WVDOH Standards Committee Meeting
Wednesday, October 1, 2025

Meeting Location: 1900 Kanawha Blvd. E., Building 5, Room 820, Charleston, WV

Also meeting virtually via Google Meet. Email distribution includes instruction.

Old Business: Standards discussed at the August 2025 meeting are below.

ITEM	Champion
3rd time to Committee. Discussed in: June, August, October The revision builds upon the Chief Engineer/State Highway Engineer change and adds updates for outdated links. FHWA has also requested to revise 105 & 106. • DD-105-*Specification, Standards, Manuals, and Material Procedure Approval Process* • DD-106-*Approval for Patented or Proprietary Products* • DD-600-*Geometric Design Project Categories* • DD-647-*Life-Cycle Costs Analysis for Pavement Design* • DD-648-*Alternate Design Alternate Bidding of Pavements* • DD-681-*Work Zone Safety and Mobility* • *DD 811-Accessibility Standard Curb Ramps and Sidewalks* • *DD 813-Bicycle/Pedestrian Accommodation* ○ Tabled by Champion at the last meeting. ○ To be tabled again until links are updated.	J. Chapman

New Business: None

ITEM	Champion
1st time to Committee. ***FHWA Area Engineer Map and Contact List*** FHWA has provided us with an updated FHWA Area Engineering map and an updated list of counties assigned to each Area Engineer. The updated contacts will be added to the ***DD-202*** contact list.	H. Chen

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 105
SPECIFICATION, STANDARDS, MANUALS, AND MATERIAL PROCEDURE APPROVAL PROCESS
August 6, 2023
Supersedes August 25, 2021

This Design Directive outlines the procedure that has been accepted by the Division for preparing and processing proposed Specifications and Special Provisions, Standards, Manuals, and Material Procedures for approval. The Publications Section of the Technical Support Division consists of three units: Specifications, Standards, and Manuals. The Materials Control, Soils, and Testing Division is the home division of the Materials Procedures.

10. Specifications

The general processing of Specifications and Special Provisions is administered through the Technical Support Division by the Specification Engineer.

Standard Specifications will be issued periodically as the need dictates. Supplemental Specifications to accompany the Standard Specifications are issued annually on January 1st and are effective on all projects let to contract thereafter. Each new Supplemental Specification replaces the previous one and incorporates changes from all previous supplemental specifications.

A searchable version of the Standard Specifications book and Supplemental Specifications is available from the Specifications webpage, located online at http://transportation.wv.gov/highways/contractadmin/specifications/

10.1 Procedure for Processing Specification Changes

Permanent specifications changes to the Standard Specifications or Supplemental Specifications should be submitted electronically to DOHSpecifications@wv.gov by the 'champion'. The originating Division will prepare the specification changes in a format conforming to Design Directive 820. A brief overview of the item and background information with reason for the changes should accompany the request.

The Specifications Engineer will review all recommendations received and transmit to the Specifications Committee for action. The champion should attend all committee meetings pertaining to their respective specification. A proposed specification must be presented at two committee meetings before it can be recommended or rejected by the Specifications Committee.

10.2 Procedure for Processing Special Provisions for Individual Projects

There may be a need to use an innovative product or an experimental procedure to address unique demands of a project. Often, these items are not covered by existing specifications, so they may require new or modified specifications to describe their material requirements, construction requirements and payment. Special Provisions (SPs) are written to address these situations.

Before drafting a SP, check with the Specifications Engineer (or ProjectWise folder: Approved Project Specific Provisions (PDF)) to determine if a SP already exists that meets the needs of the project.

SPs are processed as outlined above in 10.1. In general, the originating Division should submit proposed SP at least six months prior to their project's PS&E submission. This provides adequate time to process and resubmit any changes that may be requested by the committee.

When time does not permit this procedure, the following procedures should be followed:

a. The originating Division will prepare the draft Special Provision in a format conforming to Design Directive 820, coordinating with the Technical Support Division, Specifications Engineer for review, comment, assignment of an appropriate section number and/or pay item number.
b. The originating Division will secure the approval of the Applicable Deputy State Highway Engineer and the Federal Highway Administration as appropriate for that project. The approval of the Special Provision would only apply to the specific project. The submission for approval shall follow Design Directive 202 and may only encompass the PS&E package for advertising the project.

There are Project Specific Special Provisions that require management approval prior to their use on projects. These are listed in ProjectWise subfolder title "Requires Management Approval". The Project Manager shall provide justification of why the SP is needed to the Appropriate Deputy State Highway Engineer for approval.

10.3 Specifications Committee

The Specifications Committee review and recommend actions to proposed Specifications and Special Provisions. The committee meets on call by the Specifications Engineer with regular meetings scheduled every other month and follow the Open Government Meeting Act. Details of this act are available at: https://ethics.wv.gov/openmeetings/Pages/default.aspx.

The Specifications Committee consists of voting and non-voting members who provide expertise to review and recommend action of the proposed Specifications and Special Provisions. The committee requests comments on the provisions in the meeting agenda; and review/discuss them during the meeting. The committee meeting agenda will designate the items that are up for approval and dependent upon comments/discussion/changes the Specifications Engineer has the right to call for a vote on the final version.

The voting members consist of one representative from each of the following Divisions:

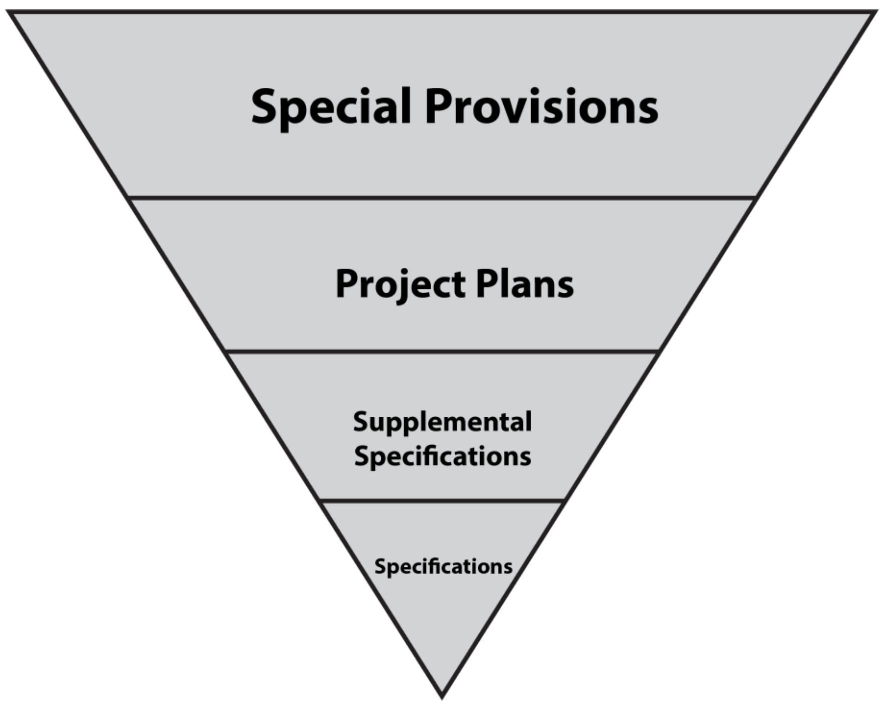
- Contract Administration Division
- Engineering Division
- Materials Control, Soil and Testing Division
- Operations Division
- Traffic Engineering Division

A quorum of 3 voting members must exist for the meeting to be valid. A majority of the present voting members is required to pass the proposed item. The Specifications Engineer shall have the authority to cast the deciding vote when a tie occurs. All approved specification changes will be sent to FHWA for comment and concurrence.

The non-voting members consist of one or more representatives from the following agencies: Federal Highway Administration, Contractors Association of West Virginia, ACEC – WV, Asphalt Pavement Association of West Virginia, American Concrete Pavement Association, Builders Supply Association of West Virginia, various vendors, and anyone from the Division or Industry that has knowledge of the specifications being discussed.

10.4 Coordination of Specifications, Special Provisions, and Project Plans

The Specifications, Supplemental Specifications, Special Provisions, and project plans are essential parts of the Contract; and a requirement occurring in one is as binding as though occurring in all. In case of discrepancy, Supplemental Specifications will govern over Specifications; Plans will govern over Specifications and Supplemental Specifications; Special Provisions will govern over Specifications, Supplemental Specifications, and Plans as prescribed in Section 105.4 of the Standard Specifications. Below is a graphic display of the hierarchy of contract documents; where the items shown above, govern over items below it.



Project plans or plan notes should not be used to change specifications. The procedure outlined in this Design Directive should be utilized when this is necessary.

20. Standards and Manuals

The general processing of Standards and Manuals is administered through the Technical Support Division by the Standards Unit Leader and the Manual Unit Leader.

Standards and Manuals will be issued periodically as the need dictates. Each revised edition supersedes the previous one and incorporates changes from all previous editions.

These publications are available in electronic format on the Division of Highways' Engineering Division Publications webpage, located online at https://transportation.wv.gov/highways/engineering/Pages/publications.aspx.

20.1 Procedure for Processing Standards or Manuals Changes

Proposed changes to any of the Division of Highways' Standards or Manuals should be submitted electronically to the Technical Support Division's Standards or Manuals Unit Leader, as appropriate. The originating Division will prepare the document changes in a format conforming to that particular document. A brief overview of the document and background information with reasons for the changes should accompany the request.

The Standards or Manuals Unit Leader will review all recommendations received and transmit them to the Standards Committee (formally known as Technical Publications Committee) or Manuals Committee for action. A proposed standard or manual or revisions to an existing document must be presented at two committee meetings before it can be recommended or rejected by the Standards or Manuals Committee, unless considered by the committee to be a minor change.

