlay. If the additional width cannot be provided, include documentation in the PFR or Scope of Work Report.

11.2.2.3 Surface Type

The type of surfacing used for the shoulder will match that used for the traveled way. See Section 11.2.2.6 for the use of rumble strips on shoulders.

11.2.2.4 Shoulder Slopes

The normal slope of the shoulder depends primarily on the surface type of the roadway section. The following summarizes MDT practices:

1. Paved. Except as noted in #2, all paved shoulders will have the same slope as the adjacent (paved) traveled way, typically 2%.

2. Existing Roadways. Existing shoulder slopes on existing roadways may be variable. If the proposed pavement work is resurfacing, the existing slope may be retained. The decision to use the existing shoulder slope should be documented in the Scope of Work Report. If the proposed pavement work is full-depth reconstruction or major rehabilitation, the shoulder slope should match the cross slope of the traveled way, typically 2%.

3. Gravel. All gravel shoulders will have the same slope as the adjacent (gravel) traveled way, typically 3%.

11.2.2.5 Subgrade Slopes

The following will apply:

1. Tangent Sections. For tangent sections, the cross slope of the top of the subgrade will be the same as the cross slope of the paved surface.

2. Superelevated Sections. For superelevated sections, the cross slope of the top of subgrade will be the same as the cross slope of the paved surface from the subgrade shoulder (hinge point in fill sections) on the high side of the section to a point directly below the edge of the shoulder on the low side of the section. From this point to the subgrade shoulder on the low side, the subgrade cross slope will be 2%. This change in subgrade cross slope results in the subgrade shoulder at the inside of the superelevated section being the same distance from the centerline of the pavement as the subgrade shoulder of the tangent section. Maintaining a constant location of the subgrade shoulder on the low side of curves maintains the ditch offset distance, avoids depressions in the ditch grade, reduces surfacing material and aides in the staking of the subgrade.

3. Variable Surfacing Depths. Where adjoining typical sections have different surfacing depths, use a taper rate of 20:1 to transition between the subgrade widths. No transition is needed for the subgrade depth as the depth of surfacing will change abruptly.

See the typical section figures in Section 11.7 for an illustration of the subgrade slope on tangent and superelevated sections.

11.2.2.6 Rumble Strips

Guidelines/Location

Rumble strips on the shoulder can potentially prevent run-off-the-road accidents by alerting sleepy or inattentive drivers. However, other factors must be considered when using rumble strips, including:

1. use of the shoulder by bicyclists,

2. impact on pavement life,

3. impact on maintenance operations, and

4. initial construction costs.

The following summarizes MDT criteria for rumble strip guidelines and location on shoulders:

1. Interstates. Provide rumble strips on both the outside and inside shoulders of all Interstate projects unless there is a specific reason not to do so. The reason(s) should be documented in the Scope of Work Report. Typically, place the rumble strips 0.5’ (150 mm) outside of the shoulder stripe. At exit ramps, end the rumble strip 100’ (30 m) upstream of the ramp taper and begin again at the gore nose after the left shoulder stripe of the exit ramp. For entrance ramps, end the rumble strip at the gore nose and begin again at the end of the ramp taper.

2. Arterials. On arterials located within designated city or urban limits, the decision to install rumble strips will be determined on a case-by-case basis using engineering judgment. Guidelines for rumble strips on all other arterials are based on the shoulder width as follows:

    a. For shoulder widths equal to or greater than 4’ (1.2 m), provide rumble strips on the shoulders of all new construction, reconstruction and overlay arterial projects. Justification to not provide rumble strips will be based on corridor continuity, approach density, bicycle use and crash history. Document the decision and justification for not using rumble strips in the Scope of Work Report. Base the justification in part on corridor continuity, approach density, bicycle usage and crash history. Place the rumble strips 0.5’ (150 mm) from the shoulder stripe.

    b. For shoulder widths less than 4’ (1.2 m), do not use rumble strips. However, in cases where there is little bicycle usage and the incidence of run-off-the-road crashes is high, consider providing rumble strips. Document the decision and justification to use rumble strips in the Scope of Work Report.

    c. Where significant bicycle usage is documented or attested to by the District Administrator and the shoulder width is 4’ (1.2 m) or less, consider the following modifications:

        (1) The use of a 4”(100 mm) offset from the shoulder stripe.
        (2) The use of a 8”(200 mm) transverse rumble strip width.

3. Bridge Decks. Do not install rumble strips on bridge decks.

4. Approaches. Discontinue the use of rumble strips across the full width of all public and private approaches.

5. Turnouts. Continue the use of rumble strips along the full length of all turnouts, including tapers (e.g., mailbox turnouts, scenic and historic marker turnouts, chain-up turnouts).

6. Guardrail. Discontinue rumble strips on outside shoulders less than 6’ (1.8 m) wide if guardrail is in place or will be installed.

7. Installation. Install rumble strips on the right shoulder on an 60’ (18.3 m) cycle pattern consisting of a 48’ (14.6 m) rumble strip and a 12’ (3.7 m) gap. Eliminate the gap on the inside shoulder of multilane highways.

Design

For guidance on the configuration and design of rumble strips, see the *MDT Detailed Drawings.*

11.2.3 Auxiliary Lanes

Auxiliary lanes are any lanes beyond the basic through travel lanes, and they are intended for use by vehicular traffic for specific functions (e.g., two-way, left-turn lanes) TWLTL. The following will apply to the design of auxiliary lanes:

1. Width. With the exception of TWLTL, the width of an auxiliary lane is typically the same as that of the adjacent through lane. In rare cases, it may be justified to provide a narrower width (e.g., restricted right-of-way).

2. Shoulders. The designer should meet the following for shoulders adjacent to auxiliary lanes:

    a. On uncurbed facilities, the shoulder width adjacent to the auxiliary lane should be the same as the normal shoulder width for the approaching roadway. At a minimum, the width may be 4’ (1.2 m), assuming the roadway has a shoulder width equal to or greater than 4’ (1.2 m).

    b. On curbed facilities, the shoulder between the auxiliary lane and curb should be the same as that for the normal roadway section, typically 2’ (0.6 m). At a minimum, the shoulder may be eliminated.

3. Cross Slope. The cross slope for an auxiliary lane will typically be the same as the adjacent through lane, typically 2%.

11.2.4 Two-Way Left-Turn Lanes (TWLTL)

Two-way left-turn lanes (TWLTL) are a cost-effective method to accommodate a continuous left-turn demand and to reduce delay and accidents.

11.2.4.1 Guidelines

The Traffic Engineering Section will determine where a TWLTL is necessary. The following provides guidance for where the TWLTL should be considered:

1. General. The physical conditions under which a TWLTL should be considered include:
   a. areas with a high number of approaches per mile (km) (e.g., 50 approaches per mile or 30 approaches total per km on both sides);
   b. areas of high-density, commercial development; and/or
   c. areas with a relatively continuous demand for mid-block left turns but where specific approaches do not have a heavy left-turn demand;
2. Functional Class. Undivided 2-lane and 4-lane urban or suburban arterials are the most common candidates for the implementation of a TWLTL. Once the TWLTL is used, these are commonly referred to as 3-lane and 5-lane facilities, respectively.
3. Traffic Volumes. Traffic volumes are a significant factor in the consideration of a TWLTL. If mid-block access is significant, then a TWLTL will be advantageous under any traffic volume level. The following are general guidelines where a TWLTL would be desirable based on volume:
   a. On existing 2-lane roadways, a TWLTL is desirable for AADT's greater than 5,000 vehicles per day (design year AADT).
   b. On existing 4-lane highways, a TWLTL is desirable for AADT's up to 30,000 vehicles per day (design year AADT).
4. Section Length. In rural areas, the section length and the number of through lanes are important considerations. Based on experience for rural and suburban

applications, only consider TWLTL where there are four or more through lanes. The application of short sections of three-lane facilities in rural areas will be determined on a site-by-site basis.

5. Crash History. On high-volume urban or suburban arterials, traffic conflicts often result because of a significant number of mid-block left turns combined with significant opposing traffic volumes. This may lead to a disproportionate number of mid-block, rear-end, left-turn and/or sideswipe crashes. A TWLTL is likely to reduce these types of crashes. The designer should review and evaluate the available crash data to determine if unusually high numbers of these crashes are occurring.

11.2.4.2 Design Criteria

Lane Width

The typical width for a TWLTL is 14' (4.2 m). TWLTL widths may be less in urban areas. In general, the desirable width should be used for facilities with higher volumes, higher speeds and/or in industrial areas. Chapter Twelve presents specific TWLTL width criteria for specific functional classes.

Existing highways that require the installation of a TWLTL are often located in areas of restricted right-of-way, and conversion of the existing cross section may be difficult. To obtain the TWLTL width, the designer may have to consider several alternatives including:

1. acquiring additional right-of-way to expand the roadway width by the amount needed for the TWLTL,
2. eliminating existing buffer areas behind curbs and reconstructing curb and gutter and existing sidewalks,
3. eliminating existing parking lanes,
4. eliminating or reducing the width of existing shoulders and ditches,
5. reducing the width of existing through lanes, and/or
6. reducing the number of existing through lanes.

The designer will have to seriously evaluate the trade-offs between the benefits of the TWLTL and the negative impacts of eliminating or reducing the width of the existing cross section elements. This may involve a capacity analysis or an in-depth evaluation of the existing accident history.

Intersection Treatment

At all intersections with public roads, the TWLTL must either be terminated in advance of the intersection to allow the development of an exclusive left-turn lane or be extended up to the intersection. Where the TWLTL is extended up to the intersection, the pavement markings will switch from two opposing left-turn arrows to one left-turn arrow only, where justified by traffic volumes. When determining the intersection treatment, consider the following:

1. Signals. At signalized intersections, the TWLTL should be terminated because these intersections will typically warrant an exclusive left-turn lane. At unsignalized intersections, the TWLTL may be extended through the intersection if an exclusive left-turn lane is not justified.

2. Turning Volumes. The left-turn demand into the intersecting road is a factor in determining the proper intersection treatment. As general guidance, if the minimum storage length will govern, it will probably be preferable to extend the TWLTL up to the intersection (i.e., provide no exclusive left-turn lane). See Chapter Twenty-eight of the *Traffic Engineering Manual* for information on the design of exclusive left-turn lanes.

3. Length of TWLTL. The TWLTL should have sufficient length to operate properly. A TWLTL can be interrupted by the need to provide specific left-turn treatments at public intersections and high-volume approaches. This may still allow room to accommodate mid-block access between these left-turn treatments.

   In rural areas, the overall length must be given serious review. On two-lane roadway, a TWLTL may encourage inappropriate passing when carried for extensive distances.

4. Operational/Safety Factors. Extending the TWLTL up to an intersection could result in operational or safety problems. Some drivers may, for example, pass through the intersection in the TWLTL and turn left just beyond the intersection into an approach which is very close to the intersection (e.g., within 30’ (10 m)). If operational or safety problems are known or anticipated at an intersection, it may be preferable to remove the TWLTL prior to the intersection (i.e., provide an exclusive left-turn lane).

11.2.5 Parking Lanes (On-Street Parking)

11.2.5.1 Guidelines

Adjacent land use may create a demand for on-street parking along an urban street. Parking lanes provide convenient access for motorists to businesses and residences. However, on-street parking reduces capacity, impedes traffic flow and increases the crash potential. It may also produce undesirable traffic operations.

The decision to retain existing on-street parking or to introduce on-street parking will be based on a case-by-case assessment in cooperation with the local community. Evaluate the following factors:

1. prior accident experience or potential safety concerns;
2. impacts on the capacity of the facility;
3. current or predicted demand for parking;
4. actual needs versus existing number of spaces;
5. alternative parking options (e.g., off-street parking);
6. input from local businesses;
7. impacts on right-of-way;
8. impacts on bicyclists and pedestrians;
9. accessibility for disabled individuals;
10. construction costs; and
11. projected traffic volumes.

If parking is restricted, the criteria in Section 18.2.8 in Part III of the *Traffic Engineering Manual* will apply.

11.2.5.2 Types

The two basic types of on-street parking are parallel and angle parking. Parallel parking is the preferred arrangement when street space is limited and traffic capacity is a major factor. Angle parking provides more spaces per linear foot (meter) than parallel parking, but a greater cross street width is necessary for its design. The total entrance and exit time for parallel parking exceeds that required for angle parking. Parallel parking also requires a vehicle to stop in the travel lane and await an opportunity to back into the parking space. However, angle parking requires the vehicle to back into the lane of travel when sight distance may be restricted by adjacent parked vehicles and where this maneuver may surprise an approaching motorist.

The following summarizes MDT practice on the selection of parking lane type:

1. General. Parallel parking is preferred to angle parking.

2. Existing Angle Parking. The order of preference for treating existing angle parking is:

    a. eliminate,
    b. convert to parallel parking,
    c. change the angle, or
    d. leave as is.

    The Department will consult with the local community before selecting an option.

    A local authority may by ordinance permit angle parking on a roadway, except that angle parking will not be permitted on any Federal-aid or State highway unless the Department determines that the roadway is of sufficient width to permit angle parking without interfering with the free movement of traffic.

3. New Parking. Where on-street parking will be introduced, only parallel parking will be acceptable.

11.2.5.3 Design

The following summarizes MDT design criteria for on-street parking:

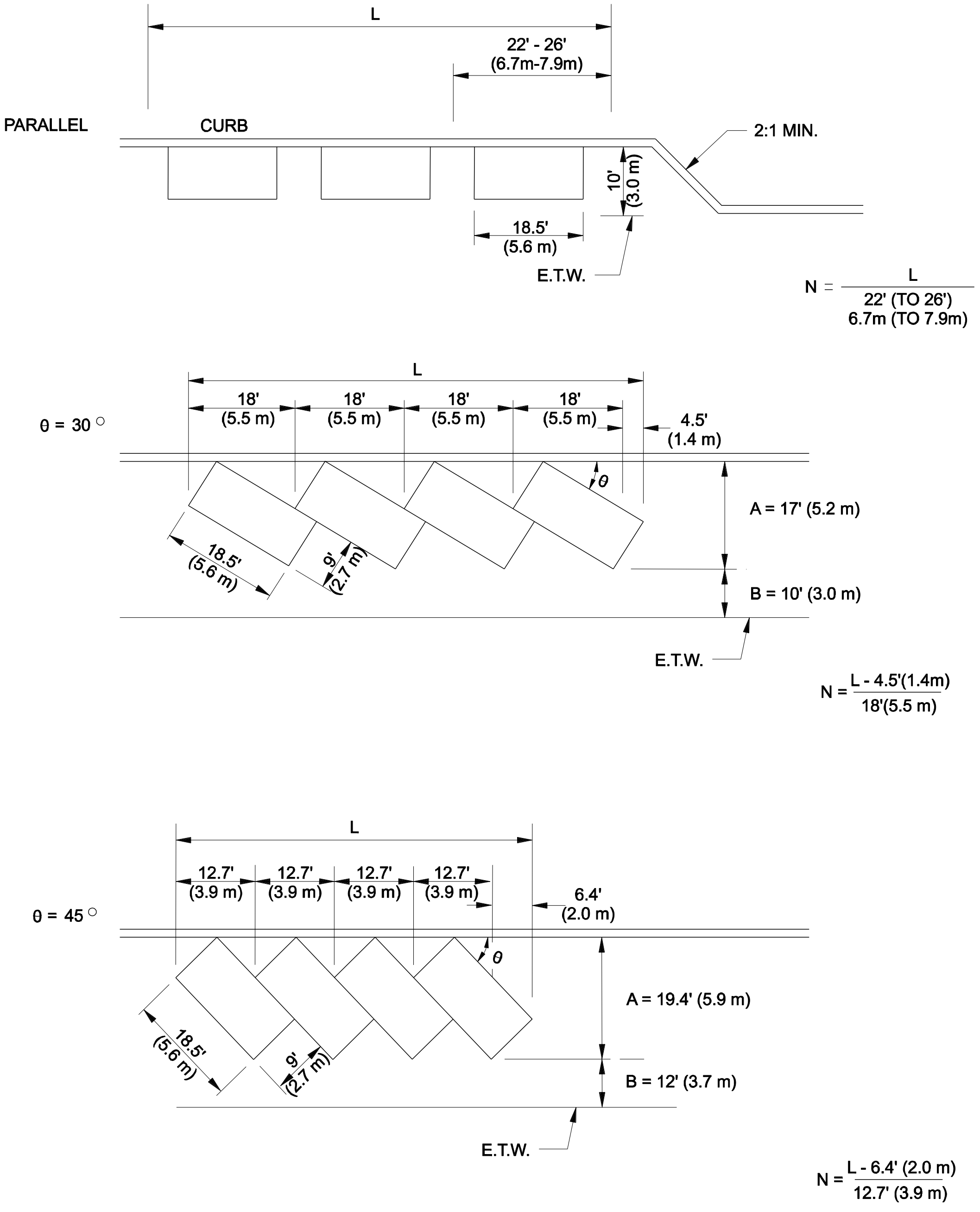
1. Stall Width. All parallel parking stalls will be 10’ (3.0 m) wide. For parallel parking, stall widths are measured from the edge of traveled way to the face of curb. For angle parking, stall widths will generally be 9’ (2.7 m).

2. Stall Layout. Figure 11.2A provides the layout criteria for parking stalls for various configurations. The figure also indicates the number of stalls which can be provided for each parking configuration for a given curb length. For angle parking, desirably, the roadway width allocated to parking will be the sum of "A" and "B" as shown in Figure 11.2A exclusive of the through travel lane. Distance "B" is that width needed by a parked vehicle to back onto the street when exiting the stall. However, in restricted areas a portion of the "B" dimension may be required for the through travel lane, thereby reducing the roadway width allocated to angle parking.

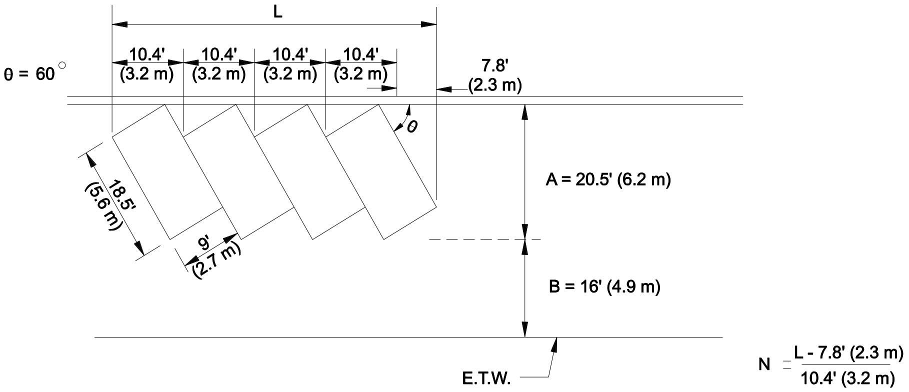
3. Cross Slope. The cross slope of the parking lane should match that of the adjacent through travel lane, typically 2%. However, exceptions are allowed for

cross slopes between 1% and 4% to fit actual field conditions. The slope of the parking lane may not be flatter than that of the adjacent through lane.

4. Accessibility for Disabled Individuals. Where on-street is permitted, a certain number of parking spaces must be provided for accessibility for the disabled, and their design must meet the accessibility design criteria. See Section 18.1 for specific information.



CURB PARKING CONFIGURATIONS
Figure 11.2A



Key: L = given curb length with parking spaces

N = number of parking spaces over distance L

A = required distance between face of curb and back of stall, assuming that bumper of parked car does not extend beyond curb face. In restricted locations, it can be assumed that the car will move forward until its tire contacts the curb. Ensure adequate sidewalk width is available for ADA requirements. In these cases, the "A" distances in the figure may be reduced as follows:

Angle of Parking	Reduction in "A"
30°	1.3’ (0.4 m)
45°	2.0’ (0.6 m)
60°	2.3’ (0.7 m)

B = minimum clear distance needed for a parked vehicle to back out of stall while just clearing adjacent parking vehicles.

E.T.W. = Edge of Traveled Way

CURB PARKING CONFIGURATIONS

(Continued)

Figure 11.2A

5. Intersection Curb Radii. Parking may need to be restricted a certain distance from intersections to allow the design vehicle (typically a WB-67(WB-20 metric)) to properly negotiate the right turn. See Section 28.3 of the *Traffic Engineering Manual* for specific information.

6. Location. For most sites, conduct a parking occupancy turnover study and a site distance evaluation. In addition to State and local regulations, when locating parking spaces consider the following:

    a. Prohibit parking within 20’ (6 m) of any crosswalk.

    b. Prohibit parking at least 10’ (3 m) from the beginning of the curb radius at mid-block approaches.

    c. Prohibit parking within 50’ (15 m) of the nearest rail of a railroad/highway crossing.

    d. Prohibit parking from areas designated by local traffic and enforcement regulations (e.g., near school zones, fire hydrants). See local ordinances for additional information on parking restrictions.

    e. Prohibit parking near bus stops (see Chapter Eighteen).

    f. Prohibit parking within 30’ (9 m) on the approach leg to any intersection with a flashing beacon, stop sign or traffic signal.

    g. Prohibit parking on bridges or within a highway tunnel.

    h. Eliminate parking across from a T- intersection.

11.2.5.4 Off-Street Parking

For design guidance of off-street parking, see Section 31.4.2 of the *Traffic Engineering Manual*.

11.2.6 Curbs and Curbed Sections

11.2.6.1 Usage

Curbs are often used on urban facilities to control drainage, delineate the pavement edge, channelize vehicular movements, control access, limit right-of-way needs, provide separation between vehicles and pedestrians and present an attractive appearance. Curbs are not used in rural areas. For urban and suburban areas, selecting a curbed section or uncurbed section depends upon many variables, and the decision will be made on a case-by-case basis. Evaluate the following factors to determine whether or not a curbed section is preferred:

1. local preference;
2. drainage impacts;
3. construction costs;
4. impacts on maintenance operations;
5. roadside safety impacts (see Chapter Fourteen);
6. sidewalk guidelines (see Section 11.2.7);
7. control of access to abutting properties;
8. impacts on traffic operations (e.g., vehicular channelization at intersections);
9. right-of-way restrictions; and
10. vehicular speeds (e.g., the use curbs is not preferred where V>45 mph (V>70 km/h)).

11.2.6.2 Curb Types/Details

Where a curbed section is required, the Department uses concrete curb exclusively. Typically, the curb will be a mountable sloped shape. This applies to both outside curbs and curbs used for raised medians. See the *MDT Detailed Drawings* for specific details of those curbs used by the Department.

11.2.6.3 Accessibility for the Disabled

Curbs must be designed with curb ramps at all pedestrian crosswalks to provide adequate access for the safe and convenient movement of physically disabled individuals. See Chapter Eighteen for details on the design and location of curb ramps.

11.2.7 Sidewalks

11.2.7.1 Guidelines

The following guidance will help determine the need for sidewalks in the project design:

1. Sidewalks Currently Exist (Roadway or Bridge). Where sidewalks currently exist along a roadway, the sidewalk will normally be replaced. If a bridge with an

existing sidewalk is replaced or rehabilitated, the sidewalk will normally be replaced.

2. Sidewalks Currently Do Not Exist (Roadway). The need for sidewalks will be determined on a case-by-case basis in cooperation with the local community. In general, the designer should consider providing sidewalks along any roadway where pedestrians normally move or would be expected to move if they had a sidewalk available (i.e., a latent demand exists). In addition, sidewalks may be required at specific sites even if they are not needed along the entire length of the roadway. These include points of community development (e.g., schools), local businesses, shopping centers and industrial plants that result in pedestrian concentrations along the highway.

   If curb and gutter are included in the roadway section, the need for sidewalks should be evaluated. This evaluation is especially critical in developing transition areas between rural and urban areas. The decision and supporting rationale should be documented.

3. Bridge Without Sidewalk/Roadway With Sidewalk. If a bridge without a sidewalk will be replaced or rehabilitated and if existing sidewalks approach the bridge, a sidewalk will normally be included in the bridge project. Even if not currently on the approaching roadway, sidewalks may still be necessary on the bridge if the approach roadway is a candidate for future sidewalks according to the discussion in Comment # 2.

   As a more general statement of MDT policy, bridge projects within urban areas will have a sidewalk where pedestrians are legally allowed, unless there is a compelling reason not to provide a sidewalk. In addition, bridges at interchanges near urban areas should normally include sidewalks to accommodate the commercial development that typically occurs in the immediate vicinity of interchanges.

4. Sidewalks Currently Do Not Exist (Underpasses). An underpass may be within the limits of a project. If the approach roadway will have sidewalks, these will be provided through the underpass, unless this would involve unreasonable costs to relocate the bridge substructure.

   A bridge reconstruction project may involve major work on or the replacement of the bridge substructure. If the bridge passes over a roadway, the bridge should allow space for the future addition of sidewalks through the underpass based on the eventual need for sidewalks on the roadway approaching the underpass.

5. One Side vs. Two Sides. Sidewalk requirements for each side of the roadway or bridge will be evaluated individually; i.e., placing a sidewalk on each side will be based on the specific characteristics of that side.

6. Approval. For all projects in urban areas, the final decision on sidewalk requirements will be made by the Highways Engineer. This applies to the roadway, bridges and underpasses.

11.2.7.2 Sidewalk Design Criteria

In determining the sidewalk design, the designer should consider the following:

1. Typical Widths. The typical sidewalk width is 5' (1.6 m), as measured from the back of the curb. Also, carefully consider compatibility with local city and community criteria during design.

2. Appurtenances. The designer should also consider the impacts of roadside appurtenances within the sidewalk (e.g., fire hydrants, parking meters, utility poles, signs). These elements will reduce the effective width because they interfere with pedestrian activity. Preferably, place these appurtenances behind the sidewalk. If they are placed within the sidewalk, the sidewalk should have a minimum clear width of 3' (915 mm); desirably, a 5' (1500 mm) clear width will be available. The clear width will be measured from the edge of the appurtenance to the edge of the sidewalk. The 3' (915 mm) minimum is necessary to meet the disabled accessibility requirements (see Section 18.1).

3. Central Business District (CBD) Areas. The entire area between the curb and building is often fully used as a paved sidewalk. Check with local agencies for potential encroachments under sidewalks.

4. Cross Slope. The maximum cross slope on the sidewalk is 2% sloped towards the roadway.

5. Buffer Areas. If the available right-of-way is sufficient, buffer areas between the curb and sidewalk are desirable. The buffer area should be at least 2' (600 mm) wide to be effective and, if practical, wider.

6. Pavement Material. Sidewalks will be concrete.

7. Bridges. The Bridge Bureau is responsible for the dimensioning and structural design of all sidewalks on bridges.

11.2.7.3 Pedestrian Rails (on Bridges)

If a sidewalk is placed on a bridge, it may be warranted to provide the standard bridge rail to separate the vehicular traffic from pedestrians and then use a pedestrian rail on the outside edge of the sidewalk. Consider the need for a separate pedestrian rail on a case-by-case basis. Evaluate the following factors:

1. design speed;
2. pedestrian volumes;
3. traffic volumes;
4. accident history;
5. geometric impacts (e.g., sight distance);
6. practicality of providing proper end treatments;
7. construction costs; and
8. local preference.

If a bridge with a sidewalk is on a designated bike route or experiences heavy bicycle traffic, the railings, barriers, etc., must be a minimum of 4.5’ (1.4 m) high. In addition, barriers should have smooth rub rails at a 3.5’ (1.1 m) height. The Bridge Bureau will be responsible for the final decision on when to use a pedestrian rail in combination with the standard bridge rail. Due to the steepness of the roadway inslopes near the bridge ends we recommend that the pedestrian rail extend at least 25’ (7.5 m) beyond the end of the bridge. The need to extend the rail and the length of the extension should be determined at the Plan-in-Hand.

11.2.8 Paved Walkways

Paved walkways are typically constructed adjacent to facilities without curb and gutter, with a minimum 3’ (1 m) buffer area, for use by pedestrians. Paved walkways may be constructed in conjunction with a curb and gutter roadway section where the walkway is established for recreational use and is designed as part of the overall landscaping. Provide a buffer area of at least 3’ (1 m) wide between the walkway and the back of curb. The guidelines for paved walkways are the same as those for sidewalks (see Section 11.2.7.1). The following will apply to the design of paved walkways:

1. Typical Width. The minimum paved width is 6’ (2.0 m). A minimum 8’ (2.4 m) width is recommended if bicycle use is anticipated.

2. Appurtenances. Do not place appurtenances within a paved walkway.

3. Cross Slope. Slope the walkway at 2% to drain (i.e., it may be sloped in either direction as determined by field conditions).

4. Separation. The separation between the roadway and the paved walkway should be as wide as practical.

5. Pavement Material. Paved walkways will typically be bituminous.

6. Bridges. The paved walkway must be transitioned back to the bridge, unless a separate, adjacent bridge is provided. The Bridge Bureau is responsible for designing the bridge to accommodate the walkway across the bridge.

7. Bicycle Paths. Where walkways will be used as bicycle paths, see Section 18.2 and the *AASHTO Guide for the Development of Bicycle Facilities*.

11.3 MEDIANS

11.3.1 Functions

A median is defined as the portion of a divided highway separating the two traveled ways for traffic in opposing directions. The principal functions of a median are:

1. to provide separation from opposing traffic,
2. to prevent undesirable turning movements,
3. to provide an area for deceleration and storage of left-turning vehicles,
4. to provide an area for storage of vehicles for emergency stopping,
5. to facilitate drainage collection,
6. to provide a recovery area for run-off-the-road vehicles,
7. to provide an area for pedestrian refuge, and
8. to provide width for future lanes.

11.3.2 Median Types

Section 11.7 provides typical sections for various median types.

11.3.2.1 Flush Medians

Flush medians are often used on urban highways and streets. The typical width for a flush median ranges from 4' (1.2 m) to 16' (5.0 m). They are paved and striped for delineation. Flush medians are appropriate for traffic volumes less than 20,000 ADT and, under favorable conditions, can provide adequate service for traffic volumes up to 30,000 ADT.

To provide proper drainage, flush medians are typically crowned in the center with a cross slope of 2% in either direction.

One potential disadvantage of flush medians is that they do not effectively deter cross-median vehicular movements. If this is perceived as a problem, provide a raised median. See Section 11.3.2.2.

Two-way left-turn lanes (TWLTL) are also considered flush medians. Desirably, the roadway cross section with a flush median will allow ultimate development for a TWLTL in urban/suburban areas. Section 11.2.4 provides information on design details for a TWLTL.

11.3.2.2 Raised Medians

A median is defined as a raised median if it contains a raised portion within its limits. Raised medians may be used on urban and suburban highways and streets to control access and left turns. The use of raised medians is not recommended adjacent to high-speed lanes (V > 45mph(70 km/h)).

Advantages

When compared to flush medians, raised medians offer several advantages:

1. Mid-block left turns are controlled.
2. Left-turn channelization can be more effectively delineated.
3. A distinct location is available for traffic signs, signals and pedestrian refuge.
4. Limited physical separation is available.
5. Uncontrolled cross-traffic movements are prevented.
6. Reduce the potential for head-on collisions.

Disadvantages

The disadvantages of raised medians when compared to flush medians are:

1. Access for emergency vehicles (e.g., fire, ambulance) may be more difficult.
2. Prohibiting mid-block left turns may overload street intersections and may increase the number of U-turns. They also may impact other streets in the corridor.
3. They may need greater roadway widths to serve the same function (e.g., left-turn lanes at intersections) because of the raised island and offset between curb and travel lane.
4. Curbs may result in adverse vehicular behavior upon impact.
5. They are more expensive to construct and more difficult to maintain.
6. Prohibiting mid-block left-turns causes drivers to take alternative access routes to and from adjacent properties.

Design

If a raised median will be used, consider the following in the design of the median:

1. Curb Type. Mountable concrete curbs are used for raised medians.

2. Width. The width of a raised median is measured from the two inside edges of the traveled ways and, therefore, includes the median shoulders. The typical median width of 20’ (6.0 m) provides for:

    a. a 2’ (0.6 m) offset from the through lane edge to face of curb on each side of the raised median (median shoulder), and

    b. a 16’ (4.8 m) raised median from face to face of curb.

    The width of the median should be of sufficient width to allow for the development of a channelized left-turn lane. Where the raised median exceeds 16’ (4.8 m), the designer should center the opposing lanes about each other or, if practical, provide offset left-turn lanes. This will enhance the ability of a left-turning vehicle to see around the opposing left-turning vehicle.

    A 20’ (6.0 m) median is the minimum desirable width in which a left-turn lane can be developed with raised median. See Chapter 12 for absolute minimum dimensions. The 20’ (6.0 m) width will provide for:

    a. a 12’ (3.6 m) left-turn lane,

    b. a minimum 4’ (1.2 m) raised portion of the median, and

    c. a 2’ (0.6 m) offset between the opposing traveled way and the raised portion of the median.

3. Surfacing. The raised portion of the median is usually paved with concrete. Alternate treatments such as landscaping should be determined at or before the plan-in–hand.

4. Lighting. Where raised medians are used, the roadway must be lighted and the medians must be delineated.

Existing

Evaluate all existing raised medians within the project limits for their current appropriateness. The existing configuration of the raised median should be evaluated with its consistency to the existing geometric needs. This includes sight distance for the left-turn bays, storage lengths and turning paths for vehicles entering and exiting the roadway.

11.3.2.3 Depressed Medians

A depressed median is typically used on freeways and other divided rural arterials. Depressed medians typically have good drainage characteristics and, therefore, are preferred on major highways.

Depressed medians should be as wide as practical to allow for the addition of future travel lanes on the inside while maintaining a sufficient future median width. The minimum width is 36’ (11.0 m). This allows the development of a depressed median with 6:1 side slopes and a ditch with sufficient depth to accommodate the water runoff. The maximum width for a depressed median is approximately 75’ (23.0 m). Beyond this, the two roadways of the divided facility are typically placed on independent alignments.

The center longitudinal slope of a depressed median should be a minimum of 0.2%.

11.3.3 Median Openings

The evaluation for median openings in raised medians should be based on the type of intersecting facility and design considerations at the candidate site. These are discussed in the following sections.

11.3.3.1 Intersecting Facility

Median openings are provided on all divided highways with partial control of access or control by regulation provided that the openings are sufficiently spaced. Median openings are appropriate:

1. at most dedicated public streets (site specific),
2. for U-turn movements on long sections of a continuous raised median, or
3. at approaches serving major traffic generators.

Examples of major traffic generators include major shopping centers and special event facilities with several events per month. Small shopping plazas or single businesses are not considered major traffic generators.

11.3.3.2 Design Considerations

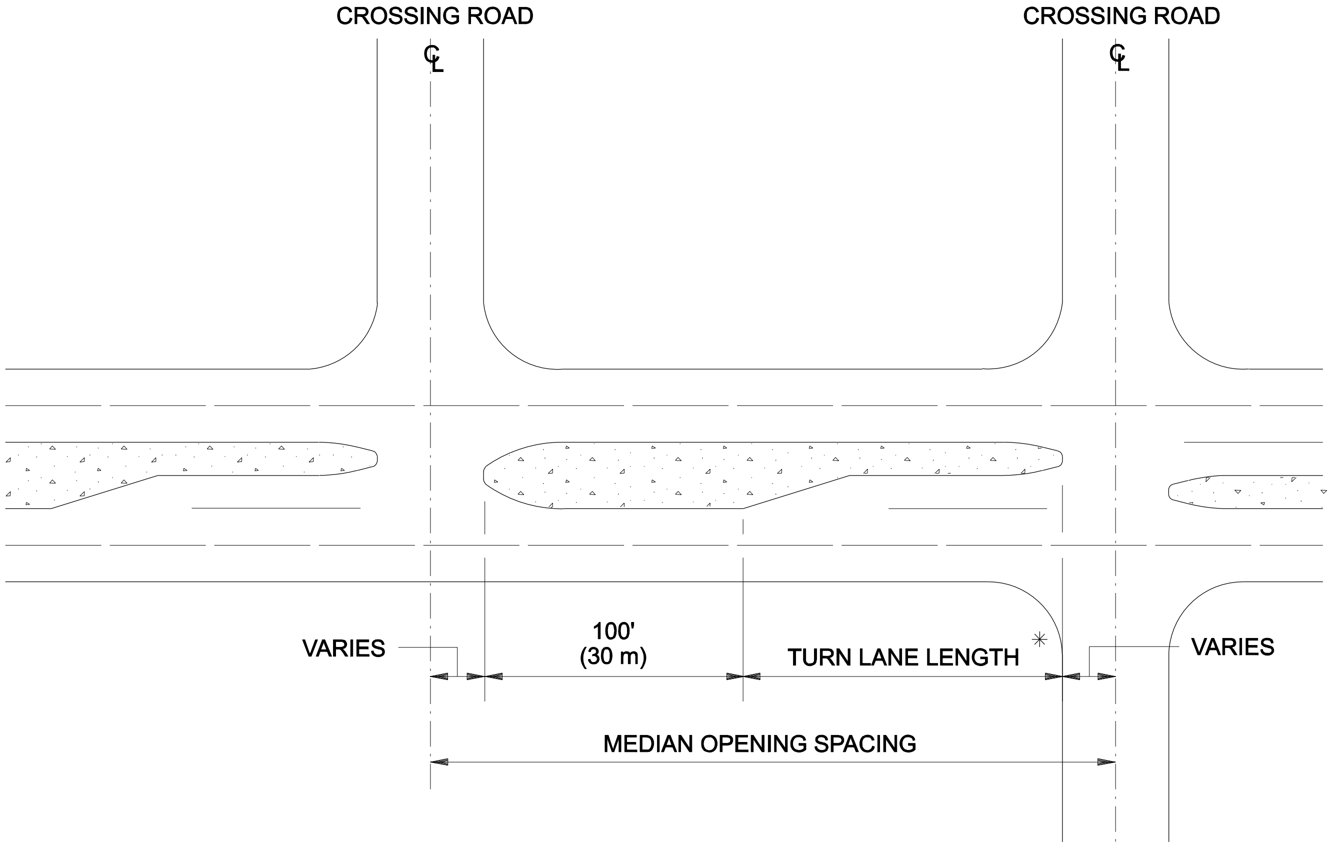
Median openings should be consistent with the following design considerations:

1. Signal Coordination. Median openings (both signalized and unsignalized) must not impair the traffic signal coordination of the overall facility.

2. Sight Distance. Do not locate median openings in areas of restricted sight distance (e.g., on a horizontal curve or near the apex of a crest vertical curve). Section 13.4 discusses the minimum intersection sight distances that should be available at a median opening.

3. Turn-Lane Length. Median openings should only be provided if the full length of a left-turn lane can be provided and if the beginning of the turn lane taper is at least 100’ (30 m) from the median nose of the previous intersection. See the schematic in Figure 11.3A. The length of the left-turn lane will be determined by the criteria in Section 28.4.2 of the *Traffic Engineering Manual*.

4. Minimum Spacing. In no case may the number of median openings exceed three per 1000’ (300 m).



✳ See Chapter Twenty-eight of the *Traffic Engineering Manual* for turn-lane lengths.

RECOMMENDED MEDIAN OPENING SPACING
(Raised Medians)
Figure 11.3A

11.4 SIDE SLOPES

Section 11.7 presents typical sections for side slopes for various highway types. Chapter Twelve presents specific criteria for fill slopes and ditch configurations in earth cuts. The following briefly discusses side slopes in general.

11.4.1 Fill Slopes

Fill slopes are the slopes extending outward and downward from the hinge point to intersect the natural ground line. The slope criteria depend upon the functional classification, fill height, urban/rural location and the presence of curbs. Although Chapter Twelve provides typical criteria for fill slopes, the designer must also consider right-of-way restrictions, utility considerations, roadside safety and roadside development in determining the appropriate fill slope for the site conditions.

11.4.1.1 Barn-Roof Sections

A barn-roof slope will provide a slope 4:1 or flatter (6:1 or flatter is desirable) to the clear zone distance. A steeper fill slope will be constructed from the edge of the clear zone to the intersection with natural ground. The barn-roof section can be used to avoid conflicts with natural or man-made features and to reduce the amount of right-of-way acquisition. However, the use of a barn roof section will require a design exception unless both slopes are equal to or flatter than the required slope for the given fill height.

11.4.1.2 Maximum Fill Slope

As indicated in Chapter Twelve, the maximum fill slope should in general be 3:1 for fill heights less than 30’ (9 m). A 3:1 slope is a practical maximum when considering maintenance operations (e.g., mowing), erosion control and roadside safety. A slope steeper than 3:1 may require a roadside barrier (see Chapter Fourteen).

11.4.2 Cut Slopes

11.4.2.1 Earth Cuts

In earth cuts on facilities without curbs, roadside ditches are provided to control drainage. The ditch section includes the inslope, ditch width and back slope as appropriate for the facility type. On facilities with curbs and no sidewalks, a shelf (3’ (1

m) typical measured from the back of curb) is provided, and the back slope is located beyond the shelf. See the typical sections in Section 11.7.

The following will apply to earth cuts:

1. Snow Drifting. One of the following two methods can be used to control snow drifting in cuts.

    a. Design the back slope so that an imaginary line between the finished shoulder and the top of the cut (intersection with natural ground) has a slope of 11:1 or flatter.

    b. Increase the width of the flat-bottomed ditch to provide additional snow storage. Used the method described in the Strategic Highway Research Program's *Design Guidelines for the Control of Blowing and Drifting Snow* to determine the necessary width of the ditch.

2. Superelevated Sections. On superelevated sections, a 6:1 side slope on the high side of the section will extend outward and downward from the subgrade shoulder a sufficient distance such that the distance from the centerline of the pavement (or traveled way for sections with depressed medians) to the end of the 6:1 side slope is the same as the distance from the centerline of the pavement to the subgrade shoulder on the tangent section. As with the break in the subgrade cross slope, the use of the extended 6:1 slope will maintain the ditch offset distance, avoid depressions in ditch grades and aid in the field staking of the subgrade. See the typical sections in Section 11.7 for an illustration.

3. Daylighting. Daylighting slopes can provide several benefits, including:

    a. enhancing aesthetics,
    b. enhancing roadside safety,
    c. providing needed fill material,
    d. removing undesirable features,
    e. obliterating existing roadbeds, and
    f. providing convenient outfall points for roadside drainage.

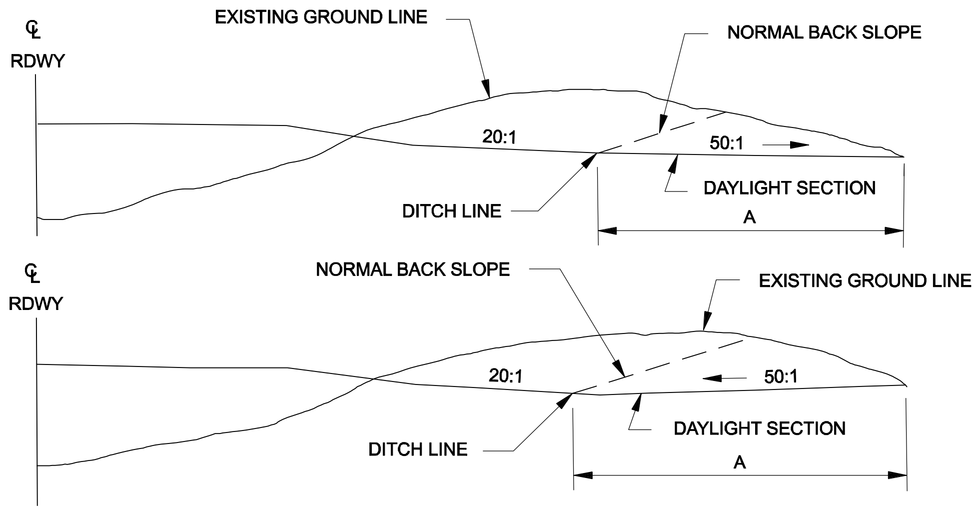
    Figure 11.4A illustrates how to daylight slopes. A 50:1 slope is typically used either away from or towards the ditch line, as appropriate. The dimension "A" in the figure refers to the lateral distance needed to excavate to daylight a slope. Whether a given site should be daylighted, based on "A", will be determined on a case-by-case basis.

Note that daylighting should not be used if it results in the need for a traffic barrier.

4. Back Slope Rounding. Utilize the standard back slope rounding detail that results in a construction limit that is 2 meters beyond the back slope catch point regardless of the back slope. Back slope rounding is not measured for payment. The cost of the rounding is included in the unit price bid for Unclassified Excavation. The rounding will be shown on the final cross sections.

   If it is determined that additional R/W is needed to accommodate utilities or furrow ditches or to address slope stability, a formal request to increase the R/W width at the top of specific cuts needs to be submitted to the Right-of-Way Bureau after the Plan-in-Hand review has been held and before the submission of final construction limits.

5. Geotechnical Investigations. Back slopes steeper than 3:1 should be reviewed for stability by the Geotechnical Section.



DAYLIGHTING
Figure 11.4A

11.4.2.2 Rock Cuts (Back Slopes)

The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

11.4.2.3 Roadside Safety

To safely accommodate a run-off-the-road vehicle, the slopes of the ditches should be as flat as practical. Chapter Fourteen presents specific criteria to determine the necessary inslope and back slope combinations which are traversable. In general, if the back slope of a non-traversable ditch section is within the clear zone, a roadside barrier will be warranted.

11.5 BRIDGE AND UNDERPASS CROSS SECTIONS

The roadway cross section must be carried over and under bridges, which often requires special considerations because of the confining nature of bridges and their high unit costs.

11.5.1 Bridges

Coordinate with the Bridge Bureau to determine widths on new and reconstructed bridges and on existing bridges to remain in place.

11.5.2 Underpasses

The approaching roadway cross section, including any auxiliary lanes, should be carried through the underpass. Sidewalks may also be necessary through the underpass. See Section 11.2.

When determining the cross section width of an underpass, the designer should also consider the likelihood of future roadway widening. Widening an existing underpass in the future can be extremely expensive and difficult. If the potential for future traffic growth and roadway expansion exists, the designer should evaluate the possibility providing additional width for the underpass. If appropriate, a reasonable allowance for future widening may be to provide sufficient lateral clearance for one additional lane in each direction.

11.5.3 Travelway Width Reductions

When approaching a narrow bridge or underpass, the travelway width may need to be reduced to allow the roadway to pass over or under a bridge. These travelway reduction transitions should be designed using the taper rates in Figure 11.5A.

The transition should be completed prior to the beginning of the approach rail, particularly when the approach rail consists of a bridge approach section and an optional terminal end section. For long runs of approach rail, the designer must determine if the length of rail can be reduced by locating the transition closer to the bridge.

Design Speed		Taper Rate
mph	km/m	
20	30	10:1
25	40	15:1
30	50	20:1
35	60	25:1
45	70	45:1
50	80	50:1
55	90	55:1
60	100	60:1
70	110	70:1
75	120	75:1

Note: Taper Length (L) = Taper Rate x Offset Distance

TAPER RATES FOR WIDTH REDUCTIONS
Figure 11.5A

11.6 RIGHT-OF-WAY

11.6.1 Definitions

The following definitions will apply:

1. Permanent R/W. Highway R/W acquired for permanent ownership by the State for activities which are the responsibility of the State for an indefinite period of time. The State obtains fee title to the property. Permanent R/W is typically acquired for the construction and maintenance of roads.

2. Permanent R/W Easements. A right for a specific purpose acquired by the State for the limited usage of property not owned by the State. Types of R/W easements include:

    a. maintenance easements,
    b. utility easements,
    c. storm sewer easements, and
    d. roadway easements.

3. Construction Permit. Temporary legal access acquired by the State, outside the permanent R/W boundaries, to construct the highway project according to its proper design but on property which is not owned by the State. See Section 11.6.4 for examples of construction permits. MDT will relinquish all rights to the permit upon completion of the contract.

4. Temporary Easement. R/W acquired for the legal right of usage by the State to serve a specific purpose for construction operations (e.g., storage of equipment). Once construction is completed, the State yields its legal right of usage and returns the land to its original condition as close as practical. If necessary, MDT has the authority to condemn property for a temporary easement.

5. Limited Access Control. Limiting access to a highway is used to maintain and protect the safety and operating capacity of the facility. It is accomplished by limiting the number of public and private approaches and allowing them only at certain locations along a given section of highway.

11.6.2 R/W Width (Typical MDT Policy)

11.6.2.1 General

The basic policy of the Department is to acquire right-of-way (R/W) of sufficient, but not excessive, width to accommodate construction and maintenance operations. Except as noted for overlay projects and construction permits, the minimum right-of-way width for all facilities will be the sum of the travel lanes, outside shoulders and median width (if applicable) plus the necessary width for fill and cut slopes or for roadside clear zones, whichever is greater, plus a border strip. See the following sections for specific criteria. Desirably, the R/W width will accommodate the anticipated ultimate development of the highway facility, if known.

The R/W width should be uniform, where practical. In urban areas, variable widths may be necessary due to existing development; varying side slopes and embankment heights may make it desirable to vary the R/W width; and, R/W limits will likely need to be adjusted at intersections and freeway interchanges. Other special R/W controls should be considered and should be coordinated between the R/W Design and Plans Section and the Road Design Section. These include:

1. In areas where the necessary R/W widths cannot be reasonably obtained, the designer may consider the advisability of using steeper slopes, revising grades or using retaining structures.
2. At horizontal curves and intersections, additional R/W may be warranted to ensure that the necessary sight distances are available in the future.

The designer will coordinate with the Right-of-Way Bureau on the design of R/W for highway projects.

11.6.2.2 Rural Areas

The following will apply to R/W widths in rural areas:

1. Application. These criteria apply to highways through low and medium value farm land, grazing land, forest land, etc. Areas of extremely high R/W costs, major improvements, historic sites, etc., must be analyzed individually and exceptions made where appropriate.
2. General. Except as noted in Sections 11.6.3 and 11.6.4, the permanent R/W in rural areas should be wide enough to include all elements of the highway cross

section plus an additional border strip from 10’ (3.0 m) to 20’ (6.0 m) in width to accommodate construction and maintenance equipment.

3. Minimum Widths. The minimum R/W width is 10’ (3 m) beyond the construction limits. The following standard R/W widths have been established as general criteria for rural areas when extremely high R/W cost is not a significant controlling factor:

    a. Interstate Projects. Facilities without frontage roads will have 80’ (25 m) minimum from the centerline of the nearest main roadway to the R/W line. Facilities with frontage roads or ramp roads will have 60’ (20 m) minimum from the center of the nearest roadway to the R/W line.

    b. Arterial Projects. These facilities will have 80’ (25 m) from the centerline of the nearest roadway to the R/W line or to the construction limits plus 10’ (3 m), whichever is greater.

    c. Collector Projects. These facilities will have 60’ (20 m) from the centerline of the nearest roadway to the R/W line or to the construction limits plus 10’ (3 m), whichever is greater.

4. Changes in Right-of-Way Widths (R/W Breaks). The following will apply:

    a. Except at property ownership lines, changes in R/W widths are typically made on a taper. Changes of 25’ (8 m) or less should be on a longitudinal transition taper of 4:1. A steeper taper may be used on width changes in excess of 25’ (8 m) or where special circumstances warrant.

    b. R/W widths should not be changed at property ownership lines unless the property line has been located and adequately tied to the highway survey such that its location is definite and defensible.

    c. The distance between R/W breaks should be a minimum of 500’ (150 m) unless it is entirely impractical to provide a uniform R/W width for this distance. The reasons for utilizing a shorter distance between breaks should be documented.

11.6.2.3 Urban Areas

Because of the restrictive conditions often encountered in urban areas, no rigid R/W widths can be established. Sound engineering judgment must be applied to obtain a logical balance among R/W costs, R/W impacts and R/W widths. Where practical, the following should be met:

1. Curbs. Urban R/W must be wide enough to accommodate the curb-to-curb width of the street plus a border strip on each side. Each border strip must be at least 8’ (2.4 m) and, preferably, should be 12’ (3.6 m) or more. The border strip is defined as the area between the curb and the R/W line.
2. Sidewalks. If a sidewalk will be constructed, the R/W limit should be at least 3’ (1 m) beyond the sidewalk.
3. Construction Limits. In most cases, the minimum R/W width is to the construction limits plus 3’ (1 m). Curb and gutter sections and the toe of fill slopes often use permits for construction.
4. Exceptions. As in rural areas, extremely high R/W costs, major improvements, historic sites, etc., may require exceptions.

11.6.3 Overlay and Widening Projects

Projects involving overlay and widening are constructed over the existing highway alignment, and construction limits normally will remain within the existing R/W. Where widening dictates the need for additional permanent R/W, the widths in Section 11.6.2 may be waived, and the minimum amount of new R/W needed may be acquired in fee. Where a minor amount of work must be accomplished outside the existing R/W, construction permits may be used as discussed in Section 11.6.4. The use of this approach is a subjective decision which should be addressed in the preparation of the scope of work and again at the preliminary field review.

11.6.4 Construction Permits

As land becomes more valuable and public criticism of land acquisition becomes more vocal, especially for the acquisition of cultivated lands, it is important to consider reasonable deviations from MDT typical procedure. However, the R/W will be designed showing the acquisition of all land within the construction limits. The decision to obtain a construction permit rather than acquire the property in fee will be made during the R/W negotiations process. In general, the following guidelines will apply to construction permits:

1. Approaches. Construction permits are required for the construction of approaches only if the work extends more than 50’ (15 m) beyond the permanent R/W.

2. Drainage. Construction permits may be used where inlet and outlet ditches from culverts or minor channel changes extend beyond the R/W width necessary to accommodate adjacent fill or cut slopes.

3. Non-Applicability. Culvert pipes, major structures, paved portions of roadways or streets, and other permanent roadway elements which will be maintained in connection with the roadway should be located on property on which the State has a permanent property right. Therefore, do not use construction permits for these permanent elements. In general, the permit areas should contain only the flattened cut and fill slope areas.

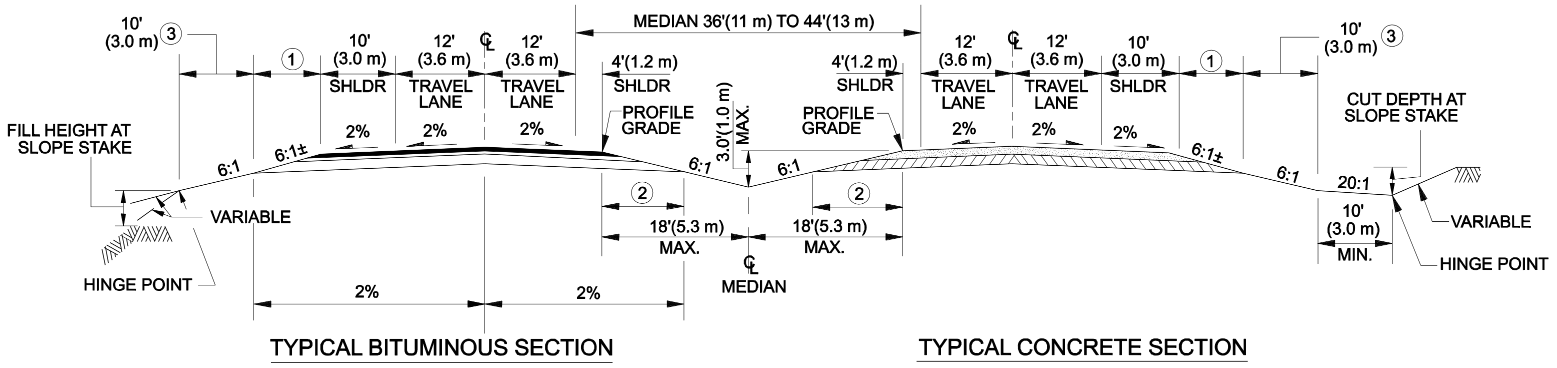
4. Fences. Because of the presence of livestock, a parcel may need to be fenced during construction. Acquisition in fee is preferred over construction permits because the cost of constructing a fence twice is typically greater than the value of the land.

5. Condemnation. MDT does not have the authority to condemn property for a construction permit. Therefore, if condemnation is required, areas covered by temporary construction permits must be changed to temporary easements.

11.7 TYPICAL SECTIONS

The following figures present typical sections which will apply to all projects. Chapter Twelve presents specific criteria which apply to various conditions. The typical section figures are:

1. Figure 11.7A"Typical Freeway Depressed Median Section (Tangent Section) (Medians 36' to 44' (11 m to 13 m))."
2. Figure 11.7B"Typical Freeway Depressed Median Section (Superelevated Section) (Medians 36' to 44' (11 m to 13 m))."
3. Figure 11.7C"Typical Freeway Depressed Median Section (Tangent Section) (Medians 44' to 76' (13 m to 23 m))."
4. Figure 11.7D"Typical Freeway Depressed Median Section (Superelevated Section) (Medians 44' to 76' (13 m to 23 m))."
5. Figure 11.7E"Typical Freeway Depressed Median Section (Tangent Section) (Medians 76' (23 m) and Over)."
6. Figure 11.7F"Typical Freeway Depressed Median Section (Superelevated Section) (Medians 76' (23 m) and Over)."
7. Figure 11.7G"Typical Freeway Flush Median Section (Tangent Section)."
8. Figure 11.7H"Typical Freeway Flush Median Section (Superelevated Section)."
9. Figure 11.7I"Typical Non-Freeway Flush Median Section (Tangent Section)."
10. Figure 11.7J"Typical Non-Freeway Flush Median Section (Superelevated Section)."
11. Figure 11.7K"Typical Raised Median Section (Tangent Section)."
12. Figure 11.7L"Typical Raised Median Section (Superelevated Section)."
13. Figure11.7M"Typical Two-Lane Rural Highway (Tangent Section)."
14. Figure 11.7N"Typical Two-Lane Rural Highway (Superelevated Section)."
15. Figure 11.7O"Typical Curbed Urban Street (Tangent Section)."
16. Figure 11.7P"Typical Curbed Urban Street (Superelevated Section)."
17. Figure 11.7Q"Off-System Rural Road (Tangent Section). "
18. Figure 11.7R"Off-System Rural Road (Superelevation Section)."



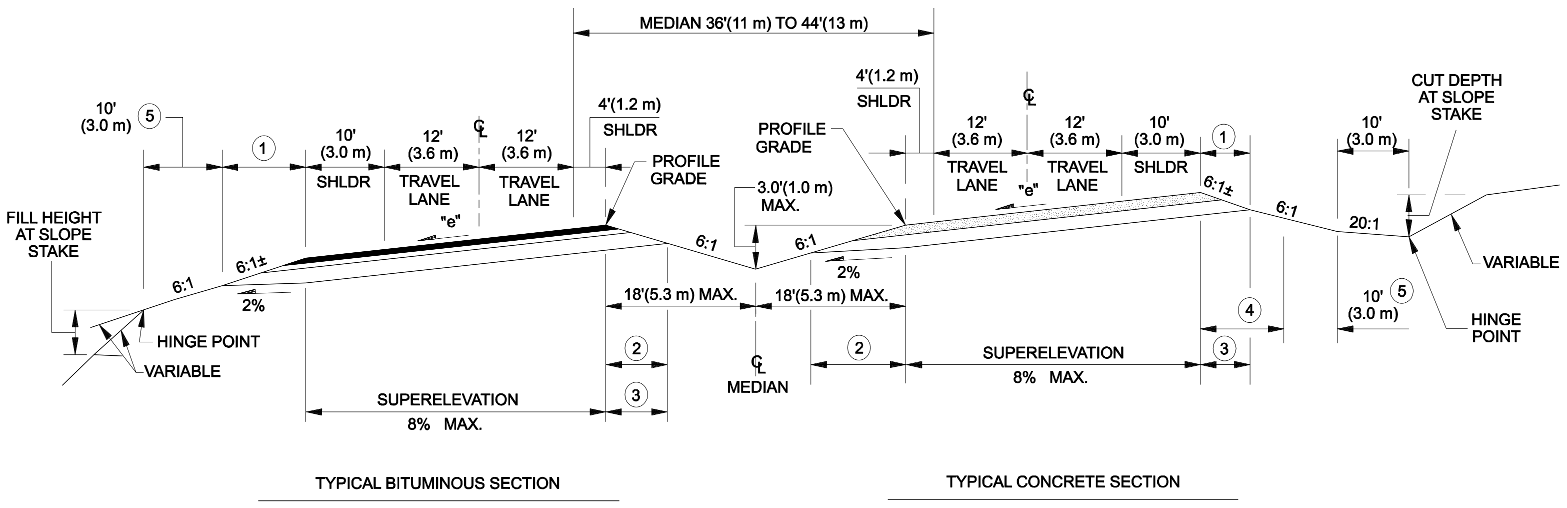
GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① Compute total width to nearest foot(0.1 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② Compute distance to nearest 0.1foot(0.01 meter) based on a true 6:1 slope.

③ For rehabilitation projects, an existing 6' (1.8 m) width may be retained with documentation.

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Tangent Section)
(Medians 36' (11 m) to 44' (13 m))
Figure 11.7A



GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot(0.1 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

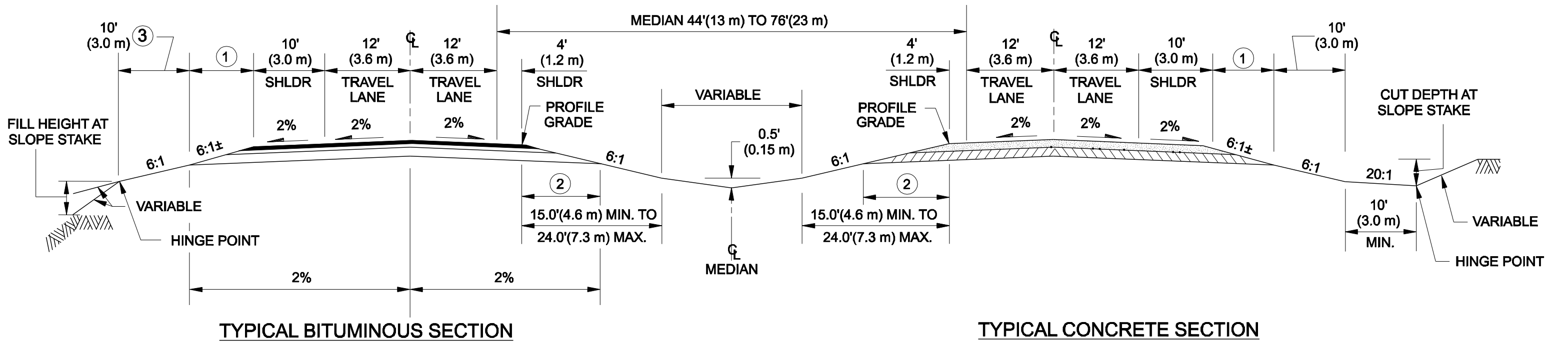
② Compute distance to nearest 0.1 foot(0.01 meter) based on a true 6:1 slope.

③ Compute distance for each superelevation on the project.

④ This distance will be equal to the ① distance on the tangent section (Figure 11.7A).

⑤ For rehabilitation projects, an existing 6' (1.8 m) width may be retained with documentation.

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Superelevated Section)
(Medians 36' (11 m) to 44' (13 m))
Figure 11.7B



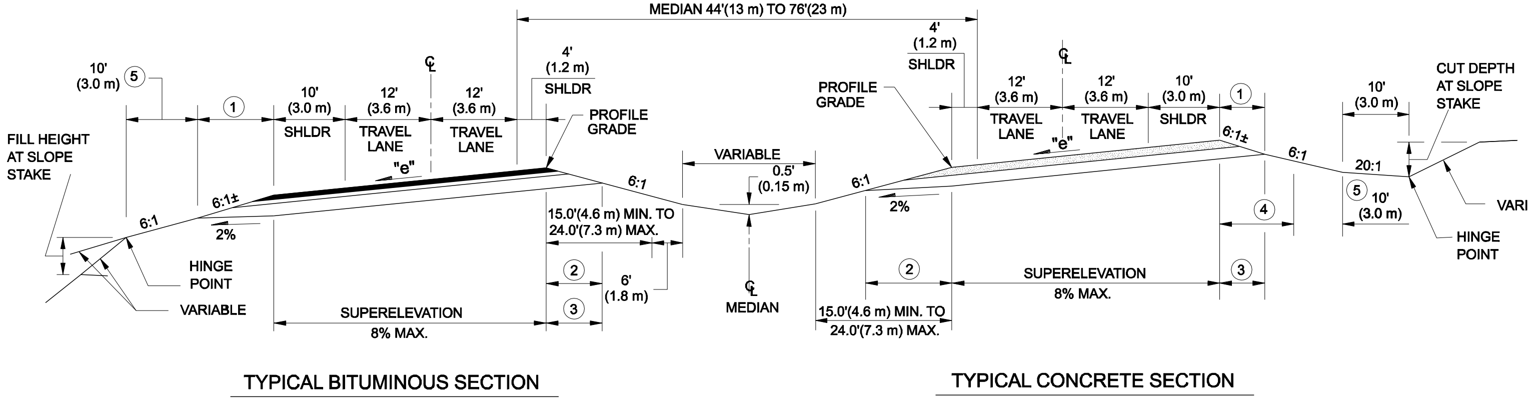
GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① Compute total width to nearest foot(0.1 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② Compute distance to nearest 0.1 foot(0.01 meter) based on a true 6:1 slope.

③ For rehabilitation projects, an existing 6’ (1.8 m)width may be retained with documentation.

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Tangent Section)
(Medians 44’ (13 m) to 76’ (23 m))
Figure 11.7C



GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

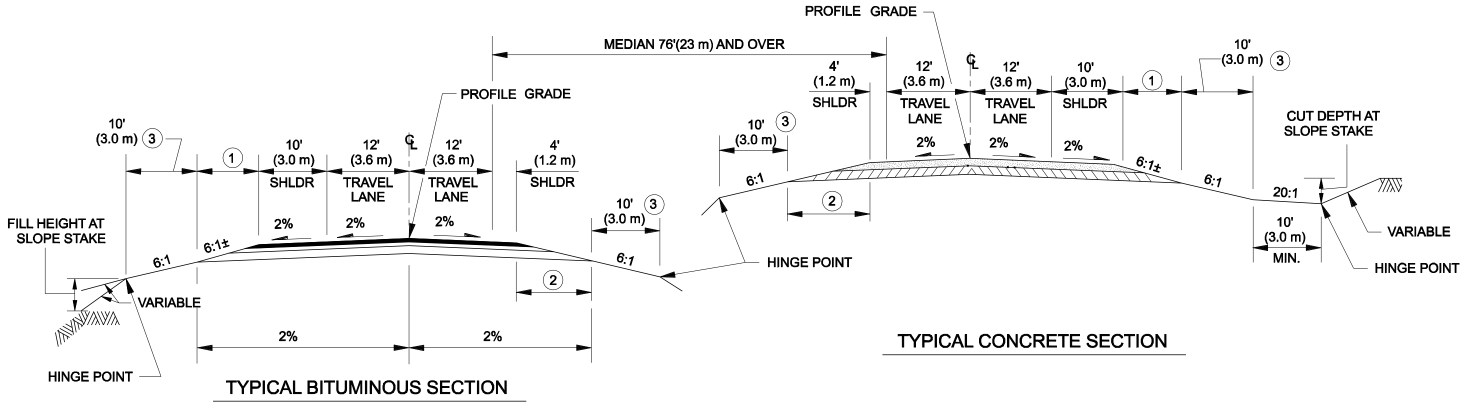
② Compute distance to nearest 0.1 foot (0.01 meter) based on a true 6:1 slope.

③ Compute distance for each superelevation on the project.

④ This distance will be equal to the ① distance on the tangent section (Figure 11.7C).

⑤ For rehabilitation projects, an existing 6’ (1.8 m) width may be retained with documentation.

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Superelevated Section)
(Medians 44’ (13 m) to 76’ (23 m))
Figure 11.7D



GENERAL NOTES:

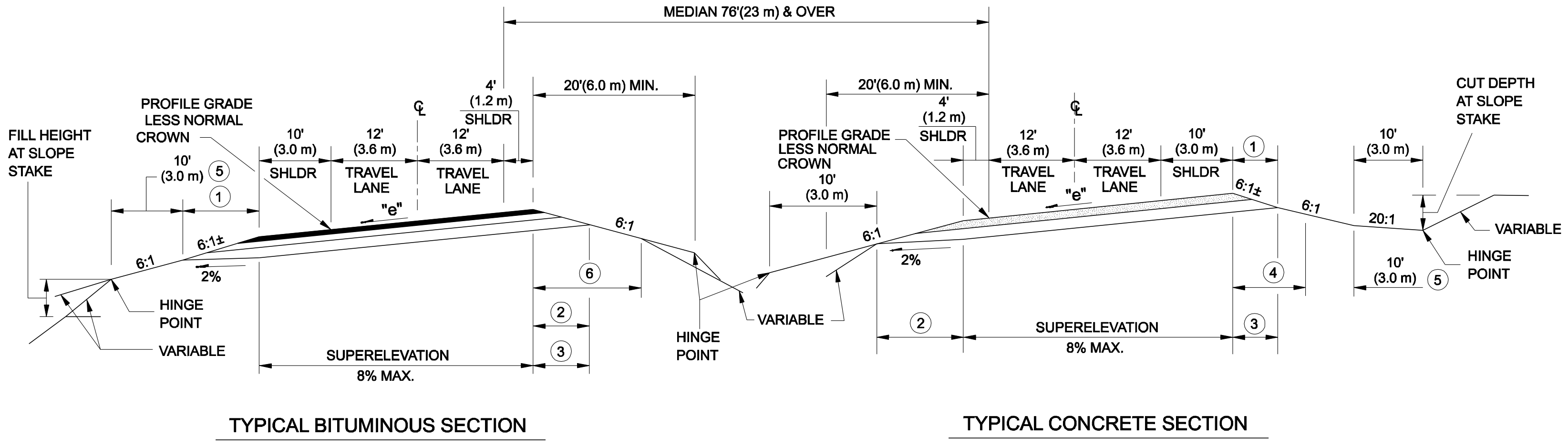
1. Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes).
2. Generally, this typical section will be used only where terrain warrants the use of independent grade lines. Median slope intersections will be determined by the designer to meet individual conditions. In cases where median widths vary (from 36' (11 m) to 76' (23 m) and over) within a given project, the profile grade will be carried on the finished median shoulder.
3. Where practical, natural growth in place between roadways should be preserved.

① Compute total width to nearest foot(0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② Compute distance to nearest 0.1 foot(0.01 meter) based on a true 6:1 slope.

③ For rehabilitation projects, an existing 6' (1.8 m) width may be retained with documentation.

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Tangent Section)
(Medians 76' (23 m) and Over)
Figure 11.7E



GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② Compute distance to nearest 0.1 foot (0.01 meter) based on a true 6:1 slope.

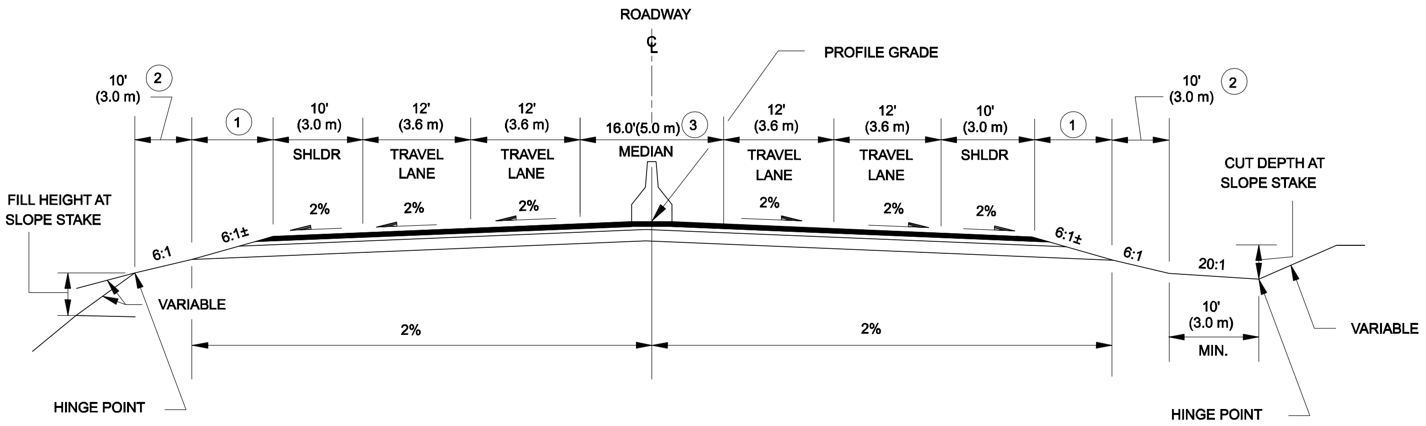
③ Compute distance for each superelevation on the project.

④ This distance will be equal to the ① distance on the tangent section (Figure 11.7E).

⑤ For rehabilitation projects, an existing 6' (1.8 m) width may be retained with documentation.

⑥ This distance will be equal to the ②,distance on the tangent section plus 10' (3.0 m).

TYPICAL FREEWAY DEPRESSED MEDIAN SECTION (Superelevated Section)
(Medians 76' (23 m) and Over)
Figure 11.7F



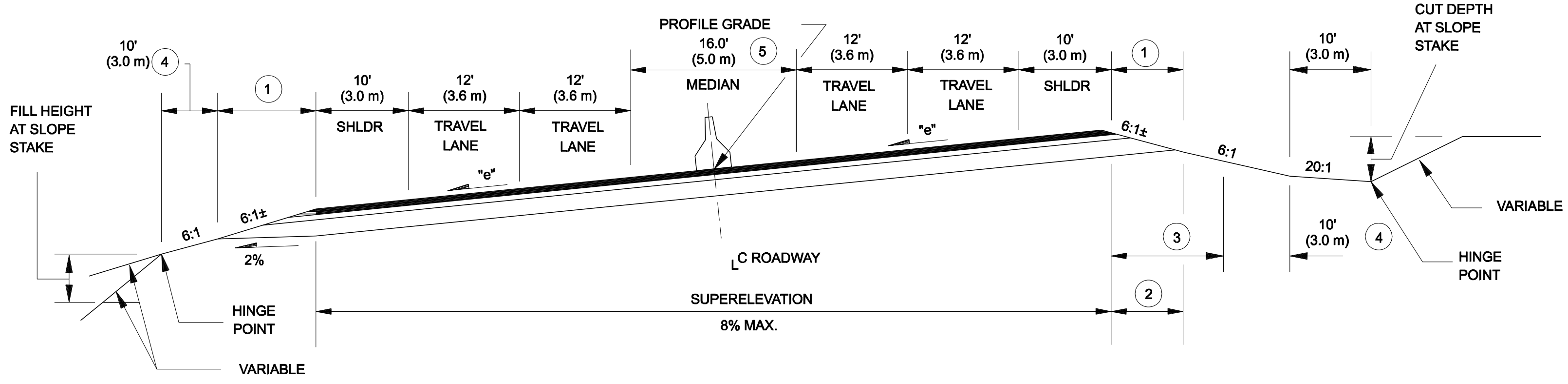
GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

② For rehabilitation projects, an existing 6’ (1.8 m) width may be retained with documentation.

③ A reduced median width may be used; see Chapter Twelve.

TYPICAL FREEWAY FLUSH MEDIAN SECTION (Tangent Section)
Figure 11.7G



GENERAL NOTE: Dimensions in figure will typically apply. See Figure 12-2 "Geometric Design Criteria for Freeways" for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

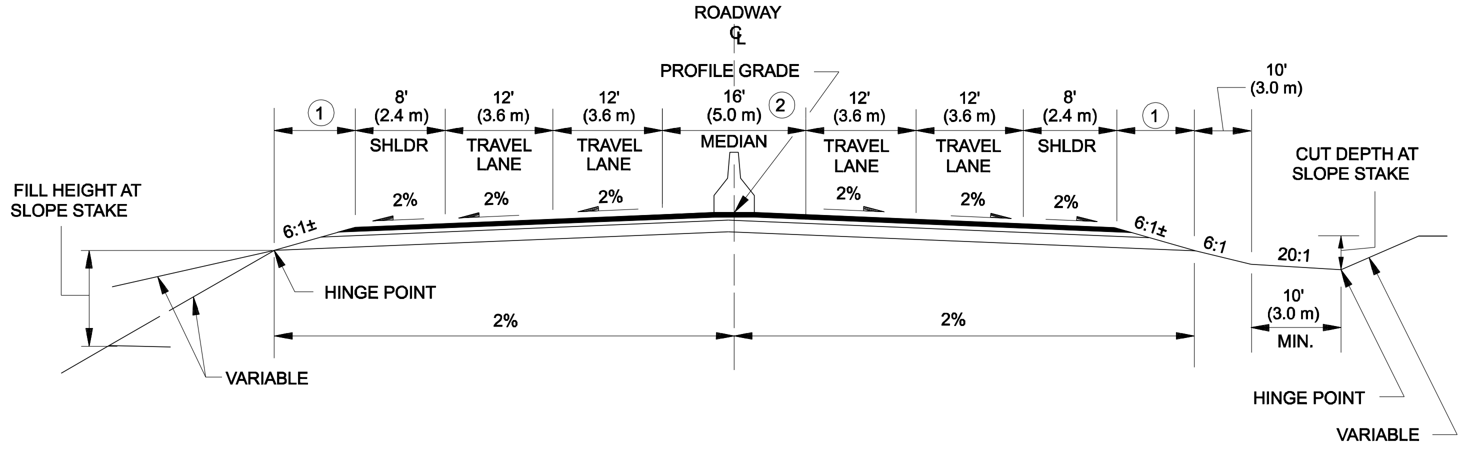
② Compute distance for each superelevation on the project.

③ This distance will be equal to the ① distance on the tangent section (Figure 11.7G).

④ For rehabilitation projects, an existing 6' (1.8 m) width may be retained with documentation.

⑤ A reduced median width may be used; see Chapter Twelve.

TYPICAL FREEWAY FLUSH MEDIAN SECTION (Superelevated Section)
Figure 11.7H



GENERAL NOTES:

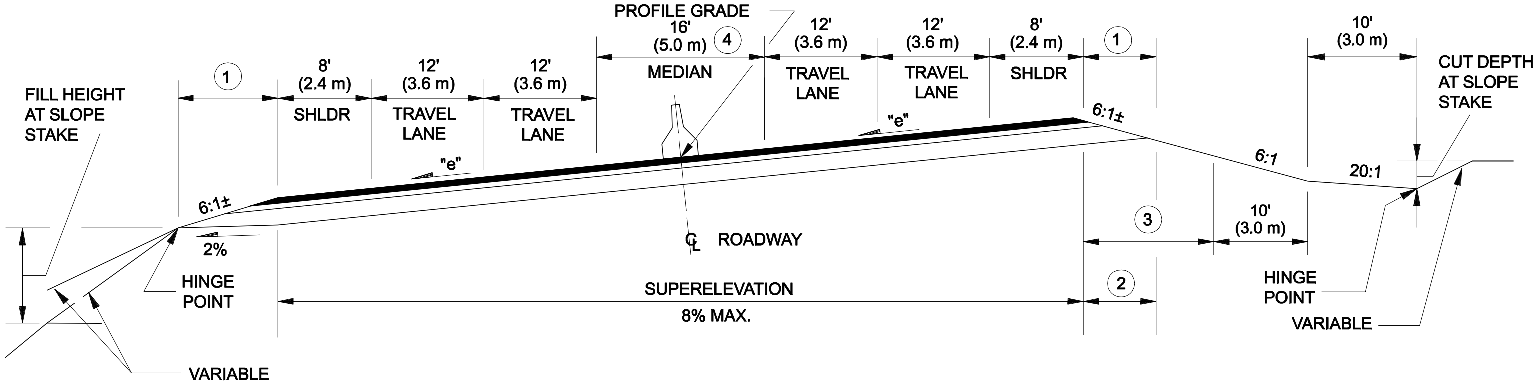
1. Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

2. The need for a median barrier will be determined on a case-by-case basis.

① Compute total width to nearest foot(0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② A reduced median width may be used; see Chapter Twelve.

TYPICAL NON-FREEWAY FLUSH MEDIAN SECTION (Tangent Section)
Figure 11.7I



GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

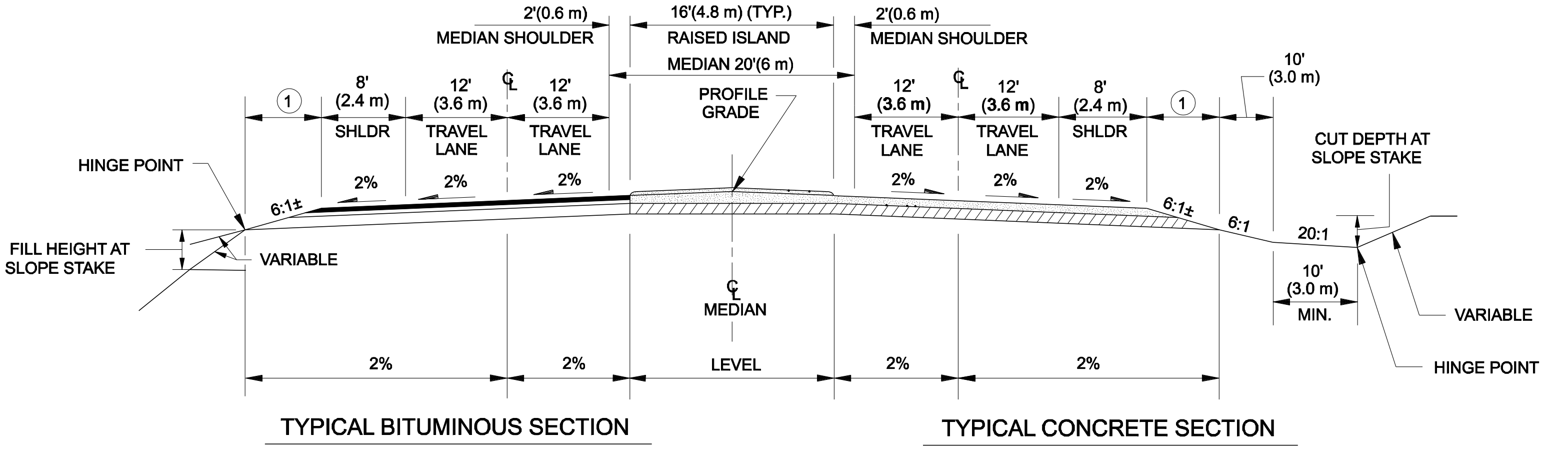
① Compute total width to nearest foot(0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot(0.01 meter).

② Compute distance for each superelevation on the project.

③ This distance will be equal to the ① distance on the tangent section (Figure 11.7I).

④ A reduced median width may be used; see Chapter Twelve.

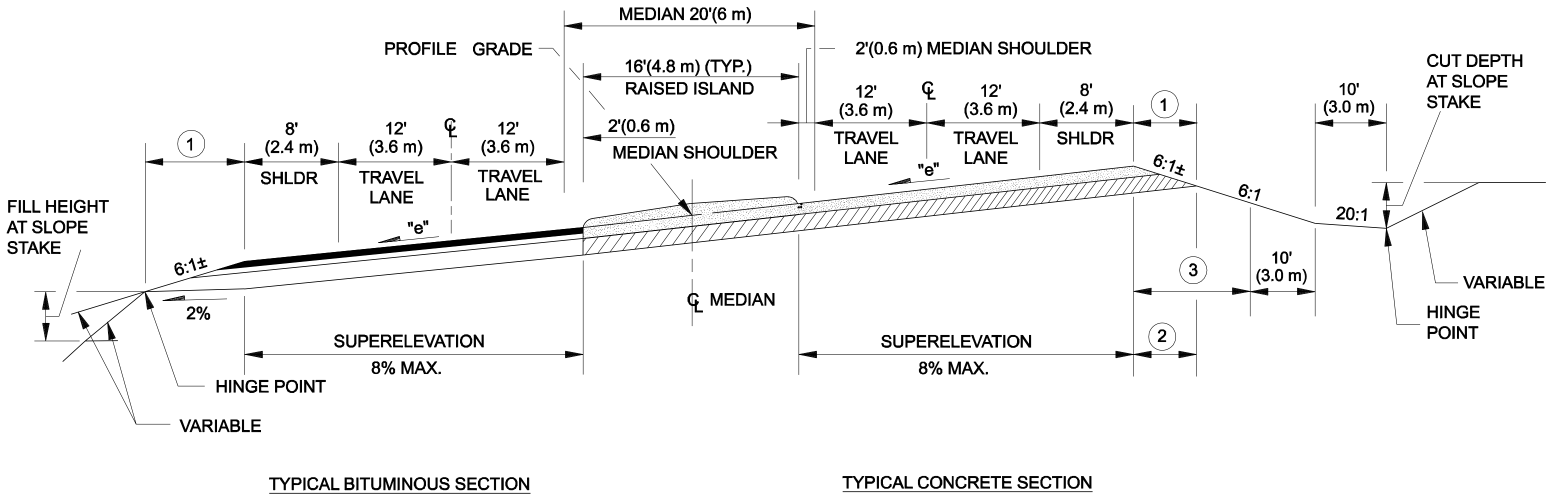
TYPICAL NON-FREEWAY FLUSH MEDIAN SECTION (Superelevated Section)
Figure 11.7J



GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① Compute total width to nearest foot(0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

TYPICAL RAISED MEDIAN SECTION (Tangent Section)
Figure 11.7K



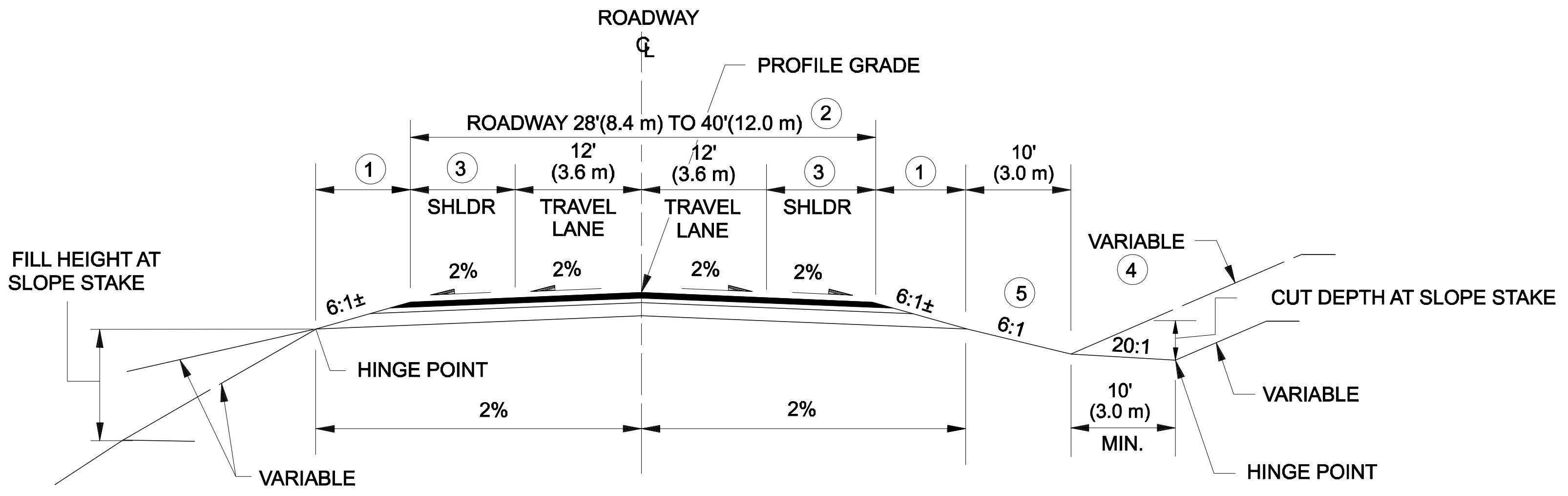
GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

② Compute distance for each superelevation on the project.

③ This distance will be equal to the ① distance on the tangent section (Figure 11.7K).

TYPICAL RAISED MEDIAN SECTION (Superelevated Section)
Figure 11.7L



GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

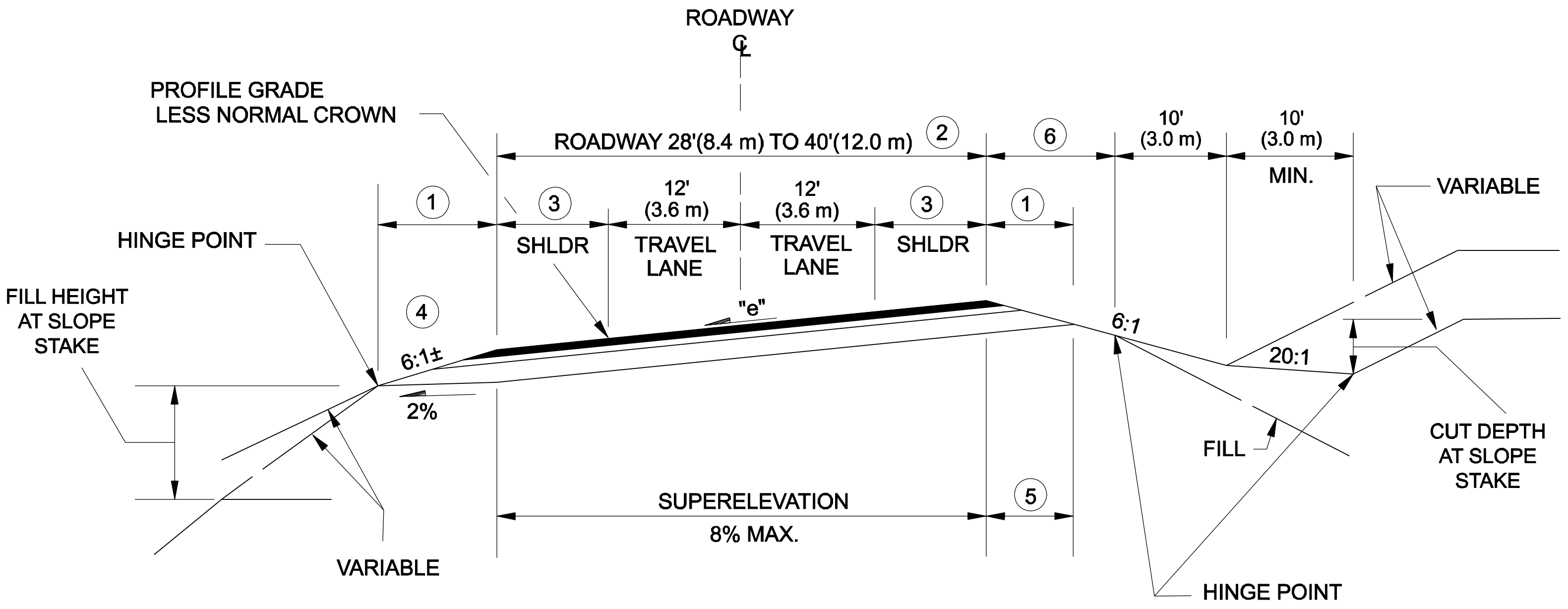
② Roadway width will vary. See Chapter Twelve for specific criteria.

③ Shoulder width will vary. See Chapter Twelve for specific criteria. New projects should include full-depth shoulders.

④ V-ditches may be used in special cases. Check Chapter Fourteen for traversability criteria for roadside ditches.

⑤ The inslope may be 4:1 for some major collectors; see Chapter Twelve for specific criteria.

TYPICAL TWO-LANE RURAL HIGHWAY (Tangent Section)
Figure 11.7M



GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① Compute total width to nearest foot (0.01 meter). Compute intermediate surfacing widths to nearest 0.1 foot (0.01 meter).

② Roadway width will vary. See Chapter Twelve for specific criteria.

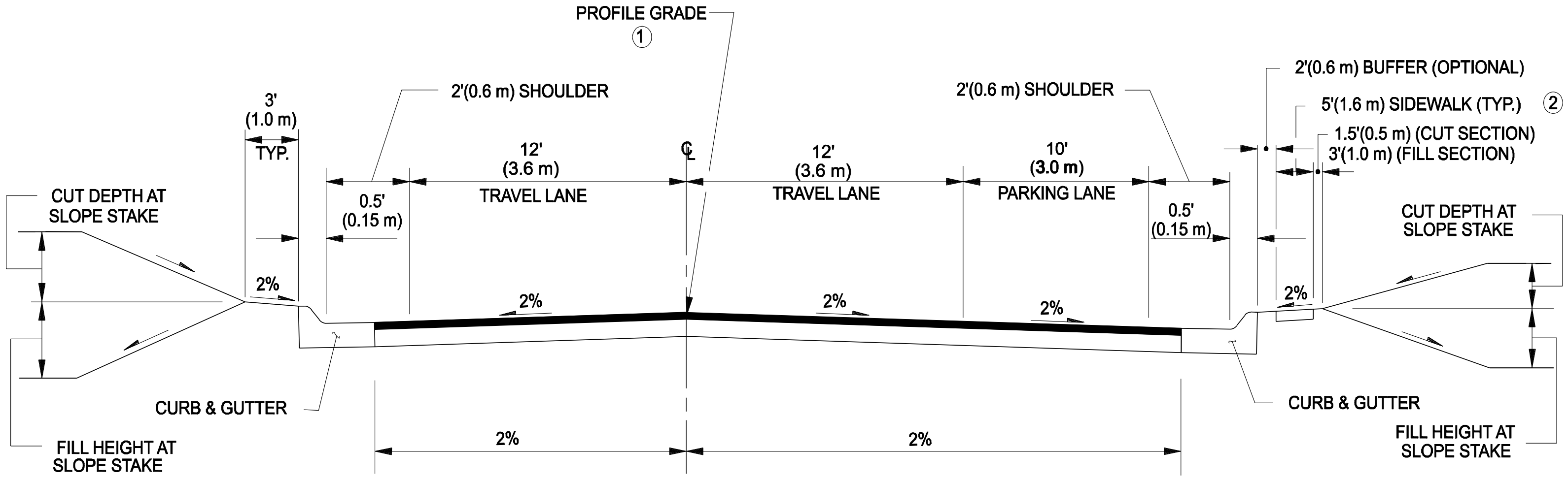
③ Shoulder width will vary. See Chapter Twelve for specific criteria. New projects should include full-depth shoulders.

④ See Chapter Five for method of computing intermediate thicknesses on low side of curves.

⑤ Compute distance for each superelevation on the project.

⑥ This distance will be equal to the ① distance on the tangent section (Figure 11.7M).

TYPICAL TWO-LANE RURAL HIGHWAY (Superelevated Section)
Figure 11.7N

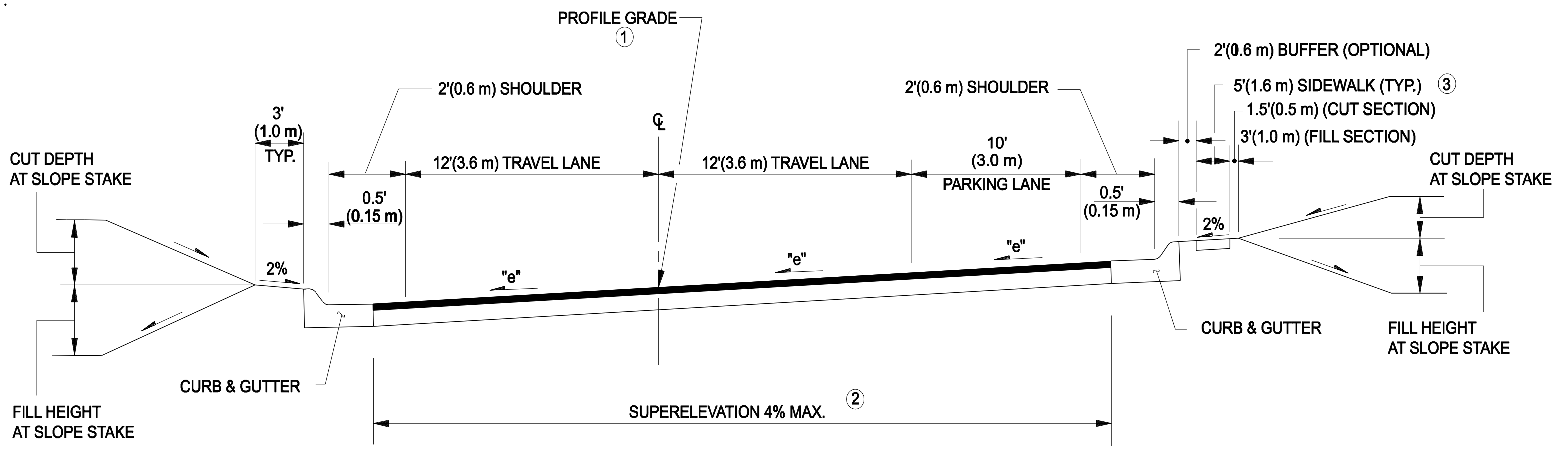


GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes).

① It may be necessary to use separate profiles at the top back of curb to promote positive drainage and to match existing development.

② See Section 11.2 for sidewalk design criteria.

TYPICAL CURBED URBAN STREET (Tangent Section)
Figure 11.7O



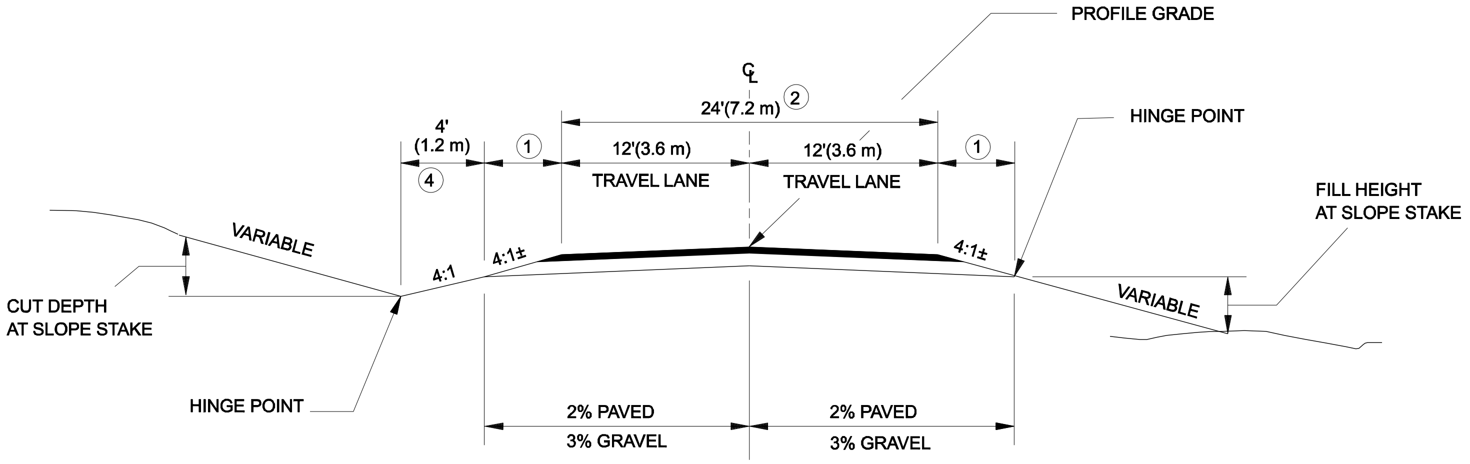
GENERAL NOTE: Dimensions in figure will typically apply. See applicable figure in Chapter Twelve for specific cross section criteria for various conditions (e.g., for cut and fill slopes). See Chapter Nine for details on superelevation.

① It may be necessary to use separate profiles at the top back of curb to promote positive drainage and to match existing development.

② Applies to low-speed urban streets V ≤ 45 mph (V ≤ 70 km/h).

③ See Section 11.2 for sidewalk design criteria.

TYPICAL CURBED URBAN STREET (Superelevated Section)
Figure 11.7P



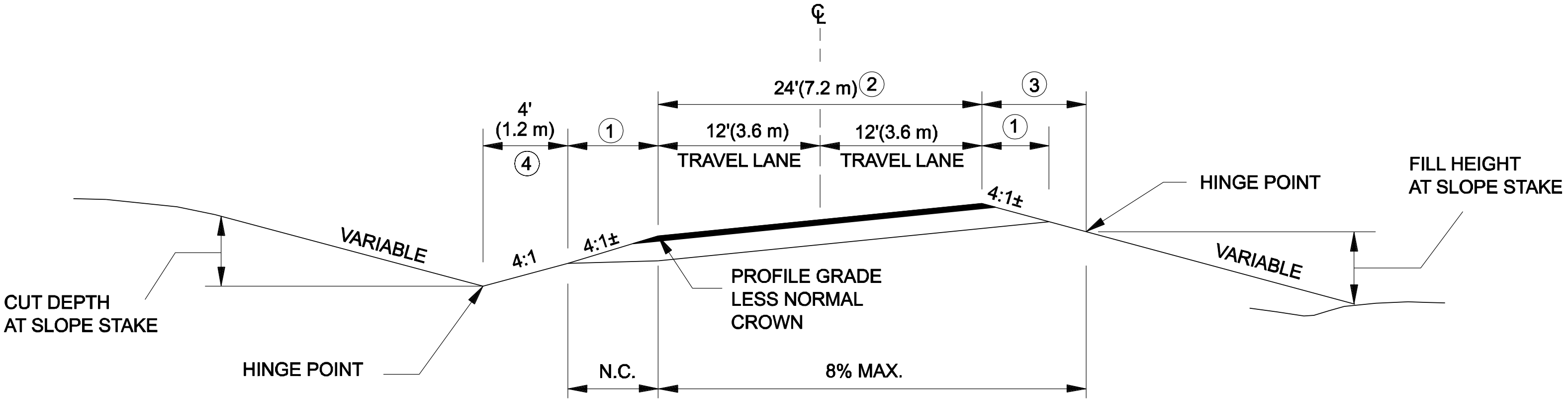
① Compute total width to nearest foot (0.1 m). Compute intermediate widths to nearest 0.1 foot (0.01 m).

② Roadway width may vary; see Chapter Twelve.

③ For ADT > 300, use the criteria for a major collector.

④ Check Chapter Fourteen for traversable requirements. For non-traversable ditches, place the toe of the ditch outside the clear zone.

OFF-SYSTEM RURAL ROAD
(Tangent Section)
Figure 11.7Q



① Compute total width to nearest foot (0.1 m). Compute intermediate widths to nearest 0.1 foot (0.01 m).

② Roadway width may vary; see Chapter Twelve.

③ This distance will be equal to the ① distance on the tangent section (Figure 11.7Q).

④ Check Chapter Fourteen for traversable requirements. For non-traversable ditches, place the toe of the ditch outside the clear zone.

OFF-SYSTEM RURAL ROAD
(Superelevated Section)
Figure 11.7R

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Twelve
GEOMETRIC DESIGN TABLES

Table of Contents

Chapter Twelve
GEOMETRIC DESIGN TABLES

12 GENERAL

This chapter presents summary tables of the Department's criteria for the geometric design of State projects. The designer should consider the following in the use of the tables:

1. Functional Classification. Figure 12-1 illustrates the designated functional classification of State highways in Montana. To determine the latest functional classification of a facility, the designer should contact the Rail, Transit and Planning Division. The selection of design values depends on the functional classification of the highway facility. Note that, in general, National Highway System facilities within the current Federal-aid system will be designed using the freeway table (Figure 12-2) and the rural/urban principal arterial tables (Figures 12-3 and 12-7). As discussed in Section 8.2, arterials and collectors are approximately equivalent to primary and secondary facilities within the former Federal-aid system.

2. Manual Section References. These tables are intended to provide a concise listing of design values for easy use. However, the designer should review the Manual section references for more information on the design elements.

3. Footnotes. The tables include many footnotes, which are identified by a number in parentheses (e.g., (6)). The information in the footnotes is critical to the proper use of the design tables.

4. Controlling Design Criteria. The tables provide an asterisk to indicate controlling design criteria. Section 8.8 discusses this in more detail and presents the process for approving design exceptions to controlling criteria.

5. Local Agency Criteria. The roads and streets agencies within Montana’s counties and cities may have developed their own geometric design criteria for local facilities. If a facility is not on the State highway system, it may be acceptable to use the local agency criteria where there are conflicts with the MDT criteria. This decision will be made on a case-by-case basis.

6. Design Speed. The assumed design speed for a project should be a logical one with respect to topography, anticipated operating speed, the adjacent land use and the functional classification of the highway. In rural areas the topography and the functional classification of the routes are generally the controlling factors. In the determination of the type of terrain, utilize the following descriptions:

   Level Terrain: The available stopping sight distances are generally long or can be made to be so without construction difficulty or major expense.

   Rolling Terrain: The natural slopes consistently fall below and rise above the roadway and occasional steep slopes offer some restriction to horizontal and vertical alignment.

   Mountainous Terrain: Longitudinal and transverse changes in elevation are abrupt and extensive grading is frequently need to obtain acceptable alignments

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MONTANA FUNCTIONAL CLASSIFICATION SYSTEM

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MONTANA FUNCTIONAL CLASSIFICATION SYSTEM
Figure 12-1

Figure 12-2

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS
(National Highway System — Interstate) U.S. Customary

<table>
<tr><th colspan="3">Design Element</th><th>Manual Section</th><th colspan="3">Rural</th><th>Urban</th></tr>
<tr><td rowspan="5">Design Controls</td><td colspan="2">Design Forecast Year (Geometrics)</td><td>8.4</td><td colspan="3">20 Years</td><td>20 Years</td></tr>
<tr><td rowspan="3">*Design Speed</td><td>Level</td><td rowspan="3">8.3</td><td colspan="3">70 mph</td><td rowspan="3">50 mph</td></tr>
<tr><td>Rolling</td><td colspan="3">60 mph</td></tr>
<tr><td>Mountainous</td><td colspan="3">50 mph</td></tr>
<tr><td colspan="2">Level of Service</td><td>8.4</td><td colspan="3">B</td><td>B</td></tr>
<tr><td rowspan="8">Roadway Elements</td><td colspan="2">*Travel Lane Width</td><td>11.2</td><td colspan="3">4 @ 12’</td><td>4 @ 12’</td></tr>
<tr><td rowspan="2">*Shoulder Width</td><td>Outside Shoulder</td><td rowspan="2">11.2</td><td colspan="3">10’ (1)</td><td>10’ (1)</td></tr>
<tr><td>Inside Shoulder</td><td colspan="3">4’ (2)</td><td>4’ (2)</td></tr>
<tr><td rowspan="2">Cross Slope</td><td>*Travel Lane</td><td rowspan="2">11.2</td><td colspan="3">2%</td><td>2%</td></tr>
<tr><td>Shoulder</td><td colspan="3">2% (3)</td><td>2% (3)</td></tr>
<tr><td rowspan="3">Median Width</td><td>Level</td><td rowspan="3">11.3</td><td colspan="3">Minimum: 36’</td><td rowspan="3">Desirable: 36’
Minimum: 16’ (4)</td></tr>
<tr><td>Rolling</td><td colspan="3">Minimum: 36’</td></tr>
<tr><td>Mountainous</td><td colspan="3">Minimum: 16’ (4)</td></tr>
<tr><td rowspan="7">Earth Cut Sections</td><td rowspan="3">Ditch</td><td>Inslope</td><td>11.4</td><td colspan="3">6:1 (Width: 6’)</td><td>6:1 (Width: 6’)</td></tr>
<tr><td>Width</td><td rowspan="2">11.4</td><td colspan="3">10’ Min.</td><td>10'</td></tr>
<tr><td>Slope</td><td colspan="3">20:1 towards back slope</td><td>20:1 towards back slope</td></tr>
<tr><td rowspan="4">Back Slope; Cut Depth at Slope Stake (5)</td><td>0’ - 5’</td><td rowspan="4">11.4</td><td colspan="3">5:1</td><td>5:1</td></tr>
<tr><td>5’ - 10’</td><td colspan="3">Level/Rolling: 4:1; Mountainous: 3:1</td><td>3:1</td></tr>
<tr><td>10’ - 15’</td><td colspan="3">Level/Rolling: 3:1; Mountainous: 2:1</td><td>2:1</td></tr>
<tr><td>> 15’</td><td colspan="3">Level/Rolling: 2:1; Mountainous: 1.5:1</td><td>1.5:1</td></tr>
<tr><td rowspan="4">Earth Fill Slopes</td><td rowspan="4">Fill Height at Slope Stake (6)</td><td>0’ - 10’</td><td rowspan="4">11.4</td><td colspan="3">6:1</td><td>6:1</td></tr>
<tr><td>10’ - 20’</td><td colspan="3">4:1</td><td>4:1</td></tr>
<tr><td>20’ - 30’</td><td colspan="3">3:1</td><td>3:1</td></tr>
<tr><td>> 30’</td><td colspan="3">2:1</td><td>2:1</td></tr>
<tr><td rowspan="10">Alignment Elements</td><td colspan="2">DESIGN SPEED</td><td>N/A</td><td>50 mph</td><td>60 mph</td><td>70 mph</td><td>50 mph</td></tr>
<tr><td colspan="2">*Stopping Sight Distance</td><td>8.6</td><td>425’</td><td>570’</td><td>730’</td><td>425’</td></tr>
<tr><td colspan="2">*Minimum Radius (e = 8.0%)</td><td>9.2</td><td>760’</td><td>1200’</td><td>1820’</td><td>760’</td></tr>
<tr><td colspan="2">*Superelevation Rate (7)</td><td>9.3</td><td colspan="3">e_{max} = 8.0%</td><td>e_{max} = 8.0%</td></tr>
<tr><td rowspan="2">*Vertical Curvature (K-value)</td><td>Crest</td><td rowspan="2">10.5</td><td>84</td><td>151</td><td>247</td><td>84</td></tr>
<tr><td>Sag</td><td>96</td><td>136</td><td>181</td><td>96</td></tr>
<tr><td rowspan="3">*Maximum Grade</td><td>Level</td><td rowspan="3">10.3</td><td colspan="3">3%</td><td rowspan="3">5%</td></tr>
<tr><td>Rolling</td><td colspan="3">4%</td></tr>
<tr><td>Mountainous</td><td colspan="3">5% (8)</td></tr>
<tr><td colspan="2">*Minimum Vertical Clearance (9)</td><td>10.6</td><td colspan="3">17.0’</td><td>17.0’</td></tr>
</table>

*** Controlling design criteria (see Section 8.8).**

Figure 12-2

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS (National Highway System — Interstate) Metric

Design Element			Manual Section	Rural			Urban
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years			20 Years
	*Design Speed	Level	8.3	110 km/h			80 km/h
		Rolling		100 km/h			
		Mountainous		80 km/h			
	Level of Service		8.4	B			B
Roadway Elements	*Travel Lane Width		11.2	4 @ 3.6 m			4 @ 3.6 m
	*Shoulder Width	Outside Shoulder	11.2	3.0 m (1)			3.0 m (1)
		Inside Shoulder		1.2 m (2)			1.2 m (2)
	Cross Slope	*Travel Lane	11.2	2%			2%
		Shoulder		2% (3)			2% (3)
	Median Width	Level	11.3	Minimum: 11 m			Desirable: **11 m** Minimum: 5 m (4)
		Rolling		Minimum: 11 m			
		Mountainous		Desirable: **11 m** Minimum: 5 m (4)			
Earth Cut Sections	Ditch	Inslope	11.4	6:1 (Width: 1.8 m)			6:1 (Width: 1.8 m)
		Width	11.4	3.0 m Min.			3.0 m
		Slope		20:1 towards back slope			20:1 towards back slope
	Back Slope; Cut Depth at Slope Stake (5)	0 m – 1.5 m	11.4	5:1			5:1
		1.5 m - 3.0 m		Level/Rolling: 4:1; Mountainous: 3:1			3:1
		3.0 m - 4.5 m		Level/Rolling: 3:1; Mountainous: 2:1			2:1
		> 4.5 m		Level/Rolling: 2:1; Mountainous: 1.5:1			1.5:1
Earth Fill Slopes	Fill Height at Slope Stake (6)	0 m - 3.0 m	11.4	6:1			6:1
		3.0 m - 6.0 m		4:1			4:1
		6.0 m - 9.0 m		3:1			3:1
		> 9.0 m		2:1			2:1
Alignment Elements	DESIGN SPEED		N/A	80 km/h	100 km/h	110 km/h	80 km/h
	*Stopping Sight Distance		8.6	130 m	185 m	220 m	130 m
	*Minimum Radius (e = 8.0%)		9.2	230 m	395 m	500 m	230 m
	*Superelevation Rate (7)		9.3	e_{max} = 8.0%			e_{max} = 8.0%
	*Vertical Curvature (K-value)	Crest	10.5	26	52	74	26
		Sag		30	45	55	30
	*Maximum Grade	Level	10.3	3%			5%
		Rolling		4%			
		Mountainous		5% (8)			
	*Minimum Vertical Clearance (9)		10.6	5.20 m			5.20 m

* Controlling design criteria (see Section 8.8).

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS (National Highway System — Interstate)

Footnotes to Figure 12-2

(1) Outside Shoulder Width. In mountainous terrain, these may be reduced to a 8' (2.4 m) minimum width where costs would be prohibitive to provide wider shoulders.

(2) Inside Shoulder Width. The following will apply:

a. For 3 or more through lanes in one direction, inside shoulders will be 10' (3.0 m) wide.

b. Where continuous curbs are used in narrow medians on ramps, the inside shoulder should desirably be 2' (0.5 m) and a minimum of 1' (0.3 m).

c. Where vertical elements (other than abutments, piers or walls) in the median are more than 1' (0.3 m) high, the minimum offset from the edge of travel lane to the element is 4' (1.2 m).

(3) Shoulder Cross Slope. Existing shoulder slopes on existing freeways may be 3.75%. If the proposed pavement work is resurfacing, the existing 3.75% slope may be retained. If the proposed pavement work is full-depth reconstruction or major rehabilitation, the shoulder slope should match the cross slope of the traveled way, typically 2%.

(4) Minimum Median Width. The minimum median width of 10' (3.0 m) may be used in urban areas with high right-of-way costs and in rugged mountainous terrain. It may also be used on any long and unusually costly bridges. The minimum median width should be the width of the two inside shoulders and the width of the base of the barrier.

(5) Cut Slopes (Rock). The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(6) Fill Slopes (Rock). In rock fills over 10' (3.0 m) high, the typical fill slope is 1.5:1. In rock fills ≤ 10' (3.0 m), the typical slope is 6:1.

(7) Superelevation Rate. See Section 9.3 for superelevation rates based on design speed and curve radii.

(8) Maximum Grade (Mountainous). Gradients of up to 7% may be provided with approval by the Preconstruction Engineer. FHWA approval may also be required.

(9) Minimum Vertical Clearance. The clearances apply to a freeway passing under a bridge. The minimum clearance includes a 6" (150 mm) additional allowance for future overlays.

Figure 12-3

GEOMETRIC DESIGN CRITERIA FOR RURAL PRINCIPAL ARTERIALS (National Highway System — Non Interstate) U.S. Customary

Design Element			Manual Section	Design Criteria		
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		
	*Design Speed	Level	8.3	70 mph		
		Rolling		60 mph		
		Mountainous		50 mph		
	Level of Service		8.4	Level/Rolling: B Mountainous: C		
Roadway Elements	*Travel Lane Width		11.2	12' (2)		
	*Shoulder Width		11.2	Varies (2)		
	Cross Slope	*Travel Lane	11.2	2%		
		Shoulder		2%		
	Median Width		11.3	Varies (3)		
Earth Cut Sections	Ditch	Inslope	11.4	6:1 (Width: 10')		
		Width	11.4	10' Min.		
		Slope		20:1 towards back slope		
	Back Slope; Cut Depth at SlopeStake (4)	0' – 5'	11.4	5:1		
		5' – 10'		Level/Rolling: 4:1; Mountainous: 3:1		
		10' – 15'		Level/Rolling: 3:1; Mountainous: 2:1		
		15' – 20'		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 20'		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (5)	0' – 10'	11.4	6:1		
		10' – 20'		4:1		
		20' – 30'		3:1		
		> 30'		2:1		
Alignment Elements	DESIGN SPEED		N/A	50 mph	60 mph	70 mph
	*Stopping Sight Distance		8.6	425'	570'	730'
	Passing Sight Distance		8.6	1835'	2135'	2480'
	*Minimum Radius (e=8.0%)		9.2	760'	1200'	1810'
	*Superelevation Rate (6)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	84	151	247
		Sag		96	136	181
	*Maximum Grade	Level	10.3	3%		
		Rolling		4%		
		Mountainous		7%		
	Mimimum Vertical Clearance (7)		10.6	17.0'		

* Controlling design criteria (see Section 8.8).

Figure 12-3

GEOMETRIC DESIGN CRITERIA FOR RURAL PRINCIPAL ARTERIALS (National Highway System — Non Interstate) Metric

Design Element			Manual Section	Design Criteria		
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		
	*Design Speed	Level	8.3	110 km/h		
		Rolling		100 km/h		
		Mountainous		80 km/h		
	Level of Service		8.4	Level/Rolling: B Mountainous: C		
Roadway Elements	*Travel Lane Width		11.2	3.6 m (2)		
	*Shoulder Width		11.2	Varies (2)		
	Cross Slope	*Travel Lane	11.2	2%		
		Shoulder		2%		
	Median Width		11.3	Varies (3)		
Earth Cut Sections	Ditch	Inslope	11.4	6:1 (Width: 3.0 m)		
		Width	11.4	3.0 m Min.		
		Slope		20:1 towards back slope		
	Back Slope; Cut Depth at SlopeStake (4)	0 - 1.5 m	11.4	5:1		
		1.5 m - 3.0 m		Level/Rolling: 4:1; Mountainous: 3:1		
		3.0 m - 4.5 m		Level/Rolling: 3:1; Mountainous: 2:1		
		4.5 m – 6.0 m		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 6.0 m		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (5)	0 - 3.0 m	11.4	6:1		
		3.0 m - 6.0 m		4:1		
		6.0 m - 9.0 m		3:1		
		> 9.0 m		2:1		
Alignment Elements	DESIGN SPEED		N/A	80 km/h	100 km/h	110 km/h
	*Stopping Sight Distance		8.6	130 m	185 m	220 m
	Passing Sight Distance		8.6	550 m	675m	750 m
	*Minimum Radius (e=8.0%)		9.2	230 m	395 m	500 m
	*Superelevation Rate (6)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	26	52	74
		Sag		30	45	55
	*Maximum Grade	Level	10.3	3%		
		Rolling		4%		
		Mountainous		7%		
	Mimimum Vertical Clearance (7)		10.6	5.20 m		

* Controlling design criteria (see Section 8.8).

GEOMETRIC DESIGN CRITERIA FOR RURAL PRINCIPAL ARTERIALS
(National Highway System — Non Interstate)

Footnotes to Figure 12-3

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Travel Lane/Shoulder Width. See the accompanying Route Segment Map to determine the applicable roadway width for the facility under design. Reconstruction projects will be designed in accordance with the criteria in Figure 12-3. **For pavement preservation projects**, the objective is to provide the maximum roadway width. This is accomplished by the following:

a. If the existing width exceeds the Route Segment width, the overlay should be accommodated by reducing the top width. If accommodating the overlay would result in a roadway width less than the Route Segment width, narrow the roadway width to a width equal to or greater than the Route Segment width, before steeping the inslopes.

b. If the overlay will result in a roadway width less than the Route Segment width, steepen the surfacing inslopes to no steeper than 4:1 to maximize the roadway width.

c. If the Route Segment width cannot be achieved with surfacing inslopes no steeper than 4:1, the roadway width may be reduced. In no case can the roadway width be reduced to less than 28’ (8.4 m).

If widening (other than inslope dressing) is necessary to provide at least an 28’ (8.4 m) roadway width with 4:1 surfacing inslopes, the project should be considered an "overlay and widening" project, and the roadway should be widened to the criteria in the accompanying Route Segment Map. This does not preclude some earthwork for safety purposes.

If 25% of an overlay and widening project or pavement preservation project requires intermittent reconstruction, then reconstruct the entire project to meet the criteria in Figure 12-3.

(3) Median Width. For two-way, left-turn lanes in rural conditions, the minimum width is 14’ (4.2 m). See Section 11.3 for additional information on median widths.

(4) Cut Slopes (Rock). The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(5) Fill Slopes (Rock). In rock fills over 10’ (3.0 m) high, the typical fill slope is 1.5:1. In rock fills ≤ 10’ (3.0 m), the typical slope is 6:1.

(6) Superelevation Rate. See Section 9.3 for superelevation rates based on design speed and curve radii.

(7) Minimum Vertical Clearance. The clearances apply to the arterial passing under a bridge. The minimum clearance includes a 6” (150 mm) additional allowance for future overlays.

Route Segment Plan
(Freeways/Principal Arterials)
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Route Segment Plan
(Freeways/Principal Arterials)
(To Be Inserted By The Department)

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Figure 12-4

GEOMETRIC DESIGN CRITERIA FOR RURAL MINOR ARTERIALS (Non-NHS — Primary) U.S. Customary

Design Element			Manual Section	Design Criteria		
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		
	*Design Speed	Level	8.3	60 mph		
		Rolling		55 mph		
		Mountainous		45 mph		
	*Level of Service		8.4	Level/Rolling: B Mountainous: C		
Roadway Elements	*Travel Lane Width		11.2	12’ (2)		
	*Shoulder Width		11.2	Varies (2)		
	Cross Slope	*Travel Lane	11.2	2%		
		Shoulder		2%		
	Median Width		11.3	Varies (3)		
Earth Cut Sections	Ditch	Inslope	11.4	6:1 (Width: 10’)		
		Width	11.4	10’ Min.		
		Slope		20:1 towards back slope		
	Back Slope; Cut Depth at Slope Stake (4)	0’ – 5’	11.4	5:1		
		5’ – 10’		Level/Rolling: 4:1; Mountainous: 3:1		
		10’ – 15’		Level/Rolling: 3:1; Mountainous: 2:1		
		15’ – 20’		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 20’		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (5)	0’ – 10’	11.4	6:1		
		10’ – 20’		4:1		
		20’ – 30’		3:1		
		> 30’		2:1		
Alignment Elements	DESIGN SPEED		N/A	45 mph	55 mph	60 mph
	*Stopping Sight Distance		8.6	360’	495’	570’
	Passing Sight Distance		8.6	1625’	1885’	2135’
	*Minimum Radius (e=8.0%)		9.2	590’	960’	1200’
	*Superelevation Rate (6)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	61	114	151
		Sag		79	115	136
	*Maximum Grade	Level	10.3	3%		
		Rolling		4%		
		Mountainous		7%		
	*Minimum Vertical Clearance (7)		10.6	17.0’		

* Controlling design criteria (see Section 8.8).

Figure 12-4

GEOMETRIC DESIGN CRITERIA FOR RURAL MINOR ARTERIALS (Non-NHS — Primary) Metric

Design Element			Manual Section	Design Criteria		
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		
	*Design Speed	Level	8.3	100 km/h		
		Rolling		90 km/h		
		Mountainous		70 km/h		
	*Level of Service		8.4	Level/Rolling: B Mountainous: C		
Roadway Elements	*Travel Lane Width		11.2	3.6 m (2)		
	*Shoulder Width		11.2	Varies (2)		
	Cross Slope	*Travel Lane	11.2	2%		
		Shoulder		2%		
	Median Width		11.3	Varies (3)		
Earth Cut Sections	Ditch	Inslope	11.4	6:1 (Width: 3.0 m)		
		Width	11.4	3.0 M Min.		
		Slope		20:1 towards back slope		
	Back Slope; Cut Depth at Slope Stake (4)	0 - 1.5 m	11.4	5:1		
		1.5 m - 3.0 m		Level/Rolling: 4:1; Mountainous: 3:1		
		3.0 m - 4.5 m		Level/Rolling: 3:1; Mountainous: 2:1		
		4.5 m - 6.0 m		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 6.0 m		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (5)	0 - 3.0 m	11.4	6:1		
		3.0 m - 6.0 m		4:1		
		6.0 m - 9.0 m		3:1		
		> 9.0 m		2:1		
Alignment Elements	DESIGN SPEED		N/A	70 km/h	90 km/h	100 km/h
	*Stopping Sight Distance		8.6	105 m	160 m	185 m
	Passing Sight Distance		8.6	490 m	615 m	675 m
	*Minimum Radius (e=8.0%)		9.2	175 m	305 m	395 m
	*Superelevation Rate (6)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	17	39	52
		Sag		23	38	45
	*Maximum Grade	Level	10.3	3%		
		Rolling		4%		
		Mountainous		7%		
	*Minimum Vertical Clearance (7)		10.6	5.20 m		

* Controlling design criteria (see Section 8.8).

GEOMETRIC DESIGN CRITERIA FOR RURAL MINOR ARTERIALS (Non-NHS — Primary)

Footnotes to Figure 12-4

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Travel Lane/Shoulder Width. See the accompanying Route Segment Map to determine the applicable roadway width for the facility under design. Reconstruction projects will be designed in accordance with the criteria in Figure 12-4. **For pavement preservation projects**, the objective is to provide the maximum roadway width. This is accomplished by the following:

a. If the existing width exceeds the Route Segment width, the overlay should be accommodated by reducing the top width. If accommodating the overlay would result in a roadway width less than the Route Segment width, narrow the roadway width to a width equal to or greater than the Route Segment width, before steepening the inslopes.

b. If the overlay will result in a roadway width less than the Route Segment width, steepen the surfacing inslopes to no steeper than 4:1 to maximize the roadway width.

c. If the Route Segment width cannot be achieved with surfacing inslopes no steeper than 4:1, the roadway width may be reduced. In no case can the roadway width be reduced to less than 28’ (8.4 m).

If widening (other than inslope dressing) is necessary to provide at least an 28’ (8.4 m) roadway width with 4:1 surfacing inslopes, the project should be considered an "overlay and widening" project, and the roadway should be widened to the criteria in the accompanying Route Segment Map. This does not preclude some earthwork for safety purposes.

If 25% of an overlay and widening project or pavement preservation project requires intermittent reconstruction, then reconstruct the entire project to meet the criteria in Figure 12-4.

(3) Median Width. For two-way, left-turn lanes in rural conditions, the minimum width is 14’ (4.2 m). See Section 11.3 for additional information on median widths.

(4) Cut Slopes (Rock). The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(5) Fill Slopes (Rock). In rock fills over 10’ (3.0 m) high, the typical fill slope is 1.5:1. In rock fills ≤ 10’ (3.0 m), the typical slope is 6:1.

(6) Superelevation Rate. See Section 9.3 for superelevation rates based on design speed and curve radii.

(7) Minimum Vertical Clearance. The clearances apply to the arterial passing under a bridge. The minimum clearance includes a 6” (150 mm) additional allowance for future overlays.

Route Segment Plan
(Minor Arterials)
(To Be Inserted By The Department)

11 X 17 Insert
After this page

Route Segment Plan
(Minor Arterials)
(To Be Inserted By The Department)

11 X 17 Insert
Before this page

Figure 12-5

GEOMETRIC DESIGN CRITERIA FOR RURAL COLLECTOR ROADS (Secondary System) U.S. Customary

Design Element			Manual Section	Design Criteria				
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)				
	*Design Speed	Level	8.3	60 mph				
		Rolling		50 mph				
		Mountainous		45 mph				
	Level of Service		8.4	Desirable: **B** Minimum: C				
Roadway Elements	TRAFFIC	Current AADT	N/A	0-299	300-999	1000-1999	2000-3000	> 3000
		DHV		50-99	100-199	200-299	300-400	>400
	*Roadway Width (Travel Lanes & Shoulders) (2)		11.2	24’	28’	32’	36’	40’
	Cross Slope	*Travel Lane	11.2	2%				
		Shoulder		2%				
	Median Width		11.3	Varies (3)				
Earth Cut Section	Ditch (4)	Inslope	11.4	DHV □ 200 — 6:1 (Width: 10’) DHV < 200 — 4:1 (Width: 6’)				
		Width	11.4	10’ Min.				
		Slope		20:1 towards back slope				
	Back Slope; Cut Depth at Slope Stake (5)	0’ – 5’	11.4	5:1				
		5’ – 10’		Level/Rolling: 4:1; Mountainous: 3:1				
		10’ – 15’		Level/Rolling: 3:1; Mountainous: 2:1				
		15’ – 20’		Level/Rolling: 2:1; Mountainous: 1.5:1				
		> 20’		1.5:1				
Earth Fill Slopes	Fill Height at Slope Stake (6)	0’ – 10’	11.4	DHV □ ≥ 200 - 6:1 DHV < 200 — 4:1				
		10’ – 20’		DHV □ ≥ 200 - 4:1 DHV < 200 — 3:1				
		20’ – 30’		3:1				
		> 30’		2:1				
Alignment Elements	DESIGN SPEED		N/A	45 mph	50 mph	60 mph		
	*Stopping Sight Distance		8.6	360’	425’	570’		
	Passing Sight Distance		8.6	1625’	1835’	2135’		
	*Minimum Radius (e=8.0%)		9.2	590’	760’	1200’		
	*Superelevation Rate (7)		9.3	emax = 8.0%				
	*Vertical Curvature (K-value)	Crest	10.5	61	84	151		
		Sag		79	96	136		
	*Maximum Grade	Level	10.3	5%				
		Rolling		7%				
		Mountainous		10%				
	*Minimum Vertical Clearance (8)		10.6	16.5’				

* Controlling design criteria (see Section 8.8).

Figure 12-5

GEOMETRIC DESIGN CRITERIA FOR RURAL COLLECTOR ROADS (Secondary System) Metric

Design Element			Manual Section	Design Criteria				
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)				
	*Design Speed	Level	8.3	100 km/h				
		Rolling		80 km/h				
		Mountainous		70 km/h				
	Level of Service		8.4	Desirable: **B** Minimum: C				
Roadway Elements	TRAFFIC	Current AADT	N/A	0-299	300-999	1000-1999	2000-3000	> 3000
		DHV		50-99	100-199	200-299	300-400	>400
	*Roadway Width (Travel Lanes & Shoulders) (2)		11.2	7.2 m	8.4 m	9.6 m	10.8 m	12.0 m
	Cross Slope	*Travel Lane	11.2	2%				
		Shoulder		2%				
	Median Width		11.3	Varies (3)				
Earth Cut Section	Ditch (4)	Inslope	11.4	DHV □ 200 — 6:1 (Width: 3.0 m) DHV < 200 — 4:1 (Width: 2.0 m)				
		Width	11.4	3.0 m Min.				
		Slope		20:1 towards back slope				
	Back Slope; Cut Depth at Slope Stake (5)	0 - 1.5 m	11.4	5:1				
		1.5 m - 3.0 m		Level/Rolling: 4:1; Mountainous: 3:1				
		3.0 m - 4.5 m		Level/Rolling: 3:1; Mountainous: 2:1				
		4.5 m – 6.0 m		Level/Rolling: 2:1; Mountainous: 1.5:1				
		> 6.0 m		1.5:1				
Earth Fill Slopes	Fill Height at Slope Stake (6)	0 - 3.0 m	11.4	DHV □ ≥ 200 — 6:1 DHV < 200 — 4:1				
		3.0 m - 6.0 m		DHV □ ≥ 200 — 4:1 DHV < 200 — 3:1				
		6.0 m - 9.0 m		3:1				
		> 9.0 m		2:1				
Alignment Elements	DESIGN SPEED		N/A	70 km/h	80 km/h	100 km/h		
	*Stopping Sight Distance		8.6	105 m	130 m	185 m		
	Passing Sight Distance		8.6	490 m	550 m	675 m		
	*Minimum Radius (e=8.0%)		9.2	175 m	230 m	395 m		
	*Superelevation Rate (7)		9.3	e_{max} = 8.0%				
	*Vertical Curvature (K-value)	Crest	10.5	17	26	52		
		Sag		23	30	45		
	*Maximum Grade	Level	10.3	5%				
		Rolling		7%				
		Mountainous		10%				
	*Minimum Vertical Clearance (8)		10.6	5.05 m				

* Controlling design criteria (see Section 8.8).

GEOMETRIC DESIGN CRITERIA FOR RURAL COLLECTOR ROADS (Non-NHS — Secondary)

Footnotes to Figure 12-5

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Travel Lane/Shoulder Width. Reconstruction projects will be designed in accordance with the criteria in Figure 12-5. **For pavement preservation projects**, the objective is to provide the maximum roadway width. This is accomplished by the following:

d. If the ADT ≥ 300 or DHV ≥ 100 and the top width exceeds 28' (8.4 m), the overlay should be accommodated by reducing the roadway to a width greater than or equal to 28' (8.4 m). If the ADT < 300 or DHV < 100 and the existing top width exceeds 24' (7.2 m), the overlay should be accommodated by reducing the roadway to a width greater than or equal to 24' (7.2 m).

e. If the overlay will result in a roadway width less than 24' (7.2 m) or 28' (8.4 m) as determined by the ADT or DHV described above, steepen the surfacing inslopes to no steeper than 4:1 to maximize the roadway width.

If widening (other than inslope dressing) is necessary to provide at least a 24' (7.2 m) or 28' (8.4 m) roadway width as determined by the ADT or DHV described above with 4:1 surfacing inslopes, the project should be considered an "overlay and widening" project. Consequently, the roadway should be widened in accordance with the criteria in Figure 12-5.

If the roadway width is less than 28' (8.4 m), add 2' (0.6 m) to each side of the roadway where a barrier is located.

If 25% of the overlay and widening project or pavement preservation project requires intermittent reconstruction, then the entire project should be reconstructed to meet the criteria in Figure 12-5.

(3) Median Width. For two-way, left-turn lanes in rural conditions, the minimum width is 14' (4.2 m). See Section 11.3 for additional information on median widths.

(4) Ditch. A V-ditch may be used with an approved design exception. For backslopes steeper than 4:1, place the toe of the backslope outside the clear zone.

(5) Cut Slopes. The designer should attempt to locate back slopes steeper than 4:1 outside the clear zone. The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(6) Fill Slopes (Rock). In rock fills over 10' (3.0 m) high, the typical fill slope is 1.5:1. In rock fills ≤ 10' (3.0 m), the typical slope is 6:1.

(7) Superelevation Rate. See Section 9.3 for superelevation rates based on design speed and curve radii.

(8) Minimum Vertical Clearance. The clearances apply to the collector passing under a bridge. The minimum clearance includes a 6" (150 mm) additional allowance for future overlays.

Figure 12-6

GEOMETRIC DESIGN CRITERIA FOR RURAL LOCAL ROADS (Off-System BR Projects) U.S. Customary

Design Element			Manual Section	Design Criteria		
Design Controls	Current ADT		N/A	≤ 300 (1)		
	*Design Speed	Paved Surface	8.3	50 mph (2)		
		Gravel Surface		45 mph (2)		
Roadway Elements	*Minimum Roadway Width		11.2	24’ (3)		
	Cross Slope	*Travel Lane	11.2	Paved: 2% Gravel: 3%		
		Shoulder		Paved: 2% Gravel: 3%		
	Median Width		11.3	Varies (4)		
Earth Cut Sections	Inslope		11.4	4:1		
	Ditch (5)		11.4	V-Ditch (1.5’ Depth)		
	Back Slope; Cut Depth at Slope Stake (6)	0’ – 5’	11.4	4:1		
		5’ – 10’		Level/Rolling: 3:1; Mountainous: 2:1		
		10’ – 15’		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 15’		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (7)	0’ – 10’	11.4	4:1		
		10’ – 20’		3:1		
		> 20’		1.5:1		
Alignment Elements	DESIGN SPEED		N/A	30 mph	45 mph	50 mph
	*Stopping Sight Distance		8.6	200’	360’	425’
	Passing Sight Distance		8.6	1090’	1625’	1835’
	*Minimum Radius (e=8.0%)		9.2	220’	590’	760’
	*Superelevation Rate (8)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	19	61	84
		Sag		37	79	96
	*Maximum Grade	Level	10.3	7%	7%	6%
		Rolling		10%	9%	8%
		Mountainous		10%	10%	10%
	*Minimum Vertical Clearance (9)		10.6	14.5’		

* Controlling design criteria (see Section 8.8).

Figure 12-6

GEOMETRIC DESIGN CRITERIA FOR RURAL LOCAL ROADS (Off-System BR Projects) Metric

Design Element			Manual Section	Design Criteria		
Design Controls	Current ADT		N/A	≤ 300 (1)		
	*Design Speed	Paved Surface	8.3	80 km/h (2)		
		Gravel Surface		70 km/h (2)		
Roadway Elements	*Minimum Roadway Width		11.2	7.2 m (3)		
	Cross Slope	*Travel Lane	11.2	Paved: 2% Gravel: 3%		
		Shoulder		Paved: 2% Gravel: 3%		
	Median Width		11.3	Varies (4)		
Earth Cut Sections	Inslope		11.4	4:1		
	Ditch (5)		11.4	V-Ditch (0.3 m Depth)		
	Back Slope; Cut Depth at Slope Stake (6)	0 - 1.5 m	11.4	4:1		
		1.5 m - 3.0 m		Level/Rolling: 3:1; Mountainous: 2:1		
		3.0 m – 4.50 m		Level/Rolling: 2:1; Mountainous: 1.5:1		
		> 4.50 m		1.5:1		
Earth Fill Slopes	Fill Height at Slope Stake (7)	0 - 3.0 m	11.4	4:1		
		3.0 – 6.0 m		3:1		
		> 6.0 m		1.5:1		
Alignment Elements	DESIGN SPEED		N/A	50 km/h	70 km/h	80 km/h
	*Stopping Sight Distance		8.6	65 m	105 m	130 m
	Passing Sight Distance		8.6	350 m	490 m	550 m
	*Minimum Radius (e=8.0%)		9.2	85 m	175 m	230 m
	*Superelevation Rate (8)		9.3	e_{max} = 8.0%		
	*Vertical Curvature (K-value)	Crest	10.5	7	17	26
		Sag		13	23	30
	*Maximum Grade	Level	10.3	7%	7%	6%
		Rolling		10%	9%	8%
		Mountainous		10%	10%	10%
	*Minimum Vertical Clearance (9)		10.6	4.40 m		

Controlling design criteria (see Section 8.8).

GEOMETRIC DESIGN CRITERIA FOR RURAL LOCAL ROADS
(Off-System BR Projects)

Footnotes to Figure 12-6

(1) AADT. For local rural roads with current AADT > 300 and/or functionally classified as a rural collector, the design criteria for rural collector roads should be used (Figure 12-5). For local roads with current AADT < 300 design the project using one of the following:

a. County standards – note that many counties do not have standards

b. The design criteria provided in Figure 12-6

c. AASHTO's *Guidelines for Geometric Design of Very Low-Volume Local Roads*. Use these guidelines only if it is not practical to meet the criteria in figure 12-6.

(2) Design Speed. See Section 8.3 for selection of design speed. For local roads requiring a higher design speed, the criteria for rural collector roads should be used (Figure 12-5). The 30 mph (50 km/h) design speed should only be used if the adjacent terrain presents obstacles that render the use of a higher design speed impractical. A formal design exception for design speed is not required for rural local roads. However, deviation from the design speeds in Figure 12-6 must be documented in the PFR, AGR and SOW reports.

(3) Roadway Width. The bridge width, adjacent paved traveled way width and county standards should be considered when establishing a roadway width, if greater than the minimum. Bridges will typically provide a minimum roadway width of 28' (8.4 m). This width should be utilized to the end of the approach guardrail.

(4) Median Width. For two-way, left-turn lanes in rural conditions, the minimum width is 14' (4.2 m). See Section 11.3 for additional information on median widths.

(5) Ditch. V-ditches can be used without prior approval. The designer should attempt to make the ditch traversable or locate it outside of the clear zone.

(6) Cut Slopes (Rock). The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(7) Fill Slopes. In rock fills over 3.0 m high, the typical fill slope is 1.5:1. In rock fills ≤ 3.0 m, the typical fill slope is 4:1. In earth fills where the fill depth > 6.0 m, the use of steeper than 1.5:1 slopes may be used if justified by a slope stability analysis.

(8) Superelevation Rate. See Section 9.3 for superelevation rates based on design speed and curve radii.

(9) Minimum Vertical Clearance. The clearances apply to the local road passing under a bridge. The minimum clearance includes a 150 mm additional allowance for future overlays.

Figure 12-7

GEOMETRIC DESIGN CRITERIA FOR URBAN PRINCIPAL ARTERIALS
(National Highway System — Non Interstate) U.S. Customary

Design Element			Manual Section	2-Lane		Multi-lane	
				Curbed	Uncurbed	Curbed	Uncurbed
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		20 Years (1)	
	*Design Speed (2)		8.3	40 –45 mph	40-50 mph	40-45 mph	40-55 mph
	Level of Service		8.4	Desirable: **B** Minimum: **C**		Desirable: **B** Minimum: **C**	
Roadway Elements	*Travel Lane Width		11.2	12’		12’	
	*Shoulder Width (3)	Outside	11.2	varies	varies	varies	varies
		Inside		N/A		2.0’	4’
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%	2% Typical (4)	2%
	Median Width		11.3	N/A		Flush: 4’ - 16’ (5) Raised: 20’(5)	
	TWLTL Width		11.2	16’		16’	
Earth Cut Sections	Ditch	Inslope	11.4	N/A	6:1 (Des\4:1 Min)	N/A	6:1(Des\ 4:1 Min)
		Width	11.4	N/A	10’ Min. (6)	N/A	10’ (6)
		Slope		N/A	20:1 towards back slope	N/A	20:1 towards back slope
	Back Slope; Cut Depth at Slope Stake (7)	0’ – 5’	11.4	5:1		5:1	
		5’ – 10’		L/R: 4:1 Mt: 3:1		3:1	
		10’ – 15’		L/R: 3:1 Mt: 2:1		2:1	
		15’ – 20’		L/R: 2:1 Mt: 1.5:1		1.5:1	
		> 20’		1.5:1		1.5:1	
Earth Fill Slopes	Fill Height at Slope Stake (8)	0’ – 10’	11.4	6:1	6:1	6:1	6:1
		10’ – 20’		4:1	4:1	4:1	4:1
		20’ – 30’		3:1	3:1	3:1	3:1
		> 30’		2:1	2:1	2:1	2:1
Alignment Elements (11)	DESIGN SPEED		N/A	40 mph	45 mph	50 mph	55 mph
	*Stopping Sight Distance		8.6	305’	360’	425’	495’
	*Minimum Radius		9.2	533’	711’	760’	960’
	*Superelevation Rate (9)		9.3 & 9.4	e_{max} = 4.0%		e_{max} = 8.0%	
	*Vertical Curvature (K-value)	Crest	10.5	44	61	84	114
		Sag		64	79	96	115
	*Maximum Grade	Level	10.3	6%	6%	6%	5%
		Rolling		7%	7%	7%	6%
		Mountainous		9%	9%	9%	8%
	*Minimum Vertical Clearance (10)		10.6	17.0’			

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

Figure 12-7

GEOMETRIC DESIGN CRITERIA FOR URBAN PRINCIPAL ARTERIALS (National Highway System — Non Interstate) Metric

Design Element			Manual Section	2-Lane		Multi-lane	
				Curbed	Uncurbed	Curbed	Uncurbed
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		20 Years (1)	
	*Design Speed (2)		8.3	60-70 km/h	70-80 km/h	60-70 km/h	60-90 km/h
	Level of Service		8.4	Desirable: **B** Minimum: **C**		Desirable: **B** Minimum: **C**	
Roadway Elements	*Travel Lane Width (3)		11.2	3.6 m		3.6 m	
	*Shoulder Width	Outside	11.2	0.6 m	2.4 m	0.6 m	2.4 m
		Inside		N/A		0.6 m	1.2 m
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%	2% Typical (4)	2%
	Median Width		11.3	N/A		Flush: 1.2 m - 5.0 m (5) Raised: 6.0 m (5)	
	TWLTL Width		11.2	4.8 m		4.8 m	
Earth Cut Sections	Ditch	Inslope	11.4	N/A	6:1(Des\4:1 Min)	N/A	6:1(Des\4:1 Min)
		Width	11.4	N/A	3.0 m Min. (6)	N/A	3.0 m (6)
		Slope		N/A	20:1 towards back slope	N/A	20:1 towards back slope
	Back Slope; Cut Depth at Slope Stake (7)	0 - 1.5 m	11.4	5:1		5:1	
		1.5 m - 3.0 m		L/R: 4:1 Mt: 3:1		3:1	
		3.0 m - 4.5 m		L/R: 3:1 Mt: 2:1		2:1	
		4.5 m – 6.0 m		L/R: 2:1 Mt: 1.5:1		1.5:1	
		> 6.0 m		1.5:1		1.5:1	
Earth Fill Slopes	Fill Height at Slope Stake (8)	0 - 3.0 m	11.4	6:1	6:1	6:1	6:1
		3.0 m - 6.0 m		4:1	4:1	4:1	4:1
		6.0 m - 9.0 m		3:1	3:1	3:1	3:1
		> 9.0 m		2:1	2:1	2:1	2:1
Alignment Elements (11)	DESIGN SPEED		N/A	60 km/h	70 km/h	80 km/h	90 km/h
	*Stopping Sight Distance		8.6	85 m	105 m	130 m	160 m
	*Minimum Radius		9.2	125 m	190 m	230 m	305 m
	*Superelevation Rate (9)		9.3 & 9.4	e_{max} = 4.0%		e_{max} = 8.0%	
	*Vertical Curvature (K-value)	Crest	10.5	11	17	26	39
		Sag		18	23	30	38
	*Maximum Grade	Level	10.3	6%	6%	6%	5%
		Rolling		7%	7%	7%	6%
		Mountainous		9%	9%	9%	8%
	*Minimum Vertical Clearance (10)		10.6	5.20 m			

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

GEOMETRIC DESIGN CRITERIA FOR URBAN PRINCIPAL ARTERIALS
(National Highway System — Non Interstate))

Footnotes to Figure 12-7

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Design Speed. The design speed for urban principal arterials should match the conditions and driver expectancy. The lower design speed should be used in more crowded business areas and areas where signalization at successive intersections regulates speed. The higher design speed should be used in all other non-transitional urban areas. In the transitional areas between rural and urban sections of roadway, the use of the criteria for rural principal arterials is generally appropriate. However, the determination of the design speed for transitional areas should be based on consideration of roadside development, number and type of approaches, lane configuration and traffic control devices.

(3) Travel Lane Width. The shoulder width is measured to the face of the curb. The shoulder width should correspond to the Route Segment Plan widths. Other considerations such as bicycle use and parking should be evaluated in determining shoulder width. An 8’ (2.4 m) outside shoulder is preferred on all multilane facilities.

(4) Cross Slopes (Curbed). The cross slope may be between 1% and 4%, depending on site conditions.

(5) Median Width. See Section 11.3 for more information on median width.

(6) Ditch. The preferred ditch width is 10’ (3 m). However, site constraints often make the use of this width impractical. If the use of a v-ditch is necessary, it should be traversable or the hinge point should be located outside of the clear zone. A design exception is required for the use of a narrower ditch.

(7) Cut Slopes. For curbed sections, see the typical section figures in Section 11.7. The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(8) Fill Slopes. For curbed sections, see the typical section figures in Section 11.7. In rock fills over 3.0 m high, the typical fill slope is 1.5:1. In rock fills ≤ 3.0 m, the typical slope is 6:1.

(9) Superelevation Rate. See Section 9.3 or 9.4 for superelevation rates based on design speed and curve radii.

(10) Minimum Vertical Clearance. The clearances apply to the arterial passing under a bridge. The minimum clearance includes a 150 mm additional allowance for future overlays.

(11) Alignment Elements. If 25% or more of an overlay and widening project or pavement preservation project requires intermittent reconstruction, then reconstruct the entire alignment to meet the criteria in Figure 12-7.

(12) If the route is a principal arterial but is not on the National Highway System, refer to the *Montana Department of Transportation Geometric Design Standards for Urban and Developed Areas*.

Figure 12-8

GEOMETRIC DESIGN CRITERIA FOR URBAN MINOR ARTERIALS (Non-NHS) U.S. Customary

Design Element			Manual Section	2-Lane		Multi-lane	
				Curbed	Uncurbed	Curbed	Uncurbed
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		20 Years (1)	
	*Design Speed (2)		8.3	35 mph	35 mph	35 mph	35 mph
	Level of Service		8.4	Desirable: **B** Minimum: C		Desirable: **B** Minimum: C	
Roadway Elements	*Travel Lane Width		11.2	11' (3)		11' (3)	
	*Shoulder Width	Outside	11.2	0'	4'	0'	4'
		Inside		N/A		0'	4'
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%	2% Typical (4)	2%
	Median Width		11.3	N/A		Flush: 4' – 16' (5) Raised: 4 - 16 (5)	
	TWLTL Width		11.2	11'		11'	
Earth Cut Slopes	Ditch	Inslope	11.4	N/A	6:1(Des\4:1 Min)	N/A	6:1(Des\ 4:1 Min)
		Width	11.4	N/A	10' (6)	N/A	10' (6)
		Slope		N/A	20:1 towards back slope	N/A	20:1 towards back slope
	Back Slope; Cut Depth at Slope Stake (7)	0' – 5'	11.4	5:1		5:1	
		5' – 10'		L/R:4:1 Mt: 3:1		3:1	
		10' – 15'		L/R:3:1 Mt: 2:1		2:1	
		15' – 20'		L/R: 2:1 Mt:1.5:1		1.5:1	
		> 20'		1.5:1		1.5:1	
Earth Fill Slopes	Fill Height at Slope Stake (8)	0' – 10'	11.4	6:1	6:1	6:1	6:1
		10' – 20'		4:1	4:1	4:1	4:1
		20' – 30'		3:1	3:1	3:1	3:1
		> 30'		2:1	2:1	2:1	2:1
Alignment Elements (11)	DESIGN SPEED		N/A	30 mph	40 mph	50 mph	
	*Stopping Sight Distance		8.6	200'	305'	425'	
	*Minimum Radius		9.2	250'	533'	760'	
	*Superelevation Rate (9)		9.3 & 9.4	emax = 4.0%		emax = 8.0%	
	*Vertical Curvature (K-value)	Crest	10.5	19	44	84	
		Sag		37	64	96	
	*Maximum Grade	Level	10.3	7%	6%	6%	
		Rolling		8%	7%	7%	
		Mountainous		10%	9%	9%	
	*Minimum Vertical Clearance (10)		10.6	17.0'			

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

Figure 12-8

GEOMETRIC DESIGN CRITERIA FOR URBAN MINOR ARTERIALS (Non-NHS) Metric

Design Element			Manual Section	2-Lane		Multi-lane	
				Curbed	Uncurbed	Curbed	Uncurbed
Design Controls	Design Forecast Year (Geometrics)		8.4	20 Years (1)		20 Years (1)	
	*Design Speed (2)		8.3	50 km/h	60 km/h	60 km/h	60 km/h
	Level of Service		8.4	Desirable: **B** Minimum: C		Desirable: **B** Minimum: C	
Roadway Elements	*Travel Lane Width		11.2	3.6 m (3)		3.6 m	
	*Shoulder Width	Outside	11.2	0 m	1.2 m	0 m	D: 1.2m
		Inside		N/A		0 m	1.0 m
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%	2% Typical (4)	2%
	Median Width		11.3	N/A		Flush: 1.2 m - 5.0 m (5) Raised: 1.2m – 5.0 m (5)	
	TWLTL Width		11.2	3.3 m		3.3 m	
Earth Cut Slopes	Ditch	Inslope	11.4	N/A	6:1(Des\4:1 Min)	N/A	6:1 (Des\ 4:1 Min)
		Width	11.4	N/A	3.0 m (6)	N/A	3.0 m
		Slope		N/A	20:1 towards back slope	N/A	20:1 towards back slope
	Back Slope; Cut Depth at Slope Stake (7)	0 - 1.5 m	11.4	5:1		5:1	
		1.5 m - 3.0 m		L/R:4:1 Mt: 3:1		3:1	
		3.0 m - 4.5 m		L/R:3:1 Mt: 2:1		2:1	
		4.5 M – 6.0 m		L/R: 2:1 Mt:1.5:1		1.5:1	
		> 6.0 m		1.5:1		1.5:1	
Earth Fill Slopes	Fill Height at Slope Stake (8)	0 - 3.0 m	11.4	6:1	6:1	6:1	6:1
		3.0 m - 6.0 m		4:1	4:1	4:1	4:1
		6.0 m - 9.0 m		3:1	3:1	3:1	3:1
		> 9.0 m		2:1	2:1	2:1	2:1
Alignment Elements (11)	DESIGN SPEED		N/A	60 km/h	70 km/h	80 km/h	
	*Stopping Sight Distance		8.6	85 m	105 m	130 m	
	*Minimum Radius		9.2	125 m	190 m	230 m	
	*Superelevation Rate (9)		9.3 & 9.4	e_{max} = 4.0%		e_{max} = 8.0%	
	*Vertical Curvature (K-value)	Crest	10.5	11	17	26	
		Sag		18	23	30	
	*Maximum Grade	Level	10.3	7%	6%	6%	
		Rolling		8%	7%	7%	
		Mountainous		10%	9%	9%	
	*Minimum Vertical Clearance (10)		10.6	5.20 m			

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

GEOMETRIC DESIGN CRITERIA FOR URBAN MINOR ARTERIALS (Non-NHS)

Footnotes to Figure 12-8

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Design Speed. The design speed for urban minor arterials should match the conditions and driver expectancy. In the transitional areas between rural and urban sections of roadway the use of the criteria for rural minor arterials is generally appropriate. However, the determination of the design speed for transitional areas should be based on consideration of roadside development, number and type of approaches, lane configuration and traffic control devices.

(3) Travel Lane Width. The lane width does not include the gutter section. 12’ (3.6 m) lanes should be used on roadways that have curb without a gutter section.

(4) Cross Slopes (Curbed). The cross slope may be between 1% and 4%, depending on site conditions.

(5) Median Width. The median width is 4’ (1.2 m) plus the width of the exclusive left-turn lane. See Section 11.3 for more information on median width.

(6) Ditch. The preferred ditch width is 10’ (3 m). However, site constraints often make the use of this width impractical. If the use of a v-ditch is necessary, it should be traversable or the hinge point should be located outside of the clear zone. A design exception is not required for the use of a narrower ditch. However, the ditch configuration must be documented in the Scope of Work Report.

(7) Cut Slopes. For curbed sections, see the typical section figures in Section 11.7. The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(8) Fill Slopes. For curbed sections, see the typical section figures in Section 11.7. In rock fills over 3.0 m high, the typical fill slope is 1.5:1. In rock fills ≤ 3.0 m, the typical slope is 6:1.

(9) Superelevation Rate. See Section 9.3 or 9.4 for superelevation rates based on design speed and curve radii.

(10) Minimum Vertical Clearance. The clearances apply to the arterial passing under a bridge. The minimum clearance includes a 150 mm additional allowance for future overlays.

(11) Alignment Elements. If 25% or more of an overlay and widening project or pavement preservation project requires intermittent reconstruction, then reconstruct the entire alignment to meet the criteria in Figure 12-8.

Figure 12-9

GEOMETRIC DESIGN CRITERIA FOR URBAN COLLECTOR STREETS (Non-NHS) U.S. Customary

Design Element			Manual Section	Design Criteria	
				Curbed	Uncurbed
Design Contols	Design Forecast Year (Geometrics)		8.4	20 Years (1)	
	*Design Speed (2)		8.3	30 mph	30 mph
	Level of Service		8.4	Desirable: **C** Minimum: D	
Roadway Elements	* Travel Lane Width		11.2	10’ (3)	
	*Shoulder Width	Outside	11.2	0’	4’
		Inside		N/A	
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%
	TWLTL Width		11.2	11’	
Earth Cut Sections	Ditch	Inslope	11.4	N/A	4:1
		Width	11.4	N/A	10’ (5) Min.
		Slope		N/A	20:1 towards back slope (5)
	Back Slope; Cut Depth at Slope Stake (6)	0 – 5’	11.4	5:1	
		5’ - 10		L/R: 4:1 Mt: 3:1	
		10’ – 15’		L/R: 3:1 Mt: 2:1	
		15’ – 20		L/R: 2:1 Mt: 1.5:1	
		> 20’		1.5:1	
Earth Fill Sections	Fill Height at Slope Stake (7)	0 – 10’	11.4	6:1	6:1
		10’ – 20’		4:1	4:1
		20’ – 30’		3:1	3:1
		> 30’		2:1	2:1
Alignment Elements (10)	DESIGN SPEED		N/A	30 mph	35 mph
	*Stopping Sight Distance		8.6	200’	250’
	*Minimum Radius (@ e_{max} = 4%)		9.2	250’	371’
	*Superelevation Rate (8)		9.4	e_{max} = 4.0%	
	*Vertical Curvature (K-value)	Crest	10.5	19	29
		Sag		37	49
	*Maximum Grade	Level	10.3	9%	9%
		Rolling		10%	10%
		Mountainous		10%	10%
	*Minimum Vertical Clearance (9)		10.6	16.5’	

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

Figure 12-9

GEOMETRIC DESIGN CRITERIA FOR URBAN COLLECTOR STREETS (Non-NHS) Metric

Design Element			Manual Section	Design Criteria	
				Curbed	Uncurbed
Design Contols	Design Forecast Year (Geometrics)		8.4	20 Years (1)	
	*Design Speed		8.3	50 km/h	50 km/h
	Level of Service		8.4	Desirable: **C** Minimum: D	
Roadway Elements	* Travel Lane Width		11.2	3.0 m (2)	
	*Shoulder Width	Outside	11.2	0 m (3)	D: 1.2 m
		Inside		N/A	
	Cross Slope	*Travel Lane	11.2	2% Typical (4)	2%
		Shoulder		2% Typical (4)	2%
	TWLTL Width		11.2	3.3 m	
Earth Cut Sections	Ditch	Inslope	11.4	N/A	4:1
		Width	11.4	N/A	3.0 m (5)
		Slope		N/A	20:1 towards back slope (5)
	Back Slope; Cut Depth at Slope Stake (6)	0 - 1.5 m	11.4	5:1	
		1.5 m - 3.0 m		L/R: 4:1 Mt: 3:1	
		3.0 m - 4.5 m		L/R: 3:1 Mt: 2:1	
		4.5 m – 6.0 m		L/R: 2:1 Mt: 1.5:1	
		> 6.0 m		1.5:1	
Earth Fill Sections	Fill Height at Slope Stake (7)	0 - 3.0 m	11.4	6:1	6:1
		3.0 m - 6.0 m		4:1	4:1
		6.0 m - 9.0 m		3:1	3:1
		> 9.0 m		2:1	2:1
Alignment Elements (10)	DESIGN SPEED		N/A	50 km/h	60 km/h
	*Stopping Sight Distance		8.6	65 m	85 m
	*Minimum Radius (@ e_{max} = 4%)		9.2	80 m	125 m
	*Superelevation Rate (8)		9.4	e_{max} = 4.0%	
	*Vertical Curvature (K-value)	Crest	10.5	7	11
		Sag		13	18
	*Maximum Grade	Level	10.3	9%	9%
		Rolling		10%	10%
		Mountainous		10%	10%
	*Minimum Vertical Clearance (9)		10.6	5.05 m	

* Controlling design criteria (see Section 8.8). L/R: Level/Rolling Mt: Mountainous

GEOMETRIC DESIGN CRITERIA FOR URBAN COLLECTOR STREETS (Non-NHS)

Footnotes to Figure 12-9

(1) Design Forecast Year (Geometrics). For overlay and widening projects, the design year for geometrics is based on the design analysis period used for the pavement design, with 8 years as a minimum design forecast year.

(2) Design Speed. The design speed for urban major collectors should match the conditions and driver expectancy. In the transitional areas between rural and urban sections of roadway the use of the criteria for rural major collectors is generally appropriate. However, the determination of the design speed for transitional areas should be based on consideration of roadside development, number and type of approaches, lane configuration and traffic control devices

(3) Travel Lane Width*.* The lane width for curbed roadways does not include the gutter section. 11’ (3.3 m) lanes should be used on roadways that have curb without a gutter section. A minimum 11’ (3.3 m) lane width and 2’ (0.6m) clearance to the face of the curb should be used for collectors that primarily serve commercial/industrial areas.

(4) Cross Slopes (Curbed). The cross slope may be between 1% and 4%, depending on site conditions.

(5) Ditch. The preferred ditch width is 10’ (3 m). However, site constraints often make the use of this width impractical. If the use of a v-ditch is necessary, it should be traversable or the hinge point should be located outside of the clear zone. A design exception is not required for the use of a narrower ditch. However, the ditch width must be documented in the Scope of Work Report.

(6) Cut Slopes. For curbed sections, see the typical section figures in Section 11.7. The back slope through rock cut sections will be determined by the Geotechnical Section based on its field investigation. At a maximum, the back slope typically will not exceed 0.25:1. For large cuts, benching of the back slope may be required.

(7) Fill Slopes. For curbed sections, see the typical section figures in Section 11.7. In rock fills over 3.0 m high, the typical fill slope is 1.5:1. In rock fills ≤ 3.0 m, the typical slope is 6:1.

(8) Superelevation Rate. See Section 9.4 for superelevation rates based on design speed and curve radii.

(9) Minimum Vertical Clearance. The clearances apply to the collector street passing under a bridge. The minimum clearance includes a 150 mm additional allowance for future overlays.

(10) Alignment Elements. If 25% or more of an overlay and widening project or pavement preservation project requires intermittent reconstruction, then reconstruct the entire alignment to meet the criteria in Figure 12-9.

18 October 2016

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Thirteen
INTERSECTIONS AT-GRADE

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Chapter Thirteen
INTERSECTIONS AT-GRADE

13.1 GENERAL

13.1.1 Chapter Contents

The intersection is an important part of the highway system. The operational efficiency, capacity, safety and cost of the system depend largely upon its design, especially in urban areas. The primary objective of intersection design is to reduce potential conflicts between vehicles, bicycles and pedestrians while providing for the convenience, ease and comfort of those traversing the intersection. In general, the Geometrics Unit within the Traffic Engineering Section performs all work on the geometric design of major intersections including those with large trucks, pedestrians, turn lanes, turning roadways, etc. The Geometrics Unit will prepare all the necessary detail sheets to clearly identify all geometric features. The road designer will place these sheets into the final plans and will calculate the necessary roadway quantities for intersections and auxiliary lanes. Any revisions to these detail sheets will be conducted by the Geometrics Unit.

Chapter Thirteen discusses the geometric design of simple at-grade intersections typically conducted by the road designer including intersection alignment and profile, turn lane guidelines, intersection sight distance and approaches. Chapter Twenty-eight and other chapters of the *Traffic Engineering Manual* present considerably more information on intersections at-grade which may apply to a project administrated by the Road Design Section. These include:

1. design vehicles for intersections (Section 28.2.2);
2. intersection spacing (Section 28.2.3);
3. capacity and level of service (Chapter Thirty);
4. turning radii types and design (Section 28.3);
5. auxiliary turn lane designs including widths, turn lane lengths, offset turn lanes and dual turn lanes (Section 28.4);
6. turning roadways (Section 28.5);
7. intersection acceleration lanes (Section 28.6);

8. channelization (Section 28.7); and

9. median openings (Section 28.8).

13.1.2 Definitions

1. Approach. A road providing access from a public way to a highway, street, road, or to an abutting property.

2. Begin Curb Return (BCR). The point along the mainline pavement edge where the curb return of an intersection meets the tangent portion.

3. Channelization. The directing of traffic through an intersection by the use of pavement markings (including striping, raised reflectors, etc.), medial separators or raised islands.

4. Comfort Criteria. Criteria which is based on the comfort effect of change in vertical direction in a sag vertical curve because of the combined gravitational and centrifugal forces.

5. Corner Island. A raised or painted island to channel the right-turn movement.

6. Design Vehicle. The vehicle used to determine turning radii, off-tracking characteristics, pavement designs, etc., at intersections.

7. End Curb Return (ECR). The point along the minor roadway pavement edge where the curb return of an intersection meets the tangent portion.

8. Grade Separation. A crossing of two highways, or a highway and a railroad, at different levels.

9. Interchange. A system of ramps in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.

10. Intersection. The general area where two or more highways join or cross at grade.

11. Intersection Sight Distance (ISD). The sight distance required within the corners of intersections to safely allow a variety of vehicular access or crossing maneuvers based on the type of traffic control at the intersection.

12. Islands. Channelization (raised or flush) in which traffic passing on both sides is traveling in the same direction.

13. Landing Area. The area approaching an intersection for stopping and storage of vehicles.

14. Medial Separator. Channelization which separates opposing traffic flows, alerts the driver to the cross road ahead and regulates traffic through the intersection.

15. Median Opening. Openings in the median (raised or depressed) on divided facilities which allow vehicles to cross the facility or to make a U-turn.

16. No Control Intersection. An intersection where none of the legs are controlled by a traffic control device.

17. Parking Lane. An additional lane for the parking of vehicles.

18. Return. The circular segment of curb at an intersection which connects the tangent portions of the intersecting legs.

19. Signalized Intersection. An intersection where all legs are controlled by a traffic signal.

20. Stop Controlled Intersection. An intersection where one or more legs are controlled by a stop sign.

21. Turn Lane. An auxiliary lane adjoining the through traveled way for speed change, storage and turning.

22. Turning Roadway. A channelized roadway (created by an island) connecting two legs of an at-grade intersection. Interchange ramps are not considered turning roadways.

23. Turning Template. A graphic representation of a design vehicle's turning path depicting various angles of turns for use in determining acceptable turning radii designs.

24. Yield Controlled Intersection. An intersection where one or more legs are controlled by a yield sign.

13.2 GENERAL DESIGN CONTROLS

13.2.1 Intersection Alignment

13.2.1.1 Horizontal Curves

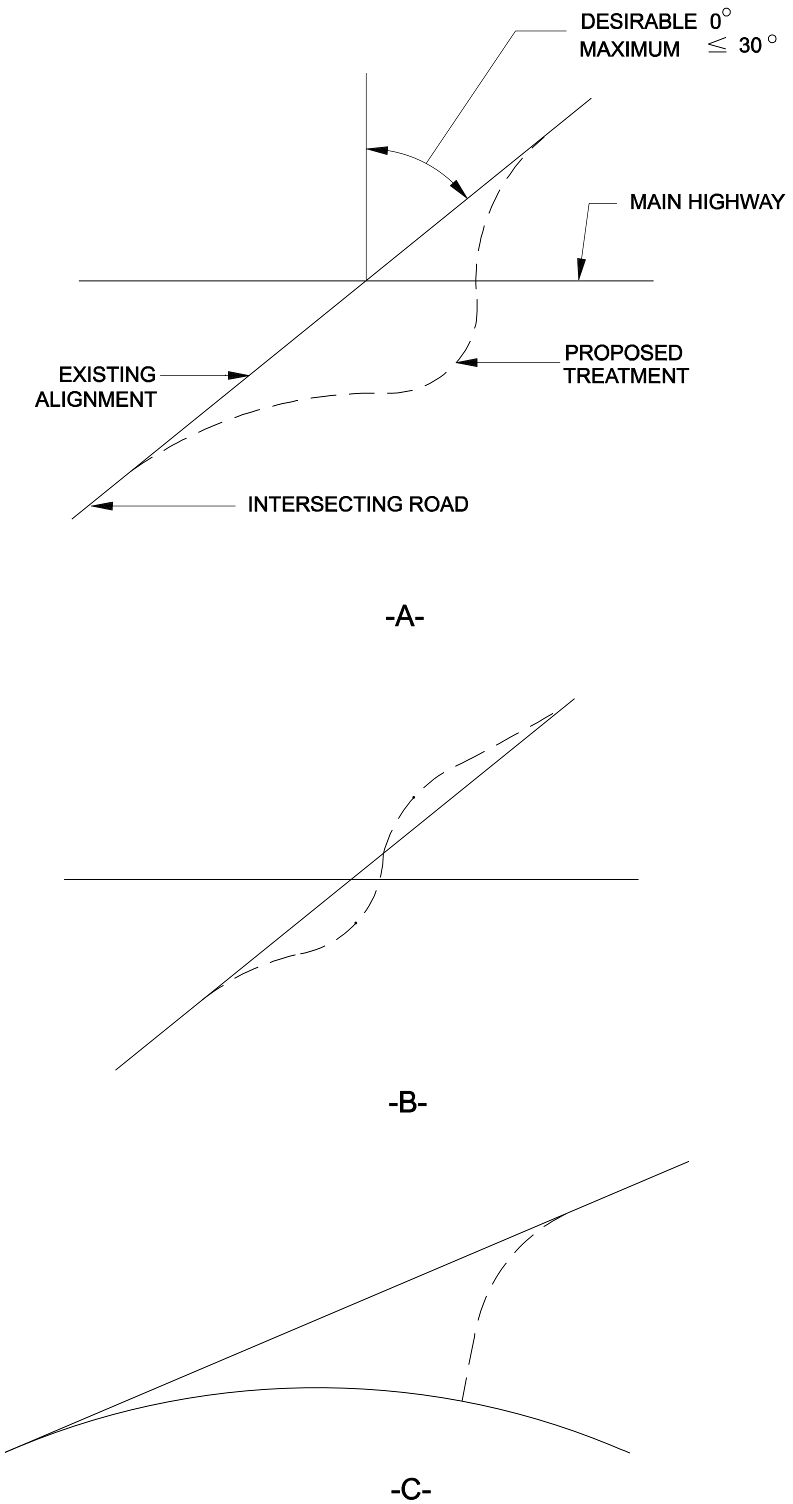
Preferably, an intersection between two roadways should be on tangent sections. When a minor road intersects a major road on a horizontal curve, the geometric design of the intersection becomes significantly more complicated, particularly for sight distance, turning movements, channelization and superelevation.

13.2.1.2 Angle of Intersection

Desirably, roadways should intersect at or as close to 90º as practical. Skewed intersections are undesirable for several reasons:

1. Vehicular turning movements become more restricted.
2. The accommodation of large trucks for turning may require additional pavement and channelization.
3. The exposure time for vehicles and pedestrians crossing the main traffic flow is increased.
4. The driver's line of sight for one of the sight triangles becomes restricted.

The intersection angle should not exceed 30º from perpendicular. Intersections with a skew greater than 30º from perpendicular must be reviewed and documented. For existing intersections, it will rarely be warranted to realign the intersection if its skew is within 30º of perpendicular. Where skew angles greater than 30º are present, the intersection may require geometric improvements (realignment, auxiliary lanes, greater corner sight distance). Figure 13.2A illustrates various angles of intersection and potential improvements that can be made to the alignment.



Note: Check the superelevation on the horizontal curve.

TREATMENTS FOR SKEWED INTERSECTIONS
Figure 13.2A

13.2.2 Intersection Profile

13.2.2.1 Gradient

The “landing area” is that portion of intersecting highways, local roads, and public and private approaches that will be used for the storage of stopped vehicles. Desirably, the landing area will slope downward from the intersection on a gradient not to exceed 3%. The landing area may slope upward from the intersection on a gradient not to exceed 3% if site constraints warrant. However, an upward sloping landing area should be avoided if practical. At a minimum, the landing area should be 75’ (25 m) for public roads and 25’ (7.5 m) for other facilities.

The gradient of the approach beyond the 25’ (7.5 m) landing should not exceed 6% for public or private approaches unless site constraints preclude its use. The gradient of Farm Field approaches should not exceed 10%. Use of steeper approach slopes does not require a design exception but must be documented in the Plan-In-Hand Report or Final Plan Review Report.

13.2.2.2 Cross Slope Transitions

One or both of the roadways approaching the intersection may need to be transitioned (or warped) to match or coordinate the cross slope and grade at the intersection. The designer should consider the following:

1. Stop Controlled. When the minor road is stop controlled, the profile gradeline and cross slope of the major road will normally be maintained through an intersection, and the cross slope of the stop-controlled leg will be transitioned to match the major road grade.

2. Signalized Intersection. At signalized intersections, or potential signalized intersections, the cross slope of the minor road will typically be transitioned to meet the grade of the major road. If both intersecting roads have approximately equal importance, the designer may want to consider transitioning both roadways to form a plane section through the intersection. Where compromises are necessary between the two major roadways, the smoother riding characteristics should be provided for the roadway with the higher travel speeds.

3. Transition Distance. In rural areas, transitioning from the normal crown to a warped section should be accomplished in a distance of 50’ (15 m). The 50’

(15 m) transition length is also desirable for urban areas but, at a minimum, the transition may be accomplished within the curb return. See Figure 13.2B.

13.2.2.3 Vertical Profile

Where the profile of the minor road is adjusted to meet the major road, this will result in angular breaks for traffic on the minor road if no vertical curve is inserted. The following options are presented in order from the most desirable to the least desirable; see Figure 13.2C:

1. Vertical Curves (SSD). Desirably, vertical curves will be used through an intersection which meet the criteria for stopping sight distance as described in Chapter Ten. For stop-controlled legs, design the approach landing vertical curve with a 30 mph (50 km/h) design speed; at free-flowing legs and at all legs of a signalized or proposed future signalized intersection, use the design speed of the roadway to design the vertical curve. The grades of the tangents for the vertical curve are the grade of the landing area (G_1) and the profile grade of the minor roadway (G_2); see Figure 13.2C. The Point of Vertical Tangency (PVT) will be located at the end of the landing (75' (25 m) from the paved shoulder of the mainline). The PVT can be shifted onto the landing area if the gradient of the landing does not exceed 3%.

2. Sag Vertical Curves (Comfort). For sag vertical curves, the next most desirable option is to design the sag to meet the comfort criteria. The length of vertical curve can be determined as follows:

U.S. Customary

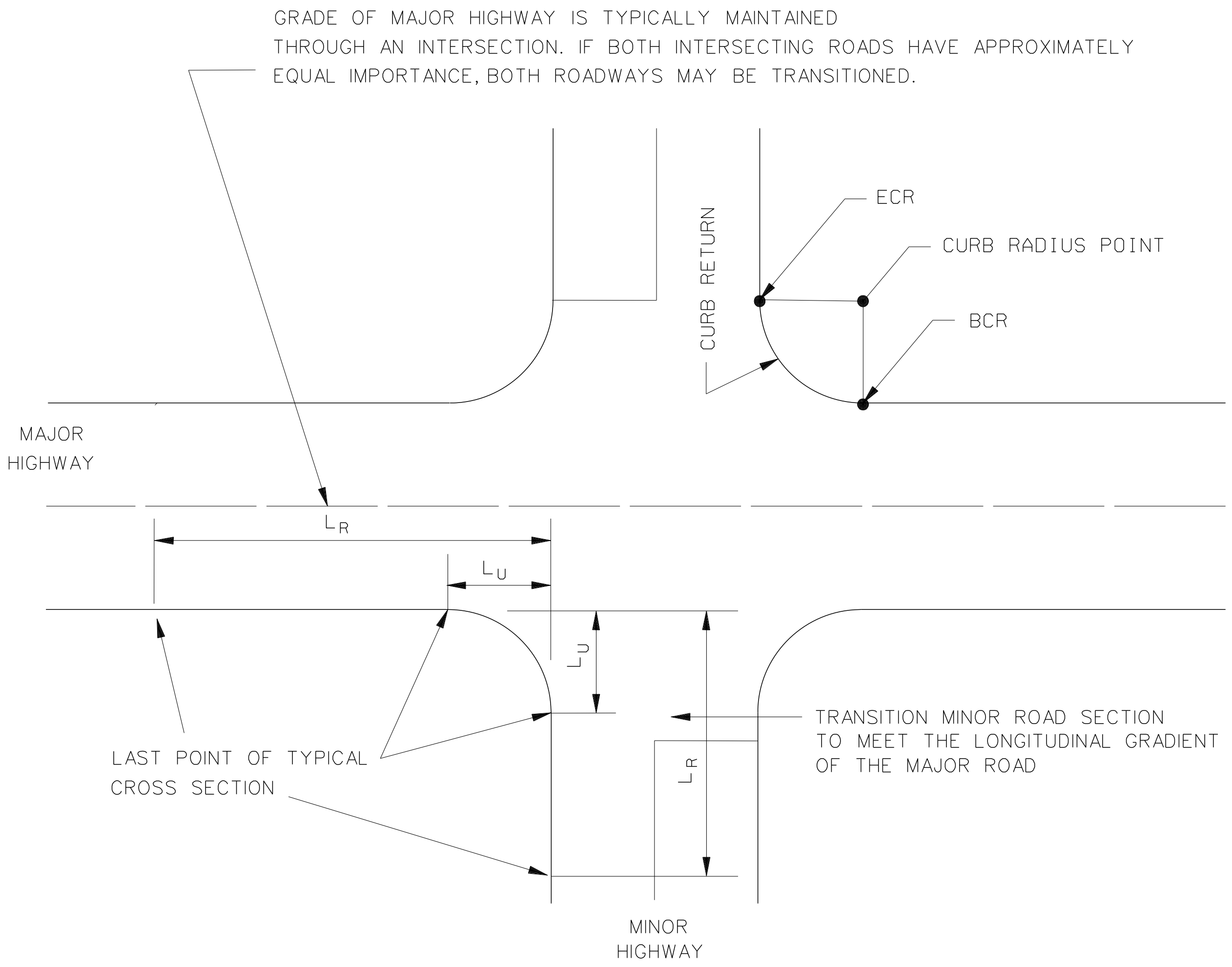
$$L = \frac{AV^2}{46.5}$$

Metric

$$L = \frac{AV^2}{395}$$

Where:

L = length of sag vertical curve, ft (m)
A = algebraic difference between grades, %
V = design speed, mph (km/h)

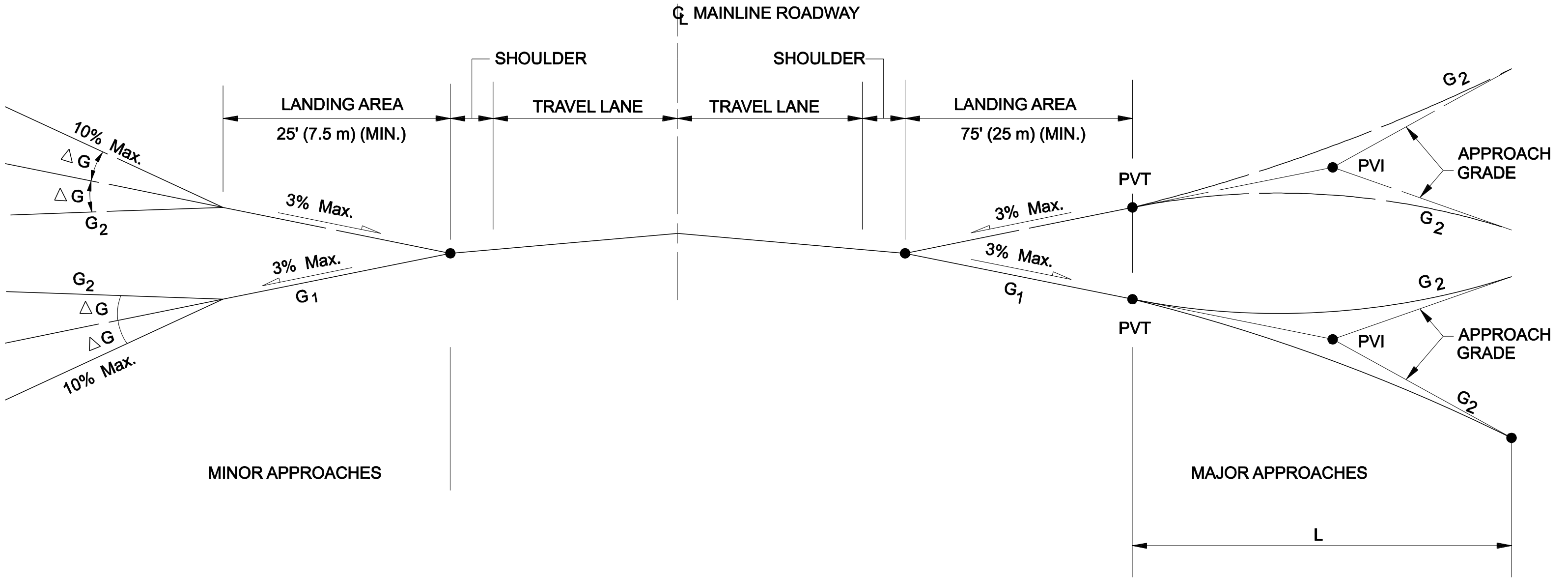


L_R = TRANSITION LENGTH FOR RURAL HIGHWAYS 50 ft (15 m)

L_U = TRANSITION LENGTH FOR URBAN HIGHWAYS

PAVEMENT TRANSITIONS THROUGH INTERSECTIONS

Figure 13.2B



Notes:

1. At signalized intersections, the most desirable rotation option will be to transition the cross slopes of all approach legs into a plane section through the intersection.

2. If practical, the gradient of the landing area where vehicles may be stored should not exceed 3%.

3. See Figure 13.2D for maximum allowable ΔG's.

4. Actual field conditions will determine the final design.

VERTICAL PROFILES OF INTERSECTING ROADS
Figure 13.2C

3. Angular Breaks. Angular breaks between the landing area and the approach gradient are typically used on minor approaches; see Figure 13.2C. For major approaches, it may be impractical to provide vertical curves on the approaches under some restricted conditions; i.e., angular breaks are necessary through the intersection. Figure 13.2D provides the maximum allowable angular breaks for various design speeds. Where angular breaks are used, the minimum distance between successive angle points should be at least 15’ (5 m).

13.2.2.4 Intersection Sight Distance

The designer needs to consider the effect the intersection profile and alignment will have on intersection sight distance. Landings with steep upgrades, may put the driver’s eye below or in line with roadway appurtenances (e.g., guardrail, signs). Also, large skewed intersections will require the driver to look back over their shoulder. For more information on intersection sight distance, see Section 13.4.

13.2.3 Turning Radii

The road designer is responsible for the turning radii design on minor intersections. Typically these designs will consist of simple curve radius. The designer should check the intersection with design vehicle turning template to ensure the design is adequate. For intersections where trucks, pedestrians, turn lanes, turning roadways, etc., are a concern, contact the Geometrics Unit in the Traffic Engineering Section for additional guidance.

Design Speed U.S. Customary	Crest Angular Breaks (ΔG)	Sag Angular Breaks (ΔG)	Design Speed Metric
mph			(km/h)
20	7.5%	4.8%	30
25	5.4%	2.7%	40
30	3.5%	1.7%	50
35	2.4%	1.2%	60
45	1.8%	0.9%	70
50	1.4%	0.7%	80
55	1.1%	0.5%	90
60	0.9%	0.4%	100

Notes:

1. *Design speed applies to the roadway with the angular break. Typically, this will be the minor roadway.*

2. *The angular break (ΔG) occurs between the landing area and approach roadway; see Figure 13.2C. (ΔG = the absolute value of G2 – G1)*

MAXIMUM CHANGE IN GRADES WITHOUT A VERTICAL CURVE

Figure 13.2D

13.3 AUXILIARY TURN LANES

13.3.1 Turn Lane Guidelines

Coordinate with the Traffic Bureau when considering the addition of any auxiliary turn lane.

13.3.1.1 Guidelines for Right-Turn Lanes

Exclusive right-turn lanes should be considered:

1. at the free-flowing leg of any unsignalized intersection on a 2-lane urban or rural highway which satisfies the criteria in Figure 13.3A;
2. at the free-flowing leg of any unsignalized intersection on a high-speed, 4-lane urban or rural highway which satisfies the criteria in Figure 13.3B;
3. at any intersection where a capacity analysis determines a right-turn lane is necessary to meet the level-of-service criteria;
4. as a general rule, at any signalized intersection where the projected right-turning volume is greater than 300 vph and where there is greater than 300 vph per lane on the mainline; or
5. at any intersection where the crash trend involves right-turning vehicles.

13.3.1.2 Guidelines for Left-Turn Lanes

Exclusive left-turn lanes should be considered:

1. at all public intersections on all multilane urban and rural highways, regardless of traffic volumes;
2. at the free-flowing leg of any unsignalized intersection on a 2-lane urban or rural highway which satisfies the criteria in Figures 13.3C, 13.3D, 13.3E or 13.3F;
3. at any intersection where a capacity analysis determines a left-turn lane is necessary to meet the level-of-service criteria;
4. as a general rule on the major roadway, at any signalized intersection;

5. at high-volume driveway approaches which satisfy the criteria in Figures 13.3C, 13.3D, 13.3E or 13.3F; or

6. at any intersection where the accident experience, traffic operations, sight distance restrictions (e.g., intersection beyond a crest vertical curve), or engineering judgment indicates a significant conflict related to left-turning vehicles.

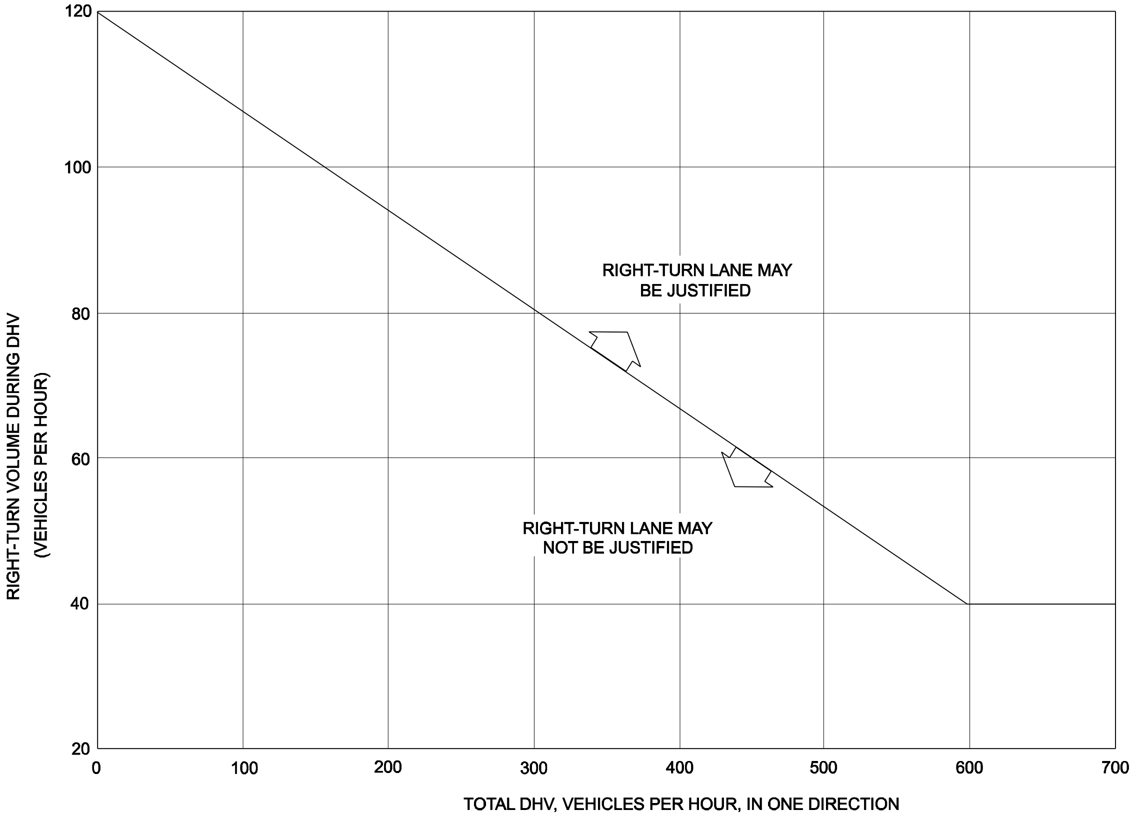
13.3.1.3 Sight Distance

When considering a right-turn lane on a through roadway, give specific attention to visibility on the side street. Decelerating vehicles in the auxiliary lane can create a moving sight obstruction. Proper placement of the stop bar on the side streets and lateral placement of right-turn lanes will allow a vehicle on the side approach to see the approaching through traffic. Combination of medial separators and channelizing islands can be used to control proper placement of stopped and decelerating vehicles.

When establishing a left-turn lane, the designer needs to consider access to and from private properties on the legs to the intersection.

13.3.2 Design of Turn Lanes

For the design of turn lanes (e.g., widths, lengths, types), see Section 28.4 of the *Traffic Engineering Manual*.



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Note: For highways with a design speed below 50 mph (80 km/h) with a DHV <300 and where right turns > 40, an adjustment should be used. To read the vertical axis of the chart, subtract 20 from the actual number of right turns.

Example

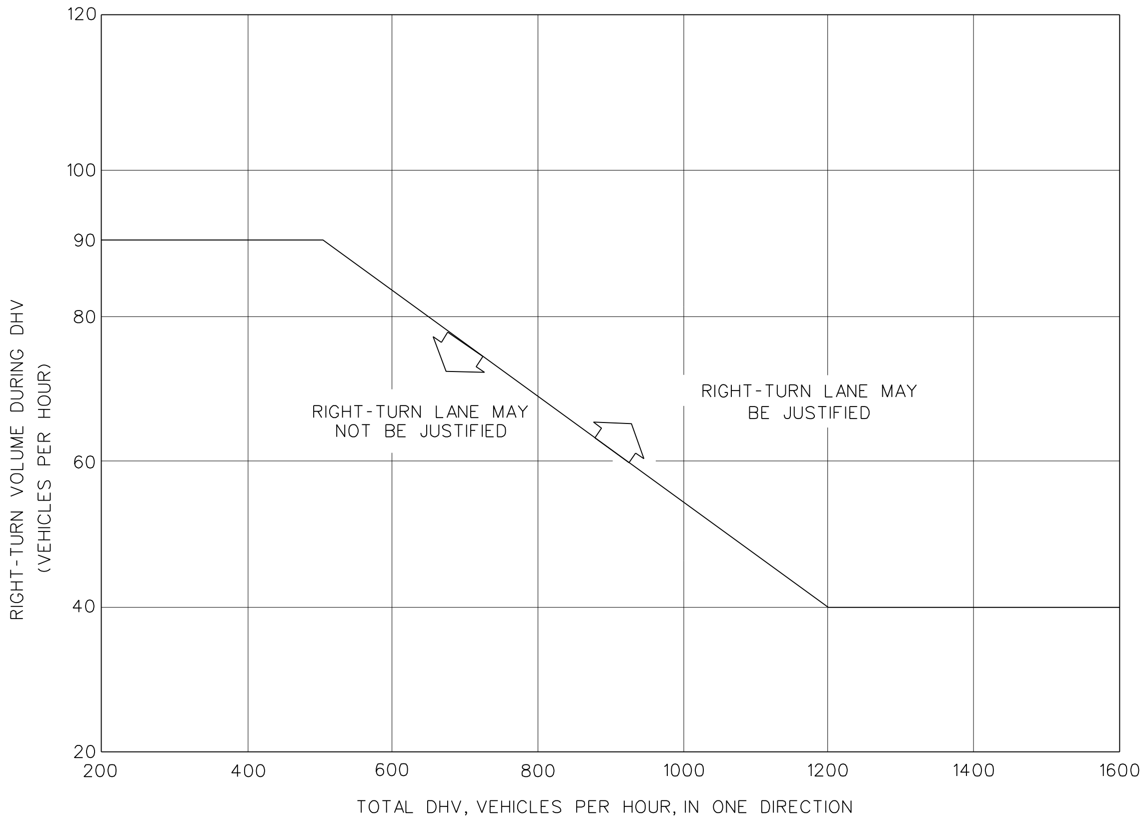
Given: Design Speed = 35 mph (60 km/h)
DHV = 250 vph
Right Turns = 100 vph

Problem: Determine if a right-turn lane is necessary.

Solution: To read the vertical axis, use 100 - 20 = 80 vph. The figure indicates that a right-turn lane is not necessary, unless other factors (e.g., high accident rate) indicate a lane is needed.

GUIDELINES FOR RIGHT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS

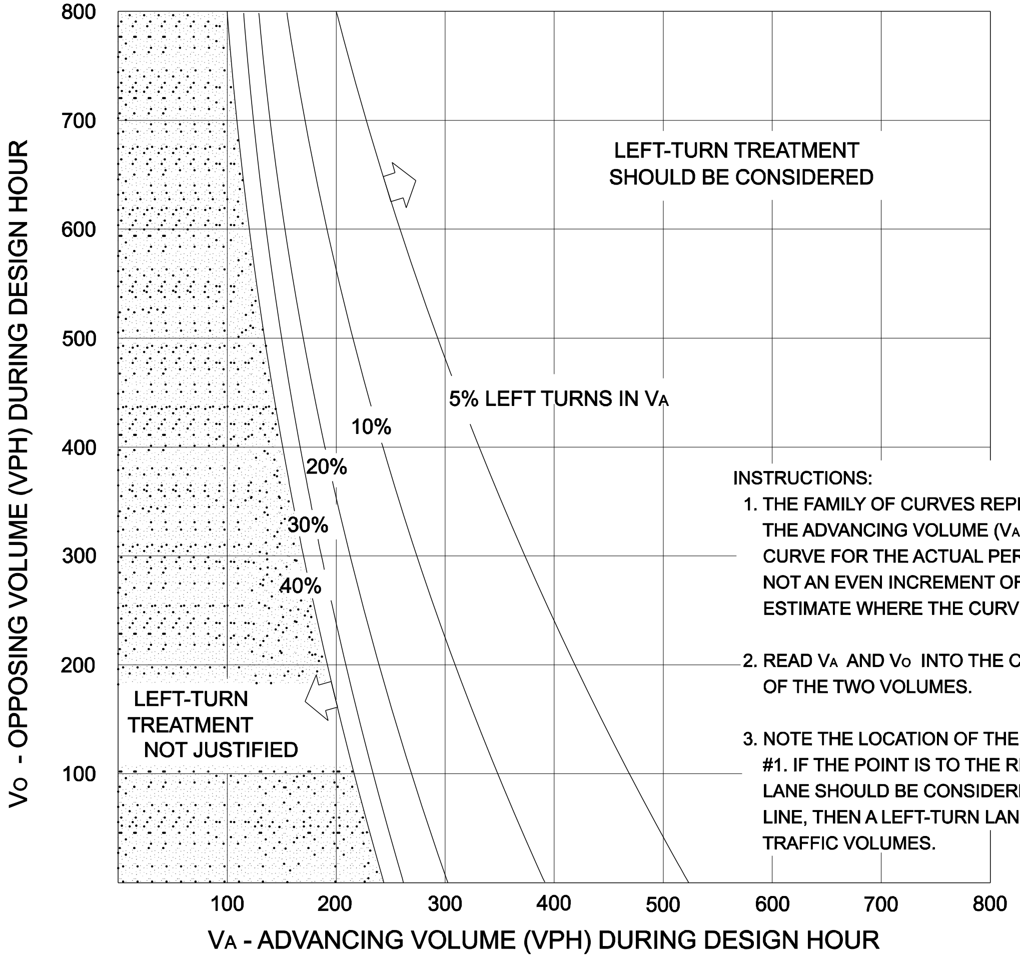
Figure 13.3A



Note: Figure is only applicable on highways with a design speed of 50 mph (80 km/h) or greater.

GUIDELINES FOR RIGHT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 4-LANE HIGHWAYS

Figure 13.3B



INSTRUCTIONS:

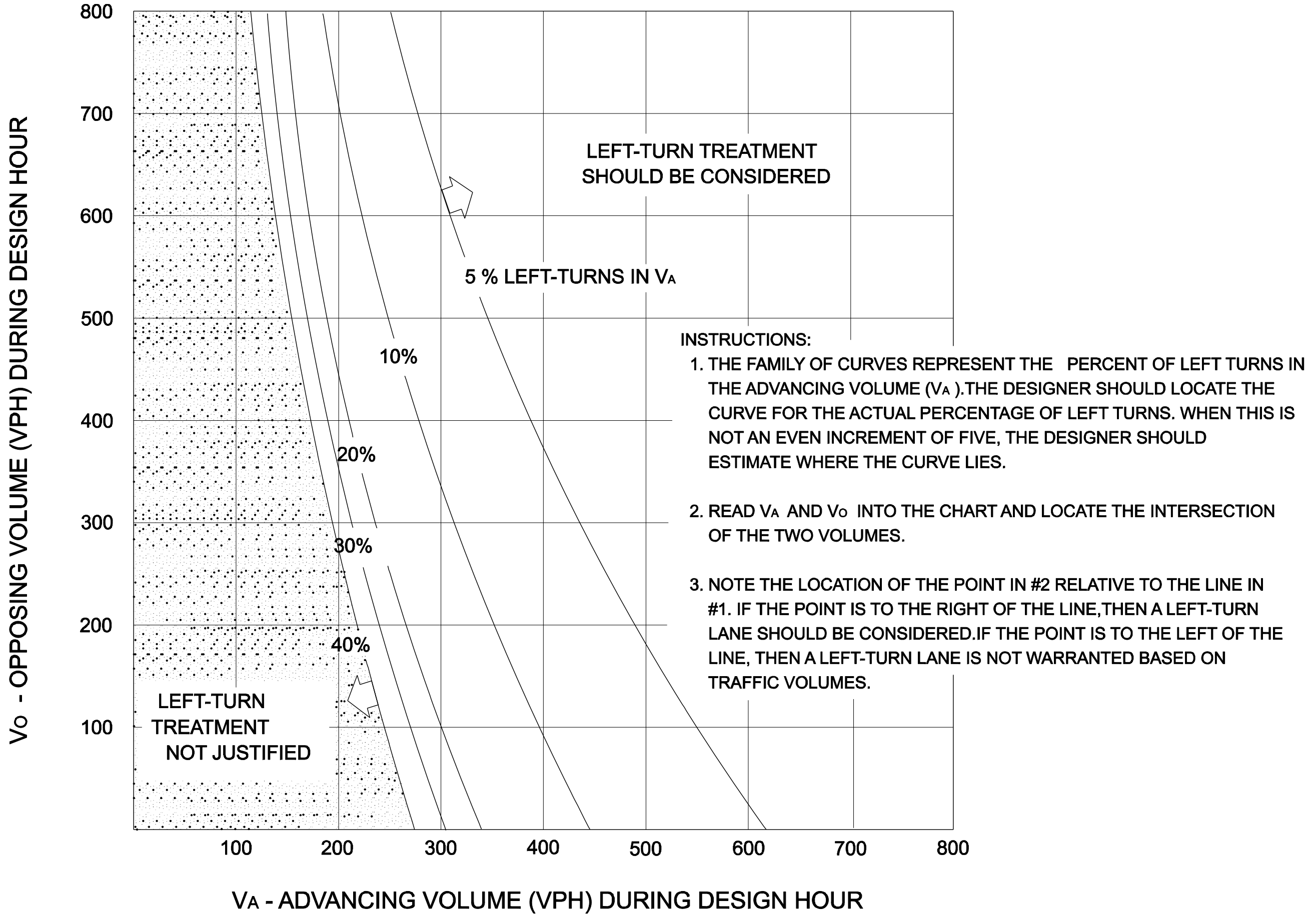
1. THE FAMILY OF CURVES REPRESENT THE PERCENT OF LEFT TURNS IN THE ADVANCING VOLUME (V_A).THE DESIGNER SHOULD LOCATE THE CURVE FOR THE ACTUAL PERCENTAGE OF LEFT TURNS. WHEN THIS IS NOT AN EVEN INCREMENT OF FIVE, THE DESIGNER SHOULD ESTIMATE WHERE THE CURVE LIES.

2. READ V_A AND V_O INTO THE CHART AND LOCATE THE INTERSECTION OF THE TWO VOLUMES.

3. NOTE THE LOCATION OF THE POINT IN #2 RELATIVE TO THE LINE IN #1. IF THE POINT IS TO THE RIGHT OF THE LINE,THEN A LEFT-TURN LANE SHOULD BE CONSIDERED.IF THE POINT IS TO THE LEFT OF THE LINE, THEN A LEFT-TURN LANE IS NOT WARRANTED BASED ON TRAFFIC VOLUMES.

VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS 60 mph(100 km/h)

Figure 13.3C



INSTRUCTIONS:

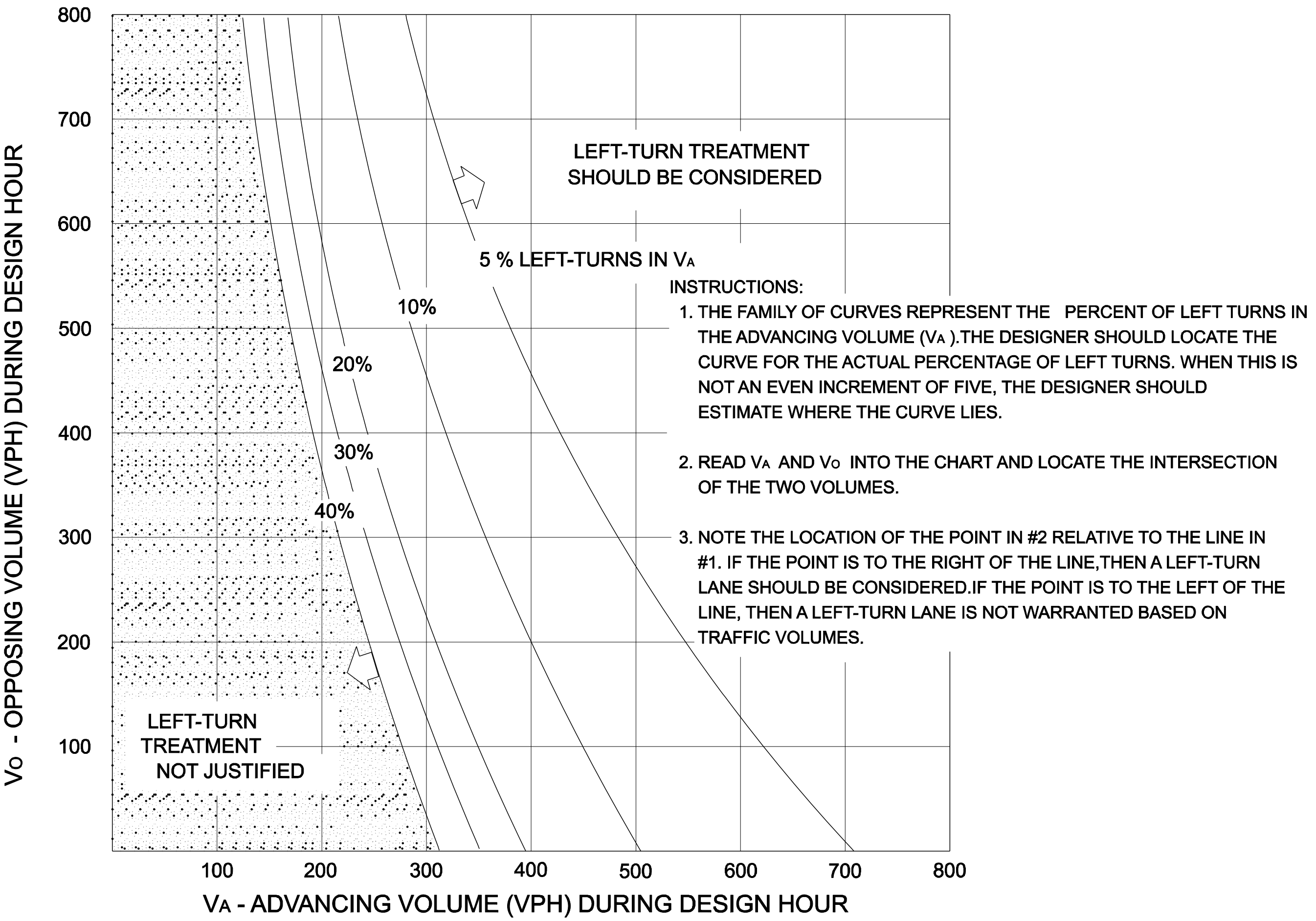
1. THE FAMILY OF CURVES REPRESENT THE PERCENT OF LEFT TURNS IN THE ADVANCING VOLUME (V_A).THE DESIGNER SHOULD LOCATE THE CURVE FOR THE ACTUAL PERCENTAGE OF LEFT TURNS. WHEN THIS IS NOT AN EVEN INCREMENT OF FIVE, THE DESIGNER SHOULD ESTIMATE WHERE THE CURVE LIES.

2. READ V_A AND V_O INTO THE CHART AND LOCATE THE INTERSECTION OF THE TWO VOLUMES.

3. NOTE THE LOCATION OF THE POINT IN #2 RELATIVE TO THE LINE IN #1. IF THE POINT IS TO THE RIGHT OF THE LINE,THEN A LEFT-TURN LANE SHOULD BE CONSIDERED.IF THE POINT IS TO THE LEFT OF THE LINE, THEN A LEFT-TURN LANE IS NOT WARRANTED BASED ON TRAFFIC VOLUMES.

VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS 55 mph (90 km/h)

Figure 13.3D



INSTRUCTIONS:

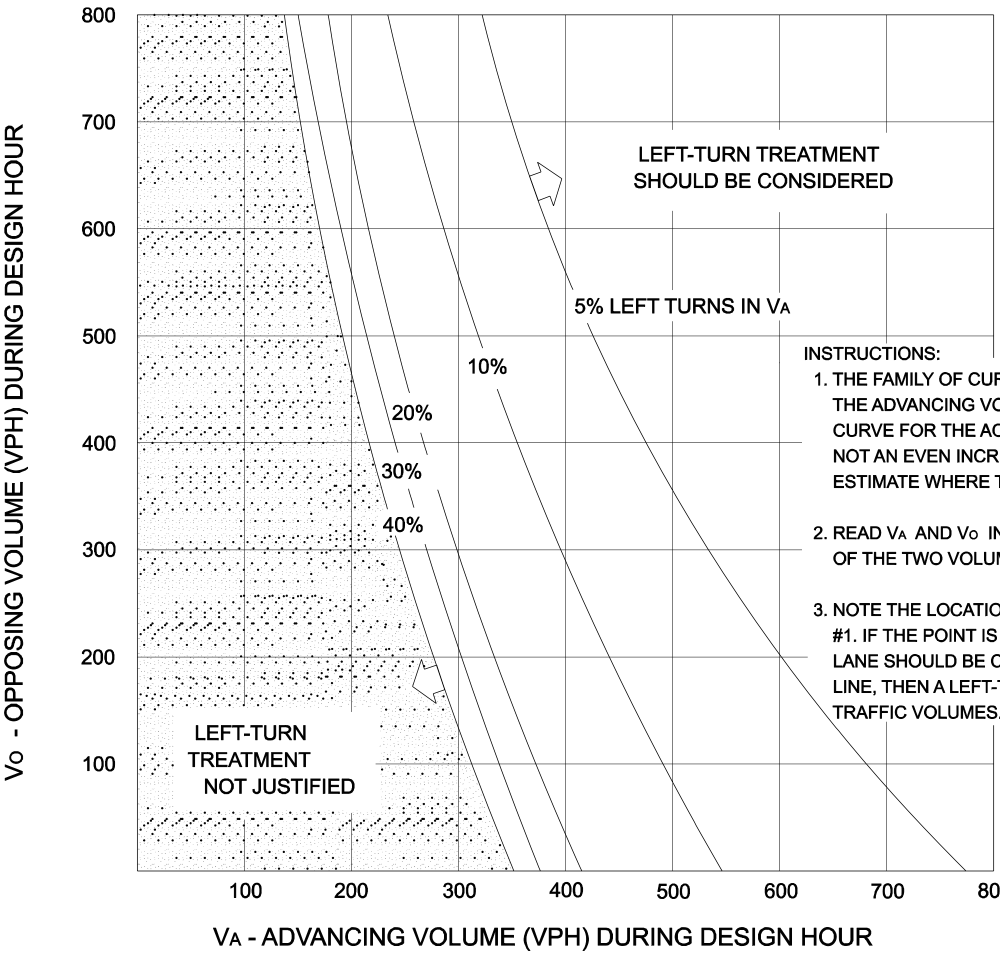
1. THE FAMILY OF CURVES REPRESENT THE PERCENT OF LEFT TURNS IN THE ADVANCING VOLUME (V_A).THE DESIGNER SHOULD LOCATE THE CURVE FOR THE ACTUAL PERCENTAGE OF LEFT TURNS. WHEN THIS IS NOT AN EVEN INCREMENT OF FIVE, THE DESIGNER SHOULD ESTIMATE WHERE THE CURVE LIES.

2. READ V_A AND V_O INTO THE CHART AND LOCATE THE INTERSECTION OF THE TWO VOLUMES.

3. NOTE THE LOCATION OF THE POINT IN #2 RELATIVE TO THE LINE IN #1. IF THE POINT IS TO THE RIGHT OF THE LINE,THEN A LEFT-TURN LANE SHOULD BE CONSIDERED.IF THE POINT IS TO THE LEFT OF THE LINE, THEN A LEFT-TURN LANE IS NOT WARRANTED BASED ON TRAFFIC VOLUMES.

VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS 50 mph (80 km/h)

Figure 13.3E



INSTRUCTIONS:

1. THE FAMILY OF CURVES REPRESENT THE PERCENT OF LEFT TURNS IN THE ADVANCING VOLUME (V_A).THE DESIGNER SHOULD LOCATE THE CURVE FOR THE ACTUAL PERCENTAGE OF LEFT TURNS. WHEN THIS IS NOT AN EVEN INCREMENT OF FIVE, THE DESIGNER SHOULD ESTIMATE WHERE THE CURVE LIES.

2. READ V_A AND V_O INTO THE CHART AND LOCATE THE INTERSECTION OF THE TWO VOLUMES.

3. NOTE THE LOCATION OF THE POINT IN #2 RELATIVE TO THE LINE IN #1. IF THE POINT IS TO THE RIGHT OF THE LINE,THEN A LEFT-TURN LANE SHOULD BE CONSIDERED.IF THE POINT IS TO THE LEFT OF THE LINE, THEN A LEFT-TURN LANE IS NOT WARRANTED BASED ON TRAFFIC VOLUMES.

VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS 45 mph (70 km/h)

Figure 13.3F

13.4 INTERSECTION SIGHT DISTANCE

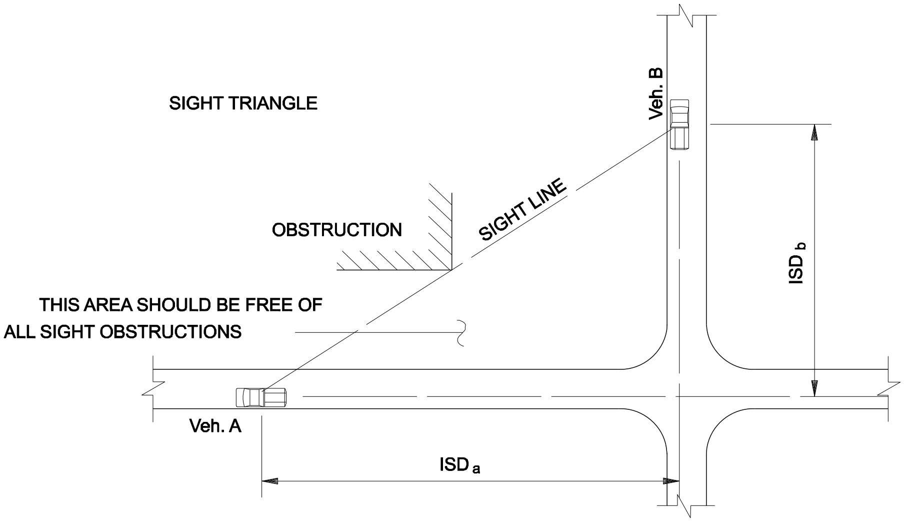
For an at-grade intersection to operate properly, adequate sight distance should be available. The designer should provide sufficient sight distance for a driver to perceive potential conflicts and to perform the actions needed to negotiate the intersection safely. The additional costs and impacts of removing sight obstructions are often justified. If it is impractical to remove an obstruction blocking the sight distance, the designer should consider providing traffic control devices or design applications (e.g., warning signs, turn lanes) which may not otherwise be considered.

In general, ISD refers to the corner sight distance available in intersection quadrants which allows a driver approaching an intersection to observe the actions of vehicles on the crossing leg(s). ISD evaluations involve establishing the needed sight triangle in each quadrant by determining the legs of the triangle on the two crossing roadways. The necessary clear sight triangle is based on the type of traffic control at the intersection and on the design speeds of the two roadways.

The Department uses gap acceptance as its basic concept in the design of intersection sight distance. This gap acceptance design is based on the criteria and theory presented in NCHRP Report 383, *Intersection Sight Distance*.

13.4.1 No Traffic Control

Intersections between low-volume and low-speed roads/streets may have no traffic control. At these intersections, sufficient corner sight distance should be available to allow approaching vehicles to adjust their speed to avoid a collision, typically 50 percent of their mid-block running speed. Figure 13.4A provides the ISD criteria for intersections with no traffic control. For approach grades greater than 3%, adjust the ISD values obtained in Figure 13.4A with the applicable ratios in Figure 13.4B.



Design Speed (mph)	15	20	25	30	35	40	45	50
*Intersection Sight Distance (ft)	70	90	115	140	165	195	220	245
Design Speed (km/h)	20	30	40	50	60	70	80	90
*Intersection Sight Distance (m)	20	25	35	45	55	65	75	90

Note: For approach grades greater than 3%, multiply the sight distance values in this table by the appropriate adjustment factor from Figure 13.4B. The grade adjustment is based on the approach roadway grade only.

Example

Given: No traffic control at intersection

	U.S. Customary	Metric
Design speed	35 mph (Highway A)	60 km/h (Highway A)
	25 mph (Highway B)	40 km/h (Highway B)

Problem: Determine legs of sight triangle.

Solution: From above table ---ISD_a = 165’ ISD_a = 55 m

ISD_b = 115’ ISD_b = 35 m

Note: This figure is not applicable for State highways.

INTERSECTION SIGHT DISTANCE
(No Traffic Control)
Figure 13.4A

U.S. Customary

Approach Grade (%)	Design Speed (mph)										
	20	25	30	35	40	45	50	55	60	65	70
-6	1.1	1.1	1.1	1.1	1.1.	1.1	1.2	1.2	1.2	1.2	1.2
-5	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2
-4	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
-3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Metric

Approach Grade (%)	Design Speed (km/h)									
	30	40	50	60	70	80	90	100	110	120
-6	1.1	1.1	1.1	1.1	1.1.	1.2	1.2	1.2	1.2	1.2
-5	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2
-4	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
-3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Note: Based on ratio of stopping sight distance on specified approach grade to stopping sight distance on level terrain. The grade adjustment is based on the approach roadway grade only.

ADJUSTMENT FACTORS FOR APPROACH SIGHT DISTANCE BASED ON APPROACH GRADE

Figure 13.4B

13.4.2 Stop Controlled/Traffic-Signal Controlled

Where traffic on the minor road of an intersection is controlled by stop signs, the driver of the vehicle on the minor road must have sufficient sight distance for a safe departure from the stopped position assuming that the approaching vehicle comes into view as the stopped vehicle begins its departure.

The stopped-controlled criteria required will also apply to a signalized intersection. This is reasonable because of the increased driver work load at intersections and the potential conflicts involved when vehicles turn onto or cross the highway. These include:

1. violation of the signal,
2. right-turns-on-red,
3. signal malfunction, and/or
4. use of flashing yellow/red mode during part of the day.

If these criteria cannot be met, give consideration to prohibiting right-turn-on-red at the intersection or prohibiting the flashing mode. This determination will be based on field investigations and will be determined on a case-by-case basis.

13.4.2.1 Basic Criteria

The Department uses gap acceptance as the conceptual basis for its intersection sight distance (ISD) criteria at stop-controlled and traffic-signal controlled intersections. The intersection sight distance is obtained by providing clear sight triangles both to the right and left as shown in Figure 13.4C. The length of legs of these sight triangles are determined as follows:

1. Minor Road. The length of leg along the minor road is based on two parts. The first is the location of the driver’s eye on the minor road. This is typically assumed to be 14.4’ (4.4 m) from the edge of traveled way for the major road and in the center of the lane on the minor road; see Figure 13.4C. The second part is based on the distance to the center of the vehicle on the major road. For right-turning vehicles, this is assumed to be the center of the closest travel lane from the left. For left-turning vehicles, this is assumed to be the center of the closest travel lane for vehicles approaching from the right; see Figure 13.4C.

2. Major Road. The length of the sight triangle leg or ISD along the major road is determined using the following equation:

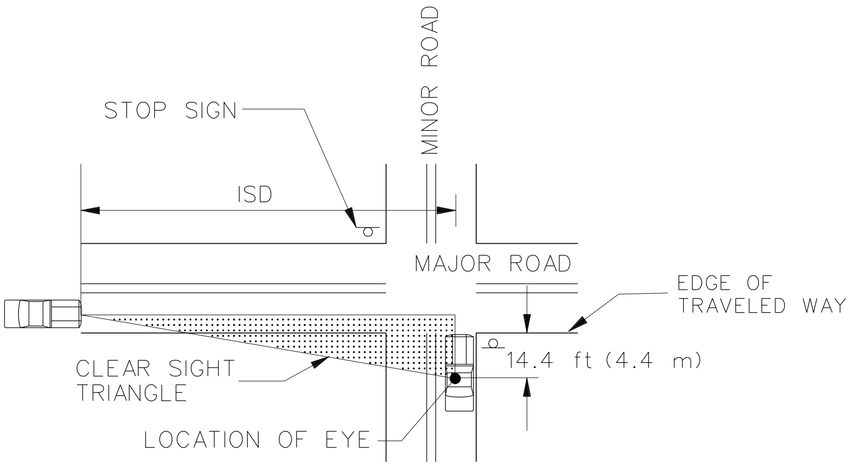
U.S. Customary *Metric*

$ISD = 1.47\ V_{major}\ t_g$ $ISD = 0.278\ V_{major}\ t_g$ (Equation 13.4-1)

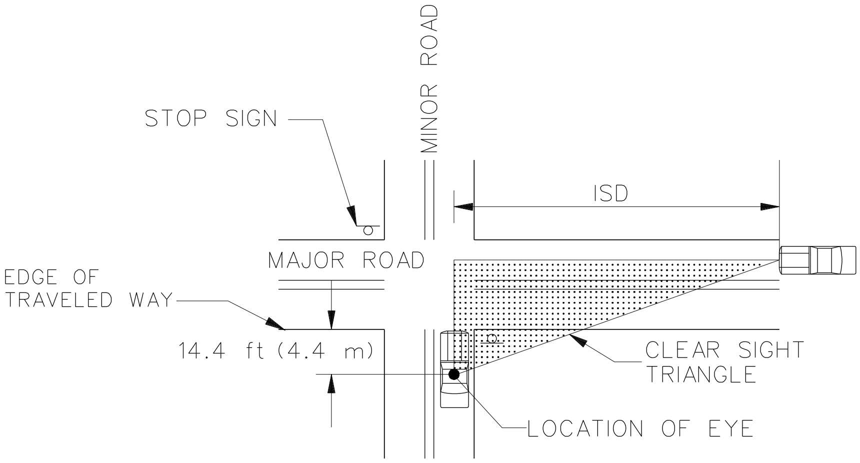
Where:

ISD = length of sight triangle leg along major road [ft (m)]
V_{major} = design speed of major road [mph (km/h)]
t_g = gap acceptance time for entering the major road (sec)

The gap acceptance time (t_g) varies according to the design vehicle, the grade on the minor road approach, the number of lanes on the major roadway, the type of operation and the intersection skew. Section 13.4.2.4 presents several examples on the application of ISD.



CLEAR SIGHT TRIANGLE FOR VIEWING TRAFFIC APPROACHING FROM THE LEFT



CLEAR SIGHT TRIANGLE FOR VIEWING TRAFFIC APPROACHING FROM THE RIGHT

CLEAR SIGHT TRIANGLES (STOP-CONTROLLED) INTERSECTIONS

Figure 13.4C

Within this clear sight triangle, if practical, the objective is to remove, lower any object or trim lower branches that obstructs the driver's view. These objects may include buildings, parked or turning vehicles, trees, hedges, tall crops, un-mowed grass, fences, retaining walls and the existing ground line. In addition, where an interchange ramp intersects the major road or crossroad near a bridge on a crest vertical curve, objects such as bridge parapets, piers, abutments or the crest vertical curve itself may restrict the clear sight triangle.

13.4.2.2 Vehicle Entering Major Roadway

To determine the intersection sight distance for vehicles turning left or right onto the major road, the designer should use Equation 13.4-1 and the gap acceptance time (t_g) presented in Figure 13.4D. Figure 13.4E, which solves Equation 13.4-1, provides the ISD values for all design vehicles on 2-lane, level facilities. The designer should also consider the following:

1. Turn Maneuver. There is only a minimal difference in the gap acceptance times between the left- and right-turning drivers. Therefore, only one gap acceptance time is provided.

2. Multilane Facilities. For multilane facilities, the gap acceptance times presented in Figure 13.4D should be adjusted to account for the additional distance required by the turning vehicle to cross the additional lanes or median. The following will apply:

   a. Left-Turns. For left turns onto multilane highways, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane, in excess of one, to be crossed by the turning vehicle. Assume that the left-turning driver will enter the left travel lane on the far side of the major road. For example, the gap acceptance time for a passenger car turning left onto an undivided six-lane facility would be 7.5 seconds plus 0.5 seconds for each of the two additional lanes needed to be crossed. The total gap time required is therefore 8.5 seconds.

   b. Right Turns. Because the turning vehicle is assumed to be turning into the nearest right through lane, no adjustments to the gap times are required.

3. Medians. For a multilane facility which does not have a median wide enough to store a stopped vehicle, divide the median width by 12’ (3.6 m) to determine the corresponding number of lanes, and then use the criteria in Comment #2a above to determine the appropriate time factor.

On multilane facilities with a median wide enough to store the stopped vehicle, the designer should evaluate the move in two steps; see Figure 13.4F:

   a. First, with the vehicle stopped on the minor road (the bottom portion in Figure 13.4F), use the gap acceptance times and distances for a vehicle turning right (Figures 13.4D and 13.4E) to determine the applicable ISD. Under some circumstances, it may be necessary to check the crossing maneuver to determine if it is the critical movement. Crossing criteria are discussed in Section 13.4.2.3.

   b. Then, with the vehicle stopped in the median (top portion in Figure 13.4F), assume a two-lane roadway design and use the gap acceptance times and distances for vehicles turning left (Figures 13.4D and 13.4E) to determine the applicable ISD.

4. Approach Grades. If the approach grade on the minor road exceeds +3%, add the following times to the basic gap acceptance times in Figure 13.4D:

   a. Left Turns. Multiply the percent grade on the approach by 0.2 and add this to the base time gap.

   b. Right Turns. Multiply the percent grade on the approach by 0.1 and add this to the base time gap. Use the adjusted t_g in Equation 13.4-1 to determine the applicable ISD. Do not apply the grade adjustment if the approach grade is negative.

Design Vehicle	Gap Acceptance Time (t_g) (sec)
Passenger Car	7.5
Single-Unit Truck	9.5
Tractor/Semitrailer	11.5

GAP ACCEPTANCE TIMES
(Right or Left Turn From Minor Road)

Figure 13.4D

U.S. Customary(Rounded for Design)

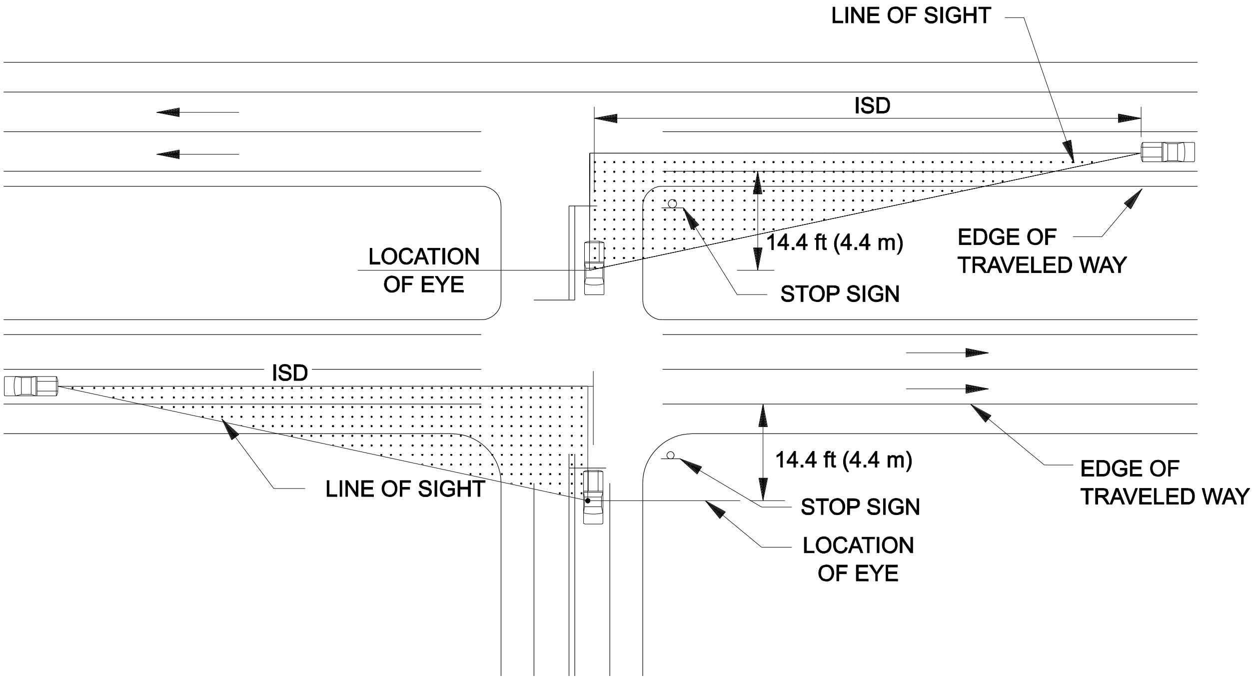
Design Speed (V_{major}) (mph)	**ISD (ft)**		
	Passenger Cars	**Single-Unit Trucks**	**Tractor/Semitrailers**
20	225	280	340
25	280	350	425
30	335	420	510
35	390	490	595
40	445	560	680
45	500	630	765
50	555	700	850
55	610	770	930
60	665	840	1015
65	720	910	1100
70	775	980	1185

Metric(Rounded for Design)

Design Speed (V_{major}) (km/h)	**ISD (m)**		
	Passenger Cars	**Single-Unit Trucks**	**Tractor/Semitrailers**
30	65	80	100
40	85	110	130
50	105	135	160
60	130	160	195
70	150	185	225
80	170	215	260
90	190	240	290
100	210	265	320
110	230	295	355

Note: These ISD values assume a minor road approach grade $\leq$ +3%.

TWO-LANE INTERSECTION SIGHT DISTANCES
(Right or Left Turn from Minor Road)
Figure 13.4E



INTERSECTION SIGHT DISTANCE
(Divided Facilities) Figure 13.4F

5. Trucks. At some intersections (e.g., near truck stops, interchange ramps, grain elevators), the designer may want to use the truck as the design vehicle for determining the ISD. The gap acceptance times (t_g) for single-unit and tractor/semitrailer trucks are provided in Figure 13.4D. ISD values for level, 2-lane roadways are presented in Figure 13.4E.

6. Height of Eye/Object. The height of eye for passenger cars is assumed to be 3.5’ (1080 mm) above the surface of the minor road. The height of object (approaching vehicle on the major road) is also assumed to be 3.5’ (1080 mm). An object height of 3.5’ (1080 mm) assumes that a sufficient portion of the oncoming vehicle must be visible to identify it as an object of concern by the minor road driver. If there is a sufficient number of trucks to warrant their consideration, assume an eye height of 7.9’ (2.4 m) for a tractor/semitrailer and 5.9’ (1.8 m) for single-unit trucks and buses. If a truck is the assumed entering vehicle, the object height will still be 3.5’ (1080 mm) for the passenger car on the major road.

7. Skew. At skewed intersections where the intersection angle is less than 60°, adjustments may need to be made to account for the extra distance the vehicle needs to travel across opposing lanes. Using the procedures discussed in Comment #2 in Section 13.4.2.2 and/or Section 13.4.2.3, determine the appropriate ISD value based on this extra travel distance.

8. Examples. For examples on the application of ISD, see Section 13.4.2.4.

13.4.2.3 Straight Through Crossing Vehicle

In the majority of cases, the intersection sight distance for turning vehicles typically will provide adequate sight distance to allow a vehicle to cross the major road. However, in the following situations, the crossing sight distance may be the more critical movement:

1. where left and/or right turns are not permitted from a specific approach and the crossing maneuver is the only legal or expected movement (e.g., indirect left turns);

2. where the design vehicle must cross more than six travel lanes or, with medians, the equivalent distance; or

3. where a substantial volume of heavy vehicles cross the highway and there are steep grades on the minor road approach.

Use Equation 13.4-1 and the gap acceptance times (t_g) and the adjustment factors in Figure 13.4G to determine the ISD for crossing maneuvers. Where medians are present, include the median width in the overall length to determine the applicable gap time. Divide this width by 12’ (3.6 m) to determine the corresponding number of lanes for the crossing maneuver.

Design Vehicle	Gap Acceptance Time (t_g) (sec)
Passenger Car	6.5
Single-Unit Truck	8.5
Tractor/Semitrailer	10.5

Adjustments:

1. <u>Multilane Highway</u>. Where the design vehicle is crossing a major road with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane in excess of two. See the discussion in Section 13.4.2.2 for additional guidance.

2. <u>Approach Grade</u>. If the approach grade on the minor road exceeds +3%, multiply the percent grade of the minor road approach by 0.2 and add it to the base gap acceptance time.

GAP ACCEPTANCE TIMES
(Crossing Maneuvers)

Figure 13.4G

13.4.2.4 Examples of ISD Applications

The following three examples illustrate the application of the ISD criteria:

Example 13-1

Given: Minor road intersects a 4-lane highway with a TWLTL.
Minor road is stop controlled.
Design speed of the major highway is 50 mph (80 km/h).
All travel lane widths are 12’ (3.6 m).
The TWLTL width is 14’ (4.2 m).
Trucks are not a concern.

Problem: Determine the intersection sight distance to the left and right from the minor road.

Solution: The following steps will apply:

1. For the vehicle turning right, the ISD to the left can be determined directly from Figure 13.4E. For the 50 mph design speed, the ISD to the left is 555’. For the 80 km/h design speed, the ISD to the left is 170 m.

2. For the vehicle turning left, the ISD must reflect the additional time required to cross the additional lanes; see Comment #2 in Section 13.4.2.2. The following will apply:

   a. First, determine the extra width required by the one additional travel lane and the TWLTL and divide this number by 12’ (3.6 m):

      U.S. Customary

      $\frac{(12+14)}{12} = 2.2$ lanes

      Metric

      $\frac{(3.6+4.2)}{3.6} = 2.2$ lanes

   b. Next, multiply the number of lanes by 0.5 seconds to determine the additional time required:

      (2.2 lanes)(0.5 sec/lane) = 1.1 seconds

   c. Add the additional time to the basic gap time of 7.5 seconds and insert this value into Equation 13.4-1:

U.S. Customary ISD = (1.47)(50)(7.5 + 1.1) = 632’

Metric ISD = (0.278)(80)(7.5 + 1.1) = 191 m

Provide an ISD of 630’ (190 m) to the right for the left-turning vehicle.

3. Check the crossing vehicle, as discussed in Section 13.4.2.3. The following will apply:

   a. First determine the extra width required by the two additional travel lanes and the TWLTL and divide this number by 12’ (3.6 m):

      U.S. Customary

      $$\frac{(12+12+14)}{12} = 3.2 \text{ lanes}$$

      Metric

      $$\frac{(3.6+3.6+4.2)}{3.6} = 3.2 \text{ lanes}$$

   b. Next, multiply the number of lanes by 0.5 seconds to determine the additional time required:

      (3.2 lanes)(0.5 sec/lane) = 1.6 seconds

   c. Add the additional time to the basic gap time of 6.5 seconds and insert this value into Equation 13.4-1:

      U.S. Customary ISD = (1.47)(50)(6.5 + 1.6) = 595’

      Metric ISD = (0.278)(80)(6.5 + 1.6) = 180 m

      The 595’ (180 m) for the crossing maneuver is less than the 630’ (190 m) required for the left-turning vehicle and, therefore, is not the critical maneuver.

<u>Example 13-2</u>

Given: Minor road intersects a 4-lane divided highway.
Minor road is stop controlled.
Design speed of the major highway is 55 mph (90 km/h).
All travel lane widths are 12’ (3.6 m).
The median width is 100’ (30.8 m).
Trucks are not a concern.

Problem: Determine the intersection sight distance to the left and right from the minor road.

Solution: The following steps apply:

1. For the vehicle turning right, the ISD to the left can be determined directly from Figure 13.4E. For the 55 mph design speed, the ISD to the left is 610'. For the 90 km/h design speed, the ISD to the left is 190 m.

2. Determine if the crossing maneuver is critical; see Section 13.4.2.3. No adjustments are required to the base time of 6.5 seconds. Therefore, use Equation 13.4-1 directly:

   U.S. Customary ISD = (1.47)(55)(6.5) = 525'

   Metric ISD = (0.278)(90)(6.5) = 163 m

   The crossing maneuver is less than the right-turning maneuver and, therefore, is not critical.

3. For the vehicle turning left, assume the passenger car is stopped in the median; see Figure 13.4F. The ISD to the right can be determined directly from Figure 13.4E. For the 55 mph design speed, the ISD to the left is 610'. For the 90 km/h design speed, the ISD to the left is 190 m. . The crossing maneuver will not be critical.

<u>Example 13-3</u>

Given: Minor road intersects a 2-lane highway.
Minor road is stop controlled.
Design speed of the major highway is 55 mph (90 km/h).
All travel lane widths are 12' (3.6 m).
The approach grade on the minor road is 4.5%.
Tractor/semitrailer trucks are a concern.

Problem: Determine the intersection sight distance to the left and right from the minor road.

Solution: The following steps will apply:

1. For the left-turning vehicle, the base gap acceptance time from Figure 13.4D is 11.5 seconds. Add the additional time due to the approach grade (0.2 seconds per percent grade) to the base gap time; see Comment #4 in Section 13.4.2.2:

(0.2)(4.5) + 11.5 = 12.4 seconds

Then, using Equation 13.4-1:

U.S. Customary ISD = (1.47)(55)(12.4) = 1003’

Metric ISD = (0.278)(90)(12.4) = 310 m

The ISD for the right-turning vehicle is determined similarly:

(0.1)(4.5) + 11.5 = 12 seconds

Then, using Equation 13.4-1:

U.S. Customary ISD = (1.47)(55)(12.0) = 970’

Metric ISD = (0.278)(90)(12.0) = 300 m

The crossing maneuver will not be critical.

13.4.3 Yield Control

At intersections controlled by a yield sign, drivers on the minor road will typically:

1. slow down as they approach the major road, typically to 60 percent of the approach speed;
2. based on their view of the major road, make a stop/continue decision; and
3. either brake to a stop or continue their crossing or turning maneuver onto the major road.

Yield control criteria is based on a combination of the no control ISD discussed in Section 13.4.1 and the stop-controlled ISD as discussed in Section 13.4.2. To determine the applicable clear sight triangles of the approaches, the following will apply; see Figure 13.4H:

1. Crossing Maneuver. Use the following to determine the legs of the clear sight triangle; Illustration a in Figure 13.4H:

    a. Minor Road. The leg on the minor road approach can be determined directly from Figure 13.4I.

b. Major Road. The leg on the major road is determined using the following equations and the times listed in Figure 13.4I:

U.S. Customary

$$t_g = t_a + \frac{w + L_a}{0.88(V_{\mathrm{minor}})}$$

$$b = (1.47)(V_{major})(t_g)$$

Metric

$$t_g = t_a + \frac{w + L_a}{0.167(V_{\mathrm{minor}})}$$

$$b = (0.278)(V_{major})(t_g)$$

Where:

b = length of leg of sight triangle along the major road ft (m)

t_g = travel time to reach and clear the major road in a crossing maneuver (sec)

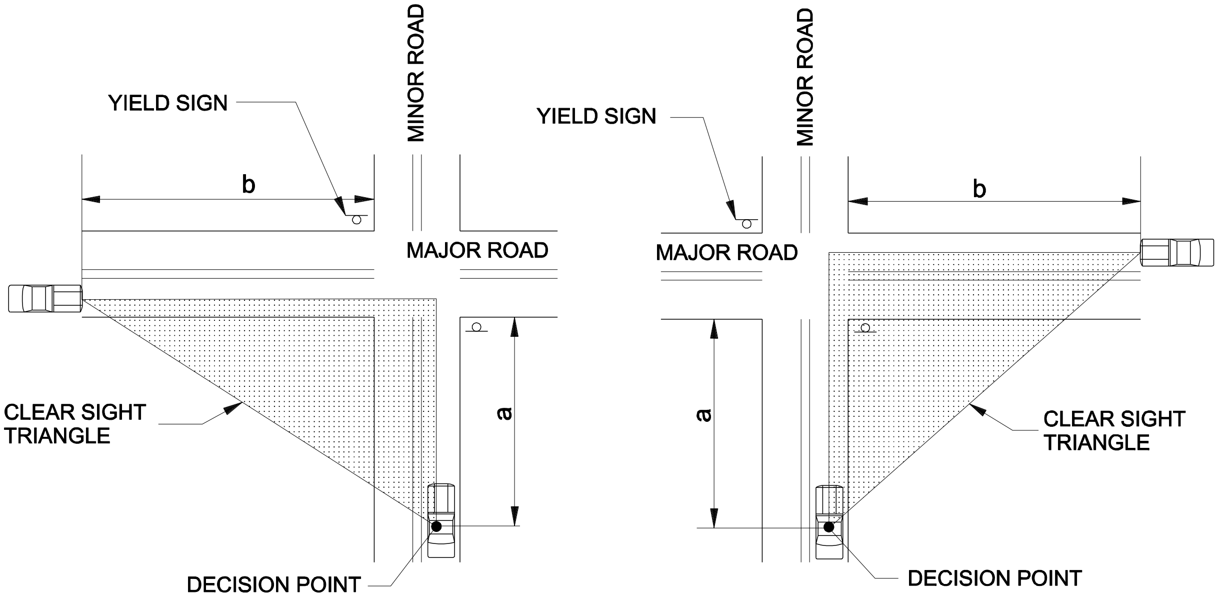
t_a = travel time to reach the major road from the decision point for a vehicle that does not stop(sec) (use appropriate value for the minor-road design speed from Figure 13.4I, adjusted for approach grade, where appropriate)

w = width of intersection to be crossed ft (m)

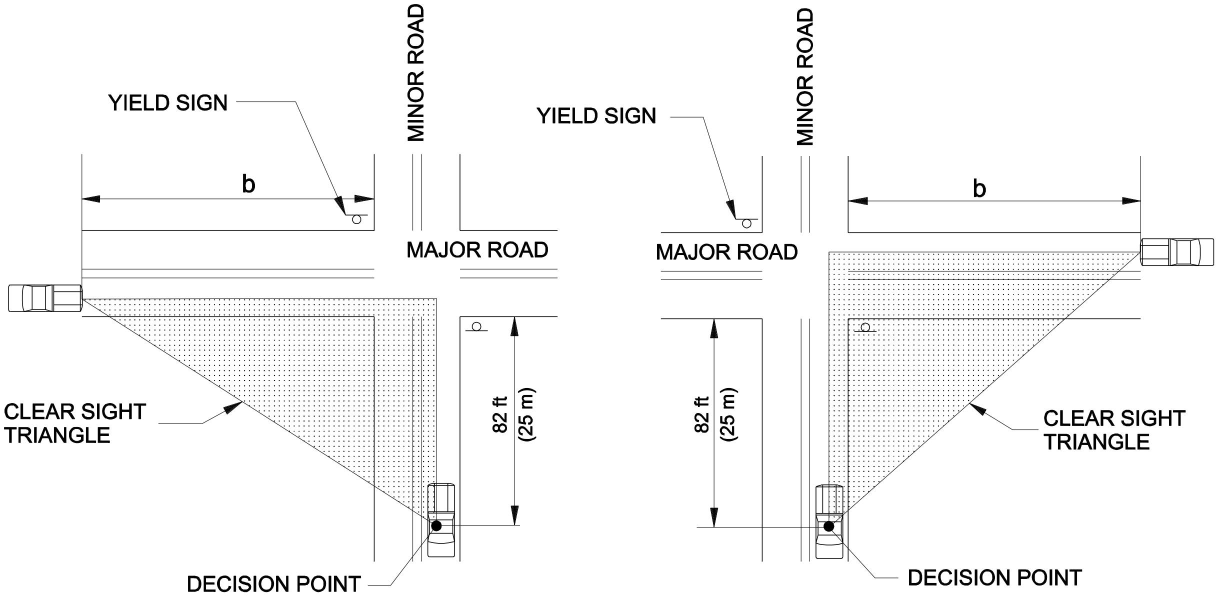
L_a = length of design vehicle ft (m)

V_{minor} = design speed of minor road mph (km/h)

V_{major} = design speed of major road mph (km/h)



a) CROSSING MANEUVERS



b) TURNING MANEUVERS

INTERSECTION SIGHT DISTANCE APPLICATION
(Yield Control)

Figure 13.4H

U.S. Customary

Design Speed (mph)	Approach Distance Along Minor Road(1) (a)(ft)	Travel Time From Decision Point to Major Road (t_a)(1)(2) (sec)
20	100	3.7
25	130	4.0
30	160	4.3
35	195	4.6
40	235	4.9
45	275	5.2
50	320	5.5
55	370	5.8
60	420	6.1
65	470	6.4
70	530	6.7

Metric

Design Speed (km/h)	Approach Distance Along Minor Road(1) (a)(m)	Travel Time From Decision Point to Major Road (t_a)(1)(2) (sec)
30	30	3.6
40	40	4.0
50	55	4.4
60	65	4.8
70	80	5.1
80	100	5.5
90	115	5.9
100	135	6.3
110	155	6.7

(1) For minor-road approach grades that exceed 3%, multiply by the appropriate adjustment factor from Figure 13.4B. Do not apply the adjustment factor to approaches with negative grades.

(2) Travel time applies to a vehicle that slows before crossing the intersection but does not stop.

ISD ASSUMPTIONS FOR YIELD CONTROLLED INTERSECTION
(Crossing Maneuver)

Figure 13.4I

2. Turning Maneuvers. For the turning left or right vehicle, the approach legs are determined as follows; Illustration b in Figure 13.4H:

   a. Minor Road. The assumed turning speed from the minor road to the major road is 10 mph (16 km/h). This corresponds to an approach distance of 82' (25 m) along the minor road leg.

   b. Major Road. To determine the legs along the major road, use the same procedures as discussed in Section 13.4.2.2 for the stop controlled intersection, Equation 13.4-1 and the gap acceptance time listed in Figure 13.4J. Because the gap acceptance time are longer than the stop-controlled gap times, it will be unnecessary to determine the sight distance criteria for the vehicle which stops at the yield sign.

Design Vehicle	Gap Acceptance Time (t_g)(sec)
Passenger Car	8.0
Single-Unit Truck	10.0
Tractor/Semitrailer	12.0

Adjustments:

If the approach grade on the minor road exceeds 3%, the following applies:

1. *For right turns, multiply the percent grade of the minor road approach by 0.1 and add it to the base gap acceptance time.*
2. *For left turns, multiply the percent grade of the minor road approach by 0.2 and add it to the base gap acceptance time.*

GAP ACCEPTANCE TIMES FOR YIELD CONTROL INTERSECTIONS
(Turning Maneuvers)

Figure 13.4J

13.4.4 All-Way Stop

At intersections with all-way stop control, provide sufficient sight distance so that the first stopped vehicle on each approach is visible to all other approaches. The ISD criteria for left or right-turning vehicles as discussed in Section 13.4.2 are not applicable in this situation. Often, intersections are converted to all-way stop control to address limited sight distance at the intersection. Therefore, providing additional sight distance at the intersection is unnecessary.

13.4.5 Stopped Vehicle Turning Left

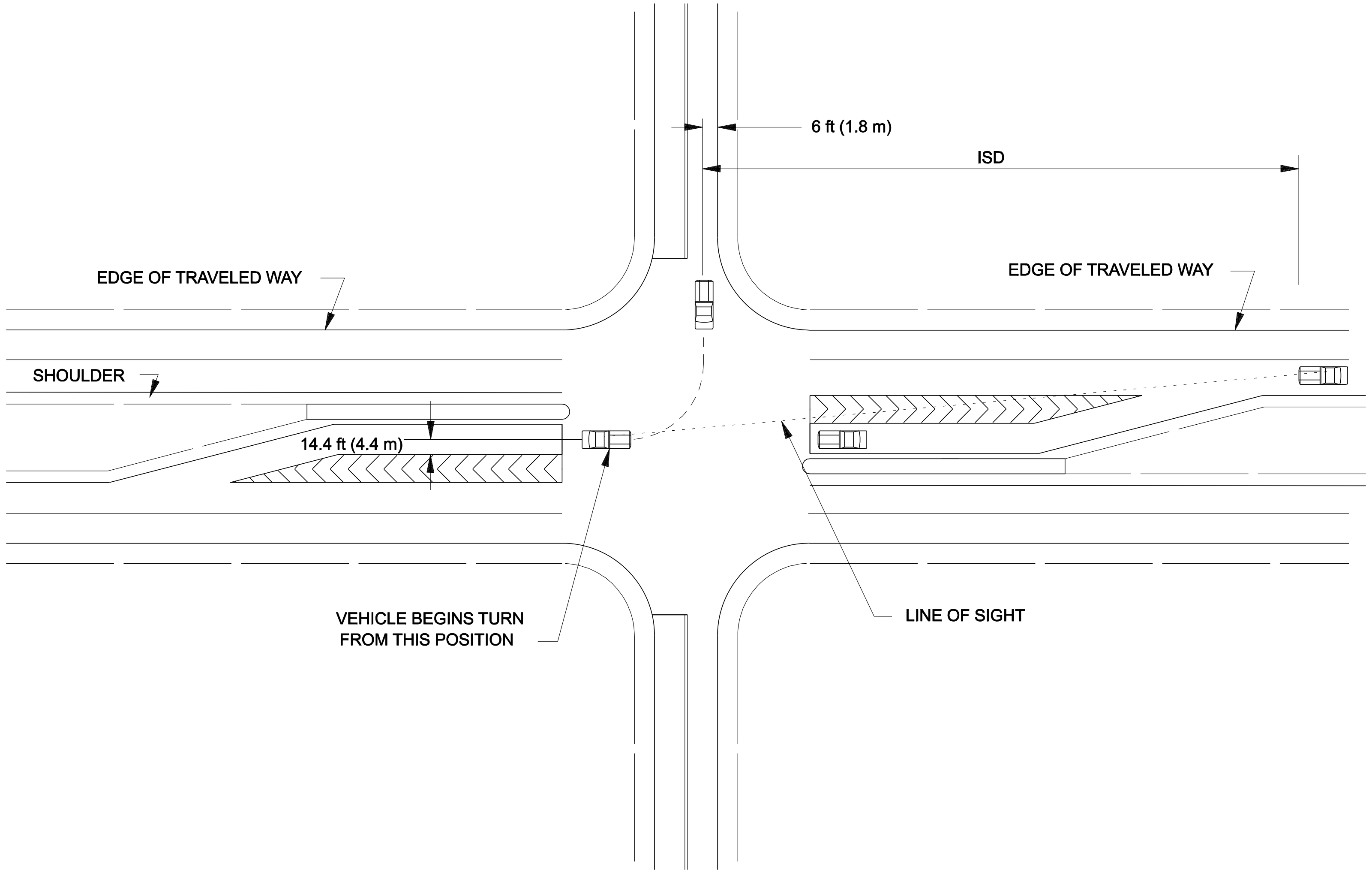
At all intersections, regardless of the type of traffic control, the designer should consider the sight distance needs for a stopped vehicle turning left from the major road. This is illustrated in Figure 13.4K. The driver must see straight ahead for a sufficient distance to turn left and clear the opposing travel lanes before an approaching vehicle reaches the intersection. In general, if the major highway has been designed to meet the stopping sight distance criteria, intersection sight distance only will be a concern where the major road is on a horizontal curve, where there is a median, or where there are opposing vehicles making left turns at an intersection.

Use Equation 13.4-1 (Page 13.4(5)) and the gap acceptance times (t_g) from Figure 13.4L to determine the applicable intersection sight distances for the left-turning vehicle. Where the crossing vehicle must cross more than one lane, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane in excess of one. Where medians are present, the designer will need to consider their effect in the same manner as discussed in Section 13.4.2.2. Figure 13.4M provides the ISD values for all design vehicles and two common left-turning situations.

13.4.6 Measures to Improve Intersection Sight Distance

The available ISD should be checked using the above noted parameters. If the ISD values from the above Sections are provided, no further investigation is needed. If the line of sight is restricted by either bridge railing, guardrail, other obstructions, or the horizontal and vertical alignment of the main road and the ISD value is not available, evaluate one or more of the following modifications, or a combination, to achieve the intersection sight distance:

1. remove the obstructions that are restricting the sight distance,
2. relocate the intersecting road farther from the end of the bridge,
3. widen the structure on the side where the railing is restricting the line of sight,
4. flare the approach guardrail,
5. revise the grades on the main road and/or the intersecting road,
6. close the intersecting road,
7. make the intersecting road one-way away from the main road, and/or
8. review other measures that may be practical at a particular location.



Notes:

1. See Figure 13.4M for ISD values.

2. See Section 13.4.5 for discussion and application.

INTERSECTION SIGHT DISTANCE FOR A STOPPED VEHICLE TURNING LEFT
(On Major Road)

Figure 13.4K

Design Vehicle	Gap Acceptance Time (t_g)(sec)
Passenger Car	5.5
Single-Unit Truck	6.5
Tractor/Semi-trailer	7.5

GAP ACCEPTANCE TIMES
(Left-Turning Vehicles from Major Road)

Figure 13.4L

U.S. Customary (Rounded for design)

Design Speed (Vmajor) (mph)	ISD (ft)					
	Passenger Cars		Single-Unit Trucks		Tractor/Semitrailers	
	Crossing 1 lane	Crossing 2 lanes	Crossing 1 lane	Crossing 2 lanes	Crossing 1 lane	Crossing 2 lanes
20	165	180	195	215	225	245
25	205	225	240	265	280	305
30	245	265	290	320	335	365
35	285	310	335	375	390	425
40	325	355	385	425	445	485
45	365	400	430	480	500	545
50	405	445	480	530	555	605
55	445	490	530	585	610	665
60	490	530	575	640	665	725
65	530	575	625	690	720	785
70	570	620	670	745	775	845
75	610	665	720	795	830	905
80	650	710	765	850	885	965

Metric (Rounded for design)

Design Speed (Vmajor) (km/h)	ISD (m)					
	Passenger Cars		Single-Unit Trucks		Tractor/Semitrailers	
	Crossing 1 lane	Crossing 2 lanes	Crossing 1 lane	Crossing 2 lanes	Crossing 1 lane	Crossing 2 lanes
30	50	55	55	65	65	70
40	65	70	75	85	85	95
50	80	85	95	105	105	115
60	95	105	110	125	130	140
70	110	120	130	145	150	160
80	125	135	145	165	170	185
90	140	155	165	185	190	210
100	155	170	185	205	210	230
110	170	185	200	225	230	255

INTERSECTION SIGHT DISTANCES
(Left-Turning Vehicles from Major Road))

Figure 13.4M

13.5 INTERCHANGES

13.5.1 General

An interchange is a system of ramps in conjunction with one or more grade separations that provides for the movement of traffic between two or more roadways on different elevation levels. The operational efficiency, capacity, safety and cost of the highway facility are largely dependent upon its design. Chapter Twenty-nine of the *Traffic Engineering Manual* provides guidance in the design of interchanges including access guidelines, selection, operations, spacing, freeway/ramp terminals, ramps and ramp/crossroad terminals.

13.5.2 Responsibilities

The following units are responsible for the planning and design of an interchange:

1. Access Review. The Rail, Transit and Planning Division will identify potential sites for a new interchange. The Traffic Engineering Section will review the need for an interchange against the guidelines presented in Section 29.1.2. of the *Traffic Engineering Manual*.

2. Interchange Type Selection. Once it has been determined that an interchange is justified, the Traffic Engineering Section will determine the appropriate interchange type for the site.

3. Geometric Layout. The Geometrics Unit in the Traffic Engineering Section will be responsible for designing the interchange layout including the horizontal alignment, the preliminary profile grade line and ramp/crossroad intersection details.

4. Interchange Design. After coordinating with the Traffic Engineering Section, the Road Design Section will be responsible for determining the final vertical alignment, earthwork quantities, drainage design and contour grading plans. In addition, the Road Design Section will coordinate with the Traffic Engineering Section to determine the necessary access-control lines and right-of-way limits.

5. Detailed Sheets. The Road Design Section in coordination with the Geometrics Unit will be responsible for preparing the detailed sheets that will be included in the construction plans.

6. <u>Consultant Projects.</u> On consultant-designed interchange projects, the consultant will be responsible for the design of all elements including type selection, geometric layout, signing, electrical work, ramp/crossroad intersection details and detailed plan preparation. The Traffic Engineering Section will be responsible for reviewing these items.

13.6 APPROACHES

The designer is referred to the Department's *Approach Standards for Montana Highways* for the Department's criteria on approaches. This publication has been prepared by the Department's Traffic Engineering Section in conjunction with the Right-of-Way Bureau and the Maintenance Division.

These regulations are adopted and issued according to the authority granted to the Montana Transportation Commission and/or the Department of Transportation under current Montana Law. Unless otherwise provided or agreed to, they apply to all highways on the Federal-Aid System. The frequency, proper placement and construction of points of access to highways are critical to the safety and capacity of those highways. These regulations are intended to provide for reasonable and safe access to highways while preserving their safety and utility to the maximum extent practical. These regulations are not intended to alter or reduce existing or future access control or access limitations, nor are they intended to alter or supersede access which has been agreed to by appropriate written contract with the Department of Transportation.

MONTANA DEPARTMENT OF
TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Fourteen

ROADSIDE SAFETY

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Section **Page**

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(Continued)

Chapter Fourteen
ROADSIDE SAFETY

The ideal roadway would be free of obstructions or other hazardous conditions within the entire highway right-of-way. This is usually not practical because of economic, environmental or drainage factors. Chapter Fourteen presents clear zone distances which should adequately provide a clear recovery space for the majority of drivers who run off the road. The Chapter also provides criteria for the use of roadside barriers, median barriers, breakaway devices and impact attenuators where providing the clear zone is not practical.

14.1 DEFINITIONS/NOMENCLATURE

1. Barrier Warrant. A criterion that identifies an area of concern which should be shielded by a traffic barrier, if judged to be practical.

2. Critical Parallel Slope. Slopes which cannot be safely traversed by a run-off-the-road vehicle. Depending on the encroachment conditions, a vehicle on a critical slope may overturn. For most embankment heights, fill slopes steeper than 3:1 are considered critical.

3. Edge of Travel Lane (ETL). The line between the portion of the roadway used for the movement of vehicles and the shoulder. The edge of travel lane is the center line, when considering opposing traffic.

4. Edge of Traveled Way (ETW). The line between the portion of the roadway used for the movement of vehicles and the shoulder regardless of the direction of travel.

5. Impact Angle. For a longitudinal barrier, the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicular path at impact.

6. Impact Attenuator (Crash Cushion). A traffic barrier used to safely shield fixed objects or other obstacles of limited dimension from approximately head-on impacts by errant vehicles.

7. Length of Need. Total length of a longitudinal barrier, measured with respect to the centerline of roadway, needed to shield an area of concern. The length of need is measured to the last point of full-strength rail.

8. Median Barrier. A longitudinal barrier used to prevent an errant vehicle from crossing the median of a divided highway. This prevents collisions between traffic traveling in opposite directions.

9. Non-Recoverable Parallel Slope. Slopes which can be safely traversed but upon which an errant motorist is unlikely to recover. The run-off-the-road vehicle will likely continue down the slope and reach its toe. For most embankment heights, if a fill slope is between 3:1 (inclusive) and 4:1 (exclusive), it is considered a non-recoverable parallel slope.

10. Parallel Slopes. Cut and fill slopes for which the toe runs approximately parallel to the flow of traffic.

11. Recoverable Parallel Slope. Slopes which can be safely traversed and upon which an errant motorist has a reasonable opportunity to stop and return to the roadway. Fill slopes 4:1 and flatter are considered recoverable.

12. Roadside Barrier. A longitudinal barrier used to shield obstacles located within an established clear zone. Roadside barriers include guardrail, half-section concrete median barriers, etc.

13. Roadside Clear Zones. The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope and/or a recovery area. The desired width is dependent upon traffic volumes, speeds and roadside geometry.

14. Roadside Obstacles. A general term to describe roadside features which cannot be safely impacted by a run-off-the-road vehicle. Roadside obstacles include both fixed objects and non-traversable roadside features (e.g., rivers).

15. Shy Distance. Distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver to the extent that he will change vehicular placement or speed.

16. Transverse Slopes. Cut and fill slopes for which the toe runs approximately perpendicular to the flow of traffic. Transverse slopes are typically formed by intersections between the mainline and approach, median crossovers or side roads.

17. Traversable Slopes. A slope or cross section in which a vehicle can safely cross. Parallel slopes 3:1 or flatter are considered traversable.

18. Utility Occupancy Area. A strip of right-of-way reserved for the placement of utilities.

14.2 ROADSIDE CLEAR ZONES

14.2.1 General Application

The clear zone widths presented in this *Manual* must be placed in proper perspective. The distances imply a degree of accuracy that does not exist. They do, however, provide a good frame of reference for making decisions on providing a safe roadside area. Each application of the clear zone distance must be evaluated individually, and the designer must exercise good judgment.

Figure 14.2A presents clear zone distances for design. When using the recommended distances, the designer should consider the following:

1. Context. If a formidable obstacle (see Section 14.3.3) lies just beyond the clear zone, it may be appropriate to remove or shield the obstacle if costs are reasonable. Conversely, the clear zone should not be achieved at all costs. Limited right-of-way or unacceptable construction costs may result in unshielded obstacles within the clear zone or may lead to the installation of a barrier. Unshielded obstacles within the clear zone, including the adjusted CZ_C for horizontal curves, must be approved through the design exception process. See Section 8.8.

2. Boundaries. The designer should not use the clear zone distances as boundaries for introducing roadside obstacles such as bridge piers, non-breakaway sign supports, utility poles or landscaping features. Place these items as far from the traveled way as practical.

3. Roadside Cross Section. The recommended clear zone distance will be based on the type of roadside cross section. Section 14.2.3 presents several schematics for the various possibilities.

4. Measurement. All clear zone distances are measured from the edge of the traveled way. For auxiliary lanes (e.g., climbing lanes, turning lanes, weaving lanes), the clear zone is measured from the edge of the auxiliary lane based on the mainline design speed and mainline design AADT.

5. Utility Occupancy Area. The designer should note that clear zones and the utility occupancy area, as discussed in the *MDT Utility Accommodation Policy*, are independent dimensions. Place utilities outside of the clear zone or the utility occupancy area, whichever is greater.

US Customary Units

Design Speed	Design AADT	Fill Slopes/Foreslopes			
		6:1 or Flatter	5:1	4:1	3:1
40 mph or less	< 750	**8**	**8**	**10**	See Procedure in Section 14.2.3.
	750-1499	**10**	**12**	**14**	
	1500-6000	**12**	**14**	**16**	
	> 6000	**14**	**16**	**18**	
45 mph	< 750	**10**	**12**	**14**	
	750-1499	**12**	**16**	**18**	
	1500-6000	**16**	**20**	**24**	
	> 6000	**18**	**24**	**26**	
50 mph	< 750	**12**	**12**	**14**	
	750-1499	**14**	**16**	**20**	
	1500-6000	**18**	**24**	**26**	
	> 6000	**20**	**26**	**28**	
55 mph	< 750	**12**	**14**	**18**	
	750-1499	**16**	**20**	**24**	
	1500-6000	**20**	**24**	**30**	
	> 6000	**22**	**26**	**32**	
60 mph	< 750	**16**	**20**	**24**	
	750-1499	**20**	**26**	**32**	
	1500-6000	**26**	**32**	**40**	
	> 6000	**30**	**36**	**44**	
70 mph	< 750	**20**	**24**	**26**	
	750-1499	**24**	**30**	**36**	
	1500-6000	**30**	**36**	**42**	
	> 6000	**32**	**38**	**46**	

CLEAR ZONE DISTANCES (ft)

Notes:

1. All distances are measured from the edge of the traveled way (ETW = 12.0' US Customary, measured from centerline).

   For clear zones, the "Design AADT" will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.
2. See Sections 14.2.2 and 14.2.4 for adjustments on horizontal curves and clear zones in cut sections.

Figure 14.2A

Metric Units

Design Speed	Design AADT	Fill Slopes/Foreslopes			
		6:1 or Flatter	5:1	4:1	3:1
60 km/h or less	< 750	2.0	2.0	3.0	See Procedure in Section 14.2.3.
	750-1499	3.0	3.5	4.5	
	1500-6000	3.5	4.5	5.0	
	> 6000	4.5	5.0	5.5	
70 km/h	< 750	3.0	3.5	4.0	
	750-1499	4.5	5.0	5.5	
	1500-6000	5.0	6.0	6.5	
	> 6000	6.0	7.5	8.0	
80 km/h	< 750	3.5	4.0	4.5	
	750-1499	5.0	5.5	6.0	
	1500-6000	5.5	7.0	8.0	
	> 6000	6.5	8.0	8.5	
90 km/h	< 750	3.5	4.5	5.5	
	750-1499	5.0	6.0	7.5	
	1500-6000	6.0	7.5	9.0	
	> 6000	6.5	8.0	10.0	
100 km/h	< 750	5.0	6.0	7.5	
	750-1499	6.0	8.0	10.0	
	1500-6000	8.0	10.0	12.0	
	> 6000	9.0	11.0	13.5	
110 km/h	< 750	5.5	6.0	8.0	
	750-1499	7.5	8.5	11.0	
	1500-6000	8.5	10.5	13.0	
	> 6000	9.0	11.5	14.0	

CLEAR ZONE DISTANCES (m)

Notes:

1. All distances are measured from the edge of the traveled lane (ETL = 3.6 m measured from centerline).

   For clear zones, the "Design AADT" will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.

2. See Sections 14.2.2 and 14.2.4 for adjustments on horizontal curves and clear zones in cut sections.

Figure 14.2A

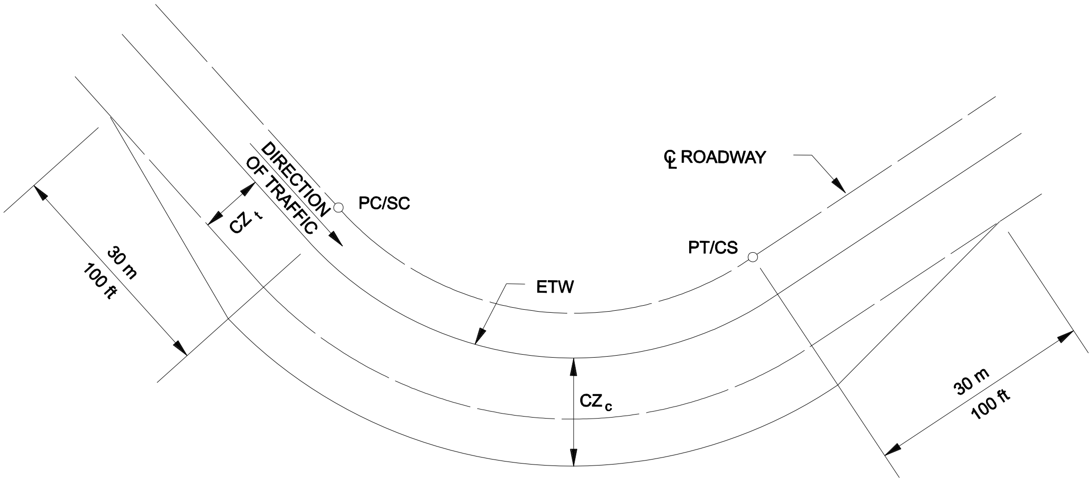
6. Roadside Clear Zone. The recommended clear zone distance from Figures 14.2A(a or b) should be selected based on the highway design speed, geometric features, slope condition and traffic volumes. Generally, select the clear zone distance for the steepest slope encountered when more than one slope falls within the clear zone.

7. Design AADT. For clear zones, the "Design AADT" will be the total AADT of the roadway including both directions of travel. This applies to both divided and undivided facilities.

14.2.2 Horizontal Curves

On the outside of horizontal curves, run-off-the-road vehicles may travel a farther distance from the traveled way before regaining control of the vehicle. The designer should modify the clear zone distance obtained from Figure 14.2A(a or b) for horizontal curvature. The modified value for horizontal curves will be used to determine if a design exception to the clear zone criteria is necessary; see Section 14.2.6.