20.2 Standards Committee and Manuals Committee

The Standards or Manuals Committee will review and recommend actions to proposed standards, manuals, or revisions to existing documents. The committee meets on call by the appropriate Unit Leader with regular Standards Committee meetings scheduled every other month (and as needed) and follow the Open Government Meeting Act. Details of this act are available at: https://ethics.wv.gov/openmeetings/Pages/default.aspx.

The Standards and Manuals Committee consists of voting and non-voting members who provide expertise to review and recommend action of the proposed standard or manual. The committee requests comments on the standard or manual in the meeting agenda; and reviews/discusses them during the meeting. The committee meeting agenda will designate the items that are up for approval and dependent upon comments/discussion/changes the presiding unit leader has the right to call for a vote on the final version.

The voting members consist of one representative from each of the following Divisions:

- Contract Administration Division
- Engineering Division
- Materials Control, Soil and Testing Division
- Operations Division
- Traffic Engineering Division

A quorum of 3 voting members must exist for the meeting to be valid. A majority of the present voting members is required to pass the proposed item.

The presiding unit leader shall have the authority to cast the deciding vote when a tie occurs.

The non-voting members consist of one or more representatives from the following agencies: Federal Highway Administration, Contractors Association of West Virginia, ACEC – WV, Asphalt Pavement Association of West Virginia, American Concrete Pavement Association, Builders Supply Association of West Virginia, various vendors, and anyone from the Division or Industry that has knowledge of the publications being discussed.

30. Material Procedures

The Material Procedures (MP) are updated on a four (4) year cycle unless the need dictates otherwise, as determined by the Materials Control Engineer who is the Chairperson of this committee. This person is referred to as "Chairperson" throughout the rest of this section. The MP Committee shall be modeled after AASHTO's Committee on Materials and Pavements (COMP); specifically, how this committee reconfirms various AASHTO procedures and processes. The Chairperson is the default Champion for the updating of these MPs, though the Chairperson may assign a Champion for a particular MP or accept a volunteer Champion.

A new MP may also be submitted by a Champion to the Committee.

30.1 Material Procedures Committee

The Material Procedures Committee consists of voting and non-voting members who provide expertise to review and recommend action on the proposed additions or changes.

The Material Procedures Committee meets on call by the Chairperson with regular meetings usually scheduled on a four (4) to eight (8) week basis.

A quorum of 3 voting members must exist for the meeting to be valid. A majority of present voting members at any meeting shall be required for approval. The Chairperson shall have the authority to cast the deciding vote when a tie occurs.

The voting members consist of one (1) representatives from the following:

- Contract Administration Division
- Materials Control, Soil and Testing Division
- Operations Division
- Technical Support Division
- Traffic Engineering Division

The non-voting members consist of one or more representatives from the following agencies: Federal Highway Administration, Contractors Association of West Virginia, ACEC – WV, Asphalt Pavement Association of West Virginia, American Concrete Pavement Association, Builders Supply Association of West Virginia, Various Venders, and anyone from the Division or Industry that has knowledge of the MP being discussed.

30.2 Procedure for Adding a New MP

All proposals are to be submitted by the Champion to the Chairperson. The purpose for the change to policy and/or reason(s) for the new MP should accompany the request. These items should be submitted within seven (7) calendar days prior to the next meeting to be considered at the meeting. The Champion, or a knowledgeable proxy must be present for all meetings pertaining to their respective MP or the MP will be pushed back to the next meeting that the Champion or proxy can be present. This requirement can be waived at the discretion of the Chairperson.

A proposed MP must be presented at two (2) Committee Meetings before it can be recommended or rejected by the Committee.

If a proposed MP is designated as minor or inconsequential in its intent, only one (1) Committee Meeting will be required for a vote of recommendation or rejection. Any voting member, or the FHWA representative may veto this designation as minor or inconsequential.

30.3 Procedure for Changing an Existing MP

A proposed MP change must be presented by the Champion at Two (2) Committee meetings before the MP can be recommended or rejected by the Committee. All Committee members should receive a copy of the MPs for review prior to the meeting . These comments should be returned to the Chairperson prior to the Committee meeting to give the Champion time to review them.

If a proposed MP change is designated as minor or inconsequential in its intent, only one (1) Committee meeting will be required for a vote of recommendation or rejection. Any voting member, or the FHWA representative may veto this designation as minor or inconsequential.

30.4 Procedure for Submission of Recommended Approvals

Pending the recommendation for approval from the committee, the Chairperson will forward the Provisional MP through the chain of command to FHWA.

A minor or inconsequential MP will not require the approval of FHWA, but will be forwarded through the chain of command at the DOH for approval. The FHWA representative for the MP Committee Meeting shall be given a chance to veto the minor or inconsequential status of the MP.

Upon receiving comment and approval by FHWA (if applicable), the updated or new MP will be published on the MCS&T webpage and be distributed to District Materials Supervisors and other interested parties.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 106
APPROVAL FOR PATENTED OR PROPRIETARY PRODUCTS

January 6, 2024
Supersedes September 6, 2023

This document provides general information and guidance regarding how to obtain approval to use a patented or proprietary product on Federal-Aid construction projects let to bid by the West Virginia Department of Transportation, Division of Highways. It is to be a reference for DOH employees in disciplines such as design, construction, traffic engineering, utilities, right of way, and environmental.

10. INTRODUCTION

(Note: most of the following has been quoted directly from the FHWA website).

The FHWA regulation in 23 CFR 635.411, "Material or Product Selection" prohibits the expenditure of Federal-aid funds on a Federal-aid highway project "for any premium or royalty on any patented or proprietary material, specification, or process" (referred to hereafter as "proprietary product"), unless specific conditions are met. This regulation is intended to ensure competition in the selection of materials, products, and processes while also allowing the opportunity for innovation where there is a reasonable potential for improved performance.

20. DEFINITION OF PATENTED OR PROPRIETARY PRODUCTS

A Patented or Proprietary Product is a product, specification, or process identified in the plans or specifications as a "brand" or trade name (e.g. 3M, Corten). However, it may also be a product so narrowly specified that only a single provider can meet the specification. A proprietary product must meet one of the conditions listed under 23 CFR 635.411(a) or (c) for Federal funds to participate in its use on a Federal-aid highway construction project. For purposes of this guidance, any reference to "proprietary product" shall mean "patented or proprietary product."

30. POLICY

The following was taken from "CFR § 635.411 Subpart D - General Material Requirements. Material or product selection" and defines the Federal Highways Administration's policy regarding patented or proprietary materials. This will be considered the West Virginia Department of Transportation, Division of Highways' policy.

a) Federal funds shall not participate, directly or indirectly, in payment for any premium or royalty on any patented or proprietary material, specification, or process specifically set forth in the plans and specifications for a project, unless:

1) Such patented or proprietary item is purchased or obtained through competitive bidding with equally suitable unpatented items (a minimum of three competing, equally suitable unpatented items should be listed in the plans as alternates if possible – see Item 30 (b) below for more requirements); or
2) The State transportation department certifies either that such patented or proprietary item is essential for synchronization with existing highway facilities, or that no equally suitable alternate exists; or
3) Such patented or proprietary item is used for research or for a distinctive type of construction on relatively short sections of road for experimental purposes. If certification is for experimental purposes, then an Experimental Work Plan must be developed and submitted to FHWA. A sample Experimental Work Plan is available at the following FHWA web address: http://www.fhwa.dot.gov/construction/contracts/pnpapprovals/samplewp.cfm, and a sample Division of Highways' Work Plan is attached to this DD.

b) When there is available for purchase more than one nonpatented, nonproprietary material, semifinished or finished article or product that will fulfill the requirements for an item of work of a project and these available materials or products are judged to be of satisfactory quality and equally acceptable on the basis of engineering analysis and the anticipated prices for the related item(s) of work are estimated to be approximately the same, the PS&E for the project shall either contain or include by reference the specifications for each such material or product that is considered acceptable for incorporation in the work. If the State transportation department wishes to substitute some other acceptable material or product for the material or product designated by the successful bidder or bid as the lowest alternate, and such substitution results in an increase in costs, there will not be Federal-aid participation in any increase in costs.
c) A State transportation department may require a specific material or product when there are other acceptable materials and products, when such specific choice is approved by the Division Administrator as being in the public interest. When the Division Administrator's approval is not obtained, the item will be nonparticipating unless bidding procedures are used that establish the unit price of each acceptable alternative. In this case, Federal-aid participation will be based on the lowest price so established.
d) Reference in specifications and on plans to single trade name materials will not be approved on Federal-aid contracts.
e) In the case of a design-build project, the following requirements apply: Federal funds shall not participate, directly or indirectly, in payment for any premium or royalty on any patented or proprietary material, specification, or process specifically set forth in the Request for Proposals document unless the conditions of paragraph (a) of this section are applicable.
f) State transportation departments (State DOTs) shall have the autonomy to determine culvert and storm sewer material types to be included in the construction of a project on a Federal-aid highway.