Figure 14.2B illustrates the application of the clear zone adjustment on a curve. Figure 14.2C provides recommended adjustments for horizontal curves.



On the inside of horizontal curves, use the clear zone distance for a tangent roadway.
CZ_t = clear zone on tangent section
CZ_c = clear zone on horizontal curve
ETW = edge of traveled way.

HORIZONTAL CURVE ADJUSTMENTS

Figure 14.2B

US Customary

Radius (ft)	Design Speed (mph)					
	40	45	50	55	60	70
2860	1.1	1.1	1.1	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.5
1430	1.2	1.2	1.3	1.3	1.4	
1270	1.2	1.2	1.3	1.3	1.4	
1150	1.2	1.2	1.3	1.4	1.5	
950	1.2	1.3	1.4	1.5	1.5	
820	1.3	1.3	1.4	1.5		
720	1.3	1.4	1.5			
640	1.3	1.4	1.5			
570	1.4	1.5				
≤ 380	1.5					

Metric

Radius (m)	Design Speed (km/h)					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	
350	1.2	1.2	1.3	1.4	1.5	
300	1.2	1.3	1.4	1.5	1.5	
250	1.3	1.3	1.4	1.5		
200	1.3	1.4	1.5			
150	1.4	1.5				
≤ 100	1.5					

Notes:

Theses tables match the *2002 Roadside Design Guide.*

1. Adjustments apply to the outside of a horizontal curve.

2. Curve radii greater than 2860 ft (900 m) do not require adjustments.

3. The applicable clear zone distance on a horizontal curve is calculated by:

   $CZ_C = (K_{CZ})(CZ_T)$

   where: CZ_C = clear zone on outside of curve

   K_{CZ} = curve adjustment factor

   CZ_T = clear zone on a tangent section from Figure 14.2A

4. For curves intermediate in the table, use a straight-line interpolation.

5. See Figure 14.2B for the application of CZ_C to the roadside around a curve.

6. Round the computed clear zone distance up to the next higher 1' (0.5 m) increment.

CLEAR ZONE ADJUSTMENT FACTORS FOR HORIZONTAL CURVES (K_{CZ})

Figure 14.2C

14.2.3 Parallel Slopes

Figure 14.2A presents the Department's criteria for clear zones on fill slopes which run parallel to the highway. The following discusses the application of the figure:

1. Recoverable Fill Slopes. For parallel fill slopes 4:1 and flatter (Figure 14.2D), the recommended clear zone distance can be determined directly from Figure 14.2A.

2. Non-Recoverable Fill Slopes. For parallel fill slopes between 3:1 (inclusive) and 4:1 (exclusive) (Figure 14.2D), adjust the clear zone to include a minimum 10’ (3.0 m) recovery area beyond the toe of the fill slope. It is recommended that sufficient right-of-way be purchased to ensure that the recovery area can be maintained and cleared of obstacles. The following procedure is used to determine the adjusted clear zone:

    a. Ensure that the slope in the recovery area beyond the toe is 4:1 or flatter. Determine the clear zone from Figure 14.2A using the slope rate beyond the toe, the applicable design speed and traffic volume.

    b. To determine the recovery area distance beyond the toe, subtract the width of the recoverable slope(s) between the ETW and the hinge point from the distance in Step #2a.

    c. If the distance in Step #2b is greater than or equal to 10’ (3.0 m), this distance will be the width of the recovery area. If the distance in Step #2b is less than 10’ (3.0 m), the minimum recovery area will be 10’ (3.0 m) beyond the toe.

    d. The adjusted clear zone is the distance from the edge of the traveled way to the outside limit of the recovery area; see Figure 14.2D.

    e. The designer should check to determine if a recoverable parallel slope(s) can be incorporated from the shoulder to the adjusted clear zone as determined in Step #'s 2b and 2c. The designer must review the benefits of providing a flatter slope versus the cost for additional embankment fill.

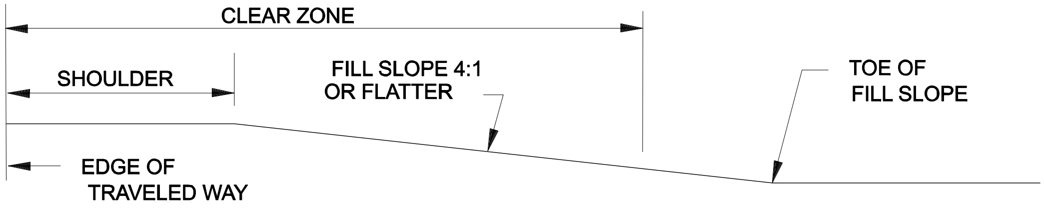
3. Barn-Roof Fill Slope This design requires less right-of-way and embankment material than a continuous, flatter slope. However, the use of barn-roof slopes requires a design exception to the Department’s slope criteria; see Section 8.8. Note: a barn-roof slope cannot be used just to eliminate guardrail.

a. Recoverable/Recoverable Barn-roof fill slopes may be designed with two recoverable slope rates; the second slope is steeper than the slope adjacent to the shoulder. If the clear zone for the flatter slope extends beyond the hinge point of the two slopes, determine the clear zone using the steeper slope.

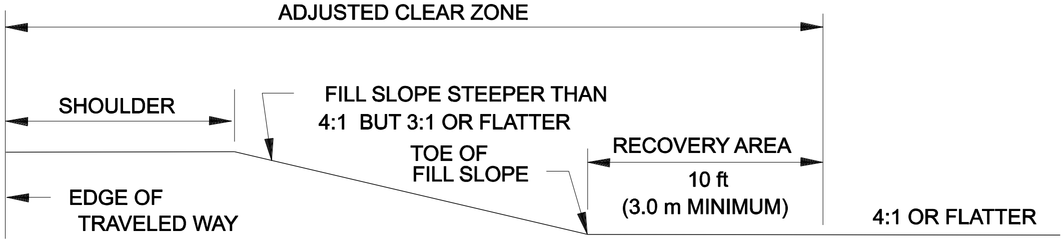
b. Recoverable/Non-Recoverable Barn-roof fill slopes may be designed with a recoverable slope leading to a non-recoverable slope (Figure 14.2D(c)). The clear zone should be provided entirely on the recoverable slope (i.e., the shoulder and recoverable slope should equal the clear zone distance). If the clear zone based on the recoverable slope extends beyond the slope break between the recoverable and non-recoverable slope, use the procedure in No. 2 above to determine the lateral extent of the clear zone.

c. Recoverable/Critical Barn-roof fill slopes may be designed with a recoverable slope leading to a critical slope (i.e., fill slopes steeper than 3:1). See Figure 14.2D(c). This barn-roof design may only be used if there are no other practical alternatives. The clear zone based on the recoverable slope rate must be provided entirely on the recoverable slope (i.e., the clear zone must equal or be less than the sum of the shoulder width and recoverable slope width). Otherwise, a barrier may be warranted. See Section 14.3.2.

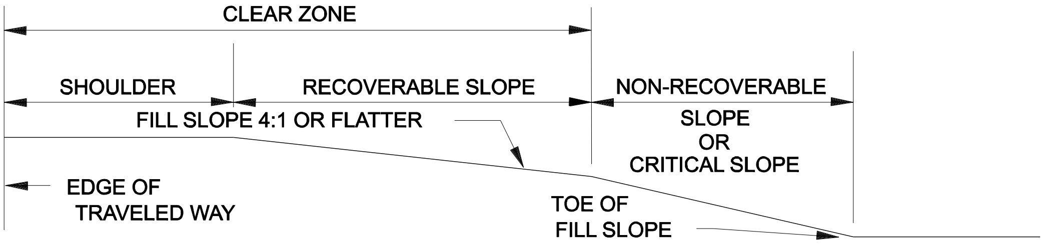
4. Critical Fill Slope. Fill slopes steeper than 3:1 are critical (Figure 14.2D(d)). These fill slopes may require a barrier if located within the clear zone. See Section 14.3.2.



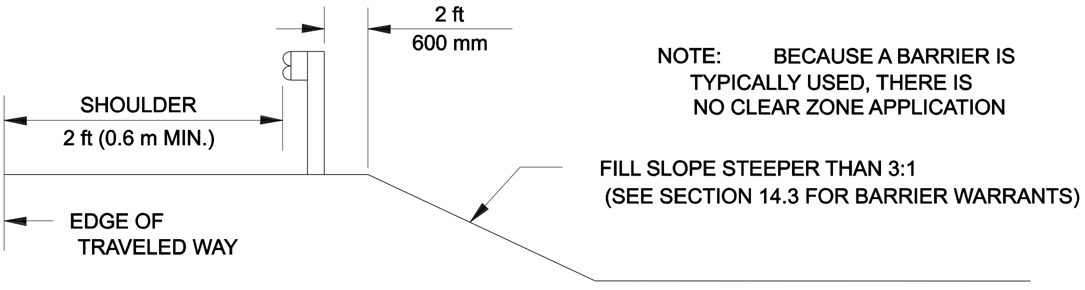
RECOVERABLE PARALLEL SLOPE (a)



NON-RECOVERABLE PARALLEL SLOPE (b)



BARN-ROOF PARALLEL SLOPE (c)



CRITICAL PARALLEL SLOPE (d)

CLEAR ZONE APPLICATION FOR FILL SLOPES

Figure 14.2D

14.2.4 Cut Slopes

Ditch sections, as illustrated in Figure 14.2E, are typically constructed in roadside cuts without curbs. The applicable clear zone across a ditch section will depend upon the inslope, the back slope, the horizontal location of the toe of the back slope, and various highway factors. Use the following procedure to determine the recommended clear zone distance:

1. Check Inslope. Use Figure 14.2A to determine the clear zone based on the ditch inslope.

2. Check Location of the Toe of Back Slope. Based on the distance from Step #1, determine if the toe of the back slope is within the clear zone. The toe of back slope is defined as the intersection of the ditch bottom and the back slope. If the toe is at or beyond the clear zone, then the designer usually need only consider roadside obstacles within the clear zone on the inslope and within the ditch. If the toe is within the clear zone, the designer should evaluate the practicality of relocating the toe of back slope. If the toe of back slope will remain within the clear zone, Step #4 will apply.

3. Check Ditch Traversability. The designer should evaluate the traversability of the ditch cross section. See Section 14.3.6.1. If the ditch is not traversable, it should be relocated outside the clear zone or reconstructed to an acceptable cross section.

4. Check for Roadside Obstacles on Back Slope (Earth Cuts). If the toe of the back slope is within the clear zone distance from Step #1 above and the ditch is traversable, provide a clear zone on the back slope. This clear zone will be a distance beyond the toe of back slope as follows:

    a. Calculate the percentage of the clear zone available to the toe of the back slope.

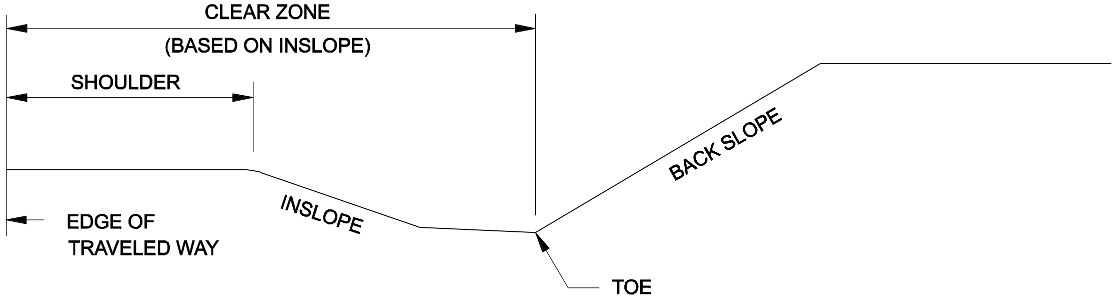
    b. Subtract this percentage from 100% and multiply the results by the clear zone for the back slope in Figure 14.2F.

    c. Add the available clear zone to the toe of the back slope to the value determined in Step #4b. Round the total up to the next higher 1' (0.5 m) increment. This yields the required clear zone from the edge of traveled way to a point on the back slope.

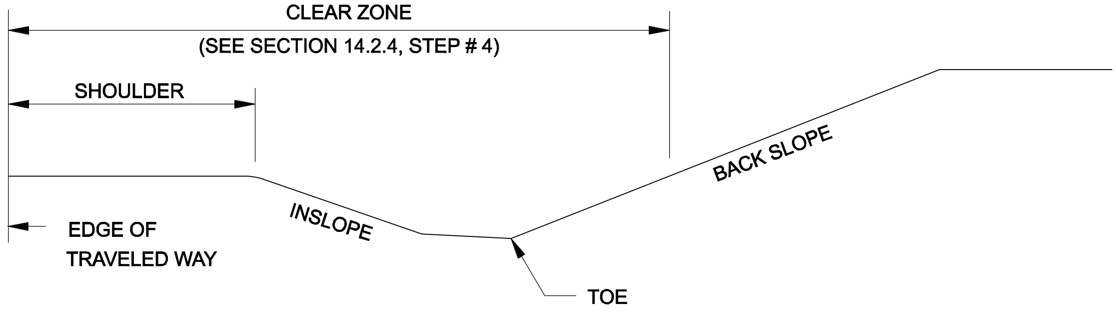
5. Clear Zones (Rock Cuts). In rock cuts with steep back slopes, no clear zone is required beyond the toe of back slope. The rock cut should be relatively smooth

to minimize the hazards of vehicular impact. If the face of the rock is rough or rock debris occurs in the ditch section, a barrier may be warranted.

* * * * * * * * * *



TOE OF BACK SLOPE NOT WITHIN CLEAR ZONE (a)



TOE OF BACK SLOPE WITHIN CLEAR ZONE (b)

CLEAR ZONE APPLICATION FOR CUT SLOPES
Figure 14.2E

US Customary

Design Speed	Design AADT	Back Slopes/Earth cuts			
		6:1 or Flatter	5:1	4:1	3:1
40 mph or less	< 750	7	7	7	7
	750-1499	10	10	10	10
	1500-6000	12	12	12	12
	> 6000	14	14	14	14
45 mph	< 750	10	10	8	8
	750-1499	14	14	12	10
	1500-6000	16	16	14	12
	> 6000	20	20	18	14
50 mph	< 750	10	10	8	8
	750-1499	16	14	12	10
	1500-6000	18	16	14	14
	> 6000	22	20	18	16
55 mph	< 750	12	12	10	8
	750-1499	16	16	14	10
	1500-6000	20	18	16	14
	> 6000	22	22	20	18
60 mph	< 750	14	14	12	10
	750-1499	20	18	16	12
	1500-6000	24	22	18	14
	> 6000	26	26	24	20
70 mph	< 750	16	16	14	12
	750-1499	22	20	18	16
	1500-6000	26	24	22	18
	> 6000	28	28	26	22

ADJUSTED BACKSLOPE CLEAR ZONE FACTORS (ft)

Notes

1. *To use this table follow procedure in Section 14.2.4 Item 4.*
2. *All distances are measured from the edge of the traveled way (ETW 12.0', measured from centerline).*
3. *For clear zones, the "Design AADT" will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.*
4. *See Section 14.2.2 for adjustments on horizontal curves.*

Figure 14.2F

Metric

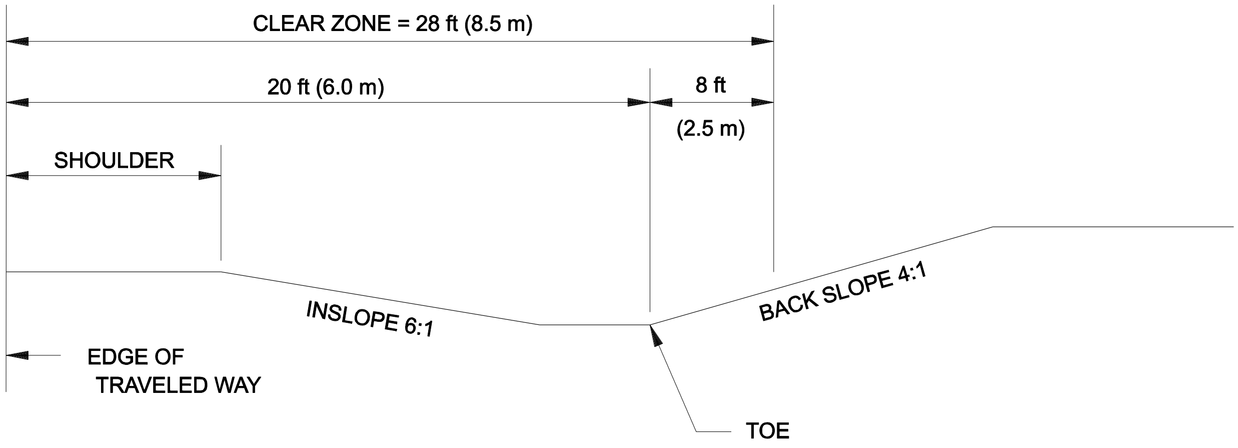
Design Speed	Design AADT	Back Slopes/Earth cuts			
		6:1 or Flatter	5:1	4:1	3:1
60 km/h or less	< 750	2.0	2.0	2.0	2.0
	750-1499	3.0	3.0	3.0	3.0
	1500-6000	3.5	3.5	3.5	3.5
	> 6000	4.5	4.5	4.5	4.5
70 km/h	< 750	3.0	3.0	2.5	2.5
	750-1499	4.5	4.0	3.5	3.0
	1500-6000	5.0	4.5	4.5	3.5
	> 6000	6.0	5.5	5.5	4.5
80 km/h	< 750	3.0	3.0	3.0	2.5
	750-1499	5.0	4.5	4.0	3.0
	1500-6000	5.5	5.0	4.5	4.5
	> 6000	6.5	6.0	5.5	5.0
90 km/h	< 750	3.0	3.0	3.0	2.5
	750-1499	5.0	5.0	4.5	3.0
	1500-6000	6.0	5.5	5.0	4.5
	> 6000	6.5	6.5	6.0	5.0
100 km/h	< 750	4.5	4.5	3.5	3.0
	750-1499	6.0	5.5	5.0	3.5
	1500-6000	7.5	6.5	5.5	4.5
	> 6000	8.0	8.0	7.5	6.0
110 km/h	< 750	4.5	4.5	4.5	3.0
	750-1499	6.0	6.0	5.5	3.5
	1500-6000	8.0	7.5	6.5	5.0
	> 6000	8.5	8.5	8.0	6.5

ADJUSTED BACKSLOPE CLEAR ZONE FACTORS (m)

Notes:

1. *To use this table follow procedure in Section 14.2.4 Item 4.*
2. *All distances are measured from the edge of the traveled way (ETW 3.6 m, measured from centerline).*
3. *For clear zones, the "Design AADT" will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.*
4. *See Section 14.2.2 for adjustments on horizontal curves.*

Figure 14.2F



CLEAR ZONE AT DITCH SECTION
(Example 14-1)
Figure 14.2G

Example 14-1 (Earth Ditch Section)

Given:	US Customary	Metric
	AADT = 7000	AADT = 7000
	Tangent Roadway	Tangent Roadway
	Inslope = 6:1	Inslope = 6:1
	Back Slope = 4:1	Back Slope = 4:1
	V = 60 mph	V = 100 km/h
	Ditch Width = 10’	Ditch Width = 3.0 m
	Toe of back slope is 20’ from ETW	Toe of back slope is 6.0 m from ETW

See Figure 14.2G above.

Problem: Determine the clear zone application across the ditch section.

Solution: Using the procedure in Section 14.2.4.

1. Check Inslope. Figure 14.2A yields a clear zone of 30’ (9.0 m), for a 6:1 inslope.

2. Check Location of Toe of Back Slope. The toe of back slope is within the clear zone. Therefore, Step #4 applies.

3. Check Ditch Traversability. As discussed in Section 14.3.6.1, the ditch in this example is a traversable ditch and, therefore, is not a roadside hazard.

4. Check for Roadside Obstacles on Back Slope. Using the procedure in Step #4:

    a. The percentage of the clear zone available to the toe of back slope is 20/30 (6/9) = 67%

    b. Subtracting this percentage from 100% yields: 100 - 67 = 33%. Figure 14.2F(a) yields a clear zone on a 4:1 back slope of 24’ (7.5 m). Multiplying this by 33% yields: (24)(0.33) = 8’, (7.5)(0.33) = 2.5 m,

    c. Adding 8’ to 20’ yields 28’, and adding 2.5 m to 6.0 m yields 8.5 m. Therefore, the total clear zone is 28’ (8.5 m), from the edge of traveled way or 8’ (2.5 m) up the 4:1 back slope.

* * * * * * * * * *

14.2.5 Curbed Sections

The clear zone width is not reduced due to the presence of curb. However, because substantial development typically occurs in these areas, it is usually impractical to remove or shield all obstacles within the clear zone. Use the following guidelines when curbs are encountered:

1. Horizontal Clearance. On low-speed urban streets ($V \leq 45$ mph (70 km/h), the minimum horizontal clearance to an obstruction is 1.5’ (500 mm) from the face of curb. However, if practical, provide a 5’ to 10’(1.5 m to 3.0 m) clearance, especially at intersections and driveway entrances.

2. Sidewalks. Where sidewalks are adjacent to the curb (i.e., there is no boulevard), locate all appurtenances behind the sidewalk, if practical. In addition, the designer must ensure that sufficient sidewalk width is available between appurtenances and the curb to meet the ADA clearance criteria; see Chapter Eighteen.

14.2.6 Design Exceptions

The designer must seek a design exception when the proposed design does not provide the clear zone criteria presented in this Section, including the horizontal curve adjustment in Section 14.2.2; i.e., the adjusted clear zone on a horizontal curve section will be used to determine if a design exception is required. If shielding obstacles outside of the clear zone is necessary the decision must be documented. See Section 8.8 for the design exception process.

14.3 ROADSIDE BARRIER WARRANTS

14.3.1 Range of Treatments

If a roadside obstacle is within the clear zone, the designer should select the treatment which is judged to be the most practical and cost-effective for the site conditions. The range of treatments listed in order of preference include:

1. eliminate the obstacle (flatten embankment, remove rock outcroppings, etc.);
2. relocate the obstacle;
3. where applicable, make the obstacle breakaway (sign posts, luminaire supports);
4. shield the obstacle with a roadside barrier; or
5. do nothing.

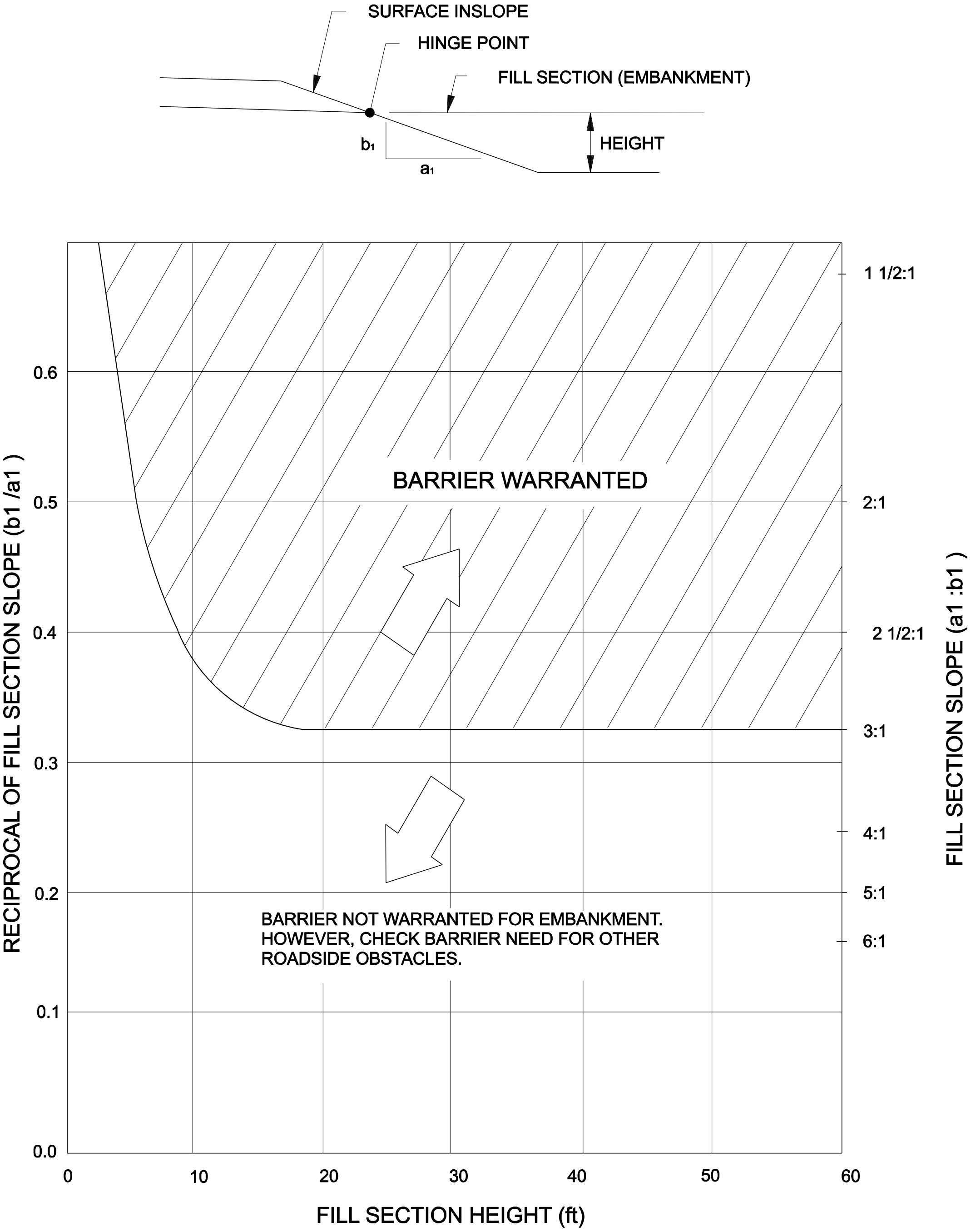
The selected treatment will be based upon the traffic volumes, roadway geometry, proximity of the obstacle to traveled way, nature of the hazard, costs for remedial action and accident experience. Where used, the designer should ensure that any roadside barrier installations are considered early in the project design. The design of an embankment slope flatter than those required by the MDT design criteria should be documented in the Scope of Work or Plan-in-Hand Report. The option to “do nothing” will require a design exception.

14.3.2 Embankments

The severity of the roadside embankment depends upon the rate of fill slope and the height of fill. For all highways, use Figure 14.3A to determine if a barrier is warranted. For low embankment heights, the criteria allow fill slopes steeper than 3:1 to remain unshielded. A barrier is not required for areas outside of the shaded region, unless there are roadside obstacles within the clear zone as determined from Section 14.2.

14.3.3 Roadside Obstacles

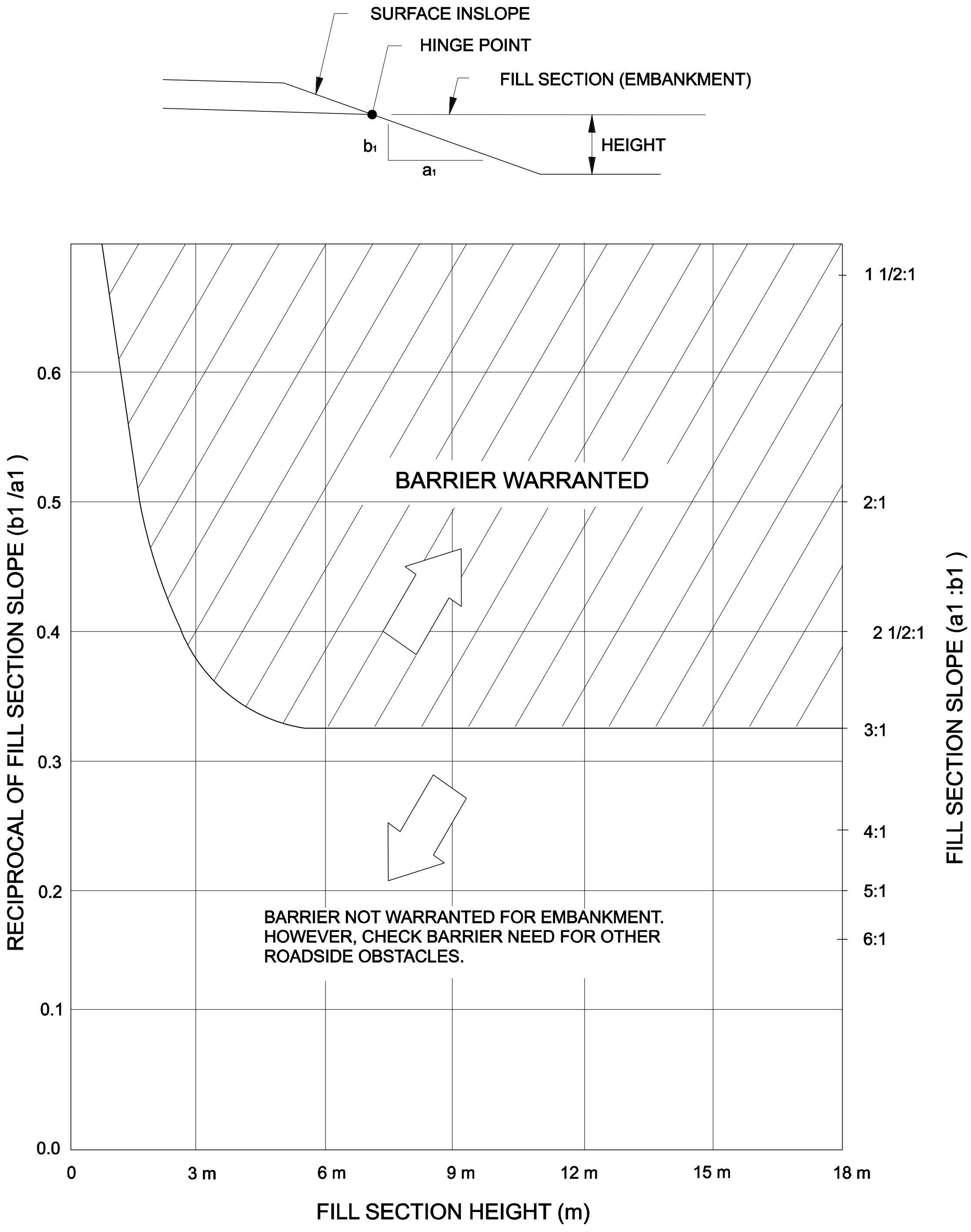
Section 14.2 presents the recommended clear zone distances for various highway conditions. These distances should be free of any fixed or non-traversable obstacles. In general, barrier warrants are based on the relative severity between impacting the barrier and impacting the obstacle. A few examples of roadside obstacles include:



NOTE: POINTS WHICH FALL ON THE SOLID LINE DO NOT WARRANT A BARRIER.

BARRIER WARRANTS FOR EMBANKMENTS

Figure 14.3A US Customary



NOTE: POINTS WHICH FALL ON THE SOLID LINE DO <u>NOT</u> WARRANT A BARRIER.

BARRIER WARRANTS FOR EMBANKMENTS
Figure 14.3A Metric

1. non-breakaway sign supports, non-breakaway luminaire supports, traffic signal poles and railroad signal poles;

2. concrete footings, etc., extending more than 4” (100 mm) above the ground;

3. bridge piers and abutments at underpasses, bridge parapet ends and pedestrian rail ends (see Figure 14.3B);

4. retaining walls and culvert headwalls;

5. trees with diameter greater than 4” (100 mm) (at maturity);

6. rough rock cuts;

7. large boulders;

8. critical parallel slopes;

9. streams or permanent bodies of water [where the depth of water ≥ 12” (300 mm)];

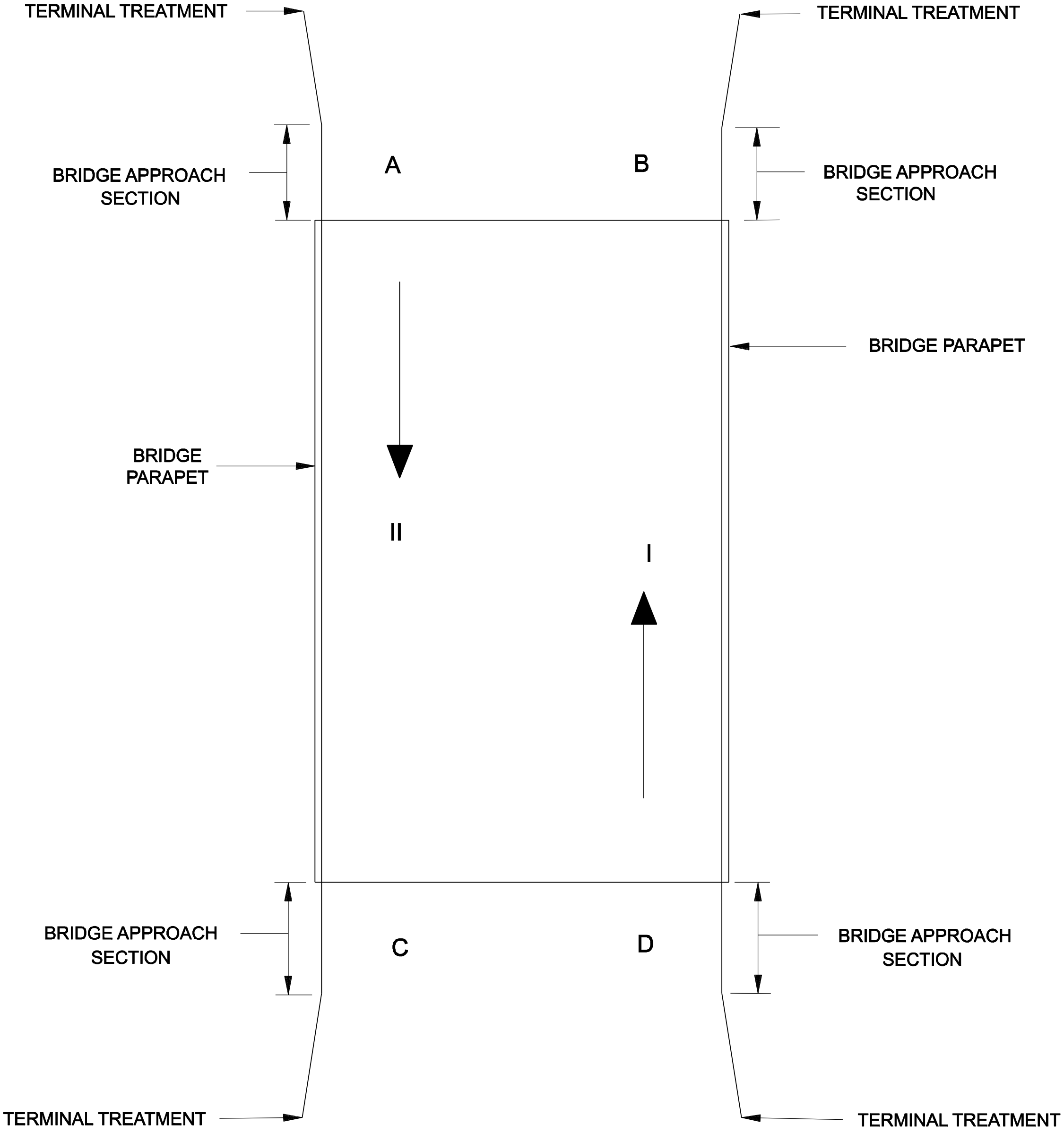
10. non-traversable ditches;

11. utility poles or towers; and

12. culvert ends

Once the designer has concluded that an obstacle is located within the clear zone, the first attempt should be to remove or relocate the obstacle or to make the object breakaway. If these are not practical, a barrier should be installed only if engineering judgment indicates it is a reasonable solution. For example, it would probably not be practical to install a barrier to shield an isolated point obstacle, such as a tree, located near the edge of the clear zone.

Shielding obstacles located just outside the clear zone may be appropriate particularly for features installed by the Department or sites that have a crash history. For example, shielding a bridge end location just outside the clear zone may be justified, due to the potential severity of the crash and running speeds higher than the design speeds. These situations should be reviewed during the development of the project.



TRAFFIC DIRECTION	BRIDGE APPROACH SECTION REQUIRED AT *
I and II	A B C D
II Only	A B
I Only	C D

* ONLY IF WITHIN CLEAR ZONE OF APPROACHING TRAFFIC

BARRIER WARRANTS AT BRIDGES

Figure 14.3B

14.3.4 Transverse Slopes

Where the highway mainline intersects an approach, side road or median crossing, a slope transverse to the mainline will be present. See Figure 14.3C. In general, transverse slopes should be as flat as practical. For slopes within the clear zone, the following will apply:

1. High-Speed Facilities. For high-speed facilities (V > 45 mph, (70 km/h)), provide a transverse slope no steeper than 6:1. Transverse slopes of 10:1 are desirable where practical.

2. Low-Speed/Urban Facilities. For low-speed facilities (V ≤ 45 mph, (70 km/h)) and for non-freeways in urban areas, transverse slopes should desirably be 6:1 or flatter. Where necessary, steeper transverse slopes may be used to provide practical designs (e.g., urban facilities with closely spaced driveways).

Slopes may be transitioned to a steeper slope beyond the clear zone. Where these criteria cannot be practically met in rural areas, consider providing a roadside barrier. The decision to use a barrier will be made on a case-by-case basis considering costs, traffic volumes, severity of the proposed transverse slope and other relevant factors.

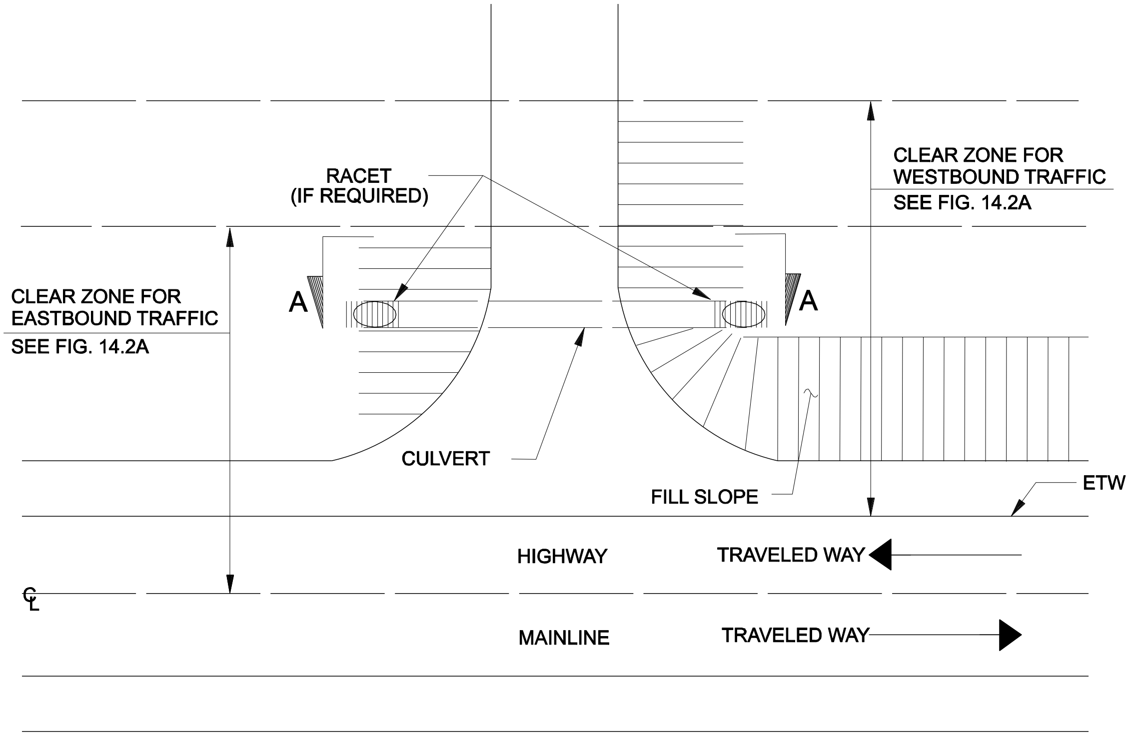
14.3.5 Rock Cuts

As indicated in Section 14.3.3, rough rock cuts located within the clear zone may be considered a roadside obstacle. The following will apply to their treatment:

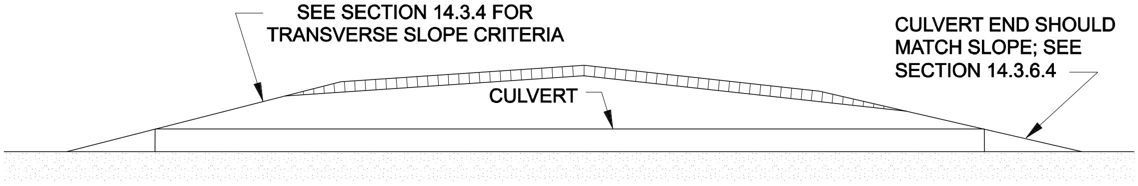
1. Obstacle Identification. There is no precise method to determine whether or not a rock cut is sufficiently "ragged" to be considered a roadside obstacle. This will be a judgment decision based on a case-by-case evaluation.

2. Debris. A roadside obstacle may be identified based on known or potential occurrences of rock debris encroaching onto the roadway. If rock debris is expected within the clear zone, a barrier for capturing the debris may be required. Contact the Geotechnical Section to determine the length of need and type of barrier required.

3. Barrier Warrant. If the rock cut is within the clear zone, a barrier may be warranted.



NOTE: ON A 1-WAY FACILITY, THE RACET ON THE DEPARTURE SIDE OF THE APPROACH IS NOT REQUIRED.



SECTION A-A

TRANSVERSE SLOPES
ON A 2-LANE, 2-WAY ROADWAYS
Figure 14.3C

14.3.6 Roadside Drainage Features

Effective drainage is one of the most critical elements in the design of a roadway or street. Drainage features should be designed and constructed considering their consequences on run-off-the-road vehicles. Ditches, curbs, culverts and drop inlets are common drainage system elements that should be designed, constructed and maintained considering both hydraulic efficiency and roadside safety.

In general, the following options, listed in order of preference, are applicable to all drainage features:

1. Construct or relocate outside the clear zone.

2. Design or modify drainage structures, with openings greater than 36” (900 mm), so that they are traversable or present a minimal hazard to an errant vehicle. If the culvert has a FETS the opening is greater than the diameter of the pipe.

3. If a drainage feature, with an opening greater than 36” (900 mm), cannot effectively be redesigned or relocated, consider shielding by a traffic barrier if the feature is in a vulnerable location and if a barrier installation is judged to be cost effective.

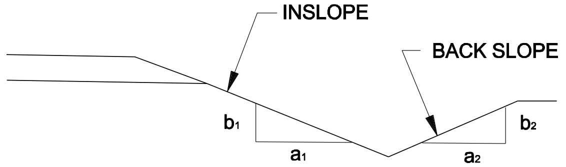
14.3.6.1 Roadside Ditches

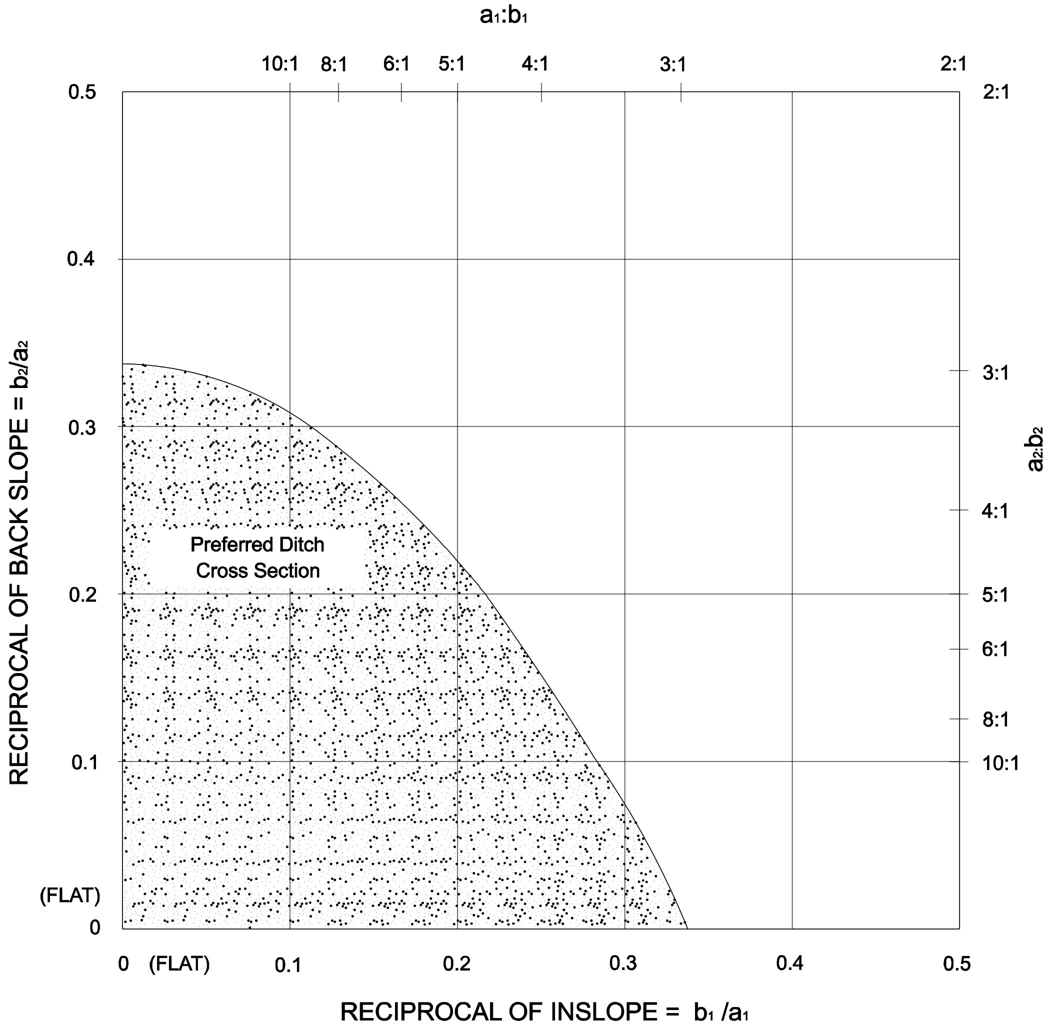
Figures 14.3D and 14.3E present inslope and back slope combinations for basic ditch configurations. Cross sections which fall in the shaded region of each of the figures are considered traversable. Ditch sections which fall outside the shaded region are considered non-traversable and should be redesigned to an acceptable cross section; otherwise, consider providing a roadside barrier.

Chapters Eleven and Twelve present MDT criteria for the configuration of roadside ditches based on functional classification and design speed. In general, these ditch sections meet the traversability criteria in Figures 14.3D and 14.3E.

14.3.6.2 Curbs

Curbs are typically used for drainage control. In general, curbs should not be used on new construction projects in rural areas. Section 14.4.3 discusses the relative placement of curbs and guardrail. The *MDT Detailed Drawings* provide information on the different types of curbs used by the Department and the criteria for their placement.

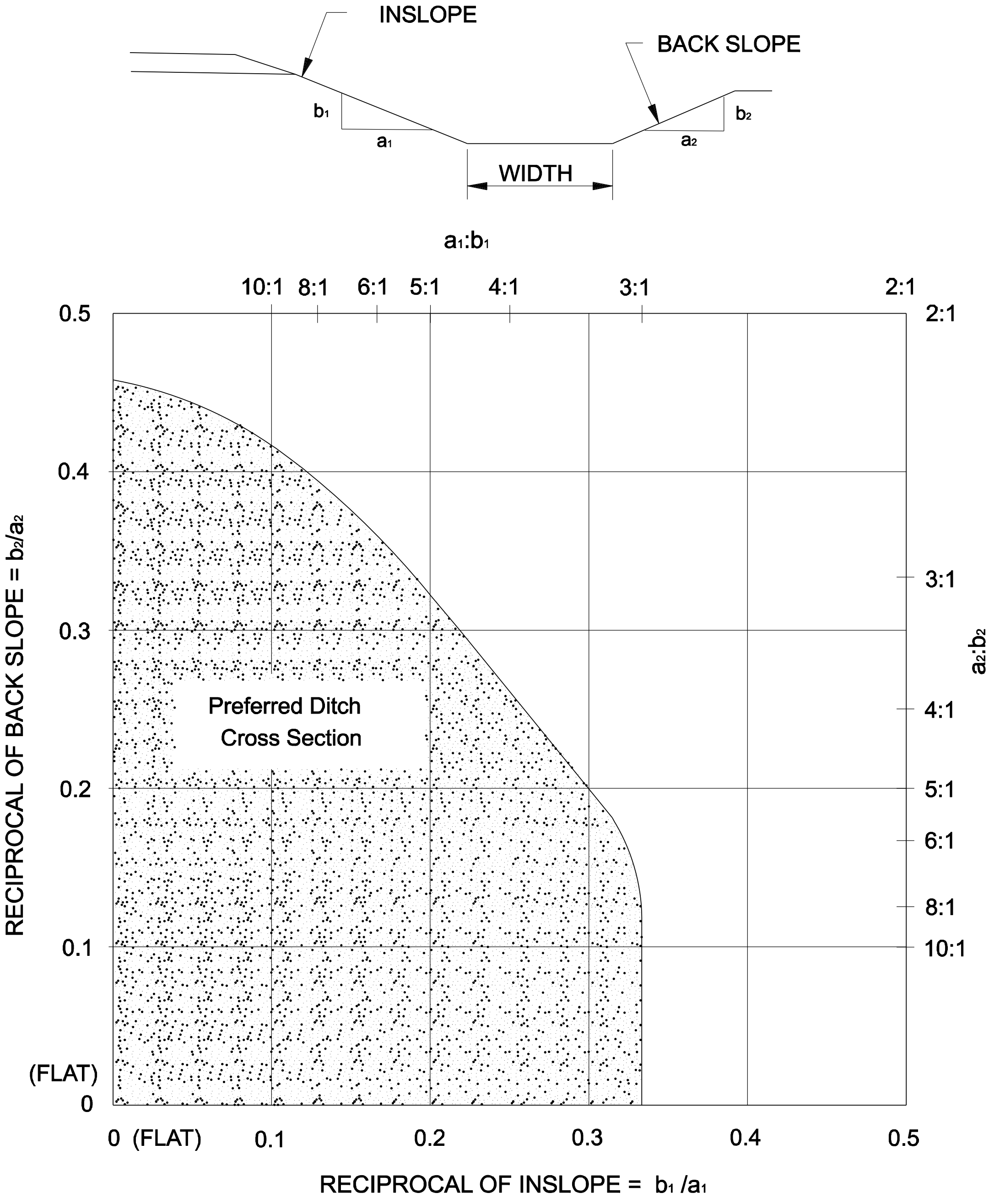




Note: This chart is applicable to all V-ditches, rounded ditches with a bottom width less than 8' (2.4 m), and trapezoidal ditches with bottom widths less than 4' (1.2 m).

PREFERRED CROSS SECTIONS FOR DITCHES
(With Abrupt Slope Changes)

Figure 14.3D



Note: This chart is applicable to all rounded ditches with a bottom width of 8' (2.4 m), or more and to trapezoidal ditches with bottom widths equal to or greater than 4' (1.2 m).

PREFERRED CROSS SECTIONS FOR DITCHES

(With Gradual Slope Changes)

Figure 14.3E

14.3.6.3 Cross Drainage Structures

Cross drainage structures should be checked to determine if their inlets/outlets are within the clear zone. If an inlet/outlet is within the clear zone on a recoverable slope, the preferred treatment is to extend the structure so the obstacle is located beyond the clear zone. Extending the pipe on a recoverable slope may result in warping the side slopes to match the opening. The longitudinal transition on both the approach and departure slope should be a minimum of 65’ (20 m) per unit incremental change in the slope ratio. For example, if the slope ratio changes from 6:1 to 7:1, the transition = 65’ (20 m); from 6:1 to 8:1, the transition length = 130’ (40 m).

Typically, it is not practical to extend a cross drainage structure to the clear zone when it is located on a non-recoverable slope. A recoverable barn-roof slope can be constructed having a slope that provides adequate clear zone width on top of the pipe. The longitudinal transition criteria should be used to determine the extent of the barn-roof slope. For example, if the existing slope is 3:1 and the barn-roof slope is 6:1, the barn-roof slope should extend 195’ (60 m) in the direction of approaching traffic. The same criteria would be applied ahead on line if the structure was located within the clear zone of the opposing traffic.

Where extending the culvert is impractical due to site conditions, other treatments (e.g., shielding with a roadside barrier, flattening the slope to provide a recoverable slope, use of a modified end section or requesting an exception to leave the obstacle) should be evaluated at the plan reviews.

For major drainage structures which are costly to extend (e.g., 5’ (1.5 m) high box culverts), shielding with a roadside barrier may often be the most practical alternative.

14.3.6.4 Parallel Drainage Structures

Parallel drainage culverts are those which are oriented approximately parallel to the main flow of traffic. They are typically used under driveways, field entrances, access ramps, intersecting side roads and median crossovers. As with cross drainage structures, the designer's primary objective should be to keep the parallel drainage structure outside the mainline clear zone, to design generally traversable slopes and to match the culvert opening with adjacent slopes. Section 14.3.4 provides the Department's criteria for transverse slope rates.

Parallel drainage structures within the clear zone should match the selected side slope and be safely treated if practical. Although many of these structures are small and present a minimal target, the addition of pipes and bars perpendicular to the mainline traffic can reduce wheel snagging in the culvert openings. The *MDT Detailed Drawings* provide additional details in the design of the road approach culvert end treatment (RACET). Provide a RACET for any pipe with a diameter of 15” (375 mm) or greater which has any portion within the clear zone. For multiple-pipe installations, the use of grates for the smaller pipes should be considered.

Parallel drainage structures may be closely spaced in urban areas because of frequent driveways and intersecting roads. In such locations, it may be desirable to convert the open ditch into a closed drainage system and backfill the areas between adjacent driveways. This treatment will eliminate the ditch section and the transverse embankments with pipe inlets and outlets.

14.4 ROADSIDE BARRIERS

14.4.1 Barrier Types

The following sections briefly describe the roadside barrier types which are approved for use by MDT. The designer should reference the *MDT Detailed Drawings* for detailed design information on each barrier type.

14.4.1.1 "W" Beam Guardrail

The "W" beam system with heavy posts is a semi-rigid system. This system has a deflection distance of 4’ (1.2 m). In general, this guardrail system is the preferred system for freeways and on high-volume, non-freeway facilities. A major objective of the heavy post system is to prevent a vehicle from "snagging" on the posts. This is achieved by using blockouts to offset the posts from the longitudinal beam and by establishing 6.25’ (1.905 m) as the maximum allowable post spacing.

The Department has approved the use of two guardrail "W" beam systems based on post types (wood and steel). Post selection for a project is at the Contractor's option. However, the Contractor must use the same post type throughout the project. Where only specific sections of rail are being replaced, the same post type must be used for the entire run of rail

14.4.1.2 Cable Guardrail

Three-cable guardrail is a flexible system with a large dynamic deflection [12’ (3.7 m) with 16’ (4.88 m) post spacing] tested with a 4,500 lb (2045 kg) car. Most of the resistance to impact is supplied by the tensile forces developed in the cable strands. Upon impact, the cables break away from the posts, and the vehicle is able to knock down these posts as it is redirected by the cables. The detached posts do not contribute to controlling the lateral deflection. However, the posts which remain in place do provide a substantial part of the lateral resistance to the impacting vehicle and are therefore critical to proper performance.

Cable guardrail is the safest of the available systems because of its large dynamic deflection. Therefore, it can only be used where a deflection distance of 12’ (3.7 m) is available behind the guardrail for considerable lengths along the roadside. Its use should be tempered by the following considerations:

1. Snow. Cable guardrail is generally only used where there is a problem with snow drifting.

2. Transitions. Do not use cable guardrail to transition into a bridge rail.

3. Slopes. Do not use cable guardrail on fill slopes steeper than 2:1, unless the distance between the back of the posts and the break in the fill slope is at least 8' (2.4 m). For fill slopes which are 2:1 or flatter, provide a minimum 2' (0.6 m) shelf between the back of posts and the break in the fill slope.

4. Minimum Radius. Do not use cable guardrail on the inside of any horizontal curves. If cable guardrail is used on the outside of sharp radius curves, the post spacing may need to be reduced. See Figure 14.4A and the *MDT Detailed Drawings* for the applicable criteria.

5. Maintenance. In general, cable guardrail requires more maintenance after impact than the "W" beam guardrail. Therefore, the higher the probability of impact, the stronger the preference for the "W" beam system.

Centerline Radius	Maximum Post Spacing
≥ 720' (220 m)	16' (4.88 m)
≥ 445' (135 m) & < 720' (220 m)	12' (3.66 m)
< 445' (135 m)	Do not use cable guardrail

CABLE GUARDRAIL POST SPACING
(On Outside of Horizontal Curves)
Figure 14.4A

14.4.1.3 Box Beam Guardrail

Box beam guardrail (weak post) is a semi-rigid system with a dynamic deflection of 5' (1.5 m). Resistance in this system is achieved through the combined flexure and tensile stiffness of the rail. Posts near the impact are designed to break or tear away, thereby distributing the impact force to adjacent posts.

Box beam guardrail is generally used in snow drift areas where cable guardrail is not acceptable (e.g., on the inside of curves, where the 12' (3.7 m) deflection distance required for cable guardrail is not available).

14.4.1.4 Concrete Barrier Rail (CBR)

The anchored CBR should be considered on the roadside to shield rigid objects where minimal deflection distance is available (i.e., the object is less than 2’ 6” (0.762 m) from the face of barrier). The CBR is typically used in front of rough rock cuts. If a rigid object is not continuous (e.g., bridge piers), the designer may use a half-section CBR. To provide the necessary lateral support, backfill should be provided behind the half-section CBR, or the CBR should be tied to a concrete surface with reinforcing steel. If this is not practical, use the full-section CBR.

14.4.1.5 Portable Barriers for Construction Sites

Chapter Fifteen provides guidance on portable barriers in construction sites.

14.4.1.6 Stiffened Guardrail

The use of stiffened rail should be considered when there is insufficient deflection distance available between the face of w-beam rail and an obstacle. Stiffened guardrail is comprised of w-beam with a combination of reduced post spacing and doubled beams. The use of different post spacings and doubled rail sections depend on whether a point obstacle or a line obstacle is being shielded.

Refer to the *MDT Detailed Drawings* for post and rail configurations.

14.4.2 <u>Barrier Selection</u>

14.4.2.1 Performance Criteria

The barrier performance-level requirements must be considered when selecting an appropriate roadside barrier. At the national level, FHWA and AASHTO are continuously examining the performance criteria to evaluate the acceptability of roadside safety appurtenances and testing these appurtenances to determine if they meet these performance criteria. Currently, *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features* has been adopted for application. MDT is responsible for remaining abreast of the state of the technology and revising its roadside safety hardware practices to comply with the national performance criteria.

Most barriers have been developed and tested for passenger cars and offer marginal protection when struck by heavier vehicles at high speeds and other than flat angles of impact. Therefore, if passenger vehicles are the primary concern, the "W" beam or cable guardrail systems will normally be selected. Locations with poor geometrics, high traffic volumes and speeds, high-crash experience, and/or a significant volume of heavy trucks and buses may require a higher performance level barrier. This is especially important if barrier penetration by a vehicle is likely to have serious consequences.

14.4.2.2 Dynamic Deflection

Also consider the dynamic deflection in barrier selection. Figure 14.4B provides the deflection distances for the various systems. If the deflection distance is not available, stiffen the railing system or use a CBR.

14.4.2.3 Maintenance

Another consideration in selecting the barrier type depends on maintenance of the system. Although the "W" beam can often sustain second hits, it must be repaired with some frequency. In areas of restricted geometry, high speeds, high traffic volumes and/or where railing repair creates hazardous conditions for both the repair crew and for motorists using the roadway, consider using the rigid CBR. The CBR also allows better control of roadside vegetation, and it provides a more convenient means to transition into bridge piers.

Figure 14.4C summarizes the advantages and disadvantages of the roadside barriers used by the Department and summarizes their typical usage.

Barrier Type	Dynamic Deflection Distances (TL 3)	Barrier Width (See Dtl. Dwgs.)	Min. Dist. From Face Rail to Obstacle
"W" Beam – Wood Posts (606-05A)	4.0' (1.2 m)	1'-7" (1.58') (0.49 m)	5.6' (1.7 m)
"W" Beam – Steel Posts (606-05B)	4.0' (1.2 m)	1'-7" (1.58') (0.49 m)	5.6' (1.7 m)
Stiffened "W" Beam – Point Obstacle 3'-1½" (952.50 mm) Post Spacing - Single Rail (606-07)	24" (0.61 m)	1'-7" (1.58') (0.49 m)	3.6' (1.1 m)
Stiffened "W" Beam – Line Obstacle 1'-6¾" (476.25 mm) Post Spacing - Doubled Rail (606-07)	13" (0.33 m)	1'-7" (1.58') (0.49 m)	2.7' (0.8 m)
Nested "W" Beam – 25'-0" (7.62 m) Span (606-09)	5.0' (1.5 m)	1'-7" (1.58') (0.49 m)	6.6' (2.0 m)
Metal Guardrail – 7' (2134 mm) Posts Posts spaced at 3'-1½" (952.50 mm), w/ 2:1 slopes & w/o widening (NEW Proposed 606-11)	3' (0.9 m)	1'-7" (1.58') (0.49 m)	4.6' (1.4 m)
Cable Guardrail (606-40)	12.0' (3.7 m)	N/A	12.0' (3.7 m)
Box Beam Guardrail (606-50)	5.0' (1.5 m)	9" (0.75') (0.23 m)	5.8' (1.8 m)
Concrete Barrier Rail (606-60)	4.5' (1.4 m)	2'-0" (0.61 m)	6.5' (2.0 m)
Anchored Concrete Barrier Rail (606-62)	1.5' (0.5 m)	2'-0" (0.61 m)	3.5' (1.1 m)

ROADSIDE BARRIER DYNAMIC DEFLECTION
Figure 14.4B

SYSTEM	ADVANTAGES	DISADVANTAGES	TYPICAL USAGE
"W" Beam Guardrail	1. Low initial cost. 2. High level of familiarity by maintenance personnel. 3. Can safely accommodate wide range of impact conditions for passenger cars. 4. Relatively easy installation. 5. Remains functional after moderate collisions.	1. Cannot accommodate impacts by large vehicles at other than flat angles of impact. 2. At high-impact locations, will require frequent maintenance. 3. Susceptible to vehicular underride and override. 4. Susceptible to vehicular snagging (without rub rail).	1. Non-freeways. 2. Freeways.
Cable Guardrail	1. Lowest initial cost. 2. Improved underride/override protection. 3. Can safely accommodate wide range of impact conditions for passenger cars. 4. Relatively easy installation. 5. Most forgiving of all systems.	1. Cannot sustain a second impact. 2. Cannot accommodate impacts by large vehicles. 3. Cannot be used with curbing. 4. Requires significant maintenance after an impact. 5. Cannot be placed on inside of any horizontal curve or on outside of horizontal curves with radii less than 445' (135 m) 6. Cannot be used to transition to bridge rail.	1. Low-volume non-freeways. 2. Areas where there are problems with snow drifting.
Concrete Barrier Rail	1. Can accommodate most vehicular impacts without penetration. 2. Little or no deflection distance required behind barrier. 3. Little or no damage sustained for most vehicular impacts; therefore, least need for maintenance. 4. No vehicular underride/override potential or snagging potential.	1. Highest initial cost. 2. For given impact conditions, highest occupant decelerations; therefore, least forgiving of barrier systems. 3. Reduced performance where offset between traveled way and barrier exceeds 15' (4.5 m.)	1. In front of rough rock cuts. 2. Where high traffic volumes are present. 3. Where high volumes of large vehicles are present. 4. Where snagging is a concern.
Box Beam Guardrail	1. Can be installed on the inside or outside of any curve. 2. Less deflection distance than cable guardrail.	1. High initial cost. 2. Cannot sustain a second impact. 3. Cannot accommodate impacts by large vehicles. 4. Requires significant maintenance after impact.	1. Areas where there are problems with snow drifting and cable guardrail cannot be used.

ROADSIDE BARRIER SELECTION

Figure 14.4C

14.4.3 Roadside Barrier Layout

14.4.3.1 Length of Need (General)

A roadside barrier must be extended a sufficient distance upstream from the obstacle (advancement length) to safely protect a run-off-the-road vehicle. Otherwise, the vehicle could travel behind the barrier and impact the obstacle. The designer should recognize that vehicles depart the road at relatively flat angles. Based on a number of field studies, the average angle of departure is estimated to be 10º. The 80th percentile is estimated to be 15º. These flat angles of departure result in the need to extend the barrier a significant distance in front of the obstacle.

The following equation is used to determine the total barrier length for a given roadside condition:

$$L_{TOTAL} = L_{ADJACENT} + L_{OBSTACLE} + L_{OPPOSING} \quad \text{(Equation 14.4-1)}$$

Where:

$L_{ADJACENT}$ = The length needed in advance of the obstacle required to protect traffic in adjacent lanes.

$L_{OBSTACLE}$ = The length of the obstacle itself.

$L_{OPPOSING}$ = The length in advance of the obstacle needed to protect traffic in opposing lanes.

The designer should note that only a portion of the terminal sections are included in the overall barrier length of need. See the *MDT Detailed Drawings* to determine the portion of the terminal section which may be included in the total length of need for the barrier.

Figure 14.4D illustrates the variables that must be considered in designing a roadside barrier to effectively shield an obstacle. Figure 14.4D also illustrates the use of a flared and non-flared design. A barrier may be flared to:

1. locate the barrier terminal farther from the traveled way,
2. minimize a driver's reaction to an obstacle near the roadway by gradually introducing a parallel barrier installation,
3. transition a roadside barrier closer to the roadway because of an obstacle, or
4. to reduce the total length of barrier need.

Also give consideration to the following disadvantages of flaring guardrail:

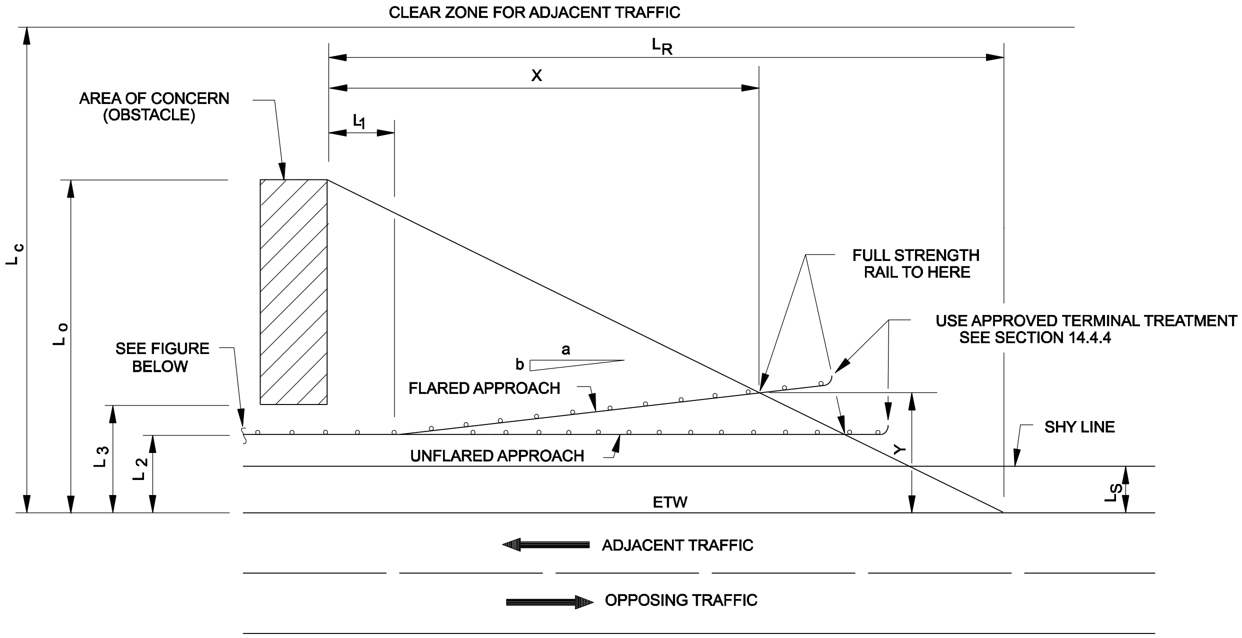
1. Flared rail results in increased impact angles with the potential for greater severity of impact.

2. Flared rail increases the likelihood the vehicle will be redirected into the opposing lane of traffic or across the roadway.

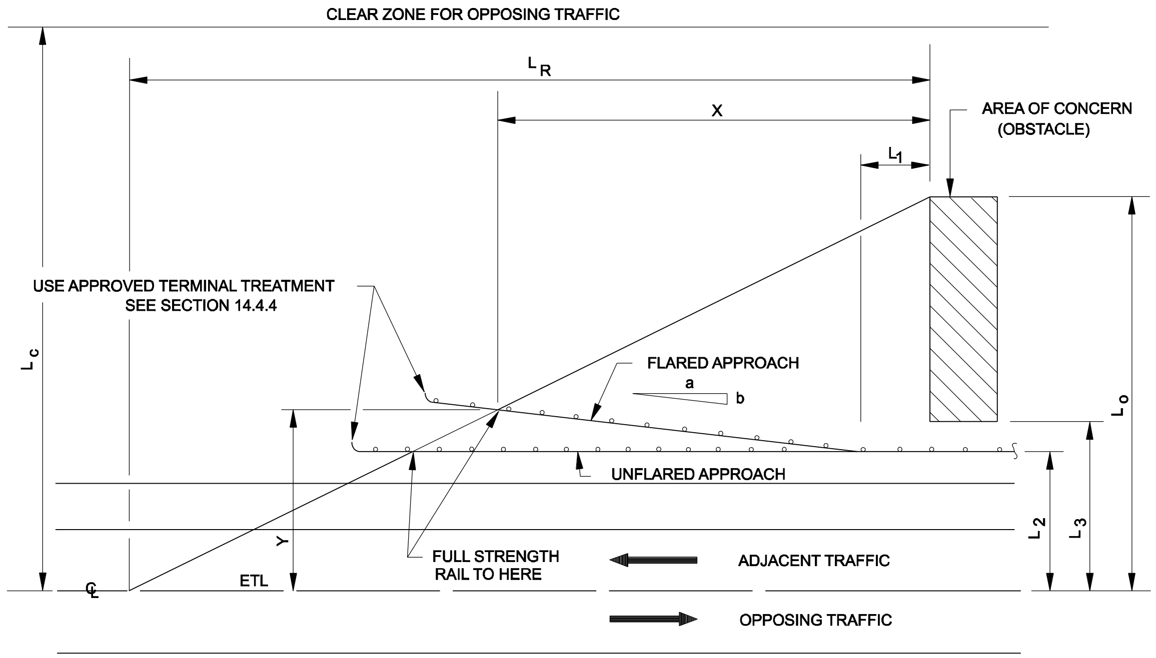
3. Grading required to provide 10:1 or flatter slopes in front of the flared section of guardrail may interfere with roadside drainage and/or may require additional right-of-way.

The preferred installation of advancement guardrail is unflared (placed parallel to the roadway). Flaring the guardrail should only be used after thorough consideration of its advantages and disadvantages. Note that Optional Terminal Sections do not function as effectively when they are flared.

Where fill slopes change within the advancement length of the rail, calculate the advancement lengths using the clear zone for each traversable slope shown on the cross sections adjacent to the obstacle. Compare the results and use the location that produces the shortest length of rail. Generally, do not interpolate intermediate locations of slope changes between cross sections.



APPROACH TREATMENT FOR ADJACENT TRAFFIC (a)



APPROACH TREATMENT FOR OPPOSING TRAFFIC (b)

BARRIER LENGTH OF NEED
Figure 14.4D

14.4.3.2 Length of Need (Embankment/Obstacle That Extends to Edge of the Clear Zone)

Once the appropriate variables have been selected, the required length of need in advance of the obstacle can be calculated from Equations 14.4-2 through 14.4-5. These equations are used when the obstacle is an embankment or a fixed object which extends to or beyond the clear zone:

Flared Design

$$X = \frac{L_O + \frac{b}{a}(L_1) - L_2}{\frac{b}{a} + \frac{L_O}{L_R}} \qquad \text{(Equation 14.4-2)}$$

$$Y = L_O - \frac{L_O}{L_R}(X) \qquad \text{(Equation 14.4-3)}$$

Unflared Design

$$X = \frac{L_R(L_O - L_2)}{L_O} \qquad \text{(Equation 14.4-4)}$$

$$Y = L_2 \qquad \text{(Equation 14.4-5)}$$

Where:

X, Y = coordinates of beginning of barrier need.

a/b = barrier flare (e.g., 15:1) (see Figure 14.4E for acceptable rates).

L_C = recommended clear zone.

L_O = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle). For a fixed object, the lateral extent of the obstacle (L_O) is the distance from the edge of the traveled way to the far side of the obstacle. If the obstacle is an embankment or a fixed object that extends beyond the clear zone, L_O is measured to the outside edge of the clear zone (L_C); i.e., L_O = L_C.

US Customary

Design Speed (mph)	Runout Length L_R (ft)				Shy Line Offset L_S (ft)	Flare Rates (a/b)		
	Design Year Traffic Volume (AADT)					Inside of Shy Line	Outside of Shy Line	
	>10 000	>5000 ≤10 000	>1000 ≤5000	≤1000			Guardrail	Concrete Barrier
70	365	315	265	230	9.2	30:1	15:1	20:1
60	265	215	200	180	8.0	26:1	14:1	18:1
55	250	200	180	165	7.2	24:1	12:1	16:1
50	215	180	165	135	6.6	21:1	11:1	14:1
45	200	165	135	115	5.6	18:1	10:1	12:1
40	170	135	115	100	4.6	16:1	8:1	10:1
30	115	100	85	85	3.6	13:1	7:1	8:1

Metric

Design Speed (km/h)	Runout Length L_R (m)				Shy Line Offset L_S (m)	Flare Rates (a/b)		
	Design Year Traffic Volume (AADT)					Inside of Shy Line	Outside of Shy Line	
	>10 000	>5000 ≤10 000	>1000 ≤5000	≤1000			Guardrail	Concrete Barrier
110	110	95	80	70	2.8	30:1	15:1	20:1
100	80	65	60	55	2.4	26:1	14:1	18:1
90	75	60	55	50	2.2	24:1	12:1	16:1
80	65	55	50	40	2.0	21:1	11:1	14:1
70	60	50	40	35	1.7	18:1	10:1	12:1
60	50	40	35	30	1.4	16:1	8:1	10:1
50	35	30	25	25	1.1	13:1	7:1	8:1

DESIGN ELEMENTS FOR BARRIER LENGTH OF NEED

Figure 14.4E

L_S = shy line offset or distance at which barrier is no longer perceived as an obstacle by a driver (see Figure 14.4E).

L_R = runout length (see Figure 14.4E).

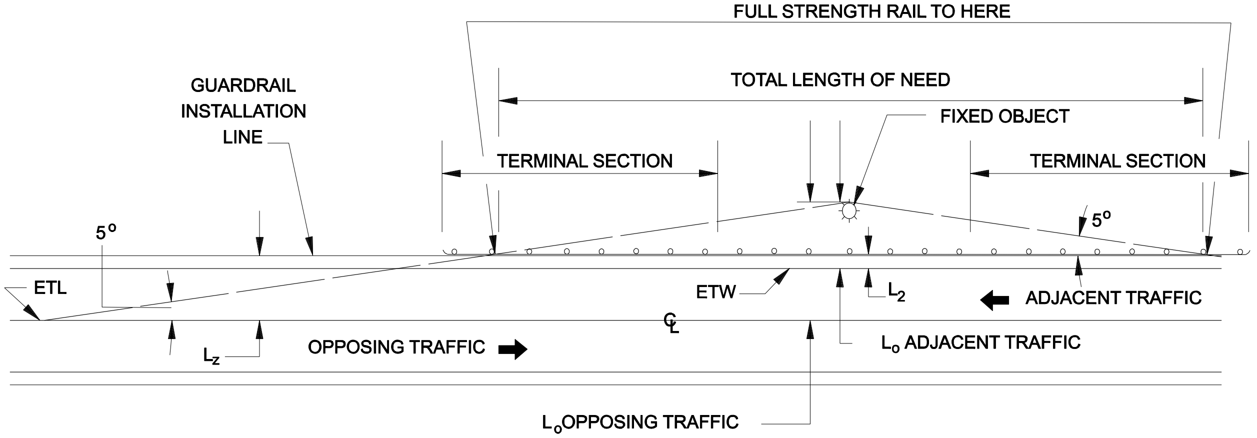
L_1 = distance from obstacle to where barrier flare begins. For bridge approaches, this will typically be the bridge transition section. Otherwise, this distance is determined based on engineering judgment.

L_2 = distance from edge of traveled way to face of barrier.

L_3 = distance from edge of traveled way to front of obstacle. (L_3 - L_2) must equal or exceed deflection distance.

14.4.3.3 Length of Need (Obstacle Within Clear Zone)

Use Equations 14.4-6 through 14.4-9 when the obstacle requiring shielding lies entirely within the clear zone (see Figure 14.4F).



BARRIER LENGTH OF NEED
(Fixed Object Within Clear Zone)
Figure 14.4F

Flared Design

$$X = \frac{(L_O - L_2) + (b/a)L_1}{(b/a) + \tan 5^\circ} \qquad \text{(Equation 14.4-6)}$$

$$Y = L_0 - X(\tan 5^\circ) \qquad \text{(Equation 14.4-7)}$$

Unflared Design

$$X = \frac{L_O - L_2}{\tan 5^\circ} \qquad \text{(Equation 14.4-8)}$$

$$Y = L_2 \qquad \text{(Equation 14.4-9)}$$

Where:

X, Y = coordinates of beginning of barrier need.

L_O = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle).

L_2 = distance from edge of traveled way to face of barrier.

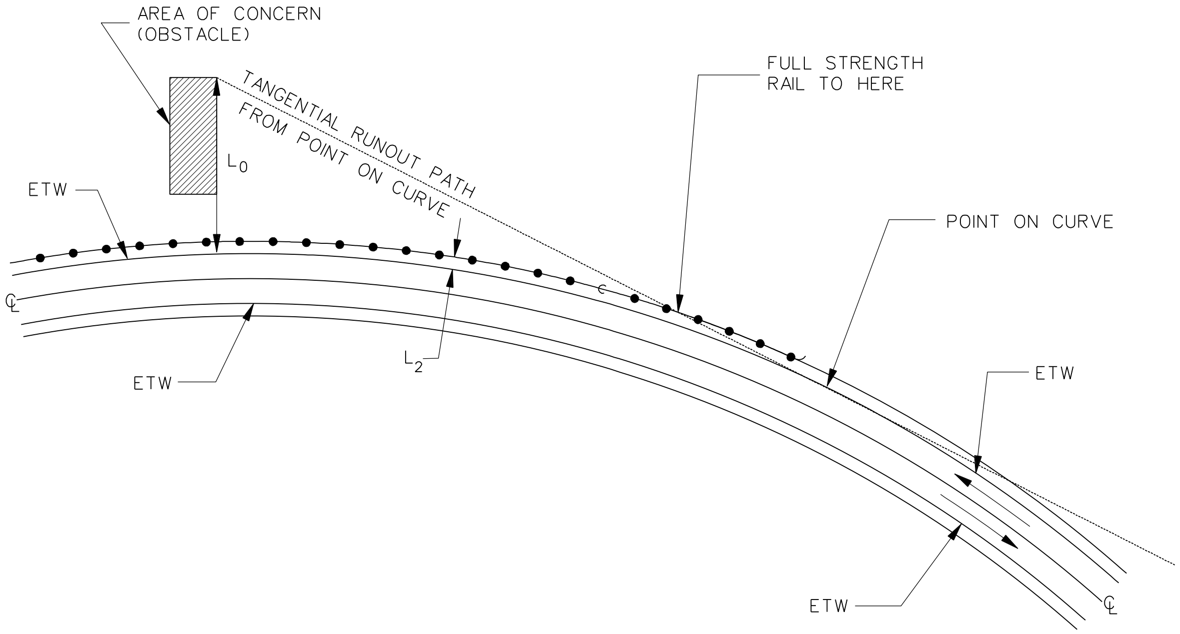
5° = departure angle.

For two-way traffic, use these formulas for the approach treatment for both the adjacent and opposing traffic. For one-way traffic, use these formulas for the approach treatment of the adjacent traffic and extend the guardrail to the far side of the obstacle.

For obstacles located near the clear zone limit, check the necessary barrier length using both the L_R formulas (Section 14.4.3.2) and the 5° angle formulas (Section 14.4.3.3). Use the method that produces the shorter overall length of guardrail.

14.4.3.4 Length of Need (Horizontal Curves)

The length of need formulas (Equations 14.4-2 through 14.4-9) are applicable to tangent highway alignment and where the roadside obstacle is on the inside of a horizontal curve. A vehicle leaving the roadway on the outside of a horizontal curve will generally follow a tangential runout path. Therefore, rather than using the theoretical L_R distance to determine the length of need, use a tangent line from the edge of the traveled way to the outside edge of the obstacle. The length of need is determined by intersecting the barrier installation line with the tangent line. See Figure 14.4G. This intersection can most readily be obtained graphically. If the tangent line is less than L_R, use this intersection. However, if the tangent line is greater than L_R, use the L_R distance from the back of the obstacle to intersect the installation line to determine the adjacent length. A flared end treatment is generally not used along a horizontal curve.



BARRIER LENGTH OF NEED
(Outside of Horizontal Curve)

Figure 14.4G

14.4.3.5 Lateral Placement

Roadside barriers should normally be placed as far as practical from the edge of the traveled way. Such placement gives an errant motorist the best chance of regaining control of the vehicle without impacting the barrier. It also improves sight distance, particularly at nearby intersections. Consider the following factors when determining barrier lateral placement:

1. Deflection: The dynamic deflection distance of the barrier, as measured from the face of the rail, should not be violated. Section 14.4.1 provides the deflection distances for the types of roadside barriers used by the Department.

2. Post Support. At a minimum, provide 2’ (600 mm) between the back of the barrier post and the slope break in a fill slope to provide adequate soil support for the post. If it is impractical to provide 2’ (600 mm) behind the rail, 7’ (2135 mm) posts may be used. The spacing of these posts must be reduced to 3’-1½” (950 mm).

3. Shy Distance. Drivers tend to "shy" away from continuous longitudinal obstacles along the roadside, such as guardrail. Guardrail should be installed at the edge of the shoulder and should provide a minimum distance of 2’ (0.6 m) from the face of the rail to the edge of the traveled way. For some roadway widths, this practice will not meet the requirement of the shy line offset as presented in Figure 14.4E. In these cases, installing the guardrail at the shy line offset distance is not practical and is not recommended.

4. Shoulder Widening. Provide a minimum distance of 2’ (600 mm) between the edge of the traveled way and the face of the rail. If this distance is not available on the existing shoulder, additional widening will be necessary to provide the minimum distance or a design exception will be required.

5. Flare Rate. See Figure 14.4E for the maximum allowable flare rates when using the flare design for advancement guardrail. If the guardrail installation lies both inside and outside of the shy line, provide a flare meeting the requirements for inside the shy line until the installation reaches the shy line offset. At the shy line offset, the flare may then be increased up to the maximum flare for outside the shy line.

14.4.3.6 Placement in Conjunction With Curbs

On high-speed facilities (V >45 mph, 70 km/h), do not place curbs in front of roadside barriers. Where curbs are used in conjunction with roadside barriers on low-speed facilities, the face of the barrier should be in line with the face of the curb (i.e., at the gutter line). Do not use curbs higher than 4” (100 mm) with a barrier on new construction facilities. Existing curb installations higher than 4” (100 mm) may remain if the installation otherwise meets MDT criteria. Measure the height of the barrier from the pavement surface (e.g., where curbs are on bridges). The designer should note that cable guardrail cannot be used in conjunction with curbing.

14.4.3.7 Placement on Slopes

Slopes in front of a barrier should be 10:1 or flatter. This also applies to the areas in front of the flared section of guardrail and to the area approaching the terminal ends. See the *MDT Detailed Drawings*.

14.4.3.8 Transitions

Barrier transitions are necessary to join two systems with different structural and/or dynamic characteristics. For example, this occurs when guardrail approaches a bridge parapet or CBR installation. The *MDT Detailed Drawings* provide details for the bridge approach section. See the *AASHTO Roadside Design Guide* for additional discussion on barrier transitions.

14.4.3.9 Minimum Length/Gaps

Short runs of barrier have limited value and should be avoided. Generally, a barrier should have at least 100’ (30 m) of standard guardrail section exclusive of terminal sections and/or transition sections. Short gaps between runs of barrier are undesirable. Therefore, gaps of less than 165’ (50 m) between barrier termini should be connected into a single run. Exceptions may be necessary for access.

14.4.4 Terminal Treatments

Barrier terminal sections present a potential roadside obstacle for run-off-the-road vehicles. However, they are also critical to the proper structural performance of the barrier system. The selection and design of the terminal end section should be carefully coordinated with the barrier system’s purpose and length of need. The designer should review the *MDT Detailed Drawings* or manufacturer’s specifications to determine what portion of the terminal section can be applied to the length of need.

New terminal systems are continually emerging to address safety problems, and devices are being improved in response to an increased understanding of safety performance, a changing vehicular fleet, the emergence of new materials and other factors.

Unless otherwise noted, see the *MDT Detailed Drawings* for details on the design and placement of the following terminal treatments that are used by the Department:

1. Optional Terminal Sections. Use the optional terminal sections in conjunction with W-beam guardrail on the approach ends for one-way facilities and approach

and departure ends for two-way facilities. The ET-Plus and SKT 350 terminal sections are the only approved optional terminal sections at this time.

2. One-Way Departure Terminal Section. This terminal section is typically used on the departure end of W-beam rail on a one-way facility. It provides structural capacity required at the terminus of the guardrail.

3. Impact Attenuators. The QuadGuard and TRACC impact attenuators are the only approved options at this time. Use these terminal sections for all concrete barriers requiring a terminal end section. See the manufacturer's specifications for design and installation details.

4. Bridge Approach Section. The *MDT Detailed Drawings* provide details for several transition systems used to connect W-beam guardrail to the rigid bridge rail. Attachments to existing structures may require a special design.

5. Intersecting Roadway Terminal Section. This terminal section is used where an approach intersects a run of guardrail or at approaches where there is insufficient room to install one of the optional terminal sections (e.g., approaches next to bridge ends). The terminal is curved around and terminated on the minor approach.

6. Cable Guardrail Terminals. This terminal type is only used with cable guardrail. Cable guardrail terminal sections are generally not considered to be an obstacle.

7. Optional Box Beam Terminal Sections. Use the optional terminal sections in conjunction with the box-beam guardrail on the approach ends for one-way facilities and approach and departure ends for two-way facilities. The WY-BET and BEAT terminal sections are the only approved optional terminal sections at this time for box beam guardrail.

8. Box-Beam Terminal Section Type 2. Use this terminal section on the departure ends of box-beam rail on one-way facilities. It provides the structural capacity required at the end of the guardrail.

14.4.5 Roadside Hardware Supports (Mailbox Supports)

Where roadside hardware (e.g., sign supports, luminaires, traffic signals, mailboxes) cannot be reasonably located outside of the clear zone, they should be made breakaway or shielded with a roadside barrier or impact attenuator. This Section discusses the criteria specifically for mailbox supports. For sign supports, luminaires, etc., see Chapter Six of the *Traffic Engineering Manual*.

Mailboxes and newspaper tubes served by carriers in vehicles may constitute a roadside obstacle, depending upon the placement of the mailbox. The designer should make every reasonable effort to replace all non-conforming mailboxes with the designs that meet the criteria in *A Guide to Mailbox Safety in Montana*, the *AASHTO A Guide for Erecting Mailboxes on Highways*, the *MDT Detailed Drawings* and Chapter Eighteen.

In general, mailboxes should meet the following criteria:

1. Heights. Mailbox heights are usually located so that the bottom of the box is 3.3' (1.0 m) to 4' (1.2 m) above the mail stop surface.

2. Post. The maximum strength supports that should be used are nominal 4" (100 mm) x 4" (100 mm) wood posts or 4" (100 mm) diameter wood posts or 2" (50 mm) diameter standard galvanized steel pipe post, embedded no more than 2' (600 mm) into the ground. The use of concrete anchors is not acceptable.

3. Multiple Mailboxes. To reduce the possibility of ramping, multiple mailboxes should be separated by a distance at least equal to three-fourths of their height above ground.

4. Neighborhood Delivery and Collection Box Units (NDCBU). NDCBU is a cluster of 8 to 16 locked boxes mounted on a pedestal or within a framework. Because the total mass for the NDCBU may range between 100 lb. (45 kg) and 200 lb. (90 kg), they are considered a roadside obstacle. NDCBUs are intended to be located in trailer parks, apartment complexes and new residential subdivisions. If there is no alternative, locate NDCBUs on low-speed facilities in conjunction with mailbox turnouts and outside of the clear zone.

14.5 MEDIAN BARRIERS

14.5.1 Warrants

The following summarizes the Department's criteria:

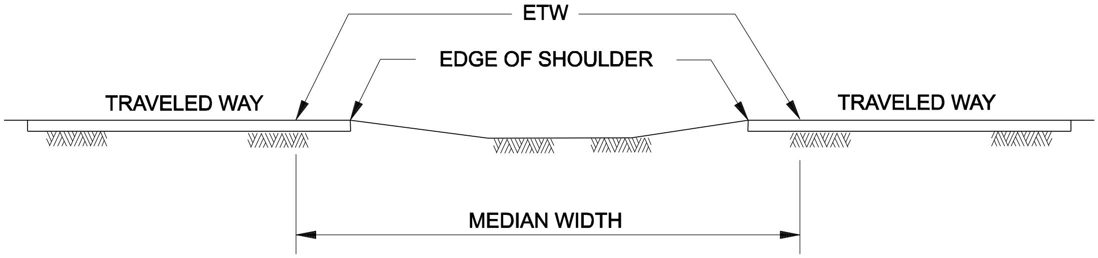
1. Freeways. Figure 14.5A presents the warrants for a median barrier based on median width and traffic volumes. The traffic volumes are based on a minimum 5-year projection. In the areas shown as optional, the decision to use a median barrier will be based on construction and maintenance costs and crossover crash experience. A median barrier may be warranted on medians not within the optional or warranted area, if a significant number of crossover crashes have occurred.

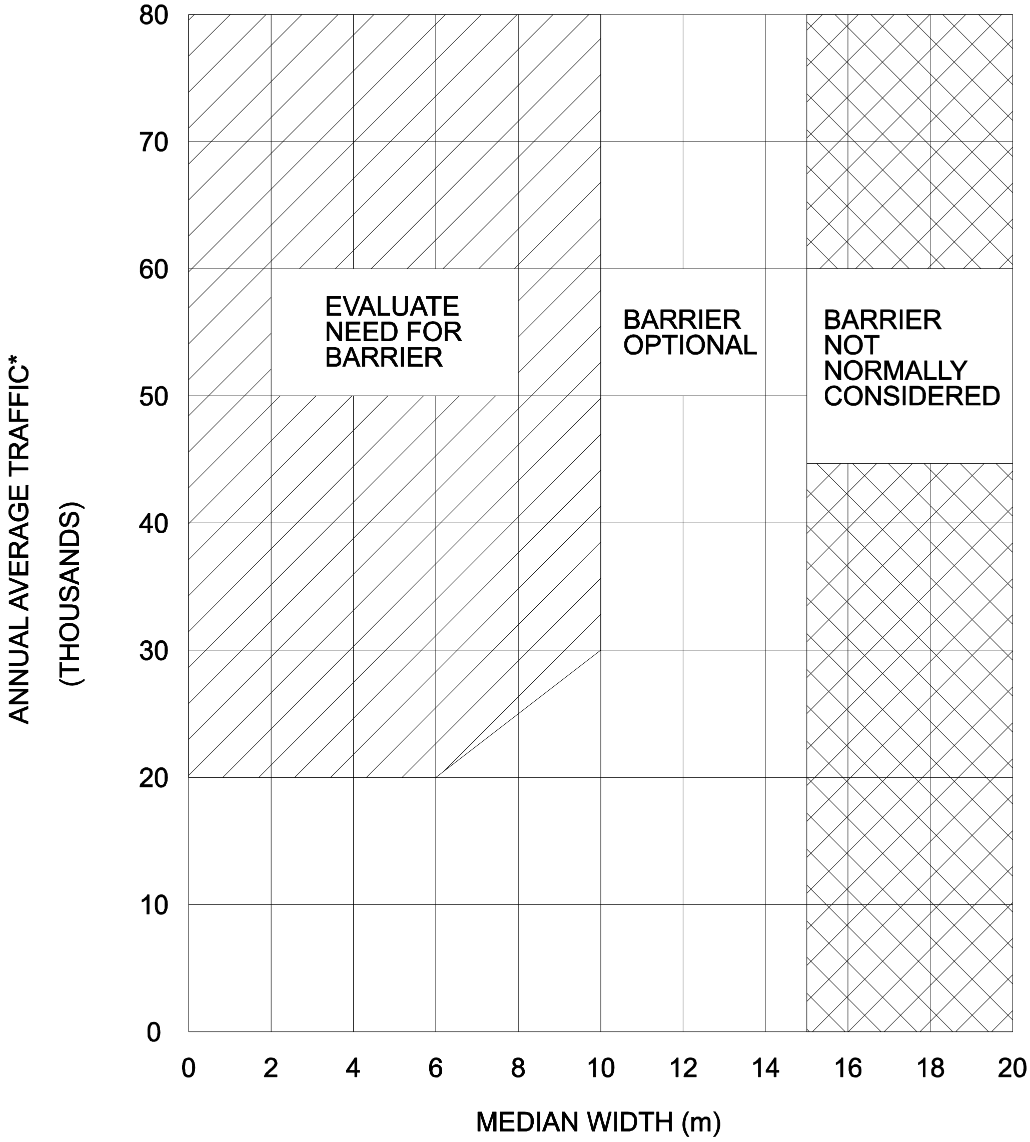
2. Non-Freeways. On other highways, judgment must be used to determine median barrier warrants. On highways without full access control, the median barrier must be terminated at intersections where it has been determined that an opening will be provided. In addition, lower speeds will reduce the likelihood of crossover crashes. Therefore, on non-freeway highways, the designer should evaluate the crash history, traffic volumes and speeds, median width, alignment, sight distance and construction costs to determine the need for a median barrier. Figure 14.5A can be used for guidance.

14.5.2 Types

When a median barrier is warranted, due to narrow medians, the Department's policy is to only use a concrete barrier rail (CBR). The CBR is a rigid system which will rarely deflect upon impact. A half-section CBR may be necessary where the median barrier must divide to go around a fixed object in the median (e.g., bridge piers). In this situation, the obstacle is typically encased within concrete to create a level surface from CBR face to CBR face.

The "W" beam guardrail is typically used within the median to protect the driver from isolated obstacles (e.g., bridge approaches, piers). The designer should review Section 14.4.3 and the MDT Detailed Drawings for the design and placement criteria of "W" Beam guardrail within the median; i.e., the median is treated as a "roadside" in these cases.

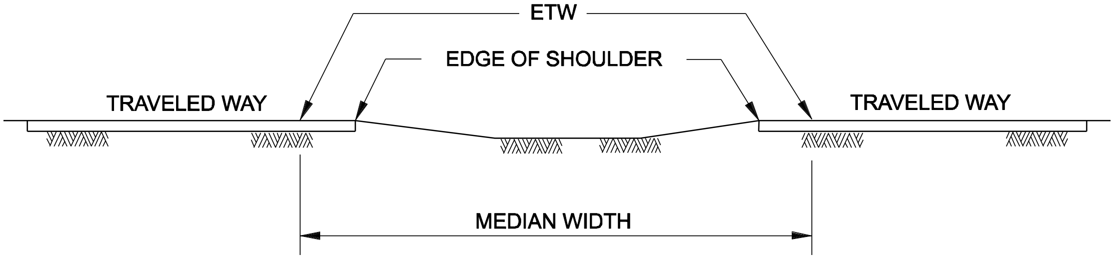


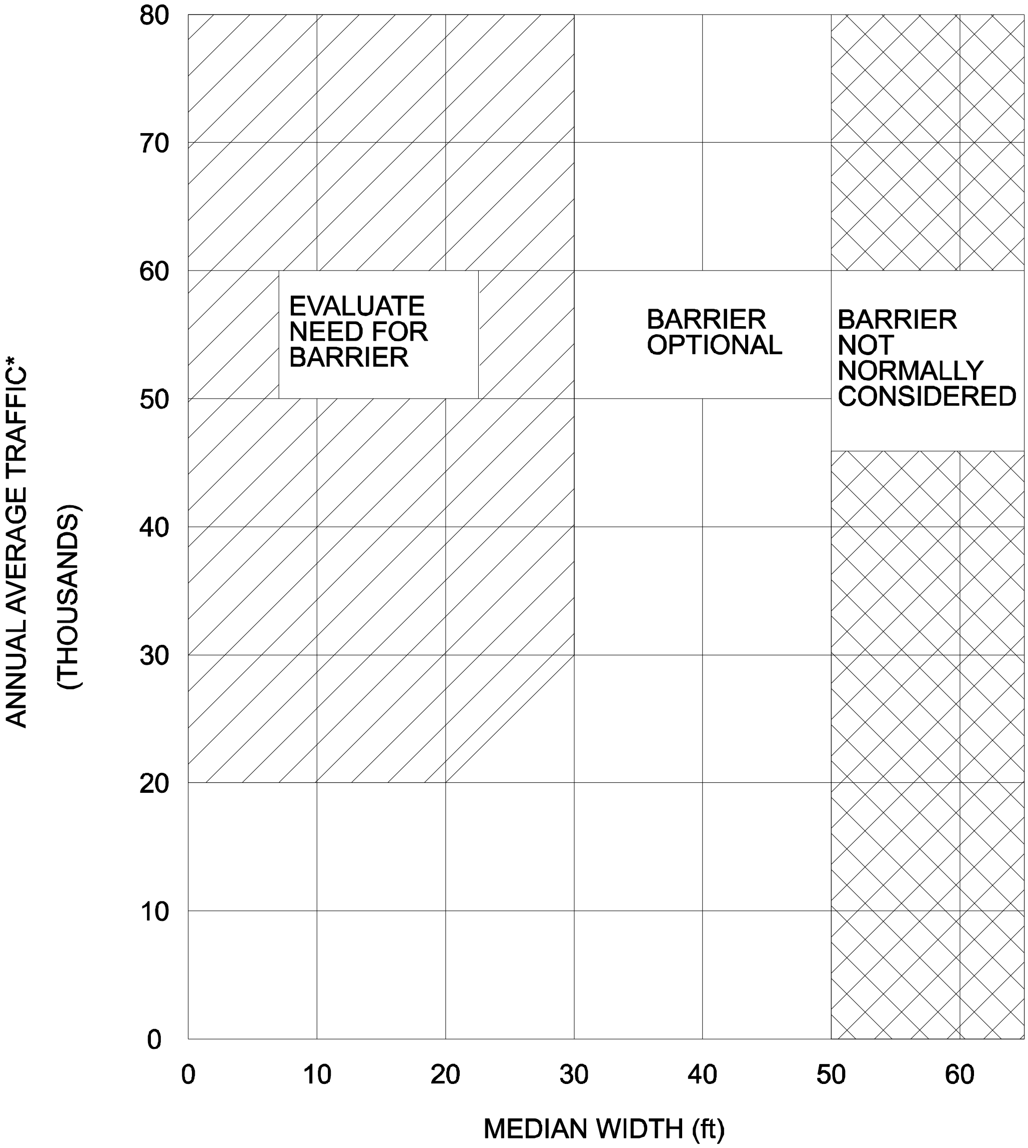


* BASED ON A MINIMUM FIVE-YEAR PROJECTION

MEDIAN BARRIER WARRANTS

Figure 14.5A (US Customary)





* BASED ON A MINIMUM FIVE-YEAR PROJECTION

MEDIAN BARRIER WARRANTS

Figure 14.5A (Metric)

14.5.3 Median Barrier Layout

Much of the information presented in Section 14.4.3 on roadside barrier layout also applies to concrete median barriers (e.g., length of need, flare rates). The following presents criteria specifically for the layout of concrete median barriers:

1. Flared/Divided Median Barriers. It may be necessary to intermittently divide a median barrier or to flare the barrier from one side to the other. A fixed object in the median may require this. The median barrier may be divided by one of these methods:
    a. A fixed object may be encased by a CBR.
    b. A half-section CBR may be used on both sides to shield a fixed object.
2. Barrier-Mounted Obstacles. If trucks or buses impact the CBR, their high center of gravity may result in a vehicular roll angle which possibly will allow the truck or bus to impact obstacles on top of the CBR (e.g., luminaire supports). If practical, move these devices to the outside, or provide additional distance between the barrier and obstacle (e.g., bridge piers).
3. Terminal Treatments. As with roadside barrier terminals, CBR terminals also present a potential roadside obstacle for run-off-the-road vehicles. Give careful consideration to the selection and placement of the terminal end. For the terminal ends of concrete barrier rail, QUADGUARD Family or TRACC impact attenuators are presently used. See Section 14.6 for more information on impact attenuators.

14.6 IMPACT ATTENUATORS (CRASH CUSHIONS)

14.6.1 General

Impact attenuators (crash cushions) are protective systems that prevent errant vehicles from impacting obstacles by either decelerating the vehicle to a stop after a frontal impact or by redirecting it away from the obstacle after a side impact. Impact attenuators are adaptable to many roadside obstacle locations where longitudinal barriers cannot practically be used.

14.6.2 Warrants

Impact attenuator warrants are the same as barrier warrants. Once an obstacle is identified, the designer should first attempt to remove, relocate or make the obstacle break away. If the foregoing is impractical, then consider an impact attenuator.

Impact attenuators are most often installed to shield fixed-point obstacles which are close to the traveled way. Examples include exit gore areas (particularly on structures), bridge piers, non-breakaway sign supports and median barrier ends. Impact attenuators are often preferable to guardrail to shield these obstacles. Site conditions and costs will determine whether to use a barrier or impact attenuator.

14.6.3 Impact Attenuator Types

Presently, the only two impact attenuators used by Department are the QuadGuard Family and the TRACC. The QuadGuard consists of crushable cartridges surrounded by steel panels set on a monorail system. It is designed for narrow obstacles 2’ (600 mm) to 7.5’ (2.3 m) wide. The backup can be either concrete or tension strut. The QuadGuard system features a “staged” cartridge design that safely decelerates the vehicle. A vehicles’s kinetic energy is gradually dissipated as a vehicle travels from the front to the rear of the system during head-on impacts. The number of bays can be varied to accommodate any design speed. The TRACC is also a staged cartridge design that functions in much the same way as the QuadGuard. The number of bays cannot be adjusted for various speeds. The designer should note that all impact attenuator types are patented and that they should contact the manufacturer for additional information on impact attenuator installations.

14.6.4 Impact Attenuator Design

Once an impact attenuator has been selected, the designer must ensure that its design is compatible with the traffic and physical conditions at the site. The following sections will provide criteria for the basic input parameters into impact attenuator design. The designer should contact the manufacturer of the system for the detailed design of the impact attenuator.

14.6.4.1 Performance Criteria

For all safety appurtenances, acceptable vehicular deceleration is determined by the occupant impact velocity as measured from full-scale crash tests. Currently, the acceptable limits of performance are based on *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features*. The manufacturer is responsible for designing the impact attenuator to meet the current national performance criteria.

14.6.4.2 Design Procedures

See Detail Drawing # 606-30A US Customary (606-30A Metric), which shows the number of bays and lengths required for each design speed to determine the appropriate number of bays and required length of the QuadGuard impact attenuator.

The TRACC uses a single size for all design speeds. It is 21’ (6.4 m) long and 2.575’ (0.785 m) from outside face to outside face.

14.6.4.3 Side Impacts

The impact attenuator design should allow for safe side impacts. Deflection and pocketing potential should always be reviewed. The QuadGuard Family and the TRACC are designed to redirect impacting vehicles on the side.

14.6.4.4 Placement

Several factors should be considered in the placement of an impact attenuator:

1. Level terrain. All impact attenuators have been designed and tested for level conditions. Vehicular impacts on devices placed on a non-level site could result in an impact at the improper height which could produce undesirable vehicular behavior. Therefore, the attenuator should be placed on a level surface or on a cross slope not to exceed 5%.

2. Curbs. No curbs should be present on new projects at proposed impact attenuator installations. On existing highways, all curbs should be removed at proposed installations if feasible, particularly those that are 4” (100 mm) or higher.

3. Surface. A paved, bituminous or concrete pad should be provided under the impact attenuator.

4. Orientation. The impact attenuator should be oriented to accommodate the probable impact angle of an encroaching vehicle. This will maximize the likelihood of a head-on impact. The proper orientation angle will depend upon the design speed, roadway alignment and lateral offset distance to the attenuator. An angle of 5º to 10º, as measured between the highway and impact attenuator longitudinal centerlines, may be appropriate. See the manufacturer's data for more information.

5. Reserve Area. The designer should, as early as practical in the project design process, determine the need for and approximate dimensions of impact attenuators. This will avoid late changes which could significantly affect the project design.

18 October 2016

MONTANA DEPARTMENT OF
TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Fifteen

MAINTENANCE AND PROTECTION OF TRAFFIC THROUGH CONSTRUCTION ZONES

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Chapter Fifteen
MAINTENANCE AND PROTECTION OF TRAFFIC THROUGH CONSTRUCTION ZONES

Traveling through a construction zone can be difficult and confusing to drivers. A well-planned traffic control design can alleviate many of these difficulties and confusions. Chapter Fifteen provides information for the road designer to develop a safe and well-conceived traffic control plan through construction zones including construction options, geometric design of crossovers and detours, and roadside safety through construction zones.

15.1 TRAFFIC MANAGEMENT

Highway construction will almost always disrupt normal traffic operations; therefore, MDT requires every project to address traffic control through construction zones. This may range in scope from very detailed plans to merely referencing the *MDT Detailed Drawings* and the *Manual on Uniform Traffic Control Devices (MUTCD)*. With much of the Department's highway program involved in upgrading existing highways, a well-conceived traffic control plan is essential. This will minimize the operational and safety problems through the construction zones.

15.1.1 Responsibilities

The Department requires a coordinated effort from various units to implement a successful traffic control plan through construction zones. The following discusses the responsibilities of these Department units:

1. Road Designer. The road designer is responsible for:
    a. determining the sequence of operations, the need for detours, crossovers, lane closures that will be used in the project;
    b. providing at least one acceptable construction method that can be used on the project;
    c. developing the geometric design for specially constructed detours, lane closures and crossovers;
    d. developing draft special provisions for traffic control and sequence of operations;

   e. ensuring that a detailed review is given to the proposed traffic control plan during the plan-in-hand review; and

   f. providing quantities for temporary pavement markings.

2. District Traffic/Construction. The District Traffic/Construction is responsible for:

   a. developing the detailed traffic control plan for the project;

   b. ensuring that the proper selection and placement of traffic control devices occurs (e.g., pavement markings, barricades, signing);

   c. addressing the roadside safety concerns through the construction zones (e.g., construction clear zones, portable concrete median barriers, placement of construction equipment and supplies);

   d. making provisions for informing the public through various media options of the necessary project information (e.g., proposed road closure); and

   e. providing quantities for traffic control devices.

3. Contract Plans Bureau. The Contract Plans Bureau is responsible for inserting into the project contract the necessary recurring special provisions relative to the maintenance and protection of traffic through construction zones.

15.1.2 Evaluations

The objective of the traffic control plan (TCP) is to provide a strategy that will efficiently and safely move traffic through or around the construction zone. To accomplish this strategy, evaluate the following when preparing a TCP:

1. Preliminary Review. Conduct a preliminary discussion of the TCP during the Preliminary Field Review. The discussion should include such items as methods of traffic control that will be feasible for the project, location of detours, duration of various construction aspects, etc. The road designer should involve the District Traffic and Construction personnel in the development of the TCP throughout the design of the project.

2. Engineering. Some of the engineering aspects to consider include:

   a. Highway Capacity. The TCP should provide adequate capacity to handle the expected traffic volumes through the construction zone or detour at an acceptable level of service. This may require converting shoulders to travel lanes, eliminating on-street parking, constructing temporary lanes, opening additional lanes during peak periods, or providing public transportation.

b. Geometrics. The TCP should have suitable geometry so that a driver can safely maneuver through the construction zone, day or night. Frequent and abrupt changes in geometrics, such as lane narrowing, lane drops or main road transitions that require rapid maneuvers, should be avoided. Section 15.3 presents geometric design criteria for construction zones.

c. Roadside Safety. Providing a safe environment both for the traveling public and construction workers is an essential element through construction zones. Traffic safety through construction zones should be an integral and high priority element of every project from planning through design and construction. Section 15.4 addresses roadside safety concerns through construction zones.

d. Overhead Lighting. If the existing roadway has overhead lighting, it must be maintained during construction.

3. <u>Constructability</u>. The road designer should evaluate the proposed construction sequence to determine if the project can be constructed based on the proposed TCP. Some of the elements the designer should evaluate include:

    a. whether or not traffic will be able to safely maneuver through all the proposed intermediate horizontal and vertical alignment steps,

    b. the location of adjacent traffic relative to worker and traffic safety,

    c. whether or not there is sufficient room for equipment maneuverability, and

    d. whether or not the construction phasing is appropriate.

4. <u>Construction</u>. There are several construction options available that will improve the TCP. These should be discussed during the design phase of the project. Some of these options include:

    a. the use of special materials (e.g., quick curing concretes that will allow traffic within hours of pouring);

    b. the use of special designs (e.g., using precast box culverts versus cast-in-place box culverts or bridges);

c. requiring special scheduling requirements which will reduce traffic disruptions (e.g., working at night near national parks);

d. developing project phasing plans which will allow traffic to use the facility prior to project completion; and

e. contractor alternate bidding methods such as A+B bidding or cost incentives/disincentives for early/late completion of construction may be useful for projects having significant traffic control issues. Where there is FHWA oversight, these methods must be justified and approved by the FHWA.

5. Operation Selection. The initial determination on whether the project will require a detour, lane closures, crossovers, temporary closures, etc. needs to be made during the Preliminary Field Review. Section 15.2 provides additional guidance for determining which of these various construction applications may be appropriate.

6. Business. In urban areas, an in-depth public involvement plan is necessary to coordinate the TCP with local businesses. If at all possible, access to at least one of any business' approach must be maintained during business hours.

7. Maintenance. Include provisions describing how road will be maintained and who will be responsible for snow removal during winter shutdown.

8. Pedestrians and Bicycles. Safe accommodation of pedestrians/bicyclists through the construction zone should be addressed early in project development. Situations that would normally warrant special pedestrian/bicyclist considerations may include locations where sidewalks traverse the construction zone, where a designated school route traverses the construction zone, where significant pedestrian/bicyclist activity or evidence of such activity exists and where existing land use generates pedestrian/bicyclist activity (e.g., parks, schools, shops).

Consider the following principles when addressing pedestrian accommodation through construction zones:

a. Physically separate pedestrians and vehicles from each other.

b. Ensure pedestrian walkways/bicycle paths are free of any obstructions and hazards (e.g., holes, debris, mud, construction equipment, stored materials).

c. Consider temporary lighting for all walkways that may be used at night, particularly if adjacent walkways are lighted.

d. Clearly delineate all hazards (e.g., ditches, trenches, excavations) near or adjacent to walkways.

e. Walkways under or adjacent to elevated work activities (e.g., bridges, retaining walls) may need to be covered.

f. Where pedestrian walkways/bicycle paths cannot be provided, then direct pedestrians/bicyclists to an alternative safe location (e.g., the other side of the street).

g. Stage construction operations so that, if there are two walkways, they both are not out of service at the same time.

h. Plan the construction so that any temporary removal of sidewalks in front of businesses, schools, etc., can occur in the shortest amount of time practical or be scheduled around non-peak pedestrian times (e.g., summer construction around schools).

i. All temporary sidewalks must meet the handicapped accessibility requirements for surface, curb ramps, sidewalk cross slopes, longitudinal slopes, etc. For more information on handicapped accessibility criteria, see Section 18.1.

15.2 CONSTRUCTION APPLICATIONS

The following sections present several construction applications that the designer should consider when developing the project phasing. The several variables that affect the needs of the construction zone include location of work, roadway type, speed, traffic volume, geometrics, vertical and horizontal alignment, pedestrians and intersections. The designer should realize that each construction zone is different and that not all applications will work on every project. For most projects, there may be more than one alternative. Typical applications should be altered to fit the conditions of the particular construction zone.

15.2.1 Work Beyond the Roadway

Traffic will generally not be impeded when the construction area is beyond the roadway (e.g., adding a second roadway to an existing 2-lane facility). The designer should ensure that there are enough access points available to the contractor to allow for construction equipment to exit, enter or cross the highway in a safe manner. Sufficient sight distance should be available to both the motorist and the equipment operator.

15.2.2 Shoulder Work and Partial Lane Closures

Shoulder work which does not encroach into the travel lane will generally have minimal impact on traffic if proper signing is provided to advise the motorist. All temporary traffic control signing and pavement markings must be in accordance with the *MUTCD*. Workers may require protection with the appropriate channelizing devices, portable concrete median barrier and/or a truck-mounted attenuator. Work spaces should be closed off by a taper or channelizing device with the appropriate length as provided in Section 15.3.4.

Partial lane closures may be appropriate where there are:

1. short construction durations;

2. minimal hazardous conditions (e.g., no dropoffs greater than 6 in.(150 mm) next to the roadway); and

3. minimal impacts to traffic.

Where partial lane closures are used, the remaining lane width should be 11’. (3.3 m). However, a 10’. (3.0 m) lane width may be utilized with low-volume roadways that have low truck volumes. Full lane closures should be considered where there is a substantial volume of wider vehicles (e.g., trucks, buses, recreational vehicles) or where construction is adjacent to high-speed traffic. The following sections provide information for full lane closures.

15.2.3 Lane Closure (2-Lane Highways)

Lane closures on 2-lane highways will generally require shifting traffic to the shoulder or providing traffic for both directions on a 1-lane roadway through the use of flaggers and pilot cars. The designer should consider alternative treatments (e.g., detours) if the lane closure will be of a long duration, substantial length, and/or if the roadway has heavy traffic volumes.

Where detours are impractical, give consideration to reconstructing existing shoulders to allow them to be used as a temporary traffic lane. Proper signing and pavement markings are necessary to shift traffic to the appropriate locations. See Section 15.3.4.

For short distances and construction sites on low-volume roads, the use of alternating traffic on 1-lane roads may be acceptable. This strategy is commonly used with the reconstruction of low-volume bridges where each side is reconstructed in separate phases. Adequate sight distance and signing must be available at the site to ensure the motorist understands the appropriate action to take. For daily closures, flaggers may be used to control traffic through the site. For long-term closures, consider using temporary traffic signals to control traffic through the construction zone.

15.2.4 Single-Lane Closures (4-Lane Highways)

Single-lane closures on divided facilities should be discussed at the Plan-in-Hand. They may be appropriate if:

1. they will only cause minor delays during peak time periods, and

2. the construction will not result in a substantial increase in hazards to traffic and/or construction personnel.

In urban or other high-volume areas, give consideration to reconstructing and shifting traffic to the shoulder or reducing lane widths to maintain both lanes of traffic through the construction area. If narrower lanes are used, care should be given to ensure wide loads can still be accommodated (e.g., alternative routes are available). All lane shifts should meet the taper lengths presented in Section 15.3.4.

15.2.5 Two-Way Traffic on Divided Highways

15.2.5.1 Guidelines

The decision on when to use 2-way traffic on a single roadway of a divided highway will be made on a project-by-project basis. The decision should be made prior to the Scope of Work and preferably at the Preliminary Field Review. The input of Construction personnel is essential. In making this decision, consider the following factors:

1. Lane and Shoulder Widths. The minimum allowable lane and shoulder widths are dependent on the volume of traffic and the percentage of trucks. Use Figure 15.2A to determine the shoulder width of the single roadway.

DHV for 12'.(3.6 m) Lane Widths	Shoulder Width
1000	4'.(1.2 m) or greater
800	2'.(0.6 m)
700	0

SHOULDER WIDTH CRITERIA
Figure 15.2A

2. Construction Efficiency. Separating the traffic from the construction activity will always result in increased construction efficiency. However, the increased efficiency may be minimal for activities that can be readily performed with stage construction (one lane at a time), such as cold milling or paving. Closure of a roadway on a divided highway provides the greatest advantage when the construction activity requires grading or an item that would result in temporary closure of one roadway, such as the replacement of a drainage structure.

3. Project Length. Closing a single roadway may result in a significant reduction in the operational efficiency of the remaining roadway. Traffic may back up behind slower vehicles if the two-way traffic is great enough and the segment of closure is greater than 4 mi.(6 km). The evaluation of these factors is covered in 15.2.5.2.

4. Width Restrictions. A single roadway should not restrict the width of vehicles because of reduced lane or shoulder widths. Where it is necessary to restrict the roadway width, the designer should coordinate with the Motor Carrier Services.

5. Alternative Detour Routes. This option is generally only practical if both roadways of a divided highway are closed at the same time. However, the designer should only consider this alternative if no other option is practical. The alternative route should be a facility equivalent to a single roadway of the divided highway. The decision to use an alternate route must include the evaluation and documentation of the features discussed in Section 15.2.7.2

6. Temporary Lanes in Flush Median. Providing temporary lanes is usually only practical where the traffic volumes would exceed the capacity of the single roadway. The length of temporary lanes should be kept to a minimum.

15.2.5.2 Design

The following provides several design considerations where 2-way traffic on a single roadway of a divided highway is used:

1. Length. Studies have found that the optimum segment length of 2-way traffic on divided highways is less than 4 mi.(6 km). Where segments exceed 4 to 5 mi.(6 to 8 km), operational efficiency is often reduced as traffic backs up behind slower vehicles. Where the DHV is less than the values shown in Figure 15.2A, the length of two-way traffic can be extended to the limits of the project. When the DHV is greater than these values, the designer should consider installing additional crossovers to alleviate congestion. The need for additional crossovers should ultimately be determined by the review team.

2. Positive Protection. Due to the complex maneuvers required by drivers at crossovers, it may be necessary to use temporary concrete barrier rail (TCBR) within the crossover; see Figure 15.4A. A TCBR should also be used between crossovers if the distance between crossovers is relatively short [0.5 mi (1 km) or less]. Where a project is longer than 0.5 mi (1 km), tubular markers will generally be used to separate traffic. The decision to use TCBR will be coordinated with the Construction Bureau and the Traffic Engineering Section.

3. Roadside Safety. The designer should consider the effect that directing traffic onto the opposing roadway will have on the roadside appurtenances. For example, existing trailing ends of unprotected bridge ends may require approach guardrail transitions or impact attenuators, and all guardrail terminals may need to be converted to an acceptable treatment. Relapping the guardrail for the temporary direction of travel is generally not required.

4. Crossovers. Consider the following in the design of crossovers:

    a. Tapers for lane drops should not be contiguous with the crossovers. See Section 15.3.4 for acceptable taper lengths and rates.

    b. The crossover should have a design speed that is no more than 25 mph (40 km/h) below the mainline design speed before the construction zone; see Section 15.3.2.

    c. The design of the crossover should accommodate the truck traffic of the roadway (e.g., surfacing widths, loads).

    d. A clear recovery area should be provided adjacent to the crossover; see Section 15.4.3.

    e. See the *MDT Detailed Drawings* for the geometric details of a typical crossover.

    f. Portable concrete barrier rail and the excessive use of traffic control devices cannot compensate for a poor geometric design of a crossover.

5. Interchanges. Access to interchange ramps on freeways should be maintained even if the work space is in the lane adjacent to the ramps. If access is not practical, ramps may be closed using proper signing for alternative ramps. Early coordination with local officials having jurisdiction over the affected cross streets will be required prior to ramp closures.

    Providing access to exit and entrance ramps may require the use of additional crossovers. Sufficient deceleration and acceleration distances should be provided.

15.2.6 Work Within or Near Intersections

If the work is within or near an intersection, consider the following guidelines:

1. Keep the work space small so that traffic can move around it.

2. For temporary work, use flaggers to assign the vehicle right-of-way.

3. Complete the work in stages so the work space can be kept to a minimum.

4. Reduce traffic volumes by detouring traffic upstream from the intersection.

Where lane shifts are used through signalized intersections, the traffic signal heads and actuated detectors will need to be re-adjusted for the appropriate lane. Contact the Traffic & Safety Bureau for information on traffic signal designs.

15.2.7 Detours

15.2.7.1 Warrants

Detours are necessary, when due to the nature of the work, traffic cannot be adequately or safely maintained through the construction project on the existing roadway. Detours provide the safest method of protecting workers within the construction zone. Detours allow the contractor to work unimpeded by traffic, which will typically accelerate the project completion time. On the other hand, detours will often cause substantial inconvenience and confusion to the motoring public.

The following presents several guidelines for where detours should be considered:

1. Detours should be considered where there is a possibility of a significant hazard to traffic and/or workers.
2. Detours should be considered where removal of traffic will substantially accelerate the project completion time.
3. Detours should be provided where construction would be impractical if traffic was maintained (e.g., total bridge reconstruction, substantially raising fill heights).
4. Detours will be required where work is done at railroad crossings. This work will generally require the closing of the roadway for 1 to 2 weeks, depending on the site.

15.2.7.2 Types

Once it has been determined that a detour is necessary, consider the following detour types:

1. <u>Existing Routes</u>. Detours along existing routes are generally the easiest option available to the designer. The following factors should be considered:
    a. Considerable public involvement and coordination with the affected communities will be necessary before traffic can be detoured onto an existing route.

b. Detours will generally require more travel time.

c. The proposed detour route should have sufficient capacity (lane and shoulder widths) to safely accommodate the additional traffic.

d. Detour traffic may significantly increase traffic delays and congestion on local roads (e.g., side streets in towns).

e. Existing traffic signals may need to be reprogrammed or temporary traffic signals installed.

f. Improvements may be required on the detour route to accommodate the increased road traffic (e.g., pavement resurfacing, increasing bridge loading capacities, roadside safety improvements).

g. Ensure that structures over the alternate route provide adequate clearance

h. Increase in the number/density of approaches on the alternate route may decrease the operational efficiency (especially where traffic is being detoured from a controlled access facility)

i. Local access and approaches may still be required within the construction area.

j. Address adequacy of the clear zone for the increased volumes

2. Temporary Roadways. Temporary roadways (e.g. adding lanes in the median, widening of the subgrade) are generally provided within the construction area versus detouring traffic around the area. Temporary roadways are typically constructed where:

a. a long detour would be required,
b. alternate routes are impractical
c. a heavy volume of traffic would need to be detoured,
d. substantial improvements would need to be made to the detour route,
e. increased truck volumes through towns would be unacceptable, and/or
f. the detour duration would be required for a long period of time.

Due to the limited space available, the geometric design of temporary roadways is often much more restricted. Sections 15.3 and 15.4 provide the geometric and roadside safety criteria that should be used for temporary roadways.

The installation of drainage structures associated with temporary roadways generally require a stage construction sequence. The preferred sequence of culvert installation should proceed from downstream to upstream. Sufficient additional culvert lengths are necessary to provide adequate lane widths and fill slopes during the installation.

3. Constructed Detours. Constructed detours are specially constructed temporary roadways that are built within the construction zone to bypass a bridge, railroad crossing or other similar "spot" construction area. These detours are constructed where it would be impractical to detour traffic on other existing routes. The majority of constructed detours are associated with the installation of drainage facilities

   Design the detours using the criteria in Sections 15.3 and 15.4. However, it should be noted that they are generally more expensive, may require the purchase of construction permits, and may have adverse environmental impacts.

15.2.8 Offset Alignment

For reconstructed projects, it may be cost effective to use a new alignment which is offset and generally parallel to the existing roadways. The determination to use an offset alignment should be made at the Preliminary Field Review. Some of the factors that should be evaluated to determine if an offset alignment may be appropriate include:

1. construction cost savings,
2. project constructability,
3. right-of-way availability and costs,
4. existing development of adjacent property, and
5. natural features.

Where an offset alignment is used, special concerns include the design of the connection to the existing roadway, obliteration of the existing roadway, and how to utilize material from the existing fills while maintaining traffic on the existing roadway. The effectiveness of an offset alignment may be reduced where a project involves substantial modifications to the vertical alignment. In these cases the construction limits often encompass the PTW.

15.2.9 Urban Routes

Construction on urban routes present their own unique set of challenges. Major considerations include:

1. Pedestrian/bicyclists issues. Refer to section 15.1.2.

2. Intensive public relations program. Provisions need to be included in the contract to notify motorists and business of closures, delays and other factors that may affect them. These can include media notification and weekly meetings with city officials and local business people.

3. Utility considerations. Replacement of Storm drain, sanitary sewer and water lines often require the closure of a street to traffic. Sequencing must be addressed in detail. Close coordination with District Construction is essential.

4. Access for emergency vehicles. Ensure that access is provided through provisions for roadway width.

5. Impacts to businesses. Impacts must be minimized as much as practical. This typically requires extensive traffic control signing plans

15.2.9.1 Detour Traffic onto an Existing Route

Detouring traffic onto other streets is fairly common for construction projects on urban routes. Closing a single block at a time in a block-by-block sequence helps to minimize disruption to local businesses as well as traffic. Since sequencing is critical in urban construction, the designer needs to coordinate extensively with District Construction. In addition to the considerations listed previously in Section 5.2.7.2, the following items need to be considered.

1. Traffic Volumes. Can the adjacent streets handle the additional traffic volumes. Temporary signing can be used to enhance traffic movements. Converting adjacent streets to one-way traffic should also be considered.

2. Pedestrian accommodation. The alternate routes should have pedestrian and ADA facilities that are equivalent to those on the existing mainline. Pedestrians may still be able to use the mainline pedestrian facilities

3. Surfacing. Are improvements to the surfacing necessary. If the detour route will need some kind of surfacing treatment before placing traffic on it, provide a sequence o ensure that it happens at the appropriate time in the contract.

15.2.9.2 Lane Closures

If sufficient room is available maintain traffic on a portion of the roadway, lane closures generally are the most cost effective method of detouring traffic. Considerations include

1. Positive Separation. Is positive separation needed for utility installation – trenches for storm drain and sanitary sewer can present significant hazards

2. Access to adjacent businesses. It may be necessary to use lane closures in conjunction with detouring traffic to existing routes.

3. ADA access – can reasonable access be provided o both sides of the street

15.2.10 Drainage Options

Where a detour would be required for a culvert replacement the designer should consider the following options:

1. Jacking and Boring. Jacking and boring a new pipe through the roadway fill may be cheaper than detouring traffic and excavating the fill to remove the existing pipe and installing the new one. Since jacking a pipe is costly, it is usually only practical when pipes are located in higher fills or when a detour would be very expensive. The designer should compare the cost to the cost of a detour and new installation. Items to consider are:

    a. Size of pipe needed - Boring anything larger than a 48" culvert may be impractical and result in undue expense, since equipment to bore larger culverts is not readily available. The designer should verify the practical size for boring culverts as it may change over time.

    b. A relatively level area at the bottom of the fill must be available to set up the jacking rig

2. Pipe Inserts/Liners. The Hydraulics Section should evaluate existing culverts to determine if an insert or liner can be installed rather than replacing the existing culvert. The feasibility of using a liner or insert will depend on the required culvert capacity and distortion in the existing culvert shape.

15.3 GEOMETRIC DESIGN

The design criteria presented in the following sections apply to temporary crossovers on divided highways, existing roadways through construction zones and detours specifically constructed for construction projects (e.g., crossovers). It does not apply to detours over existing routes. The basis for the selection of design criteria should be documented. Deviations from these criteria do not require formal design exceptions.

15.3.1 Detour Location

Recommendations for detour locations should be made at the Preliminary Field Review. Consider the following factors when determining detour locations:

1. The detour should minimize impacts to adjacent development.
2. The detour should minimize the amount and cost of utility relocations.
3. The detour should minimize environmental impacts.
4. Locate detours which cross watercourses downstream from the construction, where practical.
5. Ensure the detour is offset a sufficient distance so as not to interfere with the construction. For bridge replacements, try to provide at least 10’(3 m) between the outside edge of the new structure (usually the wingwall) and the toe of the detour cut or fill slope.
6. Evaluate the length of the detour to determine if it is cost effective to extend the detour beyond the construction zone (on short projects such as bridge replacements this decision may result in a detour that is longer than the project). For certain projects the savings in traffic control realized from extending the detour beyond the construction zone are greater than the cost of the materials to provide a longer detour.
7. Coordinate the location of detours around bridge construction sites with the Bridge Bureau to ensure that adequate offset is provided.

15.3.2 Design Speed

In addition to the geometric and physical considerations, the design of detours must take into account the expectations of the driver. Significant speed reductions through construction zones are undesirable and may lead to poor operating conditions particularly where normal traffic speeds are high. Regulatory or warning speed signs are generally ineffective with the exception, perhaps, of signs at horizontal curves. Desirably, the design speed through the work zone will not be more than 10 mph (20 km/h) below the mainline design speed before construction. The following factors should also be considered in the determination of a detour design speed:

1. Location. If the detour is in the middle of a larger construction project a lower design speed may be acceptable. The driver tends to be driving slower or is at least more aware, because of the other construction activity that occurs prior to the detour. If a detour is a part of a stand-alone bridge replacement project, the detour maybe the first feature a driver encounters, and as a consequence may be approaching it at a much higher speed.

2. Duration. If the detour is going to be in place longer than 3 months a higher design speed should be considered to provide a higher level of driver safety.

3. Sight distance. If the driver has plenty of advance warning that they are approaching a detour, a lower design speed may not violate their expectancy as much. The designer must determine if the same amount of warning is provided at night.

The minimum acceptable detour design speed is 35 mph (60 km/h). However, if the 35 mph (60 km/h) design speed is more than 10 mph (20 km/h) less than the design speed of the mainline, the reasons for its use should be documented in the Scope of Work Report. If physical constraints prohibit designing to the minimum speed, the circumstances should be documented in the Scope of Work Report along with mitigating measure incorporated to ensure the safe operation of the detour.

15.3.3 Lane/Shoulder Widths

Desirably, there will be no reduction in the cross section width through the construction zone. However, this is rarely practical. For Interstates and other divided highways, at a minimum, a 11’ (3.3 m) lane width should be maintained through the construction zone and, preferably, with a 2’ (0.6 m) or wider right and left shoulder. Under restricted conditions, a 10’ (3.0 m) wide lane may be used if there is an alternative route provided for wide vehicles. Crossovers on divided highways must provide a 12’ (3.6 m) minimum width. For other highways, the lane and shoulder width selection should be 11’ (3.3 m) or wider. The designer should minimize the use of width reductions. Where necessary, Figure 15.3A presents the minimum taper rates that should be used when reducing widths.

15.3.4 Lane Closures/Other Transitions

The designer should ensure that the taper rate conforms to the MUTCD criteria. These taper rates are shown in Figure 15.3A. Figures 15.3B and 15.3C present and illustrate, respectively, the minimum taper lengths for various taper applications in construction zones (e.g., lane closures, lane shifts).

15.3.5 Sight Distance

Changes in the geometric design of the existing highway are often necessary through construction zones (e.g., lane shifts, detours). Therefore, the available sight distance to the approaching motorist is especially important. Unfortunately, the location of many design features are often dictated by construction operations. However, some elements may have an optional location. For example, when lane closures and other transitions are specially designed, these should be located so that the approaching driver has at least the minimum stopping sight distance available to the closure or transition. The minimum stopping sight distances are presented in Section 8.6 and will be based on the construction zone design speed.

Design Speed	Taper Rate	Design Speed
mph		(km/h)
20	10:1	30
25	15:1	40
30	20:1	50
35	25:1	60
45	45:1	70
50	50:1	80
55	55:1	90
60	60:1	100
70	70:1	110
75	75:1	120

TAPER RATES FOR LANE REDUCTIONS

Figure 15.3A

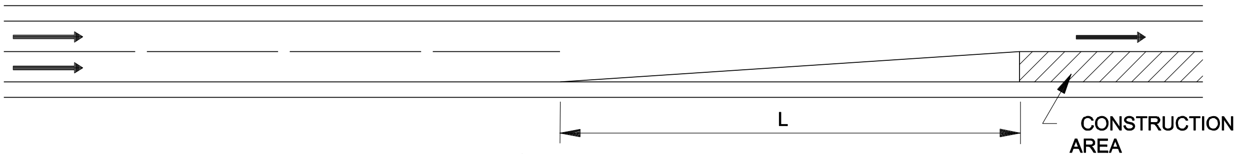
TYPE OF TAPER	TAPER LENGTH
UPSTREAM TAPERS	
Merging Taper	L Minimum
Shifting Taper	½ L Minimum
Shoulder Taper	1/3 L Minimum
Two-way Traffic Taper	100’ (30 m) Maximum
DOWNSTREAM TAPERS (Optional)	100’ (30 m)per lane

Notes:

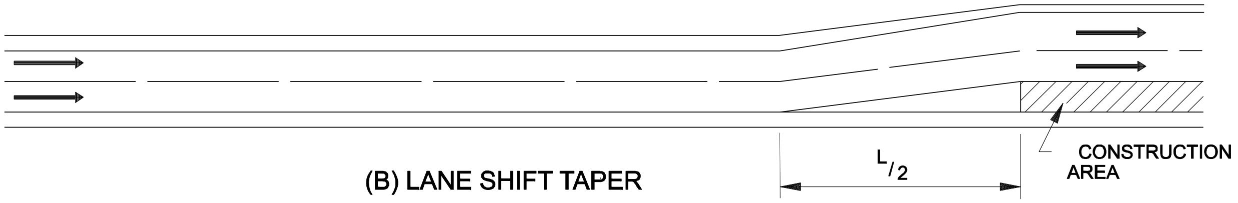
1. Length "L" determined from Figure 15.3A.
2. Figure 15.3C illustrates the various taper types.

TAPER LENGTH CRITERIA FOR CONSTRUCTION ZONES

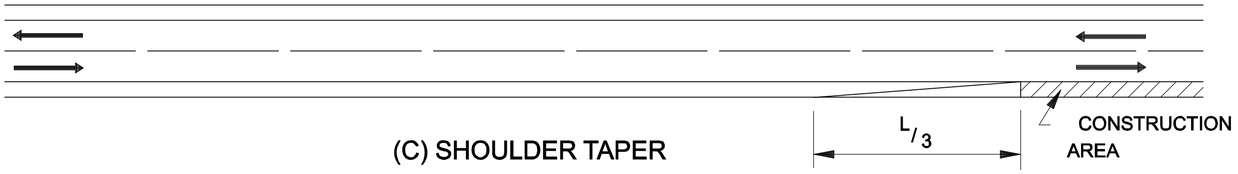
Figure 15.3B



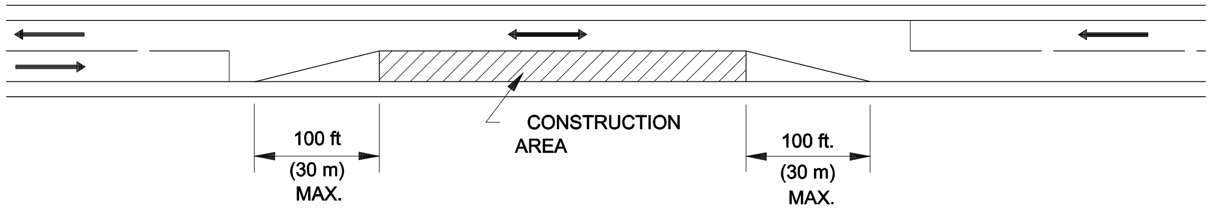
(A) MERGING TAPER



(B) LANE SHIFT TAPER

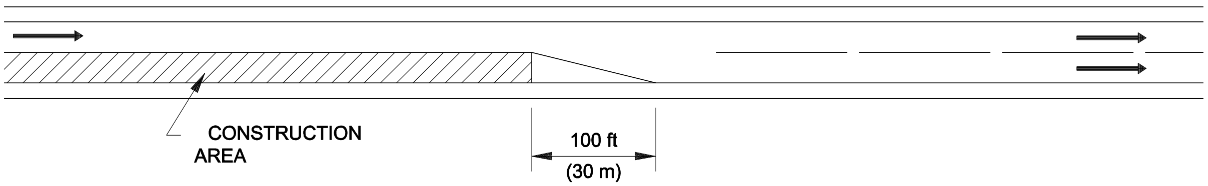


(C) SHOULDER TAPER



NOTE: REQUIRES ADDITIONAL TRAFFIC CONTROL DEVICES.

(D) TWO-WAY TRAFFIC TAPER



(E) DOWNSTREAM TAPER (OPTIONAL)

Length "L" determined from Figure 15.3A.

TAPER LENGTH CRITERIA FOR CONSTRUCTION ZONES
(Application)

Figure 15.3C

15.3.6 Horizontal Curvature

15.3.6.1 Minimum Radii/Superelevation

The minimum radii and superelevation of any horizontal curves will be determined using the selected design speed for the construction zone (Section 15.3.2). In construction zones, the AASHTO Method 2 for distributing superelevation and side friction may be used to determine the radius and superelevation rate of any curve. In this method, superelevation is introduced only after the maximum allowable side friction has been used. This results in eliminating superelevation on flatter curves and reducing the rate of superelevation on the majority of other curves.

Typically, the PTW is widened for the detour connection using the same cross slope as exists on the PTW. Figure 15.3D provides the minimum horizontal curve radii for retaining normal crown, based on AASHTO Method 2, for detour connections to tangent PTW sections. Detour connections to superelevated PTW sections should be accomplished with horizontal curves requiring the same superelevation, based on AASHTO Method 2, as the in-place superelevation of the PTW. As discussed in Section 9.3.8, the minimum distance between the PT and PC of reverse superelevated curves will be that needed to meet the superelevation runoff length requirements for the two curves.

Figure 15.3E illustrates a typical three-horizontal curve alignment for a minimum-length, 50 mph (80 km/h) constructed detour providing approximately a 50’ (15 m) offset. The following factors should be considered when establishing a detour alignment:

1. Selecting radii requiring a normal crown (NC) for curves exiting/entering tangent PTW accommodates vehicles turning onto/off the detour on the retained adverse crown of the PTW.

2. Selecting radii requiring NC allows the PC and PT of successive curves to be coincident and eliminates the need for superelevation transition lengths.

3. If selection of radii requiring superelevation is necessary, ensure that the proper transition lengths are provided as illustrated in Figure 15.3F.

4. Typical offsets between the edge of a new structure and the edge of a detour shoulder is 10’ (3.0 m).

5. Provide a 2’ (0.6 m) radius nose at the gore.

U. S. Customary

Design Speed, V mph	f_{max} (Open-Roadway Conditions)	Minimum Radii, R_{min} (for Normal Section) (e = -2%) (ft)	Minimum Radii, R_{min} (e = 8%) (ft)
20	.17	180	110
25	.17	280	170
30	.16	430	255
35	.15	630	360
45	.14	1130	615
50	.14	1390	760
55	.13	1835	965
60	.12	2405	1205
70	.11	3630	1720

Metric

Design Speed, V (km/h)	f_{max} (Open-Roadway Conditions)	Minimum Radii, R_{min} (for Normal Section) (e = -2%) (m)	Minimum Radii, R_{min} (e = 8%) (m)
30	.17	50	30
40	.17	85	55
50	.16	145	85
60	.15	220	125
70	.14	325	180
80	.14	420	230
90	.13	580	305
100	.12	790	395
110	.11	1060	505

Notes:

1. <u>Curve Radii</u>. Radii are calculated from the following equations:

U. S. Customary

$$R = \frac{V^2}{15(e + f)}$$

values for design have been rounded up to the next highest 5’ increment.

Metric

$$R = \frac{V^2}{127(e + f)}$$

values for design have been rounded up to the next highest 5 m increment.

2. Normal Section. If the normal section is maintained through the horizontal curve, the superelevation rate is -.02 assuming a typical cross slope of 2%. Therefore, the R_{min} column with e = -2% presents the minimum radii which can be used and retain the normal section through the horizontal curve.

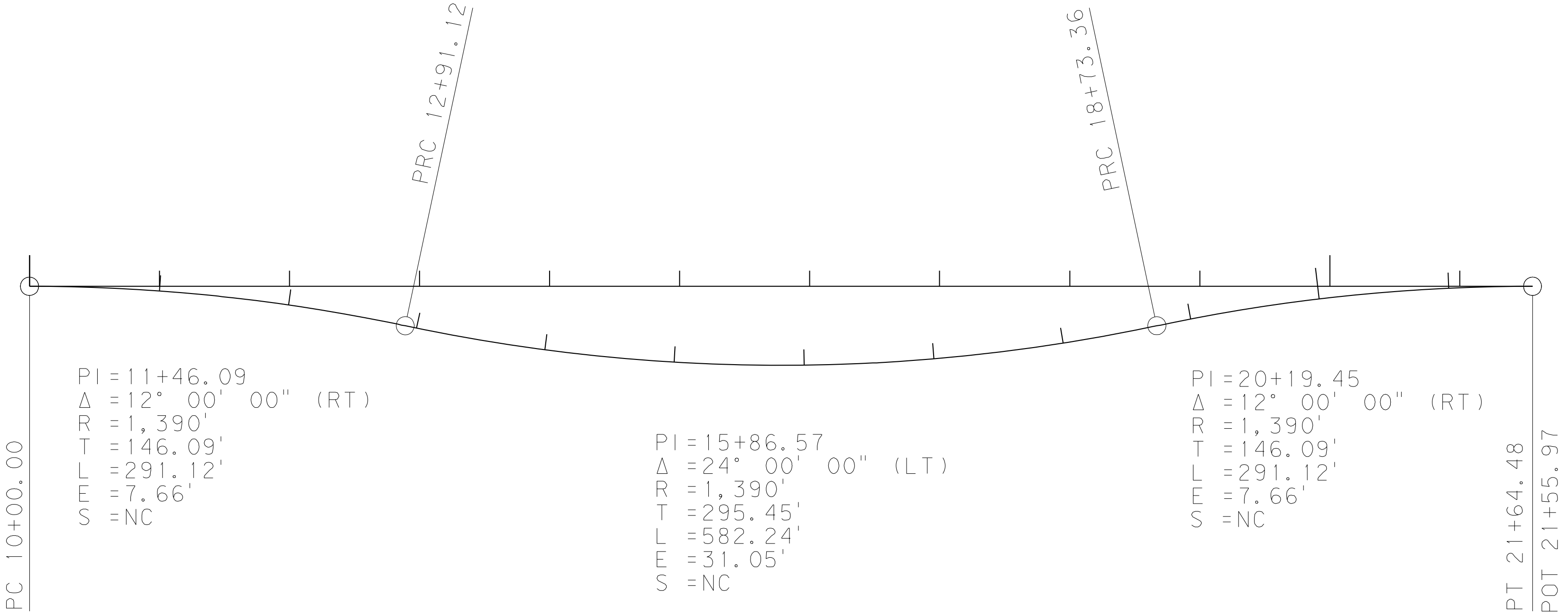
3. Other Radii. For proposed radii or superelevation rates intermediate between the table values, the equation in Note #1 may be used to determine the proper curvature layout. For example, if the construction zone design speed is 60 mph (100 km/h) and the proposed curve radius is 1640’ (500m), then the superelevation rate is:

<table>
<tr><th><i>U. S. Customary</i></th><th><i>Metric</i></th></tr>
<tr><td>$e = \frac{V^2}{15R} - f$</td><td>$e = \frac{V^2}{127R} - f$</td></tr>
<tr><td>$e = \frac{(60)^2}{(15)(1640)} - 0.12$</td><td>$e = \frac{(96.5)^2}{(127)(500)} - 0.12$</td></tr>
<tr><td colspan="2">$e = +3.0\%$ (Using nominal U.S. Customary design speed, round the calculated superelevation rate to the next highest per cent).</td></tr>
<tr><td>$e = \frac{(62.1)^2}{(15)(1640)} - 0.12$</td><td>$e = \frac{(100)^2}{(127)(500)} - 0.12$</td></tr>
<tr><td colspan="2">$e = +4.0\%$ (Using nominal Metric design speed, round the calculated superelevation rate to the next highest per cent).
Note: 100kmh equals 62.1mph</td></tr>
</table>

MINIMUM RADII FOR HORIZONTAL CURVES

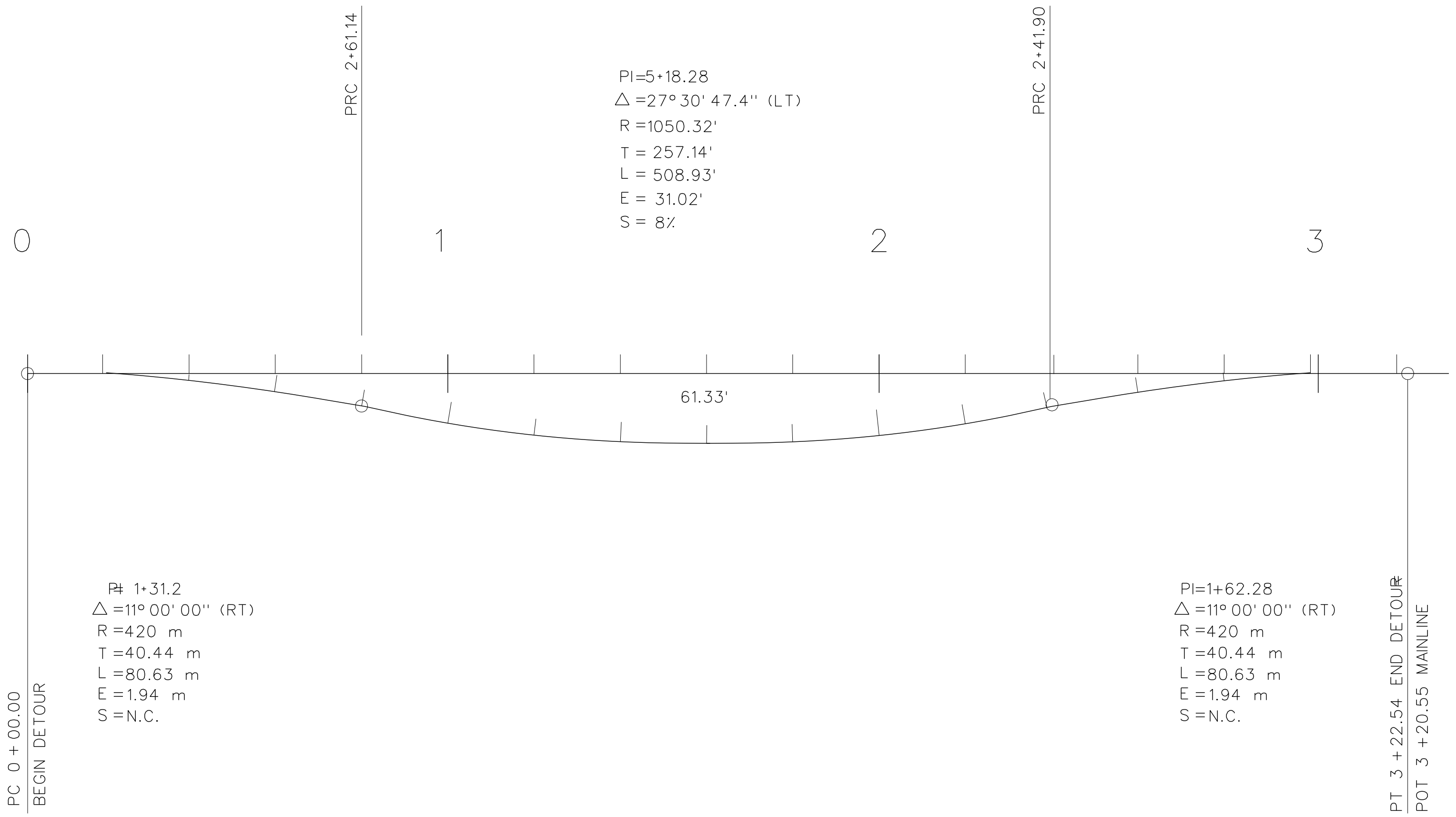
(Construction Zones)

Figure 15.3D



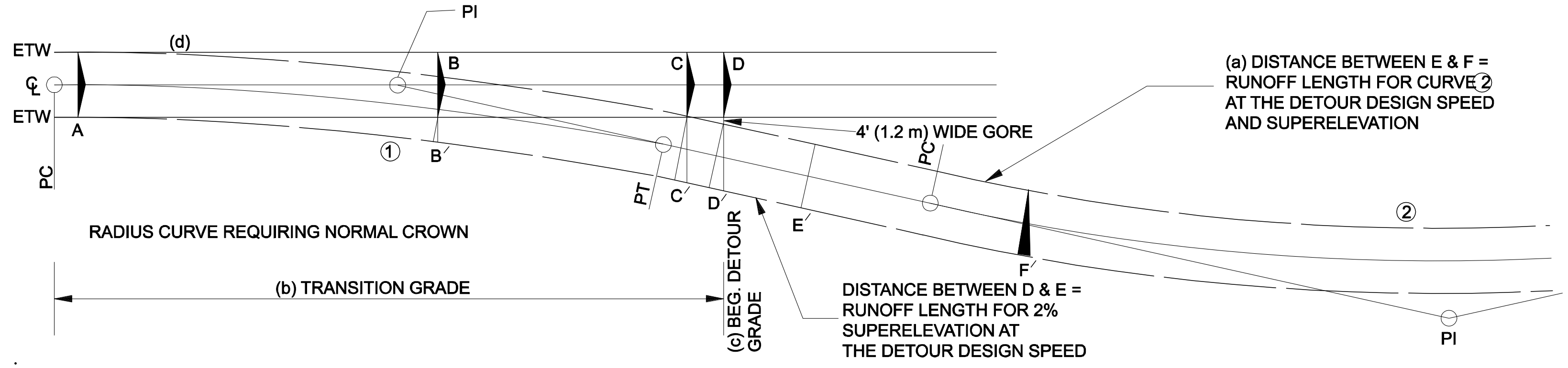
TYPICAL U.S. CUSTOMARY DETOUR ALIGNMENT
(Maintaining Normal Section)
(Design Speed: 50 mph)

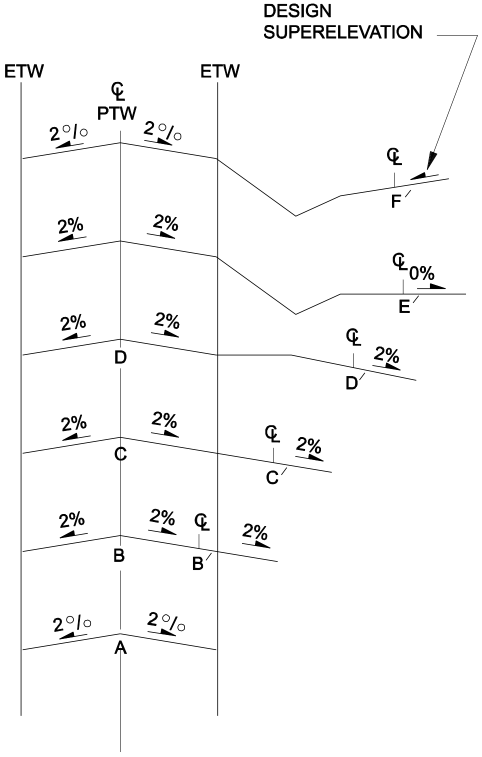
Figure 15.3E



TYPICAL METRIC DETOUR ALIGNMENT
(Maintaining Normal Section)
(Design Speed: 80 km/h)

Figure 15.3E





(a) This applies if Curve 2 is superelevated. If Curve 2 is flat enough to retain the normal crown, the PT of Curve 1 and PC of Curve 2 can be coincident. Transitioning the 2% cross slope at Section D' to normal crown can then be accomplished within Curve 2.

(b) Throughout the transition grade, detour centerline elevations are computed by multiplying the offset distance and the cross slope between the centerlines. This distance is then subtracted from the mainline centerline elevation.

(c) Independent detour grade begins at the point of full separation between mainline and detour (Section D').

(d) Detour connections to a curved present traveled way (PTW) alignment should be accomplished with a horizontal curve requiring the same superelevation, based on Figure 15.3D, as the in-place superelevation of the PTW.

HORIZONTAL CURVES FOR DETOURS
(With Superelevation)

Figure 15.3G

15.3.6.2 Transition Lengths

Section 9.3.5 presents MDT criteria for superelevation transition lengths for permanent construction projects. These lengths will be provided for detours in construction zones (based on detour design speed). Note that, as with permanent construction, the tangent runout (TR) lengths must be added to the superelevation runoff lengths to determine the total transition length.

15.3.7 Vertical Alignment

A transition grade should be used for the detour alignment from the beginning/end of the detour to the gore. An independent grade should be designed between the gores.

Throughout the transition grade area, detour centerline elevations are computed by multiplying the offset distance and the cross slope between the PTW centerline and detour centerline. This distance is then subtracted from the PTW centerline elevation to produce the detour centerline elevation.

Ensure detour grade provides minimum cover for all culvert options to accommodate the waterway opening or elevation required for placement of temporary bridge.

Vertical curve criteria presented in Chapter Ten is also applicable to detours.

15.3.8 Surfacing

Determine the type of surfacing to be used on the detour at the Preliminary Field Review and review this decision at the Plan-in-Hand. All detours for Interstate projects will be paved. Detours for projects on other routes may have paved, treated or gravel surfaces. Factors that influence the type of surfacing utilized for these detours include:

1. the ADT on the route (routes with higher ADT's will require more durable surfacing),
2. the length of time the detour will be in use, and
3. the maintenance that would be required for the various types of surfacing. The ADT will also affect the level of maintenance.

See Figure 15.3G for general guidance as to the type of surfacing for detours. The surfacing type should be determined prior to Scope of Work Report.

15.3.9 Cut and Fill Slopes

Wherever practical, construct detour cut and fill slopes according to the design criteria in Chapter Twelve. The use of 3:1 fill slopes is acceptable where a sufficient clear zone is available at the bottom of the slope. The use of steeper fill slopes may require the installation of barriers.

Although detours rarely involve excavation (cut), 3:1 cut slopes are generally acceptable in place of the 5:1 and 4:1 slopes described in Chapter Twelve. The use of slopes steeper than 3:1 for cut depths less than 10’ (3 m) should be reviewed at the Plan-in-Hand.

The anticipated traffic volumes, design speed of the detour and the length of time the detour will be in place should be weighed in determining cut and fill slopes.

15.3.10 Temporary Pavement Markings

The designer is responsible for determining the quantities of temporary pavement markings. Calculate the quantities of each 2-lane mile (kilometer) for each pavement marking application. Additionally, temporary pavement markings may be required after:

1. milling operations (if traffic will be driving on the milled surface),
2. between each pavement lift

They may also be required on existing pavements. Chapter Five presents the procedures for estimating quantities.

Current ADT	Duration of Detour Operation			
	< 5 Days	5 - 30 Days	31 Days - 3 Months	> 3 Months
< 500	gravel	gravel	dust palliative	dust palliative
500 - 1499	gravel	dust palliative	dust palliative	PMS
1500 - 6000	dust palliative	dust palliative	PMS	PMS
> 6000	dust palliative	PMS	PMS	PMS

GUIDELINES FOR SELECTION OF DETOUR SURFACING

Figure 15.3G

15.4 ROADSIDE SAFETY

As drivers traverse construction zones, they are often exposed to numerous hazards including restrictive geometrics, construction equipment and opposing traffic. Elimination of these hazards is often impractical. Regardless, consideration must be given to reducing the exposure of motorists to hazards.

15.4.1 Positive Protection

During the planning and design of a project, give careful consideration to traffic control plan alternatives that do not require the use of temporary barriers. This can often be accomplished by using detours, constructing temporary roadways, minimizing exposure time, and maximizing the separation between traffic and workers. Even with proper project planning and design, there will still be many instances where positive protection should be considered.

Because each site should be designed individually, MDT has not developed specific warrants for providing positive protection in construction zones. The Construction Bureau and field construction personnel will make the determination whether to provide positive protection in construction zones. The use of positive protection should be discussed at the Plan-In-Hand. The following provides a list of factors that should be considered:

1. duration of construction activity,
2. traffic volumes (including seasonal fluctuations),
3. nature of hazard,
4. design speed,
5. highway functional class,
6. length of hazard,
7. proximity between traffic and construction workers – consider dynamic deflection of barrier
8. proximity between traffic and construction equipment,
9. adverse geometrics which may increase the likelihood of run-off-the-road vehicles,
10. two-way traffic on one roadway of a divided highway,
11. transition areas at crossovers, and/or
12. lane closures or lane transitions.

15.4.2 Appurtenance Types

The designer's first objective should be to provide a design that eliminates the need for temporary barriers. However, this is often not practical. In addition to Chapter Fourteen and the *MDT Detailed Drawings*, the following provides general information on the roadside safety appurtenances used by the Department through construction zones:

1. Guardrail/Concrete Barrier Rail. For most construction projects, the installation of a new temporary guardrail/concrete barrier rail is usually not cost effective due to the short project life. Where used, temporary guardrail/concrete barrier rail installations must meet the permanent installation criteria set forth in Chapter Fourteen and the MDT Detailed Drawings, except where modified in Section 15.4.4.

2. Temporary Concrete Barrier Rail. The most common type of portable barrier is a temporary concrete barrier rail (TCBR). A TCBR provides the greatest protection from the construction zone and between two-way traffic, but it is also the least forgiving to the driver. The primary functions of the TCBR in construction zones are:

    a. to keep traffic from entering work areas (e.g., excavations, material storage sites);

    b. to protect workers and pedestrians;

    c. to separate two-way traffic;

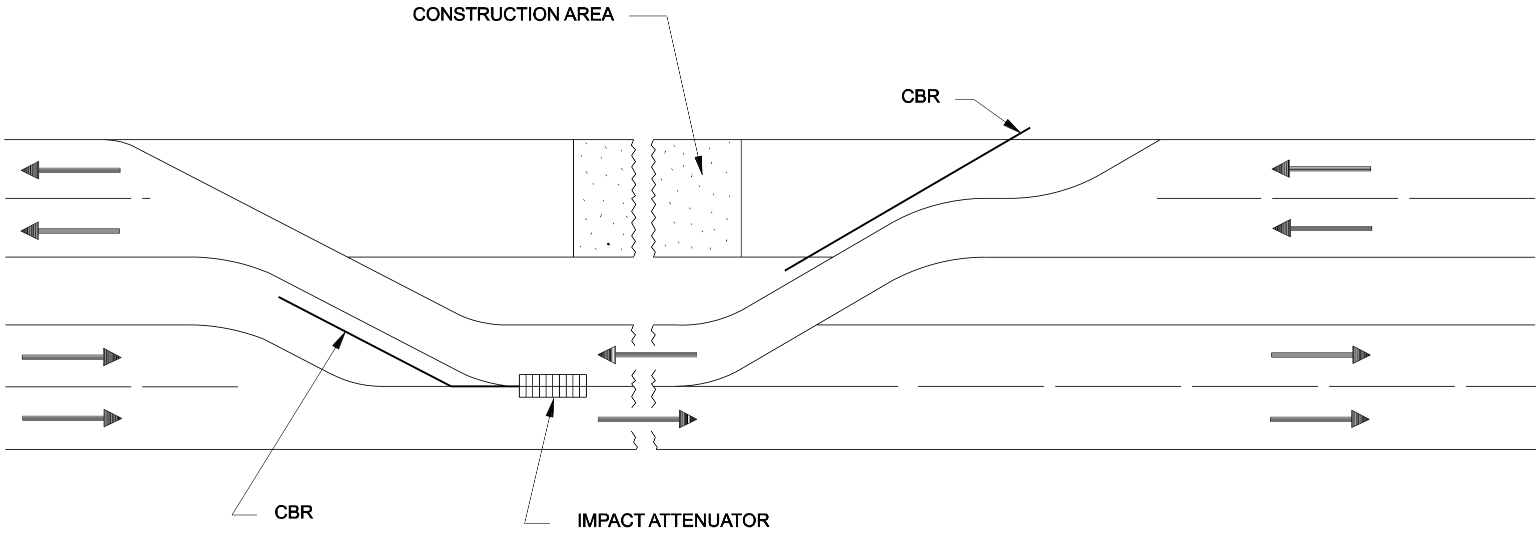
    d. to shield obstacles and edges; and

    e. to protect construction such as falsework for bridges and other exposed objects.

    Figure 15.4A illustrates the suggested locations for the CBR at crossovers to eliminate head-on accidents. For other locations, the decision on where to use a TCBR in construction zones will be determined on a site-by-site basis. The designer needs to coordinate with District Construction to determine the extent of the TCBR and how many times it will be reset. Quantities need to be provided in the plans

    Another type of barrier that may be used is a water-filled lightweight, polyethylene plastic shell. The shells are supplemented by an internal steel framework to provide additional rigidity during handling and impacts. There is also a cable at the top connecting the joints between barrier segments. Upon impact, these devices may deflect up to 12’ (3.6 m). They may be used where high portability is desired and in congested urban work sites.

3. End Treatments. Even when protected or otherwise mitigated, the ends are the most hazardous element of any barrier system. Therefore, any unprotected terminal ends for guardrail or the TCBR should be located as far as practical from the roadway or be protected with an appropriate end treatment. This includes breaks in the barrier for crossovers and/or contractor access openings.



If the crossover distance is less than 1 mile (1 km), then CBR should be used throughout the crossover.

TEMPORARY CONCRETE BARRIER RAIL LOCATIONS
(Crossovers)

Figure 15.4A

The construction zone QuadGuardCZ is the preferred end treatment to protect the blunt end of the CBR. Although a construction zone TRACC is not available at this time, the Department anticipates that one will be available in the near future. These end treatments should also be used where space does not allow the use of sand barrels at point obstacles (e.g., bridge piers). Where space is available, the CAT and Brakemaster should also be considered.

Chapter Fourteen provides information on other end treatments used by the Department. Provide the safest end treatment consistent with cost effectiveness and geometric considerations.

15.4.3 Design/Layout

In general, when designing and laying out temporary roadside safety appurtenances in construction zones, use the criteria set forth in Chapter Fourteen. However, due to the limited time exposure, it may not always be cost effective to meet the permanent installation criteria. The following provides several alternatives the designer may use in designing and laying out temporary roadside safety appurtenances:

1. Clear Zones. Applying the clear zone distances for new construction/reconstruction, as presented in Chapter Fourteen, to construction zones is often impractical. MDT has developed revised distances for clear zones through construction zones, which are presented in Figure 15.4B. Due to the hazardous conditions which typically exist in construction zones, the designer still must use considerable judgment when applying these clear zone distances. Note that it is not necessary to adjust the construction clear zones in Figure 15.4B for horizontal curvature.
2. Length of Need. As with new installations, provide a sufficient distance of a full-strength barrier prior to the hazard to minimize the potential for a vehicle to run behind the barrier and impact the hazard. For temporary layouts, determine the length of need by using an angle of 15º from the back of the hazard or from the clear zone distance off the travelway.
3. Shoulder Widening. When a temporary barrier is placed next to the shoulder, it is not necessary to provide the extra 2’ (0.6 m) shoulder widening.
4. Flare Rates. Desirably, the CBR terminus should be flared away from the traveled way to a point outside of the clear zone. Figure 15.4C presents the desirable flare rates for the CBR based on the design speed in construction zones. The designer should provide these flare rates unless under extenuating circumstances it is impractical to do so (e.g., stop conditions, driveways, intersections).

Detour Design Speed	ADT	Fill Slopes			
		6:1 or Flatter	5:1	4:1	3:1
35 mph or less	< 750	3	5	5	See Procedure in Section 14.2.3.
	750-1499	5	6	8	
	1500-6000	6	7	8	
	> 6000	8	8	10	
45 mph	< 750	5	6	7	
	750-1499	6	8	10	
	1500-6000	8	10	12	
	> 6000	10	12	13	
50 mph	< 750	6	6	8	
	750-1499	8	10	10	
	1500-6000	10	12	13	
	> 6000	12	13	15	
55 mph	< 750	6	8	10	
	750-1499	8	10	12	
	1500-6000	10	13	15	
	> 6000	11	13	16	
60 mph	< 750	8	10	12	
	750-1499	10	13	16	
	1500-6000	13	16	20	
	> 6000	15	18	23	
70 mph	< 750	10	12	14	
	750-1499	12	15	18	
	1500-6000	15	18	21	
	> 6000	16	20	23	

Notes:

1. *All distances are measured from the edge of the traveled way (ETW).*
2. *For clear zones, the ADT will be the total current ADT for both two-way roadways and one-way roadways.*
3. *See Section 14.2.4 for application of clear zones in cut sections.*

CLEAR ZONE DISTANCES (ft)
(Construction Zones - U.S. Customary)

Figure 15.4B

Detour Design Speed	ADT	Fill Slopes			
		6:1 or Flatter	5:1	4:1	3:1
60 km/h or less	< 750	1.0	1.5	1.5	See Procedure in Section 14.2.3.
	750-1499	1.5	2.0	2.5	
	1500-6000	2.0	2.5	2.5	
	> 6000	2.5	2.5	3.0	
70 km/h	< 750	1.5	1.5	2.0	
	750-1499	2.0	2.5	3.0	
	1500-6000	2.5	3.0	3.5	
	> 6000	3.0	3.5	4.0	
80 km/h	< 750	1.5	2.0	2.5	
	750-1499	2.5	3.0	3.0	
	1500-6000	3.0	3.5	4.0	
	> 6000	3.5	4.0	4.5	
90 km/h	< 750	2.0	2.5	3.0	
	750-1499	2.5	3.0	4.0	
	1500-6000	3.0	4.0	4.5	
	> 6000	3.5	4.0	5.0	
100 km/h	< 750	2.5	3.0	4.0	
	750-1499	3.0	4.0	5.0	
	1500-6000	4.0	5.0	6.0	
	> 6000	4.5	5.5	7.0	
110 km/h	< 750	3.0	3.0	4.0	
	750-1499	3.5	4.0	5.5	
	1500-6000	4.0	5.5	6.5	
	> 6000	4.5	6.0	7.0	

Notes:

4. *All distances are measured from the edge of the traveled way (ETW).*
5. *For clear zones, the ADT will be the total current ADT for both two-way roadways and one-way roadways.*
6. *See Section 14.2.4 for application of clear zones in cut sections.*

CLEAR ZONE DISTANCES (m)
(Construction Zones - Metric)

Figure 15.4B

U. S Customary

Detour Design Speed	Flare Rates
45 mph or less	9 to 1
50 mph	11 to 1
55 mph or greater	13 to 1

Metric

Detour Design Speed	Flare Rates
70 km/h or less	9 to 1
80 km/h	11 to 1
90 km/h or greater	13 to 1

FLARE RATES FOR TEMPORARY CONCRETE BARRIER RAIL

Figure 15.4C

15.5 DRAINAGE STRUCTURES

The Hydraulics Section will determine the type of temporary drainage structures that are required for detours. If a bridge will be needed the Hydraulics Section will provide the dimensions for the waterway opening.

When it is determined that a culvert can be utilized for the temporary drainage structure additional information must be provided in the plans to facilitate the removal of the culvert and fill material from the stream channel.

15.5.1 Perennial (Active) Streams

The designer should coordinate with the District Biologist early in the detour design process to determine the treatment that should be used in conjunction with the culvert installation and to address other environmental concerns associated with the detour. Prior to installing the detour culvert in a perennial stream or a stream with a high resource value, one of the following treatments will be required.

1. Place drain aggregate in the channel bottom extending 0.5 m beyond each side of the active channel. The drain aggregate should be placed to an average depth of 6” (150 mm) for the entire length of the culvert. (drain aggregate will meet the requirements of 701.10 in the Standard Specifications). This treatment is typically preferred for use in perennial streams. Or,

2. Place erosion control geotextile in the active channel. The geotextile should extend 2’ (0.5 m) beyond each side of the active channel for the entire length of the culvert.

Geotextile must also be placed on the upstream and downstream face of the detour embankment. The geotextile should be keyed into the toe of the fill and the top of the fill. It should extend at least 1 m beyond the defined channel banks. Note that the defined channel banks may not be the same as the active channel.

15.5.2 Intermittent & Ephemeral Streams

The following treatment should be used for intermittent or ephemeral streams.

1. Place drain aggregate or hay/straw in the channel bottom extending 2’ (0.5 m) beyond each side of the low water channel. The drain aggregate or hay/straw should be placed to an average depth of 6” (150 mm) for the entire length of the

culvert. (drain aggregate will meet the requirements of 701.10 in the Standard Specifications).

If wetlands/riparian areas are impacted by the detour embankment outside of the banks of any stream, geotextile, drain aggregate or hay/straw should still be placed over the affected wetlands/riparian areas to delineate the original ground elevation (i.e. the treatment will be placed the entire width and length of the base of detour embankment through wetland/riparian areas)

The following details need to be included in the plans:

1. Plan and profile of the detour. We recommend that the location where the detour will overtop (the low point) should be located at least 75’ (25 m) from the culvert.

2. A profile detail of the culvert installation including elevations

3. Cross section(s) showing the culvert invert elevations, the location of the geotextile placed on the embankment faces, and the location and extent of either the drain aggregate, geotextile or hay/straw placed in the stream channel.

4. Include quantities of drain aggregate, geotextile and hay/straw in the detour quantities summary

October 18, 2016

MONTANA DEPARTMENT OF
TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Seventeen

DRAINAGE AND IRRIGATION DESIGN

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(Continued)

Chapter Seventeen
DRAINAGE AND IRRIGATION DESIGN

Chapter Seventeen presents policies and criteria for the design of facilities to accommodate surface water. Included are policies and criteria for the design of:

1. pipe culverts,
2. special drainage facilities,
3. irrigation facilities,
4. storm drains, and
5. underdrains.

The chapter also presents design policies for special-purpose large culverts, and a group of general reference tables. See the *AASHTO Model Drainage Manual* for additional information on highway drainage. The Hydraulics Section has revised and adopted Chapters Seven, Nine, Ten and Thirteen of the *AASHTO Model Drainage Manual*. These chapters are available on MDT's website.

17.1 PIPE CULVERTS

Nearly all drainage and irrigation facilities involve the use of some type of pipe culvert. Pipe culvert design requires a determination of:

1. pipe material,
2. design service life,
3. pipe size,
4. structural requirements,
5. multiple pipe installation requirements,
6. culvert end treatments,
7. culvert inlet and outlet edge protection,
8. culvert lengths, and
9. culvert bedding/foundation.

17.1.1 Pipe Material

Pipes may be fabricated from concrete, steel, aluminum or plastic material. Material selection will be based on an evaluation of the project location's soil and water conditions. Provisions will be included to permit optional bids for pipes of different materials. The Hydraulics Section will provide information for the different pipe materials including wall thickness, size of corrugations and class of concrete for all culverts larger than 24” (600 mm) in diameter. The designer will be advised in writing of these decisions. For additional information, see the Department's policy for Optional Material for Culverts.

For reconstruction projects where existing pipes can be used in place and require lengthening, the additional lengths of pipe usually will be constructed of the same material as the existing pipe. These special conditions will be identified in recommendations at the time of the field survey.

17.1.2 Design Service Life

The issue of culvert service life will be addressed during the preliminary field review. The Hydraulics Section will use service life to determine the required wall thickness, type of coating and any special requirements for new pipes. The Hydraulics Section will evaluate the corrosive soil report, as provided by the Materials Bureau, to determine design service life. For specific design criteria, see the "Culvert Service Life Guidelines" as published in the *Hydraulics Manual*. The remaining service life of existing pipes will guide the decision to replace the pipes or use them in place. The culvert service life will comply with the following guidelines:

1. The design service life for new or replacement culverts will be:
    a. 40 years for approach pipes*;
    b. 75 years for mainline pipes;
    c. 75 years for storm drains; and
    d. for irrigation pipe, siphons and active streamflow pipes, the life of the pipe is the time it takes for the first perforation to occur. Therefore, the design service life pulled stated in the AISI charts must be doubled (e.g., for design purposes a mainline irrigation crossing effectively needs a 150-year life and a minor irrigation approach pipe needs an effective 80-year life).

* Approach pipes will not receive any coating unless specifically recommended.

2. The design service life for overlay and minor widening projects will be 20 years for all in-place culverts.
3. The design service life for pipes used in place on reconstruction and major widening projects will be:

a. 25 years for all in-place pipes except as follows;
b. 50 years for all pipes where any one of the following applies:

  - fill heights are over 15’ (4.5 m);
  - ADT is greater than 5,000;
  - grade raises over 5’ (1.5 m);
  - all 4-lane highways; and/or
  - extensions greater than 50% of the in-place length of the culvert.

17.1.3 Pipe Size

The locations and sizes of existing pipe culverts will be documented at the time of the location or pick-up survey. Any problems with existing culvert facilities, such as insufficient capacity, roadway overtopping, erosion, pipe damage, rusting/corrosion, or debris/ice obstruction, should also be noted at the time of survey.

All new mainline drainage culverts must be at least 24” (600 mm) in diameter. All new irrigation pipe culverts and approach culverts must be at least 18” (450 mm) in diameter. Equivalent arch pipes may be used.

The Hydraulics Section will provide recommendations for all irrigation crossings greater than 18” (450 mm) in diameter and drainage crossings requiring pipes greater than 24” (600 mm) in diameter. The road designer will determine the location of all minimum size drainage crossings and will design all inlet, outlet, and roadside ditches for positive drainage.

17.1.4 Structural Requirements for Reinforced Concrete Pipe

Reinforced Concrete Pipes (RCP) are identified by "class" numbers, depending on their respective strength characteristics. Four classes are available — Class 2, 3, 4 and 5. The higher the number, the stronger the pipe. Figure 17.1A identifies permissible fill heights for various classes of pipe and bedding. Concrete Arch Pipes will normally be Class 3, Wall "B". Figure 17.1B provides the equivalent RCP diameters for reinforced concrete pipe arches. Maximum fill height is measured from the top of the pipe to the point of maximum cover including the total surfacing thickness.

US Customary		
CLASS OF PIPE	MAXIMUM FILL HEIGHTS②,③	
	INSTALLATION TYPE	
	Trench	Embankment
	P=0.0①	P=0.7
	ft.	ft.
2	14	11
3	20	14
4	28	22
5	42	32
4000D①	-	40

Metric		
CLASS OF PIPE	MAXIMUM FILL HEIGHTS②,③	
	INSTALLATION TYPE	
	Trench	Embankment
	P=0.0①	P=0.7
	M	m
2	4.3	3.4
3	6.1	4.3
4	8.5	6.7
5	12.8	9.8
4000D①	-	12.2

P = Projection Ratio. A projection ratio of 0.0 is a trench condition and may be achieved by excavation below existing ground or by building embankment and excavating the trench. A projection ratio of 0.7 is for embankment conditions.

Notes:

① *Not to be used without Hydraulic Section's approval. For more information on bedding, see the* MDT Detailed Drawings.

② *This fill height table was developed using the indirect design method detailed in the ACPA* Concrete Pipe Design Manual. *This table applies only to pipes having "B" wall thickness.*

③ *Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course. Consult the Hydraulics Section for minimum cover requirements for concrete pipe if cover is less than 1.5 feet (0.5 m).*

STRUCTURAL REQUIREMENTS FOR RCP

Figure 17.1A

US Customary

Span (Inch)	Rise (Inch)	Equivalent Diameter (Inch)
18	11	15
22	13 ½	18
26	15 ½	21
28½	18	24
36¼	22 ½	30
43¾	26 ⅝	36
51⅛	31 5/16	42
58½	36	48
65	40	54
73	45	60
88	54	72
102	62	84

Metric

Span (mm)	Rise (mm)	Equivalent Diameter (mm)
460	280	375
560	345	450
660	395	525
725	460	600
920	570	750
1110	675	900
1300	795	1050
1485	915	1200
1650	1015	1350
1855	1145	1500
2235	1370	1800
2590	1575	2100

Table values are from AASHTO Materials, Standard Specifications for Transportation Materials, Part 1, M206 & M206M.

REINFORCED CONCRETE PIPE ARCHES

Figure 17.1B

Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course. Consult the Hydraulics Section for minimum cover requirements for concrete pipe if the cover is less than 1.5’ (0.5 m).

17.1.5 Structural Requirements for Corrugated Steel Pipe

Metal thickness and soil support are the principal measures of strength in Corrugated Steel Pipe (CSP). The required metal thickness depends on the following factors:

1. height of fill over pipe,
2. dimensions of corrugations,
3. shape of pipe,
4. soil compaction,
5. corner bearing pressure, and
6. soil corrosiveness.

Figure 17.1C illustrates some of the relationships between these factors. The figure shows the minimum and the maximum permissible fill heights for each combination of pipe size and metal thickness. Maximum fill height is measured from the top of the pipe to the point of maximum cover. The depth of surfacing (e.g., bituminous, gravel, concrete) is included in the height of cover. Pipes should be placed at a minimum of 0.3’ (0.1 m) to 1.0’ (0.3 m) below the bottom of the surfacing section exclusive of special borrow (i.e., surfacing subgrade). Although not desirable, pipes may extend into the special borrow course. See the fill height tables for additional information.

Normally, for steel culvert installations up to 120” (3000 mm) in diameter, CSP will be specified for installation. The fill heights for these culverts must fall within the limits of the fill height tables.

The following corrugation sizes will be specified for steel pipe:

1. 2⅔” x ½“ (68 mm x 13 mm),
2. 3” x 1” (75 mm x 25 mm), or
3. 5” x 1” (125 mm x 25 mm).

Note the corrugation sizes on the pipe summary.

Most culvert installations will be "round" pipe. Specify pipe arches only where cover is limited or where local conditions make the shape of the pipe arch more effective for carrying the water. Figure 17.1D presents structural requirements for Corrugated Steel Pipe Arch (CSPA) culverts.

US Customary

2⅔” x ½“ CORRUGATIONS ①, ② WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
12	18	213	266			
18	18	142	177			
24	18	106	133	186		
30	18	85	106	149		
36	18	71	88	124	159	
42	18	60	76	106	137	167
48	18	53	66	93	119	146
54	18		59	82	106	130
60	18			74	95	117
66	18				87	106
72	18				79	97
78	18					90
84	18					83

Metric

68 mm x 13 mm CORRUGATIONS ①, ② WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
300	0.5	66.0	82.5			
450	0.5	44.0	55.0			
600	0.5	33.0	41.2	57.8		
750	0.5	26.4	33.0	46.2		
900	0.5	22.0	27.5	38.5	49.5	
1050	0.5	18.9	23.6	33.0	42.5	51.9
1200	0.5	16.5	20.6	28.9	37.2	45.4
1350	0.5		18.3	25.7	33.0	40.4
1500	0.5			23.1	29.7	36.4
1650	0.5			21.0	27.0	33.0
1800	0.5				24.8	30.3
1950	0.5					28.0
2100	0.5					26.0

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 84” (2100 mm), the top of the pipe should be located 0.3’ (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84” (2100 mm), and larger, the top of the pipe should be located 1.0’ (0.3 m) below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the 2⅔” x ½” (68 mm x 13 mm) and the 3” x 1” (75mm x 25mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

STRUCTURAL REQUIREMENTS FOR CSP
(Welded or Lock-Seam)
Figure 17.1C

US Customary

3” x 1” *CORRUGATIONS* ①, ②

WELDED OR LOCK-SEAM STEEL PIPE

PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
54	18	54	68	95	122	150
60	18	49	61	85	110	135
66	18	44	55	78	100	122
72	18	40	51	71	92	112
78	18	37	47	66	85	104
84	18		43	61	78	96
90	18		40	57	73	90
96	18			53	69	84
102	18			50	65	79
108	18			47	61	75
114	18				58	71
120	18				55	67

Metric

75 mm x 25 mm CORRUGATIONS ①, ②

WELDED OR LOCK-SEAM STEEL PIPE

PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	16.9	21.1	29.5	38.0	46.5
1500	0.5	15.2	19.0	26.6	34.2	41.9
1650	0.5	13.8	17.2	24.2	31.1	38.1
1800	0.5	12.6	15.8	22.2	28.5	34.9
1950	0.5	11.7	14.6	20.5	26.3	32.2
2100	0.5		13.5	19.0	24.4	29.9
2250	0.5		12.6	17.7	22.8	27.9
2400	0.5			16.6	21.4	26.2
2550	0.5			15.6	20.1	24.6
2700	0.5			14.8	19.0	23.3
2850	0.5				18.0	22.0
3000	0.5				17.1	20.9

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 84” (2100 mm), the top of the pipe should be located 0.3’ (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84” (2100 mm), and larger, the top of the pipe should be located 1.0’(0.3 m) below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the 2⅔” x ½” (68 mm x 13 mm) and 3” x 1” (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

STRUCTURAL REQUIREMENTS FOR CSP
(Welded or Lock-Seam)
Figure 17.1C

US Customary

5” x 1” *CORRUGATIONS* ① *WELDED OR LOCK-SEAM STEEL PIPE*						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
54	18	48	60	84	109	133
60	18	43	54	76	98	120
66	18	39	49	69	89	109
72	18	36	45	63	82	100
78	18	33	42	58	75	92
84	18		39	54	70	85
90	18		36	51	65	80
96	18			47	61	75
102	18			45	57	70
108	18			42	54	66
114	18				51	63
120	18				49	60

Metric

125 mm x 25 mm CORRUGATIONS ① *WELDED OR LOCK-SEAM STEEL PIPE*						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	15.0	18.8	26.3	33.9	41.4
1500	0.5	13.5	16.9	23.7	30.5	37.3
1650	0.5	12.3	15.4	21.5	27.7	33.9
1800	0.5	11.3	14.1	19.7	25.4	31.0
1950	0.5	10.4	13.0	18.2	23.4	28.7
2100	0.5		12.1	16.9	21.8	26.6
2250	0.5		11.3	15.8	20.3	24.8
2400	0.5			14.8	19.0	23.3
2550	0.5			13.9	17.9	21.9
2700	0.5			13.2	16.9	20.7
2850	0.5				16.0	19.6
3000	0.5				15.2	18.6

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 84” (2100 mm), the top of the pipe should be located 0.3’ (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84” (2100 mm), and larger, the top of the pipe should be located 1.0’ (0.3 m) below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

STRUCTURAL REQUIREMENTS FOR CSP
(Welded or Lock-Seam)
Figure 17.1C

US Customary

2⅔” x ½“ CORRUGATIONS
STEEL PIPE ARCH (ALL SEAM FABRICATIONS)

PIPE DIMENSIONS SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)①				
		MINIMUM METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
21 x 15	24	9				
28 x 20	24	10**				
35 x 24	30	7**				
42 x 29	30	7**				
49 x 33	36		7**			
57 x 38③	24			8**		
64 x 43③	24			9**		
71 x 47③	24				10**	
77 x 52③	24					10**
83 x 57③	24					10**

Metric

68 mm x 13 mm CORRUGATIONS
STEEL PIPE ARCH (ALL SEAM FABRICATIONS)

PIPE DIMENSIONS SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)①				
		MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
530 x 380	0.6	2.9				
710 x 510	0.6	3.2**				
885 x 610	0.7	2.1**			②	
1060 x 740	0.8	2.1**				
1240 x 840	0.9		2.0**			
1440 x 970③	0.6			2.6**		
1620 x 1100③	0.6			2.8**		
1800 x 1200③	0.6				3.0**	
1950 x 1320③	0.6					3.1**
2100 x 1450③	0.6					3.3**

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*
In addition, for all pipe 2 2/3” x ½” (68mm x 13mm) corrugations, the top of the pipe should be located 0.3’ (0.1m) below the surfacing subgrade.

** *Based upon a 3 ton (287 kPa) corner bearing pressure. Special foundation investigation required.*

① *Based upon a 2 ton (192 kPa) corner bearing pressure except as noted. Special foundation investigation required when higher corner bearing pressures need to be developed.*

② *Thicknesses above heavy line will not be used unless specified by the Hydraulics Section.*

③ *These sizes should not be used unless site conditions preclude the use of arches* with *3” x 1” (75 mm x 25 mm) corrugations.*

STRUCTURAL REQUIREMENTS FOR CSPA
Figure 17.1D

US Customary

3" x 1" or 5" x 1" CORRUGATIONS
STEEL PIPE ARCH (ALL SEAM FABRICATIONS)

PIPE DIMENSIONS+ SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ①				
		MINIMUM METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
53 x 41	24		8④			
60 x 46	24		9④			
66 x 51	24		9④			
73 x 55	24		11④		②	
81 x 59	24		11④			
87 x 63	24		10④			
95 x 67	24		11④			
103 x 71	24			10		
112 x 75	24			10		
117 x 79	24			10		
128 x 83	24				9	

Metric

75 mm x 25 mm OR 125 mm x 25 mm CORRUGATIONS
STEEL PIPE ARCH (ALL SEAM FABRICATIONS)

PIPE DIMENSIONS+ SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ①				
		MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1340 x 1050	0.6		2.7④			
1520 x 1170	0.6		2.7④			
1670 x 1300	0.6		2.7④			
1850 x 1400	0.6		3.3④		②	
2050 x 1500	0.6		3.5④			
2200 x 1620	0.6		3.2④			
2400 x 1720	0.6		3.4④			
2600 x 1820	0.6			3.1		
2840 x 1920	0.6			3.2		
2970 x 2020	0.6			3.1		
3240 x 2120	0.6				2.8	

Notes:

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*
In addition, for all pipe arches less then 95" x 67" (2400mm x 1720mm), the top of the pipe should be located 0.3' (0.1m) below the surfacing subgrade. For all pipe arches less then 95" x 67" (2400mm x 1720mm), and larger, the top of the pipe should be located 1.0' (0.3m) below the surfacing subgrade.

\+ *Nominal dimensions per manufacturer/supplier's product information.*

① *Based upon a 2 ton (192 kPa) corner bearing pressure except as noted. Special foundation investigation required when higher corner bearing pressures need to be developed.*

② *Thicknesses above heavy line will not be used unless specified by the Hydraulics Section.*

④ *Specify 0.109" (2.77 mm) thickness for 5" x 1" (125 mm x 25 mm) corrugations.*

STRUCTURAL REQUIREMENTS FOR CSPA
Figure 17.1D

17.1.6 Structural Requirements for Structural Steel Plate Culverts

Normally, for culvert installations larger than 120” (3000 mm), Structural Steel Plate Pipe (SSPP) culverts will be specified. Figure 17.1E provides SSPP criteria for minimum and maximum fill heights permitted with various combinations of pipe size and metal thickness. The Hydraulics Section must specify adequate metal thickness for each installation. The dimension of SSPP will be called out in feet and inches (meters to three decimal places).

Figure 17.1F presents the structural requirements for Structural Steel Plate Pipe Arch (SSPPA) culverts.

17.1.7 Structural Requirements for Corrugated Aluminum Pipe

When Corrugated Aluminum Pipe (CAP) is specified or permitted as an option, determine the metal thickness requirements from Figure 17.1G for the particular conditions of pipe shape and height of fill.

17.1.8 Multiple Pipe Installations

To provide an adequate waterway, it may be necessary to install two or more adjacent culverts at one location. Identify these installations as a "double" or a "triple" installation at the station representing the center of the installation.

The spacing between outside faces of adjacent pipes normally will be a minimum of 4‘ (1.2 m) and a maximum of 8’ (2.4 m). If flared end terminal sections are used, specify at least 2’ (0.6 m) between the outside ends of adjacent terminal sections.

US Customary

6” x 2” CORRUGATIONS
STRUCTURAL STEEL PLATE PIPE

PIPE DIAMETER** (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ①						
		METAL THICKNESS (in)						
		0.109	0.138	0.168	0.188	0.218	0.249	0.280
60	18	47	68	90	103	124	146	160
72	18	39	57	75	86	103	122	133
84	18	34	49	64	73	88	104	114
96	18	29	43	56	64	77	91	100
108	18	26	38	50	57	69	81	88
120	18	23	34	45	51	62	73	80
132	18	21	31	40	47	56	66	72
144	18	19	28	37	43	51	61	66
156	20	18	26	34	39	47	56	61
168	24	17	24	32	36	44	52	57
180	24	15	23	30	34	41	48	53
192	24		21	28	32	38	45	50
204	28		20	26	30	36	43	47
216	28			25	28	34	40	44
228	32			23	27	32	38	42
240	32				25	31	36	40
252	32					29	34	38

Metric

152 mm x 51 mm CORRUGATIONS
STRUCTURAL STEEL PLATE PIPE

PIPE DIAMETER** (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ①						
		METAL THICKNESS (mm)						
		2.82	3.56	4.32	4.79	5.54	6.32	7.11
1.500	0.5	14.6	21.0	27.5	31.5	38.0	44.7	48.8
1.810	0.5	12.1	17.5	22.9	26.3	31.6	37.3	40.7
2.120	0.5	10.4	15.0	19.6	22.5	27.1	32.0	34.9
2.430	0.5	9.1	13.1	17.2	19.7	23.7	28.0	30.5
2.740	0.5	8.1	11.7	15.3	17.5	21.1	24.9	27.1
3.050	0.5	7.3	10.5	13.7	15.8	19.0	22.4	24.4
3.360	0.5	6.6	9.6	12.5	14.3	17.3	20.3	22.2
3.670	0.5	6.1	8.8	11.4	13.1	15.8	18.6	20.3
3.980	0.5	5.6	8.1	10.6	12.1	14.6	17.2	18.8
4.290	0.6	5.2	7.5	9.8	11.3	13.6	16.0	17.4
4.600	0.6	4.9	7.0	9.2	10.5	12.7	14.9	16.3
4.910	0.7		6.6	8.6	9.8	11.9	14.0	15.3
5.220	0.7		6.2	8.1	9.3	11.2	13.2	14.4
5.530	0.7			7.6	8.8	10.5	12.4	13.6
5.840	0.8			7.2	8.3	10.0	11.8	12.8
6.150	0.8				7.9	9.5	11.2	12.2
6.460	0.8					9.0	10.7	11.6

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 84” (2.120 m), the top of the pipe should be located 0.3’ (0.1 m) below the surfacing subgrade. For all pipes 84” (2.120 m), and larger, the top of the pipe should be located 1.0’ (0.3 m) below the surfacing subgrade.

** *Nominal diameters per manufacturers’/suppliers’ product information.*

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

STRUCTURAL REQUIREMENTS FOR SSPP

Figure 17.1E

US Customary

SSPPA,6” x 2” *CORRUGATIONS*
18” *CORNER RADIUS*①

PIPE DIMENSIONS ② SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ③				
		MINIMUM METAL THICKNESS (in)				
		0.109				
6’-1” x 4’-7”	24	16				
6’-4” x 4’-9”	24	15				
7’-0” x 5’-1”	24	14				
7’-3” x 5’-3”	24	13				
7’-8” x 5’-5”	24	13				
8’-2” x 5’-9”	30	12				
8’-10” x 6’-1”	30	11				
9’-9” x 6’-7”	30	10				
10’-8” x 6’-11”	30	9				
10’-11” x 7’-1”	30	9				
11’-10” x 7’-7”	36	7				
12’-8” x 8’-1”	36	6				
12’-10” x 8’-4”	48	6				
13’-5” x 8’-5”	48	5				

Metric

SSPPA, 152 mm x 51 mm CORRUGATIONS
*457-mm CORNER RADIUS*①

PIPE DIMENSIONS ② SPAN x RISE (m)	MINIMUM FILL HEIGHT* (,m)	MAXIMUM FILL HEIGHT (m) ③				
		MINIMUM METAL THICKNESS (mm)				
		2.82				
1.850 x 1.400	0.6	5.0				
1.930 x 1.450	0.6	4.8				
2.130 x 1.550	0.6	4.4				
2.210 x 1.600	0.6	4.2				
2.340 x 1.650	0.6	4.0				
2.490 x 1.750	0.8	3.7				
2.690 x 1.850	0.8	3.5				
2.970 x 2.010	0.8	3.1				
3.250 x 2.110	0.8	2.9				
3.330 x 2.160	1.0	2.8				
3.610 x 2.310	1.0	2.1				
3.860 x 2.460	1.0	1.8				
3.910 x 2.540	1.3	1.8				
4.090 x 2.570	1.3	1.5				

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. For all SSPPA pipes, the top of the pipe should be located 1.0’ (0.3 m) below the surfacing subgrade.*

Notes:

① *These sizes should not be specified unless site conditions preclude the use of CSPA or SSPPA with 31” (787 mm) corner radii.*

② *Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.*

③ *Based upon a 2 ton (192 kPa) corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.*

STRUCTURAL REQUIREMENTS FOR SSPPA

Figure 17.1F

US Customary

SSPPA,6” x 2” *CORRUGATIONS* 31” *CORNER RADIUS*						
PIPE DIMENSIONS ② SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ③				
		MINIMUM METAL THICKNESS (in)				
		0.109	0.138	0.168	0.188	
13'-6" x 9'-6"	30	12				
14'-2" x 9'-10"	30	12				
15'-7" x 10'-6"	30	11				
15'-10" x 10'-8"	30		10			
17'-2" x 11'-4"	30		10			
17'-11" x 11'-8"	30			9		
18'-1" x 11'-10"	30			9		
18'-9" x 12'-2"	36			9		
19'-11" x 12'-10"	36				7	
20'-7" x 13'-2"	36				7	

Metric

SSPPA, 152 m x 51 mm CORRUGATIONS *787-mm CORNER RADIUS*						
PIPE DIMENSIONS ② SPAN x RISE (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ③				
		MINIMUM METAL THICKNESS (mm)				
		2.82	3.56	4.32	4.79	
4.110 x 2.900	0.8	3.9				
4.320 x 3.000	0.8	3.7				
4.750 x 3.200	0.8	3.4				
4.830 x 3.250	0.8		3.3			
5.230 x 3.450	0.8		3.1			
5.460 x 3.560	0.8			2.9		
5.510 x 3.610	0.8			2.9		
5.720 x 3.710	1.0			2.8		
6.070 x 3.910	1.0				2.6	
6.270 x 4.010	1.0				2.6	

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*
For all SSPPA pipes, the top of the pipe should be located 1.0’ (0.3 m) below the surfacing subgrade.

Notes:

② *Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.*

③ *Based upon a 2 ton (192 kPa) corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.*

STRUCTURAL REQUIREMENTS FOR SSPPA

Figure 17.1F

US Customary

2⅔” x ½“ CORRUGATIONS①, ②, ③

LOCK-SEAM ALUMINUM PIPE

PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.060	0.075	0.105	0.135	0.164
12	18	113	142			
18	18	75	94			
24	18	56	71	99		
30	18		56	79		
36	18		47	66	85	
42	18			56	73	
48	18			49	63	78
54	18			43	56	69
60	18				50	62
66	18					56
72	18					45

Metric

68 mm x 13 mm CORRUGATIONS①, ②, ③

LOCK-SEAM ALUMINUM PIPE

PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
300	0.5	34.4	43.3			
450	0.5	22.9	28.7			
600	0.5	17.1	21.6	30.2		
750	0.5		17.1	24.1		
900	0.5		14.3	20.1	25.9	
1050	0.5			17.1	22.3	
1200	0.5			14.9	19.2	23.8
1350	0.5			13.1	17.1	21.0
1500	0.5				15.2	18.9
1650	0.5					17.1
1800	0.5					13.7

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

For all aluminum pipes, the top of the pipe should be located 0.3’ (0.1 m) below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the 2⅔” x ½” (68 mm x 13 mm) and 3” x 1” (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

③ *Fill heights taken from manufacturers'/suppliers' product information.*

STRUCTURAL REQUIREMENTS FOR CAP
(Lock-Seam Aluminum)
Figure 17.1G

US Customary

3” x 1“ *CORRUGATIONS* ①, ②, ③

LOCK-SEAM ALUMINUM PIPE

PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.060	0.075	0.105	0.135	0.164
30	18	52	65	91		
36	18	43	54	76	98	
42	18	36	46	65	84	
48	18	32	40	57	73	90
54	18	28	35	50	65	80
60	18		32	45	58	72
66	18		28	41	53	65
72	18		26	37	48	59

Metric

75 mm x 25 mm CORRUGATIONS ①, ②, ③

LOCK-SEAM ALUMINUM PIPE

PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
750	0.5	15.8	19.8	27.7		
900	0.5	13.1	16.5	23.2	29.9	
1050	0.5	11.0	14.0	19.8	25.6	
1200	0.5	9.8	12.2	17.4	22.3	27.4
1350	0.5	8.5	10.7	15.2	19.8	24.4
1500	0.5		9.8	13.7	17.7	21.9
1650	0.5		8.5	12.5	16.2	19.8
1800	0.5		7.9	11.3	14.6	18.0

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

For all aluminum pipes, the top of the pipe should be located 0.3’ (0.1 m) below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the* 2⅔” x ½” (*68 mm x 13 mm) and 3” x 1” (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

③ *Fill heights taken from manufacturers'/suppliers' product information.*

STRUCTURAL REQUIREMENTS FOR CAP
(Lock-Seam Aluminum)
Figure 17.1G

17.1.9 Culvert End Treatments

Consideration should be given to special treatments required for the ends of culvert installations. Specific detailed drawings and criteria for their application are presented below.

The end treatments discussed in Section 17.1.9 apply to both single and multiple-pipe installations. See the *MDT Detailed Drawings* for the standard end treatments.

17.1.9.1 Reinforced Concrete Pipe

Where fill slopes are 2:1 or steeper, concrete culverts less than 60” (1500 mm) in diameter will have no special end treatment (square ends) and will extend 2’ (0.5 m) beyond the toe of the fill slope. For pipes ≥ 60” (1500 mm), RCP terminal sections will be specified.

Where fill slopes are flatter than 2:1, RCP terminal sections will be specified for all concrete pipe.

17.1.9.2 Corrugated Metal Pipe ≤ 48” (1200 mm)

Where fill slopes are 2:1 or steeper, metal culverts 48” (1200 mm) or less in diameter will have no special end treatment (square ends) and will extend 2’ (0.5 m) beyond the toe of the fill slope.

Where fill slopes are flatter than 2:1, the following end treatment sections will be specified:

≤ 48” (1200 mm)	CMP Flared End Terminal Section (FETS)
≤ 53” S x 41” R (1340 mm x 1050 mm)	CMP Arch FETS

17.1.9.3 Corrugated Metal Pipe and Structural Plate Pipe ≥ 54” (1350 mm)

The end treatments for the types and sizes of culverts listed below apply to all fill slopes:

≥ 54” (1350 mm)	Step Bevel for CSP, SSPP and CAP
≥ 60” S x 46” R (1520 mm x 1170 mm)	Bevel on CSP Arch

≥ 6’-1” S x 4’-7” R (1.850 m x 1.400 m)	Bevel on SSPP Arch

The bevel is defined as the angle between the invert line and fill slope line.

17.1.9.4 Road Approach Culverts

Locate the entire road approach culvert including end treatment outside the clear zone where practical. FETS will be provided for all approach culverts located outside the clear zone. Where it is not practical to place approach culverts outside the clear zone, specify the 6:1 Road Approach Culvert End Treatment (RACET).

17.1.10 Roadway Orientation

The end treatments for all single concrete pipe and corrugated metal pipe installations with diameters less than 54” (1350 mm) will be installed perpendicular to the centerline of the pipe regardless of pipe skew, unless specified otherwise by the Hydraulics Section.

Concrete pipes will not be beveled or skew-beveled.

The following will apply to corrugated metal and structural plate pipe installations 54” (1350 mm) or greater in diameter:

1. Installations Perpendicular to the Roadway Centerline. Pipes will typically be designed and fabricated with the beveled ends perpendicular to the centerline of the pipe. The type of bevel will be identified on the plans (e.g., 2:1 step-bevel, 2:1 bevel, etc.).

2. Skewed Installations. The skew is defined as the angle measured left or right from a line which is perpendicular to the roadway centerline. Note: Skew-bevel or skew step-bevel end sections are cut parallel to the centerline of the roadway. The type of bevel and the amount of skew are to be identified in the Culvert Summary:

    a. Pipe skews will typically not exceed 35°.

    b. The pipe end treatment for single pipe installations will be designed as indicated below for the following skews:

0 to 15°	End treatment perpendicular to the centerline of pipe.

16° to 35°	When the fill height is less than 10’ (3 m), the end treatment should be skew beveled.
16° to 35°	When the fill height is greater than 10’ (3 m), the end treatment should be perpendicular to the centerline of the pipe and the fill warped to the pipe ends.

c. Multiple pipe installations will utilize the same end treatment as single pipe installations except that, for skews from 16° to 35°, the end treatment will be skew beveled regardless of fill height.

d. If it is determined necessary to skew-bevel a pipe end, provide concrete edge protection and cutoff walls on both ends.

e. If temporary bracing of skew-beveled pipe ends is required, it must be addressed by special provision.

f. Consider channel changes to limit pipe skew where appropriate. Environmental concerns need to be considered when using this policy.

17.1.11 Metal Pipe Culvert Extensions

The following will apply:

1. The Hydraulics Section will evaluate the remaining service life of the pipe to determine if it should be extended or replaced. This determination is generally based on the condition of the in-place culverts.

2. The length of extension includes the new end treatment section, unless the existing section will be removed and relayed. Note this in the culvert summary.

3. The road designer is responsible for determining the length of pipe extensions. The Hydraulics Section may recommend new end treatments on a case-by-case basis.

4. If the existing pipe is a metric size, the diameter will be converted to US Customary units and rounded to the nearest inch (e.g. 600mm = 24”). The pipe extensions will be called out using the available US Customary size for the pipe. When the material or configuration of the existing pipe cannot be matched, a concrete collar will be needed to connect the extension to the existing pipe. Metal bands can be used to connect CSP to SSPP where the connection is beyond the edge of the surfacing section. This will require a special detail.

5. Fill height for pipe extensions will be measured at the point of connection to the existing pipe unless otherwise specified.

17.1.12 RCP Culvert Extensions

The required minimum length of extension for concrete culverts is as follows:

1. Diameter ≤ 30” (750 mm): 10’ (3 m), including 4’ (1.0 m) of new pipe and a 6’ (2.0 m) standard terminal section.
2. 30” (750 mm) < Diameter ≤ 72” (1800 mm): 12’ (3.5m), including 4’ (1.0 m) of new pipe and a 8’ (2.5 m) standard terminal section.
3. Diameter > 72” (1800 mm): Contact the Hydraulics Section
4. If extension of the barrel is not required, a FETS can be added without any additional length of pipe.
5. Fill height for pipe extensions should be measured at the point of connection to the existing pipe.

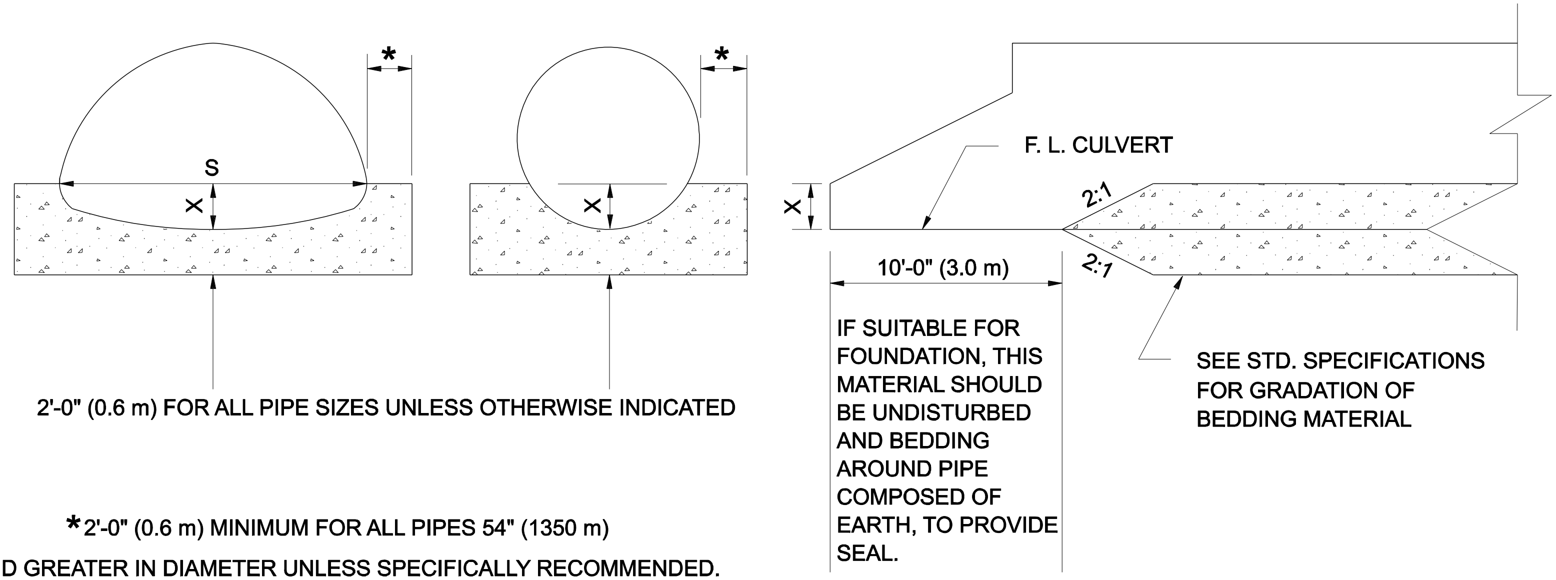
17.1.13 Culvert Bedding

Use the *MDT Detailed Drawings* and Figure 17.1H to specify culvert bedding.

For most ordinary culvert installations less than or equal to 48” (1200 mm) in diameter, it will not be necessary to include bedding quantities in the plans unless specifically recommended by the Hydraulics or Geotechnical Section.

For all culvert installations of 54” (1350 mm) in diameter and larger (and equivalent size arch culverts — 64“ x 43” (1620 mm x 1100 mm) for 2⅔“ x ½” (68 mm x 13 mm) corrugations and 60“ x 46“ (1520 mm x 1170 mm) for 3“ x 1” (75 mm x 25 mm) corrugations), specify bedding materials and quantities in accordance with the *MDT Detailed Drawings*.

When foundation material is specified, it will be placed below the bedding material. Consult the Geotechnical Section for special foundation requirements when unusual subsurface conditions exist.



*2'-0" (0.6 m) MINIMUM FOR ALL PIPES 54" (1350 m) AND GREATER IN DIAMETER UNLESS SPECIFICALLY RECOMMENDED.

NOTE: FOR X DISTANCE, SEE MDT DETAILED DRAWINGS.

BEDDING MATERIALS
(Culverts with D ≥ <u>54“ (1350 mm)</u>

Figure 17.1H

17.1.14 Culvert Inlet and Outlet Protection

The hydraulic characteristics of some drainage channels may require special protection for the roadway embankment at the inlets and outlets of culvert installations. Recommendations for special protection measures will be made at the time of the location survey or during subsequent field investigations. The Hydraulics Section will provide design information for special features.

If skew bevels are used, concrete edge protection is required to strengthen the top arch on the pipe inlet and outlet. Bolting should be similar to that shown in the MDT Detailed Drawings.

For pipes 48" (1200 mm) or less in diameter, it is not necessary to provide for special protection unless the Hydraulics Section provides specific recommendations to do so. For pipes of 54" (1350 mm) diameter and larger, provide the protective measures described in the *MDT Detailed Drawings* for, as applicable:

1. Cutoff walls at both ends,
2. Concrete edge protection at inlet, and/or
3. Culvert riprap at outlet.

Concrete pipe 54" (1350 mm) or larger in diameter that has standard end treatment should be provided with cutoff walls at both ends. However, concrete edge protection and culvert riprap should not be used in conjunction with the standard end treatment for concrete pipe unless specified by the Hydraulics Section.

See the *MDT Detailed Drawings* for estimated quantities for cutoff walls, edge protection and culvert riprap.

17.1.15 Riprap

The Hydraulics Section will typically design embankment protection, outlet aprons and other permanent erosion control features which require riprap. The road designer will calculate quantities and provide the necessary details. Show the riprap on the plans and cross sections and include the quantities in the appropriate summary.

The layout and quantities of riprap at bridge ends will be provided by the Bridge Bureau. It will be shown on both the plan and profile, and the quantities will be included in the appropriate summary.

With the exception of culvert riprap (i.e., edge protection), geotextile will be provided with all riprap installations unless otherwise specified.

17.2 SPECIAL DRAINAGE FACILITIES

17.2.1 Embankment Protectors

Generally, install embankment protectors, as shown in the *MDT Detail Drawings*, at the corners of bridges and on high fills to control runoff. Do not install embankment protectors for bridges having rail configurations without curb (e.g., T101 rail). Typical installations for bridges are described in the following:

1. Four-lane divided highway on tangent:
    a. Embankment protectors at the 4 outside corners.
    b. Bituminous curb at the 4 inside (median side) corners.
    c. Median drains with median inlet and cross drain or an outlet between structures with an embankment protector. Ditch blocks should be installed at the median inlet, and bituminous curbs should be designed to intercept drainage and prevent it from eroding the material at the ends of the structure wingwalls.
2. Four-lane divided highway on curve:
    a. Embankment protectors on the 2 outside corners on low side of curve.
    b. Bituminous curb at the 2 inside (median side) corners on low side of curve.
    c. Median drains same as on tangent section.
3. Two-lane or four-lane with narrow median:
    a. On tangent — embankment protectors at 4 corners.
    b. On curve — embankment protectors at 2 corners on low side of curve.

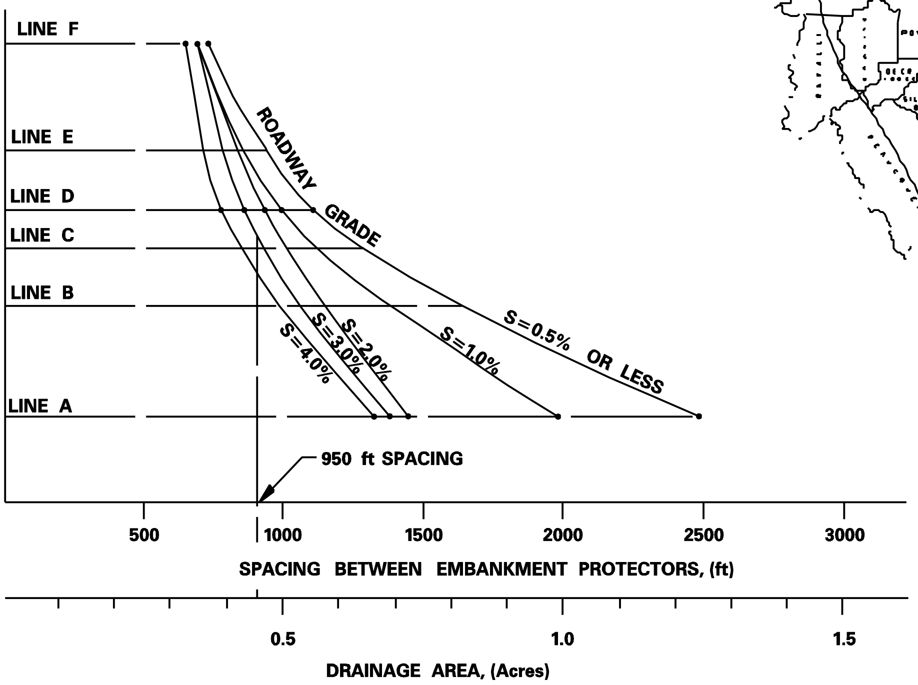
Where drainage flows toward the structure, place embankment protectors as near the structure as practical. On long, continuous sections of high fill, locate embankment protectors at intervals not exceeding the spacing shown on Figure 17.2A. Figure 17.2B prescribes appropriate spacings for median inlets. Embankment protectors must be used in conjunction with bituminous curb.

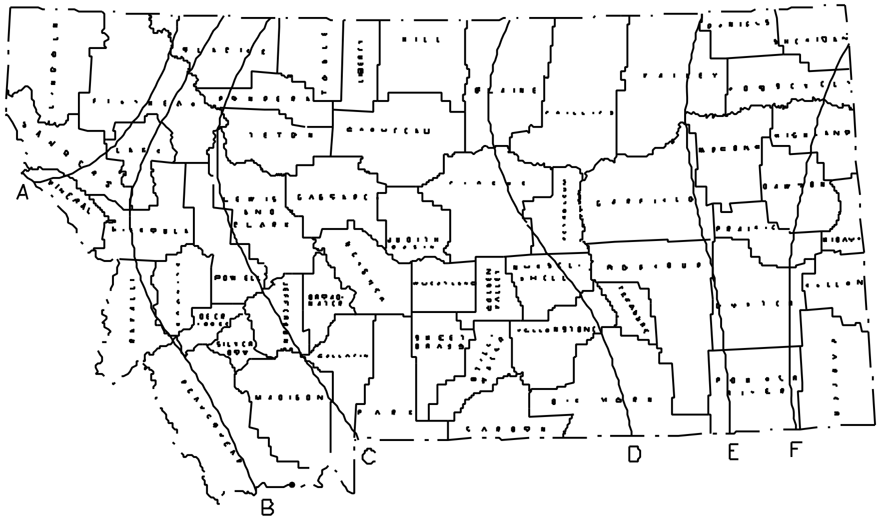
Please note that Figure 17.2A and Figure 17.2B are used for general guidance only. These figures are not to be substituted for proper engineering analysis to determine specific hydraulic requirements in unusual or site specific applications.

Example

Location: Shelby
Road Grade: 3.0%

Shelby is located between C & D
From chart, spacing= 950 ft.
This spacing will also accommodate 0.47 ac. Check the actual area.
If it is greater than 0.47 ac, the embankment protector spacing should be reduced.





Note:

Bituminous curb must be in place for this spacing criteria to apply. Spacings are for 1/2 roadway width on tangent sections. Where protectors are needed on curve sections, compute area to be drained by protector, and check the area with the area scale. If the computed area is greater than the scale reading, reduce the spacing of the embankment protectors.

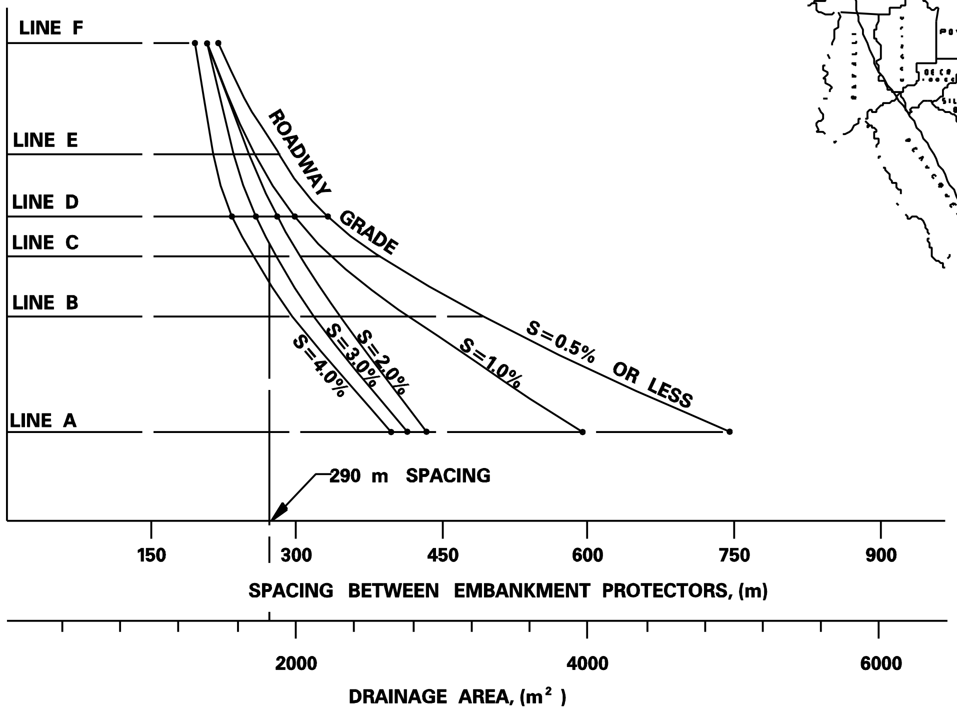
EMBANKMENT PROTECTOR SPACING

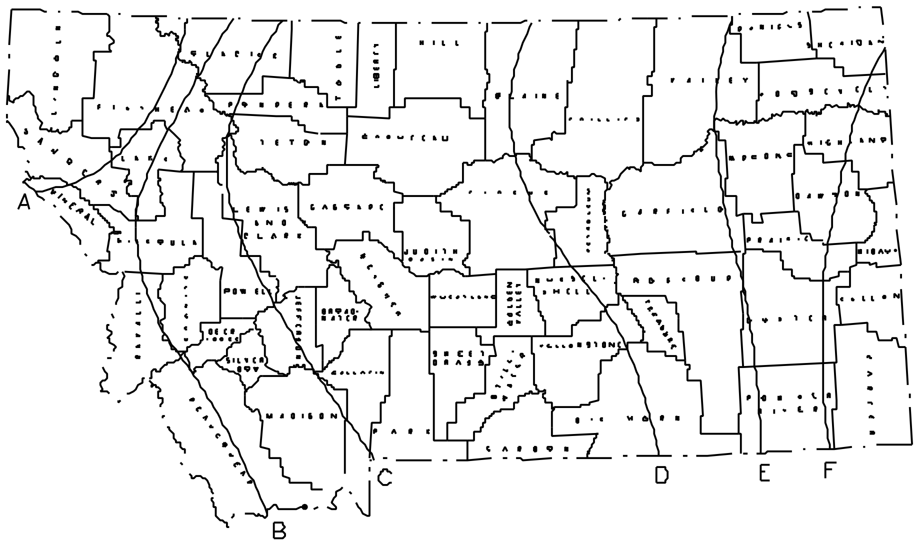
Figure 17.2A (US Customary)

Example

Location: Shelby
Road Grade: 3.0%

Shelby is located between C & D
From chart, spacing= 290 m²
This spacing will also accommodate 1900 m Check the actual area.
If it is greater than 1900 m², the embankment protector spacing
should be reduced.



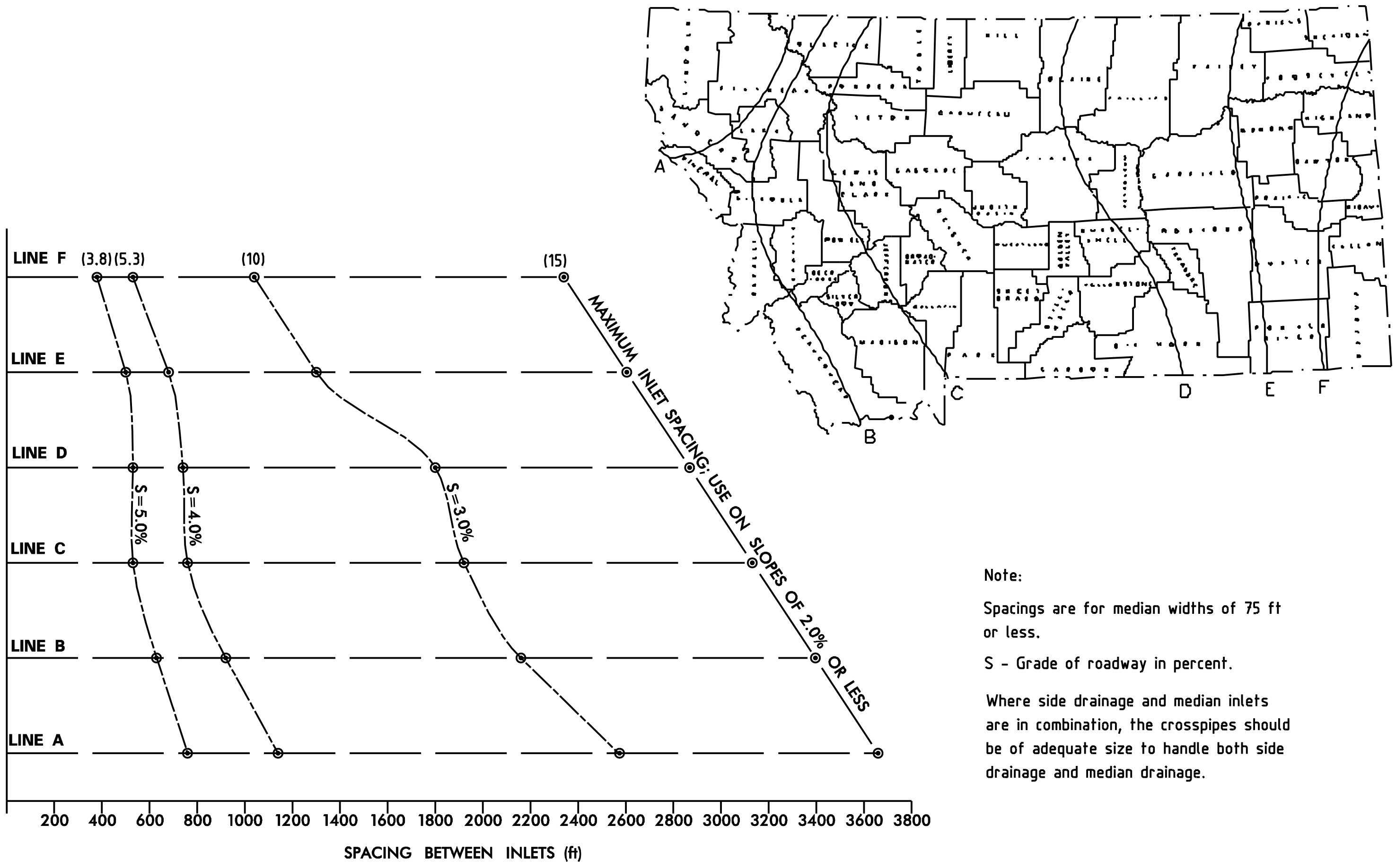


Note:

Bituminous curb must be in place for this spacing criteria to apply. Spacings are for 1/2 roadway width on tangent sections. Where protectors are needed on curve sections, compute area to be drained by protector, and check the area with the area scale. If the computed area is greater than the scale reading, reduce the spacing of the embankment protectors.

EMBANKMENT PROTECTOR SPACING

Figure 17.2A (Metric)



Note:

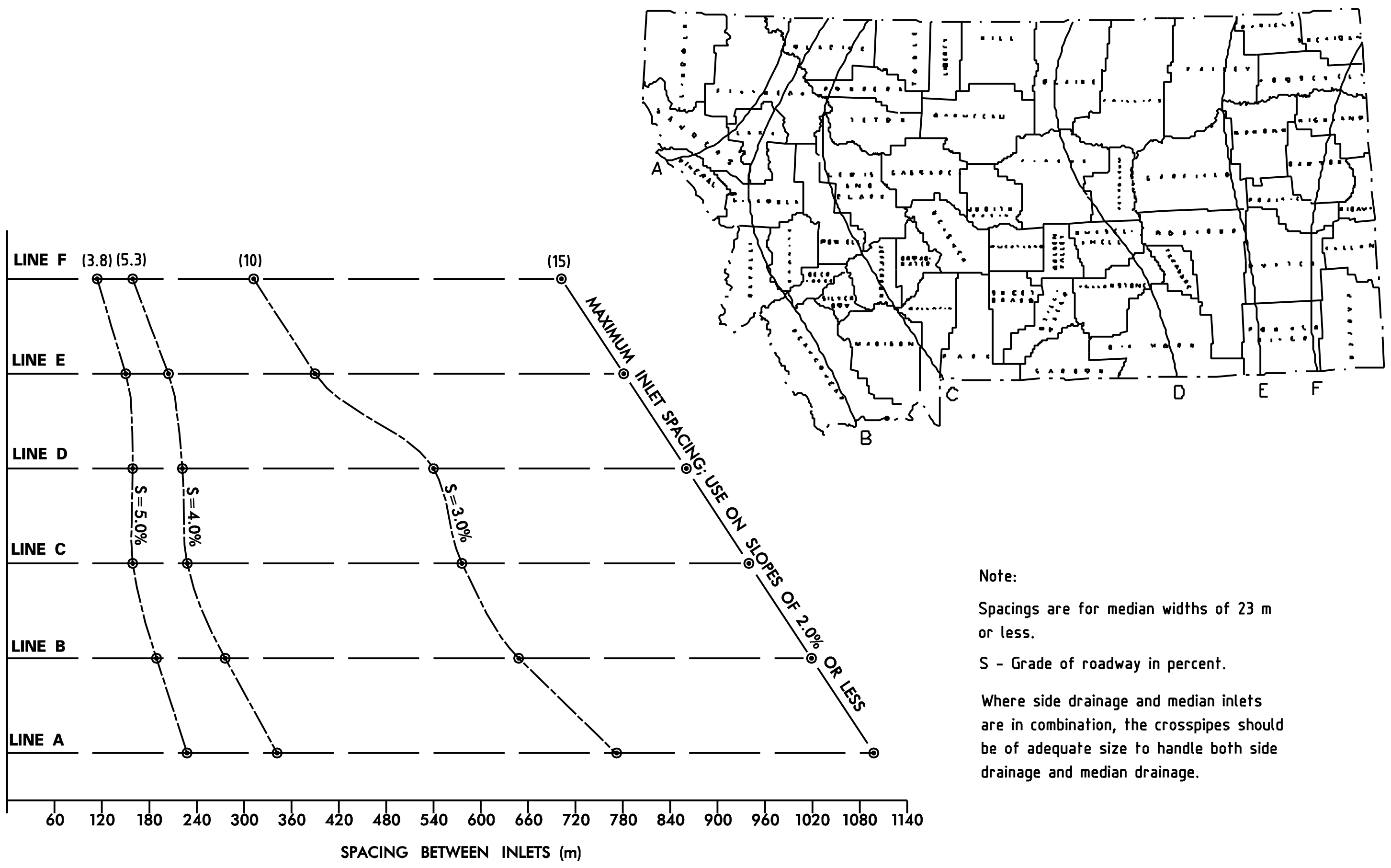
Spacings are for median widths of 75 ft or less.

S - Grade of roadway in percent.

Where side drainage and median inlets are in combination, the crosspipes should be of adequate size to handle both side drainage and median drainage.

MEDIAN INLET SPACING

Figure 17.2B (US Customary)



Note:

Spacings are for median widths of 23 m or less.

S - Grade of roadway in percent.

Where side drainage and median inlets are in combination, the crosspipes should be of adequate size to handle both side drainage and median drainage.

MEDIAN INLET SPACING

Figure 17.2B (Metric)

17.2.2 Drainage Chutes

The Concrete Drainage Chute described in the *MDT Detailed Drawings* may be used for backslope protection where the backslope intercepts a natural drainage coulee. Riprap and grouted riprap drainage chutes may be used in place of concrete.

17.2.3 Median Inlets

Three types of median inlets are available. Each type is shown in the *MDT Detailed Drawings.*

The Hydraulics Section will determine the type of inlet to be used. Specify the type clearly on the plans. Tables on the applicable *MDT Detailed Drawings* present estimated quantities of materials, but the bid item will be for the "Median Inlet Cover."

17.3 IRRIGATION FACILITIES

17.3.1 Irrigation Pipe

Irrigation facilities will require water-tight pipe. In the culvert summary and the culvert summary recap, record these pipes separately and identify them as "Irrigation" or "Siphon."

The Hydraulics Section will provide flowline and pipe invert elevations for irrigation installations. This is critical to effective operation. Minor irrigation pipes [18” (450 mm)] can be placed on the plans and cross sections by the designer without a recommendation from the Hydraulics Section. The Hydraulics Section will review these items for accuracy. If there are unusual conditions, coordinate with the Hydraulics Section to prepare clear, specific details on the plans.

Aluminum is not an option for irrigation pipe.

17.3.2 Irrigation Siphon Pipe

Some irrigation pipes will be "siphons," where the pipes are angled down under the roadway ditches with the inlet and outlet elevations higher than the roadway centerline. Siphons will be designed and the Siphon Detail Sheet will be provided by the Hydraulics Section.

17.3.3 Division Boxes

Where existing irrigation ditches are disturbed, it may be necessary to provide new division boxes. The Hydraulics Section will provide the design and details for concrete division boxes. Some types of division boxes are shown in the *MDT Detailed Drawings*.

17.3.4 Irrigation Ditch Relocations

Relocate longitudinal irrigation ditches outside of the right-of-way line. The Hydraulics Section will provide recommendations for ditch linings, if required.

To avoid irrigation ditch maintenance within the highway right-of-way, irrigation culverts of 30” (750 mm) diameter and less should be extended 24” (0.5 m) beyond the R/W line where practical. The R/W fence may be winged into the pipe ends for irrigation pipes larger than 30” (750 mm) diameter to minimize the cost of pipe extension.

17.3.5 Inlet and Outlet Headwalls

The Hydraulics Section will provide recommendations and design details for concrete headwalls. Some headwall details are included in the *MDT Detailed Drawings*.

17.4 STORM DRAINS

The detailed design of underground storm drains will be prepared by the Hydraulics Section. The design will include the size, type and location of the trunk line, manholes and drop inlets. The Hydraulics Section will also provide trench and bedding typical sections for the trunk line.

The road designer will be responsible for calculating the quantity of trunk line, trench excavation, bedding and length of lateral lines. Record all quantities for the storm drain facility in the appropriate frames. In addition, check the finished grade elevations at manholes and drop inlets and ensure that adequate cover is provided for the trunk line and laterals.

17.4.1 Storm Drain Inlets

The Hydraulics Section will recommend the types and locations. Details for storm drain inlets are provided in the *MDT Detailed Drawings*.

The road designer should check the inlet locations to determine if they are located at low points of sags. Also check the inlet locations to determine if conflicts exist with curb ramps, in-place utilities, approaches or other features.

17.4.2 Manholes

The size and location of manholes will be specified by the Hydraulics Section. The road designer should check the locations to determine if conflicts exist. Existing manholes can be adjusted up a maximum of 1’ (0.3 m) through the use of adjusting rings to match new grades.

Manholes which have been previously adjusted and manholes that require adjustments greater than 1’ (0.3 m) will require additional investigation and may result in substantial modification or replacement.

17.4.3 Bulb Out

Where bulb outs are used on urban routes with curb and gutter sections, the road designer should check bulb out locations and gutter grades to determine if the bulb outs will block the gutter flow or interfere with storm drain inlets. The Hydraulics Section will determine if existing storm drain inlets should be relocated or if new inlets or other drainage features are required to maintain roadway drainage.

17.5 UNDERDRAINS

Unusual subsurface water conditions frequently are encountered during field locations and soils surveys. Some form of underdrain will be recommended by the Geotechnical Section to alleviate such conditions.

For each underdrain, the details should clearly define the location, the type, the depth of placement and the drain aggregate and geotextile to be installed with the pipe.

The Geotechnical Section should be consulted for all sub-surface recommendations.

17.6 SPECIAL-PURPOSE LARGE CULVERTS

Large culverts frequently may be used for purposes other than to accommodate drainage. They may serve as stockpasses or vehicular underpasses with surfacing. The designer will be advised by the Right-of-Way Bureau when conditions warrant these installations. The following criteria present guidance for special-purpose large culverts.

17.6.1 Stockpasses

A standard metal pipe may be designed to serve as a stockpass by using the treatment shown in the *MDT Detailed Drawings*. It should be specified only when justified by right-of-way negotiations. The primary purpose of this structure is to serve as a stockpass. However, the majority of stockpasses also act as cross drains. Where drainage is not a consideration, the design elevation should be so as to avoid water flow. Adjacent, lower elevation culverts may also be provided for drainage when necessary. The designer should attempt to minimize stockpass length whenever practical.

The length is measured along the invert of the pipe. A right-angle crossing is preferred; however, if a skew is necessary, it should not exceed 15°.

Record stockpass culverts in a separate summary frame. Include associated paving in the additional surfacing frame.

Bedding material is required under the structure as required for CSP drain culverts.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

17.6.2 Vehicular Underpasses

Specify the circular SSPPC vehicular underpass unless directed otherwise by the Hydraulics or Geotechnical Sections. Construction and design personnel should review the installation for special construction requirements when stage construction may be specified.

Record the quantities for vehicular underpasses in a separate summary frame.

Bedding material should be specified for all large culverts.

The *MDT Detailed Drawings* show the backfill retainer and cutoff wall requirements as well as the floor surfacing criteria for the underpass. The concrete collar shown in the *MDT Detailed Drawings* will be provided for vehicular underpasses.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

17.7 ROADSIDE DRAINAGE

17.7.1 Cut sections.

Roadside ditches generally utilize a 10' (3 m) flat-bottom configuration and the grade of roadside ditches typically matches the profile grade of the roadway. However, more detailed ditch design needs to be considered for the following situations:

1. Ditches on sustained grades may carry relatively high volumes of runoff, which can result in erosion to the ditch as well as the cut-to-fill transition. When sustained grades are encountered the designer needs to consider the use of the following features:
    a. Installation of cross drains and ditch blocks to allow the runoff to outfall into a natural drainage.
    b. If no viable outfalls exist within reasonable intervals, the use of check structures to reduce the flow velocities and corresponding erosion potential must be evaluated. The designer should coordinate with the Hydraulics Section to determine spacing and type of check structures. Check structures within the clear zone should have 6:1 or flatter slopes.
    c. Some type of erosion protection should be considered at the cut-to-fill transitions (riprap chute, ditch block with embankment protector).
2. Extremely flat ditches also need additional design. Separate ditch grades need to be considered for 50' (15 m) on each side of the crest if the grades along the curve are 0.30% or less. Separate ditch grades may also be necessary on the high side of a superelevated section where the profile grade is 0.5% or less.

17.7.2 Fill Sections:

Drainage considerations in fill sections generally involve the following features:

1. The location of minimum size (24" or 600 mm) culverts is often overlooked. The road designer should review as-built plans to determine the location of existing culverts. They also need to conduct on-site reviews (A&G, PIH) to determine the location of minor natural drainages. When a project involves modification to the existing vertical alignment, the designer must also review the new profile grade to

ensure that cross drains are provided in low spots where water would otherwise be trapped.

2. Many older sections of roadway were constructed using side borrow which resulted in substantial road-side ditches adjacent to the roadway embankment. New wider templates often fill these ditches leaving no clear drainage path and often pushing runoff onto adjacent landowners.

   Designers should review these areas to determine if additional cross drains will alleviate the problem. Construction of a drain ditch at the toe of fill may be needed to convey runoff to a natural drainage.

Drainage in the roadside ditch is sometimes complicated by landowners who use the roadside ditch to carry irrigation wastewater. Although we prefer to have irrigation wastewater ditches, like all irrigation facilities constructed outside of the highway right-of-way, perpetuation of irrigation wastewater in the roadside ditch should be evaluated on a case-by-case basis. Whenever the roadside ditch is used for any irrigation purpose the designer should coordinate with the Hydraulics Section.

17.8 CULVERT EXCAVATION AND TRENCH EXCAVATION

Culvert excavation and trench excavation are not measured for payment. The quantities of culvert and trench excavation are shown for informational purposes. The costs of culvert and trench excavation are included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert removal, culvert bedding and special foundations is included in the unit prices bid for those items. The process for calculating culvert excavation and trench excavation is shown in Section 5.3

October 18, 2016

*MONTANA DEPARTMENT OF
TRANSPORTATION*

ROAD DESIGN MANUAL

Chapter Eighteen

SPECIAL DESIGN ELEMENTS

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Chapter Eighteen
SPECIAL DESIGN ELEMENTS

The designer must address numerous design elements which are not directly related to the geometric design of the roadway. Chapter Eighteen provides a discussion on these design elements including disabled accessibility requirements, bikeways, fencing, rest areas, temporary weigh stations, mail boxes, hazardous materials, cattle guards, retaining walls, bus stops/turn outs, snow fences, and railroads.

18.1 ACCESSIBILITY FOR DISABLED INDIVIDUALS

Many highway elements can affect the accessibility and mobility of disabled individuals. These include sidewalks, parking lots, buildings at transportation facilities, overpasses and underpasses. The Department's accessibility criteria comply with the 1990 *Americans with Disabilities Act* (ADA). The following sections present accessibility criteria which are based on information presented in the *ADA Accessibility Guidelines for Buildings and Facilities* (ADA Guidelines). Designers are required to meet the criteria presented in the following sections. Where other agencies or local codes require standards which exceed the ADA Guidelines, then the stricter criteria may be required. This will be determined on a case-by-case basis.

18.1.1 ADA Implementation

When implementing ADA criteria on highway projects, the designer should consider the following:

1. New Construction. ADA compliance will be measured against the new construction criteria in Section 18.1 and *ADA Guidelines*. For most projects, the designer will have the flexibility in the design to implement the new ADA construction criteria.

2. Alterations. Planned additions or alterations to existing facilities must be accomplished so that the altered facility will be accessible to and usable by persons with disabilities to the maximum extent feasible. Where existing conditions permit, new ADA construction criteria must be implemented. Also note that any element that can be made accessible should be (e.g., curb ramps), even if the facility as a whole cannot be made fully accessible. Changes that affect existing pedestrian facilities should include adjacent work as necessary to ensure that grades, finishes, and surfaces will meet or match those of the alterations.

3. Existing. For elements in existing right-of-way not otherwise being altered, the decision to upgrade individual accessibility elements will be determined on a case-by-case basis. If it is not practical to fully meet the *ADA Guidelines* criteria, each feature of accessibility should be maximized within the constraints of the site conditions at that location.

4. Temporary Access. Where a continuous route cannot be provided for pedestrians during construction, an alternative route should be available. This may require temporary walkways and curb ramps to maintain access. Sidewalk barriers should be detectable by pedestrians with low vision and pedestrians who are blind.

18.1.2 Survey and Design Considerations

18.1.2.1 Survey

During the Preliminary Field Review and field survey, locate items such as signal bases, fire hydrants, signs and drainage structures. Elevations at key points will also be needed to properly construct accessible facilities. Construction permits or right-of-way agreements may be required to transition the back of the sidewalk into approaches and features adjacent to the sidewalk.

18.1.2.2 Design

The *MDT Detailed Drawings* provide typical design options. However, items such as ramp orientation, sidewalk width and ramp width need to be shown in the plans to supplement the *MDT Detailed Drawings*. Providing individual details may be necessary for unique ramp configurations, particularly where existing sidewalks are being retrofitted with ramps. These details should include ramp width, length, orientation and location in addition to elevations and in place features that may affect ramp construction.

18.1.3 Buildings

For interior accessibility criteria, the following will apply:

1. New. All new buildings, airport terminals, rest areas, weigh stations and transit stations (e.g., stations for intercity bus, intercity rail, high-speed rail and other fixed guideway systems) shall meet the accessibility criteria set forth in the *ADA Guidelines*. The designer should review the *ADA Guidelines* to determine the

appropriate accessibility requirements for building interiors, including rest rooms, drinking fountains, elevators, telephones, etc.

2. Existing. In general, for alterations made to existing buildings or facilities, the designer must meet the accessibility requirements for the alteration made to the facility, unless it is prohibitively expensive to do so. The designer should review the *ADA Guidelines* to determine the appropriate criteria and, if required, where exceptions may be allowed.

18.1.4 Bus Stops

The following accessibility criteria apply to the construction of bus stops:

1. Bus Stop Pads. New bus stop pads constructed to be used in conjunction with a lift or ramp shall meet the following criteria:
    a. Provide a firm, stable, and slip resistant surface.
    b. Provide a minimum clear length of 8’ (2.44 m) (measured from the curb or roadway edge) and minimum clear width of 5’ (1.53 m) (measured parallel to the roadway) depending on the legal or site constraints.
    c. Connect the pad to streets, sidewalks or pedestrian paths by at least one accessible route.
    d. The slope of pad parallel to the roadway must be the same as the roadway to the maximum extent practical.
    e. For drainage purposes, provide a maximum cross slope of 2% perpendicular to the roadway.
2. Bus Shelters. Where new or replaced bus shelters are provided, install or position them to permit a wheelchair user to enter from the public way and reach a location within the shelter having a minimum clear floor area of 30” (760 mm) by 48” (1220 mm). An accessible route shall be provided from the shelter to the boarding area.

18.1.5 Parking

18.1.5.1 Off-Street Parking

The following criteria apply to off-street disabled parking spaces:

1. Minimum Number. Figure 18.1A provides the criteria for the minimum number of accessible spaces. A typical disabled stall layout is shown in Figure 18.1B.

   One out of every eight accessible spaces, but not less than one, shall have an access aisle 8’ (2.44 m) wide and must be designated as van accessible.

2. Location. Parking spaces for disabled individuals and accessible passenger loading zones that serve a particular building shall be the spaces or zones closest to the nearest accessible entrance on an accessible route. In separate parking structures or lots that do not serve a particular building, locate parking spaces for disabled individuals on the shortest possible circulation route to an accessible pedestrian entrance of the parking facility. In buildings with multiple access entrances with adjacent parking, accessible parking spaces shall be dispersed and located closest to the accessible entrances.

3. Signing and Pavement Markings. Designate parking spaces for the disabled with signs with white lettering against a blue background. These signs shall bear the international symbol of access; see the *MUTCD*. The sign shall not be obscured by a vehicle parked in the space. Van-accessible spaces shall have an additional sign stating the space is "Van-Accessible" below the symbol of accessibility. Pavement markings will comply with the *MUTCD*.

4. Dimensions. The parking spaces designated for the disabled shall be at a minimum 8’ (2.44 m) wide and desirably 9’ (2.75 m) wide with an additional 5’ (1.53 m) minimum access aisle or 8’ (2.44 m) next to van-accessible spaces, or the space should be parallel to a sidewalk on a public highway (see Figure 18.1B). Parking access aisles shall be part of an accessible route to the building or facility entrance. Parked vehicular overhangs shall not reduce the clear width of an accessible circulation route. Parking spaces and access aisles shall be level with surface slopes not exceeding 2% in all directions.

5. Parking Garages. Any parking garage or terminal should have a 9.5’ (2.90 m) vertical clearance at its entrance, exit, and along the route to and from at least two parking spaces which have a 9.5’ (2.90 m) vertical clearance. Note that the parking space itself may have a minimum vertical clearance of 8.17’ (2.49 m).

Total No. of Parking Spaces	Minimum Number of Accessible Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2% of total
1001 and over	20 plus 1 for each 100 over 1000

Notes:

a. *If one or more passenger loading zones are provided, then at least one passenger loading zone shall comply with Item # 6 in Section 18.1.5.1.*

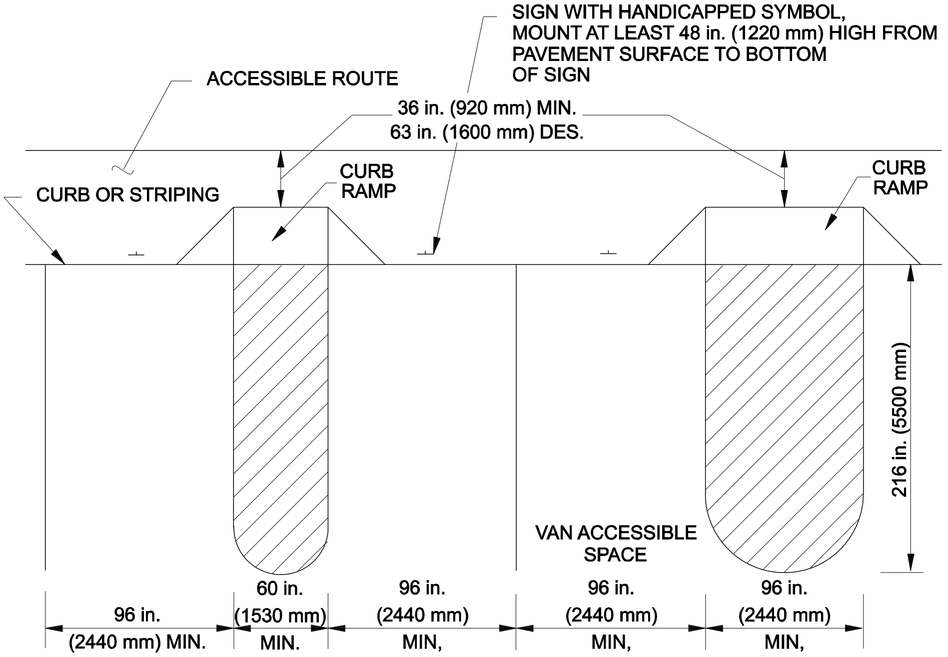
b. *Parking spaces for side-lift vans are accessible parking spaces and may be used to meet the requirements of this Section.*

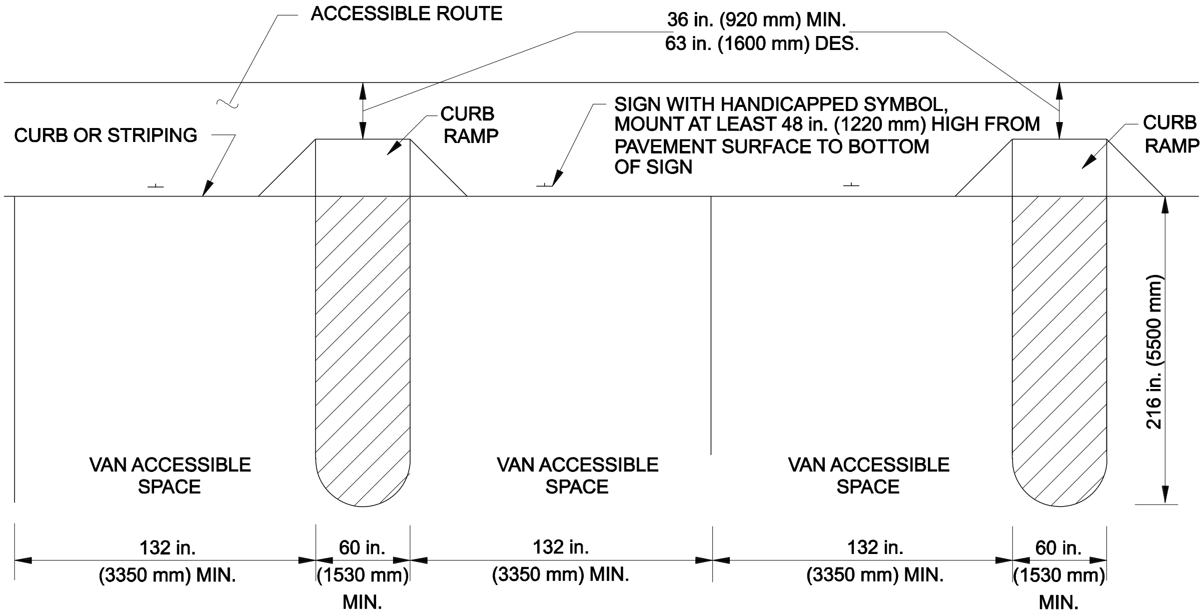
c. *The total number of accessible parking spaces may be distributed among closely spaced parking lots, if greater accessibility is achieved.*

d. *At least one of every eight spaces, but not less than one shall be van accessible.*

MINIMUM NUMBER OF ACCESSIBLE SPACES FOR DISABLED USERS

Figure 18.1A





Notes:

1. *All dimensions are in both in/ft and mm.*
2. *Two accessible parking spaces may share a common access aisle.*

DISABLED PARKING STALL DIMENSIONS
(Off-Street Parking)

Figure 18.1B

6. Passenger Loading Zones. Passenger loading zones shall provide an access aisle at least 5' (1.53 m) wide and 20' (6.10 m) long adjacent and parallel to the vehicular pull-up space. If there are curbs between the access aisle and the vehicular pull-up space, provide a curb ramp complying with Section 18.1.11. Vehicular standing spaces and access aisles shall be essentially level. Surface slopes shall not exceed 2% in all directions.

18.1.5.2 On-Street Parking

Where new on-street paid or time-limited parking is provided and designated in districts zoned for business uses, the on-street parking design desirably should meet the following accessibility criteria:

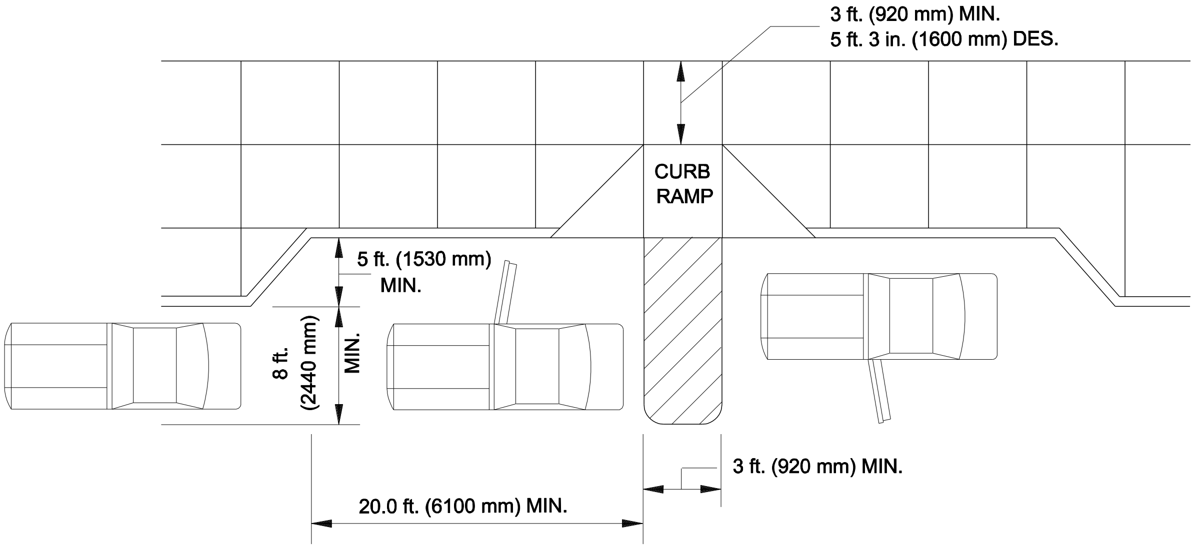
1. Minimum Number. Figure 18.1A provides the criteria for the minimum number of accessibility spaces that may also be applied to on-street parking. In general, provide one accessible space per block.

2. Location. On-street accessibility parking spaces will be dispersed throughout the project area. To the maximum extent feasible, accessible on-street parking should be located in level areas. The designer should seek input from the local governing agency early in the design process for information concerning local requirements and restrictions.

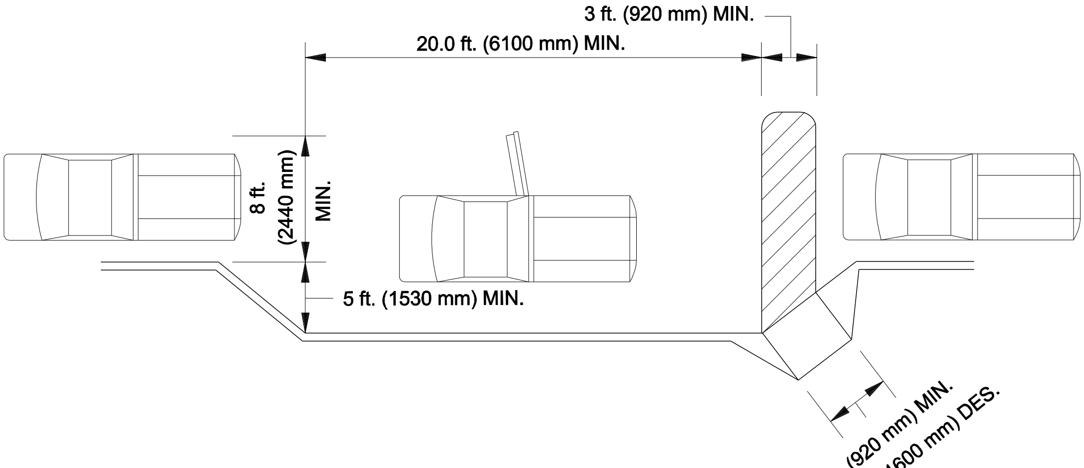
3. Dimensions. At a minimum, provide a 20' (6.10 m) parking space with a 5' (1.53 m) access aisle at the head or foot of the parking space. This is illustrated in Figure 18.1C. The traveled way shall not encroach into the access aisle.

4. Signing and Pavement Markings. Designate parking spaces for the disabled with ground-mounted signs with white lettering against a blue background. These signs shall bear the international symbol of access; see the *MUTCD*. Locate these signs so they are visible from a driver's seat. Pavement markings will conform to the *MUTCD*.

5. Curb Ramps. If there are curbs next to an on-street accessible parking space, provide a curb ramp complying with Section 18.1.11. Accessible parking spaces adjacent to intersections may be served by the sidewalk curb ramp at the intersection, provided that the path of travel from the access aisle to the curb ramp is within the pedestrian crossing area.



(a) TWO ACCESSIBLE PARALLEL PARKING SPACES IN SERIES, SEPARATED BY AN ACCESSIBLE AISLE, WITH BOTH DRIVER-SIDE AND PASSENGER-SIDE ACCESS DEMONSTRATED.



(b) SINGLE ACCESSIBLE PARALLEL PARKING SPACE WITH DRIVER-SIDE ACCESS DEMONSTRATED; PASSENGER SIDE ACCESS CAN BE PROVIDED BY PARKING IN LINE WITH STANDARD ON-STREET SPACES.

DESIRABLE DISABLED PARKING DESIGN
(On-Street Parking)

Figure 18.1C

6. Parking Meters. Where provided, parking meter controls shall be a maximum of 42” (1060 mm) above the sidewalk or pedestrian circulation path. Controls and operating mechanisms shall be operable with one hand and shall not require tight grasping, pinching or twisting of the wrist. The force required to activate controls shall be no greater than 5 lbs. (22.2 N). A firm, stable and slip-resistant area [30” (760 mm) by 48” (1220 mm)], with the least possible slope, shall be provided at the controls and shall be connected to the sidewalk by a continuous passage that is a minimum of 36” (920 mm) wide. For disabled parking stalls, the removal of parking meters, with concurrence of the local jurisdiction, is preferred.

18.1.6 Accessible Route

An accessible route is a continuous, unobstructed path connecting all accessible elements and spaces in a building, facility or site. A "site" is defined as a parcel of land bounded by a property line or a designated portion of a public right-of-way. A "facility" is defined as all or any portion of buildings, structures, site improvements, complexes, equipment, roads, walks, passageways, parking lots, or other real or personal property on a site. Interior accessible routes may include corridors, floors, ramps, elevators, lifts, and clear floor space at fixtures. Exterior accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts.

Accessible routes must be provided as follows:

1. Provide at least one accessible route within the boundary of the site from public transportation stops, accessible parking, accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve. The accessible route shall, to the maximum extent feasible, coincide with the route for the general public.

2. At least one accessible route shall connect accessible buildings, facilities, elements, and spaces that are on the same site.

3. At least one accessible route shall connect accessible buildings or facility entrances with all accessible spaces and elements and with all accessible dwelling units within the building or facility.

For highway projects, the application of the accessible route criteria applies to rest areas, recreational areas, park-and-ride lots, sidewalks next to public roadways, etc. Section 18.1.8 provides the accessibility requirements for sidewalks.

18.1.7 Non-Accessible Route

A non-accessible route is any pedestrian facility which contains features that make it impractical to meet all the criteria for accessible routes described in Section 18.1.8.1. These features include terrain that results in steep grades on the facility and narrow sidewalks or stairs where adjacent development precludes widening or replacement with ramps. These features are typically associated with existing facilities. However, they may also affect the accessibility of routes on new construction.

18.1.8 Sidewalks

Section 11.2.7 presents the Department's warrants and design criteria for sidewalks. In addition, all sidewalks must comply with the ADA Guidelines presented in the following sections. Most sidewalks along public highways are considered to be accessible routes.

18.1.8.1 Criteria for Accessible Routes

For sidewalks on accessible routes, the following accessibility criteria shall be met:

1. Width. The minimum clear width at any isolated point along an accessible route shall be 36” (920 mm), except at doors which may have a minimum width of 32” (820 mm).

2. Passing Space. If the sidewalk has less than 5’ (1.53 m) clear width for an extended distance, then passing spaces at least 5’ (1.53 m) by 5’ (1.53 m) shall be located at reasonable intervals not to exceed 200’ (61 m). A T-intersection between two walks is an acceptable passing space. Paved driveways meeting ADA requirements also provide acceptable passing space in residential areas.

3. Surface. All sidewalk surfaces shall be stable, firm and slip resistant. The longitudinal gradient should be flush and free of abrupt changes. However, changes in level up to ¼” (6 mm) may be vertical and without edge treatment. Changes in level between ¼” (6 mm) and ½” (13 mm) shall be beveled with a slope no greater than 2:1. Changes greater than ½” (13 mm) shall be accommodated with a ramp; see Section 18.1.10.

4. Drainage. Gratings should not be placed within the walking surface. If, however, gratings must be located in walking surfaces, then they shall have spaces no greater than ½” (13 mm) wide in one direction. If gratings have elongated

openings, align the grate so that the long dimension is perpendicular to the dominant direction of travel.

5. Slopes. The sidewalk cross slope, including where laydown curb is provided for public and private approaches, shall not exceed 2%. If the longitudinal gradient exceeds 5%, the sidewalk must meet the accessibility criteria for ramps; see Section 18.1.10.

6. Protruding Objects. Objects projecting from walls (e.g., signs, telephones, canopies) with their leading edges between 27” (690 mm) and 6.67’ (2.03 m) above the finished sidewalk shall not protrude more than 4” (100 mm) into any portion of the sidewalk. Freestanding objects mounted on posts or pylons may overhang their mountings up to a maximum of 12” (300 mm) when located between 27” (690 mm) and 6.67’ (2.03 m) above the sidewalk or ground surface. Protruding objects less than 27” (690 mm) or greater than 6.67’ (2.03 m) may protrude any amount provided that the effective width of the sidewalk is maintained. Where the vertical clearance is less than 6.67’ (2.03 m), provide a barrier to warn the blind or visually-impaired person.

7. Bus Stops. Where bus passenger loading areas or bus shelters are provided on or adjacent to sidewalks, they must comply with the criteria in Section 18.1.4.

8. Curb Ramps. All curb ramps on an accessible route must comply with the criteria in Section 18.1.11.

9. Driveway. All driveways on accessible routes must comply with the criteria in Section 18.1.12.

18.1.8.2 Criteria for Public Sidewalks (Non-Accessible Routes)

In general, sidewalks on non-accessible routes along public rights-of-way should meet the criteria presented in Section 18.1.8.1. However, some flexibility is required to meet the adjacent roadway conditions and to provide practical designs. The project scoping team should identify and document all non-accessible routes and facilities during the Preliminary Field Review. The criteria in Section 18.1.8.1 should be implemented, unless noted as follows:

1. Slopes. Provide the flattest longitudinal slope practical. Preferably, the longitudinal slope should not exceed 5%. For slopes greater than 5%, consider providing level landing areas at regular intervals.

2. Cross Slopes. Cross slopes greater than 2% may be used provided adjacent portions are smoothly blended. The designer should strive to achieve the flattest cross slope practical.

3. Stairs. Sidewalks with stairs are allowed on non-accessible routes, provided an unobstructed route is available between accessible entrances. Section 18.1.9 presents criteria for stairs.

4. Separation. Sidewalks adjacent to the curb or roadway may be offset to avoid a non-conforming cross slope at driveway aprons by diverting the sidewalk around the apron.

5. Protruding Objects. Even for objects on or along a sidewalk which are not fixed (e.g., newspaper vending machines, trash receptacles), the sidewalk should still meet the minimum width requirements; see Section 18.1.8.1. Fixed items (e.g., signal controller cabinets, light standards, utility poles, mailboxes, sign supports) should not be placed within the sidewalk.

18.1.9 Stairs

Stairs shall not be part of an exterior accessible route because they cannot be safely negotiated by individuals in wheelchairs. Where stairs are used, they should be designed to be accessible by other disabled individuals. Therefore, the design of stairs must comply with Section 4.9 of the *ADA Guidelines*. This includes the provision of handrails.

18.1.10 Ramps

Any part of an accessible route with a slope greater than 5% shall be considered a ramp and shall conform to the *ADA Guidelines* for the design of ramps. This includes the provision of handrails. The following criteria must be met for ramps on accessible routes:

1. Slope and Rise. The least possible slope should be used for any ramp. Figure 18.1D provides the maximum allowable ramp slopes for new construction. Curb ramps and ramps to be constructed on existing sites or in existing buildings or facilities may have slopes and rises as shown in Figure 18.1E, if space limitations prohibit the use of a 12:1 slope or less.

2. Width. The minimum clear width of a ramp shall be 36” (920 mm).

3. Landings. Ramps shall have level landings at the bottom and top of each run and shall have the following features:

Slope	Maximum Rise	Maximum Run
Steeper than 16:1 but no steeper than 12:1	30” (760 mm)	30’ (9 m)
Steeper than 20:1 but no steeper than 16:1	30" (760 mm)	40’ (12 m)

Note: A slope steeper than 12:1 is not allowed.

ALLOWABLE RAMP DIMENSIONS
(New Construction)

Figure 18.1D

Slope	Maximum Rise	Maximum Run
Steeper than 10:1 but no steeper than 8:1	3” (75 mm)	24” (600 mm)
Steeper than 12:1 but no steeper than 10:1	6” (150 mm)	60” (1 530 mm)

Note: A slope steeper than 8:1 is not allowed.

ALLOWABLE RAMP DIMENSIONS
(Existing Sites, Buildings and Facilities)

Figure 18.1E

  a. The landing shall be at least as wide as the ramp run leading to it.

  b. The landing length shall be a minimum of 5’ (1.53 m) clear.

  c. If ramps change direction at landings, the minimum landing size shall be 5’ (1.53 m) by 5’ (1.53 m).

4. <u>Handrails</u>. If a ramp run has a rise greater than 6” (150 mm) on a horizontal projection greater than 6’ (1.83 m), then it shall have handrails on both sides. Handrails are not required on curb ramps. Handrails shall have the following features:

   a. Handrails shall be provided along both sides of ramp segments. The inside handrail on switchback or dogleg ramps shall be continuous.

   b. If handrails are not continuous, they shall extend at least 12” (300 mm) beyond the top and bottom of the ramp segment and shall be parallel with the floor or ground surface.

   c. The clear space between the handrail and the wall shall be 1-½” (40 mm).

   d. Gripping surfaces shall be continuous.

   e. Top of handrail gripping surfaces shall be mounted between 34” (870 mm) and 38” (960 mm) above ramp surfaces.

   f. Ends of handrails shall be either rounded or returned smoothly to floor, wall or post.

   g. Handrails shall not rotate within their fittings.

5. <u>Cross Slope and Surfaces</u>. The cross slope of ramp surfaces shall be no greater than 2%. Ramp surfaces shall comply with the criteria for "Surface" for sidewalks; see Section 18.1.8.

6. <u>Edge Protection</u>. Ramps and landings with dropoffs shall have curbs, walls, railings or projecting surfaces that prevent people from slipping off the ramp. Curbs shall be a minimum of 2” (50 mm) high.

7. <u>Outdoor Conditions</u>. Outdoor ramps and their approaches shall be designed so that water will not accumulate on walking surfaces.

18.1.11 Curb Ramps

Curb ramps and other provisions for the disabled are required on all projects involving the provision of curbs and sidewalks at all intersections. In addition, existing curbs and sidewalks will be modified to comply with ADA requirements even if a project has no other involvement with the curb and sidewalk. Curb ramps will be constructed of concrete to visually contrast with the adjoining sidewalk. Examples of curb ramp details can be found in the *MDT Detailed Drawings*.

18.1.11.1 Location

When determining the need for a curb ramp, the designer should consider the following:

1. Intersections. For all projects, include curb ramps at all crosswalks which provide pedestrian access in that intersection. Also provide curb ramps on all corners.

2. Opposing Ramps. Always provide opposing ramps on adjacent legs of an intersection even if outside project limits.

3. Parked Vehicles. The prohibition of parking at all curb ramps needs to be considered.

4. Crosswalks. Curb ramps at marked crossings shall be wholly contained within the markings, excluding any flared sides. At intersections where there is no marked crosswalk, place the curb ramp within the area that would reasonably be expected to be used as a crosswalk.

5. Alignment. Curb ramps should be aligned with the cross walk.

6. Obstructions. The function of the curb ramp must not be compromised by other highway features (e.g., guardrail, catch basins, utility poles, signs).