40. PROCEDURE

If the designer proposes the use of a proprietary or patented product on any Federal-Aid project, the designer must obtain the approval of~~-~~ the <u>-State Highway Engineer</u> ~~-Applicable Chief Engineer~~ to use the product. The following steps should be followed to gain approval:

a) The certification will be in memo form, and be routed from the Director of the Division requesting the approval, to the <u>State Highway Engineer</u>~~-Applicable Chief Engineer~~, through the <u>Deputy State Highway Engineer – Construction and Development</u> ~~Deputy Commissioner of Highways~~. Examples of this certification memo are provided with this Design Directive.

b) The certification must include the project information (State and Federal Project Numbers, Project Name, and County the project is in),

c) A short description of the proprietary or patented item(s) being proposed,

d) Whether the proprietary or patented product is project-specific, will be used in multiple projects, used in a specific region/District or Statewide, or will programmatic with a sunset date,

e) A justification for the use of that item, to include a description of the unique need being addressed, why other available products are insufficient to meet the Division's needs, estimates or any additional costs associated with the proprietary or patented product, and any other pertinent information as may be required such as prior Division experience with the product,

f) Any catalog cut sheets from the manufacturer describing technical, use, and safety data for the product,

g) A certification statement with either of the following language, depending on whether the product is used because no equally suitable alternative for the item exists, or it is required for synchronization with existing facilities:

   "I (name of certifying official), (position title), of the (Name of contracting agency), do hereby certify that in accordance with the requirements of 23 CFR 635.411(a)(2), that this patented or proprietary item is essential for synchronization with existing highway facilities", or

   "I (name of certifying official), (position title), of the (Name of contracting agency), do hereby certify that in accordance with the requirements of 23 CFR 635.411(a)(2), that that no equally suitable alternative exists for this patented or proprietary item."

h) Signature lines indicating Approval or Disapproval by the <u>State Highway Engineer</u> ~~Applicable Chief Engineer~~, and the date action was taken will be included at the bottom of the letter,

i) The Federal Highway Administration will be included as a recipient on the distribution list for receiving approved certifications and will provide concurrence in the Division's approval.

It should be noted that if the product is being used as an Experimental Product, an

Experimental Work Plan as discussed under Section 30 "**POLICY**", must be included with the certification. A sample Experimental Work Plan is included with this Design Directive.

All proprietary item certifications are to be placed on the AASHTO website at the following address: http://apel.transportation.org/all_certified_products.aspx. Other states that use this site are Arizona, Colorado, Connecticut, Maine, Maryland, Montana, New York, & Ohio.

Also, these approved certifications will be placed on the Division's website in a Division Approved Source/Product Listing on the Materials Control, Soils, and Testing Division's page.

50. DEFINITIONS

As used in this document:

Patented or Proprietary Product: A product, specification, or process identified in the plans or specifications as a "brand" or trade name (e.g. 3M, Corten). However, it may also be a product so narrowly specified that only a single provider can meet the specification. A proprietary product must meet one of the conditions listed under 23 CFR 635.411(a) or (c) for Federal funds to participate in its use on a Federal-aid highway construction project. See Question and Answer #B1. For purposes of this guidance, any reference to "proprietary product shall mean" patented or proprietary product.

Certification: As used in 23 CFR 635.411(a)(2), the written and signed statement of an appropriate contracting agency official certifying that a particular patented or proprietary product is either:

a) Necessary for synchronization with existing facilities; or
b) A unique product for which there is no equally suitable alternative.

Synchronization: As used in 23 CFR 635.411(a)(2), providing a product that matches specific current or desired characteristics of a project. Synchronization may be based on:

a) Function (the proprietary product is necessary for the satisfactory operation of the existing facility),
b) Aesthetics (the proprietary product is necessary to match the visual appearance of existing facilities),
c) Logistics (the proprietary product is interchangeable with products in an agency's maintenance inventory), or any combination thereof.

In addition, it may be advisable to evaluate the following factors as they relate to synchronization:

a) Lifecycle (the relative age of existing systems that will be expanded and the remaining projected life of the proposed proprietary element in relation to the remaining life of the existing elements),
b) Size/extent of products and systems to be synchronized to/with, and the relative cost of the proprietary elements compared with replacing the elements requiring synchronization.

Experimental Product: As used in 23 CFR 635.411(a)(3), a patented or proprietary product used for research or for a distinctive type of construction on relatively short sections of road on an experimental basis.

Public Interest Finding (PIF): As used in 23 CFR 635.411(c), an approval by the FHWA Division Administrator, based on a request from a contracting agency, that it is in the public interest to allow the contracting agency to require the use of a specific material or product even though other equally acceptable materials or products are available.

State Department of Transportation (State DOT): The relevant department of any State charged by its laws with the responsibility for highway construction; also State Transportation Agency (STA), the "State".

Contracting Agency: Any entity administering a contract using Federal aid highway funds. Includes State DOTs, Local Public Agencies (LPAs), and other agencies that may be administering such contracts.

Local Public Agencies (LPAs): Any State DOT sub-recipient of Federal-aid highway funds.

60. REFERENCES

The following references were used to develop this Design Directive and are provided for further information and guidance for the designer:

http://www.gpo.gov/fdsys/pkg/CFR-2014-title23-vol1/xml/CFR-2014-title23-vol1-sec635-411.xml - CFR Title 23, Section 635.411 – Material or product selection, Date: April 1, 2014.

http://www.fhwa.dot.gov/programadmin/contracts/011106.cfm - Guidance on Patented and Proprietary Product Approvals, Date: January 11, 2006.

http://www.fhwa.dot.gov/programadmin/contracts/011106qa.cfm - Questions and Answers Regarding Title 23 CFR 635.411 – Material or product selection, Date: April 11, 2013.

All proprietary item certifications are to be placed on the AASHTO website at the following address: missing link

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 600
GEOMETRIC DESIGN PROJECT CATEGORIES

September 6, 2023
Supersedes May 4, 2022

The purpose of the design directive is to provide guidance to designers on the selection of geometric design criteria for the category of projects based on American Association of State Highway and Transportation Officials (AASHTO) and Federal Highway Administration (FHWA) manuals and guidance.

1.0 INTRODUCTION

This directive shall be used by designers to evaluate the project category and apply proper geometric design criteria. Each project category defines the appropriate level of compliance to various levels of geometric criteria. Geometric criteria are defined by AASHTO's Policy on Geometric Design of Highways and Streets ("Green Book") as well as various other approved manuals developed by AASHTO. FHWA also provides guidance and direction for roads on the National Highway System (NHS). Designers will identify the category of the project early in plan development and address any deviations from the criteria with project notes or design exceptions.

Many manuals and documents provide information to designers when adjustments to published values are allowed. Policies are trending to provide more flexibility to rigid standardization allowing for designs to better fit to the environment around them. For many years the Green Book has provided rigid values to be used based on road classification and volumes. The newest version of the Green Book has expanded the definition of the roads from the traditional functional systems to include contextual setting of the roadway. Performance based practical designs are becoming featured to find better solutions for DOTs as funding becomes more critical to the decision making process. Flexibility and context sensitive solutions allow for designers to meet the purpose and need of the project within budgetary limits.

2.0 PROJECT CATEGORIES

Project categories are developed to direct the designer on the proper geometric design criteria that shall be followed for the type of project to be designed. The categories are based on the type of work to be done, whether the route is on the NHS, the functional system characteristics, traffic volumes and design speed. The criteria in the different manuals and guides are based on historical values, studies and engineering judgement. The values provide guidelines to expedite the decision making and documentation of design selections.

The categories used to develop design criteria are new construction, reconstruction and "construction on existing roads". These categories are further defined as project types in the Green Book. Each category uses a performance based practical design approach to the decision making used to develop design values. New construction projects are on new alignments that use strict adherence to values and criteria developed in manuals and guides. Reconstruction projects use the existing alignment but alter the road type. Construction on existing roads are projects on existing alignments that would not be changing the roadway type and would be developed to address a specific need.

All categories shall be evaluated for their applicability as an alteration project. An alteration project is any project that meets the requirements or project description whereby Americans with Disabilities Act (ADA) facilities must be addressed. Any project defined as alteration must meet the Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right of Way (PROWAG) standards for curb ramp opening, slopes and widths. Refer to DD-811, *Accessibility Standards, Curb Ramps and Sidewalks*, for a list of projects defined as alteration.

Context and location of the roadway are fundamental items used to develop design values for flexible practical design. New construction can even be evaluated based on context of rural or urban environments. Formal design criteria can be used in rural areas due to fewer constraints than in urban, developed areas. Urban area constraints will influence the geometric design criteria and variations to criteria will need documented using performance factors based on function and context of the roadway.

2.1. New Construction: Projects that are developed in the New Construction category will use the design criteria in chapters 2 through 10 of the Green Book or other formal geometric design guidance. Generally, projects in this category shall apply "desirable" or other preferred values to geometric alignments and cross section elements. Functional and context classifications found in chapter 1 of the Green Book should be used to determine values for controlling criteria. There is flexibility allowed for these project categories, but the decisions shall be determined on performance based analysis and thoroughly documented.

2.2. Reconstruction: Projects developed under the Reconstruction category utilize existing alignments or minor changes but result in a change in roadway type. Changes in roadway type result in changes to cross sectional elements to address project needs or scope. These projects present problems when trying to adapt documented design criteria to new facilities due to existing context and constraints. These projects may not necessitate forecasting for future performance but should be part of a performance based approach to address facility needs. Green Book chapters 2 through 10 should be reviewed for geometric and cross-sectional guidance but facility context may drive decisions due to constraints within the corridor.

Projects such as intersection improvements, adding lanes and lane or shoulder widening would change the roadway type but would only cause minor changes to the existing alignment. These projects may not use the full criteria found in the Green Book due to nearby or corridor constraints.

Interstate reconstruction is a project type where variable design criteria may be applied. Cross slope information from the "A Policy on Design Standards – Interstate System" may be utilized to correct cross slopes. Criteria may be referenced from other guidance, such as correction of superelevation will use "Green Book" standards. In this case shoulder widths may be substandard to meet new construction criteria, but under the reconstruction category may not be widened since this would alter the roadway type.