7. Pedestrian Signals. The location of the curb ramp must be consistent with the operation of pedestrian-actuated traffic signals. In addition, the location of the pedestrian push-button must comply with Section 18.1.11.2.

8. Future Ramps. Curb ramps are required at all curbed intersections with sidewalks. Laydown curbs for future ramp installations are required at all curbed intersections without existing sidewalks.

18.1.11.2 Crossing Controls

If a pedestrian crosswalk and curb ramp are present at an intersection with a traffic signal that has pedestrian detectors (push buttons), the following will apply:

1. Location. Locate controls as close as practical to the curb ramp and, to the maximum extent feasible, permit operation from a level area immediately adjacent to the controls.

2. Surface. Provide a firm, stable and slip-resistant area, a minimum of 36" (920 mm) by 48" (1220 mm), to allow a forward or parallel approach to the controls.

3. Mounting Height. Place pedestrian-actuated crossing controls a maximum of 42" (1060 mm) above the sidewalk.

4. Controls. Push buttons shall be raised or flush and shall be a minimum of 2" (50 mm) in the smallest dimension. The force required to activate controls shall be no greater than 5 lbs. (22.2 N).

18.1.11.3 Types

There are two basic types of curb ramps — straight ramps, which include ramps perpendicular and parallel to the roadway, and diagonal ramps. Details for the construction of curb ramps are provided in the *MDT Detailed Drawings* and *MDT Standard Specifications*.

The following provides several suggestions for selecting the appropriate curb ramp:

1. Crosswalk Markings and Stop Bars. The placement of the crosswalk affects the placement of the curb ramps. First, determine the desired alignment of the crosswalk. Then, establish the placements of the curb ramps. Consider the following factors when establishing the location for the crosswalk and curb ramps:

    a. crosswalk visibility,
    b. size of the corner radius,
    c. right-of-way constraints,
    d. drainage,
    e. raised median ends,
    f. detector loop placement, and
    g. traffic signal pole locations.

The *MDT Detailed Drawings* and the *MUTCD* provide additional guidance for crosswalk markings and stop bars.

2. Obstructions. It is desirable to move any obstructions from curb ramps whenever practical. When this is not practical, the direction of traffic relative to the placement of the curb ramp must be considered. It is important that drivers can see pedestrians using the curb ramp.

3. Diagonal Curb Ramps. Avoid using diagonal curb ramps, especially in new construction. It is preferable to use the straight curb ramp or several straight ramps rather than to use a diagonal curb ramp.

4. Raised Medians. Where raised medians exist within a crosswalk, depress the median to the level of the crosswalk or provide curb ramps on both sides and a minimum level landing area 48' (1.22 m) long by 36" (920 mm) wide.

5. Design Restrictions. For curb ramps on non-accessible routes and where site restrictions (e.g., steeply sloped roadways, constrained right-of-way) preclude the use of a curb ramp, the designer may use one of the following designs:

    a. Where the sidewalk longitudinal slope precludes the installation of a perpendicular curb ramp, a parallel curb ramp, with its gradient measured relative to the sidewalk and street, may be used; see *MDT Detailed Drawings*. The maximum slope shall be 12:1. Provide a 5' (1.53 m) landing area at the bottom of the slope area. The cross slope of the slope area and landing area shall not exceed 2%.

    b. Where installation of a 48" (1220 mm) landing area on top of the curb ramp or other slope area is impractical, then a 36" (920 mm) landing may be provided.

    c. Another option is to lower the sidewalk to provide a shorter curb ramp distance.

    d. Where the minimum level landing areas discussed in 5a and 5b cannot be provided, the designer may provide a sloped area connecting to the street crossing with its gradients (i.e., running slope, cross slope, flare slope) measured from a plane parallel to that of the street; see *MDT Detailed Drawings*. The maximum slope shall be 12:1 and with a maximum cross slope of 2%.

18.1.12 Approaches (Driveways)

Where laydown curb rather than curb cuts are used for approaches in conjunction with sidewalks, taper the sidewalk similar to curb ramps to provide a maximum 2% slope through the approach width. Details for the tapers are provided in the *MDT Detailed Drawings*.

18.1.13 Truncated Domes

Truncated domes are a standardized detectable warning surface for sight-impaired pedestrians. The domes are installed in the sidewalk adjacent to the roadway and provide a cue that the pedestrian is moving from a pedestrian area to a vehicular area. We are required to install truncated domes on all new curb ramps and any project involving alterations to existing ramps. The truncated domes extend the width of the sidewalk and are located at the bottom of the curb ramp.

18.2 BIKEWAYS

The bicycle is classified as a vehicle according to the *Montana Codes Annotated*. Therefore, bicyclists are granted all of the rights and are subject to all of the duties applicable to the driver of any other vehicle. All State roadways can be expected to receive bicycle traffic. In rural areas, bicycling space, for the most part, will consist of a roadway shoulder. In more urban areas, bicycling space may be in the form of a shared roadway with wide curb lanes or dedicated space such as designated bicycle lanes. Separate bicycle facilities may be considered where children and casual bicyclists would be required to become involved with high traffic volume roadways. Due to pedestrian safety, sidewalks should not be considered as bicycle facilities except for child bicyclists along low-volume residential streets. This section primarily provides information on the development of new facilities to enhance and encourage safe bicycle travel.

18.2.1 Bikeway Classifications

The following bikeway definitions will apply:

1. Bikeway. Any road, path or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or will be shared with other transportation modes.

2. Widened Shoulder. Any roadway upon which a bicycle lane is not designated and which may be legally used by bicycles regardless of whether such facility is specifically designated as a bikeway.

3. Bicycle Path. A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Bicycle paths may assume different forms, as conditions warrant. They may be 2-direction, multilane facilities or, where the path would parallel a roadway with limited right-of-way, a single lane on both sides of the road.

4. Bicycle Lane. A portion of a roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists. It is distinguished from the travel portion of the roadway by a physical or symbolic barrier. Bicycle lanes may also assume varying forms but are typically included in one of the following categories:

   a. bicycle lane between parking lane and travel lane, or

b. bicycle lane between roadway edge and travel lane, where parking is prohibited.

18.2.2 Guidelines

The function of a bikeway is to provide a safe and efficient transportation facility for bicyclists without impairing the movement of other modes of travel. Well conceived and designed bikeways have a positive effect on both bicyclist and motorist behavior. Poorly conceived and designed bikeways can be counterproductive to enhancement of transportation.

On-street facilities include the bike lane, the widened curb lane and the widened shoulder. The only type of off-street facility is the bike path. A shared lane is not considered a facility type. Appropriately designed on-street facilities are usually less expensive to build and maintain than off-street facilities. Well designed off-street facilities can provide direct, non-stop connections and a safer cycling environment for a greater variety of user types.

18.2.2.1 Urban/Rural

The facility selection will typically depend on the roadway environment. The facility selection for urban and rural areas should be determined as follows:

1. Rural. The rural roadway presents a consistent situation of high-vehicular speed and relatively low traffic volumes to the bicyclist. Consequently, the bicycle facilities that should be considered for rural roadways, will typically be limited to shared roadways and may include providing wider shoulders.
2. Urban. The conditions presented to bicyclists on urban roadways may have exceeding variation from site-to-site. The following sections should be utilized to determine which facility is most appropriate.

18.2.2.2 Bicycle Paths

Bicycle paths provide the cyclist with a clear-cut route and protection from many hazardous conflicts. However, bicycle paths are typically expensive to construct. The designer should recognize that the bike path often becomes a corridor for other users (e.g., walkers, joggers).

The following guidelines may be used to justify a bicycle path:

1. high vehicular speed on adjacent roadway;
2. high vehicular traffic volume on adjacent roadway;
3. high percentage of trucks on the adjacent roadway;
4. high bicycle traffic volume;
5. substantial anticipated increase in vehicular and/or bicycle traffic volume;
6. absence of suitable alternative routes;
7. around schools, playgrounds, parks or other areas where children are expected;
8. demonstration that the facility would serve a definite purpose; and
9. reasonable indication that the bicycle path would be the safest and most economical method of providing a bicycle facility.

18.2.2.3 Bicycle Lanes

Bicycle lanes are usually preferred in urban conditions where the available area is more restricted. The occupation of a portion of a roadway by a bicycle lane implies a reasonable degree of safety for the cyclist. Conditions must be generally less severe than those which recommend a bicycle path. The use of a bicycle lane is normally restricted to bicycles, but exceptions may be made. Some sort of physical or symbolic barrier must be employed to delineate the bicycle lane from the roadway. Commonly, this is a painted stripe and symbol on the roadway surface.

The cost of installing a bicycle lane is normally a fraction of the expense associated with bicycle paths. Other advantages of bicycle lanes are the relatively minor land requirements and ease of maintenance. They can be installed in many areas where the construction of paths would be impractical. In practice, bicycle lanes may be the most practical means of developing bikeways.

The following guidelines may be used to justify a bicycle lane:

1. moderate to low vehicular speed on adjacent roadway;
2. moderate to low vehicular traffic volume on adjacent roadway

3. moderate bicycle traffic volume;
4. anticipated increase in bicycle traffic volume;
5. insufficient land to construct bicycle paths without major disruptions on the surroundings;
6. demonstration that the facility would serve a definite purpose; and
7. indication that the bicycle lane would be the safest and only feasible method of providing a bicycle facility.

Bicycle lanes should always be one-way facilities and carry traffic in the same direction as the adjacent motor vehicle traffic. If the roadway includes a parking lane, the bicycle lanes should always be placed between the parking lane and the motor vehicle lane. The minimum bicycle lane width is 4’ (1.2 m) when the lane is adjacent to the parking lane. Bicycle lanes adjacent to the curb should have a minimum width of 5’ (1.5 m).

18.2.2.4 Widened Shoulder

Widened shoulders are the most practical method of providing a bicycle facility on rural routes. Like bicycle lanes, widened shoulders can be provided at a much lower cost and can be maintained much more easily than bicycle paths. There is nothing to delineate the widened shoulder nor is its use restricted in any way.

The following guidelines may be used to justify a widened shoulder:

1. moderate bicycle traffic volume;
2. anticipated increase in bicycle traffic volume;
3. demonstration that the facility would serve a definite purpose; and
4. indication that the widened shoulder would be a safe and feasible method of providing a bicycle facility.

18.2.3 Selection

The Rail, Transit and Planning Division may determine the bikeway type and location for the bicycle facility during the planning stages. However, the Scoping Team, in conjunction with the District Office, Bicycle and Pedestrian Coordinator and local officials, will generally determine the bikeway type and location. If during the design of a project, it is determined that a bicycle facility is warranted, the designer should coordinate with the District and local officials to determine the most appropriate bikeway type.

18.2.4 Design

For design criteria of bicycle facilities, the designer is referred to the AASHTO publication *Guide for the Development of Bicycle Facilities*. The following offers a few guidelines that should be considered in the design of bicycle facilities:

1. Rumble Strips. The designer should evaluate bicycle usage to determine if rumble strips should be installed or if additional widening should be done in conjunction with rumble strip installation. Where additional shoulder widening is provided in conjunction with rumble strips, at least a 4’ (1.2 m) wide shoulder should be provided beyond the outside edge of the rumble strip.

2. Drainage Grates/Utility Covers. Drainage grates and utility covers should be kept out of the expected bicycle path wherever practical. If this cannot be accomplished, these elements should be made bicycle safe.

3. Railroad Crossings. Ideally bicycle facilities should approach at-grade railroad crossing at right angles to the rails.

4. Intersections. Bicycle lanes tend to complicate turning movements at intersections. Adequate signing and pavement markings should be provided to minimize the conflicts; see Chapter Eighteen of the *Montana Traffic Engineering Manual*.

5. Width. The desirable width of a bike lane or widened shoulder should vary with traffic volumes, percentage of trucks and running speeds on a route.

6. Geometric Design. The design of bicycle paths should address geometric issues with bicycle specific criteria. These issues are similar to the geometric issues that are addressed in the design of roads (e.g., stopping sight distance, clear zones, vertical grades, horizontal alignment).

18.3 FENCING

Fencing will be provided along rural highways to protect the driver from unexpected intrusions from outside of the right-of-way line. Requests by landowners to remove fencing will be evaluated on a case-by-case basis. Fencing prevents unauthorized and unsafe entry to the highway by vehicles, pedestrians or animals. The following sections apply to all new or rebuilt fencing with respect to highway construction projects.

18.3.1 Warrants

The need for a fence will be determined during the Alignment and Grade Review and documented in the Alignment and Grade Report. The type of fence and specific fencing issues will be resolved at the Plan-In-Hand. Continuous fencing is generally provided at the following locations:

1. along the right-of-way (R/W) line for all rural highway projects, except where it is determined to be unnecessary (e.g., absence of livestock, presence of natural barriers);

2. along all access-controlled highways;

3. near schools and residential or commercial areas to prevent children and pedestrians from entering the highway or protect them from a precipitous slope or drop off; and

4. where an agreement has been made to provide fencing between the landowner and the Department.

18.3.2 Types

The Department uses several fence types in its design. Construction details are provided in the *MDT Detailed Drawings*. The fence types used by the Department and typical applications are as follows:

1. Farm Fence. The typical farm fence is a 48" (1220 mm) tall fence with 3 to 6 barbed wire strands on wood or steel posts. This fence is commonly used along all rural non-Interstate highways. An alternative farm fence is the 48" (1220 mm) tall combination woven and barbed wire fence. Where new fencing is required, the minimum fence should be a four-strand, barbed-wire fence (Type F4). In general, use wood posts unless soil conditions, adjoining landowner preferences or other factors dictate the use of steel posts.

2. Interstate Fence. The Interstate fence is a 48” (1220 mm) tall combination woven and three-barbed wire fence on wood or steel posts. This fence is used along Interstates and other access-controlled facilities or where an agreement for its use has been made between the adjacent landowner and the Department.

3. Chain Link Fence. Chain link fencing uses steel posts embedded in concrete and may vary from 36” (915 mm) to 60” (1525 mm) tall. The chain link fence is used in place of farm fence and Interstate fence near residential areas, schools, commercial districts or other areas where pedestrians are typically present. Note that a top metal brace rail should not be used when the fence is less than 50’ (15 m) from the edge of the travel lane.

4. Temporary Fence. The contractor is typically required to provide a temporary fence at the construction site to maintain the enclosure. Selection of the fence type is typically designated in the R/W Agreement but, at minimum, should be a Type F4. The amount of temporary fence required should typically be determined by measuring the length and two times the width of the construction permit area.

5. Gates/Cattle Guards. The *MDT Detailed Drawings* illustrate the design for several gates used by the Department. The Type G2 should be specified unless otherwise noted in the R/W Agreement. Section 18.10.1 provides information on the usage and placement of cattle guards.

18.3.3 Design/Placement

The *MDT Detailed Drawings* provide the details for locating a fence at underpasses, stockpasses, steep slopes and changes in R/W widths. In addition, the designer should consider the following:

1. R/W Agreement. The R/W Agreement with the landowner will generally include the location and type of fence to be constructed, the need for a gate or cattle guard, the need to reset or to use new materials, etc. Note that, with the exception of Interstate R/W fence, the fence will become the property of the landowner and, after construction, will be responsible for its maintenance. For Interstate R/W fence, the State will retain ownership of the fence and will be responsible for its maintenance. Where an agreement cannot be reached with the landowner, the Field R/W Supervisor will make all necessary fencing determinations. In environmentally sensitive areas the designer and negotiator will coordinate with the District biologist to determine the appropriate type of fence.

2. R/W Line. The fence will follow the R/W line including all indentations and protrusions.

3. Materials. In general, the fence will be constructed of new materials, unless otherwise noted in the R/W agreement with the landowner. Existing fences should be replaced in-kind, except that the minimum replacement design will be the Type F4 barbed-wire fence. Figure 18.3A presents the criteria for where fence panels should be used. Dead men should be used to support the fence where it crosses ravines or other ground depressions.

4. Quantities. Chapter Five presents the criteria for determining project quantities for deadmen and dozer hours based on terrain. Figure 18.3A should be used to determine panel placement. For parcels where R/W agreements have not been secured when a project is submitted to the Contract Plans Section, the designer will provide an estimate of fencing quantities based on the existing fence.

5. Access-Control Facilities. Place access-control fencing along the R/W line except where noted below. Additional fencing placed outside the access-control fence will be as described in the R/W agreements. The following will apply to the placement of fencing along access-control facilities (including Interstates):

    a. Frontage Roads. Place the fence between the frontage road and the access-control facility.

    b. Stockpasses/Drainage Pipes. The fencing should tie into the ends of stockpasses or drains 60” (1500 mm) or larger in diameter and to the ends of irrigation culverts 30” (750 mm) or greater.

    c. Grade Separated Structures. The fence should tie into the grade-separated structure or may run underneath the structure.

    d. Utilities. Where utilities remain within the R/W, the fence may run between the roadway and utility to allow access from outside the R/W to the utility line.

    e. Rural Interchanges. At all rural interchanges, access-control fencing should be extended 300’ (90 m) along the crossroad from the ramp termini.

6. Stockpasses. Do not indicate the removal of stockpasses (or other large drainage pipes used by farmers for stock passages) on the plans until a copy of the signed landowner agreement permitting their removal is received by the Road Design Section. Use the *MDT Stockpass Guidelines* to determine if a new

stockpass is warranted. The Project Design Manager will coordinate the need for stockpasses with the Right-of-Way Bureau.

18.3.4 Fencing Plans

Fencing plans should be prepared on a set of full-size, white prints of the right-of-way plans. Fencing plans will be transmitted to the District Office at the time of project letting. Show the following information on the fencing plans:

1. limits of each fence type and post type,
2. locations and type of each gate, and
3. placement and type of panels (see Figures 18.3A and 18.3B).

An example of the fencing plan is shown in Figure 18.3B.

18.3.5 Snow Fences

Snow fences should be provided along portions of the roadway experiencing problems with blowing and drifting snow. Snow fences improve driver visibility and reduce the accumulation of snow and ice on the roadway. Design snow fences according to the following criteria:

1. Fences should be a minimum of 8’ (2.4 m) tall.

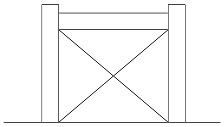
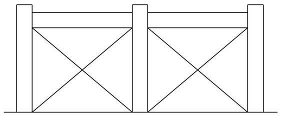
2. The snow fence should extend lengthwise 20 times the height of the fence beyond both sides of the area to be protected.

3. The distance between the fence and the shoulder of the road should be at least 35 times the height of the fence.

4. Ideally, fences should be perpendicular to the prevailing wind direction, but the angle can vary as much as 25°.

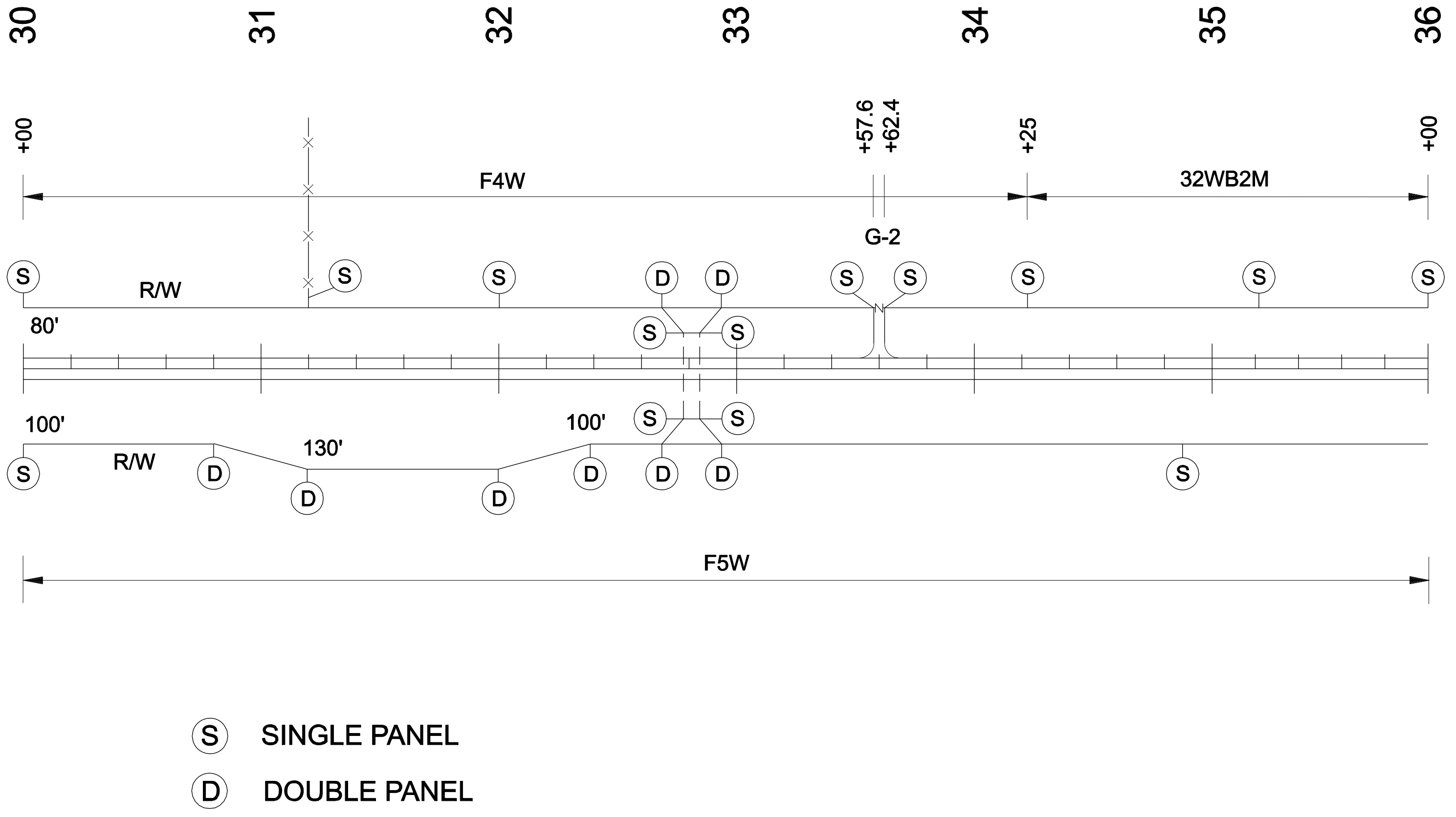
5. Fences should have a gap at the bottom equal to 10% of the height of the fence.

See the *MDT Detailed Drawings* for fence assembly.

PANEL TYPE	DESCRIPTION	APPLICATION	
		BARBED	COMBINATION WOVEN/BARBED
Single Panel	2 Posts 1 Brace Rail 2 Brace Wires 	1. Beginning or end of fence when run is 66' (20 m) – 660' (200 m). 2. Each side of gate or cattle guard when run is 66' (20 m) – 660' (200 m). 3. Runs of 66' (20 m) – 660' (200 m) for rolling or rough terrain. 4. For each intersecting side fence.	1. Beginning or end of fence when run is 33' (10 m) – 330' (100 m). 2. Each side of gate or cattle guard when run is 33' (10 m) – 330' (100 m). 3. Runs of 33' (10 m) – 330' (100 m) for rolling or rough terrain. 4. For each intersecting side fence.
Double Panel	3 Posts 2 Brace Rails 4 Brace Wires 	1. Beginning or end of fence when run is 690' (200 m)-990' (300 m). 2. Each side of gate or cattle guard when run is 660' (200 m)-990' (300 m). 3. Runs of 660' (200 m)-990' (300 m). for flat terrain. 4. All corners or change in horizontal alignment.	1. Beginning or end of fence when run is 330' (100 m)-660' (200 m). 2. Each side of gate or cattle guard when run is 330' (100 m)-660' (200 m). 3. Runs of 330' (100 m)-660' (200 m). for flat terrain. 4. All corners or change in horizontal alignment.
No Panel Required		1. Runs less than 66' (20 m).	1. Runs less than 33' (10 m).

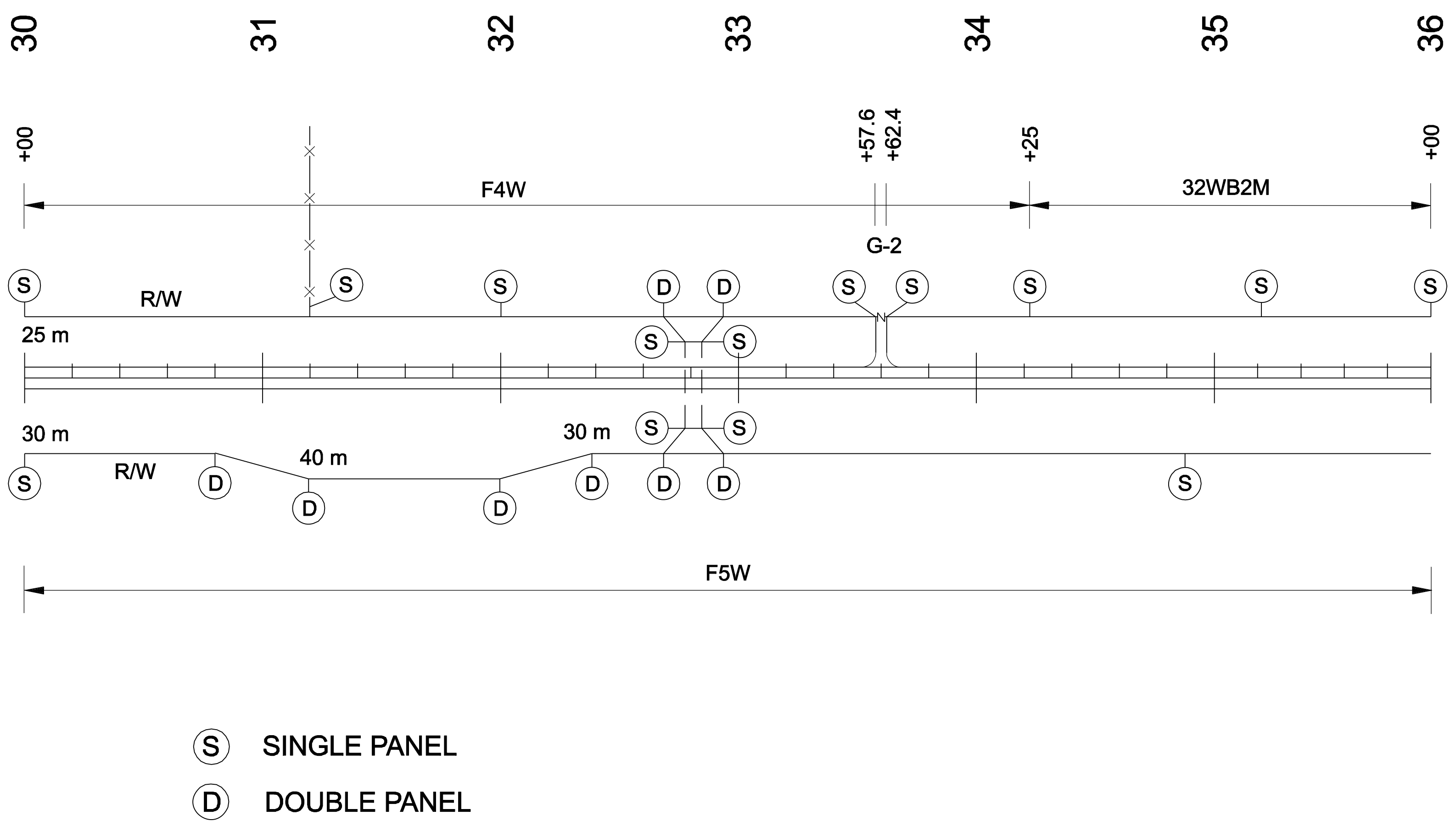
PANEL APPLICATIONS

Figure 18.3A



SAMPLE FENCING PLAN

Figure 18.3B (U.S. Customary)



SAMPLE FENCING PLAN

Figure 18.3B (Metric)

18.4 REST AREAS

Rest areas, information centers, and scenic overlooks are functional and desirable elements of the complete highway development and are provided for the safety and convenience of the highway user. Many have been constructed along freeways and other major arterials in Montana. The location and design of rest areas are based on individual highway facility and site needs. The need for a new rest area will be determined by the Rail, Transit and Planning Division in conjunction with the District Offices.

The MDT Facilities Bureau Chief will be responsible for the layout and design of all rest area structures. The Facilities Bureau Chief is also responsible for the coordination with consultants who are contracted to design rest area structures.

18.4.1 Location

Rest areas may be located on freeways or other major arterials. Along freeways, they are usually paired together (i.e., one on each side of the freeway). At the State line, only one rest area or welcome center for the incoming traffic may be provided. The Rail, Transit and Planning Division, in coordination with the Montana Rest Area Plan, will determine the general location for rest areas. The designer, in conjunction with the Districts, will be responsible for the final location of the rest area.

18.4.2 Preliminary Layout

Once it has been determined that a rest area is required and the general area has been selected, the designer is responsible for the preliminary layout. The purpose of the preliminary layout is to define the location, approximate geometrics, and determine if the proposed design is both feasible and cost effective. The following provides several site considerations the designer should review:

1. Appeal. Rest areas are show places for out-of-state visitors to Montana. If practical, locate them to take advantage of natural features (e.g., lakes, scenic views, points of special or historic interest).

2. Welcome Centers. These centers provide the opportunity to personally present information on the State of Montana and local attractions.

3. Geometrics. Locate the site away from any other interference, such as interchanges and bridges. Desirably, the rest area entrance should be at least 2 miles (3 km) from the nearest interchange.

4. Environmental. Locate and design the site so that surface runoff or treatment plant discharges will not adversely affect streams, lakes, wetlands, etc.

5. Size. The rest area should be large enough to provide sufficient parking capacity, needed facilities, picnic and stretch areas and to retain existing landscaping features.

6. Right-of-way. Factor right-of-way costs and room for future expansion into the location decision.

7. Topography. Locate rest areas where the natural topography is favorable to their development.

8. Development. Do not place rest areas adjacent to or near areas zoned residential.

9. Emergency. The location choice should consider the proximity to emergency services.

10. Water/Sewer. The area should have an adequate water supply. If commercial sanitary treatment plants are unavailable, the site must be large enough to provide for adequate sewage treatment facilities. Any proposed water/sewer facility must be designed and constructed in accordance with Department of Health and Environment Sciences regulations.

11. Additional Utilities. Other utilities, such as telephone and electricity, should be provided, if practical.

12. Other Sections. The designer will need to coordinate the design with the Traffic Engineering Section, Environmental Services and, where necessary, the FHWA.

18.4.3 Design

The following sections present criteria which should be considered in the design of the rest area.

18.4.3.1 Exits and Entrances

Access to and from rest areas along freeways will be designed by the Traffic Engineering Section. Access to rest areas along other facilities will be designed as an at-grade intersection, see Chapter Thirteen.

For more information, the designer should contact the Traffic Engineering Section.

18.4.3.2 Buffer Separation

The separation between the rest area facilities and the highway mainline should be wide enough to discourage individuals from stopping on the mainline and crossing over to the facilities. At a minimum, a 30’ (10 m) buffer area should be provided between the mainline pavement and parking areas. A buffer separation of 165’ (50 m) or more is preferable.

18.4.3.3 Rest Area Usage

Predicting the rest area usage is the key factor in determining the location and sizing of a rest area. The designer must first determine the proportion of mainline traffic that will be using the rest area. This determination is dependent upon numerous factors — rest area spacing, trip lengths, rest area locations, time of year, traffic composition, highway classification, etc. Desirably, the designer should use data from nearby and/or similar rest areas to estimate the expected traffic entering the rest area. Traffic counts can be obtained from the Rail, Transit and Planning Division. In the absence of historical data, Figure 18.4A and the following may be used:

1. <u>Design Year</u>. The typical design year for traffic projections should be 20 years.

2. <u>Highway Characteristics</u>. Rest areas on highways that pass though recreational or historic areas tend to have fewer trucks and a higher percentage of passenger cars and RV's with trailers. Where the general purpose of the highway is to move commercial traffic between cities, rest areas tend to have a higher truck usage.

3. <u>Trip Length</u>. On highways where the trip lengths are typically less than 100 mi. (160 km) (e.g., between two major cities), there is a significant reduction in the proportion of the passing traffic using the facility.

4. <u>Temporal Factors</u>. In recreational areas, rest area usage commonly is the highest during summer weekends. During the day, passenger cars tend to make

up a higher percentage of the rest area usage. At night, trucks and RV's tend to make up the higher percentage of rest area usage.

18.4.3.4 Parking

Rest area parking capacity depends upon the type of usage expected for the rest area. Figure 18.4A provides the formula and other factors to consider when determining the appropriate design hourly volume for passenger cars, recreational vehicles and trucks. Figure 18.4B illustrates a typical parking design for rest areas. Angular parking is preferred versus parallel parking because it requires less time to enter and exit. For more information on rest area parking, the designer should review the *Montana Traffic Engineering Manual* and/or contact the Traffic Engineering Section.

18.4.3.5 Pavement Design

Pavement designs for exit and entrance ramps, parking areas and connector roadways will be provided by the Pavement Management Section. All ramps and connector routes should have a 2% cross slope. Parking areas typically should be designed with a 2% cross slope; however, a 5% maximum grade may be used.

18.4.3.6 Facilities

Rest areas typically provide a building with rest rooms and public information services, picnic tables and shelters, benches, sidewalks, drinking fountains and litter receptacles. The designer should ensure that sufficient facilities are available to accommodate the expected usage of the rest area. Figure 18.4C provides the recommended number of comfort facilities that should be provided. The rest area building must meet all State and local building codes.

18.4.3.7 Utilities

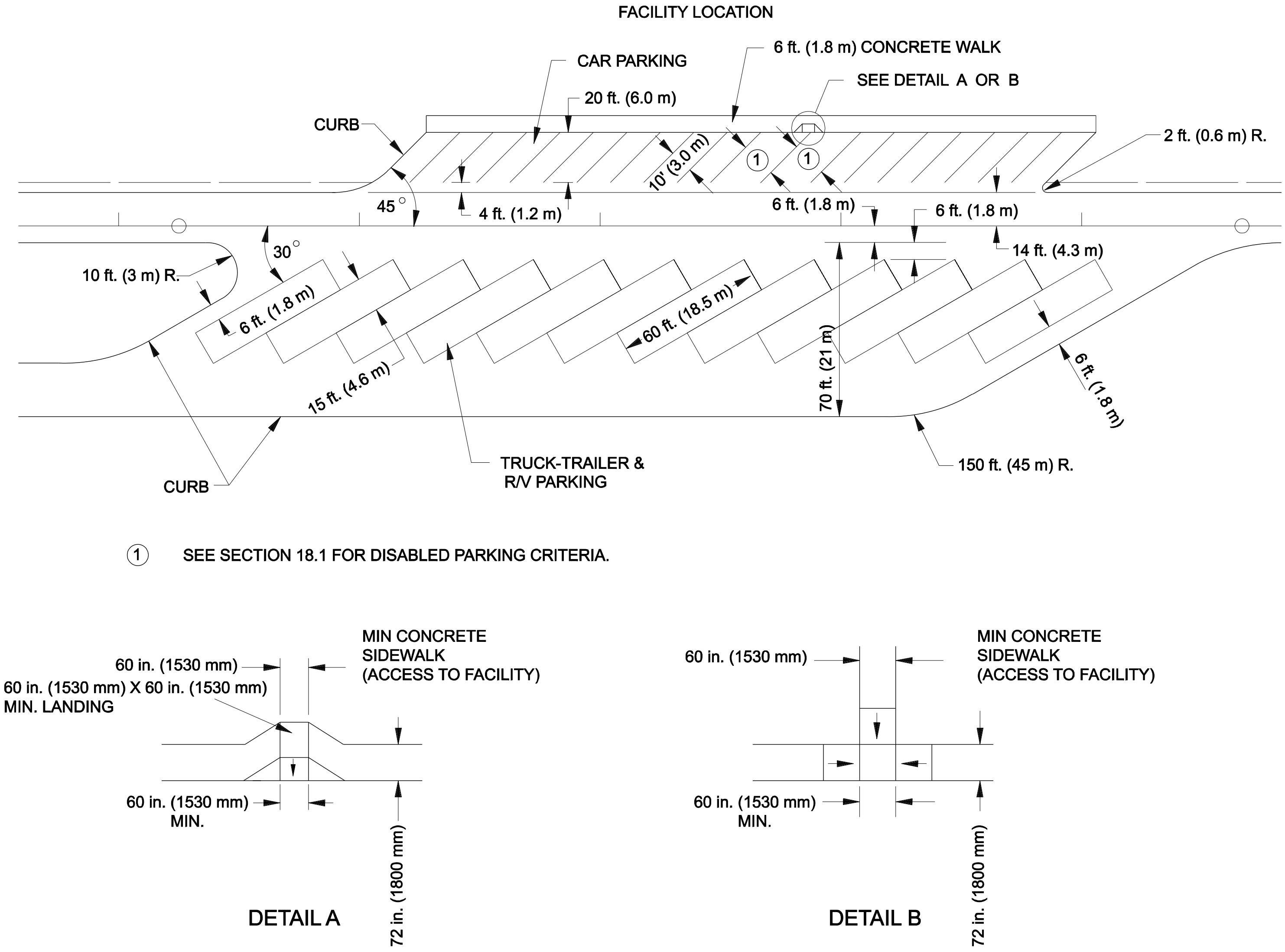
Where permanent sanitary facilities are provided, an adequate water supply, sewage disposal system and power supply will be required. Where practical, connection to existing water supplies and sewage treatment facilities is the most desirable option. The Hydraulics Section will be responsible for providing the design for an adequate water supply and sewage treatment in rest areas. The Utilities Section will be responsible for coordinating the power and telephone services at the rest area. Proper lighting provides the patron an added sense of security and safety. The Traffic Engineering Section will be responsible for the rest area lighting design.

Design Element	Factor	Cars	RV's	Trucks	Total
Mainline Traffic Data					
20 Year ADT (A)					
20 Year ADT, Directional (B)	A x 0.60				
DHV, Directional (DHV)	B x 0.135				
Mainline Traffic Composition	*(D_1)*_____Cars *(D_2)*_____RV's *(D_3)*_____Trucks	C_1=DHV x D_1	C_2=DHV x D_2	C_3=DHV x D_3	C=C_1+C_2+C_3
Vehicles Per Hour @ Rest Area (VPH)					
Cars Stopping Metropolitan Routes..................05 Normal Routes...........................09 Tourist Routes...........................13 Information & Welcome Centers 15	*(E_1)*_____Cars	VPH_1=E_1 x C_1	VPH_2=E_2 x C_2	VPH_3=E_3 x C_3	VPH=VPH_1+VP H_2+VPH_3
RV's Normal Stopping ....09 to .15	*(E_2)*_____RV's				
Trucks Normal Stopping ....09 to .15	*(E_3)*_____Trucks				
Parking Spaces					
Cars - Average Stop .25 to .33 hr. @ info. centers .... .33 to .50 hr.	(T1) Cars	P_1=VPH_1 x T_1	P_2=VPH_2 x T_2	P_3=VPH_3 x T_3	P=P_1+P_2+P_3
RV's .... .33 to .50 hr.	(T2) RV's				
Trucks .... .25 to .50 hr.	(T3) Trucks				
Facility Design (see Section 18.4.3.6)					
Persons/Hour (PH)	VPH x 3.0 occupancy x .75 use				
Number of Men	PH x 0.5				
Number of Women	PH x 0.5				
Other Facilities					
Picnic Tables.......................0.3 to 0.5	(PT)______	P x PT			
Litter Receptacles ....0.2 to 0.4	(LR)______	P x LR			
Drinking Fountains 0.1	(DF)______	P x DF			

Note to Reviewers*: The Department is to provide revisions to this figure.*

DESIGN GUIDE FOR REST AREA FACILITIES

Figure 18.4A



① SEE SECTION 18.1 FOR DISABLED PARKING CRITERIA.

SAMPLE PARKING DESIGN FOR REST AREA PARKING

Figure 18.4B

(Men) Persons/hour Using Rest Room During Design Hours	Number of Facilities - Men's Room				
				Hand Dryers	
	Urinals	Toilets	Wash Basins	Paper Towels	Air Dryers
0-105	2	2	2	2	2
106-225	3	3	4	3	4
226-315	4	4	5	4	6
316-375	5	4	5	4	7
376-435	7	4	5	5	7
436-500	9	5	7	5	8

(Women) Persons/Hour Using Rest Room During Design Hours	Number of Facilities - Women's Room			
			Hand Dryers	
	Toilets	Wash Basins	Paper Towels	Air Dryers
0-105	4	3	2	2
106-225	6	4	3	4
226-315	9	6	4	6
316-375	10	6	4	7
376-435	12	8	5	7
436-500	14	8	5	8

Note to Reviewers: *The Department is to provide revisions to this figure.*

GUIDELINES FOR COMFORT FACILITIES

Figure 18.4C

18.4.3.8 Landscaping

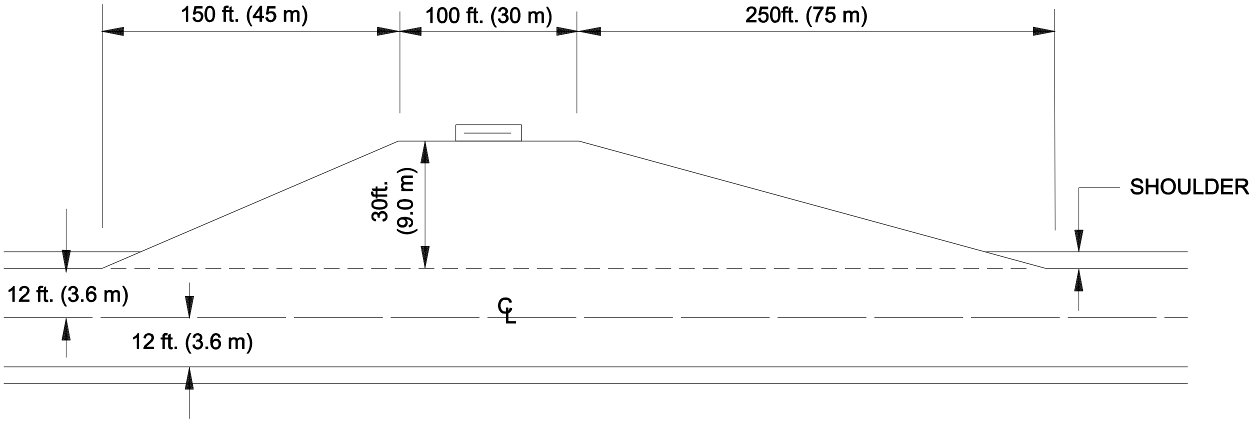
Landscape the rest area to take advantage of existing natural features and vegetation. Paths, sidewalks, and architectural style should fit naturally into the existing surroundings. Avoid deep cuts and fills. Where practical, grades should be splined to fit the natural terrain.

18.4.3.9 Accessibility for the Disabled

Design all rest areas to properly accommodate disabled individuals, including grounds, picnic areas, ramps to picnic areas, buildings, automatic door openers, sidewalk ramps and signage. The designer must realize that an accessible route is required between the truck and RV parking area to the rest area facilities. Section 18.1 provides the disabled accessibility criteria for exterior features within rest areas. The *ADA Accessibility Guidelines for Buildings and Facilities* provides the accessibility criteria for interior features.

18.4.4 <u>Historical Markers</u>

Historical markers provide visitors a chance to learn more about the history of Montana. These are common attractions on the highway system. Where historical markers are erected along the roadside, they should be placed where they will not interfere with through traffic. On Interstates, place historical markers at rest areas or on local roads near interchanges. On other facilities, historical markers may be designed as shown in Figure 18.4D. For details on the construction and erection of historical markers, the designer should contact the Traffic Engineering Section.



TYPICAL HISTORICAL MARKER TURNOUT
(2-Lane Highway)

Figure 18.4D

18.5 PORTABLE SCALE SITES

Truck weigh station installations are used to weigh trucks, to provide for vehicular safety inspection, and/or to provide a source of data for planning and research.

18.5.1 Location

Montana has adopted the portable scale concept for its weigh stations on 2-lane highways. This allows the MDT Motor Carrier Services to move the scales from site to site.

The Motor Carrier Services is responsible for the general location of portable scale sites. The designer, in conjunction with the District, is responsible for the actual selection of a site. It is desirable to select a site in a location where there is adequate right-of-way and where geometric (e.g., at the crest of a hill), topographic and environmental features lend themselves to the most economical development without undue site preparation and expense. The possibility of truck traffic circumventing the facility is also considered in locating the portable scale site.

18.5.2 Design

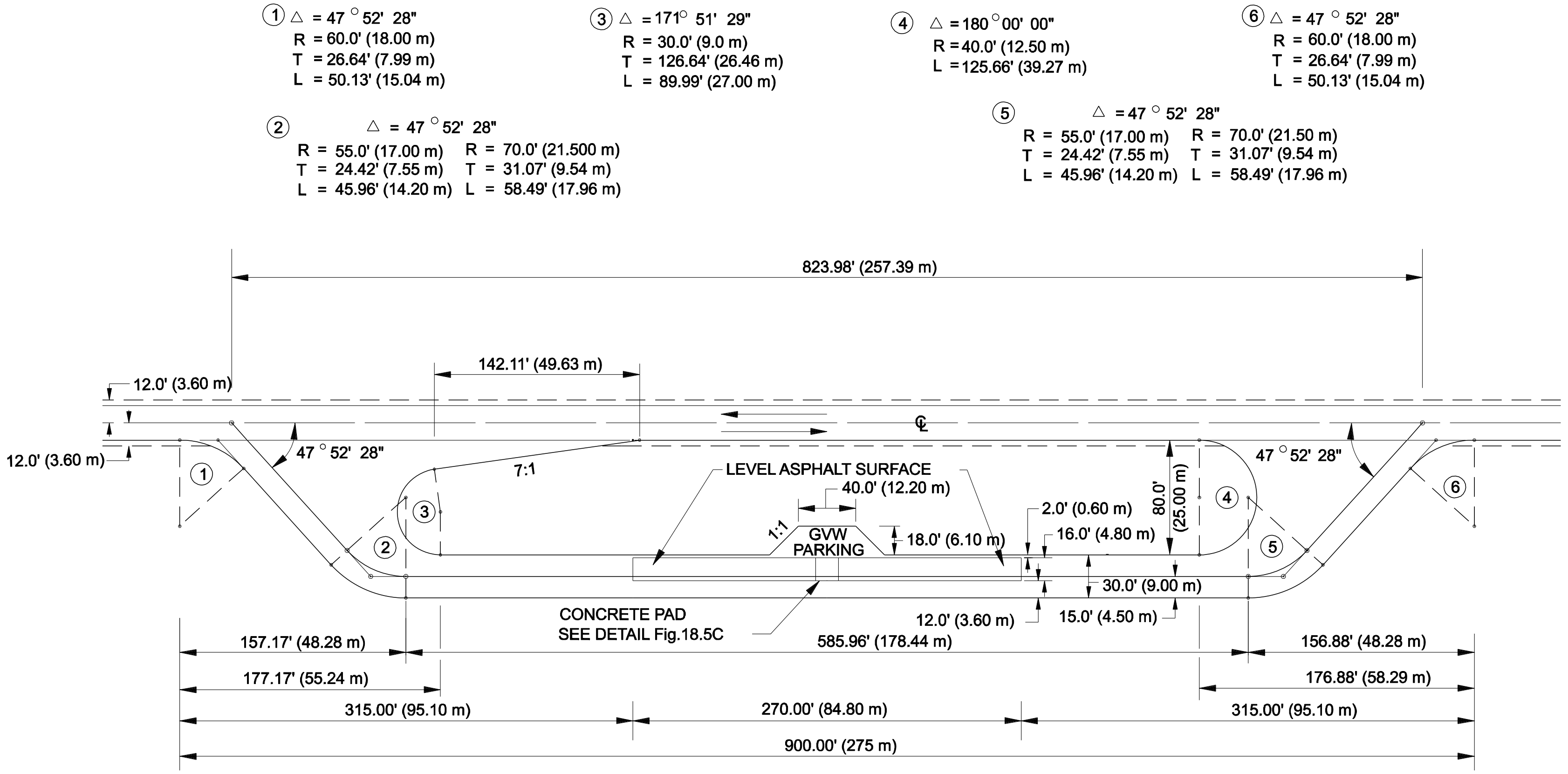
Figures 18.5A and 18.5B illustrate a Type "A" and Type "B" portable scale site design, respectively. Motor Carrier Services will be responsible for determining the appropriate Type. In addition, the designer should consider the following:

1. Exits/Entrances. Figures 18.5A and 18.5B illustrate the typical exit and entrance designs. The Traffic Engineering Section will be responsible for determining alternative exit and entrance designs.

2. Pavement Design. Pavement designs for ramps, by-pass areas and connecting roadways will be provided by the Pavement Management Section. Figure 18.5C illustrates the concrete slab design for both Type "A" and Type "B" portable scales.

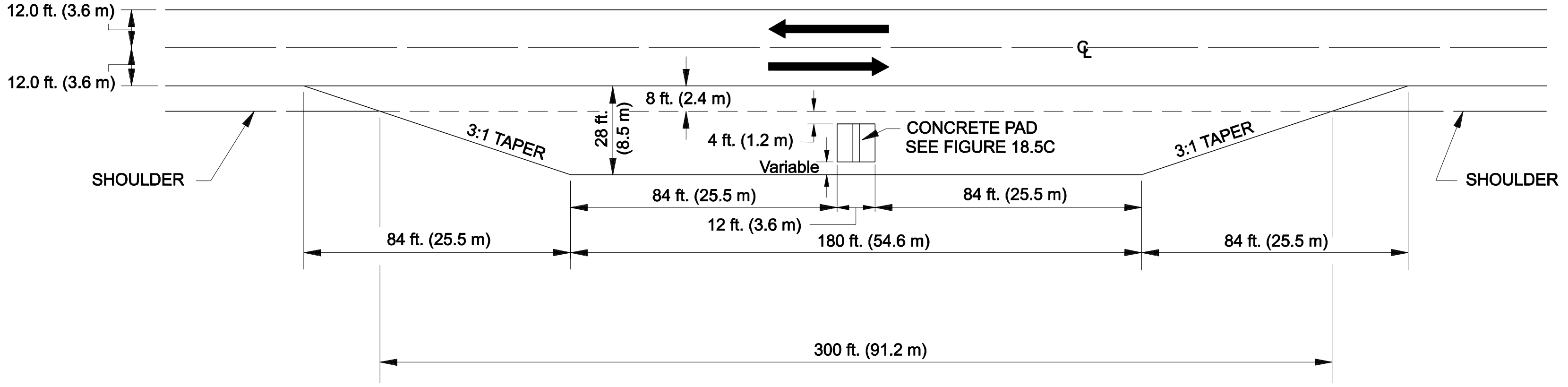
3. Geometrics. Design the scale site area so that backing maneuvers are not required (e.g., pull-through parking). Design all pavement geometrics to accommodate off tracking for the selected design vehicle.

4. Maximum Grade. Short upgrades of as much as 3%-5% do not unduly interfere with truck and bus operations. Consequently, for new construction it is desirable to limit the grade to 3%, although a maximum of 5% is allowable. Grades across the Type "A" scale must be level for 130’ (40 m) before and after the scale.



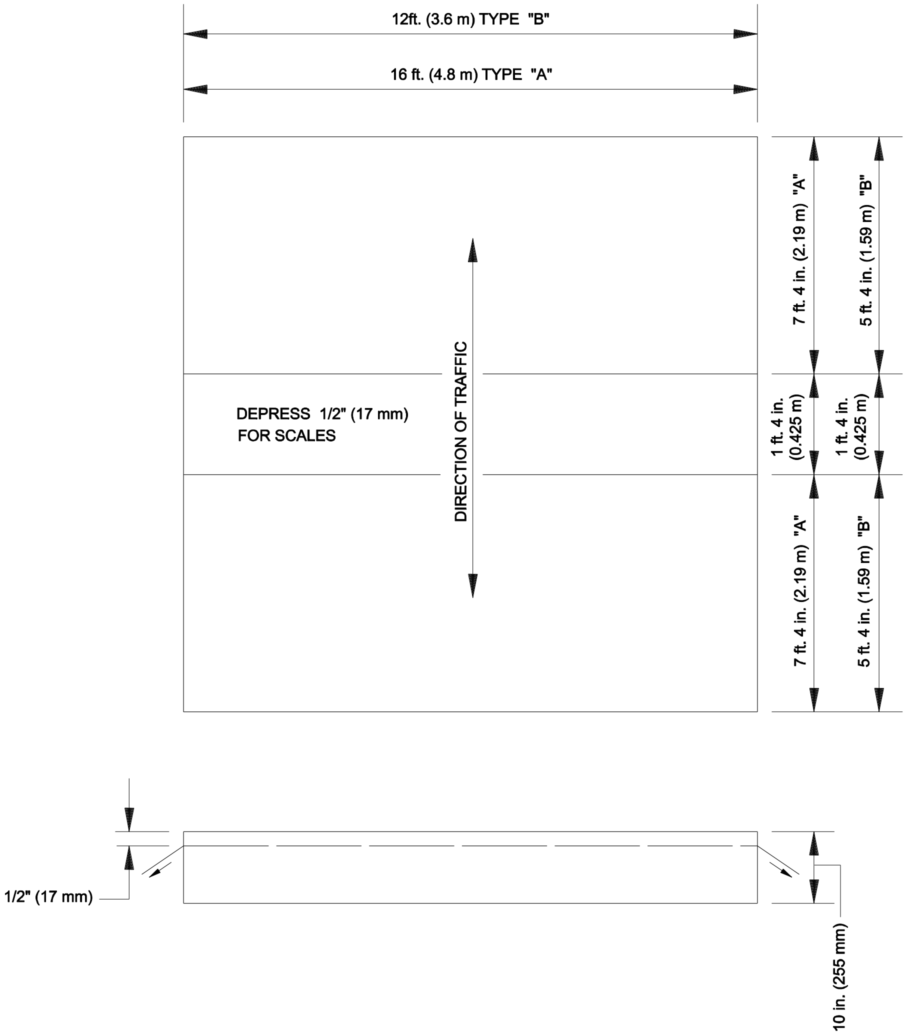
TYPICAL PORTABLE SCALE SITE
(Type "A")

Figure 18.5A



TYPICAL PORTABLE SCALE SITE
(Type "B")

Figure 18.5B



CONCRETE SLAB FOR PORTABLE SCALE SITES
(Types "A" and "B")

Figure 18.5C

5. Storage for Scales. There should be sufficient space to queue trucks waiting for the scales without backing up onto the mainline. This distance will be based on the number of trucks on the mainline, length of trucks, expected hours of operation and time required for actual weighing. The designer should check with the MDT Motor Carrier Services to determine the most appropriate time factor.

6. Traffic Control Devices. Adequate signing and pavement markings should be provided prior to and at the scale site. These traffic control devices should be designed and placed according to the *MUTCD* and the *MDT Detailed Drawings*. The designer should review the *Montana Traffic Engineering Manual* and/or contact the Traffic Engineering Section for additional details.

7. Landscaping. Design the scale site to minimize the effect on existing vegetation. The designer should also ensure that any new or existing plants will not affect the driver's sight distance to the scale site or any critical point within the scale site.

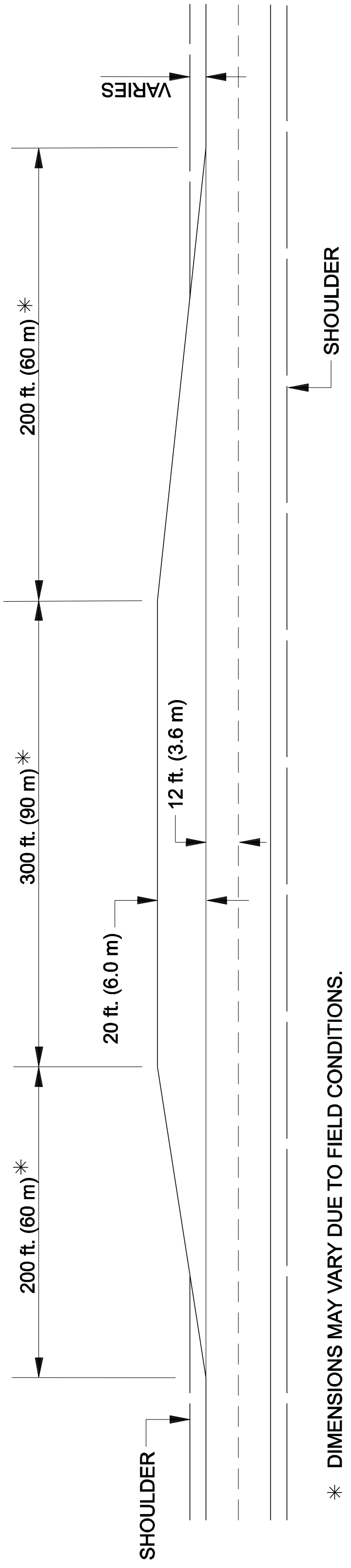
18.6 CHAIN-UP AREAS AND TRUCK TURNOUTS

Chain-up areas are used to allow trucks or vehicles to install chains in inclement weather prior to sustained upgrades. Truck turnouts allow trucks to test their brakes prior to steep downgrades. For new or reconstruction projects, chain-up areas or truck turnouts should be installed where there is a demonstrated or anticipated need. The designer should consider the following:

1. Location. Chain-up areas are located at the bases of sustained upgrades. The location of truck turnouts may depend on the amount of available right-of-way. Specific locations for both the chain-up areas and truck turnouts should be determined at the Preliminary Field Review or the Alignment Review.

2. Geometrics. The chain-up areas and the truck turnouts should be designed according to Figures 18.6A and 18.6B, respectively. Final dimensions may be dictated by site conditions; however, every attempt should be made to provide the tapers indicated. The amount of storage may vary depending on truck volumes and overall use.

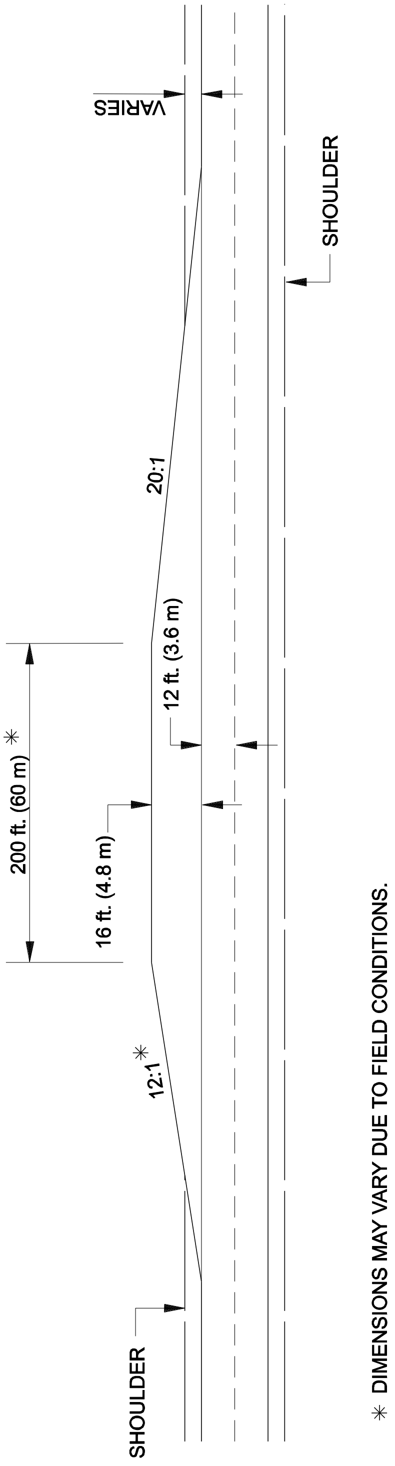
3. Pavement Design. The surfacing for the chain-up areas and truck turnouts should match the surfacing recommended for the project. Where these facilities are installed independently of a project, the surfacing should match the existing surfacing of the adjacent roadway.



✳ DIMENSIONS MAY VARY DUE TO FIELD CONDITIONS.

CHAIN-UP AREA

Figure 18.6A



✳ DIMENSIONS MAY VARY DUE TO FIELD CONDITIONS.

TRUCK TURNOUT

Figure 18.6B

18.7 MAILBOXES

Mailboxes and newspaper tubes served by carriers in vehicles may constitute a safety hazard, depending upon the placement of the mailbox. The designer should make every reasonable effort to replace all non-conforming mailboxes with designs that meet the criteria in *A Guide for Erecting Your Mailbox in the State of Montana*, the *AASHTO A Guide for Erecting Mailboxes on Highways*, and the *MDT Detailed Drawings*. Removal and replacement of mailboxes can be a sensitive issue and should be reviewed with the postal patron prior to their removal or replacement.

18.7.1 Rural Mailboxes

Mailboxes should be placed for maximum convenience to the patron, consistent with safety considerations for highway traffic, the carrier, and the patron. Consideration should be given to the minimum walking distance in advance of the mailbox site and possible restrictions to corner sight distance at intersections and driveway entrances. New installations should, where feasible, be located on the far right side of an intersection with a public road or private driveway entrance.

Boxes should be placed only on the right-hand side of the highway in the direction of travel of the carrier, except on one-way streets where they may be placed on the left-hand side. It is undesirable to require pedestrian travel along the shoulder. However, this may be the preferred solution for distances up to 200’ (60 m) when compared to the alternatives, such as constructing a turnout in a deep cut, placing a mailbox just beyond a sharp crest vertical curve (poor sight distance), or constructing two or more closely spaced turnouts.

Avoid placing mailboxes along high-speed, high-volume highways if other practical locations are available. Do not locate mailboxes where access, stopping or parking is otherwise prohibited by law or regulation. No mailbox should be at a location that would require a patron to cross the lanes of a divided highway to deposit or retrieve mail.

Placing a mail stop near an intersection will have an effect on the operation of the intersection. The nature and magnitude of this impact depends on traffic speeds and volumes on each of the intersecting roadways, the number of mailboxes at the stop, type of traffic control, how the stop is located relative to the traffic control, and the distance the stop is from the intersection. The *MDT Detailed Drawings* show possible locations of mail stops at typical rural intersections and approaches.

MDT policy is that mailbox turnouts are to be provided on all projects where the width of the shoulder is less than 6’ (1.8 m) and the ADT is greater than 300 vehicles per day. For facilities with ADTs of 300 vehicles per day or less, provide mailbox turnouts where the mailbox cannot be practically relocated to a location which at least meets the project's desirable stopping sight distance.

18.7.2 Urban Mailboxes

Urban mail delivery requires special consideration during the design process. Following these procedures during design will help minimize construction issues regarding mail delivery:

1. During the preliminary field review, make a special point of looking for mailboxes or other mail delivery features. Businesses and residences may have different considerations.
    a. Is mail delivered through slots, by hand (inside the businesses), or to mailboxes (individual or clusters)?
    b. If there are mailboxes in place, where are they located and how are they mounted?
    c. Are there conflicts with ADA requirements?
    d. Is sidewalk work going to be included in the project and will construction conflict with the current mail delivery?
2. Include a specific reference for mailboxes in the survey request. Ask for locations, types, condition, and mounting methods.
3. Discuss mail delivery at the public informational meeting. Be sure to ask the business owners and residents for comments regarding mail delivery, especially if there are mailboxes in the existing sidewalk or in an area that will become a new sidewalk section.
4. At the Alignment and Grade stage, discuss proposed mailbox placement with the postmaster. Specifically address the locations, distance from curb, and the potential for cluster boxes.
5. If mailboxes will be perpetuated or placed in new sidewalk, provide mounting information in the plan package. The detailed drawings may or may not be adequate for construction, depending on the project.
    a. Include an additional detail if necessary to ensure that the mailboxes are mounted properly.

b. Ensure adequate ADA clearance around mailboxes placed in the sidewalk.

c. Include the distance from curb and stationing for each mailbox listed in the mailbox summary frame. If special mounting methods are needed, include a note in the summary frame.

18.8 HAZARDOUS MATERIALS

Hazardous waste sites can impact all phases of highway activities, including project development, design, right-of-way, construction, and maintenance. These impacts can increase costs and delay highway projects. Ownership of a site from which there has been a release, or a threat of a release of a hazardous substance may indicate liability whether the contamination is the result of the agency's actions or those of others.

18.8.1 Responsibility

The Project Scoping Team will be responsible for identifying possible hazardous waste locations during the Preliminary Field Review. A list of these locations will be provided to the Hazardous Waste Bureau. The Hazardous Waste Section, or its consultant, will complete the Hazardous Material Review. After the Hazardous Material Review is completed, decisions then can be made regarding the site. This may include requiring the present owner to reclaim the site prior to acquisition, redesigning the project to avoid the site, or delaying or dropping the project from further development due to significant hazardous waste considerations. Preferably, all reclamation will take place before acquisition or construction; see Section 18.8.3.

18.8.2 Location

Hazardous materials can emerge almost anywhere. However, common possible locations include near storage tanks, oil wells, oil lines, illegal dumping sites, abandoned chemical plants, coal fields, service stations, paint companies, machine shops, metal processing plants, electronic facilities, dry cleaning establishments, old railroad yards, auto junkyards, landfills, or near bridges with lead base paints. Early indicators of contamination include ground water contamination of nearby wells, soil discolorations, barrels, liquid discharges, odors, abnormalities in vegetation, and extensive filling and regrading. If there is a reasonable chance a site may contain hazardous materials, contact the Hazardous Waste Section to determine if detailed testing of the site is warranted.

18.8.3 Cleanup

The Hazardous Waste Section and the District Office will be responsible for ensuring the site is free of contamination prior to acquisition of the right-of-way, or for State properties, prior to construction.

Certain special reclamation sites or materials may require a specialist contractor to determine the location and size of the contaminated area and to provide for the proper removal and disposal of the contaminated materials. .

18.8.4 Milled Material

Material milled from existing pavements is considered a solid waste. On projects that include milling, the designer should attempt to utilize the milled material on the project. The preferred uses include recycled asphalt pavement (RAP) and base gravel. Milled material can also be used to resurface frontage roads, stockpiled for later use by MDT Maintenance or given to counties for their use. The use of the material should be addressed at the Preliminary Field Review.

The milled material can be used as fill if the only other viable option is to dispose of the material. If the material is used as fill, it must be placed above the seasonally high water table and not in proximity to standing water. It must also be covered with a least 20” (0.5 m) of fill. Disposal is expensive as it requires a Class II landfill.

18.9 BUS STOPS AND TURNOUTS

18.9.1 Location

18.9.1.1 Bus Stops

If local bus routes are located on an urban or suburban highway, the designer should consider their impact on normal traffic operations. The stop-and-go pattern of local buses will disrupt traffic flow, but certain measures can minimize the disruption. The location of bus stops is particularly important. These are determined not only by convenience to patrons, but also by the design and operational characteristics of the highway and the roadside environment. If the bus must make a left-turn, for example, do not locate a bus stop in the block preceding the left turn.

There are three basic bus stop designs — far-side or near-side of an intersection, and mid-block. Advantages and disadvantages for each of these bus-stop locations are listed in Figure 18.9A. In addition, consider the following:

1. Far-Side Stops. For capacity and other reasons, far-side stops are generally preferred to near-side or mid-block bus stops.

2. Near-Side Stops. Near-side stops must be used where the bus will make a right turn at the intersection.

3. Mid-Block Stops. Mid-block bus stops may be considered where right turns at an intersection are high (250 in peak hour) and far-side stops are not practical.

18.9.1.2 Bus Turnouts

Interference between buses and other traffic can be reduced significantly by providing bus turnouts. Turnouts remove stopped buses from the through lanes and provide a well-defined user area for bus stops. Consider bus turnouts where the following conditions exist:

1. The street provides arterial service with high-traffic speeds [(e.g., greater than 35 mph (60 km/h)].

2. Bus volumes are 10 or more during the peak-hour.

3. Passenger volumes exceed 20 to 40 boardings an hour.

	Advantages	Disadvantages
Far-Side Stop	• Minimizes conflicts between right-turning vehicles and buses. • Provides additional right-turn capacity by making the curb lane available for traffic. • Minimizes sight distance problems on approaches to the intersection. • Encourages pedestrians to cross behind the bus. • Creates shorter deceleration distances for buses because the bus can use the intersection to decelerate. • Results in bus drivers being able to take advantage of the gaps in traffic flow that are created at signalized intersections.	• Multiple stopped buses may block the intersection during peak periods. • May obscure sight distance for crossing vehicles. • May increase sight distance problems for crossing pedestrians. • Can cause a bus to stop twice, first for the traffic signal and then for the far-side stop, which interferes with both bus operations and all other traffic. • May increase number of rear-end accidents because drivers do not expect buses to stop again after stopping at a red signal. • Could result in traffic queued into intersection when a bus is stopped in travel lane.
Near-Side Stop	• Minimizes interference when traffic is heavy on the far side of the intersection. • Allows passengers to access buses closest to crosswalk. • The width of the intersection allows easier re-entry into the traffic stream where curb parking is allowed. • Eliminates the potential of double stopping. • Allows passengers to board and alight while the bus is stopped at a red signal. • Provides driver with the opportunity to look for oncoming traffic, including other buses with potential passengers.	• Increases conflicts with right-turning vehicles. • May result in stopped buses obscuring curbside traffic control devices and crossing pedestrians. • May cause sight distance to be obscured for cross vehicles stopped to the right of the bus. • May block the through lane during peak period with queuing buses. • Increases sight distance problems for crossing pedestrians.
Mid-block Stop	• Minimizes sight distance problems for vehicles and pedestrians. • May result in passenger waiting areas experiencing less pedestrian congestion. • Desirable if a large generator is located mid-block. • Less walking for passengers where the distance between intersections is large. • May be appropriate where there is a fairly heavy and continuous transit demand throughout the block.	• Requires additional distance for no-parking restrictions. • Encourages patrons to cross street at mid-block (jaywalking). • Increases walking distance for patrons crossing at intersections.

COMPARISON OF BUS STOP LOCATIONS

Figure 18.9A

4. The average bus dwell time generally exceeds 30 seconds per stop.

5. During peak-hour traffic, there are at least 250 vehicles per hour in the curb lane.

6. Buses are expected to layover at the end of the trip.

7. Potential vehicular/bus conflicts warrant the separation of transit and other vehicles.

8. There is a history of traffic and/or pedestrian accidents that can be resolved by a bus turnout.

9. Right-of-way width is sufficient to prevent adverse impact on sidewalk pedestrian movements.

10. Curb parking is prohibited, at least during peak hours.

11. Sight distances prevent traffic from stopping safely behind the bus.

12. Other improvements (e.g., widening) are planned for the major roadway.

13. At location where specially equipped buses are used to load and unload disabled individuals.

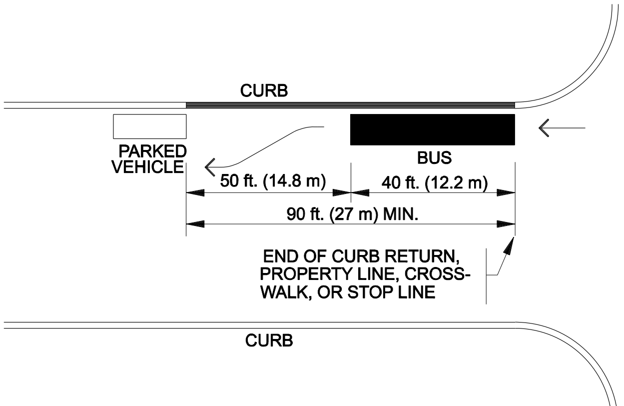
18.9.1.3 Selection

The Project Scoping Team, in conjunction with the District Office and the local transit agency, will determine the location of the bus stop or bus turnout. However, the designer usually has some control over the best placement of a bus stop or turnout location when considering layout details, intersection design and traffic flow patterns.

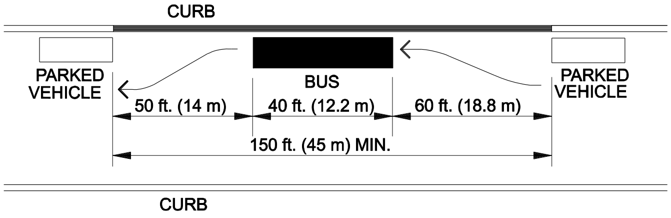
18.9.2 Design

18.9.2.1 Bus Stops

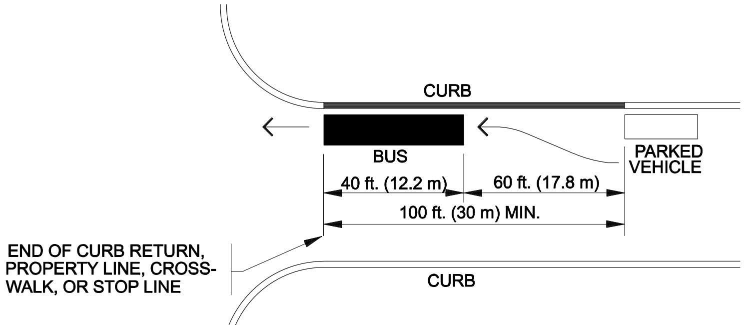
Figure 18.9B provides the recommended distances for the prohibition of on-street parking near bus stops.



FAR-SIDE BUS STOP



MID-BLOCK BUS STOP



NEAR-SIDE BUS STOP

Notes:

1. *Where articulated buses are expected to use these stops, add an additional* 20' (6 m) *to the bus distances.*

2. *Provide an additional 50' (15.2 m) of length for each additional bus expected to stop simultaneously at any given bus stop area. This allows for the length of the extra bus [40' (12.2 m)] plus 10' (2.8 m) between buses.*

ON-STREET BUS STOPS

Figure 18.9B

18.9.2.2 Bus Turnouts

Desirably, the total length of a bus turnout will allow for an entrance taper, a deceleration length, a stopping area, an acceleration length, and an exit taper. Figure 18.9C illustrates the design details for bus turnouts. Providing separate deceleration and acceleration lengths are desirable in suburban and rural areas. However, common practice is to accept deceleration and acceleration in the through lanes and only build the tapers and stopping area. In addition, consider the following:

1. Far-Side Turnouts. Typically, far-side intersection placement is desirable. Placing turnouts after signal-controlled intersections allows the signal to create gaps in traffic.

2. Near-Side Turnouts. Avoid using near-side turnouts because of conflicts with right-turning vehicles, delays to transit services as buses try to re-enter the traveled way and obstructions to traffic control devices and pedestrian activities.

3. Mid-Block Turnouts. Only use mid-block turnouts in conjunction with major traffic generators.

4. Tapers. Figure 18.9C provides information on taper lengths that may be used for entrance and exit tapers. To improve traffic operations, use short horizontal curves [100’ (30 m) radius] on the entry end and 50’ (15 m) to 100’ (30 m) curves on the re-entry end. Where a turnout is located at a far-side or near-side location, the cross street area can be assumed to fulfill the need for the exit or entry area, whichever applies.

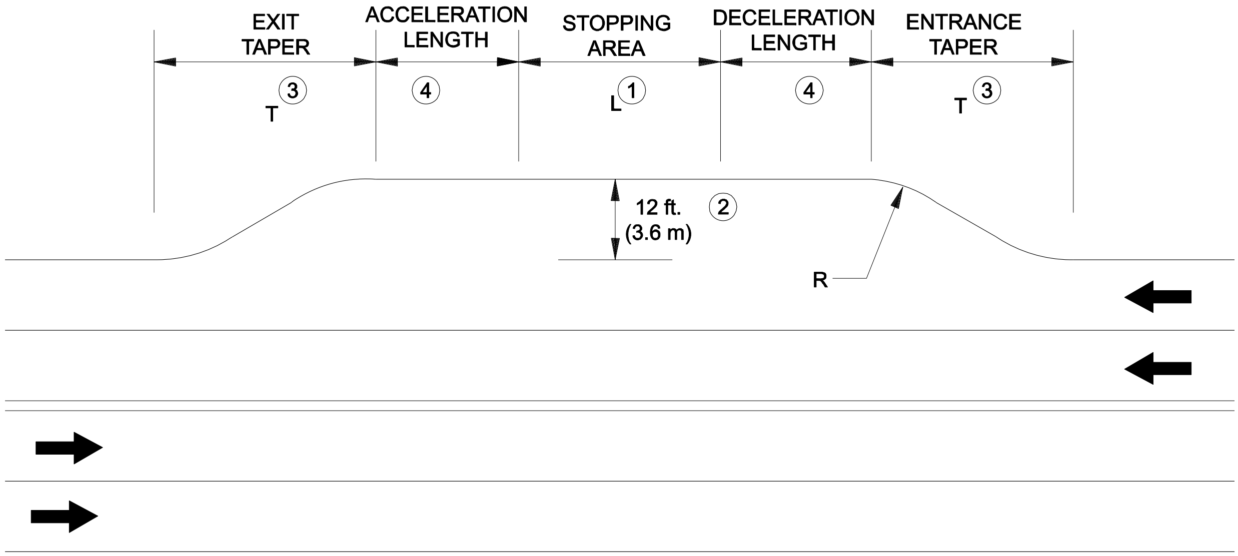
18.9.2.3 Bus Stop Pads

All new bus stops which are constructed for use with lifts or ramps must meet the disabled accessibility criteria in Section 18.1.4.

18.9.2.4 Bus Shelters

The need for bus shelters will be determined by the District Office in conjunction with the local transit agency. The designer should consider the following in the design of bus shelters:

1. Visibility. To enhance passenger safety, the shelter sides should provide the maximum transparency as practical. In addition, do not locate the shelter such that it limits the general public's view of the shelter interior.



Notes: Table and notes taken from NCHRP Report 414, High Occupancy Vehicle Systems Manual p 8-35

① *Stopping area length consists of 50' (15.2 m) for each standard 40' (12.2 m) bus and 70' (21.3 m) for each 60' (18.3 m) articulated bus expected to be at the stop simultaneously.*

② *Bus turnout width is desirably 12' (3.6 m). For traffic speeds under 30 mph (48 km/h), a 10' (3.0 m) minimum bay width is acceptable. These dimensions do not include gutter width.*

③ *Suggested taper lengths are listed below. A minimum taper of 5:1 may be used for an entrance taper from the street for a bus turnout while the merging or re-entry taper should not be sharper than 3:1*

④ *The minimum design for a bus turnout does not include acceleration or deceleration lengths. Recommended acceleration* and deceleration lengths are listed below.

TYPICAL BUS TURNOUT DIMENSIONS (Part 1)

Figure 18.9C

U.S. Customary

Through Speed mph	Entering Speed[a] mph	Acceleration Lane ft.	Deceleration Lane[b] ft.	Taper Length ft.
30	20	158	118	150
35	25	250	184	170
40	30	400	265	190
45	35	700	360	210
50	40	975	470	230
55	45	1400	595	250
60	50	1900	735	270

Metric

Through Speed km/h	Entering Speed[a] km/h	Acceleration Lane m	Deceleration Lane[b] m	Taper Length m
48	32	48	36	46
56	40	76	56	52
64	48	122	81	58
72	56	213	110	64
80	64	297	143	70
88	72	427	181	76
97	80	580	224	82

[a] *Desirably, the bus speed at the end of taper should be within 10 mph(16 km/h) of the design speed of the traveled way.*

[b] *Based on 2.5 mph/sec(4km/h/sec) deceleration speed.*

TYPICAL BUS TURNOUT DIMENSIONS (Part 2)

Figure 18.9C

2. Selection. Contact the local transit agency to determine if they use a standardized shelter design.

3. Appearance. Shelters should be pleasing and blend with their surroundings. Shelters should also be clearly identified with "bus logo" symbols.

4. Disabled Accessibility. Design the new bus shelters to meet the accessibility criteria presented in Section 18.1.4.

5. Placement. Do not place the shelter where it will restrict vehicular sight distance, pedestrian flow or disabled accessibility. It should also be placed so that waste and debris are not allowed to accumulate around the shelter.

6. Responsibility. The local transit agency is responsible for providing and maintaining the shelter.

7. Capacity. The maximum shelter size is based upon the maximum expected passenger accumulation at a bus stop between bus runs. The designer can

assume approximately 2.7 to 5.4 ft^2 (0.25 to 0.5 m^2) per person to determine the appropriate shelter size. See Section 18.1.4 for minimum disabled accessibility requirements.

18.10 MISCELLANEOUS ELEMENTS

18.10.1 Cattle Guards

The locations of cattle guard installations are typically specified in the right-of-way agreements, except for those installed on interchange ramps. All existing cattle guards should be reviewed for removal or replacement. Existing cattle guard installations which are no longer necessary should be removed, and those installations which do not meet the criteria below should be considered for relocation. In addition, the designer should consider the following:

1. R/W Line. Where used, locate cattle guards at the right-of-way line on all public or private approaches, except where it will interfere with the requirements in Comment #'s 2 and 3.

2. Ramps. Where cattle guards are required on interchange ramps, they should be located 145’ (45 m) to 165’ (50 m) from the ramp terminal, except where they may interfere with the requirements in Comment #3.

3. Width. The cattle guard should extend across the full pavement width including both shoulders. Do not reduce the paved roadway width.

4. Bases. All bases for cattle guards on public roads, including interchange ramps, should use cast-in-place concrete bases as shown in the *MDT Detailed Drawings*. Field and other private approaches may use the precast concrete base.

5. Details. The *MDT Detailed Drawings* provide the construction details for the installation of cattle guards.

18.10.2 Retaining Walls

Retaining walls often provide a desirable solution to problems related to limited right-of-way, environmental impacts, steep embankments and cuts, etc. The following describes MDT policy for the selection and design of retaining walls:

1. Need. Generally, the need for a retaining wall will be determined by the Project Scoping Team during the Preliminary Field Review. However, as the project design develops, the designer may later determine that there is a need for a retaining wall. The need for a wall should be carefully assessed as retaining walls are very expensive.

2. Location. The actual location for the retaining wall will typically be determined during the Alignment and Grade Review. The designer may make adjustments to this location depending on the project design.

3. Options. The Geotechnical Section will perform a foundation investigation of the site and will determine which retaining wall system would be acceptable for the site.

4. Design. The designer will be responsible for showing the wall location and elevation and other pertinent details of a proposed retaining wall. A listing of all acceptable retaining wall systems, as provided by the Geotechnical Section, should be provided in the plans. The Bridge Bureau will provide the design for concrete retaining walls.

5. Selection. The Contractor will select a wall system from the acceptable retaining wall list in the plans. The Contractor will be responsible for submitting detailed shop plans for the selected retaining wall design.

6. Plan Review. The Bridge Bureau will be responsible for reviewing the shop plans for any concrete retaining walls selected by the Contractor. The Geotechnical Section will be responsible for reviewing the shop plans for all other wall types.

18.10.3 Parking

Section 11.2.5 provides the warrants and design criteria for on-street parking. For design criteria on off-street parking (e.g., park-and-ride lots, rest areas), see Chapter Thirty-one of the *MDT Traffic Engineering Manual* and/or contact the Traffic Engineering Section.

18.10.4 Highway/Railroad Grade Crossings

In general, the following will apply where there is a highway/railroad grade crossing:

1. Design. The road designer is responsible for coordinating with the Utilities Section to provide the necessary information on the proposed project to the affected railroads. The road designer is also responsible for incorporating, as necessary, the information from the railroad company into the design plans.

2. Agreements. The Utilities Section in the Right-of-Way Bureau is responsible for contacting the railroad company and negotiating all agreements with the railroad companies. The Contract Plans Section is responsible for preparing the maintenance agreement for signing and other related items if the facility is

maintained by some other entity (e.g., State Secondary Route maintained by a county).

3. Signing and Pavement Markings. The Signing and Pavement Marking Unit in the Traffic Engineering Section is responsible for the signing and pavement markings on the approach to the railroad crossing. The railroad company will be responsible for the traffic control devices at the crossing.

4. Electrical. The Electrical Unit in the Traffic Engineering Section is responsible for working with the railroad to coordinate nearby traffic signals and active traffic crossing controls.

18.10.5 In-Pavement Systems

To reduce the number of pavement cuts after resurfacing and other new pavement projects are completed, the designer should contact the MDT Motor Carrier Services, the Maintenance Division, the Rail, Transit and Planning Division and the Electrical Unit in the Traffic Engineering Section to determine if they plan, in the near future, to install weigh-in-motion detectors, permanent traffic counters, weather sensors, traffic signal loop detectors, etc., into the pavement. If practical, these systems should be incorporated into the project.

The sensors for the Remote Weather Information System (RWIS) must be replaced each time any work is done on the paved surface. The sensors may be located up to 0.3 miles (0.5 km) from the RWIS tower. Consequently, if an RWIS tower is located in the vicinity of the project, contact MDT Maintenance to determine the location of the sensors. The cost of furnishing the sensors will be included in the project, but the installation will be accomplished by MDT Maintenance personnel.

18.10.6 Interchange Grading and Landscaping

Consider the grading around an interchange early in the design process. Alignment, fill and cut sections, median widths, lane widths, drainage, structural design, and infield contour grading all affect the function and aesthetics of the interchange. Properly graded interchanges allow the overpassing structure to blend naturally into the terrain. In addition, ensure that the crossroad and ramp slopes are not too steep to compromise safety and that they can support plantings that prevent erosion and enhance the appearance of the area. Flatter slopes also allow easier maintenance. Transitional grading between cut and fill slopes should be long and natural in appearance. The designer also must ensure that plantings will not affect the sight distance within the interchange and that larger plantings are a significant distance from the traveled way.

Include a contour grade detail in the plans.

18.11 FRONTAGE ROADS

18.11.1 General

Frontage roads serve numerous functions, depending on the type of facility served and the character of the surrounding area. They may be used to control access to the facility, to function as a street serving adjoining property, and to maintain circulation of traffic on each side of the main highway. Frontage roads segregate local traffic from the higher speed through traffic and serve driveways of residences and commercial establishments along the highway. Connections between the main highway and frontage roads, usually provided at crossroads, furnish access between through roads and adjacent property. Thus, the through character of the highway is preserved and is unaffected by subsequent development along the roadsides.

Frontage roads may be used on all types of highways. Their greatest use is adjacent to freeways where their primary function is to distribute and collect traffic between local streets and the freeway interchanges. In some circumstances, frontage roads are also desirable on arterial streets both in urban and suburban areas.

Despite their advantages, the use of continuous frontage roads on relatively high-speed arterial streets with intersections at grade may be undesirable. At the cross streets, the various through and turning movements at several closely spaced intersections greatly increase the accident potential. The multiple intersections are also vulnerable to wrong-way entrances. Traffic operations are improved if the frontage roads are located a considerable distance from the main highway at the intersecting crossroads in order to lengthen the spacing between successive intersections along the crossroads. See Section 18.11.3.

Frontage roads generally are parallel to the roadway for through traffic. They may or may not be continuous, and they may be provided on one or both sides of the arterial.

For private frontage or access roads, prepare an economic analysis to ensure that construction of the frontage road will be cost effective versus acquiring the property.

18.11.2 Functional Classification

The normal design elements of pavement width, cross slope, horizontal and vertical alignment, etc., should be provided consistent with the functional operation of the frontage road. That is, the same considerations relative to functional classification, design speed, traffic volumes, etc., apply to frontage roads as they apply to any other highway. The functional classification of the frontage road will be determined on a case-by-case basis.

18.11.3 Design

In the design of frontage roads, consider the following:

1. Design Criteria. The selection of the appropriate design criteria is based on the functional classification of the frontage road. Once the functional classification has been determined, select the appropriate design speed, lane and shoulder widths, etc., from the tables in Chapter Twelve.

2. One-Way/Two-Way. From an operational and safety perspective, one-way frontage roads are much preferred to two-way especially in urban areas. One-way operations may inconvenience local traffic to some extent, but the advantages in reducing vehicular and pedestrian conflicts at intersecting streets often fully compensate for this inconvenience. In addition, there is some savings in pavement and right-of-way width. Two-way frontage roads at high-volume, at-grade intersections complicate crossing and turning movements.

   Two-way frontage roads may be considered for partially developed urban areas where the adjoining street system is so irregular or so disconnected that one-way operation will introduce considerable added travel distance and cause undue inconvenience. Two-way frontage roads may also be appropriate for suburban or rural areas where points of access to the through facility from the frontage road are widely spaced.

3. Outer Separation. The area between the main highway and a frontage road or street is the outer separation. The separation functions as a buffer between the through traffic on the main highway and the local traffic on the frontage road. This separation also provides space for shoulders and ramp connections to or from the through facility.

   The wider the outer separation, the less influence local traffic will have on through traffic. Wider separations lend themselves to landscape treatments and enhance the appearance of both the highway and the adjoining property. Desirably, the outer separation between the mainline facility and the frontage road will be 100’ (30 m) in rural areas and 65’ (20 m) in urban areas. This distance is measured between the edges of the traveled ways for the mainline highway and frontage road. The minimum width of outer separation will be that which is required for the shoulder adjacent to the main highway, the frontage road shoulder (or shoulder offset) and for a median type barrier.

A substantial width is particularly advantageous at intersections with cross streets. A wide outer separation minimizes vehicular and pedestrian conflicts. At intersections, the outer separation should also be based on future traffic considerations.

A frontage road too close to the mainline highway and on the same level may justify the need for a headlight glare screen.

4. Access. Connections between the main highway and the frontage road are an important design element. On facilities with lower operational speeds and one-way frontage roads, slip ramps or simple openings in a narrow outer separation may work reasonably well. Slip ramps from one-way frontage roads and freeways are acceptable. However, slip ramps from a freeway to two-way frontage roads are undesirable because they tend to induce wrong-way entry onto the freeway and may cause accidents at the intersection of the ramp and frontage road. Therefore, on freeways and other arterials with high operating speeds and two-way frontage roads, the access to the freeway must be provided at interchanges. Figure 18.11A illustrates details for the ramp/frontage road design with one-way frontage roads.

The design in Figure 18.11A may only be used in restricted urban areas. The critical design element is the distance “A” between the ramp/frontage road merge and the crossing road. This distance must be sufficient to allow traffic weaving, vehicular deceleration and stopping, and vehicular storage to avoid interference with the merge point. Figure 29.4B also presents general guidelines which may be used to estimate this distance during the preliminary design phase. A number of assumptions have been made including weaving volume, operating speeds and intersection queue distance. Therefore, a detailed analysis will be necessary to firmly establish the needed distance to properly accommodate vehicular operation. Additional information can be found in a Transportation Research Record 682 paper entitled, “Distance Requirements for Frontage-Road Ramps to Cross Streets: Urban Freeway Design.”

Distance “B” in Figure 18.11A is determined on a case-by-case basis. It should be determined based on the number of frontage road lanes and the intersection design. This distance is typically determined by the weaving distance from the intersection to ramp entrance. For capacity analysis of the weaving section, see the *Highway Capacity Manual*. Under some circumstances this distance may be 0.0.

The following summarizes the available options for coordinating the design of the interchange ramps, frontage road and crossing road:

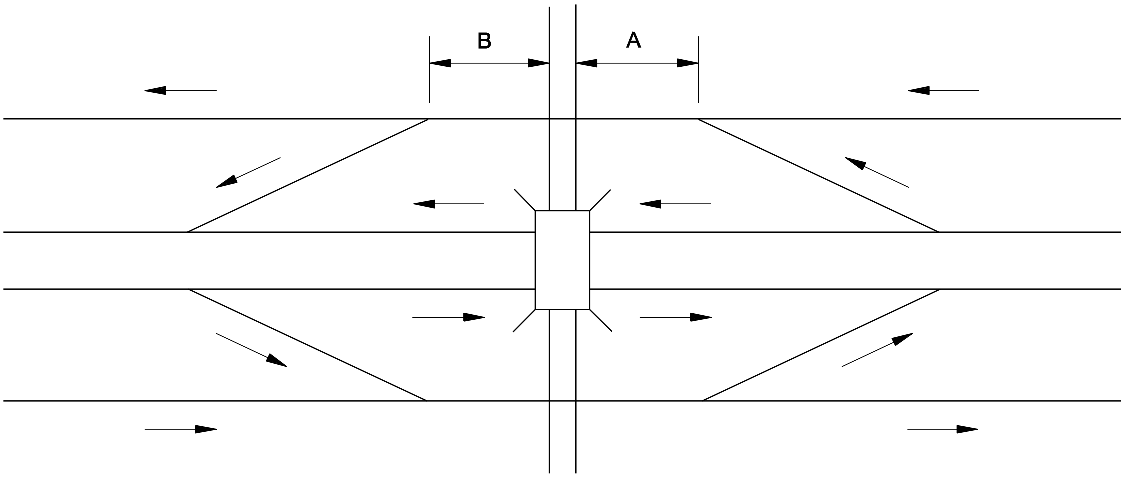
Frontage Road Volume (vph)[1]	Exit Ramp Volume (vph)[2]	"A"					
		Typical Minimum		Typical Desirable		Special Conditions	
		ft	m	ft	m	ft	m
200	140	375	115	490	150	260	80
400	275	460	140	560	170	360	110
600	410	490	150	625	190	395	120
800	550	540	165	690	210	425	130
1000	690	590	180	755	230	460	140
1200	830	640	195	870	265	475	145
1400	960	690	210	970	295	490	150
1600	1100	770	235	1065	325	525	160
1800	1240	855	260	1180	360	560	170
2000	1380	970	295	1295	395	590	180

1 *Total frontage road and exit ramp volume between merge to intersection with minor road.*

2 *Assumed to be 69% of total volume in first column.*

Note: Table values are acceptable for planning purposes; final dimensions will be based on a detailed operational analysis. This design may be used where necessary in restricted urban areas.

Distance B is typically determined by the weaving distance from the intersection to the ramp entrance, see Chapter Twenty-nine of the Montana Traffic Engineering Manual.



RAMP/CONTINUOUS FRONTAGE ROAD INTERSECTION

Figure 18.11A

1. Slip Ramps. Slip ramps may be used to connect the freeway with one-way frontage roads before (or after) the intersection with the crossing road.

2. Separate Intersections. Separate ramp/crossing road and frontage road/crossing road intersections may be accomplished by curving the frontage road away from the ramp and intersecting the frontage road with the crossing road outside the ramp limits of full access control. Figure 18.11A provides an illustration of this separation. This treatment allows the two intersections to operate independently, and it eliminates the operational and signing problems of providing the same point of exit and entrance for the frontage road and freeway ramp.

October 18, 2016

MONTANA DEPARTMENT OF

TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Twenty

COORDINATION WITH OTHER PUBLICATIONS

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(Continued)

Chapter Twenty

COORDINATION WITH OTHER PUBLICATIONS

The *Montana Road Design Manual* is not intended to present all information which may be needed by the road designer on a specific project. The *Manual* does include the majority of the road design information for the vast majority of projects designed by the Road Design Section. However, on specific projects or for specific project elements, the road designer may need to reference other publications to perform a fully comprehensive analysis of the project. Chapter Twenty briefly discusses other publications in the national highway engineering literature and those published by the Montana Department of Transportation.

20.1 NATIONAL PUBLICATIONS

For the relevant national publication, this Section provides 1) a brief description of each publication, and 2) its application on Department projects.

20.1.1 A Policy on Geometric Design of Highways and Streets

20.1.1.1 Description

The AASHTO *A Policy on Geometric Design of Highways and Streets*, more commonly known as the Green Book, discusses the nationwide policies, practices and criteria for the geometric design of highways and streets. It is intended to present a consensus view on the most widely accepted approach to the design of a variety of geometric design elements including design speed, horizontal and vertical alignment, cross section widths, intersections and interchanges. Note that the FHWA design exception process, as discussed in Section 8.8 of the *Road Design Manual*, is based on the numerical criteria presented in the *Green Book*.

20.1.1.2 Department Application

Several of the chapters within the *Montana Road Design Manual* address geometric design elements. The *Manual's* geometric design treatments have been based on the *Green Book* but tailored to the prevailing climate, topography and practices within Montana. Also, the *Montana Manual* is intended to clarify, where needed, specific presentations in the *Green Book* and to discuss geometric design information not presently included in the *Green Book*. The designer should note that, where conflicts may exist between the *Montana Road Design Manual* and the *Green Book*, the *Montana Manual* will govern.

20.1.2 Roadside Design Guide

20.1.2.1 Description

The AASHTO *Roadside Design Guide* presents the nationwide policies, practices and criteria for roadside safety along highways and streets. It is intended to present a consensus view on the most widely accepted approach to providing a reasonably safe roadside for run-off-the-road vehicles. The *Roadside Design Guide* discusses clear zones, drainage appurtenances, sign and luminaire supports, roadside barriers, median barriers, bridge rails, crash cushions and roadside safety within construction work zones. The overall objective of the *Roadside Design Guide* is to recommend an appropriate roadside safety treatment for specific sites considering the consequences of run-off-the-road accidents, specific roadway features (e.g., traffic volumes, design speed, roadside topography) and construction/maintenance costs.

20.1.2.2 Department Application

Two chapters in the *Montana Road Design Manual* address roadside safety:

1. Chapter Fourteen "Roadside Safety," and

2. Chapter Fifteen "Maintenance and Protection of Traffic Through Construction Zones."

The roadside safety criteria in these chapters are based on the criteria presented in the *Roadside Design Guide* but tailored to the prevailing practices and conditions in Montana. Also, the *Montana Road Design Manual* is intended to clarify, where needed, the presentations in the *Roadside Design Guide* and to discuss roadside safety information not included in the Roadside Design Guide. The designer should note that, where conflicts may exist between the *Montana Road Design Manual* and the *Roadside Design Guide*, the *Montana Manual* will govern.

20.1.3 Model Drainage Manual

20.1.3.1 Description

The AASHTO *Model Drainage Manual (MDM)* presents the nationwide criteria for the hydrologic and hydraulic design of drainage appurtenances for highway projects. The *MDM* discusses the most commonly used hydrologic methods in the United States (e.g., the Rational Method), and it discusses the hydraulic design of open channels, culverts, bridges, closed drainage systems, energy dissipators, etc. The *MDM* either supersedes, incorporates or references the FHWA Hydraulic Engineering Circulars and Hydraulic Design Series publications. The overall objective of the *MDM* is to present hydraulic design criteria for highway drainage features which properly consider the probability of an extreme hydraulic event, the consequences of that event and the costs of providing a drainage system which will accommodate the event.

20.1.3.2 Department Application

The Hydraulics Section is typically responsible for the hydraulic design of drainage appurtenances for all highway projects under the jurisdiction of the Department. The design is based on criteria in the AASHTO *Model Drainage Manual*, the *Montana Hydraulics Manual* and general Department practices in hydrology and hydraulics. Where conflicts exist between the *MDM* and MDT practices, the Hydraulics Section will determine the proper application.

Chapter Seventeen "Drainage and Irrigation Design" in the *Montana Road Design Manual* primarily discusses structural requirements for drainage appurtenances (e.g., maximum heights of fill and wall thicknesses for pipe culverts). It does not address hydrology and hydraulics.

20.1.4 Highway Capacity Manual

20.1.4.1 Description

The Highway Capacity Manual (HCM), published by the Transportation Research Board, presents the nationwide criteria for performing capacity analyses for highway projects. The HCM includes methodologies for freeways, weaving areas, freeway/ramp junctions, two-way two-lane facilities, intersections, etc. The basic objective of the capacity methodologies in the HCM is to determine the necessary configuration and dimensions of a specific highway element to accommodate the projected traffic volumes at a given level of service.

20.1.4.2 Department Application

The Traffic Engineering Section performs all needed capacity analyses for Department projects. The *Highway Capacity Manual* is used for all analyses with some adjustments for local highway capacity factors.

20.1.5 *Manual on Uniform Traffic Control Devices*

20.1.5.1 Description

The *Manual on Uniform Traffic Control Devices (MUTCD)*, published by the FHWA in coordination with the National Committee on Uniform Traffic Control Devices, presents nationwide criteria for the selection, design and placement of all traffic control devices. This includes highway signs, pavement markings and traffic signals. The basic objective of the *MUTCD* is to establish an effective means to convey traffic control information to the driver for uniform application nationwide. The *MUTCD* information is divided into four categories — standard, guidance, option and support. These categories are used to establish the proper application of *MUTCD* criteria for all public roads and streets within the United States.

20.1.5.2 Department Application

The Traffic Engineering Section is responsible for the use of traffic control devices on all projects under the jurisdiction of the Department. The Department has adopted the use of the *MUTCD* in its entirety, including the context of its presentation. The *MDT Detailed Drawings* and *Montana Traffic Engineering Manual* present additional information on traffic control devices which supplements the criteria in the *MUTCD*.

20.1.6 *ADA Accessibility Guidelines for Buildings and Facilities*

20.1.6.1 Description

The ADA *Accessibility Guidelines for Buildings and Facilities*, published by the U.S. Architectural and Transportation Barrier Compliance Board, presents the nationwide accessibility criteria to buildings and facilities for individuals with disabilities. The basic objective of this document is to establish the criteria mandated by the *Americans with Disabilities Act (ADA)* of 1990. It provides accessibility criteria for both interior and exterior facilities including parking spaces, sidewalks, hallways, doorways, curb ramps, ramps, stairs, telephones, drinking fountains, rest rooms, elevators, etc.

20.1.6.2 Department Application

The Department's accessibility criteria meet the *ADA Accessibility Guidelines for Buildings and Facilities*. Chapter Eighteen addresses the exterior accessibility features the designer will typically encounter including sidewalks, parking spaces, ramps, curb ramps, etc. For interior features (e.g., at rest areas), the designer should use the requirements presented in the *ADA Accessibility Guidelines for Buildings and Facilities*.

20.2 DEPARTMENT PUBLICATIONS

The Department has prepared many publications in addition to the Montana Road Design Manual which may apply to a road design project. This Section briefly discusses other relevant MDT publications.

20.2.1 *Montana Traffic Engineering Manual*

The Traffic Engineering Section is responsible for the *Montana Traffic Engineering Manual*, which is divided into the following seven parts:

1. Part I "General,"
2. Part II "Electrical,"
3. Part III "Signs/Pavement Markings,"
4. Part IV "Geometrics,"
5. Part V "Safety Projects,"
6. Part VI "Traffic Engineering Investigations," and
7. Part VII "Miscellaneous."

The major objective of the *Montana Traffic Engineering Manual* is to present MDT criteria on the design and construction plan preparation for traffic projects on the State highway system. Because of the similar responsibilities of the Road Design and Traffic Engineering Sections, much of the *Montana Road Design Manual* has been summarized or incorporated into the *Montana Traffic Engineering Manual*. In addition, the *Montana Traffic Engineering Manual* presents MDT criteria on the selection, design and placement of traffic control devices on the State highway system and the procedures and practices for highway lighting and traffic engineering investigations.

20.2.2 *Montana Hydraulics Manual*

The Hydraulics Section is responsible for the *Montana Hydraulics Manual*, which presents design criteria on the following:

1. hydraulic surveys;

2. hydrologic methods used in Montana;

3. hydraulic design of culverts, open channels, bridge waterway openings and closed drainage systems;

4. erosion control; and

5. irrigation.

The objective of the *Montana Hydraulics Manual* is to document those hydrologic and hydraulic methodologies used by the Department for the design of drainage appurtenances. The *Montana Hydraulics Manual* is consistent with the relevant Hydraulic Engineering Circulars and Hydraulic Design Series available at the time of *Montana Hydraulics Manual* publication.

20.2.3 Montana Geometric Design Standards

Based on the Intermodal Surface Transportation Efficiency Act of 1991, the Department has adopted geometric design criteria for the Federal-aid funding categories. The Montana Geometric Design Standards, in conjunction with the Montana Road Design Manual, present the minimum criteria that should be used to design highways in Montana. The minimum criteria presented in the Montana Geometric Design Standards are used as the basis for determining the need for a design exception. See Chapter Eight for more information.

20.2.4 Montana Structures Manual

The Bridge Bureau is responsible for the *Montana Structures Manual*, which is divided into the following volumes:

1. Volume I — Administration and Procedures. This volume includes discussions on MDT organization, Bridge Design process and coordination, administrative policies and procedures, plan preparation, quantity estimating, cost estimating, contract documents, and records and files.
2. Volume II — Structural Design. This volume includes discussions on the State Plane Coordinate System, structural systems, loads, bridge decks, superstructure designs, substructure and foundation designs, bridge rehabilitation, and other bridge design issues.
3. Volume III — Plan Sheets. This volume includes typical bridge plan sheets and the Bridge Standard Drawings.

20.2.5 *Approach Standards for Montana Highways*

The Traffic Engineering Section, the Right-of-Way Bureau and the Maintenance Division are responsible for the *Approach Standards for Montana Highways*, which has been adopted as a regulation by the Montana Transportation Commission. The *Approach*

Standards present instructions for obtaining an approach permit and MDT criteria on the frequency, design and construction of public and private access to State-maintained highways. The objectives of the criteria are to maintain a balance between the safe and efficient movement of traffic on the highway mainline and the need for reasonable access to the highway system by adjacent property owners.

20.2.6 MDT Detailed Drawings

The Contract Plans Section is responsible for the *MDT Detailed Drawings*. The *Drawings* provide details on various design treatments that are consistent from project to project (e.g., guardrail, fencing, drainage details), and they provide information on how to lay out or construct the design elements.

See Section 6.1 of the *Road Design Manual* for more information on the *MDT Detailed Drawings*.

20.2.7 *Montana Standard Specifications for Road and Bridge Construction*

The Construction Bureau is responsible for the *Montana Standard* Specifications for Road and Bridge Construction. The *Standard Specifications* present the work methods and materials approved by the Department for the construction of road, traffic and bridge projects. The publication presents information on :

1. bidding,
2. awarding the contract,
3. contractor duties,
4. controlling material quality,
5. contractor and Department legal requirements,
6. executing the contract, and
7. measuring and paying for contract items.

See Section 6.1 of the *Road Design Manual* for more information on the *Standard Specifications*.

The designer should note that where conflicts exist between the Road Design Manual and the Standard Specifications, the Standard Specifications will govern.

20.2.8 *Montana Materials Manual*

The Materials Bureau is responsible for the *Montana Materials Manual*, which presents the Department's criteria for sampling and testing procedures for materials used in road and bridge construction. The objective of the *Montana Materials Manual* is to coordinate with the relevant national publications (e.g., AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*) and to indicate which testing methods:

1. follow a national standard,
2. basically follow a national standard with some modification for MDT application,or
3. are unique to Montana.

20.2.9 *Montana Construction Manual*

The Construction Bureau is responsible for the *Montana Construction Manual*. The *Montana Construction Manual* supplements the *Montana Standard Specifications for Road and Bridge Construction* by providing explanatory information on:

1. contract administration,
2. earthwork,
3. drainage structures,
4. aggregate surfaces,
5. bituminous pavements,
6. rigid pavements, and
7. bridge construction.

20.2.10 *Montana Surveying Manual*

The Photogrammetry & Survey Section is responsible for the *Montana Surveying Manual*, which presents Department criteria for the following:

1. survey datums and coordination systems,
2. survey measurements and equipment,
3. errors and maximum closure,
4. preliminary surveys,
5. property corner ties,
6. notekeeping, and
7. construction surveys.

20.2.11 ***Montana Right-of-Way Manual***

The Right-of-Way Bureau is responsible for the *Montana Right-of-Way Manual*, which presents Department criteria for the following:

1. access control and encroachments,
2. appraisals and acquisitions,
3. fencing requirements,
4. R/W agreements,
5. R/W plan preparation,
6. condemnations, and
7. utilities.

20.2.12 ***Montana Maintenance Manual***

The Maintenance Division is responsible for the *Montana Maintenance Manual*, which contains Department criteria for the following:

1. maintenance of bituminous surfaces,
2. maintenance of concrete surfaces,
3. roadside landscaping and vegetation control,
4. safety and accident prevention, and
5. signs and pavement markings.

20.2.13 ***Montana CADD Manual***

The CADD Coordinator, in conjunction with various other Department Sections including the Road Design Section, is responsible for the *Montana CADD Manual*, which contains Department criteria for the following:

1. accessing the CADD software;
2. creating, editing and referencing files;
3. descriptions and applications of commands;
4. element placement and usage;
5. cell management; and
6. plotting.

20.2.14 ***Montana Consultant Users Manual***

The Consultant Design Section is responsible for the *Montana Consultant Users Manual*. The Manual provides the development process for projects designed by consultants. The MDT Project Management System has been modified so consultants can incorporate their planning values into the Department's system. The System can be used to identify the critical path of a project's development and allow the consultant and the Department to monitor progress on the consultant's projects.

The *Manual* describes the activities and provides a flowchart for project development. This *Manual* is not an all inclusive guide for the development of a set of plans.

October 18, 2016

MONTANA DEPARTMENT OF

TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Twenty One

GLOSSARY

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Chapter Twenty-one
GLOSSARY/INDEX

21.1 GLOSSARY

21.1.1 General

1. Accessible Route. An accessible route is a continuous, unobstructed path connecting all accessible elements and spaces in a building, site or facility. A "site" is defined as a parcel of land bounded by a property line or a designated portion of a public right-of-way. A "facility" is defined as all or any portion of buildings, structures, site improvements, complexes, equipment, roads, walks, passageways, parking lots, or other real or personal property on a site.

2. Arterial. Functionally classified highway which is characterized by a high degree of continuity and a capacity to quickly move relatively large volumes of traffic but often provide limited access to abutting properties. The arterial system typically provides for high travel speeds and the longest trip movements.

3. Average Running Speed. Running speed is the average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion). The average running speed is the distance summation for all vehicles divided by the running time summation for all vehicles.

4. Average Travel Speed. Average travel speed is the distance summation for all vehicles divided by the total time summation for all vehicles, including stopped delays. (Note: Average running speed only includes the time the vehicle is in motion. Therefore, on uninterrupted flow facilities which are not congested, average running speed and average travel speed are equal.)

5. Bicycle Lane. A portion of a roadway which has been designated by striping, signing and pavement markings for the exclusive use of bicyclists.

6. Bicycle Path. A bikeway physically separated from motorized vehicular traffic by an open space or barrier.

7. Bikeway. Any road, path or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or will be shared with other transportation modes.

8. Bridge. A structure, including supports, erected over a depression or obstruction, such as water, a highway, or a railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 6 m between undercopings of abutments or spring lines or arches or extreme ends of openings for multiple boxes; may include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening.

9. Bridge Length. The length of a bridge structure is the overall length measured from centerline of bearing to centerline of bearing of the abutments.

10. Bridge Roadway Width. The clear width of the structure measured at right angles to the center of the roadway between the bottom of curbs or, if curbs are not used, between the inner faces of parapet or railing.

11. Bridge to Remain in Place. An "existing bridge to remain in place" refers to any bridge work which does not require the total replacement of both the substructure and superstructure.

12. Bus. A heavy vehicle involved in the transport of passengers.

13. Collector. Functionally classified highway which is characterized by a roughly even distribution of their access and mobility functions.

14. Controlling Criteria. A list of geometric criteria requiring approval if they are not met or exceeded.

15. Crosswalk. (1) The part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway. (2) Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrians crossing by lines or other markings on the surface.

16. Department. The Montana Department of Transportation.

17. Design Exception. The process of receiving approval from the FHWA or Preconstruction Engineer for using design elements which do not meet the criteria set forth in the *State Geometric Design Standards* as control criteria and identified in this *Manual*.

18. Design Speed. Speed selected to establish specific minimum boundaries for the geometric design elements for a particular section of highway.

19. Divided Highway. A highway with separated roadways for traffic moving in opposite directions.

20. 85th Percentile Speed. The speed at or below which 85 percent of vehicles travel on a given highway.

21. Facility. All or any portion of buildings, structures, site improvements, complexes, equipment, roads, walks, passageways, parking lots, or other real or personal property on a site.

22. Freeway. The highest level of arterial. This facility is characterized by full control of access, high design speeds, and a high level of driver comfort and safety.

23. Frontage Road. A road constructed adjacent and parallel to but separated from the highway for service to abutting property and for control of access.

24. Full Control (Access Controlled). Access is allowed only at specified interchanges or at specified public approaches. It is intended to give high priority to the uninterrupted movement of through traffic. At-grade access is inconsistent with full access control.

25. Grade Separation. A crossing of two highways, or a highway and a railroad, at different levels.

26. Heavy Vehicle. Any vehicle with more than four wheels touching the pavement during normal operation. Heavy vehicles collectively include trucks, recreational vehicles and buses.

27. High Speed. For geometric design purposes, high speed is defined as greater than 70 km/h.

28. Highway, Street or Road. A general term denoting a public way for purposes of vehicular travel, including the entire area within the right of way. (Recommended usage: *in urban areas* - highway or street, *in rural areas* - highway or road).

29. Interchange. A system of interconnecting roadways in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.

30. Intersection. The general area where two or more highways join or cross, within which are included the roadway and roadside facilities for traffic movements in that area.

31. Limited Access Control. Access is allowed at specified public roads or at private driveways as specified in legal agreements and/or deeds. The established street system is given first priority in access to the highway. When it is determined that reasonable private access cannot be provided using the public access, direct private access may be allowed at specific points.

32. Local Roads and Streets. All public roads and streets under city or county jurisdiction classified below the collector level.

33. Low Speed. For geometric design purposes, low speed is defined as 70 km/h or less.

34. National Highway System (NHS). A system of highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate highway system, other principal arterials, the Strategic Highway Network and Major Strategic Highway Network connectors.

35. National Network (Trucks). A national network of highways that allow the passage of trucks of maximum dimensions and weight.

36. Non-Accessible Route. Any pedestrian facility which contains features that make it impractical to meet all of the criteria for accessible routes.

37. Operating Speed. Operating speed, as defined by AASHTO, is the highest overall speed at which a driver can safely travel a given highway under favorable weather conditions and prevailing traffic conditions while at no time exceeding the design speed. Therefore, for low-volume conditions, operating speed equals design speed.

38. Overpass. A grade separation where the subject highway passes over an intersecting highway or railroad.

39. Pace. The 15 km/h range of speeds in which the highest number of observations is recorded.

40. Posted Speed Limit. The regulatory speed limit on a highway.

41. Ramp. A short roadway connecting two or more legs of an intersection or connecting a frontage road and main lane of a highway.

42. Recreational Vehicle. A heavy vehicle, generally operated by a private motorist, engaged in the transportation of recreational equipment or facilities; examples include campers, boat trailers, motorcycle trailers, etc.

43. Regulated Access. Access is managed through the granting of revocable permits to private parties to construct and maintain an approach. This level is intended to strike a balance between the through mobility on the highway and accessibility to adjacent land use.

44. Roadway. (General) The portion of a highway including shoulders, for vehicular use. A divided highway has two or more roadways. (Construction) The portion of a highway within limits of construction.

45. Running Speed. The moving speed of a vehicle traversing a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion).

46. Rural Areas. Those places outside the boundaries of urban areas.

47. Shared Roadway. A roadway which is open to both bicycle and motor vehicle travel.

48. Signalized Intersection. An intersection where all legs are controlled by a traffic signal.

49. Site. A parcel of land bounded by a property line or a designated portion of a public right-of-way.

50. State Highway. Any public highway planned, laid out, altered, constructed, reconstructed, improved, repaired, maintained or abandoned by the Montana Department of Transportation.

51. State Maintenance System. Public highways designated by the Transportation Commission that are to be included on the State Maintenance System. This system must include all the highways that the Department maintained on July 1, 1976.

52. Stopped Controlled Intersection. An intersection where one or more legs are controlled by a stop sign.

53. Surface Transportation Program (STP). A program which provides Federal-aid funds for any public road not functionally classified as a minor rural collector or a

local road or street. However, in Montana, this program only applies to the State's primary, secondary and urban systems.

54. Truck. A heavy vehicle engaged primarily in the transport of goods and materials, or in the delivery of services other than public transportation. For geometric design and capacity analyses, trucks are defined as vehicles with six or more tires.

55. Underpass. A grade separation where the subject highway passes under an intersecting highway or railroad.

56. Urban Areas. Those places within boundaries set by the responsible State and local officials having a population of 5000 or more.

21.1.2 Qualifying Words

1. Acceptable. Design criteria which do not meet desirable values, but yet is considered to be reasonable and safe for design purposes.

2. Criteria. A term typically used to apply to design values, usually with no suggestion on the criticality of the design value. Because of its basically neutral implication, this Manual frequently uses "criteria" to refer to the design values presented.

3. Desirable, preferred. An indication that the designer should make every reasonable effort to meet the criteria and that he/she should only use a "lesser" design after due consideration of the "better" design.

4. Guidance. This category is considered to be advisory usage, recommended but not mandatory. Deviations are allowed where engineering judgment indicates that it is appropriate. The *MUTCD* prints this criteria in italics. Typical phrases include should, should be, should be considered, should be given, etc.

5. Guideline. Indicating a design value which establishes an approximate threshold which should be met if considered practical.

6. Ideal. Indicating a standard of perfection (e.g., traffic capacity under "ideal" conditions).

7. Insignificant, minor. Indicating that the consequences from a given action are relatively small and not an important factor in the decision-making for geometric design.

8. Justified. Indicating that, even though a set of conditions or warrants are met, the recommendation meets sound engineering principles.

9. May, could, can, suggest, consider. A permissive condition. Designers are allowed to apply individual judgment and discretion to the criteria when presented in this context. The decision will be based on a case-by-case assessment.

10. Minimum, maximum, upper, lower (limits). Representative of generally accepted limits within the design community but not necessarily suggesting that these limits are inviolable. However, where the criteria presented in this context will not be met, the designer will in many cases need approval.

11. Option. This category includes procedures and devices that are allowed, but carry no recommendations or mandate. The user is free to use or refrain from their use. Typical phrases include may, may be used, may be considered, etc.

12. Policy. Indicating MDT practice which the Department generally expects the designer to follow, unless otherwise justified.

13. Possible. Indicating that which can be accomplished. Because of its rather restrictive implication, this word will not be used in this *Manual* for the application of geometric design criteria.

14. Practical, feasible, cost-effective, reasonable. Advising the designer that the decision to apply the design criteria should be based on a subjective analysis of the anticipated benefits and costs associated with the impacts of the decision. No formal analysis (e.g., cost-effectiveness analysis) is intended, unless otherwise stated.

15. Shall, require, will, must. A mandatory condition. Designers are obligated to adhere to the criteria and applications presented in this context or to perform the evaluation indicated. For the application of geometric design criteria, this *Manual* limits the use of these words.

16. Should, recommend. An advisory condition. Designers are strongly encouraged to follow the criteria and guidance presented in this context, unless there is reasonable justification not to do so.

17. Significant, major. Indicating that the consequences from a given action are obvious to most observers and, in many cases, can be readily measured.

18. Standard. (Geometrics) Indicating a design value which cannot be violated. This suggestion is generally inconsistent with geometric design criteria.

Therefore, "standard" will not be used in this *Manual* to apply to geometric design criteria (*MUTCD*). These are mandatory actions that are required without exception or with exceptions so noted under the standard heading. The MUTCD prints this criteria in bold print. Typical phrases include shall, shall mean, shall be satisfied, shall consist, etc.

19. Support. This category includes all introductory or explanatory language. It may occur before, within or after any of the above categories. The *MUTCD* prints this information in normal print. Typical phrases include is, are, warrants, considered, required, etc.

20. Target. If practical, criteria the designer should be striving to meet. However, not meeting these criteria will typically not require a justification.

21. Warrant. Indicating that some threshold or set of conditions have been met. Note that, once the warranting threshold has been met, designers are obligated to adhere to the criteria and applications presented in this context or to perform the evaluation indicated. Therefore, this Manual limits the use of this word.

21.1.3 Abbreviations

1. AASHTO. American Association of State Highway and Transportation Officials.
2. ADA. Americans with Disabilities Act.
3. ANSI. American National Standards Institute.
4. APWA. American Public Works Association.
5. AREA. American Railway Engineering Association.
6. ASCE. American Society of Civil Engineers.
7. ASTM. American Society of Testing and Materials.
8. COE. Corps of Engineers, USDOD.
9. FAA. Federal Aviation Administration.
10. FEMA. Federal Emergency Management Agency.
11. FHWA. Federal Highway Administration, USDOT.

12. HAER. Historic American Engineering Record.

13. HCM. *Highway Capacity Manual*.

14. HEC. Highway Engineering Circulars and Hydraulic Engineering Center, USDOD, COE, Davis California.

15. ITE. Institute of Transportation Engineers.

16. ISTEA. Intermodal Surface Transportation Efficiency Act of 1991.

17. MDEQ. Montana Department of Environmental Quality.

18. MDFWP. Montana Department of Fish, Wildlife and Parks.

19. MDPHHS. Montana Department of Public Health and Human Services.

20. MDT. Montana Department of Transportation.

21. MEPA. Montana Environmental Policy Act.

22. MUTCD. *Manual on Uniform Traffic Control Devices*.

23. NCHRP. National Cooperative Highway Research Program.

24. NEPA. National Environmental Policy Act.

25. NHS. National Highway System.

26. NPS. National Park Service.

27. NRHP. National Register of Historic Places.

28. OSHA. Occupational Safety and Health Administration.

29. Q. Discharge or flow; typically in cubic meters per second.

30. R/W. Right-of-way.

31. RTF. Reconstruction Trust Fund.

32. SHPO. State Historic Preservation Officer.

33. STP. Surface Transportation Program.

34. TEA-21. Transportation Equity Act for the 21st Century.

35. TRB. Transportation Research Board.

36. USDOD. United States Department of Defense.

37. USDOT. United States Department of Transportation.

38. USFS. United States Forest Service.

39. USPS. United States Postal Service.

21.1.4 Project/Plan Development

1. Alignment Review. A meeting to determine and address the major project alignment concerns.

2. Alignment Review Report. A report which provides written documentation of the horizontal and vertical alignment determinations made during the preliminary alignment review.

3. Area Project Supervisor. The person who is responsible for the design of a project.

4. Award. The acceptance by the Department of a bid.

5. CADD. Computer-aided drafting and design.

6. Consultant. A firm or person, hired by MDT to conduct special studies, design projects, and/or construction management.

7. Contractor. A company or firm hired by MDT to construct the project in the field according to the plans and specifications.

8. Designer. The person who performs the majority of the project design work and preparation of the specific plan package. Depending upon the project type, the designer may be from the Bridge Bureau, Road Design Section, Traffic Engineering Section or the Consultant.

9. Engineer's Estimate. The Department's cost estimate for construction of a project.

10. Letting (Bid Opening). The time appointed for the opening of the proposals submitted by bidders.

11. MDT Detailed Drawings. Drawings approved for repetitive use, showing details to be used where appropriate.

12. Notice to Proceed. Written notice given to the contractor to begin the contract work.

13. Plan-in-Hand Review. An in-depth office and on-site review of all project elements to ensure that all details have been satisfactorily incorporated into the construction plans and that the project is ready to advance to construction.

14. Plan-in-Hand Report. A report which provides written documentation of all decisions made during the plan-in-hand office and field review meetings.

15. Plans. The contract drawings which show the location, character and dimensions of the prescribed work, including layouts, profiles, cross sections and other details.

16. Preliminary Field Review. An initial field review meeting held after a project has been nominated to determine the major design features, and to discuss other project-related issues and any potential problems.

17. Preliminary Field Review Report. A report which provides written documentation of all major determinations made during the preliminary field review meeting.

18. Project. An undertaking by the Department for highway construction, including preliminary engineering, acquisition of right-of-way and actual construction, or for highway planning and research, or for any other work or activity to carry out the provisions of the law for the administration of highways.

19. Proposal. The written offer of the bidder to perform the work described in the plans and specifications, and to furnish the labor and materials at the prices quoted by the bidder.

20. Public Hearing/Meeting. A meeting conducted by MDT to inform the general public on the Department's proposed plan of action or design proposal.

21. Quantity Summaries. A listing of the project construction quantities which are used by both the Department and the contractor for determining the project construction costs.

22. Scope-of-Work Report. A report that identifies the proposed design elements and major design features of the subject project, provides an overview of the project improvements and lists all approved design exceptions.

23. Special Provisions. Additions and revisions to the Standard and Supplemental Specifications applicable to an individual project.

24. Specifications. The compilation of provisions and requirements for the performance of prescribed work.

25. Standard Specifications. *Standard Specifications for Road and Bridge Construction*. A book of specifications approved for general application and repetitive use.

26. Supplemental Specifications. Approved conditions and revisions to the Standard Specifications.

21.1.5 Planning

1. Annual Average Daily Traffic (AADT). The total yearly volume in both directions of travel divided by the number of days in a year.

2. Average Daily Traffic (ADT). The total traffic volumes in both directions of travel in a time period greater than one day but less than one year divided by the number of days in that time period.

3. Capacity. The maximum number of vehicles which can reasonably be expected to traverse a point or uniform section of a road during a given time period under prevailing roadway, traffic and control conditions. The time period most often used for analysis is 15 minutes.

4. Categorical Exclusion (CE). A classification for projects that will not induce significant environmental impacts or foreseeable alterations in land use, planned growth, development patterns, traffic volumes, travel patterns, or natural or cultural resources.

5. Delay. The primary performance measure on interrupted flow facilities, especially at intersections. For intersections, average delay is measured and expressed in seconds per vehicle.

6. Density. The number of passenger car equivalents (PCE) occupying a given length of lane.

7. Design Hourly Volume (DHV). The one-hour vehicular volume in both directions of travel in the design year selected for determining the highway design.

8. Directional Design Hourly Volume (DDHV). The highest of two directional volumes which combine to form the DHV.

9. Directional Distribution (D). The distribution by percent, of the traffic in each direction of travel during the DHV, ADT and/or AADT.

10. Environmental Assessment (EA). A study to determine if the environmental impacts of a project are significant, thus requiring the preparation of an EIS.

11. Environmental Impact Statement (EIS). A document which is prepared when it has been determined that a project will have a significant impact on the environment.

12. Equivalent Single-Axle Loads (ESAL's). The summation of equivalent 8165-kg single-axle loads used to combine mixed traffic to design traffic for the design period.

13. Finding of No Significant Impact (FONSI). A result of an EA that shows a project will not cause a significant impact to the environment.

14. Heavy-Vehicle Adjustment Factor. A factor used in capacity analyses to determine the equivalent flow rate, expressed in terms of passenger cars per hour per lane, of heavy vehicles (i.e., trucks, buses and RVs) in the traffic stream.

15. Level of Service (LOS). A qualitative concept which has been developed to characterize acceptable degrees of congestion as perceived by motorists.

16. New Construction. Horizontal and vertical alignment construction on new location.

17. Overlay and Widening. Work primarily intended to extend the service life of the existing facility by making cost-effective improvements to upgrade the highway. It may include full-depth pavement reconstruction for up to 50% of the project length and may include horizontal and vertical alignment revisions for up to 25% of the project length.

18. Peak-Hour Factor (PHF). A ratio of the volume occurring during the peak hour to the peak rate of flow during a given time period within the peak hour (typically, 15 minutes).

19. Project Scope of Work. The basic intent of the highway project which determines the overall level of highway improvement.

20. Rate of Flow. The equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway on which the volume is collected over a time interval less than one hour.

21. Reconstruction. Reconstruction of an existing highway mainline will typically include the addition of travel lanes, reconstruction of the existing horizontal and vertical alignment for more than 25% of the project length, and/or full-depth pavement reconstruction for more than 50% of the project length.

22. Service Flow Rate. The maximum hourly vehicular volume which can pass through a highway element at the selected level of service.

23. Truck Factor (T). A factor which reflects the percentage of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream during the DHV, ADT and/or AADT. For geometric design and capacity analysis, trucks are defined as vehicles with six or more tires.

21.1.6 Geometrics

1. Approach. A road providing access from a public way to a highway, street, road or to an abutting property.

2. Auxiliary Lane. The portion of the roadway adjoining the through traveled way for purposes supplementary to through traffic movement including parking, speed change, turning, storage for turning, weaving or truck climbing.

3. Axis of Rotation. The line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile throughout the curve.

4. Back Slope. The side slope created by the connection of the ditch bottom, upward and outward, to the natural ground.

5. Barrier Curb. A longitudinal element, typically concrete, placed at the roadway edge for delineation, to control drainage, to control access, etc. Barrier curbs may range in height between 150 mm and 300 mm with a face steeper than 1 horizontal to 3 vertical.

6. Begin Curb Return (BCR). The point along the mainline pavement edge where the curb return of an intersection meets the tangent portion.

7. Broken-Back Curves. Two crest or sag vertical curves in the same direction separated by a short section of tangent (150 m or less).

8. Buffer. The area or strip, also known as a boulevard, between the roadway and a sidewalk.

9. Bus. A heavy vehicle involved in the transport of passengers.

10. Channelization. The directing of traffic through an intersection by the use of pavement markings (including striping, raised reflectors, etc.), medial separators or raised islands.

11. Comfort Criteria. Criteria which is based on the comfort effect of change in vertical direction in a sag vertical curve because of the combined gravitational and centrifugal forces.

12. Compound Curves. A series of two or more horizontal curves with deflections in the same direction and common points of curvature.

13. Corner Island. A raised or painted island used to channel the right-turn movement.

14. Critical Length of Grade. The maximum length of a specific upgrade on which a loaded truck can operate without experiencing a specified reduction in speed.

15. Cross Slope. The slope in the cross section view of the travel lanes, expressed as a percent, based on the change in vertical compared to the change in horizontal.

16. Cross Slope Rollover. The algebraic difference between the slope of the through lane and the slope of the adjacent pavement within the traveled way or gore.

17. CS. Curve to spiral, common point of circular curve and spiral of far transition.

18. Curb Cut. Any opening in a curb where the curb section is terminated.

19. Cuts. Sections of highway located below natural ground elevation thereby requiring excavation of earthen material.

20. Depressed Median. A median that is lower in elevation than the traveled way and designed to carry a certain portion of the roadway runoff.

21. Design Vehicle. The vehicle used to determine turning radii, off-tracking characteristics, pavement designs, etc.

22. Edge of Travel Lane (ETL). The line between the portion of the roadway used for the movement of vehicles and the shoulder. The edge of travel lane is the center line, when considering opposing traffic.

23. Edge of Traveled Way (ETW). The line between the portion of the roadway used for the movement of vehicles and the shoulder regardless of the direction of travel.

24. End Curb Return (ECR). The point along the minor roadway pavement edge where the curb return of an intersection meets the tangent portion.

25. Face of Curb. A distance of 0.15 m from the back of curb.

26. Farm Field Approaches. Revocable entrances to and/or from a field.

27. Fill Slope. A slope extending outward and downward from the hinge point to intersect the natural ground line.

28. Flush Median. A paved median which is level with the surface of the adjacent roadway pavement.

29. Gore Nose. The point where the paved shoulder ends and the sodded area begins as the ramp and mainline diverge from one another.

30. Grade Separation. A crossing of two highways, or a highway and a railroad, at different levels.

31. Grade Slope. The rate of slope between two adjacent VPI's expressed as a percent. The numerical value for percent of grade is the vertical rise or fall in meters for each 100 m of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).

32. Gradient. The rate of slope between two adjacent vertical points of intersection (VPI) expressed as a percent. The numerical value for percent of grade is the vertical rise or fall in meters for each 100 m of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).

33. Heavy Vehicle. Any vehicle with more than four wheels touching the pavement during normal operation. Heavy vehicles collectively include trucks, recreational vehicles and buses.

34. Hinge Point (Freeways). The point from which the fill height and depth of cut are determined. For fills, the point is located at the intersection of the inslope extension and the fill slope. For cuts, the hinge point is located at the toe of the back slope.

35. Hinge Point (Non-Freeways). The point from which the fill height and depth of cut are determined. For fills, the point is located at the intersection of the subgrade cross slope and the fill slope for tangent sections and the low side of superelevated sections. On the high side of superelevated sections, the point is located on the fill slope at a distance from the centerline equal to the distance from the centerline to the hinge point on the tangent section. For cuts, the hinge point is located at the toe of the back slope.

36. Inslope. The side slope in a cut section created by connecting the subgrade shoulder to the ditch bottom, downward and outward.

37. Interchange. A system of ramps in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.

38. Intersection. The general area where two or more highways join or cross at grade.

39. Intersection Sight Distance (ISD). The sight distance required within the corners of intersections to safely allow a variety of vehicular access or crossing maneuvers based on the type of traffic control at the intersection.

40. Island. Channelization (raised or flush) in which traffic passing on both sides is traveling in the same direction.

41. K-Value. The horizontal distance needed to produce a 1% change in gradient.

42. Landing Area. The area approaching an intersection for stopping and storage of vehicles.

43. L_C. Length of circular curve.

44. Level Terrain. Level terrain is generally considered to be flat, and has minimal impact on vehicular performance. Highway sight distances are either long or could be made long without major construction expense.

45. L_S. Length of spiral.

46. Low-Speed Urban Streets. These are all streets within urbanized and small urban areas with a design speed of 70 km/h or less.

47. Maximum Superelevation (e_{max}). The overall superelevation control used on a specific facility. Its selection depends on several factors including overall climatic conditions, terrain conditions, type of facility and type of area (rural or urban).

48. Medial Separator. Channelization which separates opposing traffic flows, alerts the driver to the cross road ahead and regulates traffic through the intersection.

49. Median. The portion of a divided highway separating the two traveled ways for traffic in opposite directions. The median width includes both inside shoulders.

50. Median Opening. Openings in the median (raised or depressed) on divided facilities which allow vehicles to cross the facility or to make a U-turn.

51. Median Slope. The slope in the cross section view of a depressed median beyond the surfacing inslope, expressed as a ratio of the change in horizontal to the change in vertical.

52. Momentum Grade. A site where an upgrade is preceded by a downgrade, thereby allowing a truck to increase its speed on the upgrade. This increase in speed allows the designer to use a higher speed reduction in the critical length of grade figure.

53. Mountable Curb. A longitudinal element, typically concrete, placed at the roadway edge for delineation, to control drainage, to control access, etc. Mountable curbs have a height of 150 mm or less with a face no steeper than 1 horizontal to 3 vertical.

54. Mountainous Terrain. Longitudinal and transverse changes in elevation are abrupt. Benching and side hill excavation are frequently required to provide the desirable highway alignment. Mountainous terrain aggravates the performance of trucks relative to passenger cars, resulting in some trucks operating at crawl speeds.

55. No Control Intersection. An intersection where none of the legs are controlled by a traffic control device.

56. Normal Crown (NC). The typical cross section on a tangent section referenced to centerline with equal downslope to the edge of pavement.

57. Open Roadways. Open roadways are all rural facilities regardless of design speed and all urban facilities with a design speed greater than 70 km/h.

58. Painted Nose. This is the point (without width) where the pavement striping on the left side of the ramp converges with the stripe on the right side of the mainline traveled way.

59. Parking Lane. An additional lane for the parking of vehicles.

60. Passing Sight Distance. For geometric design applications, the distance required for a following vehicle to maneuver around, in the opposing traffic lane, a slower vehicle and to safely return back to the appropriate travel lane.

61. Paved Walkway. That portion of the highway section constructed adjacent to facilities without curb and gutter, with a minimum of 1 m buffer area, for use by pedestrians.

62. PC. Point of curvature (beginning of curve).

63. PCC. Point of compound curvature.

64. Performance Curves. A set of curves which illustrate the effect grades will have on the design vehicle's acceleration and/or deceleration.

65. Physical Nose. This is the point where the ramp and mainline shoulders converge.

66. PI. Point of intersection of tangents.

67. PRC. Point of reverse curvature.

68. Private Approach. An approach which allows access to and/or from a commercial, industrial or residential property.

69. Profile Grade Line. A series of tangent lines connected by vertical curves. It is typically placed along the roadway centerline of undivided facilities and at the edges of the two roadways on the median side on divided facilities.

70. PT. Point of tangency (end of curve).

71. Public Approach. A connection to and/or from a dedicated street, road, alley or other dedicated public roadway to a highway facility.

72. Raised Median. A median which contains a raised portion or island within its limits.

73. Recreational Vehicle. A heavy vehicle, generally operated by a private motorist, engaged in the transportation of recreational equipment or facilities; examples include campers, boat trailers, motorcycle trailers, etc.

74. Relative Longitudinal Slope. The relative longitudinal slope is the difference between the centerline grade and the grade of the edge of traveled way.

75. Return. The circular segment of curb at an intersection which connects the tangent portions of the intersecting legs.

76. Reverse Crown (RC). A superelevated roadway section which is sloped across the entire traveled way in the same direction and at a rate equal to the cross slope on a tangent section.

77. Reverse Curves. These are two simple curves with deflections in opposite directions which are joined by a common point or a relatively short tangent distance.

78. Roadside. A general term denoting the area adjoining the outer edge of the roadway.

79. Roadway Section. The combination of the traveled way, both shoulders and any auxiliary lanes on the highway mainline.

80. Rolling Terrain. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the desirable highway alignment. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars.

81. SC. Spiral to curve, common point of spiral and circular curve of near transition.

82. Shelf. On curbed urban facilities without sidewalks, the relatively flat area (2% slope) located between the back of the curb and the break for the fill slope or back slope.

83. Shoulder. The portion of the roadway contiguous to the traveled way for the accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses. On sections with curb and gutter, the shoulder extends to the face of the curb.

84. Shoulder Slope. The slope in the cross section view of the shoulders, expressed as a percent.

85. Shoulder Width. The width of the shoulder measured from the edge of traveled way to the intersection of the shoulder slope and surfacing inslope planes. On curb and gutter sections, the width of the shoulder is measured from the edge of the traveled way to the face of curb (a point 0.15 m in front of the back of curb).

86. Sidewalk. That portion of the highway section constructed for the use of pedestrians used in combination with curb and gutter.

87. Signalized Intersection. An intersection where all legs are controlled by a traffic signal.

88. Simple Curve. A curve that has a continuous arc of constant radius which achieve the necessary highway deflection without an entering or exiting transition.

89. Slope Offset. On curbed facilities with sidewalks, the area between the back of the sidewalk and the break for the fill slope or back slope.

90. Spiral Curve. A curvature arrangement used to transition between a tangent section and a simple curve which is consistent with the transitional characteristics of vehicular turning paths. When moving from the tangent to the simple curve, the sharpness of the spiral curve gradually increases from a radius of infinity to the radius of the simple curve.

91. Spline Curve. A curve drawn using a flexible template to meet field conditions.

92. Spline Grade. A grade developed using a flexible template to meet field conditions.

93. ST. Spiral to tangent, common point of spiral and tangent of far transition.

94. Stop Controlled Intersection. An intersection where one or more legs are controlled by a stop sign.

95. Stopping Sight Distance (SSD). The sum of the distance traveled during a driver's perception/reaction or brake reaction time and the distance traveled while braking to a stop.

96. Superelevation. The amount of cross slope or "bank" provided on a horizontal curve to help counterbalance the outward pull of a vehicle traversing the curve.

97. Superelevation Rollover. The algebraic difference (A) between the superelevated traveled way slope and shoulder slope on the outside of a horizontal curve.

98. Superelevation Runoff (L). The distance needed to change the cross slope from the end of the tangent runout (adverse crown removed) to a section that is sloped at the design superelevation.

99. Superelevation Transition Length. The distance required to transition the roadway from a normal crown section to full superelevation. Superelevation transition length is the sum of the tangent runout (TR) and superelevation runoff (L) distances.

100. Surfacing Inslope. The slope extending from the edge of shoulder to the subgrade shoulder point, expressed as a ratio of the change in horizontal to the change in vertical.

101. Symmetrical Vertical Curve. A vertical curve where the horizontal distance from the VPC to the VPI equals the horizontal distance from the VPI to the VPT.

102. Tangent Runout (TR). The distance needed to transition the roadway from a normal crown section to a point where the adverse cross slope of the outside lane or lanes is removed (i.e., the outside lane(s) is level).

103. TS. Tangent to spiral, common point of spiral and near transition.

104. Toe of Slope. The intersection of the fill slope or inslope with the natural ground or ditch bottom.

105. Top of (Cut) Slope. The intersection of the back slope with the natural ground.

106. Travel/Traffic Lane. The portion of the traveled way for the movement of a single line of vehicles.

107. Traveled Way. The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

108. Truck. A heavy vehicle engaged primarily in the transport of goods and materials, or in the delivery of services other than public transportation. For geometric design and capacity analyses, trucks are defined as vehicles with six or more tires.

109. Turn Lane. An auxiliary lane adjoining the through traveled way for speed change, storage and turning.

110. Turning Roadway. A channelized roadway (created by an island) connecting two legs of an at-grade intersection. Interchange ramps are not considered turning roadways.

111. Turning Template. A graphic representation of a design vehicle's turning path depicting various angles of turns for use in determining acceptable turning radii designs.

112. Unsymmetrical Vertical Curve. A vertical curve where the horizontal distance from the VPC to the VPI is not equal to the horizontal distance from the VPI to the VPT.

113. VPC (Vertical Point of Curvature. The point at which a tangent grade ends and the vertical curve begins.

114. VPI (Vertical Point of Intersection). The point where the extension of two tangent grades intersect.

115. VPT (Vertical Point of Tangency). The point at which the vertical curve ends and the tangent grade begins.

116. Yield Controlled Intersection. An intersection where one or more legs are controlled by a yield sign.

21.1.7 Right-of-Way

1. Abandonment. The relinquishment of the public interest in right-of-way activity thereon with no intention to reclaim or use again for highway purposes.

2. Access. A legal right to enter the through lanes of a highway facility from abutting property or public streets.

3. Access Control (Control of Access). The condition in which the right of owners or occupants of abutting land or other persons to access, light, air or view in connection with a highway is fully or partially controlled by a public authority.

4. Acquisition or Taking. The process of obtaining land and land interests.

5. Construction Permit. Temporary legal access acquired by the State, outside the permanent right-of-way boundaries, to construct the highway project according to its proper design but on property which is not owned by the State.

6. Farm Field Approaches. An approach to be used only for access to agricultural lands (farm fields) and no other purpose.

7. Full Access Control. Access is allowed only at specified interchanges or at specified public approaches. It is intended to give high priority to the uninterrupted movement of through traffic. At-grade access is inconsistent with full access control.

8. Improvement. Any dwelling, out-building, other structure or fence, or part thereof, but not including public utilities, which lie within an area to be acquired for highway purposes.

9. Limited Access Control. Access is allowed at specified public roads or at private driveways as specified in legal agreements and/or deeds. The established street system is given first priority in access to the highway. When it is determined that reasonable private access cannot be provided using the public access, direct private access may be allowed at specific points.

10. Limited Access Highway (or Facility). A portion of roadway with limited access control imposed by the governing public authority.

11. Permanent Right-of-Way. Highway right-of-way acquired for permanent ownership (fee simple title) by the State for activities which are the responsibility of the State for an indefinite period of time. The State obtains fee title to the property.

12. Permanent Right-of-Way Easements. A right for a specific purpose acquired by the State for the limited usage of property not owned by the State. Types of right-of-way easements may include maintenance easements, utility easements, storm sewer easements and roadway easements.

13. Private Approach. An approach which allows access to and/or from a commercial, industrial or residential property.

14. Public Approach. A connection to and/or from a dedicated street, road, alley or other dedicated public roadway to a highway facility.

15. Regulated Access. Access is managed through the granting of revocable permits to private parties to construct and maintain an approach. This level is intended to strike a balance between the through mobility on the highway and accessibility to adjacent land use.

16. Right of Access. The right of ingress to a highway from abutting land and egress from a highway to abutting land.

17. Right-of-Way. A general term denoting land, property or interest therein, usually a strip acquired for or devoted to a highway use.

18. Right-of-Way Appraisal. A determination of the market value of property including damages, if any, as of a specified date, resulting from an analysis of facts.

19. Right-of-Way Estimate. An approximation of the market value of property including damages, if any, in advance of an appraisal.

20. Severance Damages. Loss in value of the remainder of a parcel resulting from an acquisition.

21. Temporary Easement. Right-of-way acquired for the legal right of usage by the State to serve a specific purpose for a limited period of time (e.g., maintenance and protection of traffic during construction). Once the activity is completed, the State yields its legal right of usage and returns the land to its original condition as close as practical.

21.1.8 Roadside Safety

1. Barrier Warrant. A criterion that identifies an area of concern which should be shielded by a traffic barrier, if judged to be practical.

2. Critical Parallel Slope. A slope which cannot be safely traversed by a run-off-the-road vehicle. Depending on the encroachment conditions, a vehicle on a critical slope may overturn. For most embankment heights, a fill slope steeper than 3:1 is considered critical.

3. Edge of Travel Lane (ETL). The line between the portion of the roadway used for the movement of vehicles and the shoulder. The edge of travel lane is the center line, when considering opposing traffic.

4. Edge of Traveled Way. The line between the portion of the roadway used for the movement of vehicles and the shoulder regardless of the direction of travel.

5. Impact Angle. For a longitudinal barrier, the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicular path at impact.

6. Impact Attenuator (Crash Cushion). A device used to safely shield fixed objects or other obstacles of limited dimension from approximately head-on impacts by errant vehicles.

7. Length of Need. Total length of a longitudinal barrier, measured with respect to the centerline of roadway, needed to shield an area of concern. The length of need is measured to the last point of full-strength rail.

8. Median Barrier. A longitudinal barrier used to prevent an errant vehicle from crossing the median of a divided highway. This prevents collisions between traffic traveling in opposite directions.

9. Non-Recoverable Parallel Slope. A slope which can be safely traversed but upon which an errant motorist is unlikely to recover. The run-off-the-road vehicle will likely continue down the slope and reach its toe. For most embankment heights, if a fill slope is between 3:1 (inclusive) and 4:1 (exclusive), it is considered a non-recoverable parallel slope.

10. Parallel Slopes. Cut and fill slopes for which the toe runs approximately parallel to the flow of traffic.

11. Recoverable Parallel Slope. A slope which can be safely traversed and upon which an errant motorist has a reasonable opportunity to stop and return to the roadway. A fill slope 4:1 and flatter is considered recoverable.

12. Roadside Barrier. A longitudinal barrier used to shield obstacles located within an established clear zone. Roadside barriers include guardrail, half-section concrete median barriers, etc.

13. Roadside Clear Zone. The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of

a shoulder, a recoverable slope, a non-recoverable slope and/or a recovery area. The desired width is dependent upon traffic volumes, speeds and roadside geometry.

14. Roadside Obstacle. A general term to describe roadside features which cannot be safely impacted by a run-off-the-road vehicle. Roadside obstacles include both fixed objects and non-traversable roadside features (e.g., rivers).

15. Shy Distance. The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver, to the extent that he will change vehicular placement or speed.

16. Transverse Slope. Cut and fill slopes for which the toe runs approximately perpendicular to the flow of traffic. Transverse slopes are typically formed by intersections between the mainline and approach, median crossovers or side roads.

17. Traversable Slope. A slope or cross section in which a vehicle can safely cross. A parallel slope 3:1 or flatter is considered traversable.

18. Utility Occupancy Area. A strip of right-of-way reserved for the placement of utilities.

21.1.9 Drainage

1. Allowable Headwater. The depth or elevation of the impoundment of cross-drainage flow above which damage or some other unfavorable result could occur.

2. Bridge. A structure including supports erected over a depression or an obstruction, such as water, highway or railway, and having a tract or passageway for carrying traffic or moving loads, and having an opening measured along the center of the roadway of more than 6 m between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes.

3. Catch Basin. A structure with a sump for inletting drainage from a gutter or median and discharging the water through a conduit. In common usage it is a grated inlet with or without a sump.

4. Channel. The bed and banks that confine the surface flow of a natural or artificial stream. Braided streams have multiple subordinate channels, which are within the main stream channel.

5. Cover. The extent of soil above the crown of a pipe or culvert.

6. Cross Drainage. The runoff from contributing drainage areas both inside and outside the highway right-of-way and the transmission thereof from the upstream side of the highway facility to the downstream side.

7. Culvert. A structure which is usually designed hydraulically to take advantage of submergence to increase hydraulic capacity. A structure used to convey surface runoff through embankments. A structure, as distinguished from bridges, which is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert.

8. Design Discharge or Flow. The rate of flow for which a facility is designed.

9. Design Flood Frequency. The recurrence interval that is expected to be accommodated without exceeding the adopted design constraints. The return interval (recurrence interval or reciprocal of probability) used as a basis for the design discharge.

10. Discharge. The rate of the volume of flow of a stream per unit of time, usually expressed in cubic meters per second.

11. Floodplain. The alluvial land bordering a stream, formed by stream processes, that is subject to inundation by floods.

12. Freeboard. The vertical distance between the level of the water surface, usually corresponding to design flow and a point of interest such as a low chord of a bridge beam or specific location on the roadway grade.

13. Headwater (Hw). That depth of water impounded upstream of a culvert due to the influence of the culvert construction, friction and configuration.

14. Hydraulics. The characteristics of fluid mechanics involved with the flow of water in or through drainage facilities.

15. Hydrology. The study of the occurrence, circulation, distribution and properties of the waters of the earth and its atmosphere.

16. Intensity. The rate of rainfall upon a watershed, usually expressed in meters per hour.

17. Peak Discharge. (1) The highest value of discharge attained by a flood. (2) Maximum discharge rate on a runoff hydro-graph for a given flood event.

18. Storm Drain Inlet. A structure for capturing concentrated surface flow. May be located along the roadway, in a gutter, in the highway median or in a field.

19. Time of Concentration (T_c). The time it takes water from the most distant point (hydraulically) to reach a watershed outlet. T_c varies, but often used as constant.

21.2 INDEX

Design Manual Errata

Use this page to display known technical errata that should be used now until they are incorporated into a subsequent revision. Please note that these errata do not exist in all versions of the *Design Manual*.

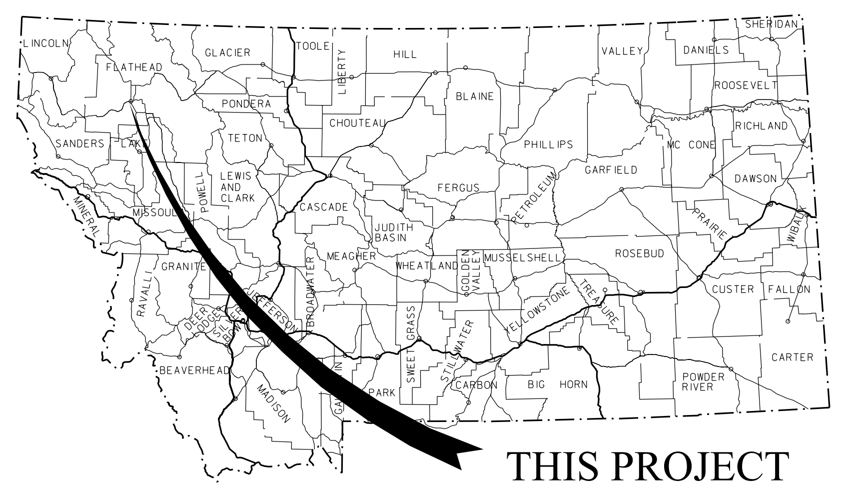
Page Updated: October 18, 2016

Chapter	Page	Location	Errata/Change	Date Listed
5	5.4(2)	Near Bottom	US Customary Example, changed 12.75 to 12.27 on example problem	July 14 2006
9	9.3(4)	Super Table	Change the maximum Radius for Metric table	January 9, 2007
4	4.3(5)	Sec 4.3.3 Item 4	Spelling - **bases** to **basis**	August 29, 2007
4	4.3(9)	Item 7 D	Change Rounding from four decimal points to two for US Customary and three for Metric	August 29, 2007
5	TOC	Sec 5.4.3 to Sec 5.4.10	Change Page numbers	August 29, 2007
5	5.1(3)	Item 5 Last paragraph	Spelling - **them determine** to **then determined**	August 29, 2007
5	5.2(19)	Sec.5.2.8 Item 2	Change **select backfill** to **special backfill**	August 29, 2007
5	5.2(18)	Sec 5.2.7		August 29, 2007
5	5.4(12)	Fig 5.4A both Frames	Remove rounding for Aggregate - Blotter - AREA(ft²)	August 29, 2007
5	5.4(12)	Fig 5.4A both Frames	Change rounding for Aggregate - Blotter – Tons/Sta from 1 to 0.1	August 29, 2007
5	5.4(12)	Fig 5.4A metric Frame	Change rounding for Aggregate – Plant Mix – m³/Sta from 0.01 to 0.1	August 29, 2007
5	5.4(12)	Fig 5.4A both Frames	Change rounding for Cement – Portland Cement – Tons/Sta from 0.1 to 0.01	August 29, 2007
5	5.4(12)	Fig 5.4A both Frames	Change rounding for Cement – Fly Ash –Tons/Sta from 0.1 to 0.01	August 29, 2007
5	5.4(17)	Item 7 second paragraph	Added to end - 4% Cement and 1% Fly Ash can be used in place of 5% cement.	August 29, 2007
5	5.4(19)	Item 2 second paragraph	Remove second paragraph	August 29, 2007
5	5.4(46)	5.4.4.6 First paragraph	Changed - **bridge decks, cattle guards** to **bridge decks, railroad crossing, cattle guards**	August 29, 2007
5	5.4(46)	Figure 5.4P	Added Text **railroad crossing,** remove title **BRIDGE END**	August 29, 2007
5	5.4(48)	Example 5.4-4	Change **1 mile (km)** to **1 mile (1.61 km)**	August 29, 2007
5	5.4(49)	Metric Example	Changed rounding to two decimals	August 29, 2007
5	5.4(49)	Sec 5.4.4.9 last paragraph	Changed **(metric) ton** to **cubic yard (cubic meter)**	August 29, 2007
5	5.4(50)	Sec 5.4.4.9 first paragraph	Changed **(metric) ton** to **cubic yard (cubic meter)**	August 29, 2007

Chapter	Page	Location	Errata/Change	Date Listed
10	10.5(2)	Figure 10.5A US Customary frame	Removed text **Minimum** and **Desirable**	August 29, 2007
10	10.5(6)	Figure 10.5C Metric frame	Change calculated K-values for Design Speed 110 & 120 from **62.8** & **72.7** to **54.4** & **62.8** respectively	August 29, 2007
12	12(21)	Figure 12-6 , Earth Cut Section, Back Slope Cut Depth	Change from **3.0M - 6.0m** to **3.0M – 4.5m**	August 29, 2007
14	14.2(14)	Figure 14.2G	Change **CLEAR ZONE = 32’** to **CLEAR ZONE = 28’**	August 29, 2007
14	14.2(15)	Section 4 C	Change **Adding 8’ to 24’** to **Adding 8’ to 20’** and **32’** to **28’**	August 29, 2007
14	14.4(12)	Unflared Design equation	$Y = \frac{L_O - L_2}{\tan 5^\circ}$ to $X = \frac{L_O - L_2}{\tan 5^\circ}$	August 29, 2007
4	4.1(2)	4.1.2.1 Item 9 d	Added note to mass diagram - d.mass diagram. **(not included in final construction plans)**	July 18, 2008
4	4.3(16)	4.3.9.1 item 6	Added note to mass diagram - d.mass diagram. **(not included in final construction plans)**	July 18, 2008
4	4.3(16)	4.3.9.1 paragraph 3	Change Construction to Preliminary - mass diagram detail sheet is included in the **preliminary** plans	July 18, 2008
12	12(4) 12(5) 12(7) 12(8) 12(12) 12(13) 12(17) 12(18) 12(23) 12(24) 12(27) 12(28)	Figure 12.-2 Figure 12.-3 Figure 12.-4 Figure 12.-5 Figure 12.-6 Figure 12.-7 Figure 12.-8 Figure 12.-9 Earth Cut Section	Clarified Inslope as a Ditch Inslope	July 18, 2008
12	12(17) 12(18)	Figure 12-5 Roadway Elements	Clarify ADT as Current, Remove Design Year – **Design Year** Traffic	July 18, 2008
12	12(23) 12(24) 12(27) 12(28)	Figure 12-7 Figure 12-8 Earth Cut Slopes Ditch Inslope 2-Lane Uncurbed	Added (Des\4:1 Min) - 6:1**(Des\4:1 Min)**	July 18, 2008
12	12(23) 12(24) 12(27) 12(28)	Figure 12-7 Figure 12-8 Earth Cut Slopes Ditch Inslope Multi-Lane Uncurbed	Added (Des\4:1 Min) - 6:1**(Des\4:1 Min)**	July 18, 2008
12	12(31)	Figure 12-9 Earth Cut Section Ditch Inslope Design Criteria Uncurbed	Change 6:1 to **4:1**	July 18, 2008
12	12(7)	Figure 12-3 Alignment Elements Min Radius 70 MPH	Changed **1820**’ to **1810**’	August 11, 2008

Sample Plans

Metric/ US Custom	Figure	Location	Errata/Change	Date Listed
US Custom	4.4D	Basis of Plan Quantities	Blotter changed from 1.8 to 1.7	Sept 10, 2007
US Custom	4.4D	Mailboxes & Mailbox Turnouts	Remove Dust Palliative and Agg. Tack	Sept 10, 2007
US Custom	4.4D	Mailboxes & Mailbox Turnouts	Add Tack = Gallons	Sept 10, 2007
US Custom	4.4D	Future Top Width	Change 2.5’ to 2.8’	Sept 10, 2007
US Custom	4.4E	Linear and Level Data	Added Example for Interstate	Sept 10, 2007
US Custom	4.4G	Typical No. 2 Widths A & A’	Change 19.1 to 19.2 and 17.3 to 17.2	Sept 10, 2007
US Custom	4.4I	Side Walk depth both typicals	Change 2.5” Cr Gravel Base to 2.5” CAC	Sept 10, 2007
US Custom	4.4I	Side walk cross slope both typicals	Change 2% to 1.5%	Sept 10, 2007
US Custom	4.4J	Both Typicals Aggregate Blotter	Change 2.3 to 2.2	Sept 10, 2007
US Custom	4.4 K-5	Surf and Add Surf Frame	Move Portland Cement and Fly Ash between Bit. Mat and Agg. Treatment	Sept 10, 2007
US Custom	4.4 K-7	Culvert Frame Item 139+90	Remove quantities for Bed. Mat, Class DD Conc. & Culvert Recap	Sept 10, 2007
US Custom	4.4 K-11	Guardrail frames note #9	Change 8.0 ft post to 7.0 ft post and add Std. Dwg. 606-11a and 606-11b	Sept 10, 2007
US Custom				Sept 10, 2007
US Custom				Sept 10, 2007
US Custom				Sept 10, 2007
US Custom				Sept 10, 2007
US Custom				Sept 10, 2007



MONTANA DEPARTMENT OF TRANSPORTATION

FEDERAL AID PROJECT STPS 503-1(4)4

Construction Project Number ⑦

GRADE, GRAVEL, PL. MIX SURF. & STRUCTURE

FOYS CANYON ROAD

(A LIMITED ACCESS FACILITY)③

FLATHEAD COUNTY

DESIGN DATA	
PRESENT 2003 A.D.T. =	210
LETTING 2004 A.D.T. =	230
DESIGN 2024 A.D.T. =	280
D.H.V. =	80
TRUCKS =	6.9%
V. =	25 mph
18 KIP ESAL'S =	65.6 DAILY
GROWTH RATE =	1.0% ANNUALLY

②

CSF = 0.99925993 (RP 3.9 TO 7.6)
⑧

LENGTH 3.6 MILES

SURFACING SOURCES - CONTRACTOR FURNISHED

1" = 10'
1" = 100'
1" = 10'

Reminders:

① *Do not use this block for "AS BUILT" projects. Use for projects that are tied for letting or projects constructed in stages or units. Leave blank or "Mask" display if not needed.*

② *Design data usually is not shown for pavement preservation projects unless grade "S" plant mix is used. For projects having two or more road segments with different design data, prepare seperate design data blocks for each segment.*

③ *Only shown for Limited Access Facilities.*

④ *Use the professional seal of the engineer in responsible charge (i.e. Highways Engineer, Bridge Engineer, Traffic & Safety Engineer, Consultant, etc.).*

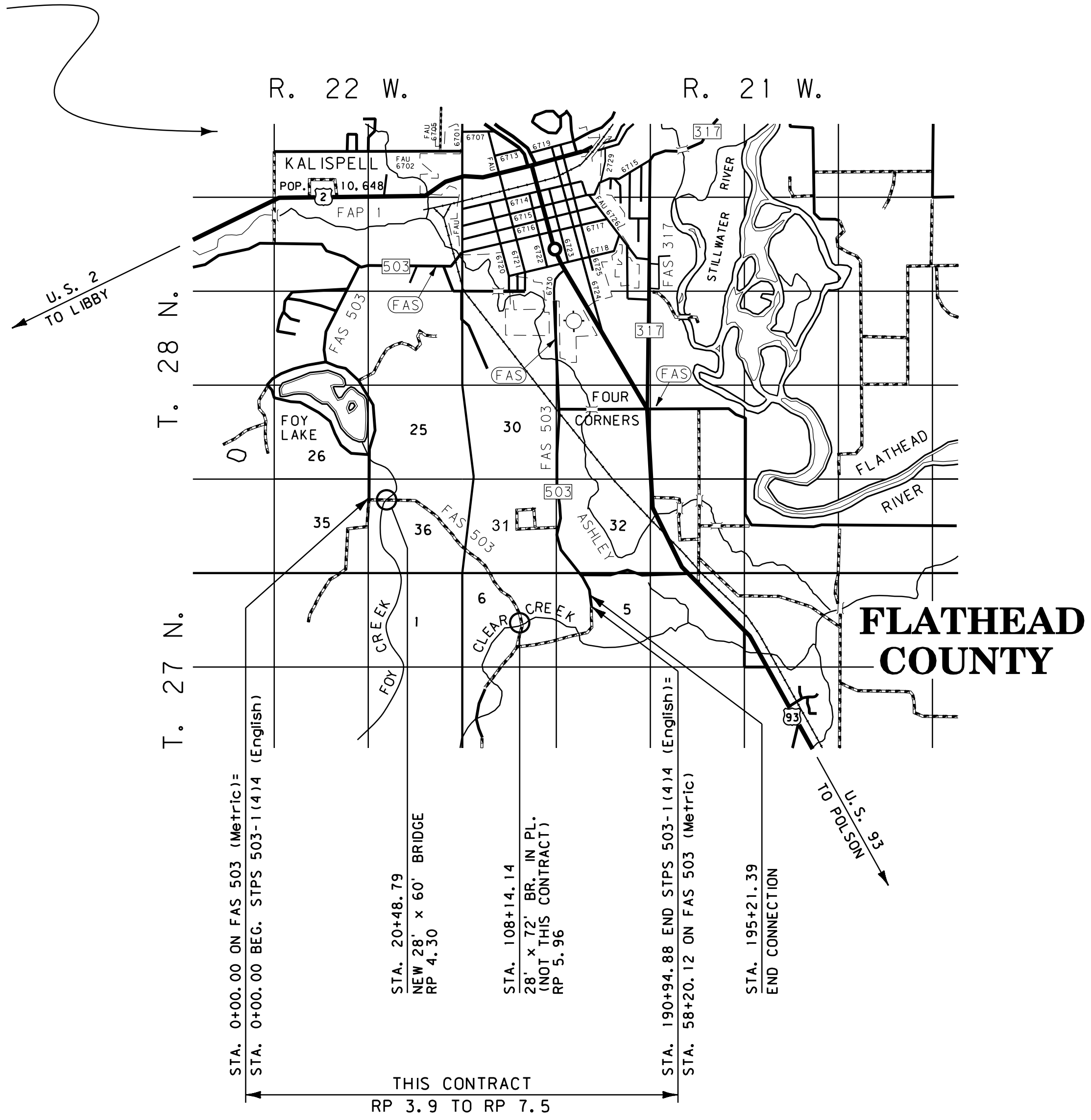
⑤ *Copy portion of county map needed from \Astro\Maps.*

⑥ *Items applicable to Consultant Projects Only.*

⑦ *Consult with The Fiscal Programming Section for appropriate Project and Agreement Numbers (also available on OPX2 Project Management System).*

⑧ *When multiple combination scale factors exist on a project, list each one of them, along with their respective RP range.*

⑤



STA. 0+00.00 ON FAS 503 (Metric)=
STA. 0+00.00 BEG. STPS 503-1(4)4 (English)

STA. 20+48.79
NEW 28' × 60' BRIDGE
RP 4.30

STA. 108+14.14
28' × 72' BR. IN PL.
(NOT THIS CONTRACT)
RP 5.96

STA. 190+94.88 END STPS 503-1(4)4 (English)=
STA. 58+20.12 ON FAS 503 (Metric)

STA. 195+21.39
END CONNECTION

THIS CONTRACT
RP 3.9 TO RP 7.5

Consultant Company Logo (Typ.) ⑥

PLANS PREPARED BY
Consultant Name, Address, and Phone Number

⑥

RELATED PROJECTS
①

ASSOCIATED PROJECT AGREEMENT NUMBERS

R/W & I.C. STPS 503-1(5)4
P.E. STPS 503-1(3)4
⑦

⑥

Consultant Name

BY ____________

DATE ____________

④ CONSULTANT SEAL XXXXPE

MONTANA
DEPARTMENT OF TRANSPORTATION

RECEIVED :

BY ____________ ____________
CONSULTANT DESIGN ENGINEER DATE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED :

____________ ____________
DIVISION ADMINISTRATOR DATE

MONTANA
DEPARTMENT OF TRANSPORTATION

APPROVED :

____________ 20 ____

MICHAEL T. TOOLEY
DIRECTOR OF TRANSPORTATION

BY ____________

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED :

____________ ____________
DIVISION ADMINISTRATOR DATE

FIG. 4.4 B

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdttle01.dgn 10/17/2016 1:02:02 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS UPN NUMBER 12345678 COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

TABLE OF CONTENTS

Reminder:

① *For GPS (State Plane coordinates) Projects, just "Control Diagram". See Fig. 4.4 F for more information.*

FIG. 4.4 C

3
2
1
MDT MONTANA DEPARTMENT OF TRANSPORTATION

c:\dgn\rmanrdttle02.dgn
10/17/2016
1:02:10 PM CPS - U1968

DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

NOTES

BASIS OF PLAN QUANTITIES

(QUANTITIES FOR ESTIMATING PURPOSES ONLY)

COMP. AGGREGATE WEIGHT = 3700 LBS. PER CUBIC YARD ⑤
COMP. WEIGHT OF PL. MIX BIT. SURF. = 3855 LBS. PER CUBIC YARD
ASPHALT CEMENT = 6.0 % OF PL. MIX BIT. SURF. ①
ASPHALT CEMENT - GRADE S - 3/4" AGG. = 5.4 % OF PL. MIX BIT. SURF. } ②
ASPHALT CEMENT - GRADE S - 1/2" AGG. = 5.8 % OF PL. MIX BIT. SURF. } ②
HYDRATED LIME = 1.4 % OF PL. MIX BIT. SURF.
ASPHALT CEMENT = 3.0 % OF RECYCLED PL. MIX (50% RAP) } ④
HYDRATED LIME = 1.4 % OF RECYCLED PL. MIX BIT. SURF. } ④
BITUMINOUS MATERIAL = 8.5 LBS. PER GAL.
DUST PALLIATIVE = 10.8 LBS. PER GAL.

AGGREGATE TREATMENT
DUST PALLIATIVE = 0.3 GAL. PER SQ. YARD
AGG TACK = 0.05 GAL. PER SQ. YARD (UNDILUTED)
TACK = 0.025 GAL. PER SQ. YARD (UNDILUTED)
SEAL = 0.40 GAL. PER SQ. YARD
COVER = 25 LBS. PER SQ. YARD
CURING SEAL = 0.2 GAL. PER SQ. YARD } ③
CTB = 3620 LBS. PER CU. YARD } ③
FLY ASH = 1.0 % OF CTB-DRY WT. } ③
PORTLAND CEMENT = 4.0 % OF CTB-DRY WT. } ③
BLOTTER = 1.7 LBS. PER SQ. FOOT } ③

Basis of Plan Quantities Reminders:

① *All grades except grade S*

② *Show for appropriate aggregate size*

③ *Applicable to projects with cement treated base (CTB)*

④ *Applicable to projects with recycled asphalt pavemet (RAP)*

⑤ *When project will use Yellowstone River Aggregate, Comp. Agg. weight = 4000 pounds per cubic yard and Pl. Mix Bit. Surf. weight = 4167 pounds per cubic yard*

APPROACHES

CONSTRUCT APPROACHES TO A 24' FINISHED TOP ON A 34' SUBGRADE UNLESS NOTED OTHERWISE IN THE PLANS.

PROVIDE THE FOLLOWING SURFACING:
0.20' PLANT MIX BITUMINOUS SURF.
0.60' CRUSHED AGGREGATE COURSE

PLANT MIX SURFACE ALL PUBLIC AND PUBLIC APPROACHES TO R/W.

QUANTITIES FOR ONE PUBLIC APPROACH:

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
CRUSHED AGGREGATE COURSE = cubic yards
ASPHALT CEMENT = tons
DUST PALLIATIVE = tons
AGG. TACK = gallons

PLANT MIX SURFACE ALL PRIVATE APPROACHES TO R/W.

QUANTITIES FOR ONE PRIVATE APPROACH:

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
CRUSHED AGGREGATE COURSE = cubic yards
ASPHALT CEMENT = tons

GRAVEL SURFACE ALL FARM FIELD APPROACHES TO R/W WITH A 12' WIDE PLANT MIX STRIP ADJACENT AND PARALLEL TO THE ROADWAY.

QUANTITIES FOR ONE FARM FIELD APPROACH:

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
CRUSHED AGGREGATE COURSE = cubic yards
ASPHALT CEMENT = tons

QUANTITIES FOR ONE FARM FIELD APPROACH: ①
40' FINISHED TOP ON A 50' SUBGRADE

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
CRUSHED AGGREGATE COURSE = cubic yards
ASPHALT CEMENT = tons

Approaches Reminder:

① *For approaches with widths differing from standard.*

APPROACHES ②

OVERLAY ALL PUBLIC APPROACHES TO R/W.

QUANTITIES FOR ONE EXISTING PUBLIC APPROACH:

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
ASPHALT CEMENT = tons
TACK = gallons

PLACE A 3' WIDE PLANT MIX STRIP ADJACENT AND PARALLEL TO ROADWAY ON ALL PRIVATE AND FARM FIELD APPROACHES.

QUANTITIES FOR ONE EXISTING PRIVATE OR FARM FIELD APPROACH:

PLANT MIX BITUMINOUS SURF. = tons
ASPHALT CEMENT = tons
TACK = gallons

Approaches Reminder:

② *For overlay projects*

COMBINATION SCALE FACTOR

ALL COORDINATES ARE STATE PLANE U.S. CUSTOMARY (SEE CONTROL DIAGRAM). CSF FROM THE BEGINNING OF PROJECT TO RP 10.0 IS 0.99945558. CSF FROM RP 10.0 TO THE END OF PROJECT IS 0.99948387.

WETLANDS

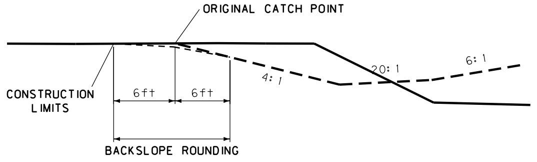
ONLY WETLANDS WITHIN THE PROJECT LIMITS HAVE BEEN DELINEATED. WETLANDS MAY EXIST BEYOND THE PROJECT LIMITS AND ANY ACTION AFFECTING SUCH WETLANDS IS THE RESPONSIBILITY OF THE CONTRACTOR.

▨ DELINEATED WETLAND AREAS
▩ IMPACTED WETLANDS

BACKSLOPE ROUNDING

BACKSLOPE ROUNDING IS NOT MEASURED FOR PAYMENT. INCLUDE THE COST OF BACKSLOPE ROUNDING IN THE UNIT PRICE BID FOR UNCLASSIFIED EXCAVATION.

BACKSLOPE ROUNDING DETAIL



PUBLIC LAND SURVEY MONUMENTS

ALL MONUMENTS TO BE REMOVED AND RELOCATED OR RESET BY STATE FORCES.

MISC. TO BE MOVED OR REMOVED BY OTHERS

ALL PRIVATELY OWNED SIGNS TO BE REMOVED BY OWNER.
ALL STATE-OWNED SIGNS TO BE MOVED BY STATE FORCES.

MAILBOXES & MAILBOX TURNOUTS

MAILBOX TURNOUTS WILL BE CONSTRUCTED AT LOCATIONS SHOWN IN THE PLANS OR AS STAKED BY THE ENGINEER.

PROVIDE THE FOLLOWING SURFACING:
MAINLINE linear feet PLANT MIX BITUMINOUS SURF.
MAINLINE linear feet CRUSHED AGGREGATE COURSE

QUANTITIES FOR ONE MAILBOX TURNOUT (FOR ESTIMATING PURPOSES ONLY):

AVERAGE LENGTH = linear feet
PLANT MIX BITUMINOUS SURF. = tons
CRUSHED AGGREGATE COURSE = cubic yards
ASPHALT CEMENT = tons
TACK = gallons

REMOVE ALL MAILBOXES AND REPLACE. PROVIDE TEMPORARY MAILBOXES. INCLUDE THE COST OF REMOVAL AND TEMPORARY MAILBOXES IN THE COST OF OTHER ITEMS.

TEMPORARY EROSION AND SEDIMENT CONTROL

① REFER TO SECTION 208 OF THE MDT DETAILED DRAWINGS FOR EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES.

② IF SITUATIONS ARE OBSERVED DURING CONSTRUCTION THAT MAY POTENTIALLY IMPACT WATER QUALITY, INCLUDING WETLAND AREAS, UTILIZE BEST MANAGEMENT PRACTICES (BMP) AND/OR TEMPORARY EROSION CONTROL MEASURES AS NECESSARY TO PROTECT THE RESOURCE.

REFER TO SECTION 208 OF THE MDT DETAILED DRAWINGS FOR EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES.

INSTALL TEMPORARY EROSION CONTROL MEASURES AS DEEMED NECESSARY BY THE ENGINEER. PAYMENT TO BE DETERMINED USING THE EROSION AND SEDIMENT CONTROL RATE SCHEDULE AND PAID UNDER MISCELLANEOUS WORK.

Temporary Erosion and Sediment Control Reminders:

① *Typical note when erosion control plans are provided.*

② *Typical note when erosion control plans are not provided (i.e. pavement preservation projects).*

LIMITED ACCESS CONTROL

THIS PROJECT IS A LIMITED ACCESS CONTROL FACILITY. OBTAIN APPROVAL FROM THE CHIEF OF THE RIGHT-OF-WAY BUREAU PRIOR TO ADDING, DELETING OR RELOCATING ANY APPROACHES.

SOILS INFORMATION

THE SOILS INFORMATION ON THE PLAN AND PROFILE SHEETS IS A BRIEF SUMMARY OF THE SOILS CLASSES. TO OBTAIN THE COMPLETE SOILS INFORMATION CONTACT THE MDT GEOTECHNICAL SECTION AT (406) 444-6281.

DO NOT DISTURB

WATER VALVE 35' RIGHT OF STA. 4+30
PROPERTY PINS LEFT OF CENTERLINE FROM STA. 2+80 TO 43+61.

CONSTRUCTION NOTES

USE EXTREME CAUTION WHEN WORKING AROUND TRANSMISSION LINE POLES LOCATED LEFT OF THE FOLLOWING STATIONS:

43+00	97+95	241+29
55+97	138+91	240+32

WARP THE FILL SLOPES AROUND POWER POLES TO BE LEFT IN PLACE FROM STATION 135+00 TO 295+76 RIGHT.

FUTURE TOP WIDTH

THE FINISHED TOP WIDTH HAS BEEN INCREASED BY 2.8' TO ACCOMODATE FUTURE SURFACING.

UTILITIES

CALL THE UTILITIES UNDERGROUND LOCATION CENTER (1-800-424-5555) OR OTHER NOTIFICATION SYSTEM FOR THE MARKING AND LOCATION OF ALL LINES AND SERVICES BEFORE EXCAVATING. ALL CLEARANCES OR DEPTHS PROVIDED FOR UTILITIES ARE FROM THE EXISTING GROUND LINE.

CLEARING AND GRUBBING

CLEAR AND GRUB TO CONSTRUCTION LIMITS. INCLUDE THE COST OF CLEARING AND GRUBBING IN THE UNIT PRICE BID FOR UNCLASSIFIED EXCAVATION. ①

Clearing and Grubbing Reminder:

① *If project is an embankment in place project, change note to "EMBANKMENT-IN-PLACE".*

① APPROACHES (FOR INFORMATION ONLY)

STATION	TYPE	linear feet				EXISTING SURFACE	PROPOSED SURFACE	tons	cubic yards	REMARKS
		WIDTH	RADIUS		LENGTH, C.L. TO R/W			PLANT MIX SURF.	CRUSHED AGG. COURSE	
			LEFT	RIGHT						
28+26	PUBLIC	24	25	25		GRAVEL	USE AS IS	~	~	RT. - COUNTY ROAD
34+99	FARM FIELD	24	25	25	85	GRAVEL	PAVED 12' APRON	8	52	RT. - REBUILD APPROACH
39+71	PRIVATE	24	25	25	85	GRAVEL	PAVE TO R/W	31	52	RT.
44+20	PRIVATE	70	25	25	65	GRAVEL	PAVED 12' APRON	15	93	RT.
46+17	PUBLIC	24	25	25	70	GRAVEL	PAVE TO R/W	25	42	LT.- PHILLIPS AVENUE
48+73	PRIVATE	24	25	25	40	GRAVEL	PAVE 12' APRON INCL. VALLEY GUTTER #	8	21	LT.
50+37	PRIVATE	50	25	25	60		PAVE TO R/W	42	73	RT. - NEW APPROACH
54+57	PUBLIC	24	25	25	45	PAVED	PAVE TO R/W	15	~	LT. - JOYLAND ROAD (FAS 237)
61+26	PRIVATE	24	25	25	35	PAVED	PAVED 12' APRON	8	~	RT.
67+03	PUBLIC	24	25	25	45	GRAVEL	PAVE TO R/W INCL. VALLEY GUTTER #	15	24	LT. - ALLEY
76+31	PUBLIC	40	25	50	50	GRAVEL	PAVE TO R/W	23	46	LT. - EATON STREET
80+54	PUBLIC	80	*	*	40	PAVED	PAVE - SEE DETAIL	46	~	RT. - HURON STREET & 4TH AVENUE
86+77	PUBLIC	52	50	50	30	GRAVEL	PAVE TO RADIUS INCL. VALLEY GUTTER #	32	10	RT. - IDAHO STREET & 3RD AVENUE
93+63	PUBLIC	24	~	~	30	PAVED	USE AS IS - SEE DETAIL	~	~	RT. - CORCORAN STREET
								②	②	

* MATCH EXISTING CURB
# SEE DETAIL

Approaches Frame Reminders:

① *This frame is applicable for urban projects.*

② *Show total surfacing quantities for each type of approach in additional surfacing frame. Do not include notes for average approach quantities if this frame is used.*

SKEW DIAGRAM

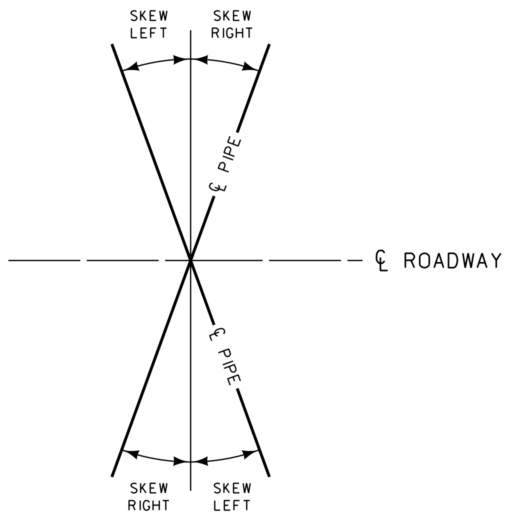


FIG. 4.4 D

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdttle03.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS	*MONTANA ROAD DESIGN MANUAL*
2		10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*		
1		1:02:18 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)	*SAMPLE PLAN SHEET (U.S. Customary Units)*

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

LINEAR AND LEVEL DATA

CENTERLINE COORDINATE TABLE

STATION	DESCRIPTION	N OR Y COORDINATE	E OR X COORDINATE	REMARKS
496+56.79	POT	30,060.7634	31,311.6190	BEG. PROJECT
532+60.70	PC	29,639.2195	32,325.9760	
538+55.31	PI	29,569.6670	32,493.3696	
544+45.67	PT	29,535.9649	32,671.4191	
582+45.64	TS	29,320.5904	33,809.4419	
584+45.64	SC	29,309.7782	33,869.4335	
588+62.14	PI	29,285.6480	33,994.0746	
592+72.28	CS	29,296.5438	34,120.5615	
594+72.28	ST	29,300.9906	34,181.3573	
625+64.01	PC	29,377.9330	35,120.5705	
629+92.32	PI	29,388.5917	35,250.6790	
634+19.03	PT	29,379.7885	35,380.9262	
690+56.00	POT	29,263.8895	37,095.6955	END PROJECT

BENCH MARKS

STATION	LOCATION	DESCRIPTION	ELEVATION
MAINLINE			
0+00.00	60.0 ft LT.	PROJECT POST	3,322.98
9+84.25	98.4 ft LT.	IRON PIN	3,399.07
19+68.50	90.4 ft LT.	IRON PIN	3,448.14
24+73.49	158.0 ft LT.	SPIKE IN POWER POLE	3,594.63
32+92.16	824.7 ft RT.	USCGS BRASS CAP C-81	3,530.51
42+65.09	105.3 ft LT.	IRON PIN	3,344.42
49+21.26	97.6 ft LT.	IRON PIN	3,361.10
COUNTY ROAD			
0+98.43	51.3 ft RT.	IRON PIN	3,344.25
8+20.21	63.9 ft RT.	IRON PIN	3,352.76
16+40.42	54.7 ft RT.	IRON PIN	3,315.12

BEARING SOURCE

① BEARINGS SHOWN ON THESE PLANS WERE COMPUTED FROM AS–BUILTS PROJECT FHP 51–2(1). FROM PT STA. 3576+81.56 TO TS STA. 3661+81.82 THE BEARING IS S 00 ° 50'00" W.

② BEARINGS SHOWN ON THESE PLANS WERE COMPUTED FROM SOLAR OBSERVATION. FROM CONTROL POINT 53B TO CONTROL POINT 53A THE BEARING IS S 23 ° 50'00" W.

③ THE BEARING SOURCE IS NAD 83–1992.
④

LEVEL DATUM SOURCE

①② U.S.C. & G.S. BENCH MARK
BRASS CAP STAMPED "4405 BUTTE"
1000.0' LT. OF STA. 412+64.99
ELEVATION 4,407.51'

① IRON PIN
100' RT. OF STA. 0+00.00
ASSUMED ELEVATION 3,280.84'

①② LEVEL DATUM IS BASED ON A U.S.C. & G.S. BENCH MARK WHICH IS LOCATED ABOUT 3.4 mi SOUTHWEST ALONG NORTHERN PACIFIC RAILWAY FROM THE STATION AT BILLINGS, 7.0' WEST OF 3RD POLE SOUTHWEST OF RP 3, 38.0' SOUTHEAST OF SOUTHEAST RAIL, 242.0' NORTHEAST OF CENTERLINE OF A ROAD CROSSING, 77.0' NORTHWEST OF CENTERLINE OF U.S. HIGHWAY 10 & 12, 2.0' NORTHWEST OF A WHITE WOODEN WITNESS POST. ABOUT 3' BELOW LEVEL OF TRACKS & ABOUT LEVEL WITH HWY., ON TOP OF 5⁄8" COPPER WEIGHTED ROD DRIVEN TO A DEPTH OF 3.0' AND IS ENCASED IN A 6" TILE WHICH PROJECTS 6", A DISK, STAMPED "G 483 1957" ELEV. = 3,168.99'. (1981 ADJUSTED)

③ LEVEL DATUM SOURCE IS NAVD 88

Reminders:

① *For projects utilizing conventional survey*

② *For projects utilizing control traverse*

③ *For projects utilizing global positioning system (GPS)*

④ *Bearing source may be either NAD 83-1992 or NAD 83-1999. List the one applicable to the project.*

⑤ *When the work on one set of lanes extends a greater distance then the other lanes, the linear data for each set of lanes should be shown separatley in the linear data.*

LENGTH OF ROADWAY		2 LANE RURAL	38,043.24 ft
LENGTH OF BRIDGE		2 LANE RURAL	316.08 ft
TOTAL LENGTH OF	NH–BR 5–1(5)7	2 LANE RURAL	38,359.32 ft
LENGTH OF ROADWAY	IN ROOSEVELT COUNTY	2 LANE RURAL	1,781.56 ft
LENGTH OF BRIDGE	IN ROOSEVELT COUNTY	2 LANE RURAL	475.13 ft
LENGTH OF ROADWAY	IN RICHLAND COUNTY	2 LANE RURAL	1,685.83 ft
LENGTH OF BRIDGE	IN RICHLAND COUNTY	2 LANE RURAL	475.13 ft
TOTAL LENGTH OF	STPS 262–1(5)3	2 LANE RURAL	4,417.65 ft
LENGTH OF ROADWAY	4 LANE URBAN		14,762.37 ft
LENGTH OF ROADWAY	4 LANE RURAL		657.68 ft
LENGTH OF ROADWAY	2 LANE RURAL		855.51 ft
TOTAL LENGTH OF	URBAN ROADWAY		14,762.37 ft
TOTAL LENGTH OF	RURAL ROADWAY		1,513.19 ft
TOTAL LENGTH OF	4 LANE ROADWAY		15,420.05 ft
TOTAL LENGTH OF	2 LANE ROADWAY		855.51 ft
TOTAL LENGTH OF	STPP–STPU 29–4(7)84		16,275.56 ft
LENGTH OF ROADWAY	4 LANE URBAN		6,379.13 ft
LENGTH OF ROADWAY	4 LANE RURAL		56,677.72 ft
LENGTH OF ROADWAY	URBAN (NOT THIS CONTRACT)		606.17 ft
LENGTH OF BRIDGE	RURAL		78.02 ft
TOTAL LENGTH OF	URBAN		6,985.30 ft
TOTAL LENGTH OF	RURAL		56,755.74 ft
TOTAL LENGTH OF	IR 15–5(83)270		63,741.04 ft
		WESTBOUND	
LENGTH OF ROADWAY		RURAL	31,196.10 ft
LENGTH OF ROADWAY		RURAL	316.70 ft
TOTAL LENGTH OF IM	90–7(86)354	RURAL	31,512.8 ft
⑤		EASTBOUND	
LENGTH OF ROADWAY		RURAL	31,213.62 ft
LENGTH OF ROADWAY		RURAL	317.22 ft
TOTAL LENGTH OF IM	90–7(86)354	RURAL	31,530.84 ft

FIG. 4.4 E

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdttle04.dgn 10/17/2016 1:02:26 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

① CONTROL TRAVERSE ABSTRACT

POINT NAME/NUMBER	N OR Y COORDINATE	E OR X COORDINATE	POINT ELEVATION	LOCATION AND DESCRIPTION
445-A	10,000.0000	10 000.0000	3,194.90	2" ALUMINUM CAP & 5/8" REBAR MARKED 445A 3,930.0 ft SW OF HOGANS SLOUGH CROSSING I-90, ON THE CENTERLINE OF THE MEDIAN AT STA. 530+00.00
445-B	11,092.0449	11,581.0351	3,188.34	2" ALUMINUM CAP & 5/8" REBAR MARKED 445B 2,009.2 ft SW OF HOGANS SLOUGH CROSSING I-90 ON THE CENTERLINE OF THE MEDIAN AT STA.549+20.80
445-C	11,682.8018	12,694.1381	3,185.94	2" ALUMINUM CAP & 5/8" REBAR MARKED 445C 781.0 ft SW OF HOGANS SLOUGH CROSSING SOUTH FRONTAGE RD. AND 28.0 ft SOUTH OF THE CENTERLINE OF SOUTH FRONTAGE RD. ON THE SHOULDER SLOPE
445-W	12,745.2549	12,451.6181	3,184.64	NAIL SET IN CENTERLINE OF PAVEMENT ON OVERLAND AVE. 1,185.0 ft SW OF PEACHTREE RD. ON OVERLAND AVE.
445-X	13,978.0860	14,168.0089	3,177.73	2" ALUMINUM CAP & 5/8" REBAR MARKED 445X 690.0 ft SOUTH OF KING AVE. ON OVERLAND AVE. IN THE MEDIAN ISLAND NEAR THE QUALITY INN
445-Y	15,020.0499	14,028.0879	3,179.44	NAIL SET IN NORTH PARKING LANE OF HENESTA DR. PAVEMENT 200.0 ft WEST OF 20TH ST. WEST
445-Z	14,725.2539	14,477.4751	3,176.35	2" ALUMINUM CAP & 5/8" REBAR MARKED 445Z 430.0 ft WEST OF THE INTERSECTION OF KING AVE. AND CARBON ST. AT THE END OF ACCESS ROAD, NEAR UTILITY POLE
446-W	14,715.9259	16,164.0341	3,171.08	2" ALUMINUM CAP & 5/8" REBAR MARKED 446W 560.0 ft EAST OF THE INTERSECTION OF KING AVE. AND S 18TH ST. WEST AND 30.0 ft SOUTH OF THE CENTERLINE OF KING AVE.
446-X	15,401.6230	17,744.3907	3,168.69	2" ALUMINUM CAP & 5/8" REBAR MARKED 446X 60.0 ft WEST OF THE INTERSECTION OF LAUREL RD. AND PARKWAY LN. ON THE MEDIAN ISLAND
446-Y	14,799.6184	18,237.4810	3,168.16	NAIL SET IN LARGE MEDIAN ISLAND 70.0 ft NE OF THE INTERSECTION OF PARKWAY LN. AND KING AVE. EAST
446-Z	14,096.2848	19,487.6775	3,160.33	2" ALUMINUM CAP & 5/8" REBAR MARKED 446Z 1,380.0 ft EAST OF THE INTERSECTION OF PARKWAY LN. AND SOUTHGATE DR. AND 40.0 ft SOUTH OF THE CENTERLINE OF SOUTHGATE DR.
446-D	12,806.2707	19,486.3009	3,160.92	2" ALUMINUM CAP & 5/8" REBAR MARKED 446D 2,780.0 ft EAST OF THE INTERSECTION OF MULLOWNEY LN. AND MIDLAND RD. AND 20.0 ft NORTH OF THE CENTERLINE OF MIDLAND RD.
446-C	12,730.9911	18,640.4222	3,164.37	2" ALUMINUM CAP & 5/8" REBAR MARKED 446C 1,940.0 ft EAST OF THE INTERSECTION OF MULLOWNEY LN. AND MIDLAND RD. AND 50.0 ft SOUTH OF THE CENTERLINE OF MIDLAND RD.
446-B	11,494.4662	17,831.8471	3,168.26	2" ALUMINUM CAP & 5/8" REBAR MARKED 446B 35.0 ft SE OF THE SE CORNER OF THE ROADWAY INN MOTEL PARKING LOT & 110.0 ft SE OF THE MOST EASTERLY LIGHT POLE ON THE SOUTH EDGE OF THE PARKING LOT
446-A	10,641.9560	16,869.8340	3,169.94	LAG BOLT SET IN CENTERLINE OF PAVEMENT ON MULLOWNEY LN. 355.0 ft SOUTH OF THE INTERSECTION OF MULLOWNEY LN. AND HOLIDAY AVE.
445-D	10,781.9803	14,247.7247	3,179.46	2" ALUMINUM CAP & 5/8" REBAR MARKED 445D 240.0 ft SOUTH OF THE INTERSECTION OF MULLOWNEY LN. AND HOLIDAY AVE. AND 2,626.0 ft WEST OF THE CENTERLINE OF MULLOWNEY LN.
445-V	11,708.4551	10,528.8379	3,193.58	2" ALUMINUM CAP & 5/8" REBAR MARKED 445V NORTH OF GABEL RD. AND ADJACENT TO HOGANS SLOUGH

NOTE - VERTICAL CONTROL ESTABLISHED FROM CONTROL TRAVERSE POINTS.

<u>Reminders</u>:

For GPS (State Plane Coordinates)

① *Revise heading to read Control Abstract.*

② *Revise heading to read Control Diagram.*

③ *Include note.*

④ *Do not connect points with lines.*

⑤ *When multiple combination scale factors exist on a project, list each one of them, along with their respective RP range.*

⑥ *Control may be based on NAD 83-1992 or NAD 83-1999. List the one applicable to the project.*

⑤ CSF = 0.99926508 (RP 445.0 TO RP 446.0)
CSF = 0.99930844 (RP 446.1 TO RP 447.0)

② CONTROL TRAVERSE DIAGRAM

SCALE: 1" = 600'

NOTE:
③ THIS PROJECT WAS SURVEYED UTILIZING THE GLOBAL POSITIONING SYSTEM (GPS). ALL COORDINATES ARE U.S. CUSTOMARY STATE PLANE NAD 83-1992. ALL SURVEY ⑥ AND STAKING REQUIRES THE USE OF A COMBINATION SCALE FACTOR (CSF).
⑤ THE CSF FOR THIS PROJECT IS 0.99925993. ALL DIMENSIONS ON THE PLANS ARE GRID DIMENSIONS AND MUST BE DIVIDED BY THE CSF TO ARRIVE AT GROUND DIMENSIONS.

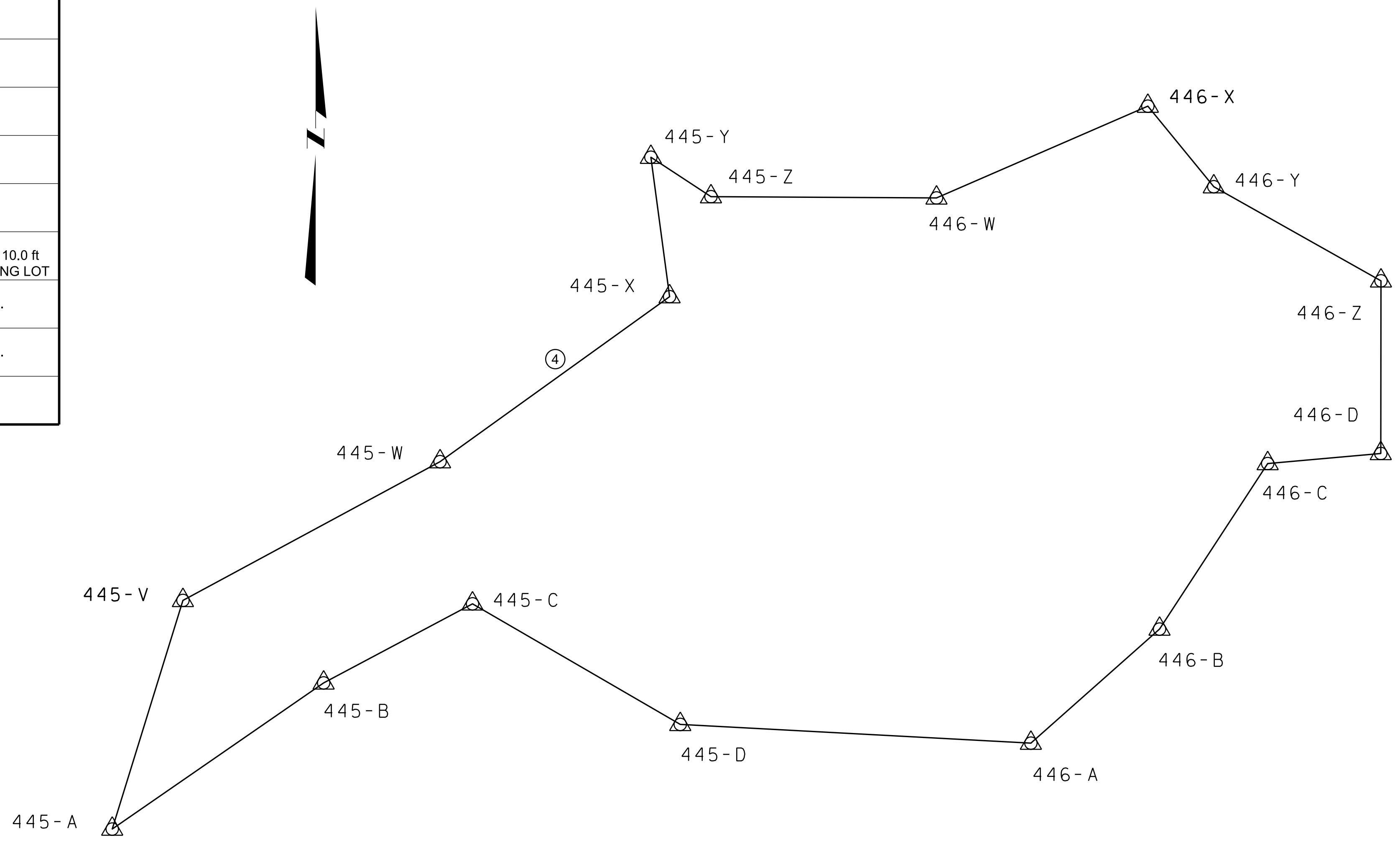


FIG. 4.4 F

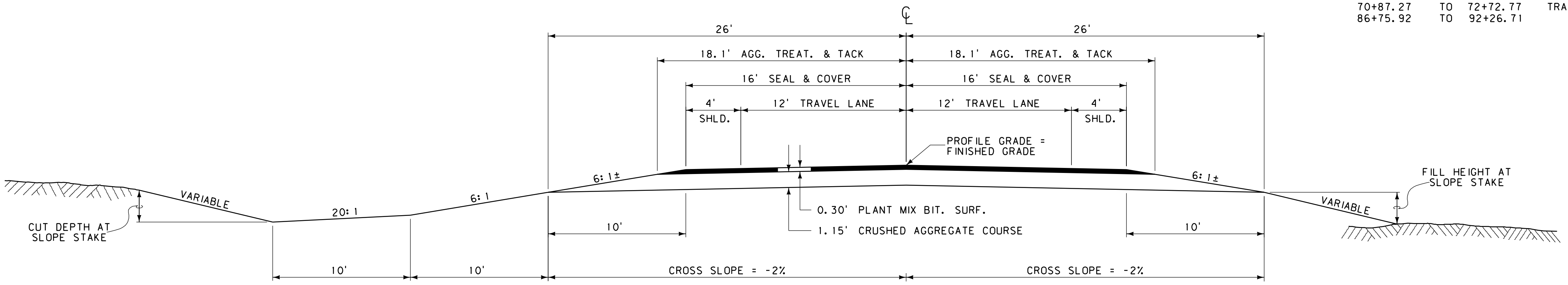
MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrdtrve01.dgn 10/17/2016 1:02:35 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	DESIGNER NAME SUPERVISOR NAME CHECKER NAME	DATE DATE DATE	ROAD PLANS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE PLAN SHEET (U.S. Customary Units)	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

(Reconstruct Project Tangent Typical Section Example)

TYPICAL SECTION NO. 1

```
32+04.49     TO  36+12.60
36+12.60     TO  38+51.10    TRANS. TYP. NO. 1 TO TYP. NO. 2
48+96.92     TO  59+89.04 BE
61+09.38 BE  TO  70+87.27
70+87.27     TO  72+72.77    TRANS. TYP. NO. 1 TO TYP. NO. 2
86+75.92     TO  92+26.71
```



SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 10

QUANTITIES									
UNIT	AGGREGATE			UNIT	BITUMINOUS MATERIAL			AGG. TREAT.	
	COVER	PLANT MIX	CR. AGG. COURSE		ASPHALT CEMENT	SEAL	TACK	DUST PALLIATIVE	AGG. TACK
AREA square feet		10.23	50.72	square yards PER STATION		356	402	402	402
cubic yards PER STATION		37.9	187.9	tons PER STATION	4.39	0.61		0.65	
tons PER STATION		73.1		gallons PER STATION			10		20
square yards PER STATION	356								

BACK SLOPES *	
0'-5'	5:1
5'-10'	4:1
10'-15'	3:1
15'-20'	2:1
OVER 20'	1.5:1

* SEE CROSS SECTIONS FOR DEVIATIONS

FILL SLOPES *	
0'-10'	6:1
10'-20'	4:1
20'-30'	3:1
OVER 30'	2:1

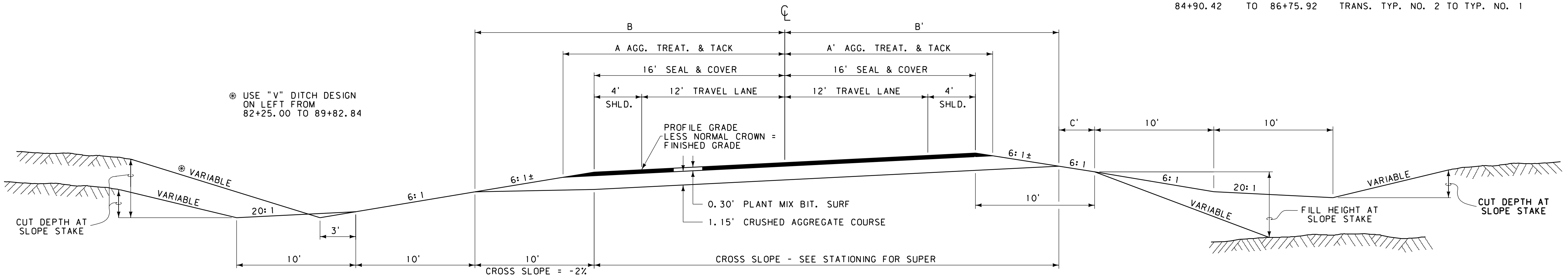
* SEE CROSS SECTIONS FOR DEVIATIONS

(Reconstruct Project Superelevated Typical Section Example)

TYPICAL SECTION NO. 2

```
38+51.10  TO  46+58.42   (7% LT.)
46+58.42  TO  48+96.92   TRANS. TYP. NO. 2 TO TYP. NO. 1
72+72.77  TO  84+90.46   (5% RT.)
84+90.42  TO  86+75.92   TRANS. TYP. NO. 2 TO TYP. NO. 1
```

⊛ USE "V" DITCH DESIGN ON LEFT FROM 82+25.00 TO 89+82.84



SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 10

FOR QUANTITIES SEE TYPICAL NO. 1

SUPER %	WIDTHS (ft)				
	A	B	A'	B'	C'
5%	18.6	26	17.4	23	3
7%	19.2	26	17.2	22	4

REVERSE DIMENSIONS FOR CURVES RT.

FIG. 4.4 G

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdtype01.dgn	DESIGNED BY	DESIGNER NAME	DATE	ROAD PLANS	MONTANA ROAD DESIGN MANUAL
2		10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE		SAMPLE PLAN SHEET (U.S. Customary Units)
1		1:02:43 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE	COUNTY NAME(S)	

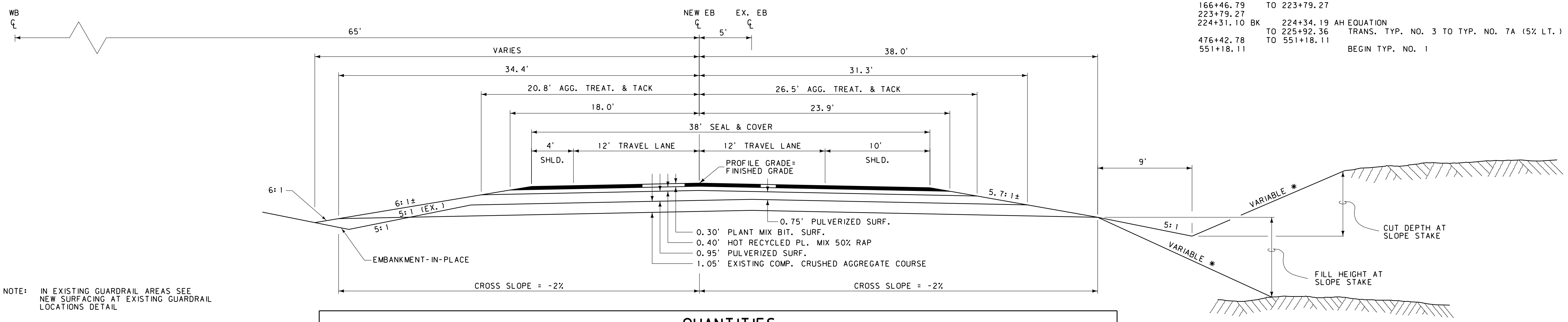
PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

(Cold Mill, Pulverize, R.A.P. Project Typical Section Example)

10/17/2016
Highways & Engineering
Division

TYPICAL SECTION NO. 3

```
137+69.69     TO 145+78.90
145+78.90     TO 147+88.90     TRANS.TYP. NO. 3 TO TYP. NO. 7 (5% RT.)
166+46.79     TO 223+79.27
223+79.27
224+31.10 BK     224+34.19 AH EQUATION
              TO 225+92.36     TRANS. TYP. NO. 3 TO TYP. NO. 7A (5% LT.)
476+42.78     TO 551+18.11
551+18.11                      BEGIN TYP. NO. 1
```



NOTE: IN EXISTING GUARDRAIL AREAS SEE NEW SURFACING AT EXISTING GUARDRAIL LOCATIONS DETAIL

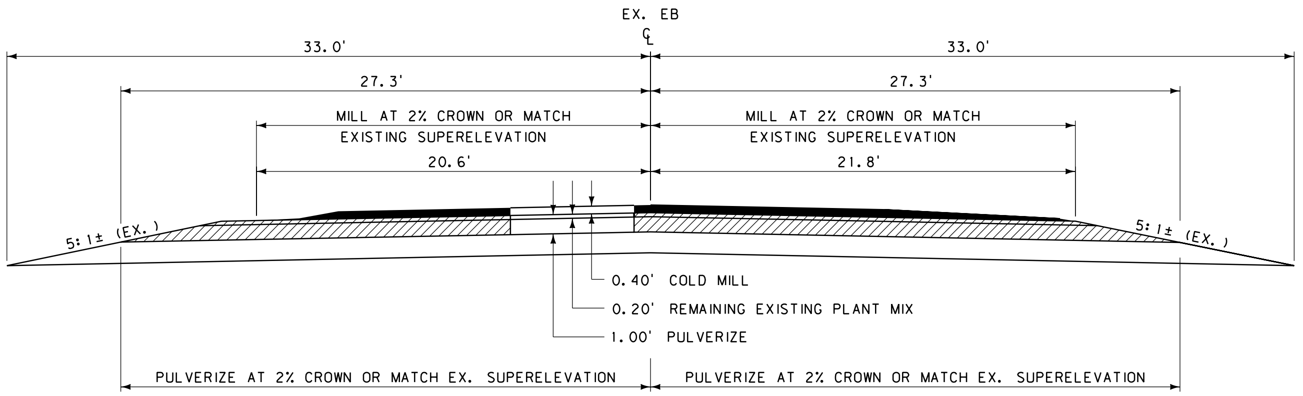
* NOTE: EXISTING CUT AND FILL SLOPES

SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 20

QUANTITIES

UNIT	AGGREGATE			UNIT	BITUMINOUS MATERIAL				AGG. TREAT.		COLD MILLING
	COVER	PLANT MIX	RECYCLED PL. MIX 50% RAP		ASPHALT CEMENT	ASPHALT CEMENT 50% RAP	SEAL	TACK	DUST PALLIATIVE	AGG. TACK	
AREA square feet		11.99	17.84	square yards PER STATION			422	1577	526	526	471
cubic yards PER STATION		44.4	66.1	tons PER STATION	4.96	3.82	0.72		0.85		
tons PER STATION		85.6	127.4	gallons PER STATION				39		26	
square yards PER STATION	422										

COLD MILL/PULVERIZE DETAIL – TYPICAL SECTION NO. 3, NO. 7, NO. 7A



EXISTING GUARDRAIL AREA

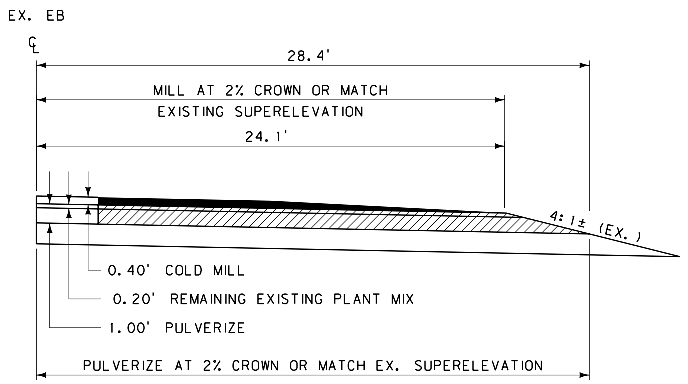


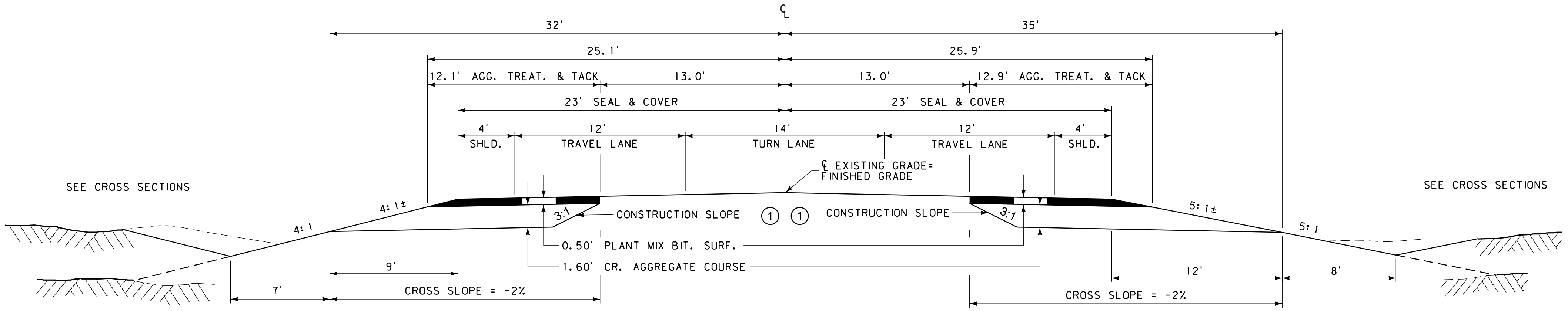
FIG. 4.4 H-1

3
2
1
serving you with pride
MONTANA DEPARTMENT
OF TRANSPORTATION
c:\dgn\rmanrdtype02.dgn
10/17/2016
1:02:52 PM CPS - U1968
DESIGNED BY DESIGNER NAME DATE
REVIEWED BY SUPERVISOR NAME DATE
CHECKED BY CHECKER NAME DATE
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.

(Notch & Widening Project Typical Section Example)

TYPICAL SECTION NO. 1

1966+10.89 TO 1993+86.48
1993+86.48 TO 1998+16.27 TRANSITION TYP. 1 TO EXISTING 28' ROADWAY



Reminder:

① *When notching & widening an existing Roadway Typical, it is impractical to achieve an exact vertical faced notch. Provide a 3:1 construction slope as shown from the bottom of the plant mix surfacing to the top of the subgrade. Draw the 3:1 slope on the cross sections as well. Quantities are calculated using this construction slope. Consult the district construction personnel to confirm that the use of a 3:1 construction slope is appropriate.*

QUANTITIES

UNIT	AGGREGATE			UNIT	BITUMINOUS MATERIAL			AGG. TREAT.	
	COVER	PLANT MIX	CR. AGG. COURSE		ASPHALT CEMENT	SEAL	TACK	DUST PALLIATIVE	AGG. TACK
AREA square feet		11.25	44.63	square yards PER STATION		511	278	278	278
cubic yards PER STATION		41.7	165.3	tons PER STATION	4.82	0.87		0.45	
tons PER STATION		80.4		gallons PER STATION			7		14
square yards PER STATION	511								

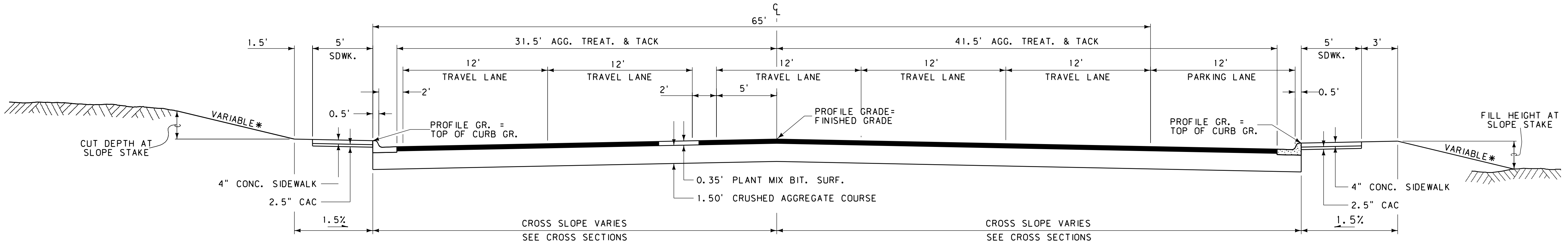
SURFACING SECTION DESIGN BASED ON
THE TOP 2 FEET OF SUBGRADE
HAVING AN R-VALUE OF 20

FIG. 4.4 H-2

(Urban Reconstruct Project Typical Section Example)

TYPICAL SECTION NO. 1

5+83.60	TO	6+75.00	
6+75.00	TO	8+22.64	TRANS. TYP. NO. 1 TO TYP. NO. 2



* CONSTRUCT CUT AND FILL SLOPES AS FLAT AS PRACTICAL (SEE CROSS SECTIONS)

SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 5

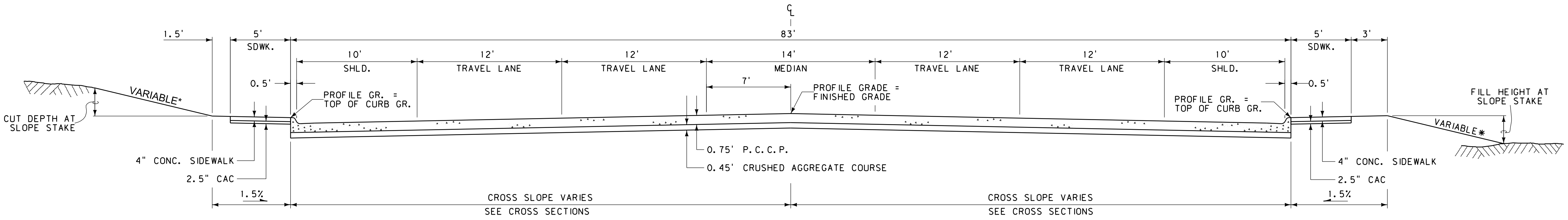
QUANTITIES

UNIT	AGGREGATE		UNIT	BIT. MATERIAL		AGG. TREAT.	
	PLANT MIX	CR. AGG. COURSE		ASPHALT CEMENT	TACK	DUST PALLIATIVE	AGG. TACK
AREA square feet	25.55	114.90	square yards PER STATION		811	811	811
cubic yards PER STATION	94.6	425.6	tons PER STATION	10.94		1.31	
tons PER STATION	182.3		gallons PER STATION		20		41

(Urban P.C.C.P. Project Typical Section Example)

TYPICAL SECTION NO. 2

16+40.42	TO	36+35.60	
36+35.60	TO	36+67.59	TRANS. TYP. NO. 2 TO TYP. NO. 3
40+19.91	TO	102+41.99	
102+41.99	TO	102+74.02	TRANS. TYP. NO. 2 TO TYP. NO. 3



* CONSTRUCT CUT AND FILL SLOPES AS FLAT AS PRACTICAL (SEE CROSS SECTIONS)

SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 15

QUANTITIES

UNIT	AGGREGATE	P.C.C.P.
	CR. AGG. COURSE	0.75'
AREA square feet	37.35	
cubic yards PER STATION	138.3	
square yards PER STATION		922.2

FIG. 4.4I

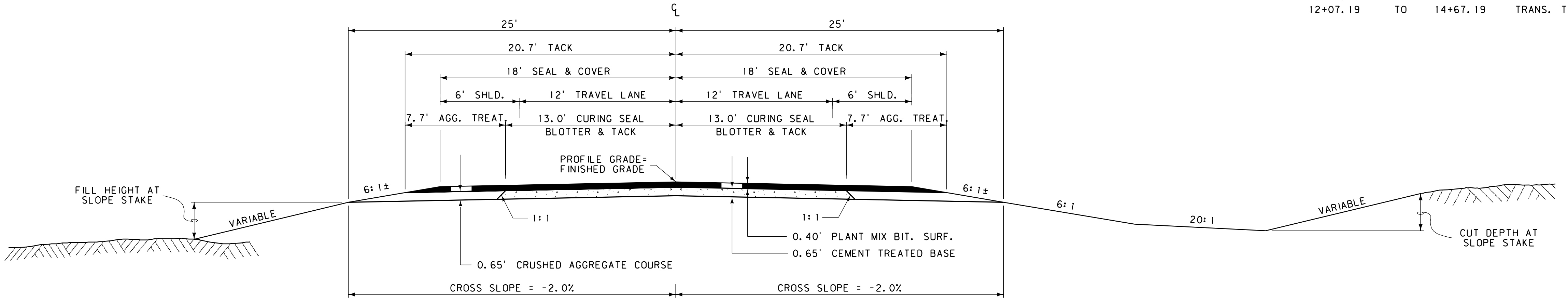
3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdtype03.dgn 10/17/2016 1:03:09 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	DESIGNER NAME SUPERVISOR NAME CHECKER NAME	DATE DATE DATE	ROAD PLANS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE PLAN SHEET (U.S. Customary Units)	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678	PROJECT NO. SHEET 999 OF 999

(Reconstruct with C.T.B. Project Typical Section Example)

TYPICAL SECTION NO. 1

AMSTERDAM RD.

8+77.19 TO 12+07.19 TRANS. P.T.W. TO TYP. NO. 1
12+07.19
12+07.19 TO 14+67.19 TRANS. TYP. NO. 1 TO TYP. NO. 2



QUANTITIES

UNIT	AGGREGATE					UNIT	BITUMINOUS MATERIAL				CEMENT	AGG. TREAT.	
	COVER	PLANT MIX	CR. AGG. COURSE	CEMENT TR. BASE	BLOTTER MATERIAL		ASPHALT CEMENT	SEAL	TACK	CURING SEAL	PORTLAND CEMENT	DUST PALLIATIVE	AGG. TACK
AREA square feet		15.48	12.38	17.32		square yards PER STATION		400	749	289		171	171
cubic yards PER STATION		57.3	45.9	64.2		tons PER STATION	6.63	0.68		0.25	5.81	0.28	
tons PER STATION		110.5	84.8	*116.1	2.2	gallons PER STATION			19				9
square yards PER STATION	400												

* FOR INFORMATION ONLY

SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 10

FILL SLOPES *	
0 - 10'	6:1
10 - 20'	4:1
20 - 30'	3:1
OVER 30'	2:1

* SEE CROSS SECTIONS FOR DEVIATIONS

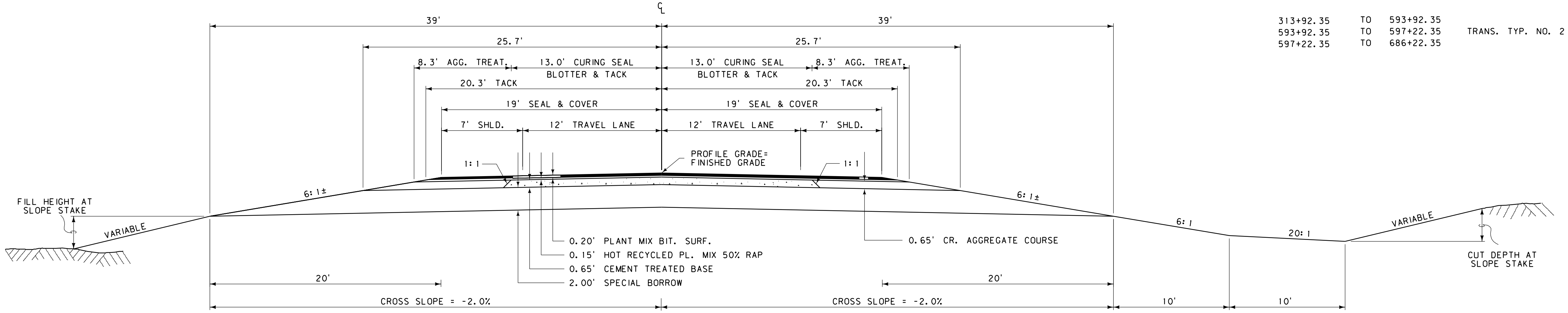
BACK SLOPES	
0 - 5'	5:1
5 - 10'	4:1
10 - 15'	3:1
15 - 20'	2:1
OVER 20'	1.5:1

* SEE CROSS SECTIONS FOR DEVIATIONS

(Reconstruct with C.T.B. & R.A.P. Project Typical Section Example)

TYPICAL SECTION NO. 2

313+92.35 TO 593+92.35
593+92.35 TO 597+22.35 TRANS. TYP. NO. 2 TO NO. 3
597+22.35 TO 686+22.35



QUANTITIES

UNIT	AGGREGATE							UNIT	BITUMINOUS MATERIAL					CEMENT		AGG. TREAT.	
	COVER	PLANT MIX	RECYCLED PL. MIX	CR. AGG. COURSE	SPECIAL BORROW	CEMENT TR. BASE	BLOTTER MATERIAL		ASPHALT CEMENT	RECYCLED A.C.	SEAL	TACK	CURING SEAL	PORTLAND CEMENT	FLY ASH	DUST PALLIATIVE	AGG. TACK
AREA square feet		7.86	6.24	13.23	129.40	17.32		square yards PER STATION			422	740	289			184	184
cubic yards PER STATION		29.1	23.1	49.0	479.3	64.2		tons PER STATION	3.37	1.34	0.72		0.25	4.64	1.16	0.30	
tons PER STATION		56.1	44.5			*116.1	2.2	gallons PER STATION				19					9
square yards PER STATION	422																

* FOR INFORMATION ONLY

SURFACING SECTION DESIGN BASED ON THE TOP 2 FEET OF SUBGRADE HAVING AN R-VALUE OF 5

FIG. 4.4 J

3
2
1
MDT serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
c:\dgn\rmanrdtype04.dgn
10/17/2016
1:03:19 PM CPS - U1968
DESIGNED BY DESIGNER NAME DATE
REVIEWED BY SUPERVISOR NAME DATE
CHECKED BY CHECKER NAME DATE
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.
SHEET 999 OF 999

SUMMARY

⑤ GRADING * (For Uncl. Exc. Projects with Borrow)

STATION ①	cubic yards UNCL. EXC. ⑥	UNCL. BORROW	EMB.+ ②	ROADBED COMPAC-TION ③	REMARKS
8+14.14					
	4,515		4,515		
20+73					
	2,859		2,859		
25+89					
	151,404		151,404		
92+42					
	178,420		178,420		
150+36					
	173,169		173,169		
196+06					
	25,990		25,990		
221+72		④			
	182,713	86,415	269,128		
287+48.36					
TOTAL	719,070	86,415	# 805,485	840,571	

* SEE MASS DIAGRAM FOR DISTRIBUTION OF GRADING QUANTITIES
# FOR INFORMATION ONLY

Grading Frame Reminders:

① *Balance points are rounded to nearest foot.*

② *Volumes are adjusted by shrink factor. THIS IS NOT A BID ITEM. Include footnote for clarity.*

③ *Add this column on projects where roadbed compaction has been requested as a bid item. Show only the project total.*

④ *Borrow or excess is shown in last balance. (Typically)*

⑤ *All quantities shown in grading frame will be reflected in the mass diagram.*

⑥ *If excavation is adjusted for rock, both actual and adjusted excavation columns must be shown, actual exc. for pay quantities, adj. exc. to determine borrow/excess volumes. (See chapter 5.)*

⑤ GRADING * (For Uncl. Exc. Projects with Excess Excavation)

STATION ①	cubic yards UNCL. EXC. ⑥	EXCESS EXC.	EMB.+ ②	REMARKS
8+14.14				
	4,515		4,515	
20+73				
	2,859		2,859	
25+89				
	151,404		151,404	
92+42				
	178,420		178,420	
150+36				
	173,169		173,169	
196+06				
	25,990		25,990	
221+72		④		
	269,128	86,415	182,713	
287+48.36				
TOTAL	805,485	# 86,415	# 719,070	

* SEE MASS DIAGRAM FOR DISTRIBUTION OF GRADING QUANTITIES
# FOR INFORMATION ONLY

ADDITIONAL GRADING (For Uncl. Exc. Projects)

STATION ② FROM	TO	cubic yards ① INCL. IN ROADWAY UNCL. EXC. ③	EMB.+ ④	ADD. UNCL. EXC. ⑤	REMARKS
7+15.72	8+15.72	20	210		CONN. TO P.T.W.
8+15.72	287+48.36		⑨ 28,780		TOPSOIL REPLACEMENT + 35%
11+32			175		PUBLIC APP. RT.
41+57				20	OUTLET DT. LT.
50+20			560		FARM FIELD APP. LT.
56+56				25	INLET & OUTLET DITCHES
56+66			⑥ 20		DITCH BLOCK LT.
66+60	101+05		⑦ 8,005		SUBEXCAVATION REPLACEMENT
76+69.95	77+69.95		270		MAILBOX TURNOUT RT.
77+07		105	250		PRIVATE APP. RT.
135+33	140+33		⑦ 1,910		DIGOUT REPLACEMENT
187+34	192+24			110	IRRIGATION DITCH RELOCATION RT.
188+65	199+80		⑦ 4,330		MUCK EXCAVATION REPLACEMENT
199+15.35	202+15.35		1,590		MCS SCALE SITE
250+82				20	INLET DT. RT.
250+82	254+27			145	GRADE TO DRAIN LT.
255+91	262+51	⑩ 2,615			SUBEXCAVATION
266+08	278+88		1,190		GUARDRAIL EMBANKMENT WIDENING LT.
287+48.36	288+48.36	85	145		CONN. TO P.T.W.
SUBTOTAL		~	~	⑧ 320	

Additional Grading Frame Reminders:

① *Round to nearest 5 cubic yards, use 5 cubic yards as a minimum.*

② *Quantities are added to mainline earthwork volumes. This is a listing of the entries in the run as added quantities.*

③ *Material is usable for embankment construction.*

④ *Volumes are adjusted by shrink factor. THIS IS NOT A BID ITEM.*

⑤ *Material is unusable for embankment construction.*

⑥ *All embankment quantities should be added to mainline quantities.*

⑦ *Uncl. exc. material is acceptable as replacement material-special borrow is not required. (In this example.)*

⑧ *Add add. exc. to the mainline uncl. exc. for project total on estimate. This quantity is not reflected in the mass diagram.*

⑨ *Topsoil replacement quantities are adjusted by project shrink factor. Only the project total is shown.*

⑩ *Material is usable for embankment construction. (In this example.)*

SUBEXCAVATION * (For Uncl. Exc. Projects)

STATION FROM	TO	cubic yards UNCL. EXC.	SPECIAL BORROW ② ⑤	REMARKS
137+01	147+64	6,259	6,780	
255+91	262+47	# 2,615 ④		
TOTAL ③ ①		6,259	6,780	

* SEE DETAIL SHEET
# INCLUDED IN ROADWAY QUANTITIES

Subexcavation Frame Reminders:

① *Add subexcavation quantities to uncl. exc. for project total on estimate.*

② *Volumes are not adjusted by shrink factor.*

③ *If subexc. material is unusable for embankment construction, show quantity in this frame only. (Do not show on mass diagram.)*

④ *If subexc. material may be used in roadway embankments, show quantity in add. grading frame in the "included in roadway" column and "#" the quantity shown in subexc. frame with note stating "included in roadway quantities".*

⑤ *Include a special provision for in-place measurement needed for special borrow.*

SURFACING

STATION FROM	TO	linear feet GROSS	NET	+	-	FOR	square yards RECYCLE ASPHALT PAVEMENT	gals RECYCLE AGENT	REMARKS
387+13.91									
421+13.91	423+22.83				210.00	BRIDGE			
516+07.32	518+37.27				230.00	BRIDGE			
	706+65.94	31,952.03	31,512.03				82,712	16,796	WESTBOUND DRIVING LANES ONLY
387+13.91									
421+13.91	423+22.83				210.00	BRIDGE			
516+07.32	518+37.27				230.00	BRIDGE			
	706+65.94	31,952.03	31,512.03				82,712	16,796	EASTBOUND DRIVING LANES ONLY
TOTAL		63,904.06	63,024.06	~	880.00		165,424	33,592	

FIG. 4.4 K-1

3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrdsume01.dgn	DESIGNED BY	DESIGNER NAME	DATE
2		10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE
1		1:03:27 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

SUMMARY

SURFACING

(Overlay Project Example)

STATION		linear feet				FOR	tons	AGGREGATE		BITUMINOUS MATERIAL			REMARKS
		GROSS	NET	+	-		HYDRATED LIME	sq. yards	tons	tons		gals	
FROM	TO							COVER TYPE ①	PLANT MIX BIT. SURF. GRADE S NV - ③	ASPHALT CEMENT PG ②	SEAL CRS-2P	TACK SS-1	
752+17.72													
758+89.67	760+12.67				123.00	BRIDGE							
777+82.94	777+53.64			29.30		EQUATION							
	777+53.64	2,535.92	2,442.22					19,586	1,986	107.2	33.3	544	TYP. SEC. NO. 1
SUBTOTAL		2,535.92	2,442.22	29.30	123.00		~	19,586	1,986	107.2	33.3	544	NORTH BOUND
752+07.58													
758+77.13	760+00.13				123.00	BRIDGE							
777+70.60	777+53.64			16.96		EQUATION							
	777+53.64	2,546.06	2,440.02					19,568	1,967	106.2	33.3	536	TYP. SEC. NO. 2
SUBTOTAL		2,546.06	2,440.02	16.96	123.00		~	19,568	1,967	106.2	33.3	536	SOUTH BOUND
777+53.64													
788+86.19	788+87.99				1.80	EQUATION							
837+47.77	837+53.67				5.91	EQUATION							
	846+72.74	6,919.10	6,911.39					52,908	5,303	286.4	89.9	1,448	TYP. SEC. NO. 3
SUBTOTAL		6,919.10	6,911.39	~	7.71		~	52,908	5,303	286.4	89.9	1,448	NORTH BOUND & SOUTH BOUND
TOTAL		9,460.09	9,352.51	23.13	130.71		130	92,062	9,256	499.8	156.5	△ 2,528	

△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

Surfacing Frame Reminders:

① *Determine cover type and insert in heading. Use Type I for all rural areas. Use Type II in areas where higher ADT and turning movements are a concern. Determine proper usage during Plan-in-Hand.*

② *Provide appropriate asphalt cement grading, i.e. PG 64-28. Use appropriate percentage of asphalt cement based on aggregate size. (See chapter 5.)*

③ *Provide appropriate pl. mix. aggregate size; either 1/2" or 3/4".*

SUBEXCAVATION *

(For Emb.-in-Place Projects)

STATION		cubic yards ①		REMARKS
FROM	TO	EMB. IN PLACE	SPECIAL BORROW ③	
137+01	147+64	4,951	5,472	
TOTAL ②		# 4,951	5,472	

* SEE DETAIL SHEET
# INCLUDED IN GRADING FRAME

Subexcavation Frame Reminders:

① *Volumes are not adjusted by shrink factor.*

② *Place quantity in grading frame as a line item and "#" the quantity shown in subexc. frame with note stating "included in grading frame."*

③ *Include a special provision stating in-place measurement of special borrow.*

GRADING

(For Emb.-In-Place Projects)

STATION ①		cubic yards		REMARKS
FROM	TO	EXC. ②	③ EMB. IN PLACE	
8+14.14	287+48.36	1,246	6,270	
			④ 2,616	DISPOSAL OF UNSUITABLE MATERIAL
			⑤ 1,635	TOPSOIL REPLACEMENT
		210	9,240	ADDITIONAL GRADING
			4,951	SUBEXCAVATION
TOTAL		# 1,456	⑥ 24,712	

FOR INFORMATION ONLY

Grading Frame Reminders:

① *Show project total only - no balances will be designated.*

② *Excavation is not a bid item - material is available for embankment construction. Include footnote for clarity.*

③ *Volumes are not adjusted by a shrink factor.*

④ *Disposal of unsuitable roadway excavation is measured and paid as Emb.-in-Place (Poor material not accounted for in subexcavation or other quantities).*

⑤ *Topsoil replacement volumes are not adjusted by shrink factor.*

⑥ *See section 5.2.7 of Rd. Design Manual and explanation of 25,000 cubic yards limit.*

ADDITIONAL GRADING

(For Emb.-in-Place Projects)

STATION		cubic yards ⑥			REMARKS
		INCL. IN GRAD. FRAME		ADD. EMB. IN PLACE # ③	
FROM	TO	EXC. ①	② EMB. IN PLACE		
7+15.72	8+15.72	20	155		CONN. TO P.T.W.
11+32			130		PUBLIC APP. RT.
41+57				20	OUTLET DT. LT.
50+20			420		FARM FIELD APP. LT.
56+56				25	INLET & OUTLET DITCHES
56+66			20		DITCH BLOCK LT.
66+60	101+05		④ 2,660		SUBEXCAVATION REPLACEMENT
76+69.95	77+69.95		195		MAILBOX TURNOUT RT.
77+07		105	185		PRIVATE APP. RT.
135+33	140+33		④ 1,415		DIGOUT REPLACEMENT
187+34	192+24			110	IRRIGATION DITCH RELOCATION RT.
188+65	199+80		④ 1,895		MUCK EXCAVATION REPLACEMENT
199+15.35	202+15.35		1,175		MCS SCALE SITE
250+82				20	INLET DT. RT.
250+82	254+27			145	GRADE TO DRAIN LT.
266+08	278+88		885		GUARDRAIL EMBANKMENT WIDENING LT.
287+48.36	288+46.36	85	105		CONN. TO P.T.W.
SUBTOTAL		⑤ 210	⑤ 9,240	⑦ 320	

③ # EXCAVATION QUANTITIES-MATERIAL UNSUITABLE FOR ROADWAY EMBANKMENTS

Additional Grading Frame Reminders:

① *Excavation is not a bid item - material is available for embankment construction.*

② *Volumes are not adjusted by shrink factor.*

③ *Material is unusable for embankment construction.*

④ *Excavated material obtained from roadway template or uncl. borrow source is acceptable as replacement material - special borrow is not required. (In this example.)*

⑤ *Subtotals are shown in grading frame to be added to mainline quantities, with remark "Additional Grading."*

⑥ *Round to nearest 5 cubic yards, use 5 cubic yards as a minimum.*

⑦ *Add additional Emb.-in-Place to the mainline Emb.-in-Place for the project total on estimate. This quantity is not used to determine amount of borrow required.*

FIG. 4.4 K-2

3	serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume02.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS	*MONTANA ROAD DESIGN MANUAL*
2			10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*		*SAMPLE PLAN SHEET (U.S. Customary Units)*
1			1:03:36 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)	

PROJECT LOCATION DESCRIPTION		PROJECT NO.	
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999	OF 999

SUMMARY

SURFACING

(Overlay Project Example)

STATION		linear feet				FOR	tons	AGGREGATE					BITUMINOUS MATERIAL				AGG. TREATMENT		REMARKS
		GROSS	NET	+	-		HYDRATED LIME	sq. yards	tons		cubic yards		tons			gals	tons	gals	
FROM	TO							COVER TYPE ②	PLANT MIX BIT. SURF. GRADE S - ④	HOT RECYCLE P.M.S. 50% RAP	CRUSHED AGG. COURSE	SHOULDER GRAVEL	ASPHALT CEMENT PG ③	HOT RECYCLE A.C. PG ③	SEAL CRS- 2P	TACK SS-1	DUST PALLIATIVE	AGG. TACK SS-1	
2178+95.22																			
2328+98.82	0+00.00			232,898.82		PROJECT EQUATION													
	160+07.91	-201,887.30	31,011.52					108,527	10,648	15,327			575.0	459.8	184.5	6,423			TYP. NO. 1
						ADDITIONAL SURFACING		2,137	239	85	1,139	20	13.0	2.6	3.6	34	0.6	17	
SUBTOTAL		-201,887.30	31,011.52	232,898.82	~		368	110,664	10,887	15,412	1,139	20	587.9	462.4	188.1	6,457	0.6	17	CUSTER COUNTY
160+07.91	479+36.55	31,928.64	31,928.64					111,737	10,964	15,781			592.1	473.4	190.0	6,613			TYP. NO. 1
479+36.55																			
479+75.92	480+00.00				24.08	EQUATION													
	480+00.00	63.45	39.37					141	13	19			0.7	0.6	0.2	8			TRANS. TYP. NO. 1 TO TYP. NO. 2
480+00.00	526+39.99	4,639.99	4,639.99					14,208	1,401	2,028		184	75.7	60.8	24.2	852			TYP. NO. 2
526+39.99	532+03.51	563.52	563.52					1,684	172	252			9.3	7.6	2.9	106			TYP. NO. 3
532+03.51	533+08.50	104.99	104.99					335	37	55			2.0	1.7	0.6	23			TRANS. TYP. NO. 3 TO EX. B.E.
						ADDITIONAL SURFACING		512	269	651	2,952	366	14.6	19.5	0.9	82	5.4	164	
SUBTOTAL		37,300.59	37,276.51	~	24.08		443	128,617	12,856	18,786	2,952	550	694.3	563.6	218.8	7,684	5.4	164	FALLON COUNTY
TOTAL		-164,586.71	68,288.03	232,898.82	24.08		811	239,281	23,743	34,198	4,091	570	1,282.2	1,026.0	406.9	△ 14,141	6.0	181	

△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

ADDITIONAL SURFACING (INCLUDED IN SURFACING FRAME)

(Overlay Project Example)

STATION		linear feet				FOR	tons	AGGREGATE					BITUMINOUS MATERIAL				AGG. TREATMENT		REMARKS
		GROSS	NET	+	-		HYDRATED LIME	sq. yards	tons		cubic yards		tons			gals	tons	gals	
FROM	TO							COVER TYPE ②	PLANT MIX BIT. SURF. GRADE S - ④	HOT RECYCLE P.M.S. 50% RAP	CRUSHED AGG. COURSE	SHOULDER GRAVEL	ASPHALT CEMENT PG ③	HOT RECYCLE A.C. PG ③	SEAL CRS- 2P	TACK SS-1	DUST PALLIATIVE	AGG. TACK SS-1	
664+04.46	664+39.27					CONNECTION		1,148	11				0.6		2.0	3			
733+95.44	736+65.13					MAILBOX TURNOUT		493	9	11		13	0.5	0.3	0.8	5			RT.
761+00.17	763+69.86					MAILBOX TURNOUT		493	9	11		7	0.5	0.3	0.8	5			LT.
11+90.00	12+55.65					CULVERT REPLACEMENT				63	184			1.9		8	0.6	17	0.35' HOT RECYCLE PMS ON 1.45' CAC
12+22.81						STOCKPASS			6		3		0.3						
						2 - PUBLIC APPROACHES			46				2.5			13			
						2 - PRIVATE APPROACHES		①	53		94		2.9		①				
						16 - FARM FIELD APPROACHES			106		858		5.7						
SUBTOTAL		~	~	~	~		~	2,134	240	85	1,139	20	13.0	2.5	3.6	34	0.6	17	CUSTER COUNTY
352+09.43	352+89.32					CULVERT REPLACEMENT				77	225			2.3		10	0.6	17	0.35' HOT RECYCLE PMS ON 1.45' CAC
389+62.71	389+96.67					CULVERT REPLACEMENT				33	95			1.0		4	0.3	10	0.35' HOT RECYCLE PMS ON 1.45' CAC
400+18.48	401+45.61					CULVERT REPLACEMENT				122	358			3.7		16	1.0	30	0.35' HOT RECYCLE PMS ON 1.45' CAC
412+26.48	412+67.00					CULVERT REPLACEMENT				39	114			1.2		5	0.3	10	0.35' HOT RECYCLE PMS ON 1.45' CAC
475+72.18	480+19.69					TRUCK TURNOUT		512	44	60		98	2.4	1.8	0.9	25			LT.
504+67.36	505+69.39					CULVERT REPLACEMENT				93	220			2.8		11	0.7	20	0.40' HOT RECYCLE PMS ON 1.40' CAC
529+52.76	533+08.50					DIGOUT REPLACEMENT				228	893			6.8			2.5	77	
						2 - PUBLIC APPROACHES			42				2.3			12			
						2 - PRIVATE APPROACHES		①	57		102		3.1		①				
						19 - FARM FIELD APPROACHES			126		944		6.8						
						GUARDRAIL WIDENING						268							
SUBTOTAL		~	~	~	~		~	512	269	652	2,951	336	14.6	19.6	0.9	△ 83	5.4	164	FALLON COUNTY

△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

Surfacing Frame and Additional Surfacing Frame Reminders:

① *Discuss the need to apply seal and cover to approaches, turnouts, etc., during the Plan-in-Hand.*

② *Determine cover type and insert into heading. Use Type I for all rural areas. Use Type II in urban areas where higher ADT and turning movements are a concern. Determine proper usage during the Plan-in-Hand.*

③ *Provide appropriate asphalt cement grading, i.e. PG 64-28. Use appropriate percentage of asphalt cement, based on aggregate size and %RAP. (See chapter 5.)*

④ *Provide appropriate pl. mix aggregate size; either 1/2" or 3/4".*

FIG. 4.4 K-3

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume03.dgn 10/17/2016 1:03:44 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

SUMMARY

SURFACING

(Reconstruction Project Example)

STATION		linear feet				FOR	tons	AGGREGATE					BITUMINOUS MATERIAL			AGG. TREATMENT		REMARKS
		GROSS	NET	+	-		HYDRATED LIME	sq. yards	tons	cubic yards			tons		gals	tons	gals	
FROM	TO							COVER TYPE ②	PLANT MIX BIT. SURF. GRADE D #	CRUSHED AGG. COURSE	SPECIAL BORROW ④	TRAFFIC GRAVEL	ASPHALT CEMENT PG ③	SEAL CRS- 2P	TACK SS-1	DUST PALLIATIVE	AGG. TACK SS-1	
37+71.60	45+43.88	772.28	772.28					2,928	800	827	3,702		48.0	5.0	90	5.7	172	TYPICAL SECTION NO. 2
45+43.88	49+94.50	450.62	450.62					1,807	484	497	2,160		29.0	3.1	54	3.4	104	TYPICAL SECTION NO. 4
49+94.50	51+87.96	193.44			193.44	BRIDGE												
51+87.96	52+82.94	94.98	94.98					380	101	105	455		6.1	0.6	11	0.8	22	TYPICAL SECTION NO. 4
						ADDITIONAL SURFACING		1,280	528	789			31.7	2.2	47	2.4	74	
TOTAL		1,511.32	1,317.88	~	193.44		* 27	6,395	1,913	2,218	6,317	131	* 114.8	10.9	△ 202	* 12.3	* 372	

GRADE D COMMERCIAL
* FOR INFORMATION ONLY, INCLUDE IN COST OF GRADE D COMMERCIAL PL. MIX SURFACING
△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

ADDITIONAL SURFACING

(INCLUDED IN SURFACING FRAME) *(Reconstruction Project Example)*

STATION		linear feet				FOR	tons	AGGREGATE					BITUMINOUS MATERIAL			AGG. TREATMENT		REMARKS
		GROSS	NET	+	-		HYDRATED LIME	sq. yards	tons	cubic yards			tons		gals	tons	gals	
FROM	TO							COVER TYPE ②	PLANT MIX BIT. SURF. GRADE D #	CRUSHED AGG. COURSE	SPECIAL BORROW	TRAFFIC GRAVEL	ASPHALT CEMENT PG ③	SEAL CRS- 2P	TACK SS-1	DUST PALLIATIVE	AGG. TACK SS-1	
34+76.32	37+71.60	295.28	295.28			CONNECTION TO P.T.W.		939	262	279			15.7	1.6	30	1.9	57	TRANS. TYP. NO. 1 TO TYP. NO. 2
	37+71					MAILBOX TURNOUT RT.			17	25			1.0		1			
						3 - PRIVATE APPROACHES		①	84	152			5.0	①				
						3 - FARM/FIELD APPROACHES			21	148			1.3					
						GUARDRAIL WIDENING			55	109			3.3		7			
						RADIUS CONN. WITH HWY 200		341	89	77			5.3	0.6	9	0.6	17	
SUBTOTAL		~	~	~	~		~	1,280	528	790	~	~	* 31.6	2.2	△ 47	* 2.5	* 74	

GRADE D COMMERCIAL
* FOR INFORMATION ONLY, INCLUDE IN COST OF GRADE D COMMERCIAL PL. MIX SURFACING
△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

<u>Surfacing Frame and Additional Surfacing Frame Reminders</u>:

① *Discuss the need to apply seal and cover to approaches, turnouts, etc., during the Plan-in-Hand.*

② *Determine cover type and insert into heading. Use Type I for all rural areas. Use Type II in areas where higher ADT and turning movements are a concern. Determine proper usage during the Plan-in-Hand.*

③ *Provide appropriate asphalt cement grading, i.e. PG 64-28.*

④ *Include special borrow in surfacing frame when quantities are shown on the typical section.*

FIG. 4.4 K-4

SUMMARY

SURFACING

(Reconstruct with CTB Project Example)

STATION		linear feet				FOR	tons	AGGREGATE							BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT		REMARKS
								sq. yards	tons			cubic yards			tons			gals	tons		tons	gals	
FROM	TO	GROSS	NET	+	-		HYDRATED LIME	COVER TYPE ②	PLANT MIX BIT. SURF. GR. S - ④	PLANT MIX BIT. SURF. GRADE C	BLOTTER SAND SURF. GRADE 4	CEMENT TREATED BASE	CRUSHED AGG. COURSE	TRAFFIC GRAVEL	ASPHALT CEMENT PG ③	SEAL CRS- 2P	CURING SEAL CRS-2	TACK SS-1	PORTLAND CEMENT	FLY ASH	DUST PALLIATIVE	AGG. TACK SS-1	
71+52.23	77+41.90	589.67	589.67					3,826	722		29	1,471			39.0	6.5	3.2	202	106.5	26.6			TYPICAL NO. 1
77+41.90	80+25.36	283.46	283.46					1,622	312		12	640			16.8	2.8	1.4	87	46.3	11.6			TRANS. TYP. NO. 1 TO TYP. NO. 3
80+25.36	102+60.37	2,235.01	2,235.01					11,406	2,179		87	4,503			117.7	19.4	9.7	608	326.0	81.5			TYPICAL NO. 3
102+60.37	104+72.97	212.60	212.60					1,194	225		9	463			12.2	2.0	1.0	63	33.5	8.4			TRANS. TYP. NO. 3 TO TYP. NO. 4
104+72.97	119+39.14	1,466.17	1,466.17					8,792	1,673		66	3,424			90.3	14.9	7.4	468	247.9	62.0			TYPICAL NO. 4
119+39.14	120+84.38	145.24	145.24					942	183		7	326	65		9.9	1.6	0.8	49	23.6	5.9	0.2	7	TRANS. TYP. NO. 4 TO TYP NO. 5
120+84.38	154+19.95	3,335.57	3,335.57					23,590	4,616		146	7,173	3,033		249.3	40.1	16.2	1,174	519.3	129.8	9.8	298	TYPICAL NO. 5
154+19.95	159+02.23	482.28	482.28					3,077	597		19	902	438		32.2	5.2	2.0	150	65.3	16.3	1.4	43	TRANS. TYP. NO. 5 TO TYP. NO. 6
159+02.23	167+29.00	826.77	826.77					4,009	801		22	1,116	752		43.3	6.8	2.5	195	80.8	20.2	2.4	74	TRANS. TYP. NO. 6 TO TYP. NO. 7
167+29.00																							
567+63.45	568+68.45				105.00	NEW STRUCTURE																	
	579+39.63	41,210.63	41,210.63					173,820	34,706		912	45,573	37,380		1,874.1	295.5	100.9	8,275	3,299.5	824.9	121.6	3,674	TYPICAL NO. 7
						ADDITIONAL SURFACING			1,910	115			5,023		103.2						14.3	89	
TOTAL		50,787.40	50,787.40	~	105.00		671	232,278	47,924	115	1,309	65,591	46,691	9,456	2,588.0	394.8	145.1	△ 11,271	4,748.7	1,187.2	149.7	4,185	

△ FOR INFORMATION ONLY - BASED ON ONE APPLICATION

ADDITIONAL SURFACING (INCLUDED IN SURFACING FRAME)

(Reconstruct with CTB Project Example)

STATION		linear feet				FOR	tons	AGGREGATE							BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT		REMARKS
								sq. yards	tons			cubic yards			tons			gals	tons		tons	gals	
FROM	TO	GROSS	NET	+	-		HYDRATED LIME	COVER TYPE ②	PLANT MIX BIT. SURF. GR. S - ④	PLANT MIX BIT. SURF. GRADE C	BLOTTER SAND SURF. GRADE 4	CEMENT TREATED BASE	CRUSHED AGG. COURSE	TRAFFIC GRAVEL	ASPHALT CEMENT PG ③	SEAL CRS- 2P	CURING SEAL CRS-2	TACK SS-1	PORTLAND CEMENT	FLY ASH	DUST PALLIATIVE	AGG. TACK SS-1	
42+00.00	82+18.50					PEDESTRIAN WALKWAY				115			198										
						GUARDRAIL WIDENING			131				254		7.1								
						MAILBOX TURNOUTS (2)			13				24		0.7								
						14 - PUBLIC APP. - 24' WIDE		①	446				814		24.1	①					9.1	57	
						8 - PUBLIC APP. - 40' WIDE			368				646		19.8						5.2	32	
						30 - PRIVATE APPROACHES			774				1,389		41.8								
						26 - FARM FIELD APPROACHES			177				1,694		9.6								
424+54.00						STOCKPASS			1				4		0.1								
SUBTOTAL		~	~	~	~		~	~	1,910	115	~	~	5,023	~	103.2	~	~	~	~	~	14.3	89	

Surfacing Frame and Additional Surfacing Frame Reminders:

① *Discuss the need to apply seal and cover to approaches, turnouts, etc., during the Plan-In-Hand.*

② *Determine cover type and insert into heading. Use Type I for all rural areas. Use Type II in areas where higher ADT and turning movements are a concern. Determine proper usage during the Plan-In-Hand.*

③ *Provide appropriate asphalt cement grading, i.e. PG 64-28. Use appropriate percentage of asphalt cement based on aggregate size. (See chapter 5.)*

④ *Provide appropriate pl. mix aggregate size; either 1/2" or 3/4".*

FIG. 4.4 K-5

SUMMARY

① BITUMINOUS PAVEMENT REMOVAL

STATION		square yards	REMARKS
		BIT. PAVEMENT REMOVAL	
FROM	TO		
138+10.00	139+10.00	301	CONNECTION TO P.T.W.
146+08.26	147+08.26	301	BRIDGE END
148+47.70	149+47.70	301	BRIDGE END
226+08.92		215	CONNECTION TO HWY 300 LEFT
226+08.92		215	CONNECTION TO HWY 300 RIGHT
421+02.95	422+02.95	301	CONNECTION TO P.T.W.
TOTAL		1,634	

Bituminous Pavement Removal Frame Reminder:

① *Provide detail for width and depth of pavement removal.*

① COLD MILLING *

STATION		square yards	REMARKS
		COLD MILLING *	
FROM	TO		
9+70.00	10+70.00	344	CONNECTION TO P.T.W.
94+51.00	95+51.00	344	BRIDGE APPROACH
95+51.00	96+10.06	207	BRIDGE DECK
96+10.06	97+10.06	344	BRIDGE APPROACH
SUBTOTAL		1,239	STPP FUNDING
95+44.80	96+44.80	344	CONNECTION TO P.T.W.
SUBTOTAL		344	URBAN FUNDING
TOTAL		1,583	

* SEE DETAILS

Cold Milling Frame Reminder:

① *Provide detail for width and depth of cold milling.*

CLEARING & GRUBBING ①

STATION		acres	REMARKS
		CLEARING AND GRUBBING	
FROM	TO		
0+00	164+04	3.5	RIGHT SIDE ONLY
0+00	262+47	5.7	LEFT SIDE ONLY
393+70	590+55	9.6	LEFT AND RIGHT
TOTAL		18.8	

Clearing and Grubbing Frame Reminder:

① *Discuss the use of this bid item at Plan-in-Hand.*

CONCRETE LINED DITCH *

STATION		linear feet	cubic yards			square yards	REMARKS
		CONCRETE LINED DITCH	SPECIAL BACKFILL	DRAIN AGG.	BANK PROTEC-TION	GEO-MEMBRANE	
FROM	TO				TYPE 4	LIGHT	
231+22	231+35	13.0	2				DIVISION BOX
231+35	233+42	207.0	18	3.9			
233+42							INLET HEADWALL
233+68							OUTLET HEADWALL
233+68	235+55	187.0	16	3.5			
235+55							CUTOFF WALL
230+63	231+22	59.0	5		7.1	24	
235+55	235+88	33.0	3		12.8	33	
233+22	233+68	46.0	4	0.7			
TOTAL		545.0	48	8.1	19.9	57	

* SEE DETAIL SHEET

CATTLE GUARD

STATION	each				REMARKS
	CATTLE GUARD			RESET CATTLE GUARD	
	10 feet	12 feet	24 feet		
12+67				1	LEFT - RESET ON R/W LINE (24') ①
44+26		1			LEFT
75+40			1		RIGHT
117+10	1				RIGHT
145+58				1	RIGHT - RESET AT STA. 144+83 (24') ①
TOTAL	1	1	1	2	

Cattle Guard Frame Reminder:

① *Show reset cattle guard size in remarks section.*

CONCRETE DRAINAGE CHUTES

STATION	cubic yards	REMARKS
	CLASS ① CONCRETE	
12+45	4.6	LEFT
48+90	3.7	LEFT
80+53	4.2	RIGHT
TOTAL	12.5	

Concrete Drainage Chute Frame Reminder:

① *Obtain concrete class from hydraulics section.*

CHANNEL RESTORATION & FISH PASSAGE *

STATION		square yards		cubic yards						lump sum	each		REMARKS
		GEOTEXTILE PERM. EROS. CNTRL. __ SURVIVABILITY CLASS __ ③	COCONUT BLANKET	CLASS "AC" CONCRETE	CRUSHED AGG. COURSE	RANDOM RIPRAP	SPECIAL BACKFILL	STREAM-BED MATERIAL	CHANNEL EXC.	WILLOW CUTTINGS	BOULDER CLUSTERS	ROCK WEIRS	
FROM	TO					CL. 2							
194+71.37		783		28.4	16	261.2	242	112	39		8		
224+77.28		446		23.8	14	133.0	229	47	46		8		
237+52								72					FISH PASSAGE
326+10.08		470		18.4	12	140.3	163	171	118		7		
343+89	345+04		1,473					713	Δ 1,118	1		5	CHANNEL CHANGE LT. & FISH PASSAGE
TOTAL		1,699	1,473	70.6	① 42	534.5	634	1,115	203	1	23	5	

* SEE DETAIL SHEET
Δ INCLUDED IN ROADWAY QUANTITIES ②

Channel Restoration and Fish Passage Frame Reminders:

① *Add this quantity to quantity from surfacing frame and total for cost estimate.*

② *Confirm this quantity is shown in the additional grading frame for payment.*

③ *Consult with Geotechnical Section to determine Survivability and Class of Erosion Control Geotextile, based on subgrade conditions.*

FIG. 4.4 K-6

3 2 1	serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume06.dgn 10/17/2016 1:04:09 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

SUMMARY

① CULVERTS (INCLUDED IN CULVERT SUMMARY RECAP)

STATION ②	BASIC BID ITEMS											PIPE OPTIONS in		COATING *⑥	END SECTIONS ③		cubic yards				square yards	linear feet	SKEW ANGLE	CULVERT IN PL. in x ft	REMARKS
		linear feet				cubic yards					square yards														
	CULVERT PIPE in	LENGTH OF PIPE	RELAY CULVERT		REMOVE CULVERT	CULVERT EXC. **	FOUND-ATION MATERIAL	BEDDING MATERIAL	CLASS "DD" CONCRETE	CULVERT RIPRAP CLASS 1	GEOTEX-TILE #	CONCRETE STEEL - 2 2/3 x 1/2 CORR. ALUMINUM - 2 2/3 x 1/2 CORR.	CLASS OR THK.		LEFT	RIGHT	FOUND-ATION MATERIAL	BEDDING MATERIAL	CLASS "DD" CONCRETE	RANDOM RIPRAP CLASS 1	GEOTEX-TILE #	HEIGHT OF COVER			
98+43	24	108				70						24 RCP 24 CSP 24 CAP	CL.2 0.109 0.060	NONE YES NONE	FETS FETS FETS	FETS FETS FETS						4.9			DRAIN
126+41	36	132				100						36 RCP 42 CSP ~	CL.2 0.109	NONE YES	FETS FETS	FETS FETS						6.6	5° RT.		DRAIN
139+90	58 1/2 x 36 ④	96				5						58 1/2 x 36 RCPA 60 x 46 CSPA ⊕ ~	CL.3 0.138	NONE YES	FETS 2:1 BEVEL	FETS 2:1 BEVEL		72	4.6	9.0		3.3			DRAIN
141+17	18	50				5						18 RCP 18 CSP 18 CAP	CL.2 0.079 0.060	NONE NONE NONE	FETS FETS FETS	FETS FETS FETS						1.6			APP. LT.
175+30	42	96				15						42 RCP 57 x 38 CSPA ~	CL.2 0.109	NONE YES	FETS 2:1 BEVEL	FETS 2:1 BEVEL						3.3			DRAIN
201+05	96	4 x 116				1160		534	21.2	46.0		~ 96 CSP ⊕ ~	0.109	YES	2:1 ◪	2:1 ◪		534	21.4	46.0		4.6			DRAIN 4 PIPES
202+99	36	98				40						~ 36 CSP ~	0.109	YES	FETS	FETS						3.9			DRAIN
203+94	18	50				5						18 RCP 18 CSP 18 CAP	CL.2 0.079 0.060	NONE NONE NONE	FETS FETS FETS	FETS FETS FETS						2.0			APP. LT.
301+51	18 IRR.	142			71.9	100						~ 18 CSP IRR. ~	0.079	YES	SQ.	SQ.						4.9	10° LT.	18 x 71.9 CSP IRR.	IRR.
303+97	112 x 75 IRR.	96				255		115	7.1	13.8		~ 112 x 75 CSPA IRR. ⊕ ~	0.079	YES	SQ.	2:1 BEVEL		115	7.1	13.8		4.9			IRR. SEE DETAIL FOR INLET
307+19	24 IRR.	102				5						24 RCP IRR. 24 CSP IRR. ~	CL.2 0.079	NONE YES	FETS FETS	FETS FETS						4.9			IRR.
310+43	73 x 45 IRR.	2 x 102				280		156	9.8	24.7		73 x 45 RCPA IRR. 81 x 59 CSPA IRR. ⊕ ~	CL.3 0.079	NONE YES	FETS 2:1 BEVEL	FETS 2:1 BEVEL		156 187	9.8 8.9	24.7 18.4		5.9			IRR. DOUBLE PIPE
310+70					64.0	40																		24 x 64.0 CSP	
312+07	24	52				5						24 RCP ~ ~	CL.2	NONE	FETS	FETS						9.8		24 x 95.1 RCP	DRAIN LENG. 12 FT LT. & 40 FT RT.
315+29	24	30				5						~ 24 CSP ~	0.079	NONE	RACET	RACET						1.6		24 x 100.1 RCP	APP. RT. LENG. 18 FT LT. & 12 FT RT.
323+65	18	6	6		6.6	5						18 RCP ~ ~	CL.2	NONE	~	FETS						4.6		18 x 98.4 RCP	DRAIN RELAY FETS LT. NEW FETS RT.
331+14	18	28	46		45.9	60						18 RCP ~ ~	CL.2	NONE	~	~						4.6		18 x 45.9 RCP	APP. LT. RELAY & LENGTHEN
350+00	18 SIPHON	100				50						~ 18 CSP SIPHON ~	0.079	YES	Δ	Δ						5.9			SIPHON
351+97	18 SIPHON	122				60						18 RCP SIPHON 18 CSP SIPHON ~	CL.2 0.079	NONE YES	Δ Δ	Δ Δ						4.9			SIPHON
360+01	144 ⑤	124				240	133	220	10.9	23.0	205	~ 144 SSPP ~	0.109	YES	2:1 ◪	2:1 ◪	133	220	10.9	23.0	205	12.1			DRAIN
TOTAL	~	~	52		188.4	~	133	1,097	53.6	116.5	205	~	~	~	~	~	~	~	~	~	~	~	~	~	

STABILIZATION
* SEE STANDARD SPEC. SECT. 709.04 ⑥
** FOR INFORMATION ONLY
◪ STEP BEVEL
Δ SEE SIPHON DETAIL SHEET
⊕ 3" x 1" CORR.