2.3. Construction Projects on Existing Roads: Projects developed under the Construction Projects on Existing Roads (CPER) category are projects that have no or minor changes to the existing alignment and no changes to the roadway type. CPER project types are similar to what has historically been referred to as RRR (restoration, rehabilitation, resurfacing). These projects use flexible criteria based on existing performance to address the facility needs or scope of the project. Projects may use Green Book design criteria, but other manuals may also be used for documenting design criteria of the project. The CPER category will encompass several other subcategories based on the requirements of the project. Projects within the category need to meet different thresholds of documentation and coordination. CPER projects may include resurfacing, slide correction, bridge deck replacements, safety upgrade and other preventive maintenance projects.

A subcategory of the CPER is a maintenance project. An example of a maintenance project is the common resurfacing project. These projects use the existing alignments and are not intended to alter the roadway type. These projects are developed to restore rideability and prolong the serviceability of the existing surface.

3.0 PROJECT CATEGORY EXAMPLES

The following are definitions and examples of work types for the project categories. The bulleted lists below are not all inclusive, especially for CPER. Any project meeting the criteria of Alteration Project must meet standards defined in PROWAG.

3.1. Alteration Project: An Alteration Project is project defined by "DOJ/FHWA Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps When Streets Roads or Highways are Altered Through Resurfacing". Treatments that are considered alterations of the road surface are:

- Open-graded surface course
- Cape seals
- Mill and fill/Mill and overlay
- Hot in-place recycling
- Microsurfacing/Thin-lift overlay
- Addition of new layer of asphalt
- Asphalt and concrete rehabilitation and reconstruction
- New construction
- Widening of the existing pavement typical section
- Addition of turning lanes
- Pavement rubblization
- Installation of new drainage structures to improve existing drainage characteristic

Treatments that are NOT considered alteration projects are:

- Crack filling and sealing
- Surface sealing
- Chip, Slurry, and Fog seals
- Scrub sealing
- Joint crack seals
- Joint repairs
- Dowel bar retrofit
- Spot high-friction treatment
- Diamond grinding
- Pavement patching
- Shoulder repairs
- Pipe and inlet repairs
- Pulling and restoration of ditches
- Guardrail repair and installation
- Re-striping

For additional information on alteration project definitions use the following link for guidance.

USDOT FHWA Civil Rights Website
https://highways.dot.gov/civil-rights/programs/ada/department-justicedepartment-transportation-joint-technical-assistance1

~~https://www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta_glossary.cfm~~

3.2. New Construction: Defined as an Alteration Project, on new alignment meeting full compliance with design guidance. Guidance can be found in the latest adopted editions found in section *Policies, Manuals and Guidance.*

- New Interstate
- New Four Lane Divided Highway
- New Two Lane Highway

3.3. Reconstruction: Defined as an Alteration Project, on an existing alignment (or make only minor changes to the alignment) that alters the basic roadway type. Designers use standards approved in various design guidance criteria to make performance based practical design decisions that are documented. These concepts generally follow guidance provided in Green Book allowing for more flexibility based on surrounding system characteristics and context.

- Adding Lanes or a Median
- Adding Auxiliary Lanes
- Widening Lanes or Shoulders
- Intersection Improvements
- Bridge Replacement
- Sidewalk Construction
- Interstate Reconstruction

3.4. Construction Projects on Existing Roads: Defined as an Alteration Project, on an existing alignment (except for minor changes) that maintains the basic roadway type and uses practical engineering concepts to re-establish some portion of initial serviceability or Level of Service. Projects may not follow the formal DD-202 process, but quality assurance and control may be supplemented by Safety Reviews, ADA Exception Justification Reports and other documentation to support design decisions.

- Resurfacing, Restoration and Rehabilitation (RRR)
- NHS Resurfacing
- Guardrail Installation
- Bridge Deck Replacement

3.4.1. Construction Projects on Existing Roads (Preventive Maintenance): Defined as an alteration project, on an existing alignment (except for minor changes) that maintains the basic roadway type and uses practical engineering concepts to re-establish the rideability or corridor functionality.

- NHS Resurfacing
- Non-NHS resurfacing
- Slide Repair
- Bridge Deck Overlays
- Pipe Replacement
- Microsurfacing

3.4.2. Construction Projects on Existing Roads (Maintenance): Defined as a non-alteration project, on an existing alignment (except for minor changes) that maintains the basic roadway type and uses practical engineering concepts to extend the service life.

- Joint and Pavement Sealing
- Diamond Grinding
- Joint Repair and Dowel Bar Retrofit
- Pavement Patching
- Guardrail Repairs
- Pulling and Restoration of Ditches

- Restriping

4.0 POLICIES, MANUAL AND GUIDANCE

The following represents a list of approved policies and manuals for designers to document geometric design decisions.

- A Policy on Geometric Design of Highway and Streets, 2018, 7th Edition
- A Policy on Design Standards – Interstate System, May 2016
- Highway Safety Manual, 2014, 1st Edition
- Roadside Design Guide, 2011, 4th Edition
- Manual for Assessing Safety Hardware, 2016, 2nd Edition
- LFRD Bridge Design Specifications, 9th Edition
- LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1st Edition
- Manual on Uniform Traffic Control Devices 2009, Revision 1 and 2
- Guidelines for Geometric Design of Low-Volume Roads, 2019, 2nd Edition
- WVDOH Design Directives
- WVDOH Structure Directives

Any errata, supplemental or new editions of the listed documents, formally adopted by FHWA on federal aid eligible projects. The use of AASHTO approved documents prior to FHWA adoption on non-NHS projects is acceptable.

5.0 DOCUMENTATION

The following shall provide a minimum of documentation requirements of the project category. The flexibility provided in the geometric design policy may necessitate additional documentation on performance based decisions. The documentation, if not based on published standards, shall thoroughly address design applicability in type, nature and context to function of the corridor or facility. The use of practical engineering concepts for CPER projects should be based on long held performance based decisions that meet system wide goals. When controlling criteria is being addressed by the scope of the project and appropriate limits cannot be obtained, variances shall be documented using DD-605 *Design Exception Policy*.

5.1. New Construction: The geometric design decisions shall be documented as reference to applicable manuals using tables, charts, or section reference. Design exception documents shall be used to identify nonstandard dimensions. The use of less than desirable values for any dimension not defined as a controlling criteria value, shall be submitted for approval by the appropriate Deputy State Highway Engineer ~~Chief Engineer~~.

5.2. Reconstruction: The geometric design decisions affecting roadway type shall be documented and referenced to the applicable manual using table, charts, or section reference. Design exceptions narrative should reflect performance based practical design decisions that identify the context of the surrounding area and improvements to the facility within funding constraints.

5.3. Construction Projects on Existing Roads: Projects designated as CPERs shall use flexible performance based solutions to address facility needs. Depending on facility designation as an NHS route, the documentation will vary. Based on the type of work, the project may be documented using formal documentation, or decisions can be based on historical performance that meet the yearly fiscal or program monetary constraints. In all cases the designer shall analyze safety concerns, accident data and address ADA concerns when documenting project decisions.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 647
LIFE-CYCLE COSTS ANALYSIS FOR PAVEMENT DESIGN
September 6, 2023
Supersedes June 15, 2010

This Design Directive (DD) gives guidance for the Division of Highways' (DOH) policy on Life-Cycle Cost Analysis (LCCA) for pavements.

This DD provides a means to standardize the process required to analyze and report the pavement design Life-Cycle Costs throughout all development units of the DOH. The general procedure for performing the LCCA is detailed herein. References for more in-depth LCCA analyses are also given.

10. General

The purpose of an LCCA for a particular pavement design within a defined *pavement segment* is to evaluate the overall long-term economic efficiencies of competing design alternates. Initial (construction) and discounted future (future rehabilitations, user, etc.) costs over the projected life of the pavement are added together to obtain a Net Present Value (NPV) for each *pavement type* selected. This process improves decisions concerning the utilization of limited funding for pavement in a construction project within a *pavement segment.*

20. Life-Cycle Cost Analysis (LCCA)

The WVDOH generally follows the LCCA methodology recommended in the FHWA Pavement Division's interim technical bulletin *Life-Cycle Cost Analysis in Pavement Design – in Search of Better Investment Decisio*ns, 1998. The publication number for this document is *FHWA-SA-98-079* and is available electronically at https://www.fhwa.dot.gov/pavement/lcca/lccafact/ ~~isddc.dot.gov/OLPFiles/FHWA/013017.pdf~~ . It contains standard procedures for estimating and comparing the long-term costs of *asphalt* and *Plain Jointed Portland Cement Concrete* (PCC) pavements over an analysis period under specified traffic and environmental conditions. The WVDOH uses an analysis period of at least 40 years for both the asphalt and PCC pavements. See *DD-641, Pavement Type Selection Guide*, for more information regarding pavement type selection parameters, and *DD-646, Pavement Design Guide*, for information concerning the design of the pavement structure itself.

The WVDOH generally follows the FHWA's recommendations for LCCA input data unless local data is available. Local input data includes, but is not limited to, traffic characterization, duration of construction, and construction costs. It is important to note that only differential costs are considered between alternates in the LCCA.

The Life Cycle Cost Analysis, if required per DD-641, will be performed on each *pavement segment* upon receipt of necessary soils data, existing pavement cores, and traffic data.

The base bid quantities for grading will be for the thicker pavement section. The *designer* may allow a lower profile grade but hold the cross-section to avoid additional earthwork. The profile grade can be lowered by using a straight horizontal taper rate of 0.25%. This will occur at, but not be limited to, the ends of structures and at tie-ins to existing pavements. If the *designer* does not allow a lower profile grade, bid items for adjusting the grade must be added to the contract and included in the LCCA for that particular alternate; however, the contractor will not be permitted to raise the profile grade above that shown for the thickest pavement alternate. Costs common to each pavement alternate such as mobilization, signing/pavement marking, grading, drainage, rights-of-way, utility relocation, etc. are not included.