Culverts Frame Reminders:

① *This frame used when culvert material type is optional - culvert summary recap must accompany this frame.*

② *Pipe location rounded to nearest foot*

③ *List new end sections only - end sections included in length of new pipe for payment.*

④ *Arch pipes listed as span X rise*

⑤ *SSPP diameters in inches. SSPPA sizes in feet and inches.*

⑥ *Coating specifications could include 709.04, 709.05, or 709.12 in accordance with recommendations from the Materials Bureau and Hydraulics Section.*

FIG. 4.4 K-7

SUMMARY

① CULVERTS

STATION ②	linear feet											COATING * ④	END SECTIONS ③		linear feet			cubic yards				linear feet	SKEW ANGLE	CULVERT IN PL. in x ft	REMARKS
	RCP						RCP IRRIGATION		CSP - 2 2/3" x 1/2" CORR.						RELAY CULVERT	CLEAN CULVERT	REMOVE CULVERT	CULVERT EXC. **	BEDDING MATERIAL	CLASS "DD" CONCRETE	RANDOM RIPRAP	HEIGHT OF COVER			
	CLASS 2				CLASS 3	CLASS 4	CLASS 2		0.064 THK.	0.138 THK.	0.168 THK.										CLASS 1				
	18"	24"	36"	48"	24"	24"	18"	24"	18"	72"	84"		LEFT	RIGHT											
13+65		6										NONE	~	FETS	6	52	6.6	5				4.6		24 x 60.0 RCP	RELAY FETS LT.
51+84		52										NONE	FETS	FETS				5				9.8		24 x 80.1 RCP	LENGTHEN 12' LT. & 40' RT.
63+78					42							NONE	~	FETS	4		4.9	5				14.1		24 x 74.1 RCP	RELAY 4' RT. LENGTHEN 40' LT.
79+69	28											NONE	~	~	46		45.9	25				4.6		24 x 45.9 RCP	APP. LT.
90+06												NONE	~	~			30.2	25						15 x 30.2 RCP	APP. LT.
111+71				32								NONE	FETS	FETS				5				7.5		48 x 100.1 RCP	LENGTHEN 14' LT. & 18' RT.
125+33			16									NONE	~	~	16	46	16.4	5				3.6		36 x 62.0 RCP	RELAY FETS LENGTHEN 8' LT. & RT.
133+53						22						NONE	SQ.	~				5				34.1		24 x 91.9 RCP	LENGTHEN 22' LT.
148+23		36										NONE	RACET	RACET		30		20				1.6		24 x 45.9 RCP	APP. RT. LENG. 16' LT. & 20' RT.
155+25										Ŧ 20		YES	2: 1 BEVEL	2: 1 BEVEL				5	9	4.7	13.1	10.2	11° RT.	72 x 84.0 CSP	LENGTHEN 10' LT. & RT.
166+47									18			NONE	FETS	FETS		59	3.3	5				4.9		18 x 58.1 CSP	REMOVE 4' LT. LENG. 6' LT. & 12' RT.
174+64											Ŧ 16	YES	1.5: 1 BEVEL	~				5	5	4.7	11.8	9.5		84 x 78.1 CSP	LENGTHEN 16' LT.
197+90	42											NONE	FETS	FETS				5				8.9		18 x 42.0 RCP	APP. LT. LENGTHEN 22' LT. & RT.
213+42												NONE	~	~			38.1	15						15 x 38.1 RCP	APP. RT.
234+25							40					NONE	FETS	FETS				5				7.9		18 x 71.9 RCP IRR.	LENGTHEN 20' LT. & RT.
236+52								22				NONE	~	FETS				5				8.2		24 x 91.9 RCP IRR.	LENGTHEN 22' RT.
TOTAL	70	94	16	32	42	22	40	22	18	20	16	~	~	~	72	187	145.4	~	14	9.4	24.9	~	~	~	

Ŧ 3" X 1" CORRUGUTAION
* SEE STANDARD SPEC. SEC. 709.04 ④
** FOR INFORMATION ONLY

Culverts Frame Reminders:

① *Use this frame when culvert material type for mainline and approach pipes is non-optional. Culvert summary recap is not used with this frame.*

② *Pipe location rounded to nearest foot.*

③ *List new end sections only - end sections include length of new pipe for payment.*

④ *Coating specifications could include 709.04, 709.05, or 709.12 in accordance with recommendations from the Materials Bureau and Hydraulics Section.*

① APPROACH PIPE (INCLUDED IN CULVERT SUMMARY RECAP)

STATION ②	BASIC BID ITEMS						PIPE OPTIONS in				END SECTIONS ③		linear feet	SKEW ANGLE	CULVERT IN PL. in x ft	REMARKS
	CULVERT PIPE in	linear feet				cubic yards	CONCRETE - CLASS 2	STEEL - 2 2/3 x 1/2 CORR. 0.064 THK.	ALUMINUM - 2 2/3 x 1/2 CORR. 0.060 THK.	CORRUGATED POLYETHYLENE PIPE			HEIGHT OF COVER			
		LENGTH OF PIPE	REMOVE CULVERT	RELAY CULVERT	CLEAN CULVERT	CULVERT EXC. **					LEFT	RIGHT				
10+20	18	70				15	18	~	~	~	RACET	RACET	1.3			RT.
44+55	18	70				5	18	18	18	18	RACET	RACET	1.6			RT.
62+01	24	78				5	24	⑤ * 24	24	24	FETS	FETS	2.0			LT.
79+43	18	106				20	18	* 18	18	18	FETS	FETS	3.9			LT.
106+79	18	76				5	18	18	18	18	FETS	FETS	1.6	15° LT.		RT.
116+63	18	78				5	18	18	18	18	FETS	FETS	1.6			RT.
179+69	18	28	45.9	46		60	18	~	~	~	~	~	4.6		18 x 45.9 RCP	LT. - LENGTHEN 12' LT. & 16' RT.
190+06	18	96	29.9			65	18	18	18	18	FETS	FETS	3.9		15 x 29.9 RCP	LT.
225+33	18	30	6.6	6		5	~	18	~	~	FETS	~	5.9		18 x 67.9 CSP	RT. - RELAY FETS RT. LENG. 18' LT. & 12' RT.
228+84			64.0			50	~	~	~	~					18 x 64.0 RCP	LT.
248+23	18	16	13.1	12		5	18	~	~	~	~	~	2.6		18 x 66.9 RCP	LT. - RELAY FETS LENGTHEN 8' LT. & RT.
248+23	18 IRR.	84				15	18 IRR.	18 IRR.	~	~	FETS	FETS	2.6			RT. - IRR.
250+13	28 1/2x18 ④	72				25	28 1/2x18 CL. 3	* 28x20	28x20 0.075	~	~	~				LT.
266+44					72										18 x 70.5 CSP	LT.
TOTAL	~	~	159.5	64	72	~	~	~	~	~	~	~	~	~	~	

*COAT PIPE PER STANDARD SPEC. SEC. 709.04 ⑤
** FOR INFORMATION ONLY

Approach Pipe Frame Reminders:

① *Use this frame only when plastic pipe is a recommended option for approach pipe, otherwise combine with culvert summary. Culvert summary recap must accompany this frame.*

② *Pipe location rounded to nearest foot.*

③ *List new end section only - end section included in length of new pipe for payment.*

④ *Arch pipes listed as span x rise.*

⑤ *When coating is required on an approach pipe, add a footnote specifying the coating specifications as shown here. Coating specifications could include 709.04, 709.05, or 709.12 in accordance with recommendations from the Materials Bureau and Hydraulics Section.*

FIG. 4.4 K-8

3
2
1
serving you with pride
MONTANA DEPARTMENT
OF TRANSPORTATION
c:\dgn\rmanrdsume08.dgn
10/17/2016
1:04:25 PM CPS - U1968
DESIGNED BY *DESIGNER NAME* *DATE*
REVIEWED BY *SUPERVISOR NAME* *DATE*
CHECKED BY *CHECKER NAME* *DATE*
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.
SHEET 999 OF 999

SUMMARY

① CULVERT SUMMARY RECAP

BASIC BID ②	linear feet				cubic yards				square yards
	NEW PIPE (TOTAL)	RELAY CULVERT	CLEAN CULVERT	REMOVE CULVERT	FOUND-ATION MATERIAL	BEDDING MATERIAL	CLASS "DD" CONCRETE	RANDOM RIPRAP CLASS 1	GEOTEXTILE STABILIZATION
18"	526								
18" IRR.	84								
18" SIPHON	122								
18" RCP CL. 2	148								
18" CSP x 0.064" THK.	30								
18" CSP IRR. x 0.079" THK.	142								
18" CSP SIPHON x 0.079" THK.	100								
24"	186								
24" IRR.	102								
24" RCP CL. 2	52								
24" CSP x 0.079" THK.	30								
28.50" x 18.00"	72								
36"	132								
36" CSP x 0.109" THK.	98								
42"	96								
58.50" x 36.00"	96								
73.00" x 45.00" IRR.	204								
96" CSP x 0.109" THK.	464								
112" x 75" CSPA IRR. x 0.079" THK.	96								
144" SSPP x 0.109" THK.	124								
TOTAL	③ ~	116	72	347.9	133	1,097	53.6	116.5	205

Culvert Summary Recap Frame Reminders:

① *Used in conjunction with Optional Culvert (see Fig. 4.4 K-7) and Optional Approach Pipe (see Fig. 4.4 K-8) Summaries.*

② *For pipes with optional material types, list pipes by diameter, Irr., or Siphon only. For pipes with only one material type specified, also list the material type and class or thickness. Separate out the optional and non-optional pipes, even if they are the same size.*

③ *Enter project totals only.*

CURB

STATION		linear feet				sq. yards		linear feet		REMARKS
		CONCRETE CURB AND GUTTER		REMOVE ① CURB AND GUTTER		CONCRETE VALLEY GUTTER		BITUMINOUS CURB ②		
FROM	TO	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
36+09.00	37+04.00								95.0	INCLUDES 2 - 25' RADII
37+04.00	43+04.00	677.8								INCLUDES 2 - 20' RADII
37+04.00	42+98.60		656.5							
42+98.60	43+52.60						18.0			
SUBTOTAL		677.8	656.5				18.0		95.0	NH FUNDING
43+52.60	49+48.20	646.7								INCLUDES 2 - 15' RADII
43+41.20	49+48.20		669.0							INCLUDES 2 - 20' RADII
44+30.80	48+81.90			498.7						
44+72.40	48+96.00				447.5					
SUBTOTAL		646.7	669.0	498.7	447.5					CMAQ FUNDING
TOTAL		2,650.0		946.2		18.0		95.0		

Curb Frame Reminders:

① *If curb removal is included in reconstruction cross section, curb removal is included with street excavation quantity. Otherwise, include removal in cost of new curb and gutter, show removal here as a bid item if no new curb and gutter .*

② *When existing bituminous curb will be removed, handle the same way as curb and gutter removal.*

① DUCTILE IRON FITTINGS

DESCRIPTION	25% CITY FUNDS		100% CITY FUNDS	
	QUANTITY	WEIGHT (lb)	QUANTITY	WEIGHT (lb)
8" PLUG			2	101
8" x 8" x 6" TEE			2	348
10" PLUG			1	64
10" x 10" x 6" TEE	1	249	1	249
10" x 10" x 8" TEE			1	260
10" x 10" x 10" TEE			1	311
10" x 6" REDUCER	2	115		
10" 90° BEND	1	190		
18" x 20" INCREASER/REDUCER	2	1,019		
20" x 20" x 6" TEE			2	1,451
20" x 20" x 8" TEE			1	734
20" x 20" x 10" TEE	2	1,508		
20" 90° BEND	1	679		
TOTAL (INCLUDED IN WATER LINE FRAME)	~	3,760	~	3,518

Ductile Iron Fittings Frame Reminder:

① *Use this frame if there are a variety of different fittings to reduce the size of the Water Line frame. If a small number of fitting types is needed, or if plastic fittings are used, columns can be added to the Water Line frame instead.*

① CULVERTS - ALTERNATE A1

STATION ④	linear feet	END SECTIONS		cubic yards						square yards	linear feet	SKEW ANGLE	REMARKS
	DOUBLE CELL RCB *			## CULVERT EXCAVATION	FOUNDATION MATERIAL	BEDDING MATERIAL	SPECIAL BACKFILL	CLASS "DD" CONCRETE	RANDOM RIPRAP	GEOTEXTILE STABILIZATION	HEIGHT OF COVER		
	11' x 11'	LEFT	RIGHT						CLASS 1				
43+73	110	2:1 SLOPE	2:1 SLOPE	715	243	141	556	12.2	25.0	445	5.9		S00566004+0.0001 DRAIN ③
TOTAL	110	~	~	715	243	141	556	12.2	25.0	445	~	~	

* SEE DETAIL
QUANTITY SHOWN FOR INFORMATIONAL PURPOSES ONLY. CULVERT EXCAVATION IS INCLUDED IN THE UNIT BID PRICE FOR NEW PIPE.

① CULVERTS - ALTERNATE A2

STATION ④	linear feet	*# COATING	END SECTIONS		cubic yards							square yards	linear feet	SKEW ANGLE	REMARKS
	SSPPA - 6" x 2" CORR.				## CULVERT EXCAVATION	FOUNDATION MATERIAL	BEDDING MATERIAL	SPECIAL BACKFILL	CLASS "DD" CONCRETE	RANDOM RIPRAP	* FLOWABLE FILL	GEOTEXTILE STABILIZATION	HEIGHT OF COVER		
	0.109" THK.														
	14' -5" x 10'- 0"		LEFT	RIGHT						CLASS 1					
41+73	2 at 104	YES	2:1 BEVEL	2:1 BEVEL	765	298	442	955	19.0	34.4	186.6	460	6.9		S00566004+0.0001 DRAIN ③
TOTAL	208	~	~	~	765	298	442	955	19.0	34.4	186.6	460	~	~	

*# SEE STANDARD SPEC. 709.04
* SEE DETAIL
QUANTITY SHOWN FOR INFORMATIONAL PURPOSES ONLY. CULVERT EXCAVATION IS INCLUDED IN THE UNIT BID PRICE FOR NEW PIPE.

Culverts-Alternate Frame Reminders:

① *When reinforced concrete box (RCB) is an alternate (optional) bid item, then use these alternate frames. Use the non-optional or optional culvert frame for any non-alternate RCB call-out.*

② *The use of alternate bid items/frames should be discussed and agreed to at the Plan-In-Hand.*

③ *If a culvert is replacing an existing bridge, add NBI number in remarks.*

④ *Pipe location rounded to nearest foot.*

DETOUR *

STATION		lump sum	① ② REMARKS
		CONST., MAINTAIN & REMOVE DETOUR	
FROM	TO		
40+84.65	47+90.03	0.16	CULVERT REPLACEMENT
141+65.03	161+42.29	0.44	DRY CREEK
252+01.18	270+19.16	③ 0.40	HAY CREEK
TOTAL		1	

* SEE DETAIL SHEET

Detour Frame Reminders:

① *Depending on specifics of project, this item may be revised to Construct & Maintain, Maintain, Maintain & Remove, or Remove.*

② *Provide quantities to construct on detail sheet.*

③ *If practical, prorate lump sum for each detour based on length.*

FIG. 4.4 K-9

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume09.dgn 10/17/2016 1:04:34 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.

SUMMARY

EMBANKMENT PROTECTORS

STATION		linear feet				cubic yards	REMARKS
		EMBANKMENT PROTECTOR* 12"		BITUMINOUS CURB		BANK PROTEC-TION	
FROM	TO	LEFT	RIGHT	LEFT	RIGHT	TYPE 3	
456+21		50				1.6	25° ELBOW ①
456+21	456+81.70			60.7			
SUBTOTAL		50		60.7			
TOTAL		50		60.7		1.6	

* CULVERT EXC. INCLUDED IN COST OF EMB. PROTECTOR

Embankment Protectors Frame Reminder:

① *Specify degree of bend on elbow.*

GABIONS *

STATION		cubic yards		REMARKS
FROM	TO	GABIONS	SPECIAL ① BORROW	
50+85.00	52+41.00	52	136	RIGHT, SEE DETAIL
63+98.00	65+55.00	52	110	RIGHT, SEE DETAIL
136+15.00	136+93.00	26	60	RIGHT, SEE DETAIL
224+08.00	225+64.00	52	149	RIGHT, SEE DETAIL
455+84.00		31	~	RIGHT, SEE GABION SILL DETAIL
532+48.00	534+82.00	78	110	LEFT, SEE DETAIL
543+31.00	547+24.00	131	258	LEFT, SEE DETAIL
562+66.00	572+08.00	314	849	LEFT, SEE DETAIL
575+79.00	578+94.00	105	269	LEFT, SEE DETAIL
602+03.00	603+59.00	52	124	LEFT, SEE DETAIL
676+51.00	676+90.00	13	22	RIGHT, SEE DETAIL
686+02.00	689+17.00	105	186	RIGHT, SEE DETAIL
714+90.00	715+68.00	26	44	RIGHT, SEE DETAIL
723+43.00	724+99.00	52	102	RIGHT, SEE DETAIL
TOTAL		1,089	2,419	

* SEE DETAILS

Gabions Frame Reminder:

① *Use Special Borrow for base material. Include a special provision stating the measurement of Special Borrow for payment is the final in-place volume. Provide material specifications for the special borrow.*

EQUIPMENT

STATION		hours		REMARKS
FROM	TO	MOTOR GRADER	DOZER	
568+23	607+50	11		RIGHT SIDE OF ROAD ONLY
738+08	770+89		8	LEFT AND RIGHT SIDE OF ROAD
TOTAL		11	8	

EDGE DRAIN *

STATION		linear feet		REMARKS
FROM	TO	EDGE DRAIN	CORR. PLASTIC PIPE 6"	
107+45	120+57	1,312.0	180	DAYLIGHT TO DITCH AHEAD W.B.
109+91	123+03	1,312.0	42	DAYLIGHT TO DITCH AHEAD E.B.
219+49	222+61	312.0	42	DAYLIGHT TO MEDIAN BACK E.B.
220+48	222+61	213.0	24	DAYLIGHT TO DITCH BACK W.B.
TOTAL		3,149	288	

* SEE DETAIL SHEET

FINISH GRADE CONTROL

STATION		course foot	REMARKS
FROM	TO	FINISH GRADE CONTROL ①	
0+00.00	312+33.60	31,250	SUBGRADE MAINLINE
0+00.00	312+33.60	31,250	BASE COURSE MAINLINE
106+31.56	184+95.73	7,900	SUBGRADE CLIMBING LANE
106+31.56	184+95.73	7,900	BASE COURSE CLIMBING LANE
239+99.34		550	SUBGRADE INTERSECTING ROAD
239+99.34		550	BASE COURSE INTERSECTING ROAD
TOTAL		79,400	

Finish Grade Control Frame Reminder:

① *Round up to the nearest 50' increment.*

DIGOUT EXCAVATION * ④

STATION		cubic yards		square yards	REMARKS
FROM	TO	DIGOUT EXC. ①	SPECIAL BORROW ② ③	GEOTEXTILE STABILIZATION	
651+25	656+17	2,407	1,564	1,794	
835+96	839+90	2,166	1,407		
329+72	333+03.02	4,238	2,753		
336+97.02	340+22	3,597	2,337		
TOTAL		12,408	8,061	1,794	

* SEE DETAIL SHEET

Digout Excavation Frame Reminders:

① ② Measured and paid the same for both Uncl. Exc. and Emb.-in-Pl. projects.

② Volumes are not adjusted by shrink factor.

③ Include a special provision stating the measurement of Special Borrow for payment is the final in-place volume. Provide material specifications for the special borrow.

④ Do not use digout excavation on new construction/reconstruction projects. For these projects, removal of unsuitable material is paid for as either unclassified excavation or muck excavation.

FENCING

STATION		linear feet					each			linear feet		REMARKS
		FARM FENCE				TEMP. FENCE	FARM FENCE PANEL		DEADMAN	FARM GATE		
FROM	TO	TYPE F2W-32WW	TYPE F3M-39WW	TYPE F4M	TYPE F5W		SINGLE	DOUBLE		TYPE G2	TYPE G3	
0+00.00	99+90.20			9,990.2			12	6				LEFT - TIE TO EXISTING FENCE
99+90.20	100+06.20									16		LEFT
100+06.20	156+82.70				5,676.5		8	1				LEFT - WING TO PIPE
156+82.70	294+02.20				13,719.5		17	4				LEFT - WING TO PIPE
294+02.20	377+82.40	8,380.2					21	5				LEFT
377+82.40	377+98.40										16	LEFT
377+98.40	383+73.20	574.8					2					LEFT - TIE TO EXISTING FENCE
0+00.00	89+02.20		8,902.2				30					RIGHT - TIE TO EXISTING FENCE
89+02.20	89+18.20									16		RIGHT
89+18.20	156+82.60			6,764.4			8	3				RIGHT - WING TO PIPE
156+82.60	214+18.50			5,735.9			10	1				RIGHT - WING TO PIPE
214+18.50	245+85.50			3,167.0			5					RIGHT
245+85.50	246+25.50									40		RIGHT
246+25.50	383+73.50	13,748.0					34	8				RIGHT - TIE TO EXISTING FENCE
TOTAL		22,703.0	8,902.2	25,657.5	19,396.0	5,757.9	147	28	70	72	16	

FIG. 4.4 K-10

3	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume10.dgn	DESIGNED BY	DESIGNER NAME	DATE	ROAD PLANS	MONTANA ROAD DESIGN MANUAL	PROJECT LOCATION DESCRIPTION	PROJECT NO.
2	serving you with pride	10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE	COUNTY NAME(S)	SAMPLE PLAN SHEET (U.S. Customary Units)	CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999
1		1:04:42 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE				

SUMMARY

GUARDRAIL

STATION		linear feet										⑥ each														REMARKS ⑧
		① REMOVE GUARDRAIL		② ⑨ METAL GUARDRAIL		③ BOX BEAM GUARDRAIL		④ CABLE GUARDRAIL		⑤ INTERSECTING ROADWAY TERMINAL SECTION		OPTIONAL TERMINAL SECTION		ONE-WAY DEPARTURE TERMINAL SECTION		OPTIONAL BOX BEAM TERMINAL SECTION		BOX BEAM ONE-WAY DEPARTURE TERMINAL SECTION		CABLE GUARDRAIL TERMINAL SECTION		⑦ BRIDGE APPROACH SECTION TYPE 1		⑦ BOX BEAM BRIDGE APPROACH SECTION TYPE 1		
FROM	TO	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
NEW RAIL																										
477+51.80	479+64.30				137.5								1										1			
478+34.51	479+47.01			37.5								1										1				
480+86.71	482+99.21			137.5								1										1				
480+04.10	482+16.60				137.5								1										1			
577+19.00	588+31.50				1,012.5								2													
586+79.99	591+92.49			450.0								1		1												
604+32.41	630+94.91				2,600.0								1		1											
642+42.49	681+42.49			3,800.0								2														
689+11.19	695+47.69				562.5						62.5		1													24.0 ft RADIUS
706+36.48	713+61.48				662.5								1		1											
798+89.99	801+80.18						234.0										1		1							
835+81.17	838+60.38						180.0										1								1	
836+71.23	838+60.44					90.0										1								1		NEW BOX BEAM - DUE TO DRIFTING
1049+55.87	1099+35.87							4,928.0												6						NEW CABLE RAIL - DUE TO DRIFTING (3 RUNS)
REMOVE RAIL																										
478+26.80	479+64.30		137.5																							W-BEAM RAIL IN PLACE
478+22.01	479+47.01	125.0																								W-BEAM RAIL IN PLACE
481+61.71	482+99.21	137.5																								W-BEAM RAIL IN PLACE
480+91.60	482+16.60		125.0																							W-BEAM RAIL IN PLACE
534+61.94	542+61.94		800.0																							CABLE RAIL IN PLACE
577+40.49	587+48.49		1,008.0																							CABLE RAIL IN PLACE
587+29.99	591+13.99	384.0																								CABLE RAIL IN PLACE
837+03.02	837+90.52	87.5																								W-BEAM RAIL IN PLACE
1049+55.87	1098+55.87	4,900.0																								W-BEAM RAIL IN PLACE
SUBTOTAL		5,634.0	2,070.5	4,425.0	5,112.5	90.0	414.0	4,928.0			62.5	5	7	1	2	1	2		1	6		2	2	1	1	
TOTAL		7,704.5		9,537.5		504.0		4,928.0		62.5		12		3		3		1		6		4		2		

Guardrail Frame Reminders:

① Remove guardrail measured to the nearest 0.1 ft.

② See Fig. 5.4L for computing w-beam guardrail quantities.

③ See Fig. 5.4N for computing box beam guardrail quantities.

④ See Fig 5.4M for computing cable guardrail quantities.

⑤ *See Fig 5.4O for computing I.R.T. section quantities. When the approach is not perpendicular to mainline, provide a detail showing the I.R.T. section general layout.*

⑥ *Length not included in length of guardrail, but included for station range.*

⑦ *Check bridge plans to ensure bridge approach section type matches bridge rail type and bridge end stations.*

⑧ *Note the radius for Intersecting Roadway Terminal Sections. Note the number of runs of cable guardrail.*

⑨ *If 2.0 ft widening behind rail is unattainable, include a column for "Metal Guardrail 7.0 ft Posts." (see Dtl. Dwg. 606-11A & 606-11B) If stiffened guardrail is required (see Dtl. Dwg. 606-07), include a column for "Stiffened Guardrail Sections." If raise guardrail or reset guardrail is needed, add these columns using the same rounding criteria as for Remove Guardrail.*

CONCRETE BARRIER RAIL

④ STATION		each							REMARKS
FROM	TO	REMOVE CONCRETE BARRIER RAIL ③	CONCRETE BARRIER RAIL	TALL CONCRETE BARRIER RAIL	CONCRETE BARRIER RAIL TRANS.	CONCRETE BARRIER RAIL ② TERMINAL SECTION	REMOVE IMPACT ATTEN-UATOR	IMPACT ATTEN-UATOR 6 BAY ①	
334+98.23	335+20.31							1	E.B. SH. RT.
335+20.31	347+20.31		120						E.B. SH. RT.
347+20.31	347+30.31					1			E.B. SH. RT.
368+00.36	368+80.36	8							W.B. SH. RT. (TAPERED END SECT.)
368+00.36	368+10.36					1			W.B. SH. RT.
368+80.36	378+60.36	98							FROM W.B. SH. RT. TO MED. C/L
368+10.36	378+60.36		105						FROM W.B. SH. RT. TO MED. C/L
378+60.36	413+00.36	344							MED. C/L
378+60.36	386+00.36		74						MED. C/L
386+00.36	386+10.36				1				MED. C/L
386+10.36	399+60.36			135					MED. C/L
399+60.36	399+70.36				1				MED. C/L
399+70.36	414+70.36		150						MED. C/L
413+03.31	413+25.39						1		MED. C/L
414+70.36	414+92.44							1	MED. C/L
TOTAL		450	449	135	2	2	1	2	

Concrete Barrier Rail Frame Reminders:

① *Impact attenuator may be shown in the guardrail frame when used in combination with metal guardrail.*

② *Only use as a one-way departure terminal.*

③ *Existing concrete barrier rail not meeting the current NCHRP 350 crash-tested design, as shown in the Detailed Drawings, designated to be removed, should be replaced with new concrete barrier rail. Exceptions to this rule should be discussed at Plan-in-Hand.*

④ *Stations should be in 10.0 ft increments for Concrete Barrier Rail and in the applicable increment for the size of Impact Attenuators selected.*

CONCRETE BARRIER RAIL

④ STATION		each							REMARKS
FROM	TO	REMOVE CONCRETE BARRIER RAIL ③	CONCRETE BARRIER RAIL	TALL CONCRETE BARRIER RAIL	CONCRETE BARRIER RAIL TRANS.	RESET CONCRETE BARRIER RAIL ③	RESET IMPACT ATTEN-UATOR	IMPACT ATTEN-UATOR 6 BAY ①	
TEMPORARY LOCATION									
220+60.89	220+82.97							1	MED. - 8.0 ft RT.
220+82.97	252+02.97		312						MED. TO B.E. - 8.0 ft RT.
222+33.10	252+03.10	297							MED. TO B.E. (INCL. TAPERED END SECT.)
254+05.05	302+35.05	483							MED. FROM B.E. (INCL. TAPERED END SECT.)
254+05.05	268+55.05		145						MED. FROM B.E. - 8.0 ft RT.
268+55.05	268+65.05				1				MED. - 8.0 ft RT.
268+65.05	289+15.05			205					MED. - 8.0 ft RT.
289+15.05	289+25.05				1				MED. - 8.0 ft RT.
289+25.05	300+65.05		114						MED. - 8.0 ft RT.
300+65.05	300+87.13							1	MED. - 8.0 ft RT.
FINAL LOCATION									
220+60.89	220+82.97						1		MED. C/L
220+82.97	252+02.97					312			MED. C/L TO B.E.
254+05.05	268+55.05					145			MED. C/L FROM B.E.
268+55.05	268+65.05					1			MED. C/L (TRANSITION RAIL)
268+65.05	289+15.05					205			MED. C/L (TALL RAIL)
289+15.05	289+25.05					1			MED. C/L (TRANSITION RAIL)
289+25.05	300+65.05					114			MED. C/L
300+65.05	300+87.13						1		MED. C/L
TOTAL		780	571	205	2	778	2	2	

FIG. 4.4 K-11

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume11.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS
2		10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*	
1		1:04:50 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

SUMMARY

MAILBOXES

STATION	each	REMARKS
	MAIL-BOXES	
1342+56	2	LEFT
1388+49	7	LEFT
TOTAL	9	

① MANHOLES IN PLACE *

STATION	each		REMARKS
	ADJUST MANHOLE		
	LEFT	RIGHT	
2+23.0	1		2' LEFT
13+16.2	1		2' LEFT
29+56.9		1	3' RIGHT
144+52.0	1		2' LEFT
199+81.9		1	3' RIGHT
SUBTOTAL	3	2	
TOTAL	5		

* FUNDING - 75% STATE, 25% CITY

Manholes In Place Frame Reminder:

① *See Utility Agreement for funding splits.*

MEDIAN CROSSOVER *

STATION		lump sum	① ② REMARKS
FROM	TO	CONST., MAINTAIN & REMOVE CROSS-OVER	
89+00	96+05	0.5	DOUBLE CROSSOVER
226+80	233+85	③ 0.5	DOUBLE CROSSOVER
TOTAL		1	

* SEE DETAIL SHEET

Median Crossover Frame Reminders:

① Depending on specifics of project, this item may be revised to Construct & Maintain, Maintain, Maintain & Remove, or Remove.

② Provide quantities to construct on detail sheet.

③ When crossover characteristics are significantly different, prorate the lump sum for each crossover to more closely represent the amount of work required to construct them.

TEMPORARY GUARDRAIL

STATION		linear feet		each	each					REMARKS
		TEMPORARY METAL GUARDRAIL		TEMPORARY CONCRETE BARRIER RAIL	TEMPORARY BRIDGE APPROACH SECTION TYPE 1		TEMPORARY OPTIONAL TERMINAL SECTION		TEMPORARY IMPACT ATTENUATOR	
FROM	TO	LEFT	RIGHT		LEFT	RIGHT	LEFT	RIGHT		
6+92.05	8+82.05			19					1	E.B. MOSSMAIN INTCH. - 6 BAY ATTEN.
15+92.45	17+02.45			11					1	E.B. CANAL - 6 BAY ATTEN.
51+22.85	53+52.85			23					1	E.B. COUNTY RD. SEPARATION - 6 BAY
89+00.00										NEW MEDIAN CROSSOVER
91+15.80	92+40.80		75.0					1		E.B. SHILOH OVERPASS
91+25.00	92+50.00	75.0					1			E.B. SHILOH OVERPASS
93+40.30	97+52.80	337.5			1		1			E.B. CANYON CREEK
93+40.30	97+52.80		337.5			1		1		E.B. CANYON CREEK
135+12.22	136+72.22			16					1	E.B. HOGANS SLOUGH - 4 BAY ATTEN.
7+13.00	9+03.00			19					1	W.B. MOSSMAIN INTCH. - 6 BAY ATTEN.
16+28.00	17+38.00			11					1	W.B. CANAL - 6 BAY ATTEN.
51+61.00	53+91.00			23					1	W.B. COUNTY RD. SEPARATION - 6 BAY
90+32.21	91+57.21	75.0					1			W.B. SHILOH
90+42.71	91+67.71		75.0					1		W.B. SHILOH
91+67.94	95+80.44	337.5			1		1			W.B. CANYON CREEK
91+67.94	95+80.44		337.5			1		1		W.B. CANYON CREEK
135+31.00	136+91.00			16					1	W.B. HOGANS SLOUGH - 4 BAY ATTEN.
SUBTOTAL		825.0	825.0		2	2	4	4		
TOTAL		1,650.0		138	4		8		8	

IRRIGATION STRUCTURES

STATION		cubic yards		sq. yards	each						REMARKS
		CLASS "DD" CONC.	RANDOM RIPRAP	GEOTEXTILE PERM. EROS. CNTRL.	CANAL GATE	HEAD GATE	TRASH GUARD	CHECK	TURNOUT	REMOVE IRRIGATION STRUC-TURE	
FROM	TO		CL. 1	__ SURVIVABILITY CLASS __ ①	1' - 6"	1' - 6"					
38+62		5.0	7.3	46							CANAL CHECK 100' RT. - SEE DETAIL
46+92	49+71								1		IRR. DT. 100' LT.
51+22										1	TURNOUT 72' LT.
51+94		2.6	5.2	11			2				TRANSITIONS LT. & RT. *
56+96						1					LT.
57+42					1						RT.
65+26								1			LT. - SEE DETAIL
TOTAL		7.6	12.5	57	1	1	2	1	1	1	

* 2' - 0" CONC. INLET & OUTLET TRANS. (B = D + 1'-0")

Irrigation Structures Frame Reminder:

① *Consult with Geotechnical Section to determine Survivability and Class of Erosion Control Geotextile, based on subgrade conditions.*

MEDIAN CONCRETE CURB

STATION		linear feet		sq. yards	① REMARKS
		MEDIAN CONCRETE CURB	REMOVE MEDIAN CURB	CONCRETE	
FROM	TO	TYPE A		4"	
16+02.94	16+34.96	147.3		86.2	ISLAND LEFT
18+13.34	22+83.75	945.9		286.8	MEDIAN - INCL. RADII & TAPERS
29+88.67	35+45.07		1,116.1		MEDIAN - INCL. RADII
72+31.26	82+69.09	2,080.7			MEDIAN - INCL. RADII
TOTAL		3,173.9	1,116.1	373.0	

Median Concrete Curb Frame Reminder:

① *Reinforcing steel, expansion joint material, excavation, back fill, aggregate base, and disposal of surplus material are included in the cost of concrete.*

② *If median curb removal is included in reconstruction cross section, curb removal is included with street excavation quantity or New Meidan Curb. Otherwise, include removal in cost of new median curb , show removal here as a bid item if no new median curb .*

FIG. 4.4 K-12

3
2
1
MDT
MONTANA DEPARTMENT OF TRANSPORTATION
c:\dgn\rmanrdsume12.dgn
10/17/2016
1:04:59 PM CPS - U1968
DESIGNED BY *DESIGNER NAME* *DATE*
REVIEWED BY *SUPERVISOR NAME* *DATE*
CHECKED BY *CHECKER NAME* *DATE*
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.
SHEET 999 OF 999

SUMMARY

MEDIAN INLETS

STATION	each			REMARKS
	MEDIAN INLET		ADJUST MEDIAN INLET	
	TYPE 2			
49+00.00			1	
54+93.00			1	
58+30.50	1			CENTER IN MED. & CONNECT TO W.B. CULV.
69+99.00			1	
116+58.80			1	
96+71.90			1	
TOTAL	1		5	

MISCELLANEOUS ITEMS

STATION		lump sum	cubic yards	REMARKS
FROM	TO			
32+15.00	49+21.00		1,740	CONTAMINATED SOIL REMOVAL - STORM SEWER TRENCH
127+62		1		RESET HISTORICAL MARKER RT.
301+87		1		REVISE ROAD WEATHER INFORMATION SITE

MUCK EXCAVATION *

STATION		cubic yards		REMARKS
		MUCK EXC. ①	SPECIAL BORROW ② ③	
FROM	TO			
49+21	82+02	16,676	20,927	
TOTAL		16,676	20,927	

* SEE DETAIL SHEET

Muck Excavation Frame Reminders:

① ② *Measured and paid for on both Uncl. Exc. and Emb.-in-Place projects.*

② *Volumes are not adjusted by shrink factor.*

③ *Include a special provision stating the measurement of special borrow for payment is the final in-place volume.*

OBLITERATE ROADWAY

STATION		stations	REMARKS
		OBLIT-ERATE ROADWAY	
FROM	TO		
0+00	72+00	72	LEFT
184+00	213+00	29	RIGHT
305+00	333+00	28	RIGHT
TOTAL		129	

PAVEMENT MARKINGS

ITEM	UNIT	INTERIM * APPLICA-TION	FINAL APPLICA-TION	TOTAL
STRIPING - WHITE PAINT	gallon	252		252
STRIPING - YELLOW PAINT	gallon	107		107
WORDS & SYMBOLS - WHITE PAINT	gallon	1		1
STRIPING - 4" YELLOW PLASTIC	foot		564	564
STRIPING - 24" WHITE PLASTIC	foot		43	43
WORDS AND SYMBOLS - WHITE PLASTIC	sq. foot		68.9	68.9
TEMPORARY PAVEMENT MARKINGS ①	mile			21.9
STRIPING - 4" WHITE EPOXY	gallon		258	258
STRIPING - 4" YELLOW EPOXY	gallon		111	111

* BASED ON 2 APPLICATIONS (DOES NOT APPLY TO S&C PROJECT)

Pavement Markings Frame Reminder:

① *Temporary pavement markings quantities estimated by road designer; all other pavement marking quantities provided by Traffic and Safety Bureau.*

PLANT MIX LINED DITCH *

STATION		linear feet	tons		REMARKS
		PL. MIX LINED DITCH ①	PL. MIX SURF. GR. B ②	ASPHALT CEMENT PG 64-28 ②	
FROM	TO				
6+30	14+07	777.0	46	2.8	
TOTAL		777.0	# 46	# 2.8	

* SEE DETAIL SHEET
# FOR INFORMATION ONLY

Plant Mix Lined Ditch Frame Reminder:

① *A detail must be provided to show width and depth of plant mix.*

② *If there is other plant mix surfacing on the project, specify the same type as in the surfacing frame.*

PULVERIZATION

STATION		square yards	REMARKS
		PAVEMENT PULVERIZATION	
FROM	TO		
137+69.69	247+45.51	66,759	FULL WIDTH - TYP. NO. 3
247+45.51	456+40.09	201,723	FULL WIDTH - TYP. NO. 3
456+40.09	551+18.11	57,723	FULL WIDTH - TYP. NO. 3
TOTAL		326,205	

① RANDOM RIPRAP

STATION		cubic yards		square yards		REMARKS
		RANDOM RIPRAP		GEOTEXTILE PERM. EROS. CNTRL. __ SURVIVABILITY CLASS __ ②	RIPRAP REVEGE-TATION	
FROM	TO	CL. 2	CL. 3			
189+73	191+73	442.5		667	534	RIVER BANK EMBANKMENT PROTECTION
200+98	202+95	433.6		600	480	RIVER BANK EMBANKMENT PROTECTION
305+97.77			760.2	995		BRIDGE END
309+04.33			665.2	785		BRIDGE END
454+40	456+03	303.4		433	347	RIVER BANK EMBANKMENT PROTECTION
TOTAL		1,179.5	1,425.4	3,480	1,361	

Random Riprap Frame Reminder:

① *Excavation is included in the cost of riprap.*

② *Consult with Geotechnical Section to determine Survivability and Class of Erosion Control Geotextile, based on subgrade conditions.*

REMOVE STRUCTURE

STATION	lump sum	REMARKS
	REMOVE STRUC-TURE ①	
3685+14	0.23	22.0'x46.0' WOOD STR. (P00001229+00271) ②
3805+77	0.11	20.0'x24.0' CONCRETE BOX
3910+76	0.18	20.0'x40.0' STEEL BRIDGE
4200+30	0.29	22.0'x60.0' WOOD STRUCTURE
4305+28	0.19	24.0'x36.0' STEEL BRIDGE
TOTAL	1	

Remove Structure Frame Reminders:

① *Prorate lump sum for each structure based on square feet of bridge deck.*

② *If bridge is replaced with another structure (bridge or culvert), add NBI number in Remarks.*

FIG. 4.4 K-13

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume13.dgn 10/17/2016 1:05:07 PM CPS - U1968	DESIGNED BY DESIGNER NAME DATE REVIEWED BY SUPERVISOR NAME DATE CHECKED BY CHECKER NAME DATE	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*	PROJECT LOCATION DESCRIPTION CSF = 0.9999999	UPN NUMBER 12345678	PROJECT NO. SHEET 999 OF 999

SUMMARY

① BRIDGE END BACKFILL

STATION		cubic yards	square yards	
		BRIDGE END BACKFILL ② ③	GEOTEXTILE STABILIZATION	REMARKS
FROM	TO			
282+50.00	287+50.00	5,900		BRIDGE END BENT#1
292+10.00	297+10.00	5,900		BRIDGE END BENT#2
TOTAL		11,800		

Bridge End Backfill Frame Reminders:

① *Use this frame when bridge end backfill has been specified in conjunction with Geotech recommendation.*

② *Volumes are not adjusted by the shrink factor.*

③ *Include a special provision stating the measurement for payment is the final in-place volume.*

REVEGETATION

STATION		lump sum	cubic yards	acres			
		REVEGE-TATION	TOPSOIL SALVAGING & PLACING *	SEED *	FERTI-LIZER *	CONDITION SEEDBED *	REMARKS
FROM	TO						
36+09	37+40	1	48	0.10	0.10	0.10	INCLUDES CONN. TO P.T.W.
TOTAL		1	~	~	~	~	

* FOR INFORMATION ONLY

① ROAD LEVELER OPERATIONS

STATION		hours	
		ROAD LEVELER OPER-ATIONS	REMARKS
FROM	TO		
4872+80	5841+73	292	
TOTAL		292	

Road Leveler Operations Frame Reminder:

① *For dressing CTS riding course. Do not include Finish Grade Control for CTS.*

RUMBLE STRIPS

STATION		miles		gals	
		① RUMBLE STRIPS		FOG SEAL SS-1 *	REMARKS
FROM	TO	CONTIN-UOUS	INTER-MITTENT		
758+93.90	1092+07.71	6.3		320	E.B. LT.
758+93.90	1092+07.71		6.0	304	E.B. RT.
758+93.90	1092+07.71		6.0	304	W.B. LT.
758+93.90	1092+07.71	6.3		320	W.B. RT.
SUBTOTAL		12.6	12.0	1,248	
TOTAL		24.6		~	

* FOR INFORMATION ONLY, INCLUDE IN THE COST OF RUMBLE STRIPS

Rumble Strips Frame Reminder:

① *Deduct gaps for bridges, approaches, or ramps from length of rumble strip.*

RIPRAP REVEGETATION

STATION	square yards	
	RIPRAP REVEGE-TATION	REMARKS
114+68.83	312	LT. & RT.
115+52.43	464	LT. & RT.
TOTAL	776	

SIDEWALK

STATION		square yards								linear feet	
		① CONCRETE SIDEWALK				TRUNCATED DOMES		② REMOVE SIDEWALK		WIDTH	REMARKS
		4"		6"							
FROM	TO	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT		
118+38.02	121+83.27	158.7		85.8		2.2				5.0	INCL. 1-30' R, 1-20' R & EXTENSION
118+38.09	121+83.27		184.8		34.4		2.2			5.0	INCL. 1-30' R, 1-20' R
123+35.96	126+14.30	163.9		56.9		2.2				5.0	INCL. 2-20' R & EXTENSIONS
123+35.96	126+14.30		123.7		53.6		2.2			5.0	INCL. 2-20' R
127+15.22	131+10.24							201.9			
127+04.40	131+41.40								235.6		
SUBTOTAL		322.6	308.5	142.7	88.0	4.4	4.4	201.9	235.6		
TOTAL		631.1		230.7		8.8		437.5		~	

Sidewalk Frame Reminders:

① *Reinforcing steel, expansion joint material, excavation, backfill, aggregate base, and disposal of surplus material are included in cost of sidewalk.*

② If sidewalk removal is included in reconstruction cross section, sidewalk removal is included with street excavation quantity. Otherwise *include removal in cost of new sidewalk. show removal here as a bid item if no new sidewalk*

SPECIAL BORROW ③

STATION		cubic yards	
		SPECIAL BORROW ② ①	REMARKS
FROM	TO		
8+14.14	287+48.36	104,236	
TOTAL		104,236	

Special Borrow Frame Reminders:

① *Volumes are not adjusted by the shrink factor.*

② *Include a special provision stating the measurement for payment is the final in-place volume.*

③ *When special borrow has been specified in conjunction with the typical section, show the special borrow in the surfacing summary frame and not here.*

FIG. 4.4 K-14

3 2 1	MDT MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume14.dgn 10/17/2016 1:05:15 PM CPS - U1968	DESIGNED BY *DESIGNER NAME* *DATE* REVIEWED BY *SUPERVISOR NAME* *DATE* CHECKED BY *CHECKER NAME* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.

SUMMARY

STOCKPASS

STATION	linear feet		cubic yards					square yards	tons	cubic yards	linear feet	END SECTIONS	COATING *	REMARKS
	CSP - 3" x 1" CORR. 0.08 THK.		CULVERT EXC. **	FOUND-ATION MATERIAL	BEDDING MATERIAL	CLASS "DD" CONCRETE	CULVERT RIPRAP	GEOTEXTILE STABILIZATION	PLANT MIX BIT. SURF.	CR. AGG. COURSE	HEIGHT OF COVER			
	96"						CLASS 1		INCL. IN ADD. SURF.					
65+62	90		545	324	99	7.5	16.1	861	6	6	5.9	2:1 ⊕	YES	STOCKPASS & DRAIN
TOTAL	90		∼	324	99	7.5	16.1	861	∼	∼	∼	∼	∼	

* SEE STANDARD SPEC. 709.04
⊕ STEP BEVEL
** FOR INFORMATION ONLY

① STORM DRAIN *

STATION		linear feet					cubic yards		each									linear feet	REMARKS
		RCP IRRIGATION CLASS 3				PVC SDR-35	BEDDING MATERIAL	TRENCH EXC. **	REMOVE DROP INLET	RESET DROP INLET	DROP INLET		MANHOLE			COMB. TY. 3 MH., TY. IV D.I.		SLOTTED DRAIN	
											TYPE 3			TYPE 3					
FROM	TO	12"		24"		12"					LEFT	RIGHT		48"	60"	48"		12"	
90+84.0	91+70.0			83.7			33	65											NEW STORM DRAIN LEFT
90+84.0		80.4						40		1		1		1					STORM DRAIN LATERAL
91+70.0						80.4		40			1	1		1					STORM DRAIN LATERAL
91+70.0	96+49.9			477.4			183	190											NEW STORM DRAIN LEFT
96+49.9		80.4						40			1	1			1				STORM DRAIN LATERAL
96+49.9	98+36.0			184.1			78	145	1										NEW STORM DRAIN LEFT
98+36.0	101+54.2			302.2			144												
101+54.2		39.4						20								1			NEW STORM DRAIN LEFT
101+54.2	101+70.6						7	5										16.4	STORM DRAIN LATERAL
																			NEW STORM DRAIN LEFT
SUBTOTAL											2	3							
TOTAL		200.2		1,047.4		80.4	445	∼	1	1	5			2	1	1		16.4	

* FUNDING - 50% STATE, 50% CITY
** FOR INFORMATION ONLY

Storm Drain Reminder:

① *See Storm Drain agreement for funding splits.*

TOPSOIL & SEEDING ④

STATION		cubic yards	acres						square yards	REMARKS
		TOPSOIL SALVAGING & PLACING	③ SEED			FERTILIZER		CONDITION SEEDBED ①	SOD	
FROM	TO		NO. 1			NO. 1				
16+48.62	28+10.47	292						0.6	2,668	LT. & RT. SIDE
28+10.47	31+69.85	548	1.0			1.0		1.0		LT. SIDE ONLY
28+10.47	33+14.70	82						0.2	756	RT. SIDE ONLY
32+25.43	34+07.35	10							100	LT. SIDE ONLY
38+05.77	43+63.52	190	0.2			0.2		0.2		RT. SIDE ONLY
40+68.86	43+63.52	124	0.2			0.2		0.2		LT. SIDE ONLY
TOTAL		1,246	1.4			1.4		2.2	3,524	

TOPSOIL & SEEDING ④

STATION		cubic yards	acres							REMARKS
		TOPSOIL SALVAGING & PLACING	③ SEED			FERTILIZER		CONDITION SEEDBED ①	MULCH ②	
FROM	TO		NO. 1	NO. 2	NO. 3	NO. 1	NO. 2			
8+14.14	32+80.84	1,024	1.2		0.7	1.2		1.9		INCLUDES CONNECTION TO P.T.W.
32+80.84	65+61.68	3,174	3.5	1.2	1.2	3.5	1.2	4.7	1.2	
65+61.68	98+42.52	4,697	6.7	1.0	1.2	6.7	1.0	7.9	1.0	INCLUDES GRADE TO DRAIN AREA LEFT
98+42.52	131+23.36	2,715	4.0		1.2	4.0		6.2		
131+23.36	164+04.20	3,320	4.9		1.2	4.9		6.1		
164+04.20	196+85.04	2,454	3.0	0.5	1.2	3.0	0.5	4.2	0.5	
196+85.04	229+65.88	1,623	1.7		1.2	1.7		2.9		
229+65.88	262+46.72	4,064	4.4	2.0	1.2	4.4	2.0	5.6	2.0	
262+46.72	287+48.36	3,159	5.2		0.7	5.2		5.9		INCLUDES CONNECTION TO P.T.W.
TOTAL		26,230	34.6	4.7	9.8	34.6	4.7	45.4	4.7	

Topsoil & Seeding Frame Reminders:

① Area of condition seedbed = Area 1 plus Area 3 plus sod.

② Area of mulch = Area 2.

③ Include areas up to the R/W limits except for area steeper than 1.5:1.

④ See Dtl. Dwg. No. 610-00 for proper placement of Topsoil and Seeding.

FIG. 4.4 K-15

3
2
1
serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
c:\dgn\rmanrdsume15.dgn
10/17/2016
1:05:25 PM CPS - U1968
DESIGNED BY *DESIGNER NAME* *DATE*
REVIEWED BY *SUPERVISOR NAME* *DATE*
CHECKED BY *CHECKER NAME* *DATE*
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.
SHEET 999 OF 999

SUMMARY

UNDERDRAIN

STATION		linear feet		square yards	cubic yards		REMARKS
		CORR. PERF. PLASTIC PIPE	CORR. PLASTIC PIPE	GEOTEXTILE STABILIZATION	TRENCH EXC.*	FILTER MATERIAL	
FROM	TO	6"	4"				
184+71.1	198+37.6	1,360		1,442	210	210	
186+68.0	199+73.8	1,306		1,379	195	195	RIGHT
198+37.6	199+34.4	96		100	15	15	LEFT - CONNECTION TO 4" PIPE
199+73.8	203+47.8	510		509	80	80	RIGHT - CONNECTION TO 4" PIPE
199+34.4	200+33.1		98				LEFT - CONNECTION TO DROP INLET
203+47.8	203+95.0		48				RIGHT - CONNECTION TO MANHOLE
TOTAL		3,272	146	3,340	~	500	

* FOR INFORMATION ONLY

① WATER VALVE BOXES *

STATION	each				REMARKS
	ADJUST WATER VALVE BOX		RESET WATER VALVE BOX		
	LEFT	RIGHT	LEFT	RIGHT	
40+12.8	1				15.7 ft LEFT
47+77.9	1				15.1 ft LEFT
58+71.7			1		32.8 ft LEFT - RESET 16.4 ft LEFT
63+17.9				1	19.0 ft RIGHT - RESET 16.4 ft RIGHT
SUBTOTAL	2		1	1	
TOTAL	2		2		

* FUNDING - 75% STATE, 25% CITY

<u>Water Valve Boxes Frame Reminder</u>:

① *See Utility Agreement for funding splits.*

WETLAND SITE *

STATION		lump sum	REMARKS
		WETLAND MITIGATION SITE	
FROM	TO		
560+04	566+60	1	RT.
TOTAL		1	

* SEE DETAIL

① WATER LINE

STATION		each		linear feet				lbs	each					linear feet		each					cubic yards	REMARKS
		WATER SERVICE WITH CORPORATION STOP		PVC WATER PIPE				DUCTILE IRON FITTINGS	GATE VALVE *					STEEL CASING	SPECIAL INST. OF PIPE	CONNECTION		DIS - CONNECT EXISTING MAIN #	PLUG LINE	FIRE HYDRANT D	FLOWABLE FILL	
				CL. 150			CL. 200							0.35 THK.								
FROM	TO	1"		6"	8"	10"	18"		6"	8"	10"	18"	20"	36"		6"	20"					
938+71		1																				
939+11		1																				
941+60	946+19	9																				
SUBTOTAL		11																				FUNDING - 100% STATE
936+12.20	960+69.55						2,559														2,021	
936+12.20												1										INCL. TAPPING TEE
940+68.24														49	49							UNDER RAILROAD
941+20.73											1		1									
941+20.73	960+69.55					2,041															621	
941+43.70																2		2				
941+53.54											1		1									
960+69.55											1		1			1	1		1			
SUBTOTAL						2,041	2,559	3,759			3	1	3	49	49	3	1	~	1		2,642	FUNDING - 75% STATE 25% CITY
940+28.87						66			1											1		
941+37.14				16		49					1									1		
941+61.95						10														1		
944+88.19				52	72					2	2		1							2		
SUBTOTAL				68	72	125		3,519	1	2	3		1							5		FUNDING - 100% CITY
TOTAL		11		68	72	2,166	2,559	7,278	1	2	6	1	4	49	49	3	1	~	1	5	2,642	

* INCL. VALVE BOX
D INCL. AUXILIARY GATE VALVES AND 1 TAPPING TEE
\# INCLUDED IN COST OF OTHER ITEMS

<u>Water Line Frame Reminder</u>:

① *See Utility Agreement for funding splits. Trench excavation is included in cost of water pipe.*

FIG. 4.4 K-16

3 2 1	MDT serving you with pride MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdsume16.dgn 10/17/2016 1:05:33 PM CPS - U1968	DESIGNED BY *DESIGNER NAME* *DATE* REVIEWED BY *SUPERVISOR NAME* *DATE* CHECKED BY *CHECKER NAME* *DATE*	ROAD PLANS COUNTY NAME(S)	*MONTANA ROAD DESIGN MANUAL* *SAMPLE PLAN SHEET (U.S. Customary Units)*

PROJECT LOCATION DESCRIPTION		PROJECT NO.	
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999	OF 999

FOR MDT INTERNAL DISTRIBUTION ONLY

HYDRAULIC DATA SUMMARY *

STATION	STREAM NAME (IF NAMED)	△1 SIZE / TYPE STRUCTURE ① ①A ④	DESIGN FLOOD			BASE FLOOD (1%)		OVERTOPPING FLOOD ② ③			REMARKS (FLOOD OF RECORD, Qp(max), ETC.) ⑤
			MAGNITUDE (ft³/s)	FREQUENCY (%)	H.W. ELEV. (ft)	MAGNITUDE (ft³/s)	H.W. ELEV. (ft)	MAGNITUDE (ft³/s)	APPROX. FREQUENCY (%)	H.W. ELEV. (ft)	
368+60		30" CSP	~	~	~	~	~	~	~	~	PM NO. 10
407+81		30" CSP	~	~	~	~	~	~	~	~	PM NO. 10
447+17.03	Porcupine Creek	115' - 3 Span Bridge	5,103	1	2,056.4	5,103	2,056.4	8,663	0.2	2,060.8	
491+63	Porcupine Creek Overflow	130' - 3 Span Bridge	3,655	1	2,054.4	3,655	2,054.4	6,205	0.2	2,056.5	
520+05		42" S x 29" R CSPA	39	2	2,075.2	71	2,076.8	49	1.8	2,076.8	
583+53		Dbl. 14' S x 4' R RCB	968	2	2,059.9	1,303	2,061.0	1,081	1.6	2,060.7	
620+31	Ivy Coulee	Dbl. 120" CSP	1,794	2	2,054.3	2,433	2,056.0	1,928	1.8	2,055.4	
655+28		Dbl. 60" S x 46" R CSPA	251	2	2,060.3	328	2,060.5	251	2.0	2,060.4	
674+28	Milk River Coulee	Dbl. 14' S x 10' R RCB	2,567	2	2,058.5	3,489	2,059.4	2,627	1.9	2,058.7	
683+89		36" CSP	~	~	~	~	~	~	~	~	PM NO. 10
708+27		30" CSP	~	~	~	~	~	~	~	~	PM NO. 10
835+14		Dbl. 10' S x 4' R RCB	692	2	2,100.3	932	2,100.7	699	1.9	2,100.4	
857+41		30" CSP	~	~	~	~	~	~	~	~	PM NO. 10
871+03		Dbl. 12' S x 5' R RCB	1,342	2	2,107.6	1,812	2,107.9	664	8.0	2,107.0	Overflows to Station 835+14
879+40		30" CSP	~	~	~	~	~	~	~	~	PM NO. 10

Hydraulic Data Summary Reminder:

△1 *CSP will normally be shown in this column when pipe options are shown in the plans. If only one option is shown, that will be the material referenced in this column.*

NOTES:

* H.W. ELEVATIONS SHOWN ARE BASED UPON PEAK FLOW ANALYSIS UNLESS NOTED IN REMARKS COLUMN.

① STRUCTURE SIZE OR TYPE AND RELATED HYDRAULIC DATA MAY NOT REFLECT CHANGES MADE DUE TO R/W OR OTHER CONSIDERATIONS (I.E., STOCKPASS ADDED, STRUCTURE SIZE OR TYPE CHANGED, ROAD GRADE CHANGED DURING CONSTRUCTION, ETC.)

①A BRIDGE LENGTH SHOWN EQUALS THE WATER SURFACE WIDTH IN THE OPENING AT THE DESIGN H.W. ELEVATION MEASURED NORMAL TO FLOW.

② OVERTOPPING IS DEFINED AS FLOW OVER THE ROAD, FLOW THROUGH A SIGNIFICANT RELIEF STRUCTURE, OR FLOW OVER THE BASIN DIVIDE, WHICHEVER IS LOWER.

③ FOR THOSE CROSSINGS NOTED BY Qp(max) IN THE REMARKS COLUMN, OVERTOPPING DOES NOT OCCUR AND THE FLOOD MAGNITUDE LISTED CORRESPONDS TO THE FLOOD OF SECTION 650.115(a)(1)(ii) OF FEDERAL-AID POLICY GUIDE; SUBCHAPTER G, PART 650, SUBPART A (Dec. 1991)
THE FLOOD SPECIFIED IS SUBJECT TO STATE-OF-THE-ART CAPABILITY TO ESTIMATE THE EXCEEDANCE PROBABILITY. (PIPES 0.5%; BRIDGE 0.2%)

④ HIGHWATER ELEVATIONS MAY VARY SLIGHTLY DEPENDING UPON THE PIPE OPTION SELECTED.

⑤ PROCEDURE MEMORANDUM NO.10, HYDRAULICS MANUAL CHAPTER 9 APPENDIX H.

EXCEEDANCE PROBABILITIES

25 YEAR	4% CHANCE
50 YEAR	2% CHANCE
100 YEAR	1% CHANCE
200 YEAR	0.5% CHANCE
500 YEAR	0.2% CHANCE

Nashua E. & W.
Valley Co.
NH 1-9(25)555

FIG. 4.4 L

3
2
1
MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

c:\dgn\rmanrdhdse01.dgn
10/17/2016
1:05:41 PM CPS - U1968

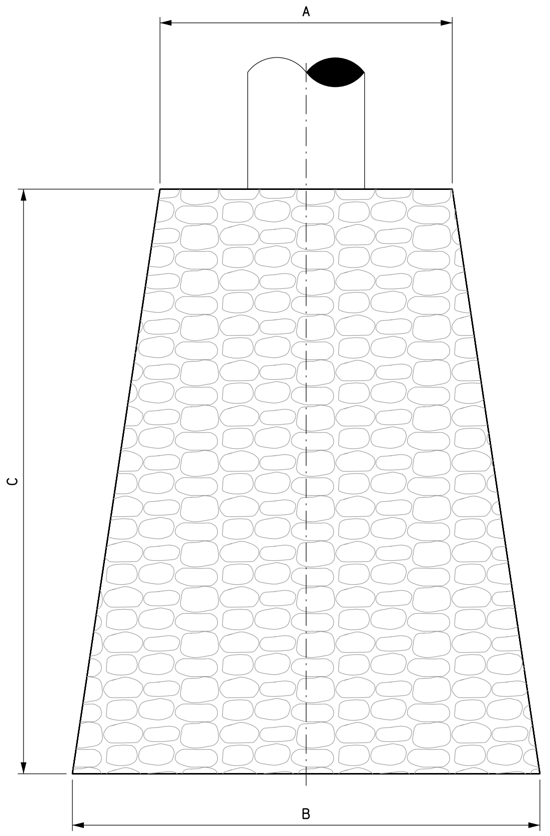
DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS
COUNTY NAME(S)

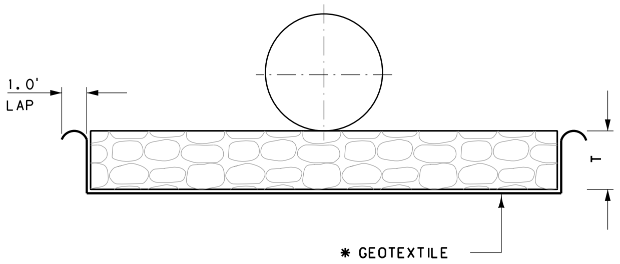
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999



PLAN VIEW



ELEVATION VIEW

MIN. T FOR
STREAM BANK EROSION BLANKET

CLASS 1 RIPRAP = 1.3 FT
CLASS 2 RIPRAP = 2.6 FT
CLASS 3 RIPRAP = 3.0 FT

OUTLET RIPRAP APRON								
STATION	PIPE SIZE/TYPE	DIMENSIONS (FT)				RIPRAP APRON (yd^3)	✱ GEOTEXTILE (yd^2)	REMARKS
		A	B	C	T		PERM. EROS. CNTRL. __ SURVIVABILITY CLASS __ ①	
42+49	84" DRAIN	8.9	15.4	20.7	1.3	12.2	38.2	
115+12	DBL. 132" SSPP	23.6	33.5	32.8	1.3	45.5	122.5	

Outlet Riprap Apron Reminders:

① *Consult with Geotechnical Section to determine Survivability and Class of Erosion Control Geotextile, based on subgrade conditions.*

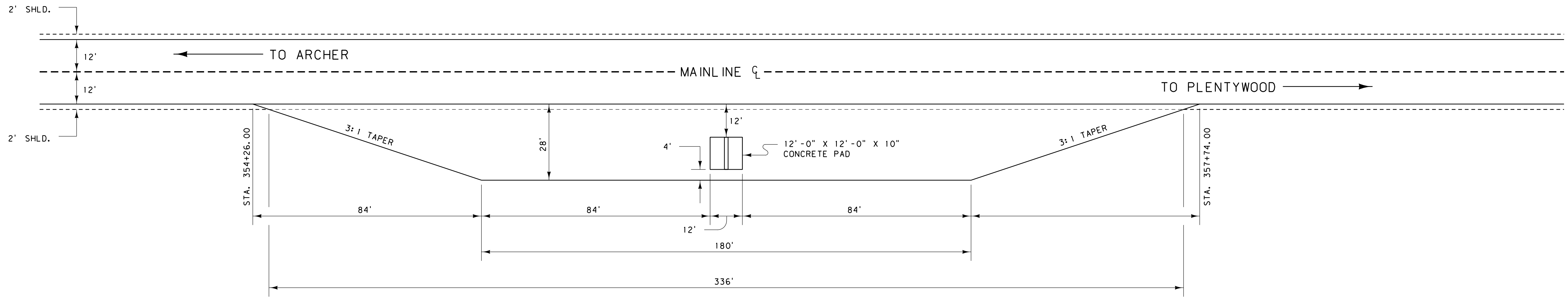
Richland Co. Line-North
Outlet Riprap Apron Detail
Richland Co.
STPS 261-2(4)28
Not To Scale

FIG. 4.4 M-1

3 2 1	serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrddete01.dgn 10/17/2016 1:05:49 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	*DESIGNER NAME* *SUPERVISOR NAME* *CHECKER NAME*	*DATE* *DATE* *DATE*	ROAD PLANS COUNTY NAME(S)

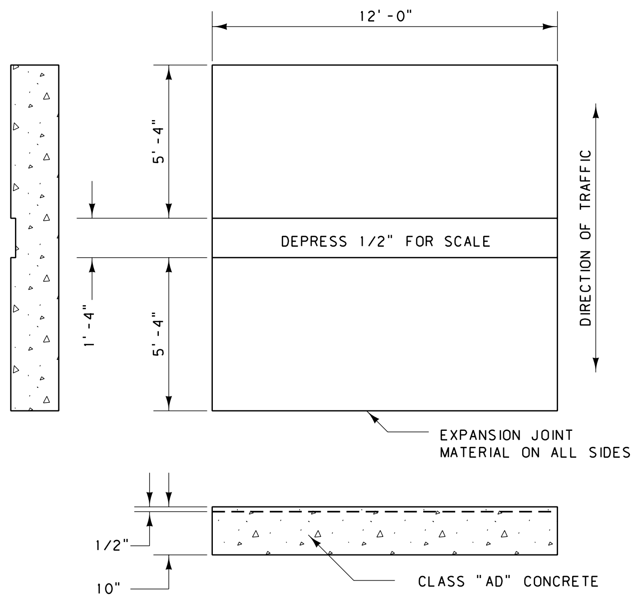
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999



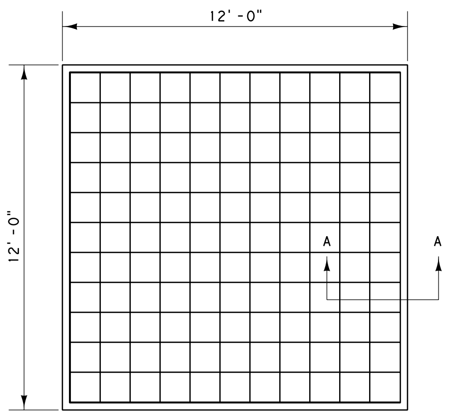
PAD DETAIL

NOT TO SCALE

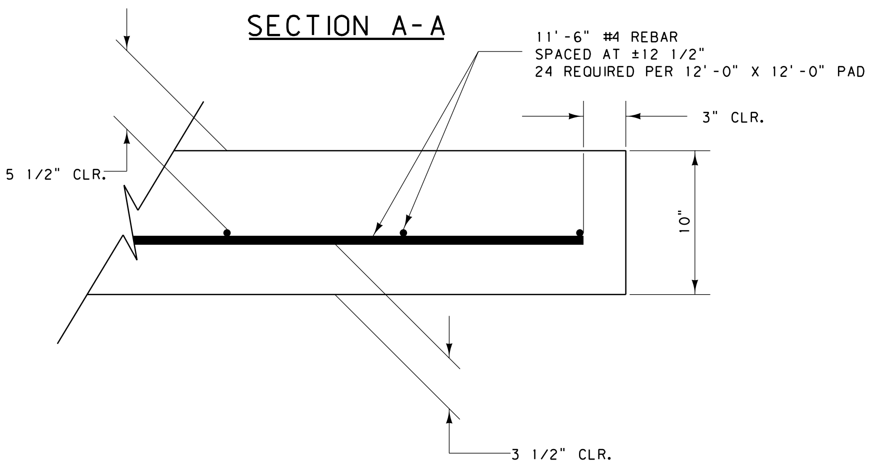


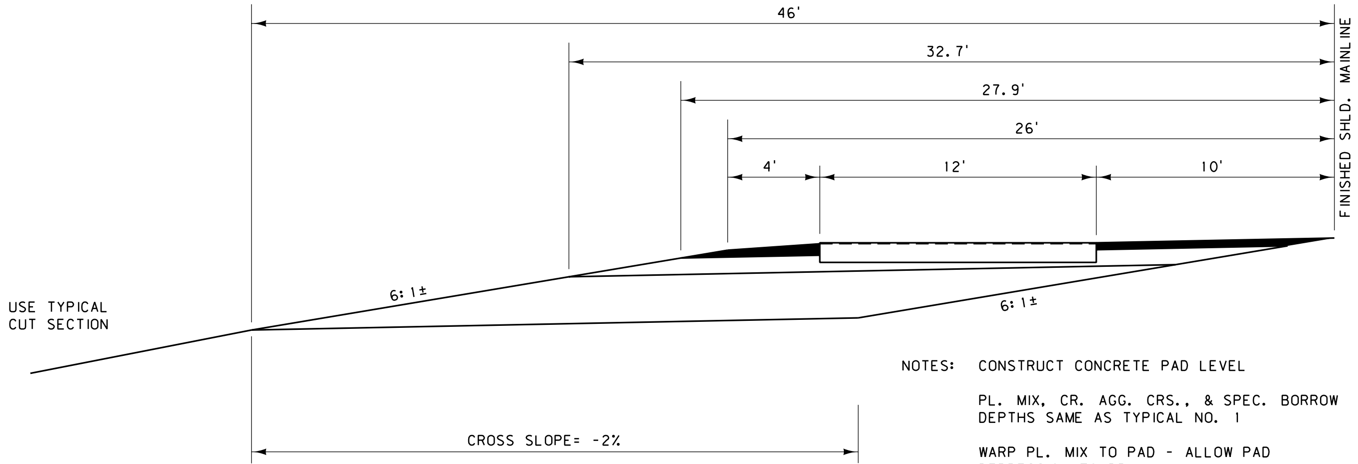
REINFORCING STEEL PLAN

NOT TO SCALE



SECTION A-A





NOTES: CONSTRUCT CONCRETE PAD LEVEL

PL. MIX, CR. AGG. CRS., & SPEC. BORROW DEPTHS SAME AS TYPICAL NO. 1

WARP PL. MIX TO PAD - ALLOW PAD DEPRESSION TO DRAIN

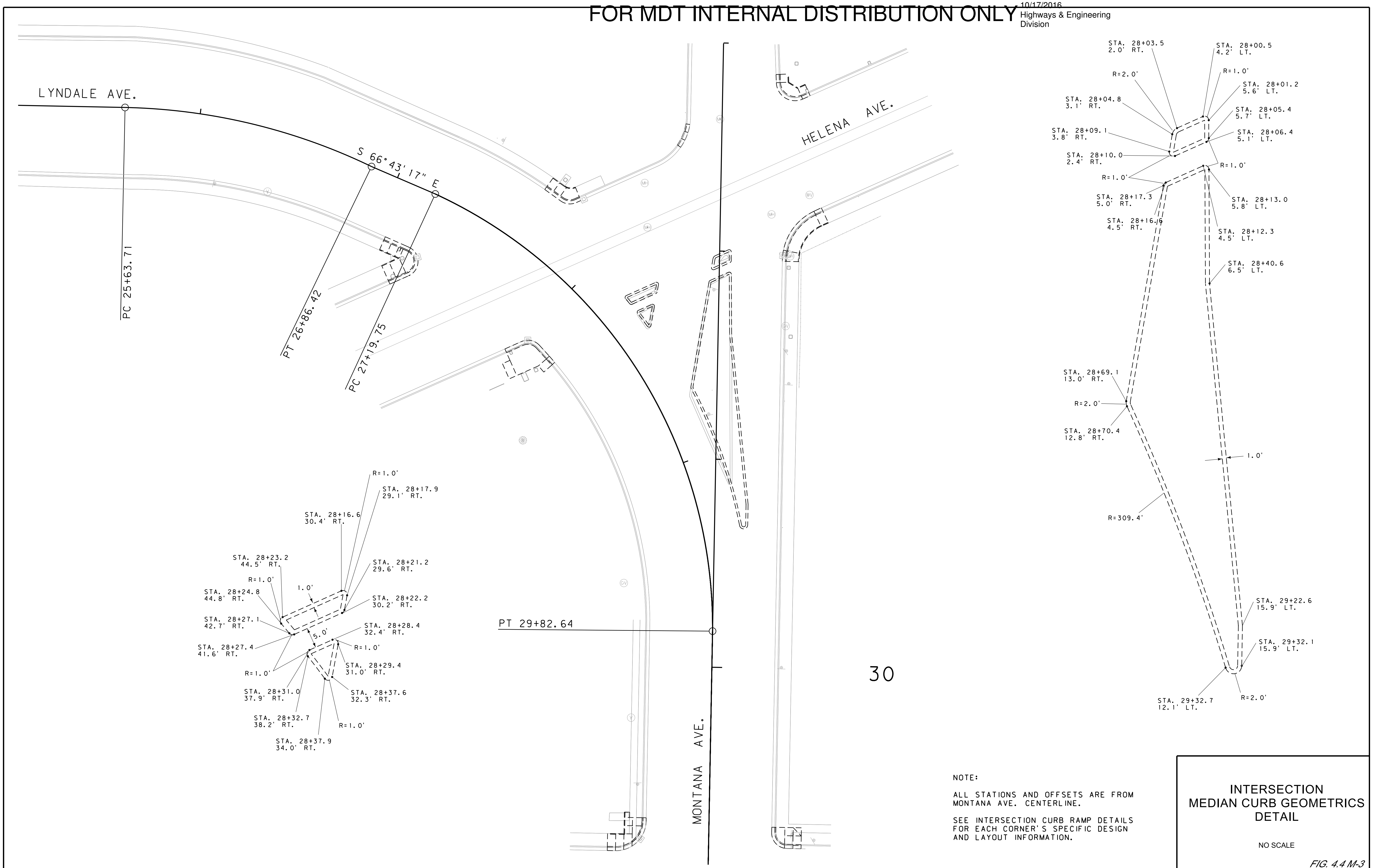
PAD QUANTITIES	
CLASS "AD" CONCRETE	4.4 cy
GR. 60 REINF. STEEL	184 lbs*
EXPANSION JOINT MATERIAL	48 ft*

* INCLUDED IN UNIT PRICE BID FOR CONCRETE

DETAIL
M.C.S. SCALE SITE
TYPE "B"
STA. 356+00.00

NO SCALE

FIG. 4.4 M-2



NOTE:

ALL STATIONS AND OFFSETS ARE FROM MONTANA AVE. CENTERLINE.

SEE INTERSECTION CURB RAMP DETAILS FOR EACH CORNER'S SPECIFIC DESIGN AND LAYOUT INFORMATION.

INTERSECTION MEDIAN CURB GEOMETRICS DETAIL

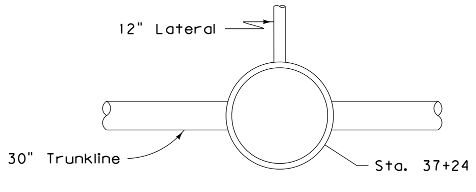
NO SCALE

FIG. 4.4 M-3

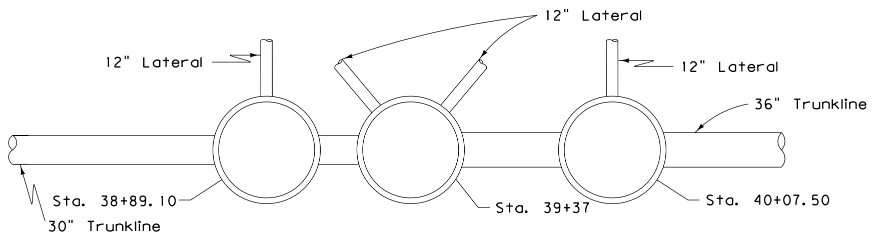
3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete03.dgn	DESIGNED BY	DESIGNER NAME	DATE	ROAD PLANS
2		10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE	
1		1:06:05 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE	COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

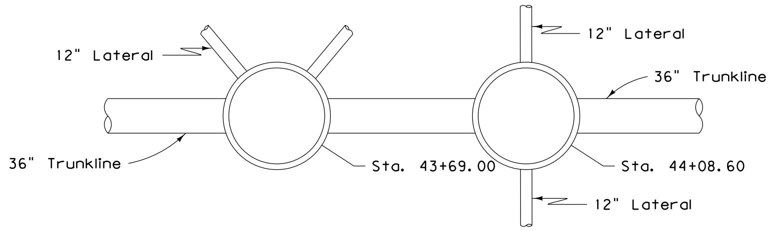
PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999



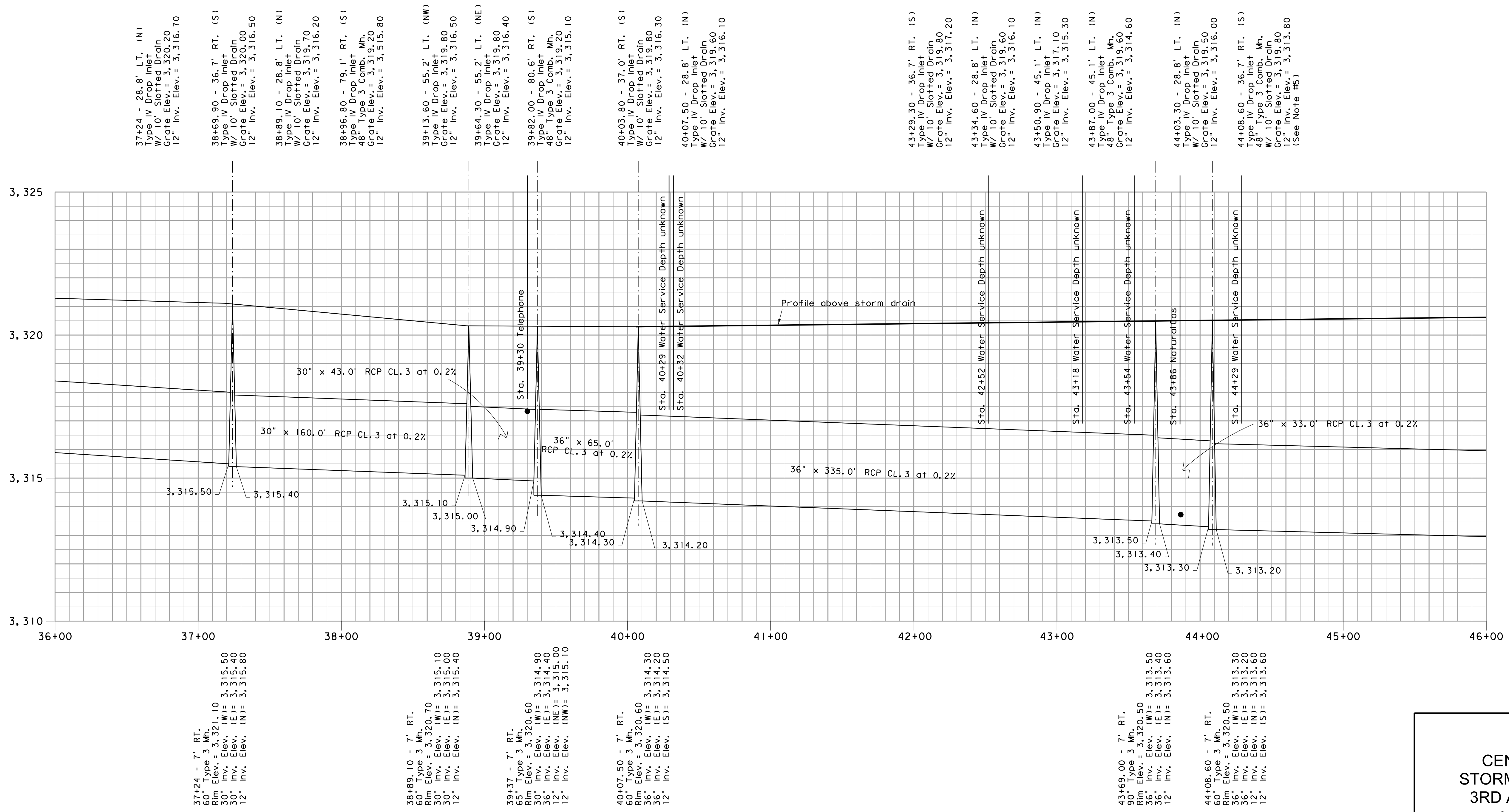
PLAN VIEW
No Scale



PLAN VIEW
No Scale



PLAN VIEW
No Scale

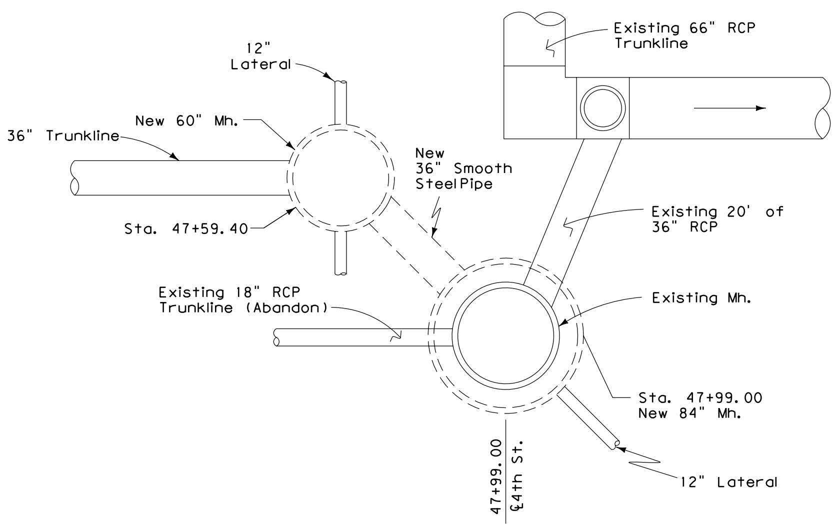


CENTRAL AVE. W.
STORM DRAIN PROFILE
3RD AVE. TO 9TH ST.
Scale: 1" = 2' Vertical
1" = 40' Horizontal

FIG. 4.4 M-4

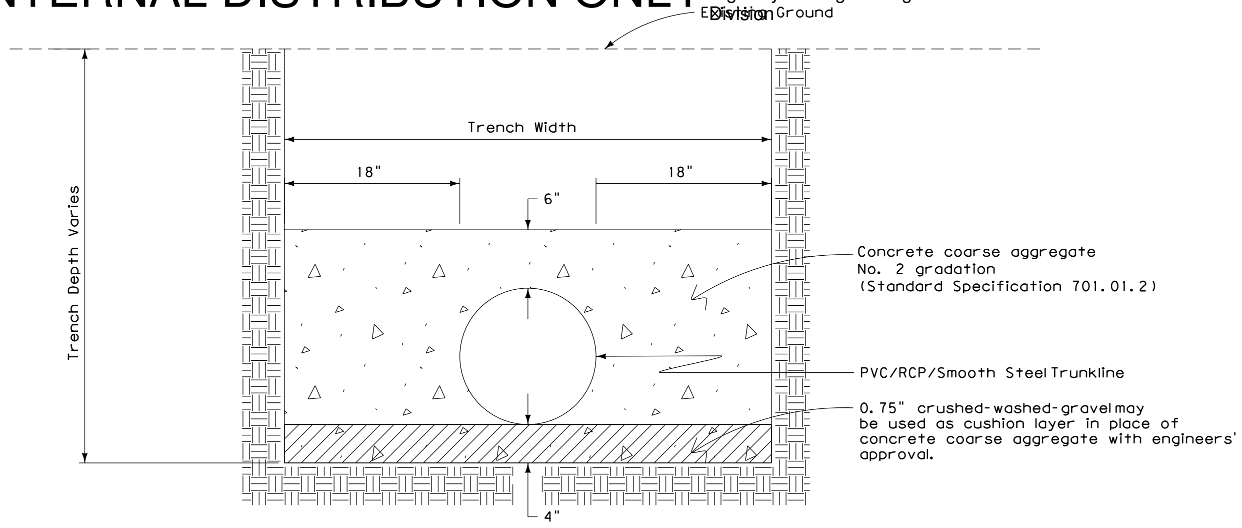
3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete04.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS	*MONTANA ROAD DESIGN MANUAL*
2		10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*		*SAMPLE PLAN SHEET (U.S. Customary Units)*
1		1:06:14 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)	

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999



PLAN VIEW

No Scale

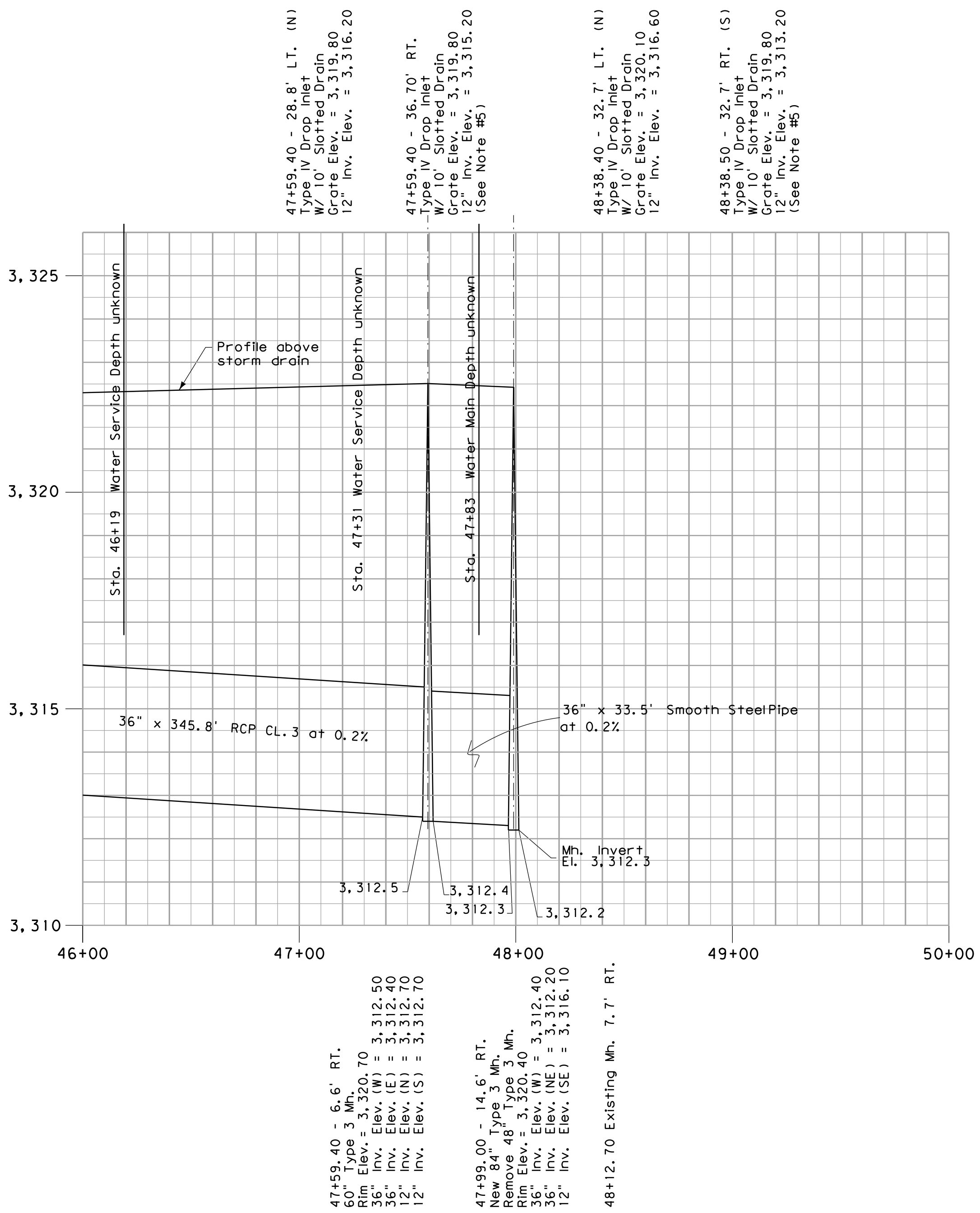


TRUNKLINE / LATERAL BEDDING DETAIL △1 △2

No Scale

Notes:

1. See Detailed Drawing No. 604-04 & 604-06 for MDT Type IV Drop Inlet.
2. Minimum slope on 12" RCP lateral lines from inlets to manholes shall be 0.75% min.
3. Use irrigation class RCP for the trunkline.
4. Use 12" irrigation class RCP for laterals.
5. At Sta. 44+08.60 RT. to 47+59.40 RT., Use AWWA C200 Steel water pipe with a thickness of 0.5". (See Standard Specifications 709.01.2). All welding will be done in accordance to Standard Specifications 556.03.10.
6. Maximum cushion layer thickness shall be 4". Keep cushion layer moist until backfill begins.



Mh. Station	① Edge to Edge Length	② Center To Center Length
26+82.90		
	183.2'	188.1'
28+71		
	168.2'	176.1'
30+47.10		
	43.8'	48.7'
30+95.80		
	190.3'	195.2'
32+91		
	181.2'	186.1'
34+77.10		
	242.0'	246.9'
37+24		
	160.2'	165.1'
38+89.10		
	42.7'	47.9'
39+37		
	65.3'	70.5'
40+07.50		
	355.3'	361.5'
43+69.00		
	33.4'	39.6'
44+08.60		
	③ 345.9'	③ 350.8'
47+59.40		
	33.7'	39.6'
47+99.00		

① Inside edge to inside edge of manhole used for slope.

② Center to center of manhole - bid length.

③ AWWA C200 Steel water pipe with a thickness of 0.5". (See Standard Specifications 709.01.2). All welding will be done in accordance to Standard Specifications 556.03.10.

Storm Drain Reminders:

△1 RCP will normally be specified for laterals.

△2 Bedding is generally not required for laterals unless specified by hydraulics.

CENTRAL AVE. W.
STORM DRAIN PROFILE
3RD AVE. TO 9TH ST.

Scale: 1" = 2' Vertical
1" = 40' Horizontal

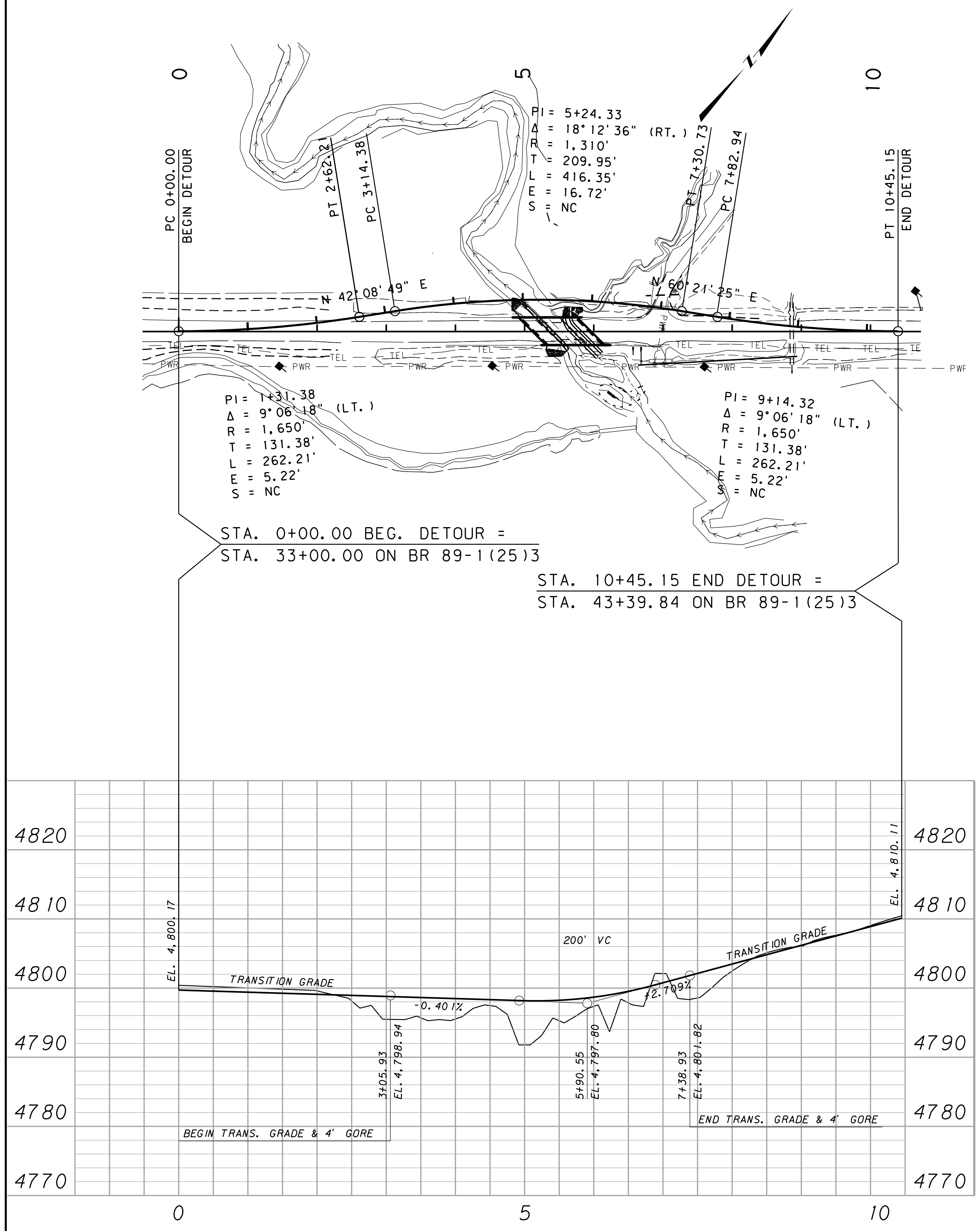
FIG. 4.4 M-5

3	serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrddete05.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*
2			10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*
1			1:06:22 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS	*MONTANA ROAD DESIGN MANUAL*	PROJECT LOCATION DESCRIPTION		PROJECT NO.
COUNTY NAME(S)	*SAMPLE PLAN SHEET (U.S. Customary Units)*	CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

⊙ FOR INFORMATIONAL PURPOSES ONLY

DETOUR DESIGN SPEED = 35 mph



⊙ DETOUR GRADING

STATION		cubic yards			square yards	REMARKS
		EXC.	EMB. +	BORROW	GEOTEXTILE STABILIZATION	
FROM	TO					
0+00.00	4+63.00		2,366	2,366	388	
5+28.00	10+45.15		2,087	2,087	529	
TOTAL		~	4,453	4,453	917	

30% SHRINKAGE

⊙ PAVEMENT MARKINGS

ITEM	UNIT	TOTAL
WHITE PAINT	gallon	13
YELLOW PAINT	gallon	13

⊙ DETOUR SURFACING

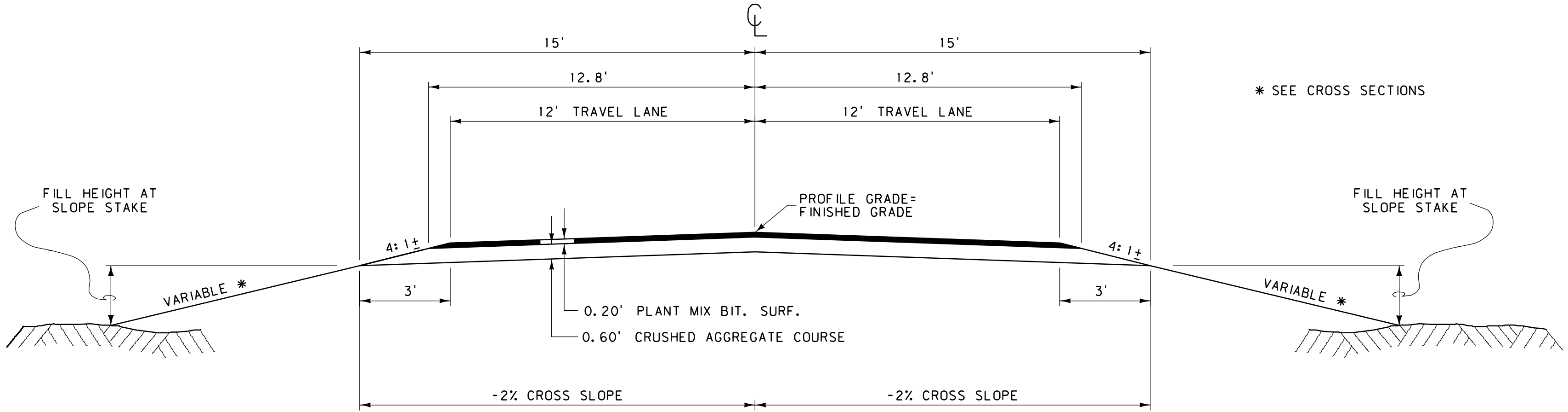
STATION		linear feet				FOR	AGGREGATE		REMARKS
		GROSS	NET	+	-		tons	cubic yards	
							PLANT MIX BIT. SURF. GRADE C	CRUSHED AGG. COURSE	
FROM	TO								
0+00.00				~	~				
4+63.00	5+28.00				65.00	BRIDGER CREEK X-ING DETOUR			TEMP. BRIDGE *
	10+45.15	1,045.15	980.15				336	634	DETOUR TYPICAL SECTION
							67		20% CONTINGENCY TO PATCH DET.
TOTAL		1,045.15	980.15	~	~		403	634	

* INCLUDED IN LUMP SUM FOR DETOUR

⊙ DETOUR METAL GUARDRAIL

STATION		linear feet				each				REMARKS
		METAL GUARDRAIL		INTERSECTION ROADWAY TRANSITION 24.0' RADIUS		BRIDGE APPROACH SECTION TYPE 2		OPTIONAL TERMINAL SECTION		
FROM	TO	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
3+25.50	4+63.00		62.5				1		1	
3+88.00	4+63.00					1		1		
5+28.00	6+77.00	100.0		62.5		1				
5+28.00	6+03.00						1		1	
SUBTOTAL						2	2	1	2	
TOTAL		162.5		62.5		4		3		

DETOUR TYPICAL SECTION



* SEE CROSS SECTIONS

0+00.00	TO	3+05.93	MATCH CROSS SLOPE OF MAINLINE
3+05.93	TO	4+05.93	TRANSITION FROM MAINLINE CROSS SLOPE TO N.C.
4+05.93	TO	6+38.93	
6+38.93	TO	7+38.93	TRANSITION FROM N.C. TO MAINLINE CROSS SLOPE
7+38.93	TO	10+45.15	MATCH CROSS SLOPE OF MAINLINE

DETOUR DETAIL

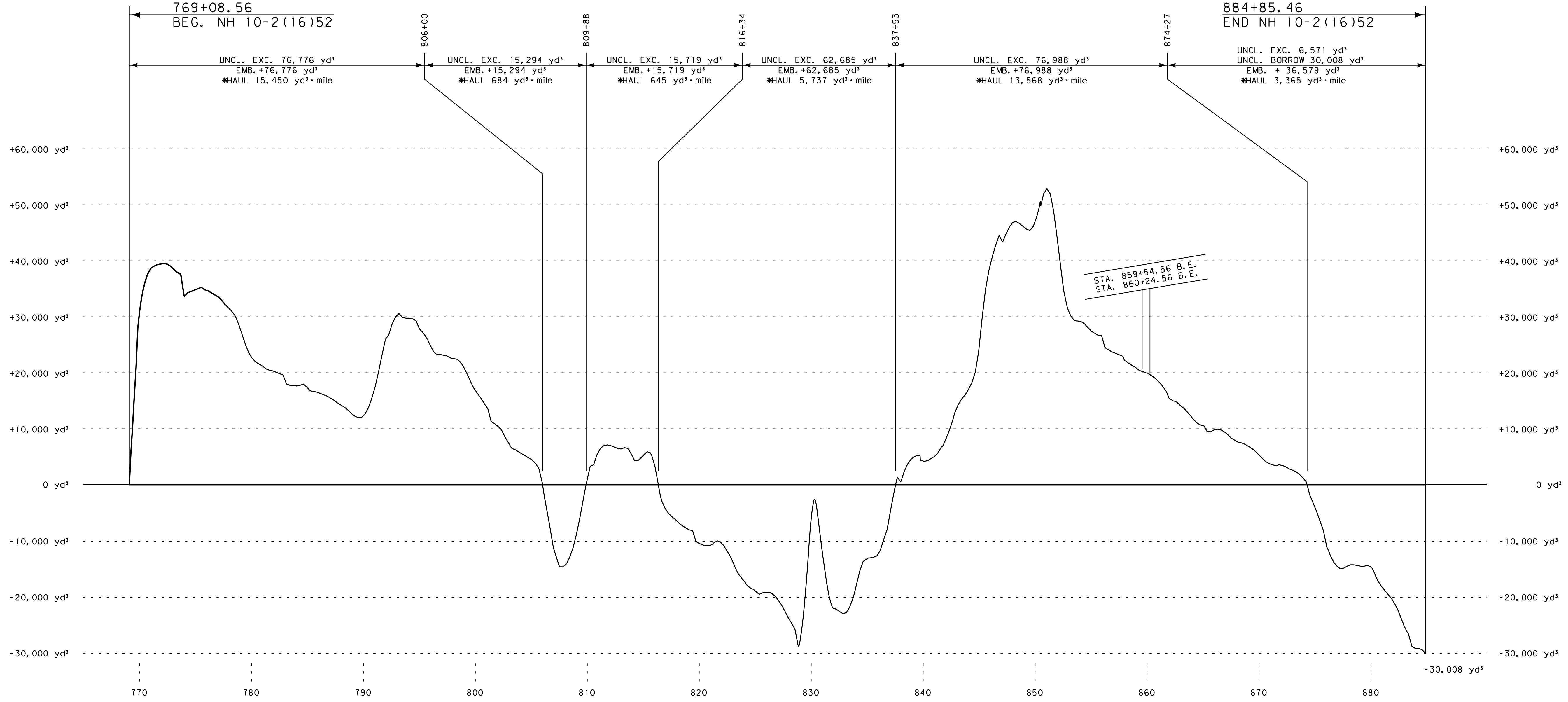
NO SCALE

FIG. 4.4 M-6

3 2 1	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete06.dgn 10/17/2016 1:06:30 PM CPS - U1968	DESIGNED BY DESIGNER NAME DATE REVIEWED BY SUPERVISOR NAME DATE CHECKED BY CHECKER NAME DATE	ROAD PLANS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

MASS DIAGRAM



* HAUL SHOWN FOR INFORMATIONAL PURPOSES ONLY

SCALE: ①
HORIZONTAL - 1" = 500'
VERTICAL - 1" = 10,000 yd³ ②
SHRINK FACTOR 35%

① *Produce scales in multiples of:*

1" = 10 units
1" = 20 units
1" = 30 units
1" = 40 units
1" = 50 units

② *To calculate scale of drawing:*

A.) Select scale that measures 10 units between grid lines.
B.) Divide value shown for one grid by 10 = value of one unit.
C.) Multiply value of one unit by scale selected.
D.) Divide by 2 (for half-size sheet) = scale of drawing (for full-size sheet).

Ex. - Horizontal scale of this drawing

A.) Select 1" = 10 units on scale - 10 = 1,000' shown
B.) 1,000' divided by 10 = 100'
C.) 100' mulitplyed by 10 = 1,000'
D.) 1,000' divided by 2 = 500'
Scale 1" = 500' (for full-size sheet)

Ex. - Vertical scale of this drawing

A.) Select 1" = 20 units on scale - 10 = 10,000 yd³ shown
B.) 10,000 yd³ divided by 10 = 1,000 yd³
C.) 1,000 yd³ mulitplyed by 20 = 20,000 yd³
D.) 20,000 yd³ divided by 2 = 10,000 yd³
Scale 1" = 10,000 yd³ (for full-size sheet)

FIG. 4.4 M-7

3
2
1
serving you with pride
MONTANA DEPARTMENT
OF TRANSPORTATION
c:\dgn\rmanrddete07.dgn
10/17/2016
1:06:38 PM CPS - U1968

DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

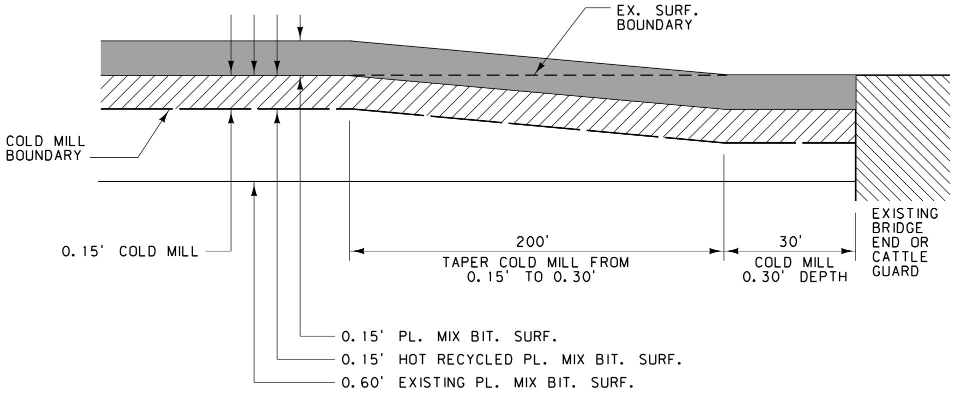
PROJECT NO.
SHEET 999 OF 999

BRIDGE ENDS & CATTLE GUARDS

▨ HOT RECYCLED PL. MIX BIT. SURF.

■ PL. MIX BIT. SURF.

FROM	TO
32+32.45	34+02.45 B.E.
40+12.73 B.E.	42+42.73



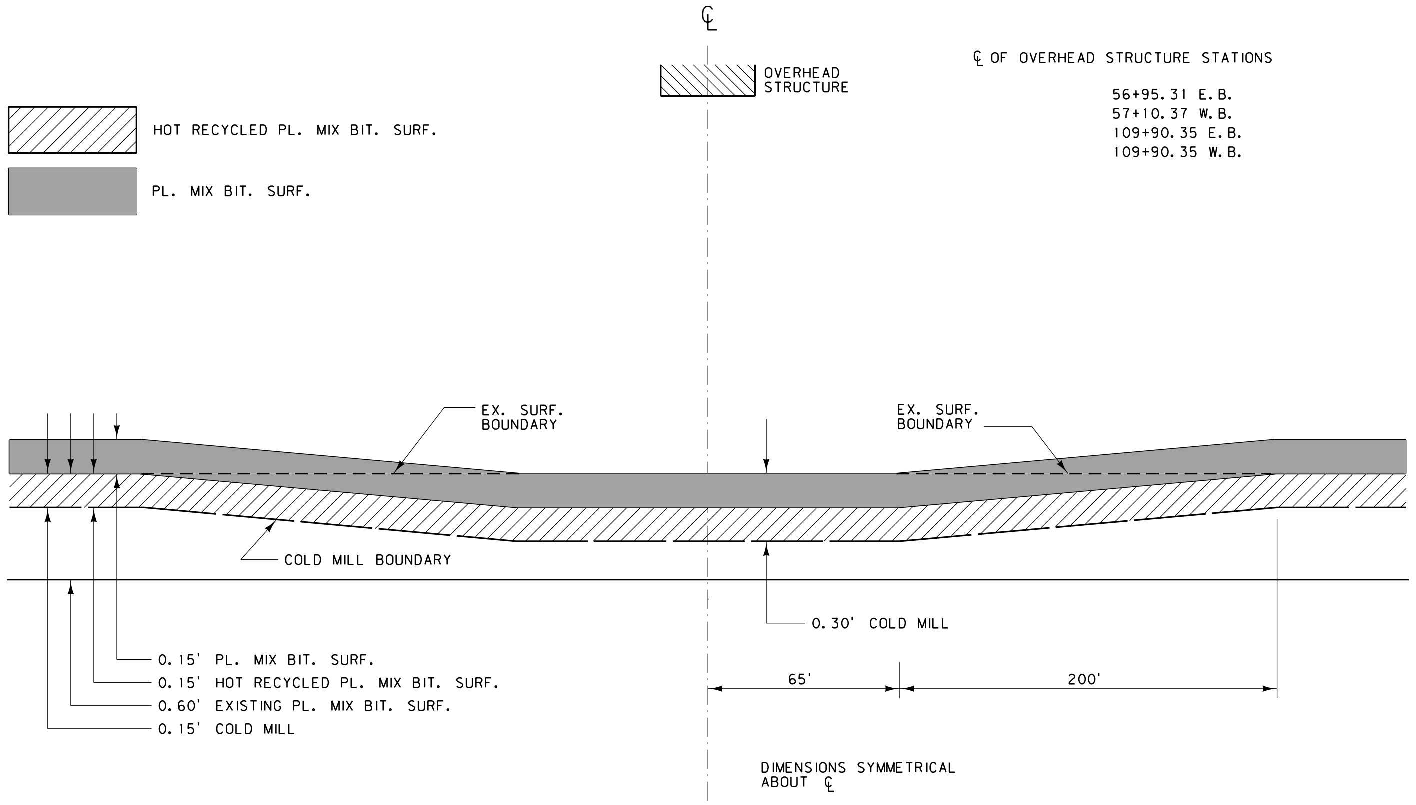
OVERHEAD STRUCTURES

▨ HOT RECYCLED PL. MIX BIT. SURF.

■ PL. MIX BIT. SURF.

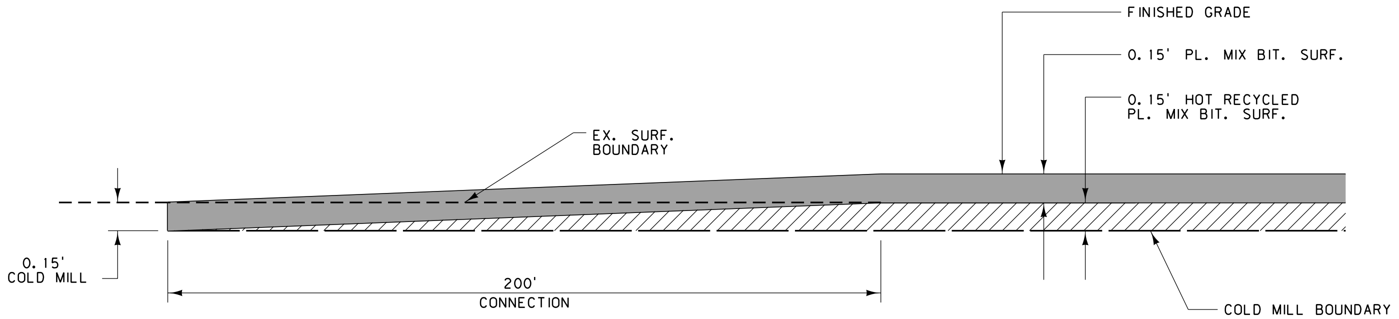
℄ OF OVERHEAD STRUCTURE STATIONS

56+95.31 E.B.
57+10.37 W.B.
109+90.35 E.B.
109+90.35 W.B.



CONNECTIONS

263+56.23 TO 265+56.23 BEG. PROJ. CONNECTION
567+00.00 TO 569+00.00 END PROJ. CONNECTION

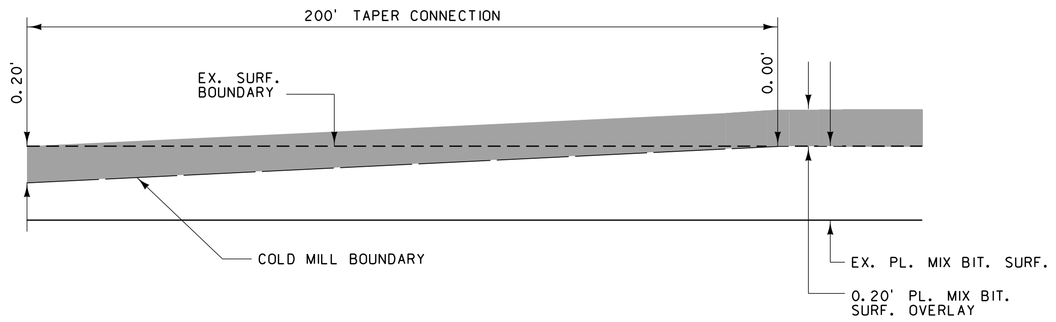


▨ HOT RECYCLED PL. MIX BIT. SURF.

■ PL. MIX BIT. SURF.

CONNECTIONS

7+34.94 TO 9+34.94 BEG. PROJ. CONNECTION
116+68.77 TO 118+68.77 END PROJ. CONNECTION



(Typical Rural Project Examples)

COLD MILLING
DETAILS

NO SCALE

FIG. 4.4 M-8

3	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrddete08.dgn	DESIGNED BY	ROAD PLANS
2		10/17/2016	REVIEWED BY	
1		1:06:46 PM CPS - U1968	CHECKED BY	COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

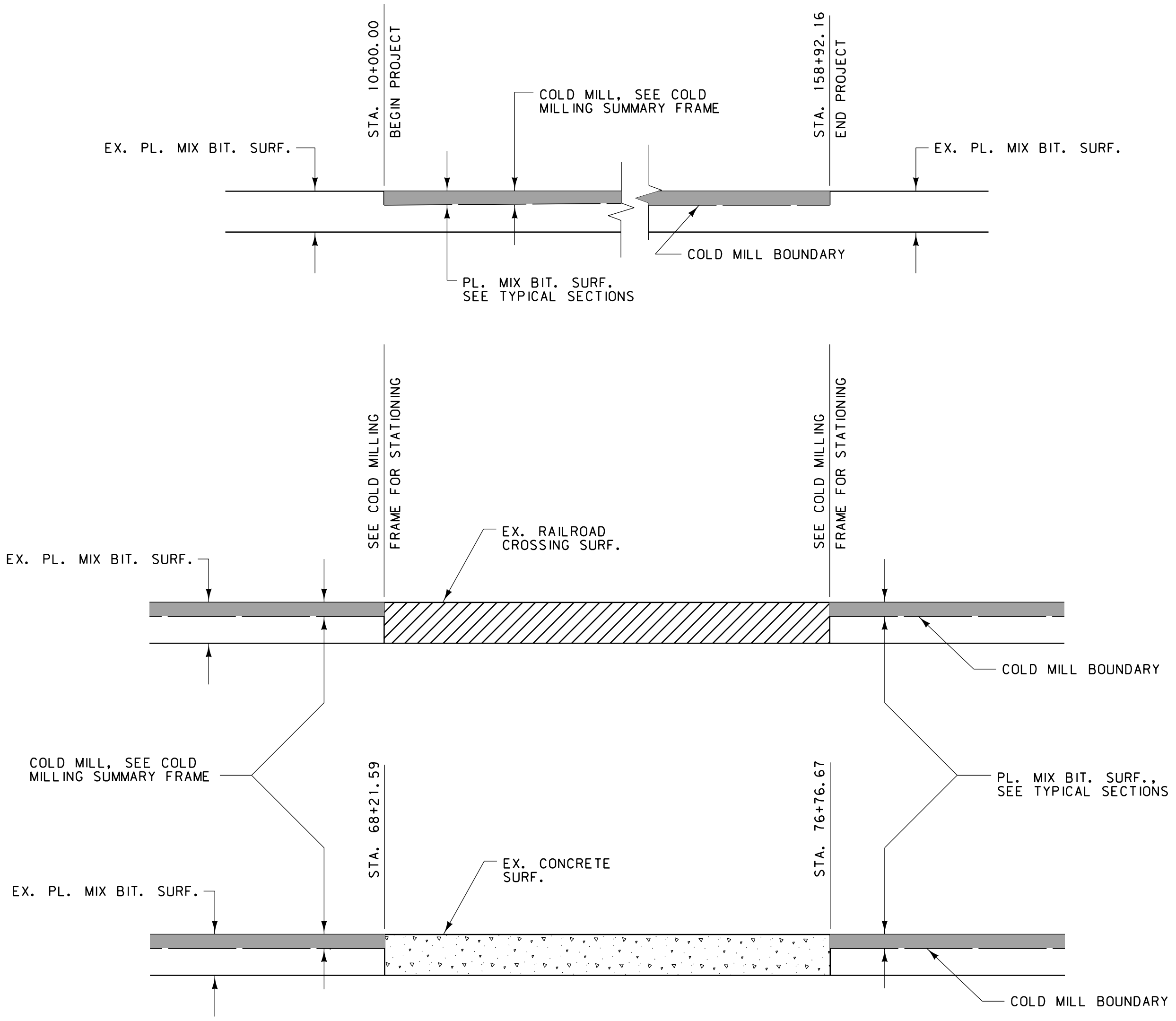
PROJECT LOCATION DESCRIPTION

CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.

SHEET 999 OF 999

MAINLINE COLD MILLING DETAILS

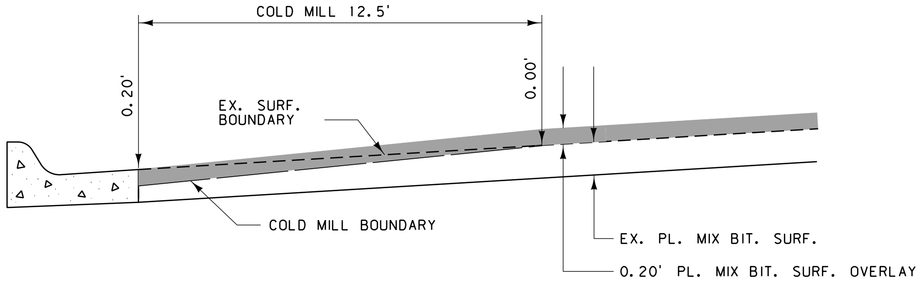


CURB & GUTTER SHOULDER COLD MILLING DETAIL

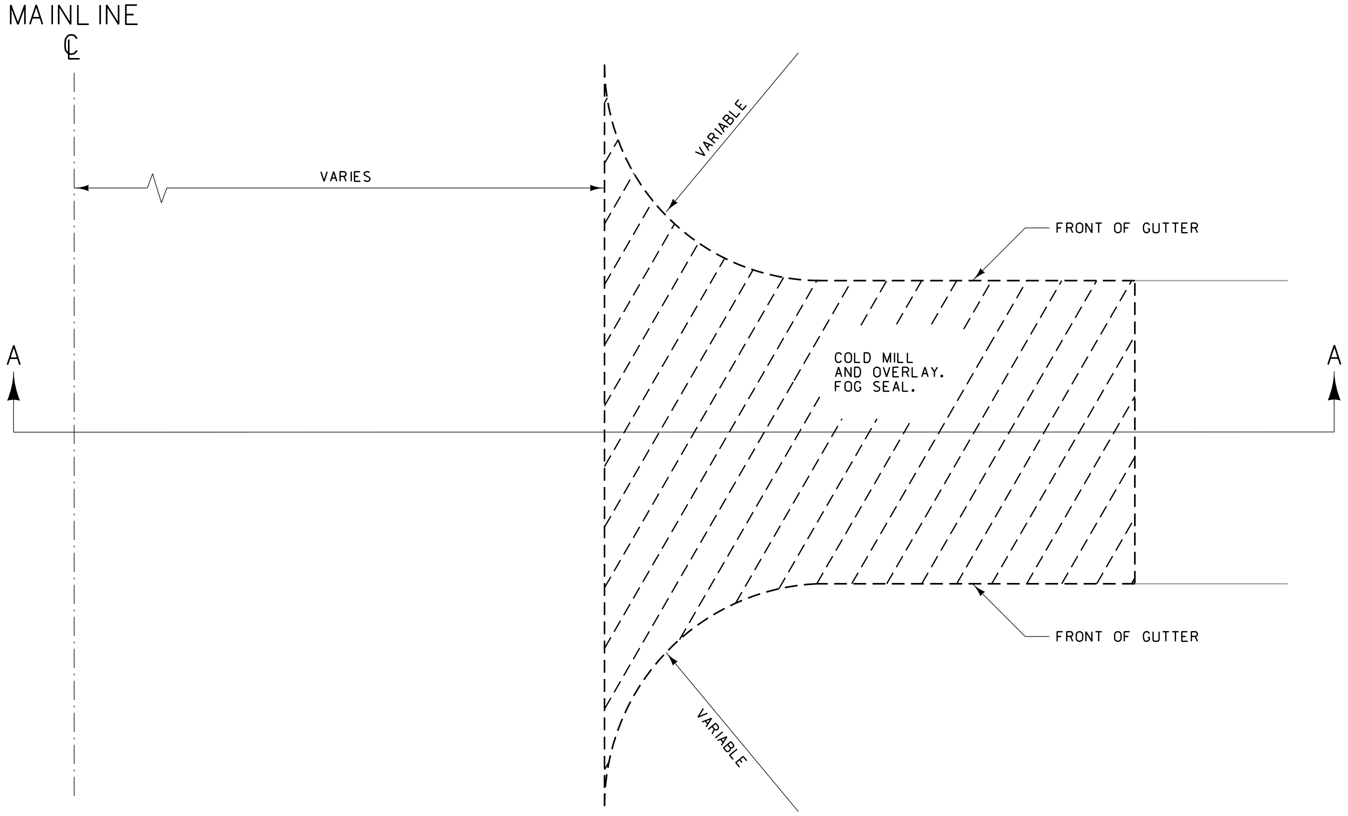
HUNGRY HORSE: 122+66.99 TO 182+75.00 LT.
136+81.00 TO 182+75.00 RT.

CORAM: 306+29.99 TO 336+95.01 LT. & RT.

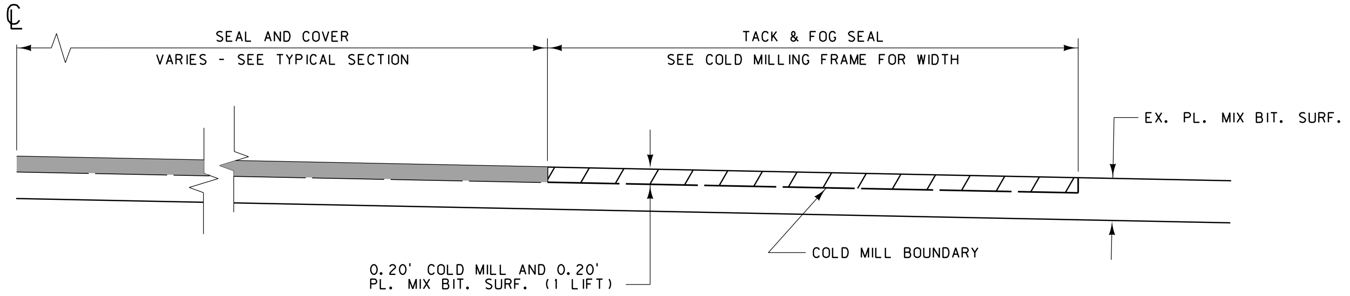
W. GLACIER: 675+00.00 TO 688+49.21 BK. =
2+52.89 AH. TO 6+19.32 RT. & LT.



STREET INTERSECTION COLD MILLING AND SURFACING DETAIL



SECTION A-A



(Typical Urban Project Examples)

COLD MILLING
DETAILS

NO SCALE

FIG. 4.4 M-9

MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

c:\dgn\rmanrddete09.dgn
10/17/2016
1:06:54 PM CPS - U1968

DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS
COUNTY NAME(S)

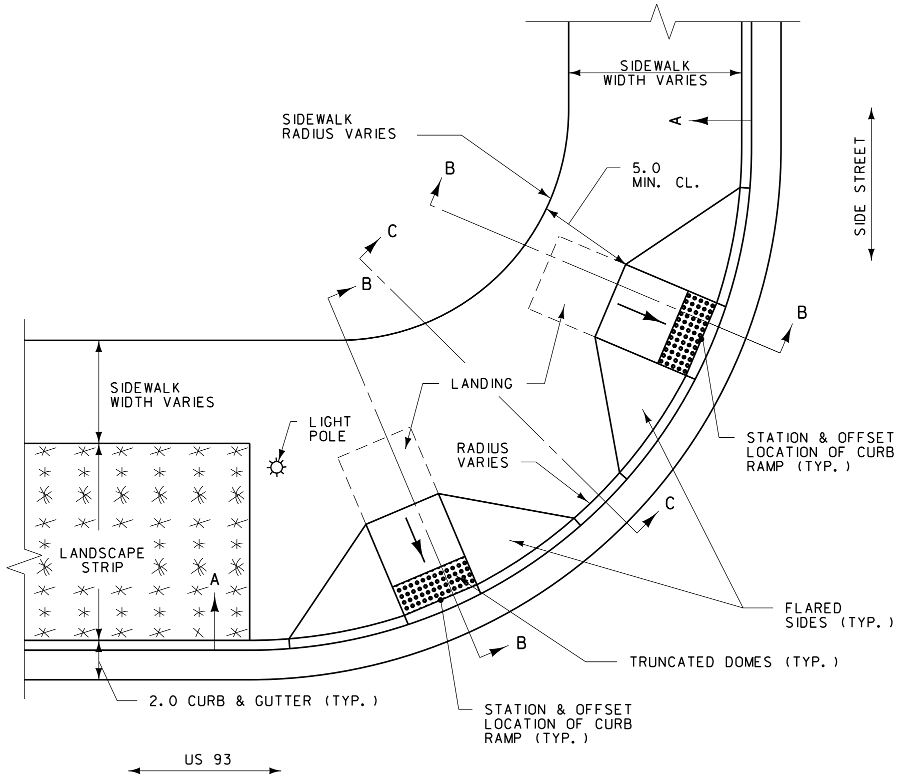
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

DIAGONAL PERPENDICULAR CURB RAMP DETAILS

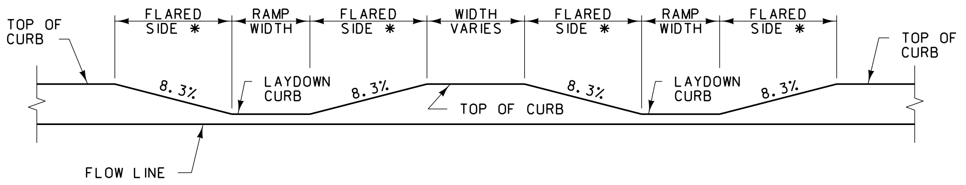
US 93



PLAN

NEW CONSTRUCTION REQUIREMENTS:

1. THE MINIMUM LENGTH OF THE LANDING IS 5'.
2. THE DESIRABLE SLOPE FOR THE CURB RAMP IS 5% (1:20) OR FLATTER. THE MAXIMUM CURB RAMP SLOPE IS 8.3% (1:12).
3. THE DESIRABLE CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 1.5% (1:66.7). THE MAXIMUM CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 2% (1:50).
4. THE DESIRABLE SLOPE OF THE FLARED SIDE OF THE CURB RAMP IS 8.3% (1:12) OF FLATTER. THE MAXIMUM FLARED SIDE SLOPE IS 10% (1:10).
5. PROVIDE TRUNCATED DOMES ON THE BOTTOM 2' OF EACH RAMP AS SHOWN SEE DTL. DWG. NO. 608-40 FOR TRUNCATED DOMES DETAILS.
6. FOR ADDITIONAL DETAILS, SEE DTL. DWG. NO. 608-25, 608-35, AND 609-05.

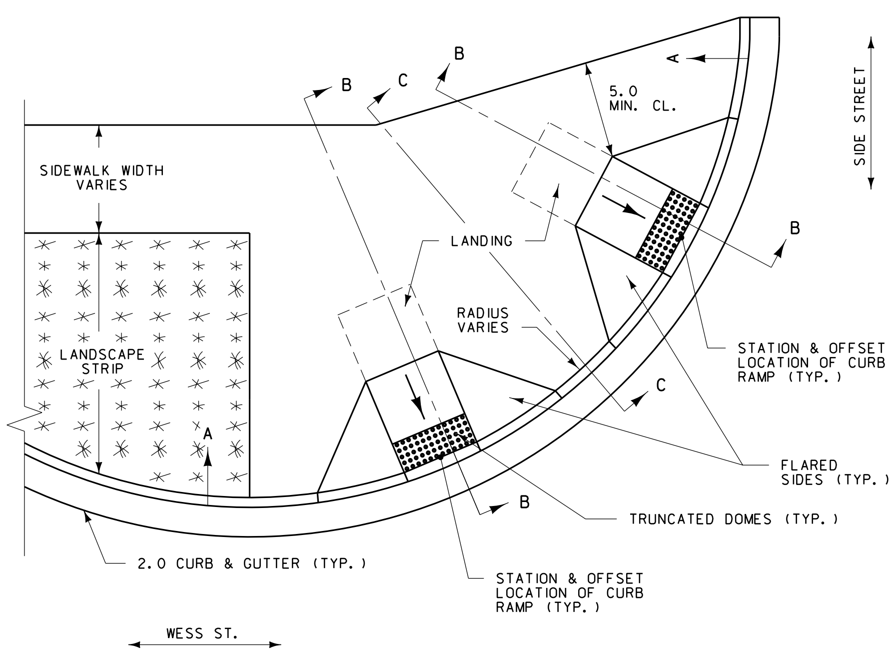


* ADJUST FLARED SIDE LENGTH AS NEEDED TO MAINTAIN DESIRABLE SLOPES

SECTION A-A

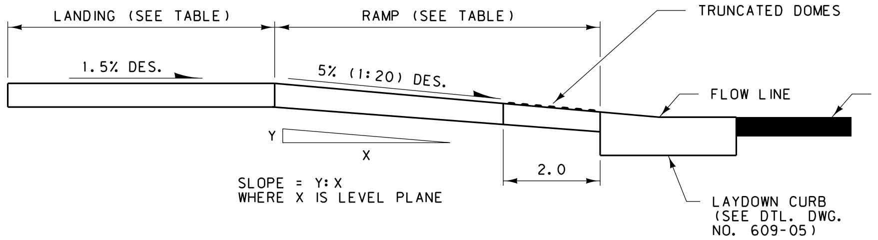
DIAGONAL PERPENDICULAR CURB RAMP DETAILS

WESS ST.



PLAN

STATION US 93	OFFSET (FT)	RAMP AND TRUNCATED DOME WIDTH (FT)	RAMP LENGTH (FT)	RAMP DESIGN SLOPE (%)	LANDING LENGTH (FT)
288+55.00	21.9 RT.	5.0	10.2	5.0	5.0
288+65.20	22.5 LT.	5.0	10.2	5.0	5.0
288+71.50	38.3 RT.	5.0	6.9	7.5	5.0
288+80.50	38.1 LT.	5.0	6.9	7.5	5.0
294+27.40	22.7 LT.	5.0	8.5	6.0	5.0
294+27.40	22.7 RT.	5.0	8.5	6.0	5.0
294+42.70	34.7 LT.	8.0	6.2	8.3	5.0
294+42.70	34.7 RT.	5.0	6.2	8.3	5.0
294+81.20	34.7 LT.	8.0	6.2	8.3	5.0
294+81.20	34.7 RT.	5.0	6.2	8.3	5.0
294+96.40	22.7 LT.	5.0	7.9	6.5	5.0
294+96.40	22.7 RT.	5.0	7.9	6.5	5.0
298+07.10	22.7 LT.	5.0	7.9	6.5	5.0
298+07.10	22.7 RT.	5.0	7.2	7.0	5.0
298+22.20	34.7 LT.	5.0	8.5	6.0	5.0
298+22.20	34.7 RT.	5.0	7.2	7.0	5.0

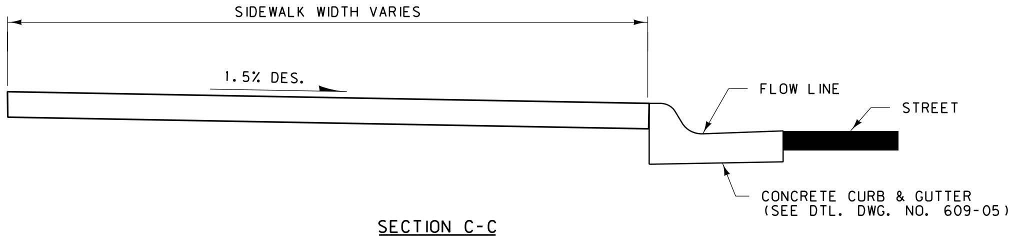


SECTION B-B

STATION WESS ST.	OFFSET (FT)	RAMP AND TRUNCATED DOME WIDTH (FT)	RAMP LENGTH (FT)	RAMP DESIGN SLOPE (%)	LANDING LENGTH (FT)
0+10.00	15.3 LT.	5.0	10.2	5.0	5.0
0+10.90	15.5 RT.	5.0	10.2	5.0	5.0
0+25.30	29.1 LT.	5.0	7.2	7.0	5.0
0+26.20	29.7 RT.	5.0	7.2	7.0	5.0
2+11.90	16.5 LT.	5.0	7.9	6.5	5.0
2+11.90	16.5 RT.	5.0	7.9	6.5	5.0
2+24.40	28.5 LT.	8.0	6.9	7.5	5.0
2+24.40	28.5 RT.	5.0	6.9	7.5	5.0
2+58.50	28.5 LT.	8.0	7.2	7.0	5.0
2+71.00	16.5 LT.	5.0	8.5	6.0	5.0

NOTES:

1. ALL DIMENSIONS ARE FEET (FT) UNLESS OTHERWISE NOTED.
2. SEE SIDEWALK SUMMARY FRAME FOR WIDTHS OF SIDEWALK.
3. SEE PLAN & PROFILE SHEETS AND GEOMETRIC DETAILS FOR RADII OF CURB & GUTTER AND SIDEWALK.