User delay costs are another important element in LCCA. Estimation of user delay costs follows the procedures in *Life-Cycle Cost Analysis in Pavement Design – In Search of Better Investment Decisions*, 1998. The user delay costs considered are the differential costs between competing alternates such as work zone costs including duration, setting traffic control, resetting traffic control for construction phasing, etc. User delay costs can differ by pavement type. The designer must carefully examine all facets of the planned work to accurately estimate user delay costs. Routine maintenance is not included in this analysis.

User costs are further divided into the *working day* and *non-working day* daily user costs. In most cases, the travel capacity of a construction zone on a *working day* is less than the capacity on a *non-working day.* For the purposes of this Directive, a *non-working day* is any day throughout the course of construction that traffic is not impeded in any way by lane/shoulder closures. User costs associated with *non-working days* are excluded from the analysis.

If the LCCA is performed on an entire pavement segment and the segment is not being fully constructed in one contract, then the result of the analysis will be pro-rated using the contract length divided by the entire *pavement segment* length. See *DD-648, Alternate Design Alternate Bidding of Pavements*, for more information on this matter.

30 Alternate Design Alternate Bid (ADAB)

The ADAB bid process is described in greater detail in *DD-648*.

40 Steps in LCCA

A standard procedure has been developed to perform the LCCA analysis. The *project manager* is responsible for the LCCA, using software that is specifically designed for use with *Life-Cycle Cost Analysis in Pavement Design – In Search of Better Investment Decisions*, 1998. The following steps are to be followed:

40.1 Project Selection

Criteria to be used for evaluating projects for inclusion in the LCCA process are described in DD-641.

40.2 Alternative Pavement Design Strategies

See DD-646 for selection of alternate design strategies and for information on the pavement design and rehabilitation process itself. The analysis period shall be at least 40 years.

The designer will develop reasonable design strategies for each alternative based on past pavement performance; that is, an initial pavement structure followed by a series of rehabilitations to cover the analysis period. The analysis period will be the same for each alternative considered.

40.3 Estimate Agency Costs

Initial agency costs of the pavement section are the construction costs incurred by the WVDOH. These are official estimates prepared by the Division's *designer* or *project manager*. See the latest issue of DD-707, Development of Engineer's Estimate, for more information regarding the development of the official cost estimate.

Future agency costs are the costs incurred by the WVDOH to overlay, rehabilitate, or reconstruct the roadway in the 40 year (or longer) analysis period specified. All of these future costs must be considered in the LCCA for each pavement type considered for use.

40.4 Estimate User Costs

User costs are estimated according to the recommendations made in *Life-Cycle Cost Analysis in Pavement Design – In Search of Better Investment Decisions*, 1998. As stated above, only work zone user costs are estimated in the LCCA process. Estimation of user costs requires three steps: calculate the appropriate daily user costs, determine the duration of the construction activities and apply the daily user costs to the expected duration of the construction.

Data used for computation of LCCA user delay costs will be obtained from the Traffic Engineering Division and the Planning Division. The *designer* will be responsible for compiling all the required information from these sources and running the aforementioned program.

40.5 Compute Net Present Value (NPV)

In the broadest sense, LCCA is a form of economic analysis used to evaluate the long-term economic efficiency between investment options; therefore, the NPV of cash flow is calculated.

Economic analysis focuses on the relationships between costs, timings of costs, and discount rates employed. Once all costs and their timings have been developed, future costs must be discounted to the year of initial construction (the "base year") and added to the initial cost (the construction estimate cost) to determine the NPV for each LCCA alternate. Again, more information on the calculation and use of NPV is available in *Life-Cycle Cost Analysis in Pavement Design*, 1998. The designer is encouraged to consult this publication. Software designed from this publication will be used to determine the NPV of all cash flows.

Once completed, all LCCA's should be subjected to a sensitivity analysis. Sensitivity analysis is a technique used to determine the influence of major LCCA inputs, assumptions, projections, and estimates on the various LCCA results. In a sensitivity analysis, major input values are varied over a reasonable range of values, while all of the other variables remain constant. The input variables may then be ranked according to their effect on the results. This allows the designer to subjectively get a feel for the impact of the variability of individual inputs on overall LCCA results.

Sensitivity analyses, at a minimum, evaluate the influence of the discount rate on LCCA results. The discount rate accounts for the time value of money. It takes into account fluctuations in the inflation and interest rates to show the actual rate of increase in the value of money over time. Using the discount rate allows the designer to use today's dollars in the LCCA. The higher the discount rate, the lower the present value of future cash flows. The discount rate to be utilized in all LCCA's will be the latest effective 30-year value of *real treasury interest rates* on *treasury notes* and *bonds* of *specified maturities* as given in the United States' Office of Management and Budget's *Circular A-94*, Appendix C. A table summarizing the past history of and giving the latest years' rate is available at https://www.whitehouse.gov/wp-content/uploads/2023/12/CircularA-94AppendixC.pdfhttp://www.whitehouse.gov/omb/circulars/a094/dischist.pdf.

If the *designer* finds that any LCCA is sensitive to a particular input, then the *designer* is to perform LCCA's utilizing a reasonable range of that input, and submit these results to the Deputy State Highway Engineer Chief Engineer of Development in the package required by DD-641.

50. Comments

As projects utilizing LCCA are *let to construction*, their associated unit bid prices will be monitored to determine any trends in costs. Also, salvage values will not be considered in the LCCA's.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 648
ALTERNATE DESIGN AND ALTERNATE BIDDING OF PAVEMENTS
September 6, 2023
Supersedes June 15, 2010

This Design Directive (DD) gives guidance on the West Virginia Division of Highways' (WVDOH) policy on *alternate design and alternate bidding* (ADAB) of pavements.

Use of this DD provides a means to standardize the process required to utilize ADAB for pavements throughout all development units of the DOH; however, this DD does not detail the procedure for designing pavements and performing life-cycle cost analyses (LCCA), but references to publications written in detail concerning these subjects are given for the *designer's* use.

10. General

The objective of the ADAB process is to promote more cost-effective usage of highway construction funds. This is achieved by allowing contractors to select the *pavement type* constructed through the bidding process; consequently, increasing competition as well as making that competition more equitable. The Federal Highway Administration's (FHWA) Memorandum: *Clarification of FHWA Policy for Bidding Alternate Pavement Type on the National Highway System*, November 13, 2008, can be accessed at: http://www.fhwa.dot.gov/pavement/081113.cfm.

The ADAB process requires the WVDOH to consider future roadway rehabilitation, traffic control associated with that rehabilitation, and user delay costs. The process utilizes traditional *life-cycle cost analysis* (LCCA) concepts to model the cost of pavement section alternatives over a selected performance period. The selection process is then accomplished through an ADAB procedure, which essentially allows the bidder with the lowest *life-cycle costs* (LCC) to determine which pavement type will be constructed. See DD-647, *Life-Cycle Cost Analysis of Pavements*, for more information concerning LCCA.

To accomplish the ADAB process, the "A + B + C" bidding method is utilized for all bids submitted. Factor "A" is the contractor's bid, factor "B" is the time *in days* to construct the initial pavement, and factor "C" is the *net present value* (NPV) of all future rehabilitation costs, plus the NPV of *present* and *future* user costs for the pavement's analysis period. The lowest bidder is identified by adding "A + C".

The time factor "B" is not normally added to the contractor's bid. This factor may be used on projects that consist of total pavement reconstruction in order to capture the user costs associated with the initial construction. This *time factor* is usually zero (0) because most projects are on new alignments, and traffic is not impeded during the initial construction of a project.

If a particular project is not approved by the Deputy State Highway Engineer ~~Chief Engineer~~ of Development or the FHWA's *Special Experimental Projects No. 14 – Alternative Contracting* (SEP-14) for the ADAB process, then the *designer* is to consider the following to recommend a *pavement type only* for approval:

- The LCCA
- *Secondary factors* as described in DD-641, *Pavement Type Selection Guide*, Section 40
- Sound engineering judgment

If the ADAB process is approved on any particular project, the *designer* may be required to submit a request to the FHWA headquarters, through the local office, to approve the use of ADAB on a project-by-project basis under the FHWA's SEP-14.

The following FHWA website contains additional information concerning SEP-14 submittals:
https://www.fhwa.dot.gov/construction/cqit/sep14.cfm~~www.fhwa.dot.gov/programadmin/contracts/sep_a.cfm~~

20. Criteria for Selection of Projects for the ADAB Procedure

Section 30 of DD-641 describes the criteria to be followed for selection of projects that will use the ADAB procedure for bidding of alternate pavement types.

30. Alternate Design and Alternate Bid (ADAB)

The ADAB bid model is accomplished by adding a factor "C" to each contractor's base bid factor "A". Factor "C" represents future rehabilitation and user delay costs for a particular pavement alternate. The implementation of ADAB, in general, may result in comparing multiple competing pavement structures with differing total thicknesses between the top of the sub-grade and the final pavement surface. A threshold of 20 percent in the difference of the NPV of the LCCA is a reasonable zone within which pavement types can compete.

In a contract in which the pavement is bid by the ADAB procedure, both the *asphalt* and the *jointed plain concrete* pavements shall be bid as a *pavement system* in square yards (sy). The *pavement system* is the entire pavement section, including fine grading, sub-grade, base and pavements. This approach allows an equal bidding process.

Note: The contract documents will include price adjustment factors for fuel, asphalt, and cement.

40. Steps in ADAB

A standard procedure has been developed to perform the ADAB analysis. This procedure has the following steps.

40.1 Project Selection

Criteria to be used for evaluating projects for inclusion in the ADAB process are described in DD-641, as mentioned in "Section 20" above.

40.2 Alternative Pavement Design Strategies

Refer to DD-641 for selection of alternate design strategies for the chosen analysis period, and DD-646, *Pavement Design Guide* for information regarding the pavement design process.

40.3 Estimate Agency Costs

Initial agency costs are the construction costs incurred by the WVDOH. These are official estimates prepared by the Division's *designer* or *project manager*. See the latest issue of DD-707, *Development of Engineer's Estimate*, for more information regarding the development of the official cost estimate.

Future agency costs are the costs incurred by the WVDOH to overlay, rehabilitate, or reconstruct the roadway in the 40 year (or longer) *analysis period* specified. All of these future costs must be considered in the LCCA for each pavement type considered for use.

40.4 Estimate User Delay Costs

See DD-647 for more information concerning computation of user delay costs.

40.5 Compute Net Present Value (NPV)

Refer to DD-647 for more information concerning computation of the NPV for each pavement alternate considered.

40.6 Analyze Results And Calculate Life-Cycle Cost Adjustment Factor "C"

After the total NPV for each alternate is computed, the results are then compared. If the difference in the total NPV between the lowest two alternates is greater than 20 percent, the alternate with the lower total NPV <u>only</u> is selected for bidding. The *designer* shall eliminate any pavement alternate that is considered, in the *designer's* judgment, to be impracticable for the project. Otherwise, alternate pavement designs will be included in the bidding documents and a *life-cycle cost* adjustment factor "C" will be included in the *schedule of prices* for each alternate.

The *life-cycle cost adjustment* factor, "C", is calculated as ***C = total NPV of the LCCA – construction cost.*** As part of the ADAB process, this "C" factor will be added to the contractors' bid. The lowest bidder identified by adding the "C" factor to the contractors' base bid "A" factor; thus, the lowest total is then selected.

If the LCCA is performed on an entire *pavement segment* and the *segment* is not being fully constructed in one contract, then the "C" factor will be pro-rated using the project length divided by the entire *pavement segment* length.

If the "C" factors are essentially equal (1% or less of the lowest cost initial *pavement section*) for all of the paving alternates considered, then "C" factors do not need to be added to the contractor's bids in order to determine the low bid.

Refer to "Section 30" of this DD for information on the handling of multiple pavement types in both the LCCA and bidding processes.

50. Comments

As Projects utilizing LCCA are *let* to construction, their associated unit bid prices are monitored to determine any trends in costs. Also, salvage values are not be considered in the LCCA's.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVES 681
WORK ZONE SAFETY AND MOBILITY
January 3, 2024
Supersedes November 1, 2023

The West Virginia Division of Highways (WVDOH) is committed to providing a safe and efficient work zone environment. It is the Division's goal to minimize traffic delays to the traveling public, reduce work zone crashes and fatalities, and to promote a safe work place by improving mobility of the motorist and providing the utmost protection of the construction work force.

Compliance with this policy will benefit the traveling public, construction industry, and the business community by reducing work zone accidents, construction, and travel time.

The attached policy outlines procedures to be followed during all phases of development and construction or maintenance. It also assigns responsibilities for implementation to fulfill its requirements.

The requirements of this policy apply to all highway projects, regardless of the funding source.

Background

The Federal Highway Administration (FHWA) published the Final Rule on Work Zone Safety and Mobility, 23 CFR 630 Subpart J in September 2004. This rule, referred to as Work Zone Safety and Mobility, applies to State and local governments that receive Federal-aid highway funding. All transportation agencies are required to comply with the provisions of the Rule. This rule updates and broadens the former regulation, "Traffic in Highway and Street Work Zones," to address present and future work zone issues.

The final rule requires agencies to:

- Implement a policy that facilitates systematic consideration of work zone safety and mobility on all Federal-aid highway projects. Implementing the policy for nonFederal-aid highway projects is also encouraged.
- Develop procedures to assess and manage work zone impacts throughout the various stages of the project's development and construction. The agency must consider work zone impacts during project development, manage work zone impacts during construction, and assess work zone performance after implementation.
- Use work zone data to manage work zone impacts for specific projects and to improve the State processes and procedures.
- Ensure personnel are trained appropriately to the work zone job decisions for which they are responsible.
- Perform process reviews at intervals no greater than two years.

The final rule also requires each agency to identify significant projects as early as possible and provide Traffic Management Plans (TMP) with strategies in accordance with the complexity of the project. The Plans, Specifications and Estimate are required to include pay items for the TMP.

Additional information on the Final Rule on Work Zone Safety and Mobility is available at: http://www.ops.fhwa.dot.gov/wz/resources/final_rule.htm.

Classification of Projects

Significant Project

A significant project is one that, alone or in combination with other concurrent projects nearby is anticipated to cause sustained work zone impacts that are greater than what is considered tolerable based on this policy and/or engineering judgment. Work zone impacts refer to work zone-induced deviations from the normal range of transportation system safety and mobility. The extent of the work zone impacts may vary based on factors such as, functional classification, area type (urban, rural), traffic and travel characteristics, type of work being performed, time of day/night, and complexity of the project. These impacts may extend beyond the physical location of the work zone itself, and may occur on the roadway on which the work is being performed, as well as on other highway corridors and other modes of transportation.

The WVDOH shall identify upcoming projects that are expected to be significant. A significant project shall be identified at the Project Programming stage and re-evaluated periodically throughout to the project development and delivery process. For full oversight projects, the determination of significance should be made in cooperation with the FHWA. The State's work zone policy provisions, the project's characteristics, and the magnitude and extent of the anticipated work zone impacts should be considered when determining whether a project is significant or not.

All Interstate or Expressway projects that have an ADT greater than or equal to 25,000 or projects on other state highway routes that have an ADT greater than or equal to 15,000 and that occupy a location for more than three days with either intermittent or continuous lane closures will be considered significant. Exceptions for NHS significant projects may be granted from the FHWA. Exceptions on non-NHS significant projects may be granted from the State Highway Engineer ~~Applicable Chief Engineer~~. Exceptions to these criteria will be granted based on ability to show that the specific project does not have sustained work zone impacts.

Project Levels

Depending on the complexity of the project, it will be assigned a classification of transportation management plan Level I, II or III, which determines the TMP requirements for the project. Any project identified as a significant project is a Level III project. Level II projects are those with a moderate level of construction activity with the primary traffic impact limited to the roadway containing the work zone. Level I projects are those with low complexity and may include simple construction projects, maintenance or utility work. Further information on these levels and the TMP requirements and recommendations associated with each is provided under "Plan Requirements" section of this policy.

Transportation Management Plans and Work Zone Management Strategies

The *Transportation Management Plan (TMP*) provides strategies to manage the work zone impacts of a project. At a minimum, the TMP includes a Temporary Traffic Control Plan (TTC). A Public Information (PI) component and a Transportation Operations (TO) component may also be included depending on the anticipated impacts. The overall success of a TMP must first be initiated early in the design process and developed throughout the design and delivery of the project.

The *Temporary Traffic Control plan (TTC)* describes Temporary Traffic Control measures to be used for facilitating the road user's passage through a work zone or an incident area. The TTC plan should be consistent with WVDOH policies, guidelines, and standards as described in this policy and in the "Manual on Temporary Traffic Control for Streets and Highways", 2006 Edition. TTC Strategies include:

- Control Strategies
- Traffic Control Devices
- Project Coordination, contracting and innovative construction strategies

The *Public Information (PI)* component of the TMP should include communication strategies that seek to inform all affected stakeholders about the project, the expected work zone impacts, and the changing conditions of the project. The scope of the PI component should be determined by the level of the project as set forth in this document. PI Strategies include:

- Public Awareness Strategies
- Motorist Information Strategies

The *Transportation Operations (TO)* component of the TMP should include the identification of strategies that will be used to mitigate impacts of the work zone on the operation and management of the transportation system within the impact area. TO Strategies include:

- Demand Management Strategies
- Corridor/Network Management Strategies
- Work Zone Management Strategies
- Traffic/Incident Management Strategies

Various work zone management strategies may be employed to minimize traffic delays, increase traveler and worker safety, and complete the work in a timely manner while maintaining access for businesses and residents. The strategies listed above are not meant to be all-inclusive, but to present a number of suggestions for consideration while developing TMPs. For a more extensive listing and general information on work zone management strategies refer to Appendix A of this directive.

The plans, specifications, and estimates shall include the TMP and appropriate individual pay items. Additional guidelines for development and implementation of TMPs can be found in the "TMP Guidelines" section of this policy.

Training

All WVDOH personnel will be trained in temporary traffic control design, deployment, operation, and maintenance consistent with the level of their responsibility. Individuals may gain this training through either division provided courses or outside sources. The Development, Construction, and Operations Divisions shall each work with the Training Section of Personnel to develop training programs for Central Office and District Staff in their organization. Guidelines for who should be trained and suggested courses are included in Appendix B of this directive.

Stakeholders and Public Information

Highway improvements and the work zones to implement them are intended for the benefit of the traveling public. WV DOH personnel will work with appropriate stakeholders at every stage of projects to develop work zone strategies and keep them informed. Detailed information on stakeholders is included in Appendix C of this directive.

In addition to the work zone specific Public Information activities, the WVDOH provides general work zone information to the public through various outlets. These include, among other things, publication of a statewide work zone map and work zone driving safety tips, posting of current work zone locations and conditions to the internet, promotion of Work Zone Safety Awareness Week, and advertisement of work zone related messages via radio, television, and billboards. Through these efforts, WVDOH positively promotes work zone safety and mobility, as motorists gain access to information they need to plan their trips and become more work zone conscious.