SECTION C-C

(Typical New Construction Example)

DIAGONAL
PERPENDICULAR
CURB RAMP
DETAILS

NO SCALE

FIG. 4.4 M-10A

3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete10.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*
2		10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*
1		1:07:02 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*

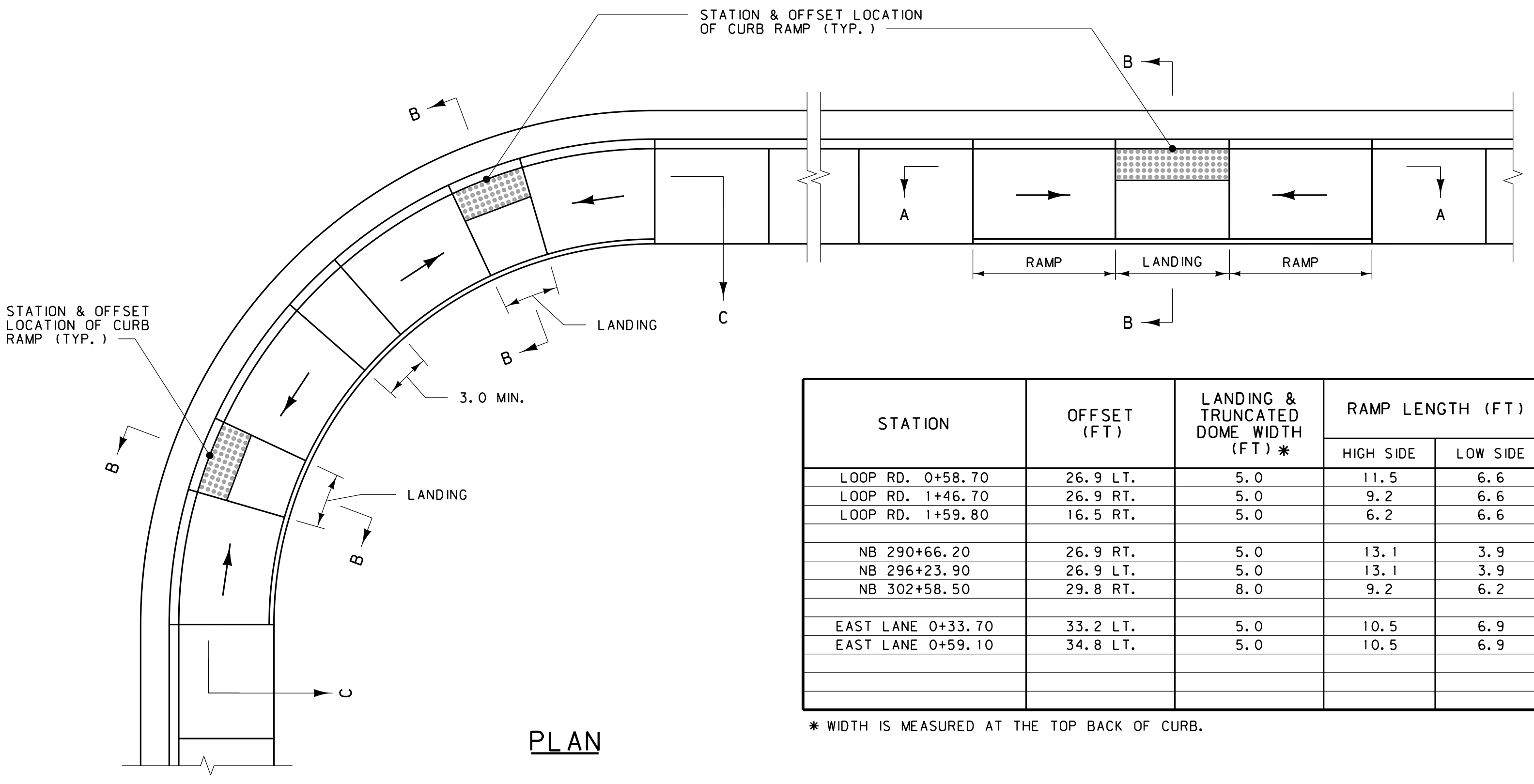
ROAD PLANS

COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

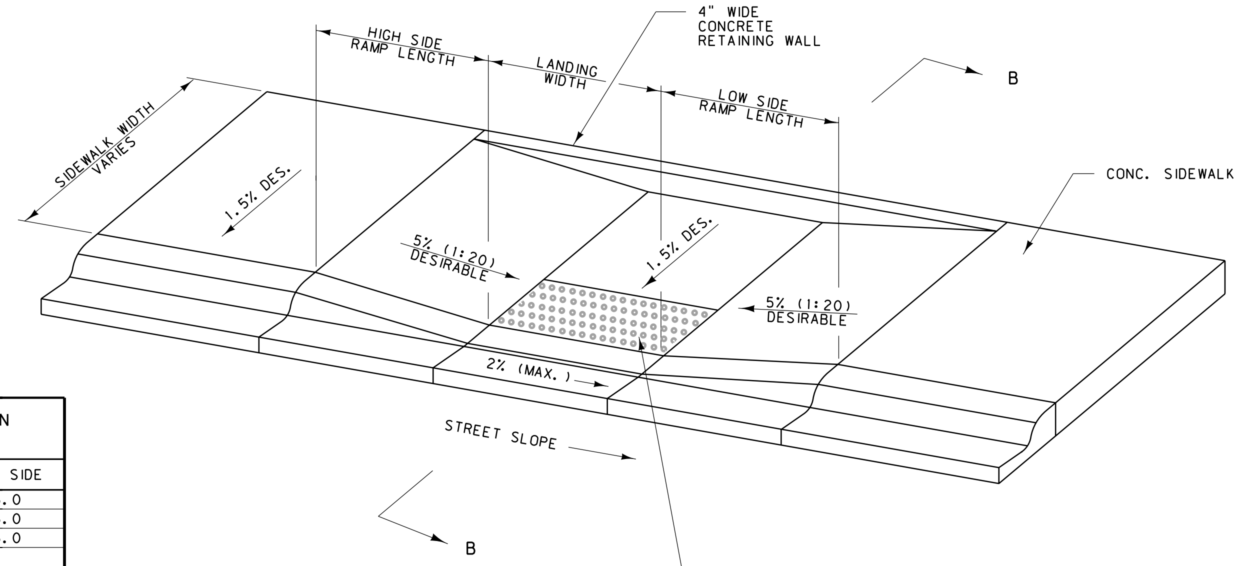
PARALLEL CURB RAMP DETAILS



PLAN

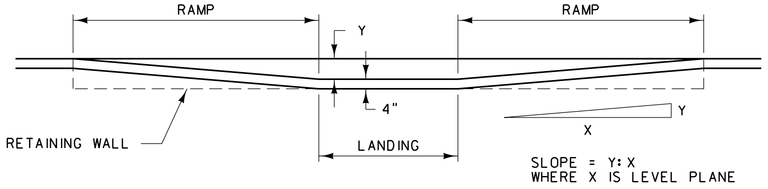
STATION	OFFSET (FT)	LANDING & TRUNCATED DOME WIDTH (FT) *	RAMP LENGTH (FT)		RAMP DESIGN SLOPE (%)	
			HIGH SIDE	LOW SIDE	HIGH SIDE	LOW SIDE
LOOP RD. 0+58.70	26.9 LT.	5.0	11.5	6.6	5.0	5.0
LOOP RD. 1+46.70	26.9 RT.	5.0	9.2	6.6	6.5	5.0
LOOP RD. 1+59.80	16.5 RT.	5.0	6.2	6.6	8.3	5.0
NB 290+66.20	26.9 RT.	5.0	13.1	3.9	8.3	5.0
NB 296+23.90	26.9 LT.	5.0	13.1	3.9	8.3	5.0
NB 302+58.50	29.8 RT.	8.0	9.2	6.2	6.5	5.0
EAST LANE 0+33.70	33.2 LT.	5.0	10.5	6.9	5.0	5.0
EAST LANE 0+59.10	34.8 LT.	5.0	10.5	6.9	5.0	5.0

* WIDTH IS MEASURED AT THE TOP BACK OF CURB.



ISOMETRIC

STREET SLOPE	RAMP LENGTH (FT)			
	AT 8.3% SLOPE		AT 5% SLOPE	
	LOW SIDE	HIGH SIDE	LOW SIDE	HIGH SIDE
0.00 %	5.0	5.0	8.3	8.3
1.00 %	4.5	5.7	6.9	10.4
2.00 %	4.0	6.6	6.0	13.9
3.00 %	3.5	8.3	4.9	22.1
4.00 %	3.0	10.9	4.1	~
5.00 %	2.6	14.9	3.4	~



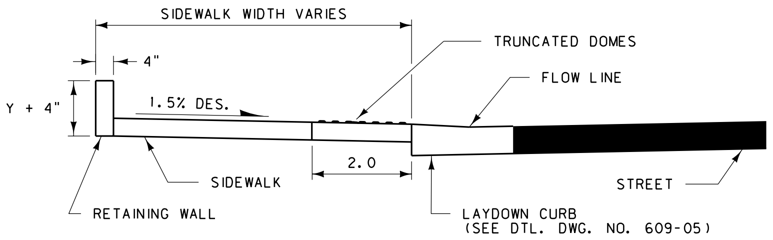
SECTION A-A

NEW CONSTRUCTION REQUIREMENTS:

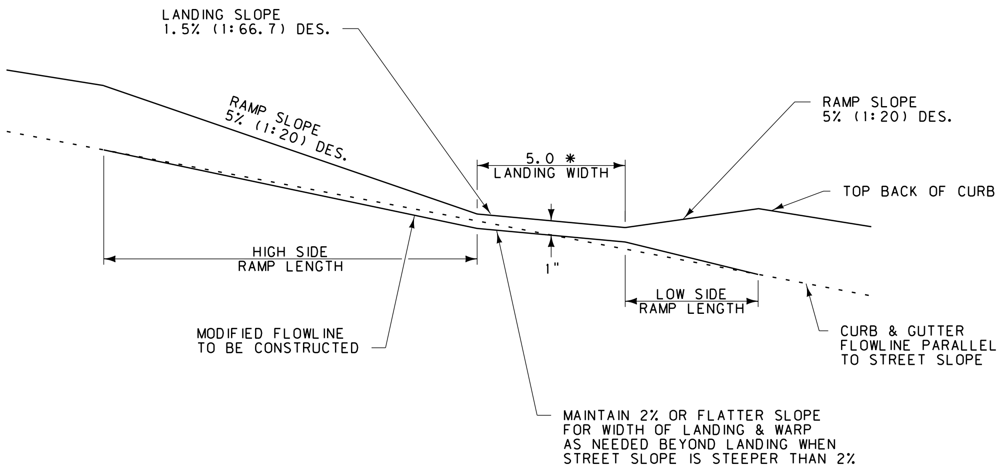
1. THE MINIMUM WIDTH OF THE LANDING IS 5'.
2. THE DESIRABLE SLOPE FOR THE CURB RAMP IS 5% (1:20) OR FLATTER. THE MAXIMUM CURB RAMP SLOPE IS 8.3% (1:12).
3. THE DESIRABLE CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 1.5% (1:66.7). THE MAXIMUM CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 2% (1:50).
4. PROVIDE TRUNCATED DOMES ON THE BOTTOM 2' OF EACH LANDING AS SHOWN. SEE DTL. DWG. NO. 608-40 FOR TRUNCATED DOMES DETAILS.
5. FOR ADDITIONAL DETAILS, SEE DTL. DWG. NO. 608-30 AND 609-05.

NOTES:

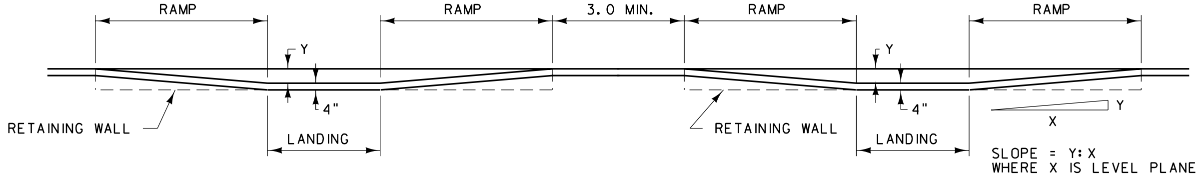
1. ALL DIMENSIONS ARE FEET (FT) UNLESS OTHERWISE NOTED.
2. SEE SIDEWALK SUMMARY FRAME FOR WIDTHS OF SIDEWALK.
3. SEE PLAN & PROFILE SHEETS FOR RADII OF CURB & GUTTER.
4. THE COST OF THE RETAINING WALL IS INCLUDED IN THE UNIT PRICE BID FOR CONCRETE SIDEWALK.



SECTION B-B



PROFILE



SECTION C-C

* RAMP LENGTHS ARE FIGURED ASSUMING A 5.0' LANDING WIDTH AT THE TOP BACK OF CURB. WHEN WIDTHS OTHER THAN THIS ARE USED, MAKE THE NECESSARY ADJUSTMENTS TO THE RAMP LENGTHS TO ACHEIVE THE DESIRED SLOPES.

(Typical New Construction Example)

PARALLEL
CURB RAMP
DETAILS

NO SCALE

FIG. 4.4 M-10B

3
2
1
serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
c:\dgn\rmanrddete10.dgn
10/17/2016
1:07:06 PM CPS - U1968

DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

COUNTY NAME(S)

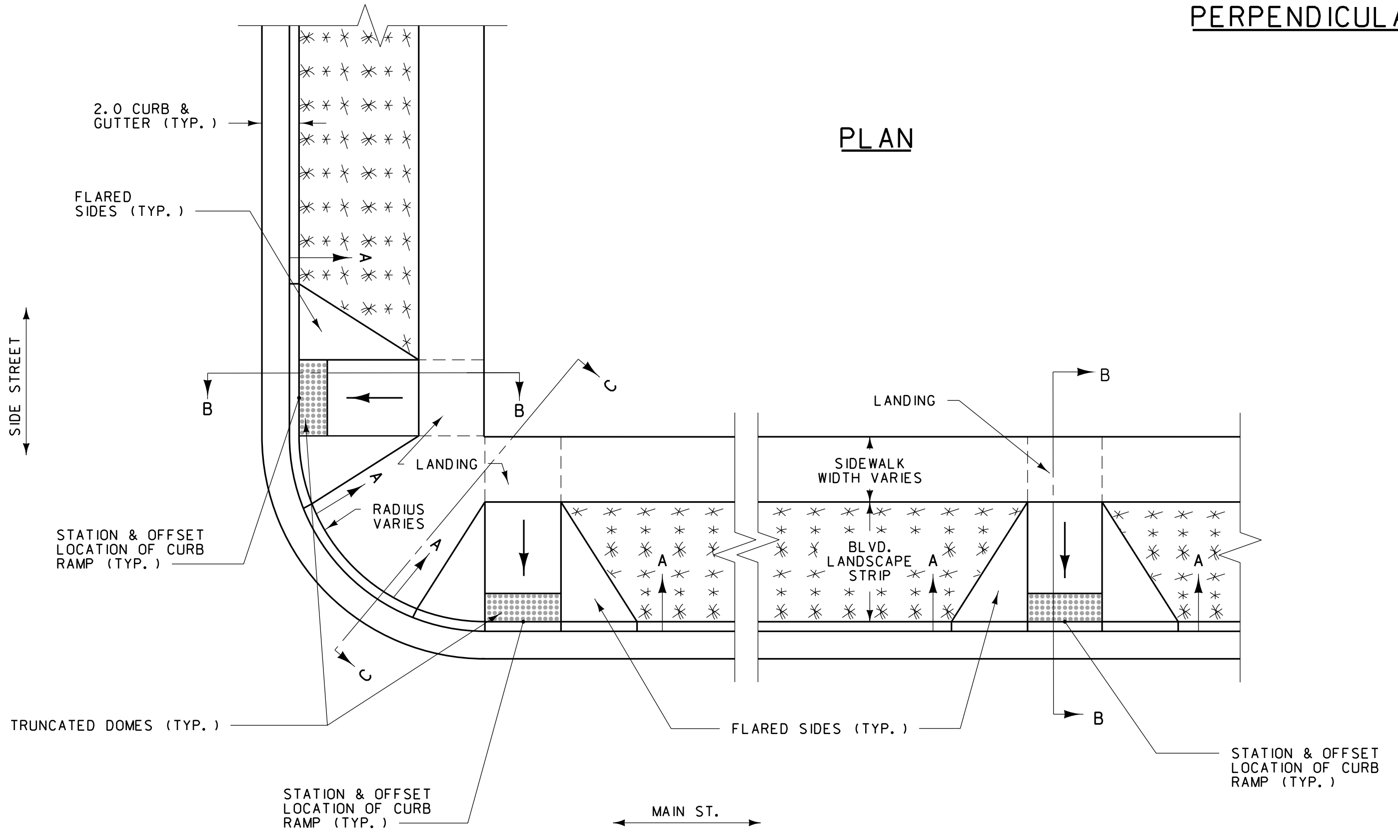
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

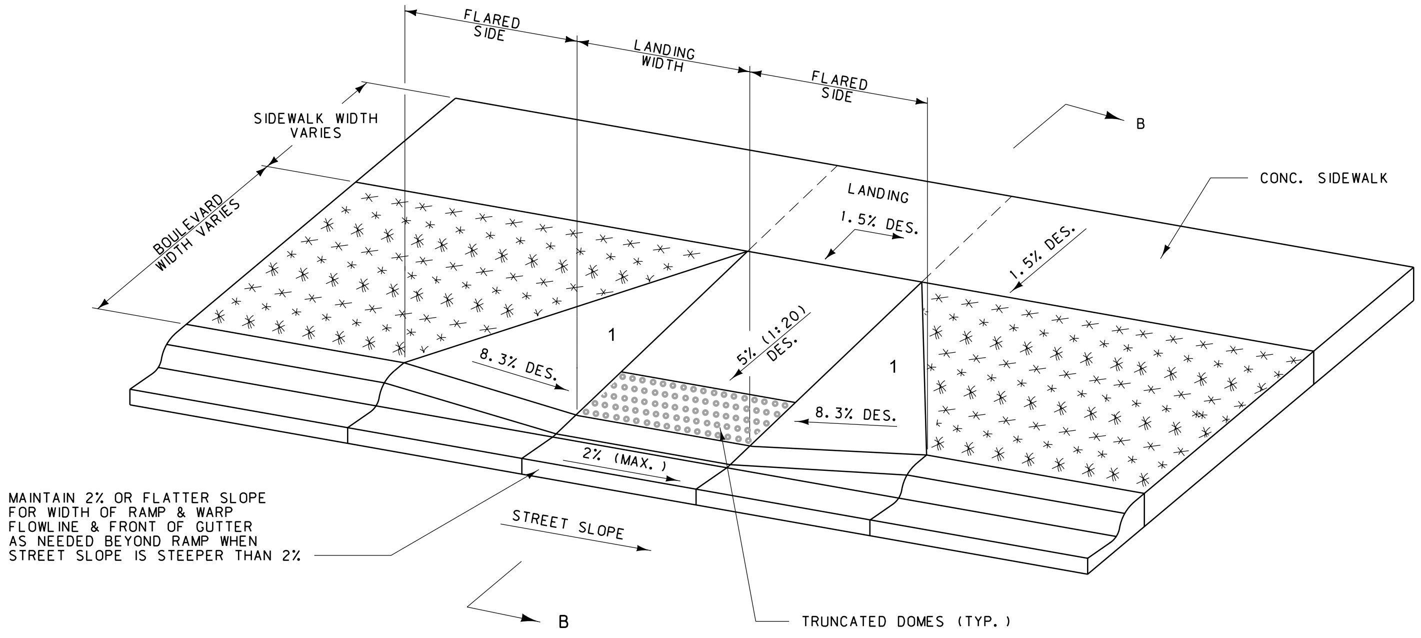
PROJECT NO.
SHEET 999 OF 999

PERPENDICULAR CURB RAMP DETAILS

PLAN

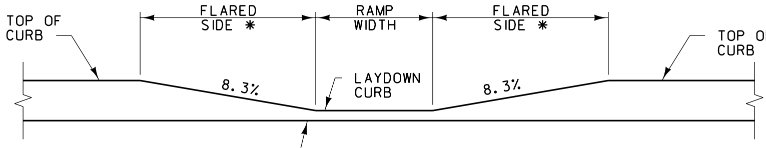


ISOMETRIC



Reminder:

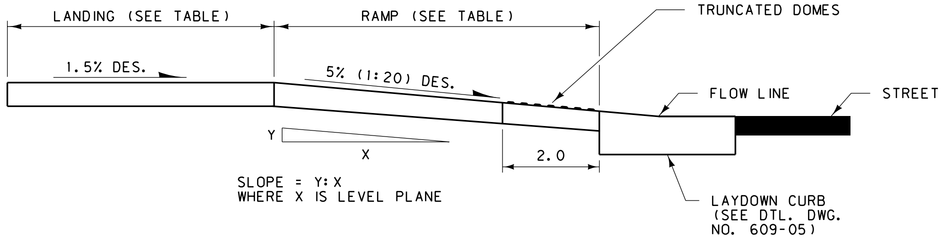
1 *Flared sides can be constructed using concrete or boulevard material.*



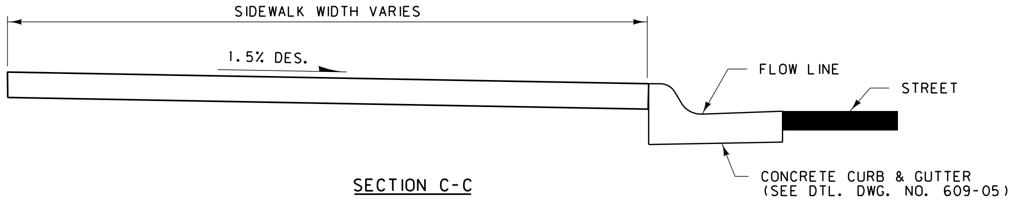
* ADJUST FLARED SIDE LENGTH AS NEEDED TO MAINTAIN DESIRABLE SLOPES

SECTION A-A

STATION MAIN ST.	OFFSET (FT)	RAMP AND TRUNCATED DOME WIDTH (FT)	RAMP LENGTH AND BLVD WIDTH (FT)	RAMP SLOPES (%)	LANDING LENGTH (FT)
88+55.00	37.4 LT.	5.0	6.0	8.3	7.0
88+65.20	37.4 RT.	5.0	6.0	8.3	7.0
88+72.30	20.2 LT.	5.0	8.0	6.5	5.0
88+82.50	20.2 RT.	5.0	8.0	6.5	5.0
94+27.40	20.2 LT.	5.0	8.0	6.5	5.0
94+27.40	20.2 RT.	5.0	8.0	6.5	5.0
94+44.70	37.4 LT.	8.0	6.0	8.3	7.0
94+44.70	37.4 RT.	5.0	6.0	8.3	7.0
94+79.10	37.4 LT.	8.0	6.0	8.3	7.0
94+79.10	37.4 RT.	5.0	6.0	8.3	7.0
94+96.40	20.2 LT.	5.0	8.0	6.5	5.0
94+96.40	20.2 RT.	5.0	8.0	6.5	5.0
98+07.10	20.2 LT.	5.0	8.0	6.5	5.0
98+14.60	20.2 RT.	5.0	8.0	6.5	5.0
98+24.40	37.4 LT.	5.0	6.0	8.3	5.0
98+31.90	37.4 RT.	5.0	6.0	8.3	5.0



SECTION B-B



SECTION C-C

NEW CONSTRUCTION REQUIREMENTS:

1. THE MINIMUM LENGTH OF THE LANDING IS 5'.
2. THE DESIRABLE SLOPE FOR THE CURB RAMP IS 5% (1:20) OR FLATTER. THE MAXIMUM CURB RAMP SLOPE IS 8.3% (1:12).
3. THE DESIRABLE CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 1.5% (1:66.7). THE MAXIMUM CROSS SLOPE OF THE SIDEWALK, RAMP, OR LANDING IS 2% (1:50).
4. THE DESIRABLE SLOPE OF THE FLARED SIDE OF THE CURB RAMP IS 8.3% (1:12) OF FLATTER. THE MAXIMUM FLARED SIDE SLOPE IS 10% (1:10).
5. PROVIDE TRUNCATED DOMES ON THE BOTTOM 2' OF EACH RAMP AS SHOWN. SEE DTL. DWG. NO. 608-40 FOR TRUNCATED DOMES DETAILS.
6. FOR ADDITIONAL DETAILS, SEE DTL. DWG. NO. 608-25, 608-35, AND 609-05.

NOTES:

1. ALL DIMENSIONS ARE FEET (FT) UNLESS OTHERWISE NOTED.
2. SEE SIDEWALK SUMMARY FRAME FOR WIDTHS OF SIDEWALK.
3. SEE PLAN & PROFILE SHEETS AND GEOMETRIC DETAILS FOR RADII OF CURB & GUTTER.

(Typical New Construction Example)

PERPENDICULAR
CURB RAMP
DETAILS

NO SCALE

FIG. 4.4 M-10C

3
2
1

MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

c:\dgn\rmanrddete10.dgn
10/17/2016
1:07:09 PM CPS - U1968

DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

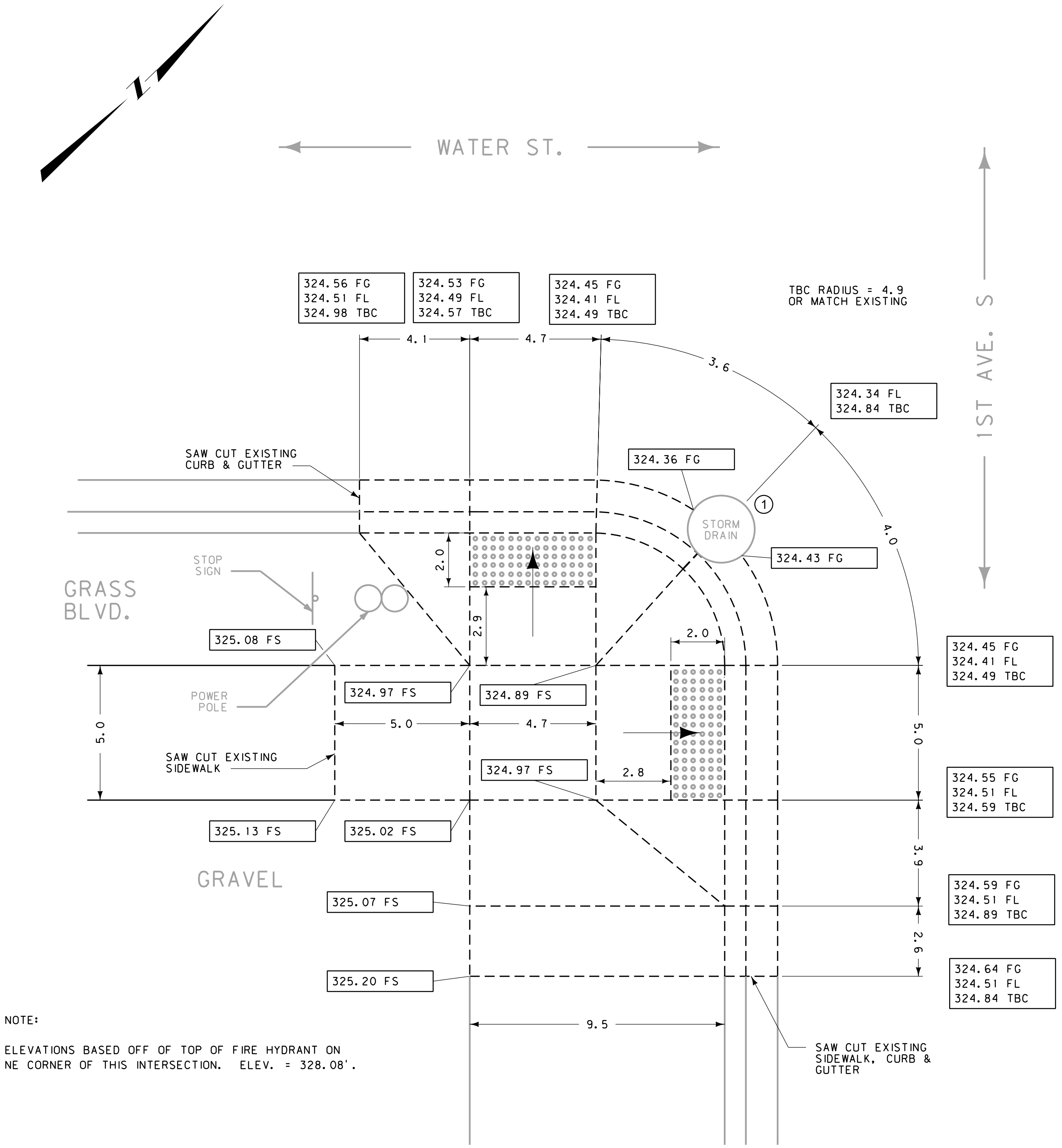
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

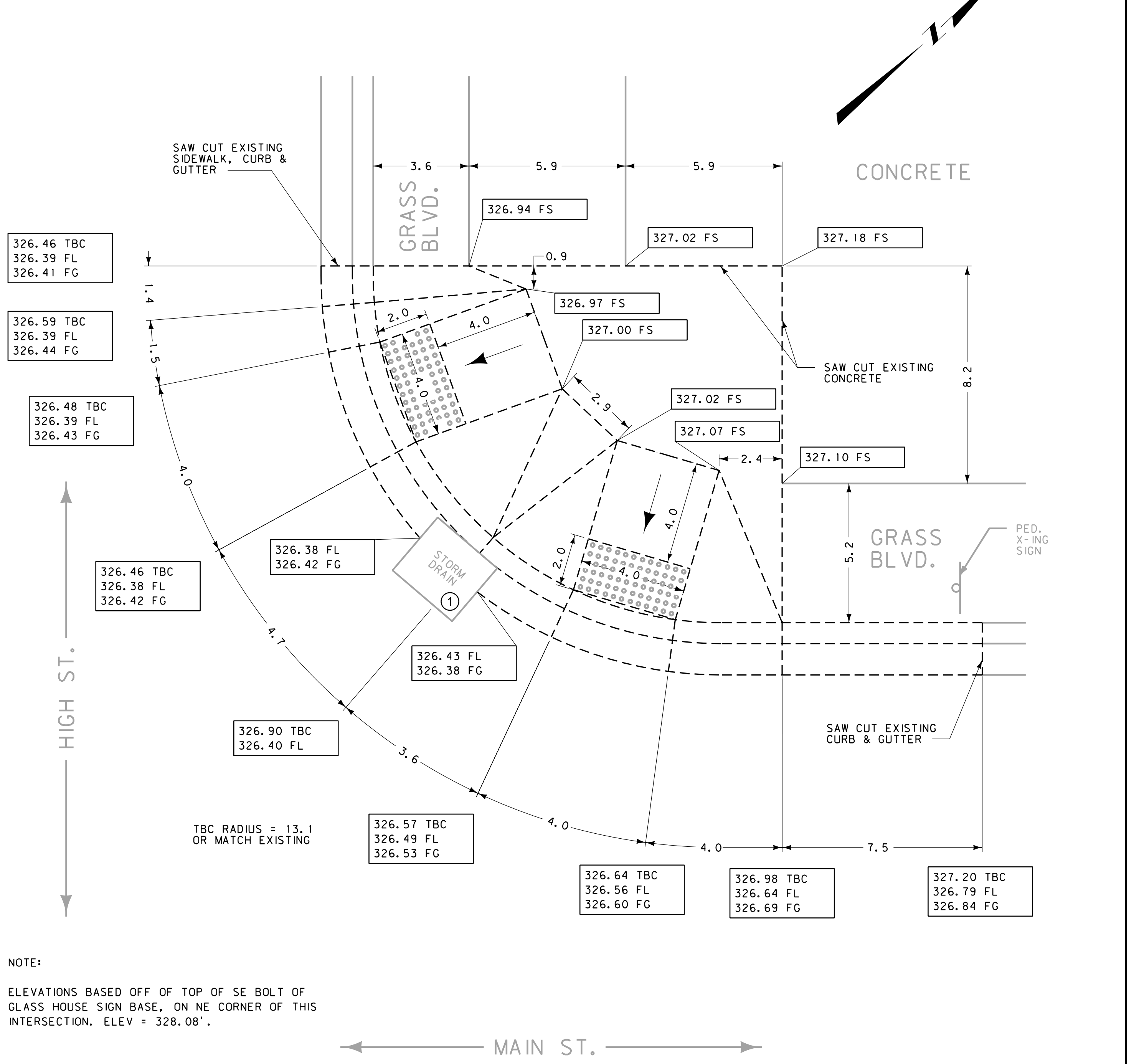
INTERSECTION OF 1ST AVE. S & WATER ST.
SOUTHWEST CORNER



NOTE:

ELEVATIONS BASED OFF OF TOP OF FIRE HYDRANT ON NE CORNER OF THIS INTERSECTION. ELEV. = 328.08'.

INTERSECTION OF MAIN ST. & HIGH ST.
NORTHEAST CORNER



NOTE:

ELEVATIONS BASED OFF OF TOP OF SE BOLT OF GLASS HOUSE SIGN BASE, ON NE CORNER OF THIS INTERSECTION. ELEV = 328.08'.

LEGEND

FS = FINISHED SURFACE ELEV.
TBC = TOP BACK OF CURB ELEV.
FL = FLOW LINE ELEV.
TRW = TOP OF RETAINING WALL ELEV.
FG = FRONT OF GUTTER ELEV.

▨ TRUNCATED DOMES

PROVIDE TRUNCATED DOMES ON THE BOTTOM 2' OF EACH RAMP AS SHOWN. SEE DTL. DWG. NO. 608-40 FOR TRUNCATED DOMES DETAILS.

NOTES:

ALL DIMENSIONS AND ELEVATIONS ARE LINEAR FEET UNLESS OTHERWISE NOTED.

ALL CURB AND GUTTER DIMENSIONS ARE ALONG TBC.

CONTRACTOR VERIFY ELEVATIONS IN THE FIELD PRIOR TO CONSTRUCTION.

MATCH EXISTING ELEVATIONS AT ALL JOINTS BETWEEN NEW AND EXISTING CONCRETE. ELEVATIONS SHOWN AT MATCH LINE LOCATIONS ARE APPROXIMATE.

SEE DETAILED DRAWINGS FOR STANDARD SIDEWALK, CURB & GUTTER AND RETAINING WALL DETAILS.

Curb Ramp Detail Reminder:

① *Curb ramps must be designed such that there is not a conflict with existing drainage structures (i.e. storm drains, curb inlets, etc.).*

(Typical Alteration to Existing Facility Example)

CURB RAMP DETAILS

NO SCALE

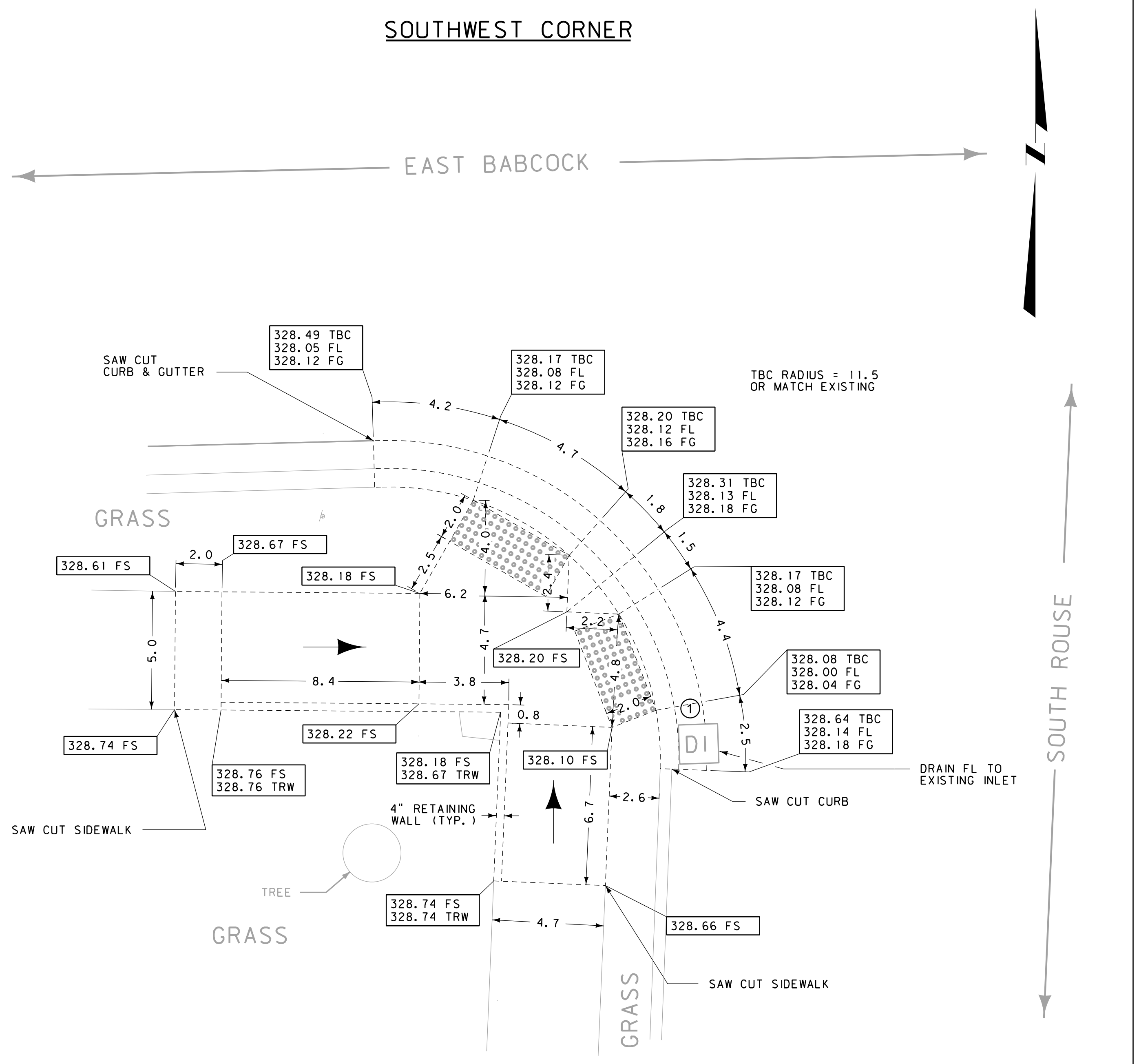
FIG. 4.4 M-11

3	MDT serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrddete11.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS
2			10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*	
1			1:07:17 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)

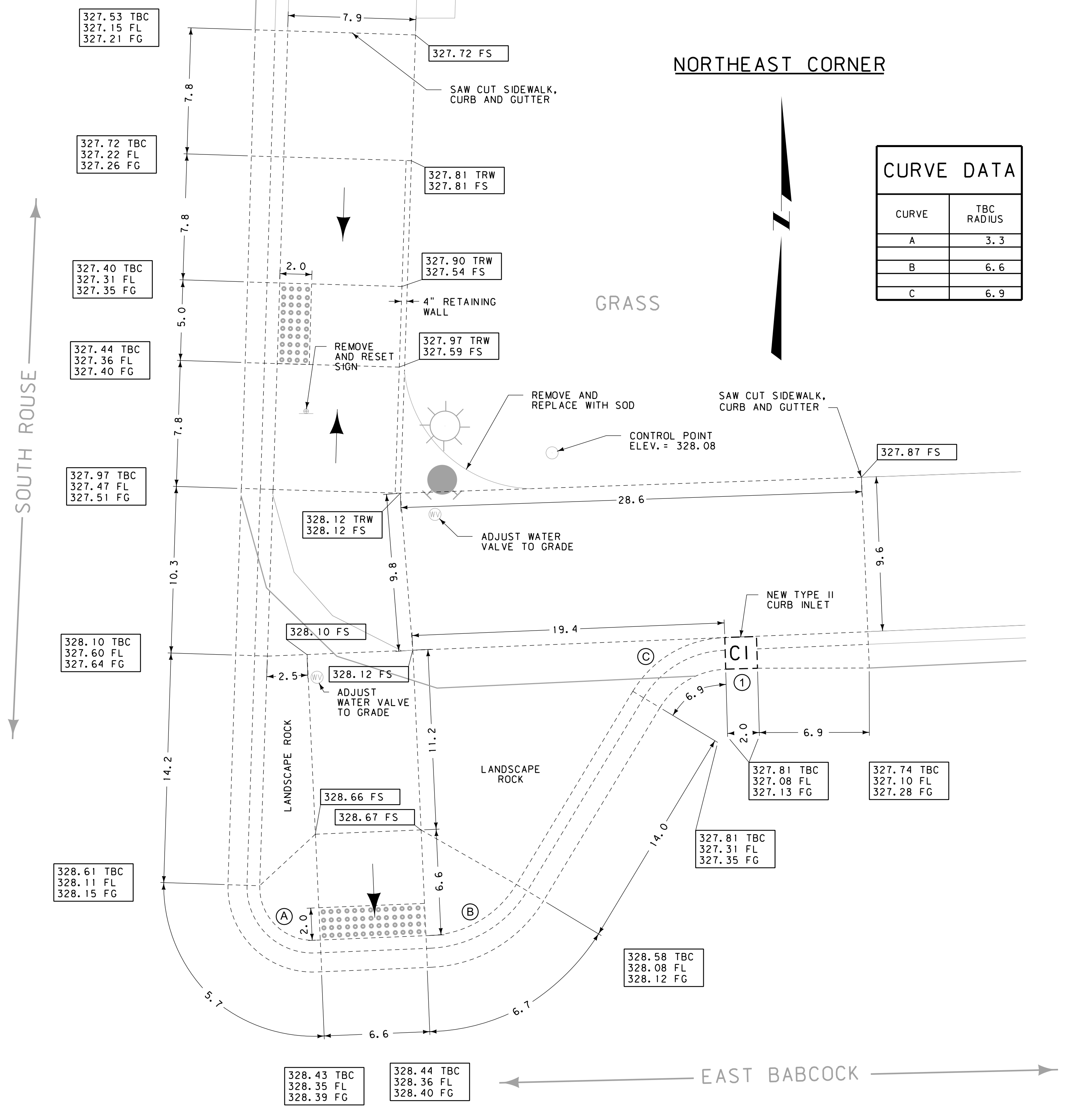
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

SOUTHWEST CORNER



NORTHEAST CORNER



CURVE DATA	
CURVE	TBC RADIUS
A	3.3
B	6.6
C	6.9

LEGEND

FS = FINISHED SURFACE ELEV.
TBC = TOP BACK OF CURB ELEV.
FL = FLOW LINE ELEV.
TRW = TOP OF RETAINING WALL ELEV.
FG = FRONT OF GUTTER ELEV.

▨ TRUNCATED DOMES

PROVIDE TRUNCATED DOMES ON THE BOTTOM 2' OF EACH RAMP AS SHOWN. SEE DTL. DWG. NO. 608-40 FOR TRUNCATED DOMES DETAILS.

NOTES:

ALL DIMENSIONS AND ELEVATIONS ARE LINEAR FEET UNLESS OTHERWISE NOTED.

ELEVATIONS BASED OFF OF ALUMINUM CAP LOCATED NORTHEAST CORNER OF THIS INTERSECTION. ELEV. = 328.08'.

MATCH EXISTING ELEVATIONS AT ALL JOINTS BETWEEN NEW AND EXISTING CONCRETE. ELEVATIONS SHOWN AT MATCH LINE LOACTIONS ARE APPROXIMATE.

SEE DETAILED DRAWINGS FOR STANDARD SIDEWALK, CURB & GUTTER AND RETAINING WALL DETAILS.

ALL CURB AND GUTTER DIMENSIONS ARE ALONG TBC.

CONTRACTOR VERIFY ELEVATIONS IN THE FIELD PRIOR TO CONSTRUCTION.

Curb Ramp Detail Reminder:

① Curb ramps must be designed such that there is not a conflict with existing drainage structures (i.e. storm drains, curb inlets, etc.).

(Typical Alteration to Existing Facility Example)

INTERSECTION OF
E. BABCOCK & S. ROUSE
CURB RAMP DETAILS

NO SCALE

FIG. 4.4 M-12

3
2
1

MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

c:\dgn\rmanrddete12.dgn
10/17/2016
1:07:25 PM CPS - U1968

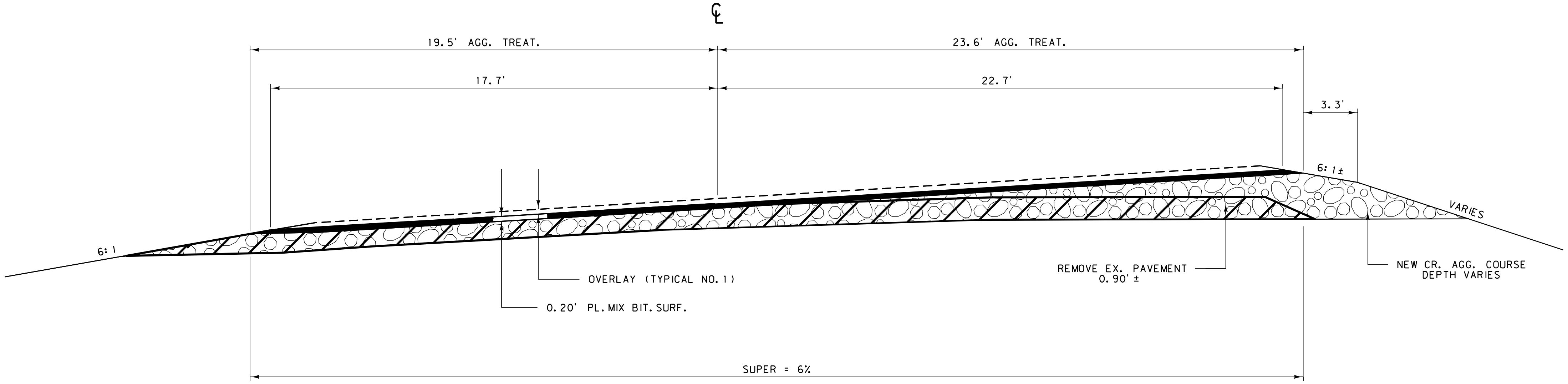
DESIGNED BY	*DESIGNER NAME*	*DATE*
REVIEWED BY	*SUPERVISOR NAME*	*DATE*
CHECKED BY	*CHECKER NAME*	*DATE*

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999 UPN NUMBER 12345678

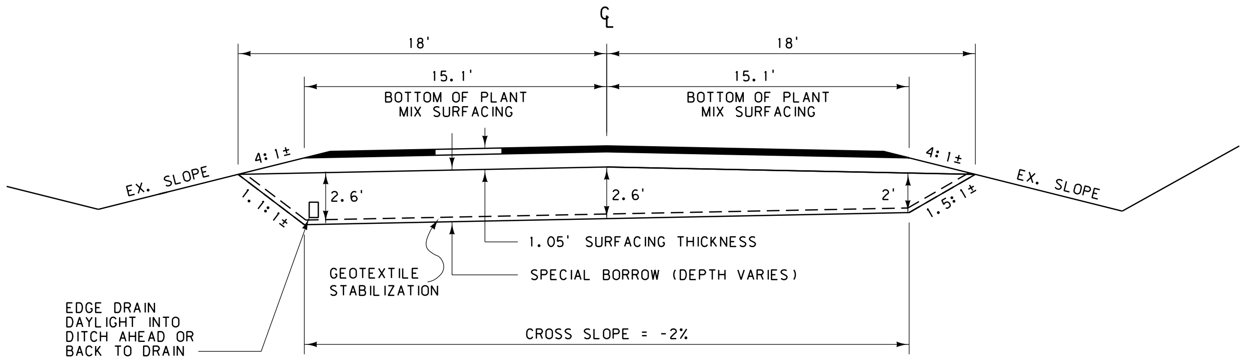
PROJECT NO.
SHEET 999 OF 999



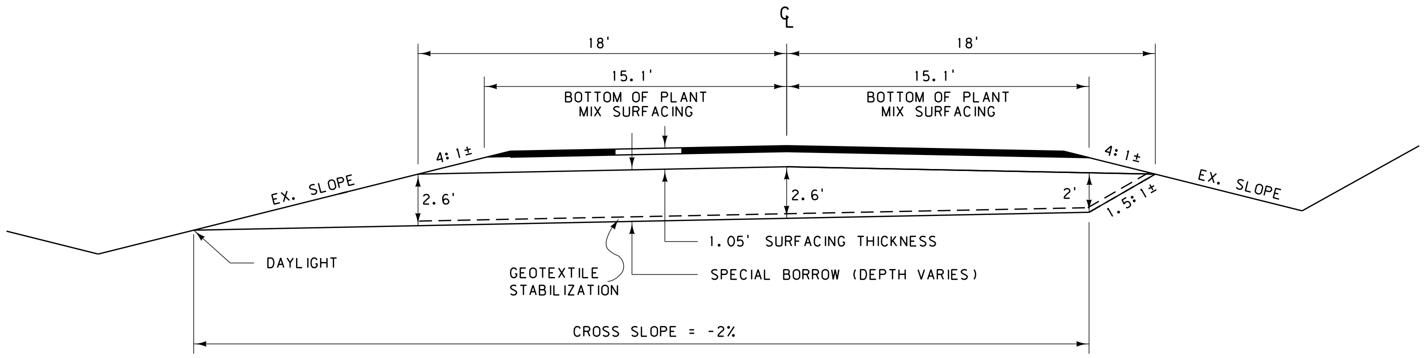
QUANTITIES*

UNIT	AGGREGATE		UNIT	BIT. MATERIAL	AGG. TREAT.	
	PLANT MIX	CR. AGG. COURSE		ASPHALT CEMENT	DUST PALLIATIVE	AGGREGATE TACK
AREA square feet	8.35	57.69	square yards PER STATION		479	479
cubic yards PER STATION	30.9	213.7	tons PER STATION	3.58	0.78	
tons PER STATION	59.6		gallons PER STATION			24.0

*OVERLAY QUANTITIES NOT INCLUDED, SEE TYPICAL NO. 1 FOR OVERLAY QUANTITIES



123+00.00 TO 134+48.00
311+65.00 TO 316+55.00
409+60.00 TO 414+20.00



134+48.00 TO 145+95.00
294+40.00 TO 311+65.00

RE-SUPER CURVE
STA. 15+81.94
TO STA. 39+59.43 E.B.

NO SCALE

DIGOUT DETAILS

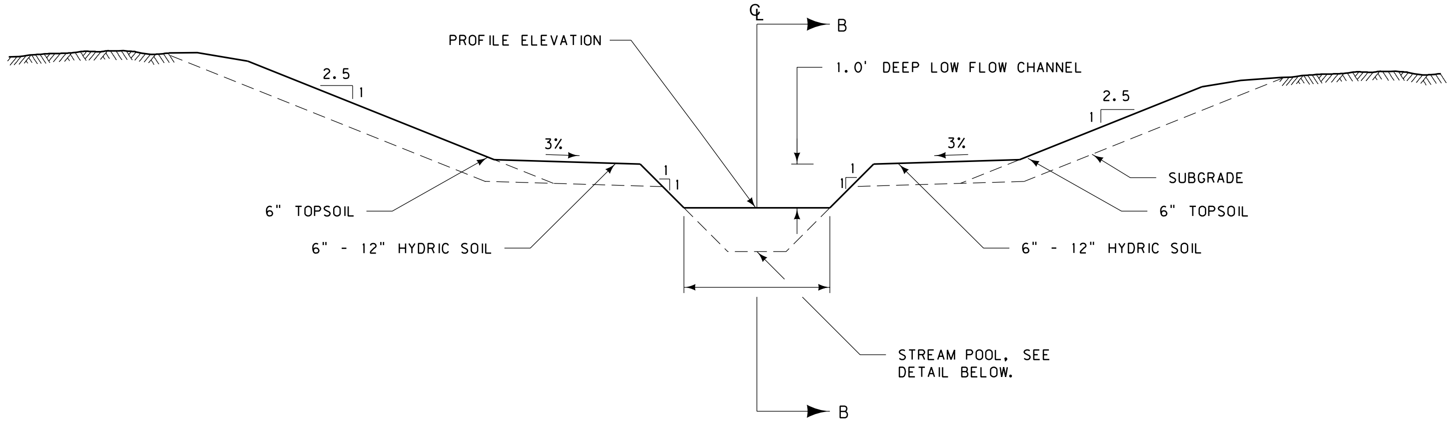
NO SCALE

FIG 4.4 M-13

3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete13.dgn	DESIGNED BY	DESIGNER NAME	DATE	ROAD PLANS	MONTANA ROAD DESIGN MANUAL
2		10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE		SAMPLE PLAN SHEET (U.S. Customary Units)
1		1:07:33 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE	COUNTY NAME(S)	

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

CHANNEL RELOCATION
TYPICAL SECTION
SECTION A - A

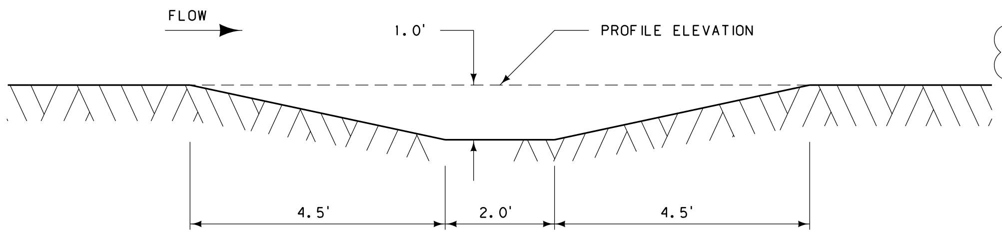


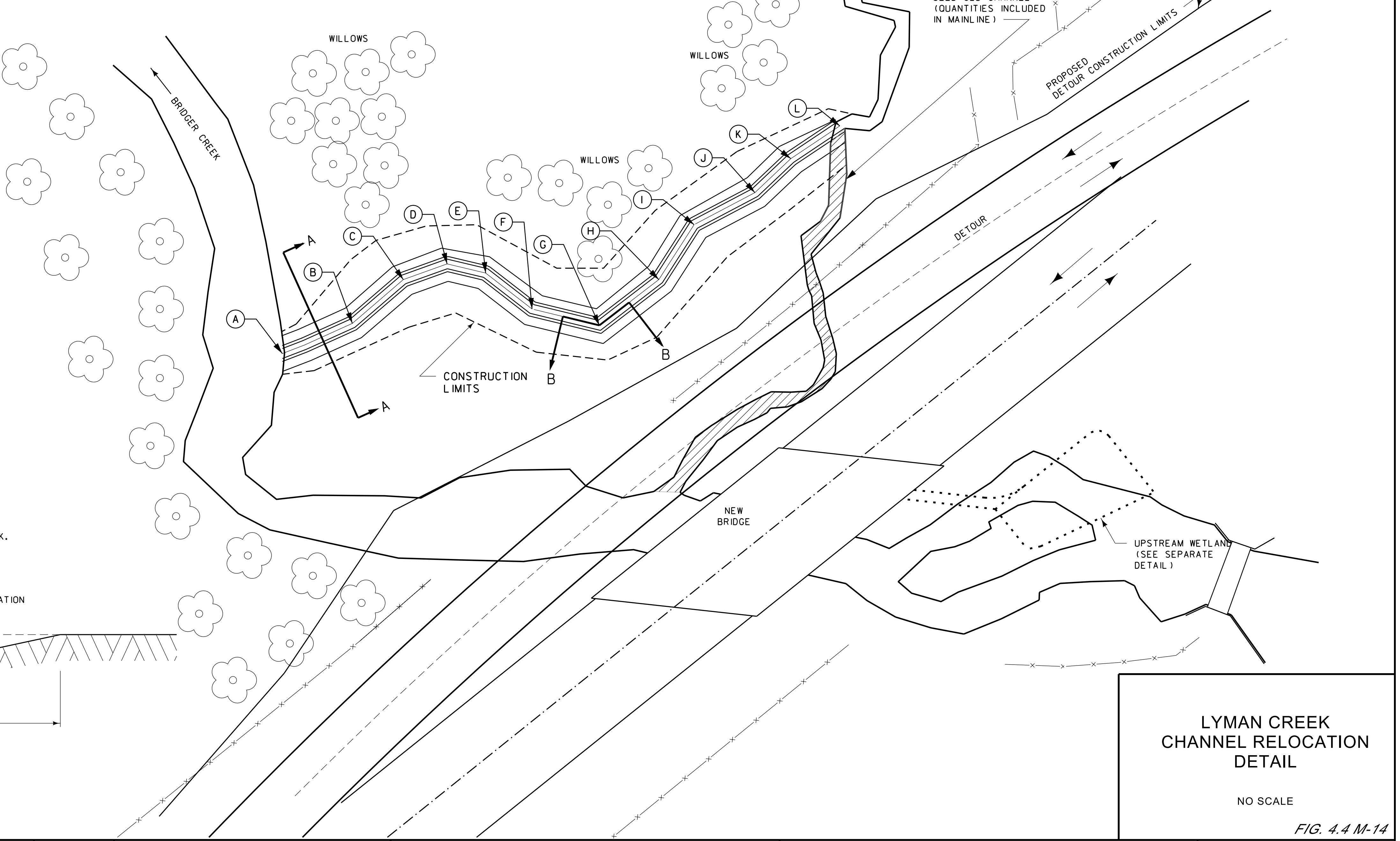
CHANNEL CENTERLINE COORDINATE TABLE

POINT	PROFILE ELEVATION	N OR Y COORDINATE	E OR X COORDINATE
A	4,790.16	534,658.14	1,585,591.08
B	4,790.85	534.668.77	1,585,615.75
C	4,791.47	534,684.19	1,585,633.73
D	4,791.90	534,689.73	1,585,649.15
E	4,792.26	534,686.52	1,585,662.76
F	4,792.78	534,673.82	1,585,679.10
G	4,793.41	534,668.08	1,585,702.82
H	4,794.09	534,684.19	1,585,723.79
I	4,794.69	534,703.54	1,585,736.25
J	4,795.31	534,714.86	1,585,757.64
K	4,795.77	534,726.84	1,585,770.34
L	4,796.29	534,738.39	1,585,787.60

STREAM POOL DETAIL
SECTION B - B

CONSTRUCT POOL TO APPROXIMATE DIMENSIONS
SHOWN BELOW AT POINTS B, C, D, E, F, G, H, I, J, & K.





LYMAN CREEK CHANNEL RELOCATION

LENGTH - REMOVED = 166.0'

LENGTH - NEW = 237.9'

EXISTING SLOPE = 2.6%

NEW SLOPE = 2.6%

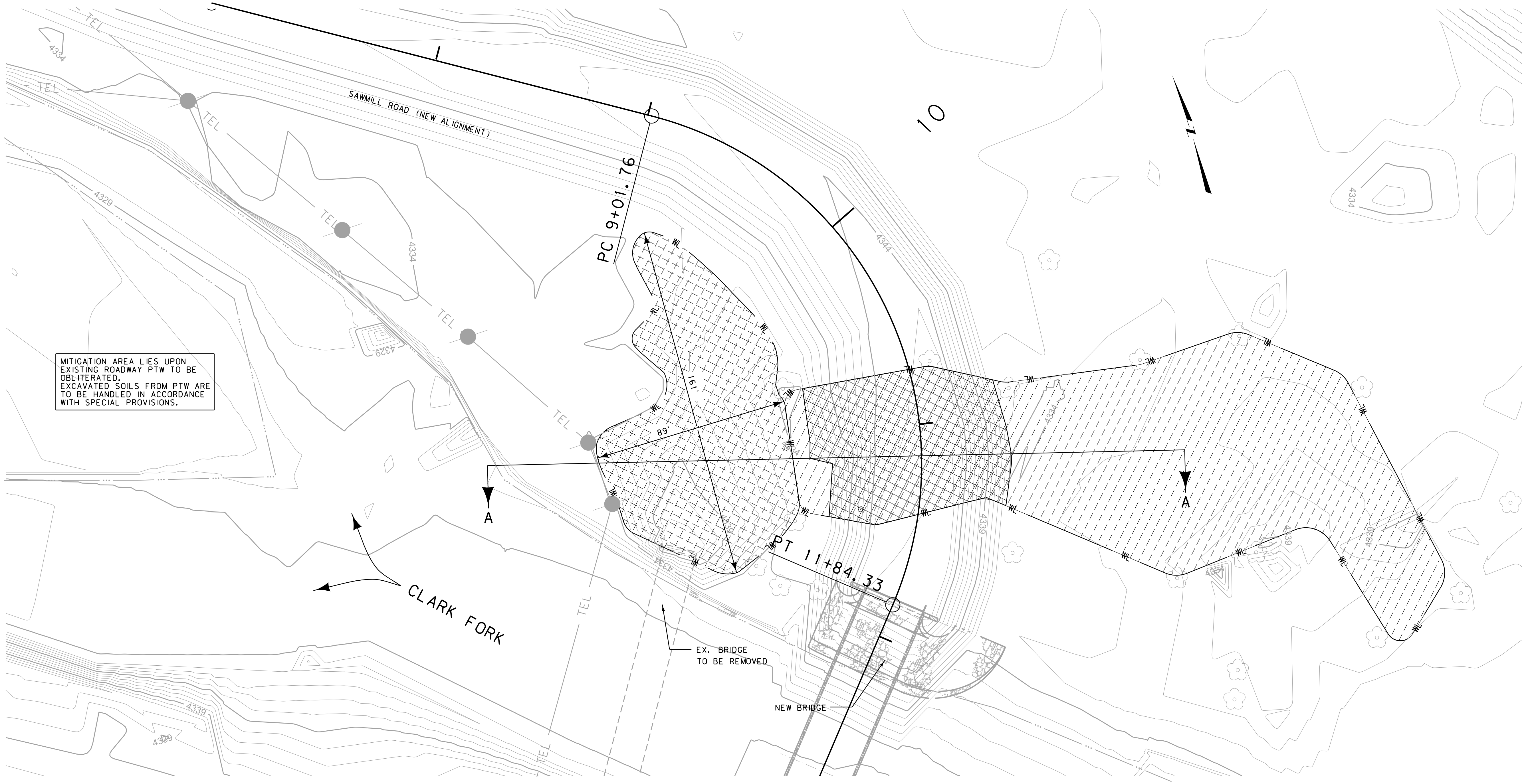
LYMAN CREEK
CHANNEL RELOCATION
DETAIL

NO SCALE

FIG. 4.4 M-14

MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete14.dgn 10/17/2016 1:07:41 PM CPS - U1968	DESIGNED BY REVIEWED BY CHECKED BY	DESIGNER NAME SUPERVISOR NAME CHECKER NAME	DATE DATE DATE	ROAD PLANS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999



MITIGATION AREA LIES UPON EXISTING ROADWAY PTW TO BE OBLITERATED.
EXCAVATED SOILS FROM PTW ARE TO BE HANDLED IN ACCORDANCE WITH SPECIAL PROVISIONS.

CLARK FORK ON SAWMILL ROAD

MITIGATED WETLANDS

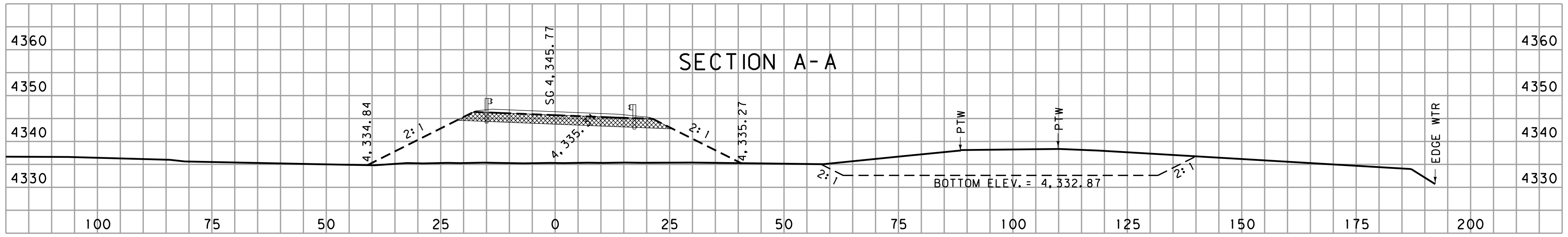
AREA = 0.210 acres

IMPACTED WETLANDS

AREA = 0.124 acres

WETLANDS

AREA = 0.507 acres


SECTION A-A

CONTOUR INTERVAL = 1.0'

WETLAND MITIGATION
POWELL COUNTY BRIDGES
CLARK FK/SAWMILL RD
DETAIL

NO SCALE

FIG 4.4 M-15

3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrddete15.dgn	DESIGNED BY	DESIGNER NAME	DATE	ROAD PLANS	MONTANA ROAD DESIGN MANUAL	PROJECT LOCATION DESCRIPTION		PROJECT NO.
2		10/17/2016	REVIEWED BY	SUPERVISOR NAME	DATE					
1		1:07:50 PM CPS - U1968	CHECKED BY	CHECKER NAME	DATE	COUNTY NAME(S)	SAMPLE PLAN SHEET (U.S. Customary Units)	CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

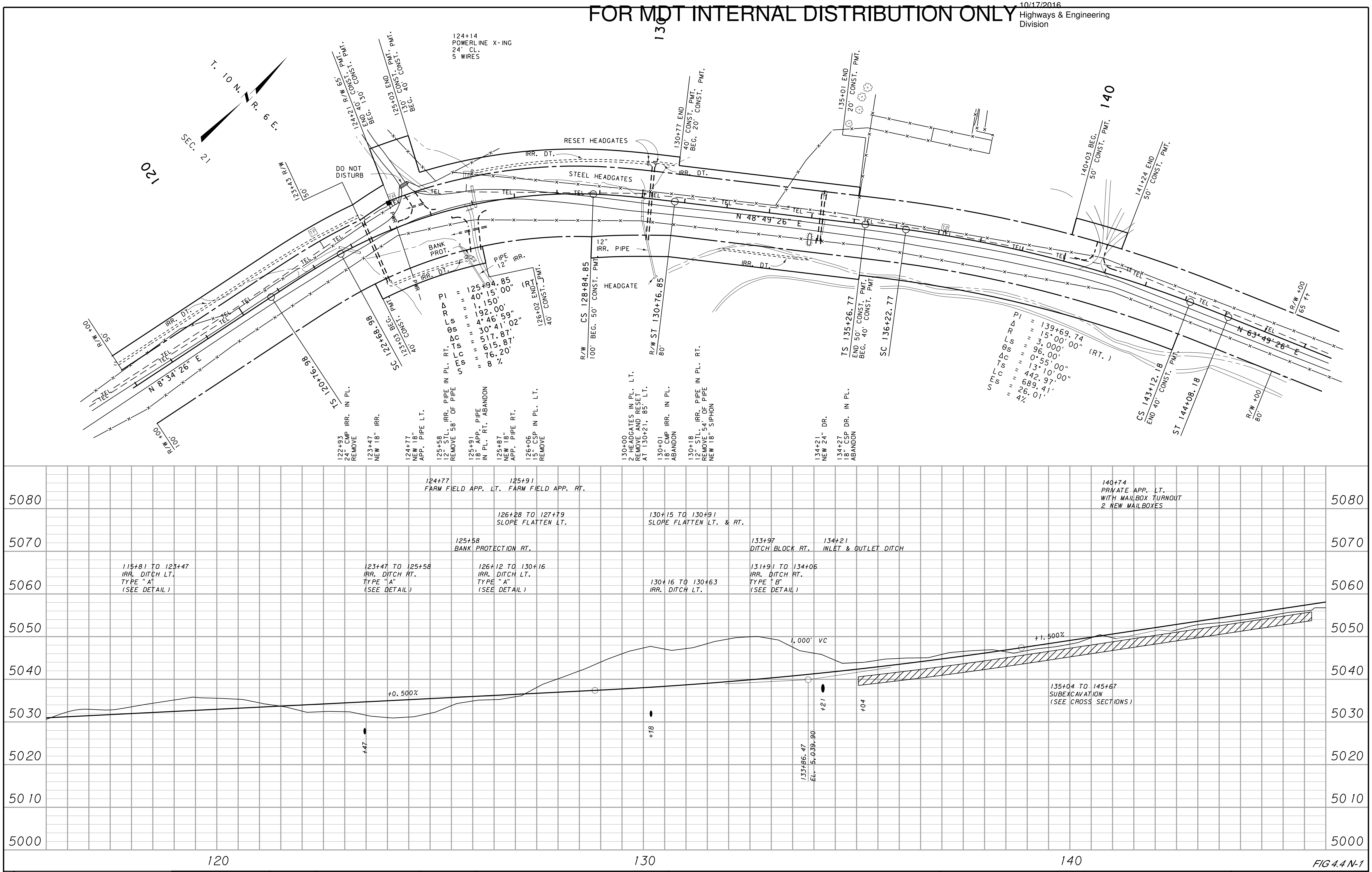


FIG 4.4 N-1

3
2
1
MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride
c:\dgn\rmanrdplpe01.dgn
10/17/2016
1:07:59 PM CPS - U1968
DESIGNED BY DESIGNER NAME DATE
REVIEWED BY SUPERVISOR NAME DATE
CHECKED BY CHECKER NAME DATE
ROAD PLANS
COUNTY NAME(S)
MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)
PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678
PROJECT NO.
SHEET 999 OF 999

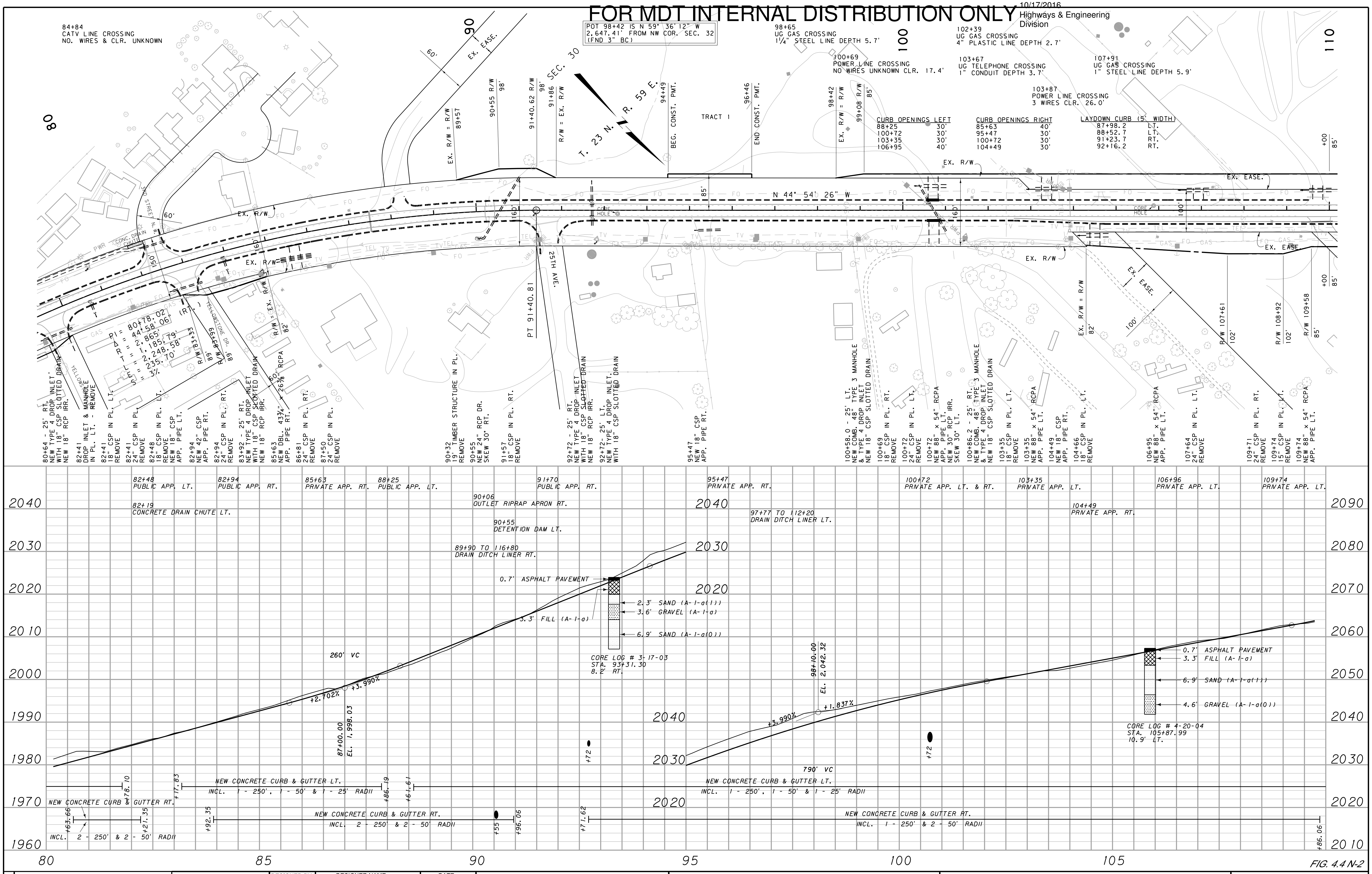


FIG. 4.4 N-2

MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrdplpe04.dgn 10/17/2016 1:08:08 PM CPS - U1968	DESIGNED BY DESIGNER NAME DATE REVIEWED BY SUPERVISOR NAME DATE CHECKED BY CHECKER NAME DATE	ROAD PLANS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE PLAN SHEET (U.S. Customary Units)	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678	PROJECT NO. SHEET 999 OF 999

10/17/2016
Highways & Engineering
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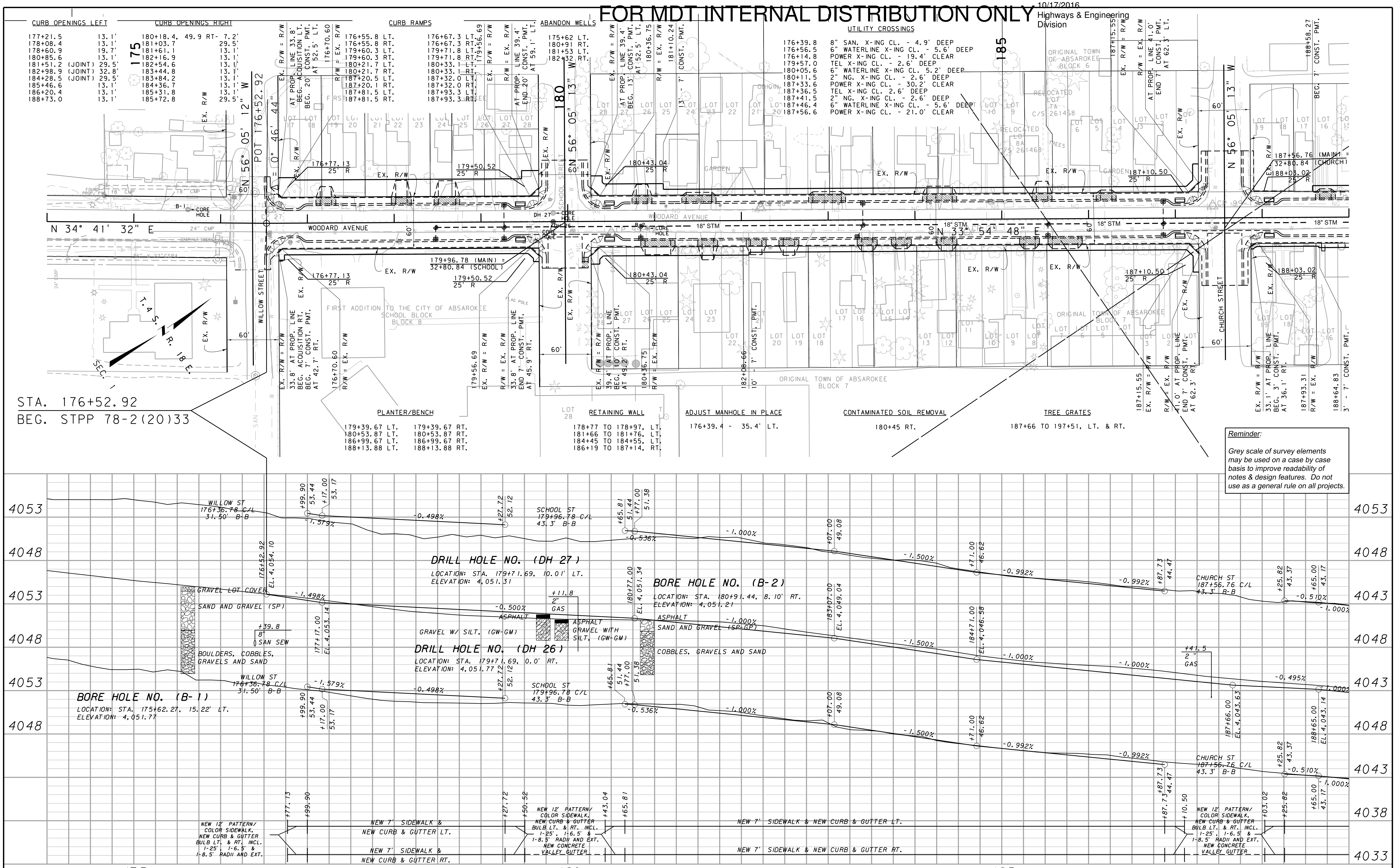

CURB OPENINGS LEFT

177+21.5		13.1'
178+08.4		13.1'
178+60.9		19.7'
180+85.6		13.1'
181+51.2	(JOINT)	29.5'
182+98.9	(JOINT)	32.8'
184+28.5	(JOINT)	29.5'
185+46.6		13.1'
186+20.4		13.1'
188+73.0		13.1'

CURB OPENINGS RIGHT

180+18.4, 49.9 RT-	7.2'
181+03.7	29.5'
181+61.1	13.1'
182+16.9	13.1'
182+54.6	13.1'
183+44.8	13.1'
183+84.2	13.1'
184+36.7	13.1'
185+31.8	13.1'
185+72.8	29.5'

CURB RAMPS

176+55.8 LT.	176+67.3 LT.
176+55.8 RT.	176+67.3 RT.
179+60.3 LT.	179+71.8 LT.
179+60.3 RT.	179+71.8 RT.
180+21.7 LT.	180+33.1 LT.
180+21.7 RT.	180+33.1 RT.
187+20.5 LT.	187+32.0 LT.
187+20.1 RT.	187+32.0 RT.
187+81.5 LT.	187+93.3 LT.
187+81.5 RT.	187+93.3 RT.

ABANDON WELLS

175+62 LT.
180+91 RT.
181+53 LT.
182+32 RT.

UTILITY CROSSINGS

176+39.8	8" SAN. X-ING CL. - 4.9' DEEP
176+56.5	6" WATERLINE X-ING CL. - 5.6' DEEP
176+14.8	POWER X-ING CL. - 19.4' CLEAR
179+57.0	TEL X-ING CL. - 2.6' DEEP
180+05.6	6" WATERLINE X-ING CL. 5.2' DEEP
180+11.5	2" NG. X-ING CL. - 2.6' DEEP
187+33.6	POWER X-ING CL. - 30.2' CLEAR
187+36.5	TEL X-ING CL. 2.6' DEEP
187+41.5	2" NG. X-ING CL. - 2.6' DEEP
187+46.4	6" WATERLINE X-ING CL. - 5.6' DEEP
187+56.6	POWER X-ING CL. - 21.0' CLEAR

PLANTER/BENCH

179+39.67 LT.	179+39.67 RT.
180+53.87 LT.	180+53.87 RT.
186+99.67 LT.	186+99.67 RT.
188+13.88 LT.	188+13.88 RT.

RETAINING WALL

178+77 TO 178+97, LT.
181+66 TO 181+76, LT.
184+45 TO 184+55, LT.
186+19 TO 187+14, RT.

ADJUST MANHOLE IN PLACE

176+39.4 - 35.4' LT.

CONTAMINATED SOIL REMOVAL

180+45 RT.

TREE GRATES

187+66 TO 197+51, LT. & RT.

Reminder:

Grey scale of survey elements may be used on a case by case basis to improve readability of notes & design features. Do not use as a general rule on all projects.

FIG. 4.4 O

3
2
1
MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride
c:\dgn\rmanrdplpe02.dgn
10/17/2016
1:08:25 PM CPS - U1968

DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

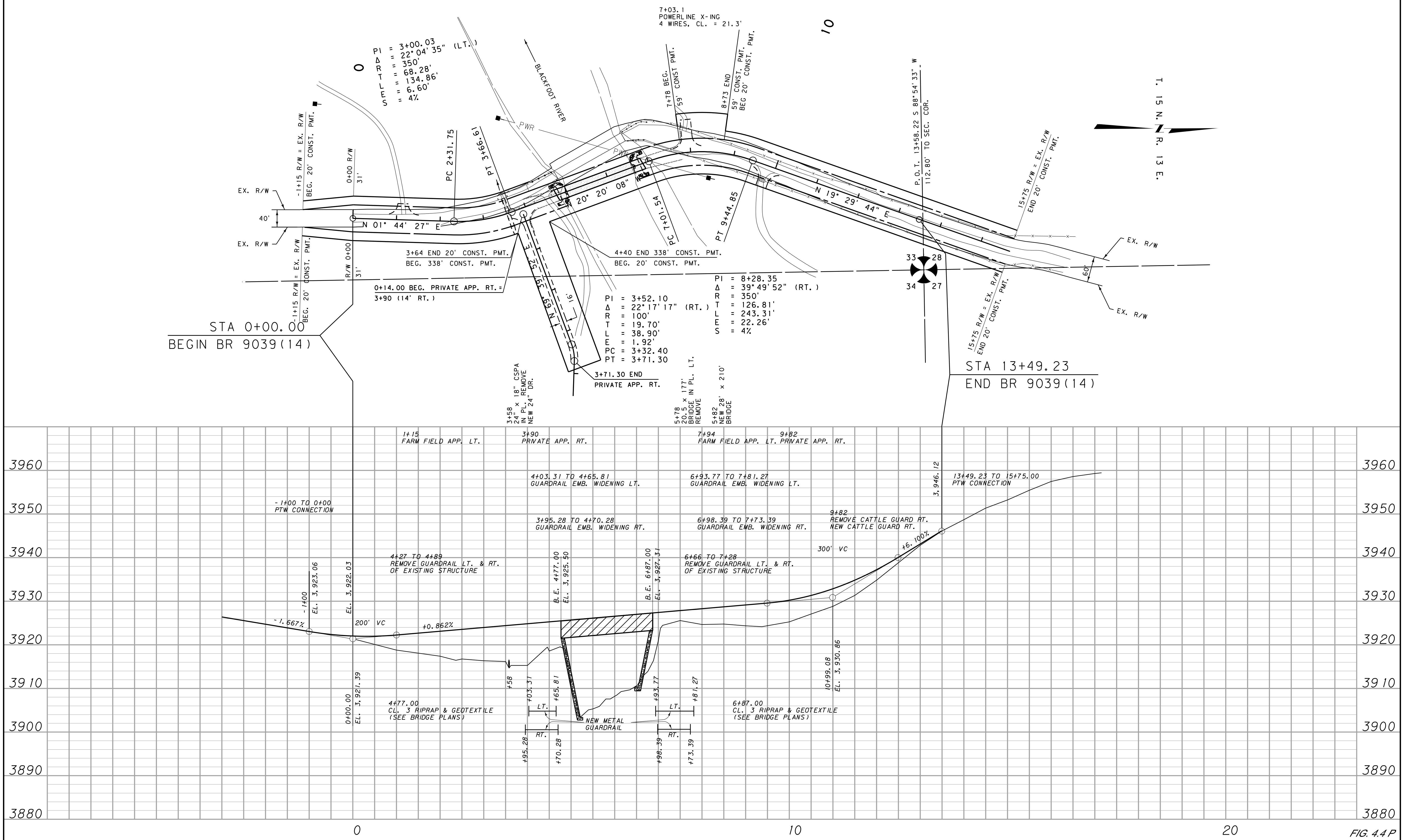

FIG. 4.4 P

3	MONTANA DEPARTMENT OF TRANSPORTATION serving you with pride	c:\dgn\rmanrdplpe03.dgn	DESIGNED BY DESIGNER NAME DATE	ROAD PLANS	MONTANA ROAD DESIGN MANUAL
2		10/17/2016	REVIEWED BY SUPERVISOR NAME DATE		SAMPLE PLAN SHEET (U.S. Customary Units)
1		1:08:33 PM CPS - U1968	CHECKED BY CHECKER NAME DATE	COUNTY NAME(S)	

PROJECT LOCATION DESCRIPTION

CSF = 0.9999999

UPN NUMBER 12345678

PROJECT NO.

SHEET 999 OF 999

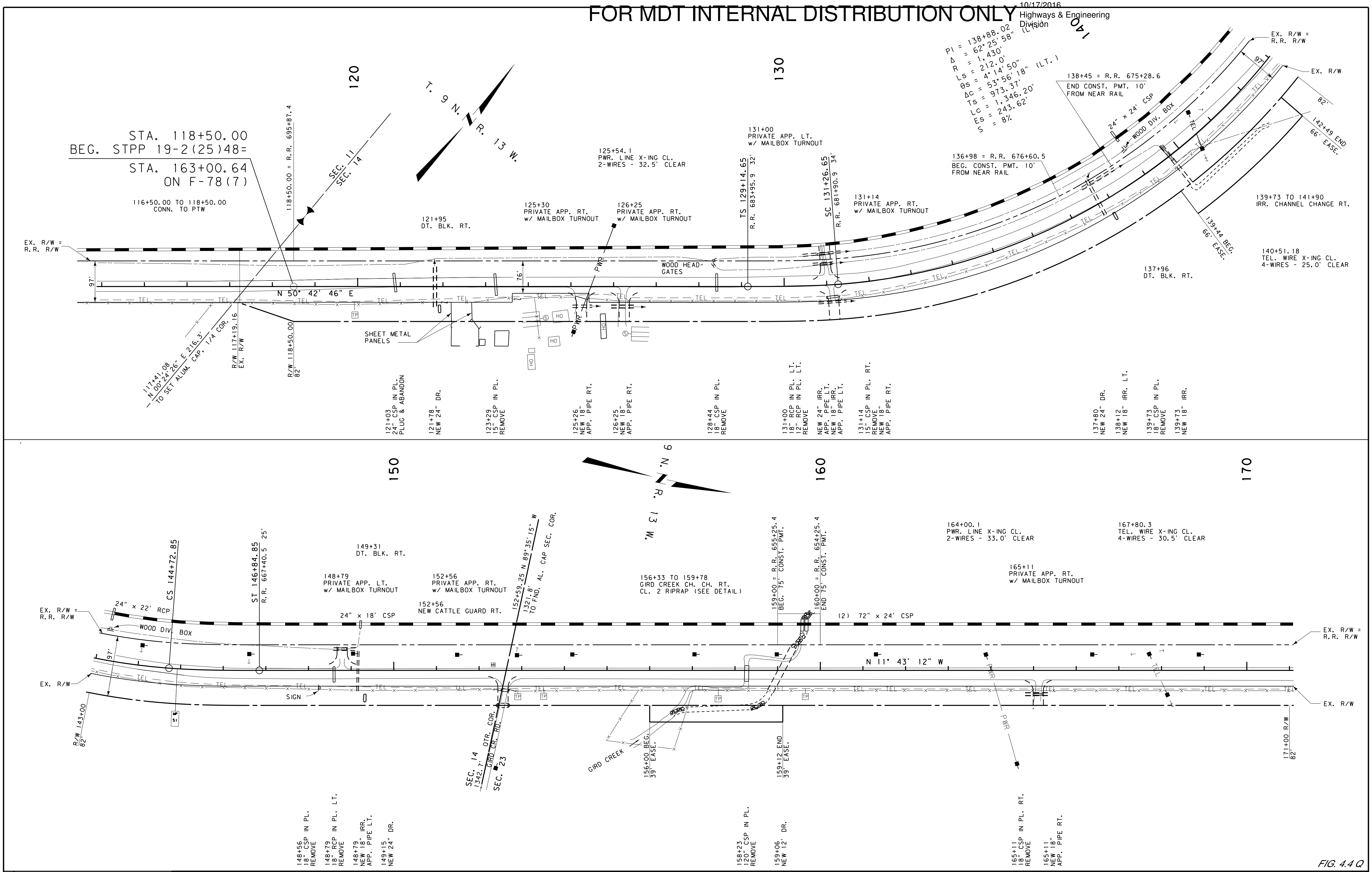

FIG. 4.4 Q

3
2
1

serving you with pride

MONTANA DEPARTMENT OF TRANSPORTATION

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10/17/2016
1:08:41 PM CPS - U1968

DESIGNED BY DESIGNER NAME DATE
REVIEWED BY SUPERVISOR NAME DATE
CHECKED BY CHECKER NAME DATE

ROAD PLANS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

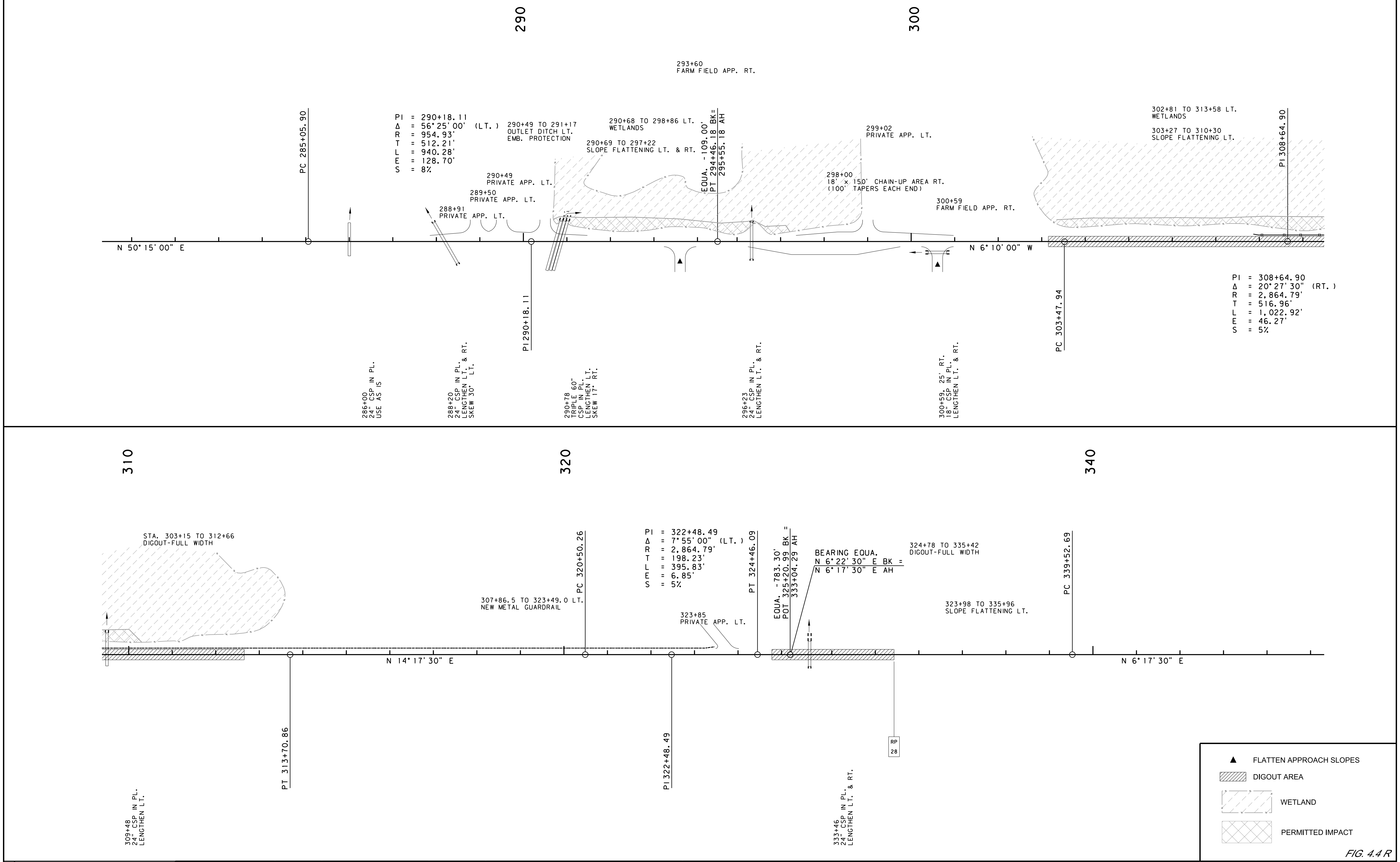


FIG. 4.4 R

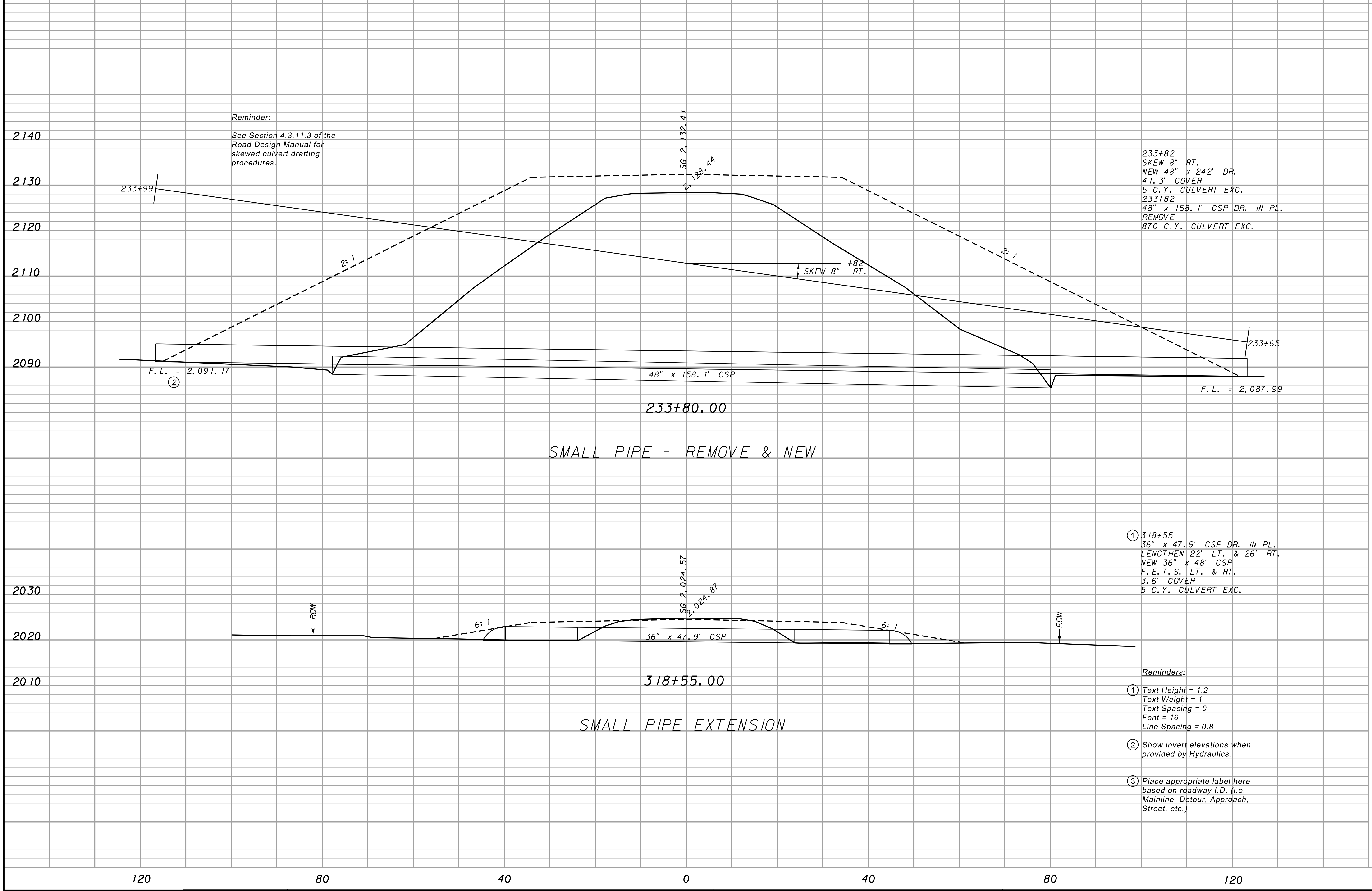
3		c:\dgn\rmanrdplne02.dgn	DESIGNED BY	*DESIGNER NAME*	*DATE*	ROAD PLANS
2	MONTANA DEPARTMENT	10/17/2016	REVIEWED BY	*SUPERVISOR NAME*	*DATE*	
1	serving you with pride OF TRANSPORTATION	1:08:49 PM CPS - U1968	CHECKED BY	*CHECKER NAME*	*DATE*	COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE PLAN SHEET (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION		PROJECT NO.
CSF = 0.9999999	UPN NUMBER 12345678	SHEET 999 OF 999

Reminder:

See Section 4.3.11.3 of the Road Design Manual for skewed culvert drafting procedures.



233+82
SKEW 8° RT.
NEW 48" x 242' DR.
41.3' COVER
5 C.Y. CULVERT EXC.
233+82
48" x 158.1' CSP DR. IN PL.
REMOVE
870 C.Y. CULVERT EXC.

233+80.00

SMALL PIPE - REMOVE & NEW

① 318+55
36" x 47.9' CSP DR. IN PL.
LENGTHEN 22' LT. & 26' RT.
NEW 36" x 48' CSP
F.E.T.S. LT. & RT.
3.6' COVER
5 C.Y. CULVERT EXC.

318+55.00

SMALL PIPE EXTENSION

Reminders:

① Text Height = 1.2
Text Weight = 1
Text Spacing = 0
Font = 16
Line Spacing = 0.8

② Show invert elevations when provided by Hydraulics.

③ Place appropriate label here based on roadway I.D. (i.e. Mainline, Detour, Approach, Street, etc.)

Cut	Fill
0	2,910
25	288

FIG. 4.4 S-1

MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

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10/17/2016
4:11:56 PM CPS - U1968

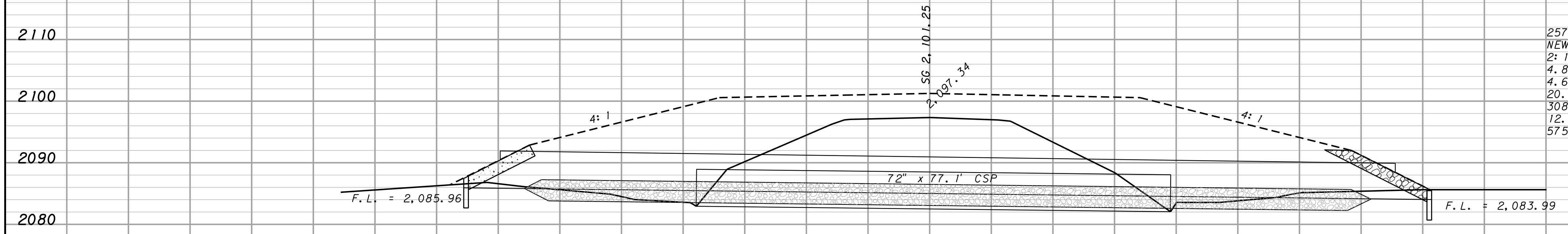
DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

③ MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

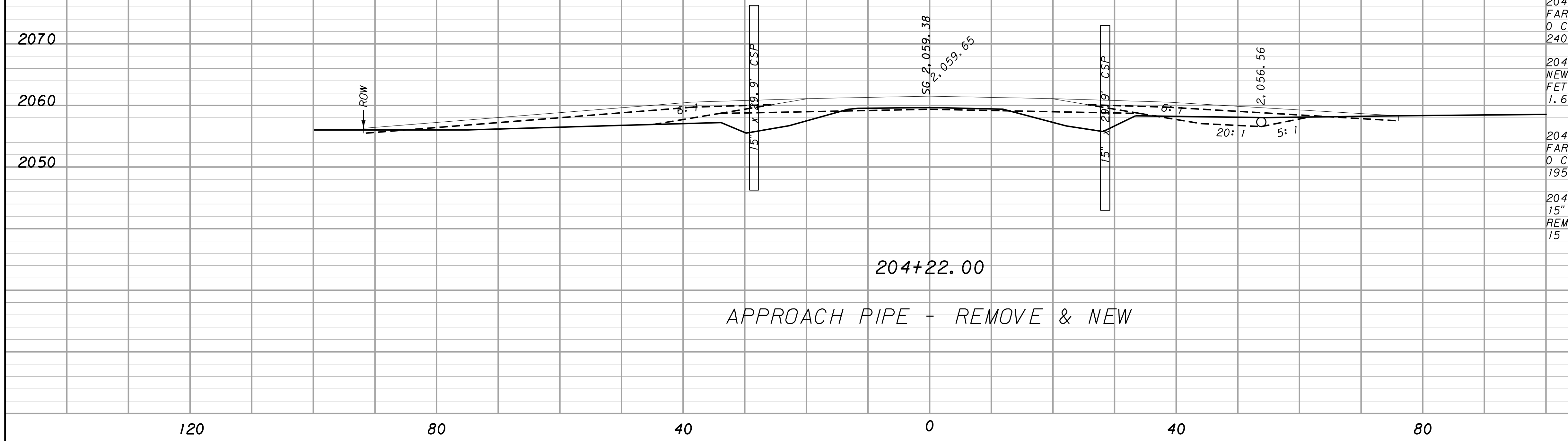


257+13
NEW DBL. 72" x 158' CSP
2:1 STEP BEVEL LT. & RT.
4.8 C.Y. CL. DD CONC. CUT OFF WALLS LT. & RT.
4.6 C.Y. CL. DD CONC. INLET EDGE PROTECTION
20.4 C.Y. CL. 1 CULVERT RIPRAP OUTLET
308 C.Y. BEDDING MATERIAL
12.5' COVER
575 C.Y. CULVERT EXC.

257+09
72" x 77.1' CSP DR. IN PL.
REMOVE
240 C.Y. CULVERT EXC.

257+09.00

LARGE DOUBLE PIPE - ROUND CSP



204+25
15" x 29.9' CSP IN PL. LT.
REMOVE
15 C.Y. CULVERT EXC.

204+22
FARM FIELD APP. LT.
0 C.Y. EXC.
240 C.Y. EMB.+

204+22
NEW 18" x 60' APP. PIPE RT.
FETS LT. & RT.
1.6' COVER

204+22
FARM FIELD APP. RT.
0 C.Y. EXC.
195 C.Y. EMB.+

204+22
15" x 29.9' CSP IN PL. RT.
REMOVE
15 C.Y. CULVERT EXC.

204+22.00

APPROACH PIPE - REMOVE & NEW

Cut	Fill
0	1,312
7	20

FIG. 4.4 S-2

serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
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10/17/2016
4:11:59 PM CPS - U1968

DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

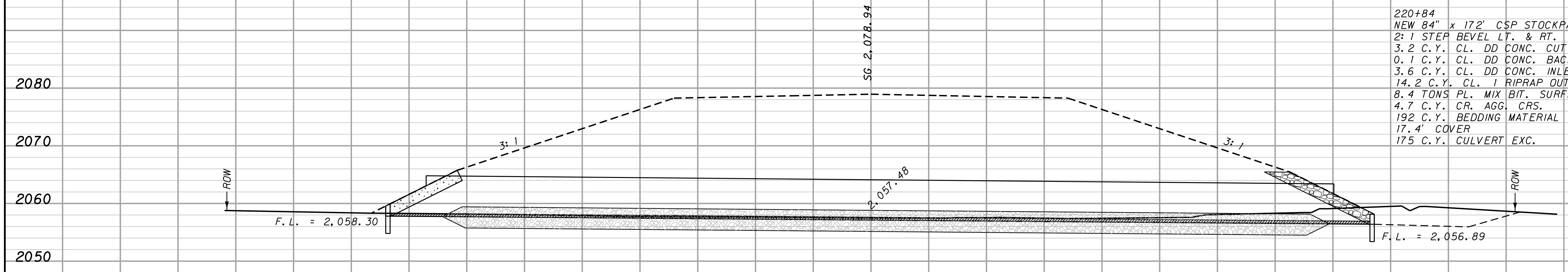
MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

Cut	Fill
0	968
0	759

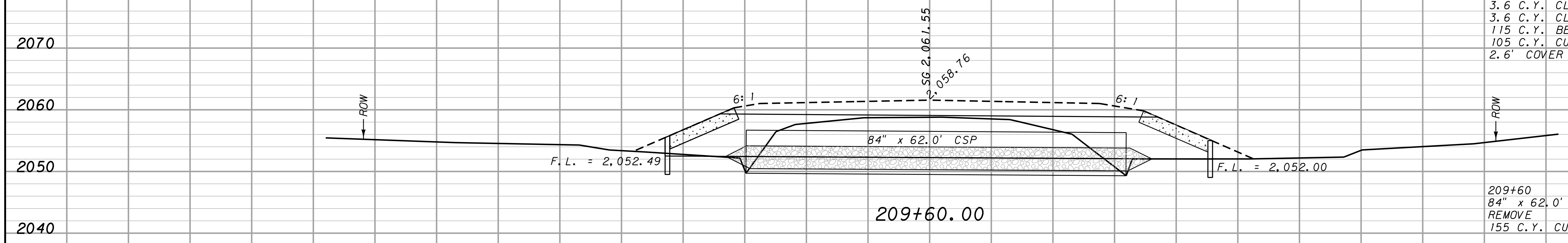


220+85.00

STOCKPASS / DRAIN

220+84
NEW 84" x 172' CSP STOCKPASS/DR.
2:1 STEP BEVEL LT. & RT.
3.2 C.Y. CL. DD CONC. CUT OFF WALLS LT. & RT.
0.1 C.Y. CL. DD CONC. BACKFILL RETAINERS LT. & RT.
3.6 C.Y. CL. DD CONC. INLET EDGE PROTECTION
14.2 C.Y. CL. 1 RIPRAP OUTLET EDGE PROTECTION
8.4 TONS PL. MIX BIT. SURF.
4.7 C.Y. CR. AGG. CRS.
192 C.Y. BEDDING MATERIAL
17.4' COVER
175 C.Y. CULVERT EXC.

220+84
OUTLET DT. RT.
45 C.Y. ADD. EXC.



209+60.00

LARGE SINGLE PIPE - CSP ARCH

209+60
NEW 128" x 83" x 88' CSPA
2:1 BEVEL LT. & RT.
4.2 C.Y. CL. DD CONC. CUT OFF WALLS LT. & RT.
3.6 C.Y. CL. DD CONC. INLET EDGE PROTECTION
3.6 C.Y. CL. DD CONC. OUTLET EDGE PROTECTION
115 C.Y. BEDDING MATERIAL
105 C.Y. CULVERT EXC.
2.6' COVER

209+60
84" x 62.0' CSP DR. IN PL.
REMOVE
155 C.Y. CULVERT EXC.

FIG. 4.4 S-3

serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
c:\dgn\rmanrdlaye01.dgn
10/17/2016
4:12:03 PM CPS - U1968

DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

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10/17/2016
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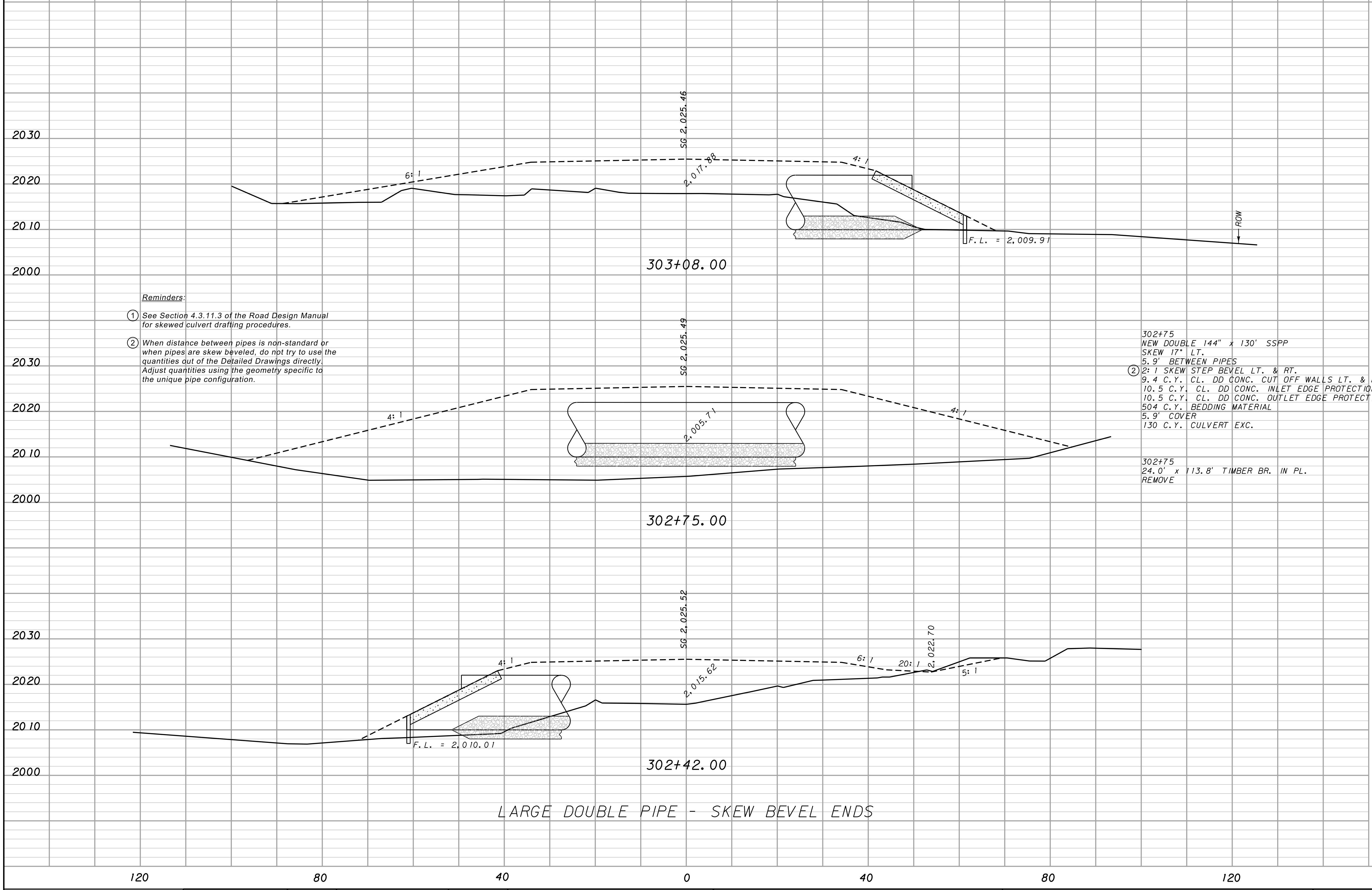
Cut	Fill
0	2,074
12	2,076
217	513



Reminders:

① See Section 4.3.11.3 of the Road Design Manual for skewed culvert drafting procedures.

② When distance between pipes is non-standard or when pipes are skew beveled, do not try to use the quantities out of the Detailed Drawings directly. Adjust quantities using the geometry specific to the unique pipe configuration.

302+75
NEW DOUBLE 144" x 130' SSPP
SKEW 17° LT.
5.9' BETWEEN PIPES
② 2:1 SKEW STEP BEVEL LT. & RT.
9.4 C.Y. CL. DD CONC. CUT OFF WALLS LT. & RT.
10.5 C.Y. CL. DD CONC. INLET EDGE PROTECTION
10.5 C.Y. CL. DD CONC. OUTLET EDGE PROTECTION
504 C.Y. BEDDING MATERIAL
5.9' COVER
130 C.Y. CULVERT EXC.

302+75
24.0' x 113.8' TIMBER BR. IN PL.
REMOVE

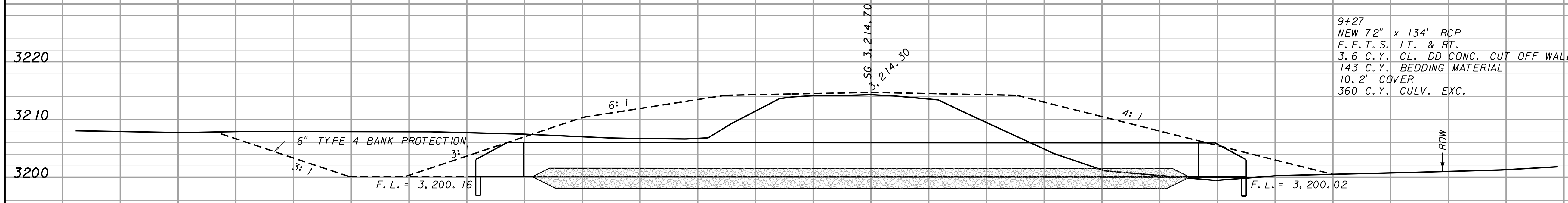
LARGE DOUBLE PIPE - SKEW BEVEL ENDS

FIG. 4.4 S-4

serving you with pride	MONTANA DEPARTMENT OF TRANSPORTATION	c:\dgn\rmanrdlaye01.dgn 10/17/2016 4:12:06 PM CPS - U1968	DESIGNED BY DESIGNER NAME DATE REVIEWED BY SUPERVISOR NAME DATE CHECKED BY CHECKER NAME DATE	MAINLINE CROSS SECTIONS COUNTY NAME(S)	MONTANA ROAD DESIGN MANUAL SAMPLE CROSS SECTIONS (U.S. Customary Units)	PROJECT LOCATION DESCRIPTION CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

Cut	Fill
641	1, 150
421	1, 785

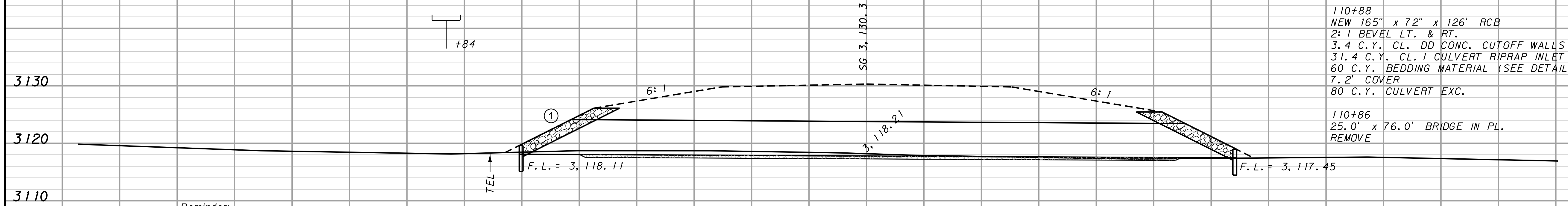


9+27
NEW 72" x 134' RCP
F. E. T. S. LT. & RT.
3. 6 C. Y. CL. DD CONC. CUT OFF WALLS LT. & RT.
143 C. Y. BEDDING MATERIAL
10. 2' COVER
360 C. Y. CULV. EXC.

9+00 TO 9+20
42 C. Y. TYPE 4 BANK PROTECTION LT.
(FACE SLOPE FARTHEST FROM CENTERLINE)

9+20. 00

LARGE SINGLE PIPE - RCP



110+88
NEW 165" x 72" x 126' RCB
2: 1 BEVEL LT. & RT.
3. 4 C. Y. CL. DD CONC. CUTOFF WALLS LT. & RT.
31. 4 C. Y. CL. 1 CULVERT RIPRAP INLET & OUTLET EDGE PROT.
60 C. Y. BEDDING MATERIAL (SEE DETAIL)
7. 2' COVER
80 C. Y. CULVERT EXC.

110+86
25. 0' x 76. 0' BRIDGE IN PL.
REMOVE

Reminder:

① Inlet could include either concrete edge protection or riprap.
The type of material needed is specified by the Hydraulics Section.

110+80. 00

REINFORCED CONCRETE BOX

120 80 40 0 40 80 120

FIG. 4.4 S-5

MONTANA DEPARTMENT
OF TRANSPORTATION
serving you with pride

c:\dgn\rmanrdlaye01.dgn
10/17/2016
4:12:09 PM CPS - U1968

DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999 UPN NUMBER 12345678

PROJECT NO.

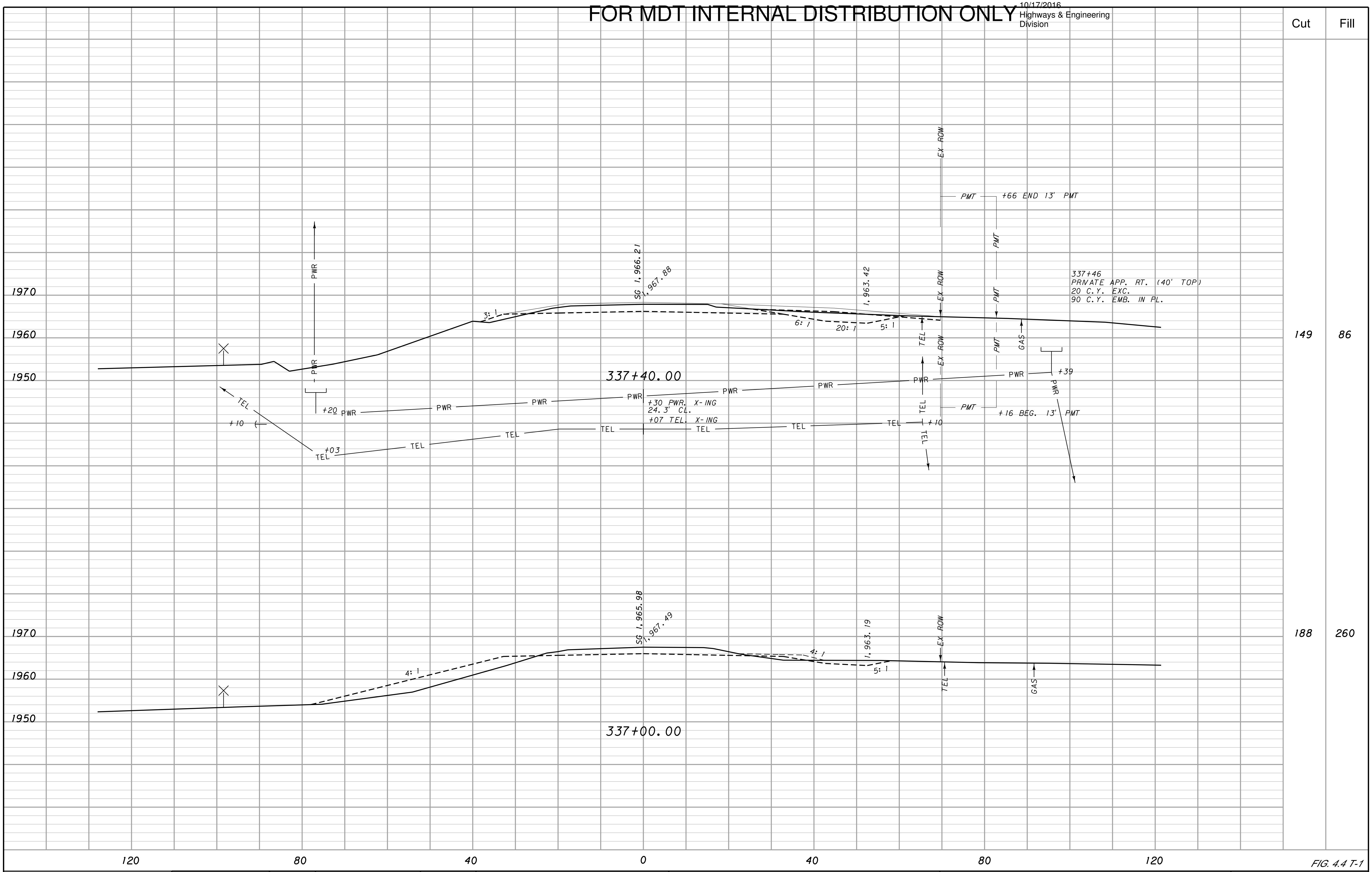


FIG. 4.4 T-1

MONTANA DEPARTMENT OF TRANSPORTATION
serving you with pride

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DESIGNED BY	DESIGNER NAME	DATE
REVIEWED BY	SUPERVISOR NAME	DATE
CHECKED BY	CHECKER NAME	DATE

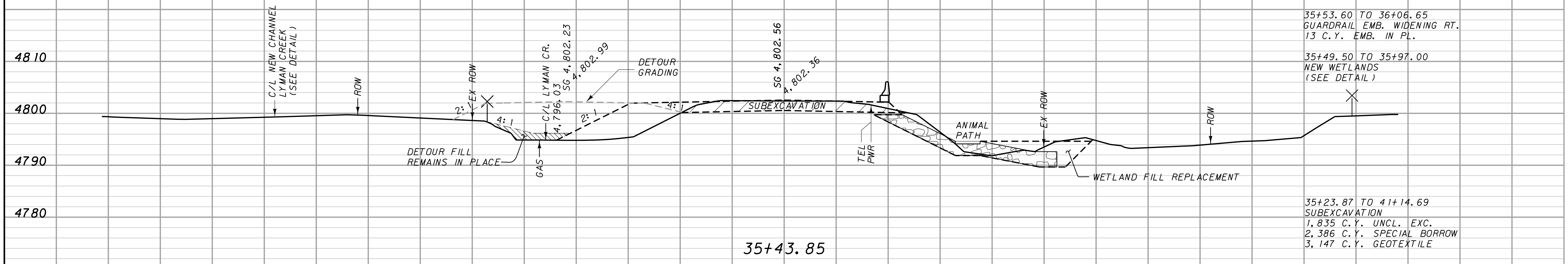
MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

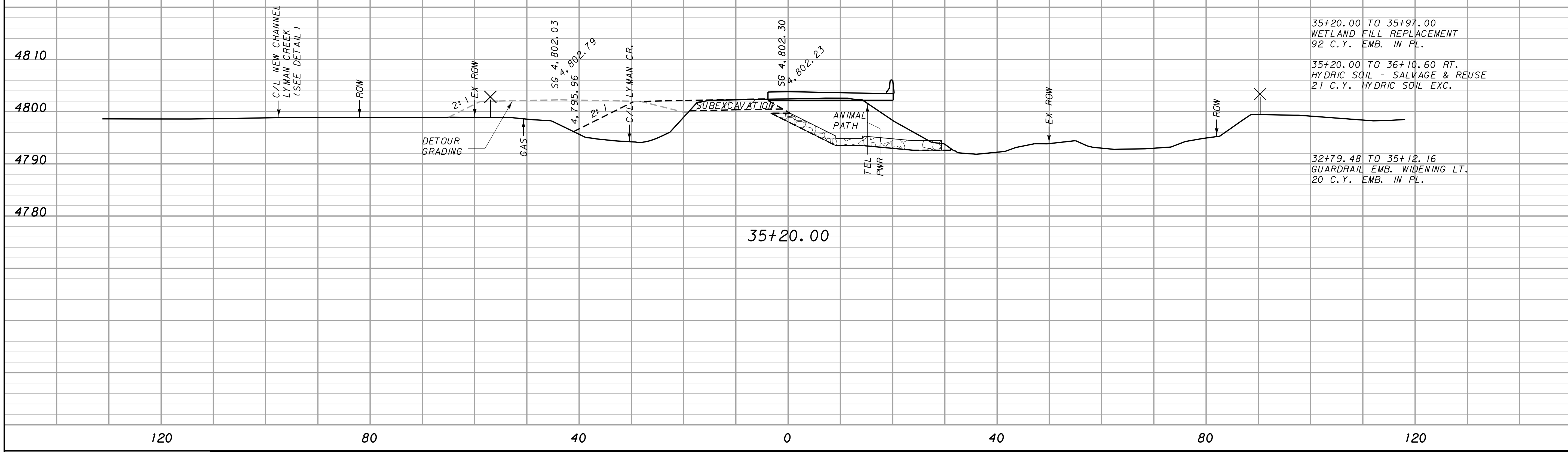
Cut	Fill
13	94
22	0



35+53.60 TO 36+06.65
GUARDRAIL EMB. WIDENING RT.
13 C.Y. EMB. IN PL.

35+49.50 TO 35+97.00
NEW WETLANDS
(SEE DETAIL)

35+23.87 TO 41+14.69
SUBEXCAVATION
1,835 C.Y. UNCL. EXC.
2,386 C.Y. SPECIAL BORROW
3,147 C.Y. GEOTEXTILE



35+20.00 TO 35+97.00
WETLAND FILL REPLACEMENT
92 C.Y. EMB. IN PL.

35+20.00 TO 36+10.60 RT.
HYDRIC SOIL - SALVAGE & REUSE
21 C.Y. HYDRIC SOIL EXC.

32+79.48 TO 35+12.16
GUARDRAIL EMB. WIDENING LT.
20 C.Y. EMB. IN PL.

FIG. 4.4 T-2

serving you with pride
MONTANA DEPARTMENT OF TRANSPORTATION
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MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

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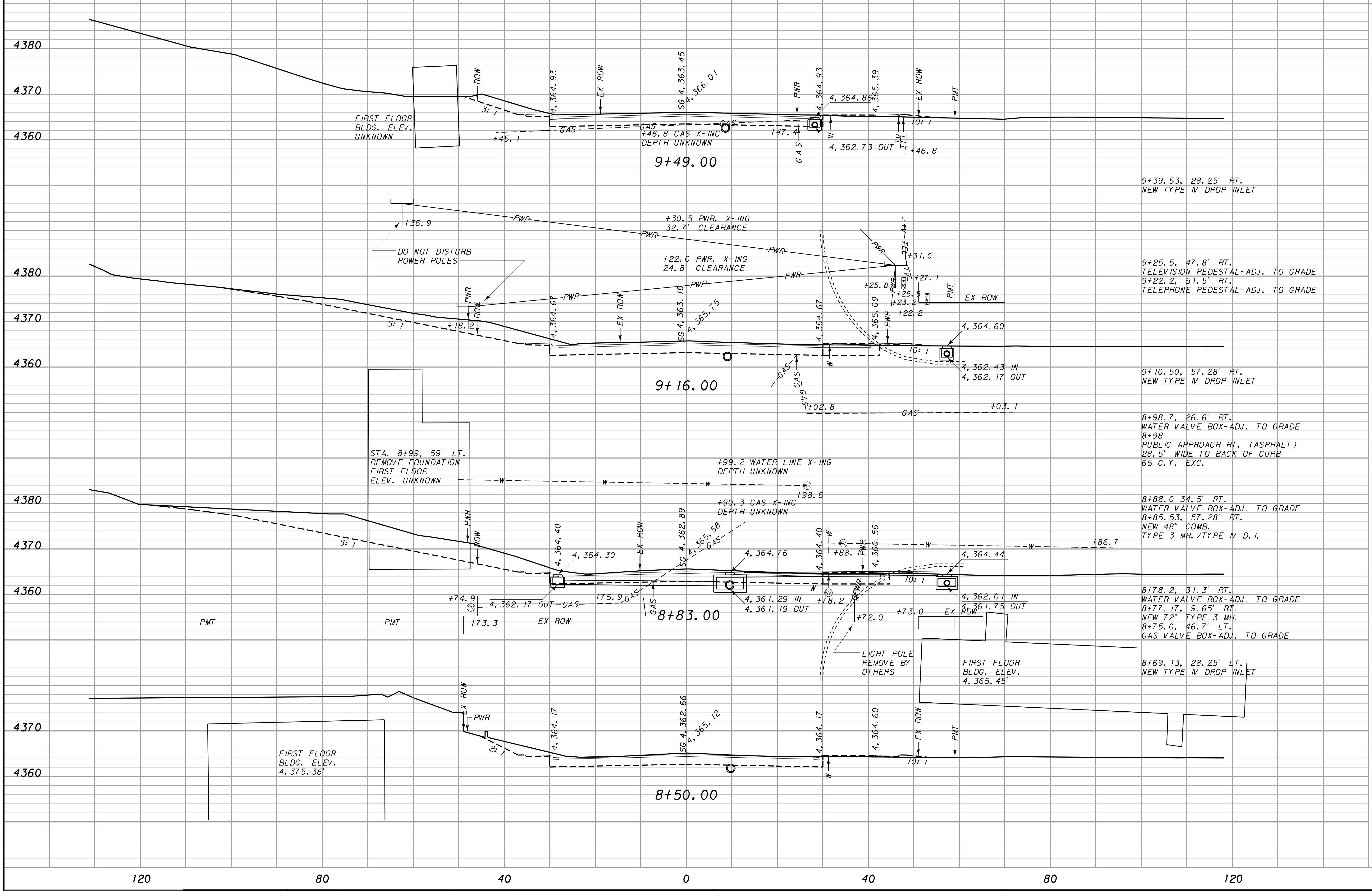

9+39.53, 28.25' RT.
NEW TYPE IV DROP INLET

9+25.5, 47.8' RT.
TELEVISION PEDESTAL-ADJ. TO GRADE
9+22.2, 51.5' RT.
TELEPHONE PEDESTAL-ADJ. TO GRADE

9+10.50, 57.28' RT.
NEW TYPE IV DROP INLET

8+98.7, 26.6' RT.
WATER VALVE BOX-ADJ. TO GRADE
8+98
PUBLIC APPROACH RT. (ASPHALT)
28.5' WIDE TO BACK OF CURB
65 C.Y. EXC.

8+88.0 34.5' RT.
WATER VALVE BOX-ADJ. TO GRADE
8+85.53, 57.28' RT.
NEW 48" COMB.
TYPE 3 MH./TYPE IV D.I.

8+78.2, 31.3' RT.
WATER VALVE BOX-ADJ. TO GRADE
8+77.17, 9.65' RT.
NEW 72" TYPE 3 MH.
8+75.0, 46.7' LT.
GAS VALVE BOX-ADJ. TO GRADE

8+69.13, 28.25' LT.
NEW TYPE IV DROP INLET

Cut	Fill
280	7
417	5
344	7
183	8

FIG. 4.4 T-3

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CHECKED BY	CHECKER NAME	DATE

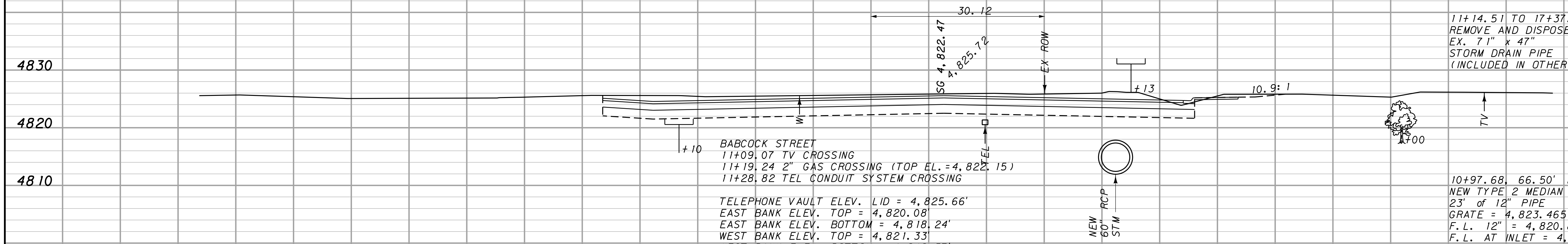
MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999

Cut	Fill
373	20
180	20



BABCOCK STREET
11+09.07 TV CROSSING
11+19.24 2" GAS CROSSING (TOP EL.=4,822.15)
11+28.82 TEL CONDUIT SYSTEM CROSSING

TELEPHONE VAULT ELEV. LID = 4,825.66'
EAST BANK ELEV. TOP = 4,820.08'
EAST BANK ELEV. BOTTOM = 4,818.24'
WEST BANK ELEV. TOP = 4,821.33'
WEST BANK ELEV. BOTTOM = 4,818.57'
NORTH BANK ELEV. TOP = 4,821.33'
NORTH BANK ELEV. BOTTOM = 4,820.51'

11+13.00

11+14.51 TO 17+37.02
REMOVE AND DISPOSE OF
EX. 71" x 47"
STORM DRAIN PIPE
(INCLUDED IN OTHER ITEMS)

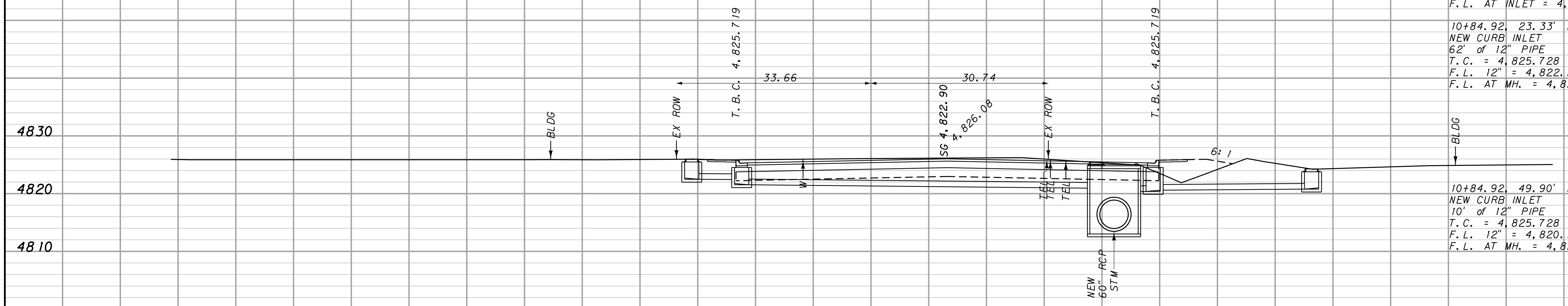
10+97.68, 66.50' RT.
NEW TYPE 2 MEDIAN INLET
23' of 12" PIPE
GRATE = 4,823.465
F.L. 12" = 4,820.83
F.L. AT INLET = 4,820.64

10+95.49 TO 13+91.68 RT.
60" x 292.0' RCP

10+95.49, 41.63' RT.
NEW TYPE 3
100" MANHOLE

10+89.19, 33.17' LT.
NEW TYPE 2 MEDIAN INLET
16' of 12" PIPE
GRATE = 4,825.433
F.L. 12" = 4,822.80
F.L. AT INLET = 4,822.67

10+84.92, 23.33' LT.
NEW CURB INLET
62' of 12" PIPE
T.C. = 4,825.728
F.L. 12" = 4,822.21
F.L. AT MH. = 4,821.72



10+84.92, 49.90' RT.
NEW CURB INLET
10' of 12" PIPE
T.C. = 4,825.728
F.L. 12" = 4,820.57
F.L. AT MH. = 4,820.47

10+80.00

120 80 40 0 40 80 120

FIG. 4.4 T-4

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OF TRANSPORTATION
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MAINLINE CROSS SECTIONS
COUNTY NAME(S)

MONTANA ROAD DESIGN MANUAL
SAMPLE CROSS SECTIONS (U.S. Customary Units)

PROJECT LOCATION DESCRIPTION
CSF = 0.9999999
UPN NUMBER 12345678

PROJECT NO.
SHEET 999 OF 999