Transportation Management Plan Guidelines

This section provides guidelines for developing and implementing project TMPs. These guidelines shall also be in compliance with the most recent version of The West Virginia Division of Highways Design Directives (DD). These plans will enhance our accountability and ensure that all options have been considered during the project development process as described in DD-200. These guidelines are to be used by Project Managers, Roadway and Bridge Designers, Traffic Engineers, Planning and Research Engineers, Maintenance Engineers, and all

Districts within the Division of Highways responsible for acquiring the information to develop Transportation Management Plans. The FHWA Area Engineer shall be involved in each step of the project's review process on full federal oversight projects. These guidelines require the evaluation of work zone traffic control and communication strategies during the project development process and during all phases of construction. All Temporary Traffic Control Plans shall be in compliance with the information published in the "Manual on Temporary Traffic Control for Streets and Highways, Latest Edition." Any deviations from the Manual shall be approved by the Traffic Engineering Division and noted in the plans and project file.

Initial Engineering – Identify potential work zone impacts using field observations, review of available crash data, and other relevant operational information. Determine preliminary work zone management strategies in conjunction with alternative project options and design schemes. Identify other coordination issues such as utilities, enforcement, and community impacts.

Relevant operational information should include but is not limited to, project definition (scope, project level of complexity, roadway and traffic characteristics, and TMP category), construction phasing/staging of equipment and materials, as well as temporary traffic control, public communications and transportation operations strategies.

Acquire traffic and crash data, develop a preliminary public information plan, and explore possible alternate/detour routes. A preliminary cost estimate for the projects transportation management plan shall be developed during this phase of the Project Development in accordance with DD-200 and DD-202.

Preliminary Engineering – Assess impacts of various work zone management alternatives. Consider design, construction, contracting and transportation management options. Select appropriate strategies. Develop TMP, including appropriate items in plans, specifications, and estimates for the project.

Public Information Meeting – Review the Preliminary TMP as incorporated by the Roadway Designer (includes Temporary Traffic Control Plan, Public Information Plan, and Transportation Operations Plan, as required) in accordance with DD-201.

Pre-Bid Conference – Complete the significant projects final TMP for review in accordance with DD-104 and include in pre-bid conference discussion.

Construction – Inspect the work zone during the first week of each phase of construction (Project Engineer, District Traffic Engineer, and Contractor) to ensure the compliance with the TMP and monitor safety and operation. Consult appropriate stakeholders to evaluate strategy performance and keep them informed. Review the TMP as needed to improve the work zone performance.

Any required changes to the TMP to enhance the work zone's safety and mobility shall be approved by the Traffic Engineering Division. All such changes shall be documented and, if the project is a full federal oversight project, should be reviewed with an FHWA Area Engineer. An on-site review of the project's work zone traffic control by the Project Engineer, District Traffic Engineer, Contractor, and a representative from the Traffic Engineering Division's Safety, Planning, and Analysis Section shall be conducted within 48 hours of any fatal incident/crash within the work zone.

Report all fatal crashes that occur within the limits or that may be work zone related to the Traffic Safety, Planning & Analysis Section of the Traffic Engineering Division.

Transportation Management Plan Evaluation – For significant projects, a review of the effectiveness of the project's TMP shall be completed during a Post Construction meeting and included with the Post Construction Report. A copy of the specific information on the effectiveness of the TMP will be forwarded to the Central Office Traffic Engineering Division's Design and Operations Sections for review.

Roles and Responsibilities

The following guidance is provided to ensure that each member of the project development process understands their role and responsibilities in the development of the project's TMP. Individuals noted below shall have direct responsibilities for the proper development of the TMP during the Plan Development Process.

Engineering Division

Shall ensure the proper design and presentation of all aspects of the TMP by providing the following detailed information in the plan development:

- Profile, alignment, superelevation and lane widths for all traffic lanes, turning lanes, lane shifts and detour routes not identified on existing roadways
- Earthwork/grading that must be completed prior to the next construction phase
- Utility work that can be completed within the project's guidelines for the TMP
- Identify all temporary pavement locations and temporary drainage items
- Illustrate the placement of all temporary signs, messages boards, electric arrows, devices, barriers, attenuators, temporary pavement markings and markers in the temporary traffic control plans for all construction phases (excluding temporary lane and shoulder closings) for Traffic Engineering Division's information and review.
- Identify and note all signal timing within the work zone and all detour routes
- Complete TMP cross sections
- Complete special design details and insert sheets
- Movement and staging of equipment and materials
- Need and placement of temporary bridge parapet and traffic barriers
- Need for the setting of beams over traffic
- Use of temporary bridges
- Need for demolition over traffic
- All temporary/permanent easements needed for construction are included in the plans
- Ensure that all utilities will not conflict with temporary traffic control and other safety devices for all phases of construction.

Traffic Engineering Division

Shall ensure the safety of the construction workers and the safe movement of traffic through the project's work zone by providing the Project Manager with the following recommendations, and verifying that the applicable information is included in the project's TMP:

- Lane width(s)
- Number of recommended traffic lane and turning lanes
- Provide existing pavement markings
- On-site and off-site detour routes
- Identify and provide all signal phasing within the work zone and all detour routes
- Requirements on the use of barriers, devices, and attenuators, etc
- Type and placement of all signs, message boards, electric arrows, etc
- Type and location of pavement markings and markers for each phase
- Time of day, weekend, and holiday restrictions
- Access to all businesses and private dwellings
- Transportation operations recommendations • Perform assessment of the Work Zone Traffic Impact
- Perform annual work zone review.

Programming Division

- Program project funding from Federal and State balances
- Coordinate schedules between adjacent or nearby projects to mitigate conflicts

Planning Division

- Collect and maintain traffic volume data as necessary for the project area
- Using information provided by the project manager, identify and report significant project
- Review appropriate PS&E items for level of anticipated TMP in projects.

Operations Division

- Monitor maintenance operations with ongoing projects and be compliant with the WVDOH Permitted Lane Closure Map to ensure statewide uniformity
- Coordinate district level maintenance projects with ongoing projects • Provide assistance to field maintenance organizations during emergencies.
- Ensure that appropriate staff are trained at the project level who has the primary responsibility, with sufficient authority, for implementing the TMP and other safety and mobility aspects of the project.

Office of Communications

Ensure that the transportation management plan is communicated to appropriate key stakeholders (motorists, police, businesses, schools, emergency service providers, residents, elected officials and media). Strategies will include:

- Developing a project-specific communications plan to keep key stakeholders informed about construction-related impacts before and during construction
- Communicating and promoting ways that users can avoid construction-related delays
- Developing an emergency communications plan which outlines steps to be taken during a major incident and includes emergency contact information
- Determine the need and types of community meetings needed to inform the public on the various aspects of the construction project
- Continuously update the WVDOH “projects under construction” webpage to alert motorists of such projects and available alternate routes.

District Engineers/Managers

Ensure the appropriate district staff shall implement the transportation management plan as set forth in this document. The key responsibilities include:

- Designate appropriate staff to review work zone traffic control during first week of each new phase of construction for all significant projects and identify areas of need for improvement
- Designate appropriate staff to monitor locations of projects and recommend change in TMP if needed due to proximity of projects
- Coordinate with other districts when lane closures or projects are affected by other lane closures or projects across district boundaries
- Ensure lane closures for all projects are in compliance with the Permitted Lane Closure Map

- Coordinate short-term maintenance activities with existing projects of a longer duration
- Designate appropriate staff to participate in work zone fatal crash accident reviews and gather any needed information from the accident in a timely fashion
- Ensure that appropriate staff are trained at the project level, and who has the primary responsibility, with sufficient authority, for implementing the TMP and other safety and mobility aspects of the project.

Contractor – Responsibilities of the contractor include:

- Designating a certified trained person at the project level who has the primary responsibility, with sufficient authority, for implementing the TMP and other safety and mobility aspects of the project
- Ensure that all contractor personnel are trained in traffic control to a level consistent with each of their responsibilities
- Advising the Project Engineer, as required, at least two working days before any work requiring a lane closure begins
- Working with the Project Engineer to ensure all lane closures are minimized
- Ensuring work zones are neat, orderly and effective for the safety of highway workers and motorists
- Minimizing delay and disruption experienced during construction
- Performing quality control of work zones to promote consistency and ensure compliance with contract documents, policies, and guidelines
- Recommend traffic control improvements to the Project Engineer to address field conditions pertaining to traffic flow, visibility, and worker and motorist safety.

Work Zone Fatal Crash Review -- A Fatal Crash Review Team may investigate all fatal traffic crashes that are work zone related. The team will be comprised of the following personnel: District Construction (or Maintenance) Engineer (or representative), Project (or Maintenance) Supervisor, Claims Investigator, District Safety Officer, District Traffic Engineer/Technician, and Traffic Engineering Division Representative. The team's responsibilities include to conduct a review of work zone, field documentation, any modifications made to the Traffic Control Plan, the crash report (if available), and develop any recommendations as appropriate.

Work Zone Review Team – The Work Zone Review Team will consist of representatives from Central Office, District, FHWA, and may consist of stakeholders. Responsibilities of the review team:

- Conduct annual reviews of work zone planning, design, implementation, management, and operation in multiple districts to ensure compliance with this policy
- Identify and document strengths and weaknesses observed during the review
- Communicate findings and recommendations to WVDOH management and personnel

Plan Requirements

This section provides guidance to Central Office and District Personnel for establishing a project's TMP requirements based on the project's level of complexity. These guidelines categorize a project into three types of transportation management. The project's level identifies the minimum TMP requirements and recommendations to be used by personnel responsible for the development and implementation for of a project. In general, the TMP shall consist of a temporary traffic control plan and as required, public information and a transportation operations plan. The specific project level requirements for plan content are listed below:

Level I

- Typical Projects: Minimum plan, Single Phase Construction, Maintenance projects, Utility and Work done under Permit
- Project Type: Simple Project – widening of pavement, adding turn lanes or entrances. Sequence consists of temporary lane closures and flagging operations with no shifting of traffic onto temporary pavement and with two-way traffic operation maintained at all times or at new construction locations with no existing traffic.
- Impact on Traffic: All lane closures and time restrictions will comply with the WVDOH Permitted Lane Closure Map
- Major Components:
- Temporary Traffic Control Plan – Major components will consist of General Notes, Typical Sections, and if needed, special details. (This information may be presented as in a narrative format with illustrations/sketches as necessary):
    - General Notes:
        - Identify the work zone location
        - Identify the length and width of the work zone
        - Identify the lanes affected by the project work
        - Note the hours the work zone will be active
        - Identify potential location(s), with the R/W, for construction equipment and material storage
        - Define the proposed traffic control by referencing the specific case(s) in the Manual on Temporary Traffic Control for Streets and Highways, Latest Edition
        - Note any entrances, intersections or pedestrian access points that will be affected by the work zone or by the traffic control devices
    - Typical Sections:
        - Illustrate lane configuration(s) in the work zone
    - Special Details:
        - Show schematically the placement of all traffic control devices
        - Place all traffic control devices and follow symbol conventions for identifying traffic control devices in accordance with the standards in the Manual on Temporary Traffic Control for Streets and Highways, Latest Edition, in the plans
        - Show all details, dimensions and explanatory notes required to execute the traffic control plan

- Public Information Plan – A public information plan is recommended for a roadway when the traffic volumes exceed the allowable ADT and the time of closure is established by the permitted lane closure maps. The public information plan shall provide the following information (this information may be presented in the project plans as part of the Temporary Traffic Control plan in a narrative format):
  - A process to notify the media, District Engineer and staff of scheduled work plans and traffic delays.
- Transportation Operations Plan – A Transportation Operations Plan is recommended when the work zone is greater than ½ mile in length and/or travel lane(s) are reduced. The transportation operations plan shall provide the following information (this information below is minimum requirements and should be presented in the project plans as part of the Temporary Traffic Control Plans in a narrative format):
  - A contact list of local emergency response agencies
  - A process to notify the District Engineer and staff, Traffic Engineering Division, and stakeholders of any incidents and expected traffic delays
  - Procedures to clear the incident and restore normal project traffic operations
  - Details of the process to review incidents for the purpose of modifying the Temporary Traffic Control Plan to reduce the frequency and severity of such incidents.
    - Submit a detour contingency plan, if approved by project manager/designer.

Level II

- Typical Projects: Moderate level of construction activity with the primary traffic impact limited to the roadway containing the work zone.
- Project Type: Moderately Complex Project – widening of pavement and bridges, additional thru lanes and pavement rehabilitation. Sequence consists of lane closures in one or both directions with shifting of traffic that may include temporary pavement or detours for the duration of the work.
- Impact on Traffic:
  - All lane closures and time restrictions will comply with the WVDOH Permitted Lane Closure Map.
- Major Components:
  - Temporary Traffic Control Plan – Major components shall consist of General Notes, Typical Sections, Detail Plans, and if needed, special details. Each component shall provide the following information per construction phase. This information shall be placed on a coordinated plan sheet. (This information may be presented as in a narrative format with illustrations/sketches as necessary):
    - Detail Plans which include all information listed under Level One Projects plus (this information shall be regarded as a minimum) :
      - Narrative describing the Sequence of Construction

- Type and location of all temporary signs for the work zone and all detour routes
- Type and location of all temporary pavement markings
- Type and location of all temporary pavement
- Type and location of all temporary barrier
- Type and location of all impact attenuator/end treatments
- A list of calendar dates for Holidays and any special event(s) within project time frame
- Identify potential location(s), with the R/W, for construction equipment and material storage
- Define the proposed temporary traffic control plan by referencing the specific case(s) in the Manual on Temporary Traffic Control for Streets and Highways, Latest Edition.
- Note any entrances, intersections or pedestrian access points that will be affected by the work zone or by the traffic control devices

▪ Typical Sections shall contain all the information listed for Level One Projects

▪ Special Details/Cross Sections/ Profiles shall contain all the information listed for Category One Projects.

o Public Information Plan – A public information plan is recommended for a roadway when the traffic volumes exceed the allowable ADT and the time of closure is established by the permitted lane closure maps. The public information plan shall provide the following information (this information may be presented in the project plans as part of the Temporary Traffic Control plan in a narrative format):

▪ All information listed under Level One Projects.

o Transportation Operations Plan – A Transportation Operations Plan is recommended when the work zone is greater than ½ mile in length and/or reduced travel lane(s). The transportation operations plan shall provide the following information (this information below is minimum requirements and should be presented in the project plans as part of the Temporary Traffic Control Plans in a narrative format):

▪ All information listed under Level One Projects.

Level III (Significant Projects)

These projects are anticipated to cause sustained work zone impacts greater than what is considered tolerable based on policy or engineering judgment. They should be identified early in the project development process in accordance to DD-200 and in cooperation with the FHWA.

- Typical Projects: Long duration construction or maintenance projects on Interstate and Expressway routes that have an ADT equal to or greater than 25,000 or on other state highway route that has an ADT equal to or greater than 15,000 that occupies a location for more than three days with either intermittent or continuous lane closures. Also, this includes Interstates, Expressways, or other state highway route that may have multi-phase construction, high accident rates, full closures, or multiple work zones (two or more) within two miles of each other.

- Project Type: Complex Project – Multi-phase construction that as a minimum may add additional through lanes, bridge rehabilitation, interchange construction or reconstruction, pavement rehabilitation, reconstruction, and widening on high volumes of traffic as described above. Sequence consists of lane closures in one or both directions with traffic shifting several times and that may include temporary pavement or detours for the duration of the work. Impact of work zone on stakeholders extends beyond the work zone and affects alternate and/or detour routes.
- Impact on Traffic:
  - An assessment of the work zone impact will be completed using Quewz 98, Quickzone 1.0, or and operational-level traffic analysis software simulation program such as CORSIM.
  - Lane closure analysis will be performed and/or approved by the Traffic Engineering Design/Operations Section(s) at the request of the Project Manager/ Project Designer.
  - All lane closures and time restrictions will comply with the WVDOH Permitted Lane Closure Map
- Major Components:
- Temporary Traffic Control Plan – Major components shall consist of General Notes, Typical Sections, Detail Plans, and if needed, special details. Each component shall provide the following information per construction phase. This information shall be placed on a coordinated plan sheet. (This information shall be presented as in a narrative format with illustrations/sketches):
  - Detail Plans which include all information listed under Level Two Projects plus (this information shall be regarded as a minimum) :
  - A list identifying the location of reduced lane width(s)
  - Typical Sections shall contain all the information listed under Level Two Projects
  - Special Details/Cross Sections/ Profiles shall contain all the information listed under Level Two Projects.

- Public Information Plan – A public information plan is required for a roadway when the traffic volumes exceed the allowable ADT and the time of closure is established by the permitted lane closure maps. The public information plan shall provide the following information (this information may be presented in the project plans as part of the Temporary Traffic Control plan in a narrative format):
  - All information listed under Level One Projects.

- Transportation Operations Plan – A Transportation Operations Plan is required when the work zone is greater than ½ mile in length and/or results in reduced travel lane(s). The transportation operations plan shall provide the following information (this information below is minimum requirements and should be presented in the project plans as part of the Temporary Traffic Control Plans in a narrative format):

- All information listed under Level One Projects.

Operational Analysis

QUEWZ – 98 Program

The Division of Highways uses the computer program QUEWZ to determine the queues and user costs that are associated with work zone lane c1osures. Based on the type of lane closures, traffic volumes, time schedules, etc., the program will provide the user with the expected queue length and estimated user costs. The designer may use this program to ensure the proposed traffic control plan is still cost effective. The program user should review the user's manual to determine how to use the program. This analysis will be performed by the Traffic Engineering Division's Design Section.

Inputs

The user must provide the following inputs into the program:

1. lane closure configurations,
2. the schedule of work activities (e.g., work activity hours, lane constriction hours), and
3. the traffic volumes approaching the freeway segment.

The program provides default values for:

1. cost update factor,
2. percentage of trucks,
3. speeds and volumes at various points on a speed-volume curve,
4. capacity of a lane in the work zone,
5. maximum acceptable delay to motorist, and
6. critical length of queue.

To obtain meaningful results, the designer should consider revising the default values to meet the site location. For example, it should be noted that the program assumes that for queues longer than 20 minutes that some drivers will divert. To account for actual queues and the corresponding user costs, the designer may need to adjust the 20-minute time frame to meet the project situation. The designer should review the user's manual to determine if the default values are applicable to the location under consideration.

Outputs

QUEWZ has two output options - road user cost and lane closure schedule. The road user cost output option analyzes a specified lane closure configuration and schedule of work activities and provides estimates of traffic volumes, capacities, speeds, queue lengths, diverted traffic and additional road user costs for each hour affected by the lane closure. The lane closure schedule option summarizes the hours of the day when a given number of lanes can be closed without causing excessive queuing.

In addition to the values obtained from the program, supplemental user cost calculations may be required where changes are expected based on existing traffic patterns and volumes. Supplemental calculations for detours are typically required where an exit or entrance ramp within the construction zone (including those using crossovers) will be closed and where the designer judges that the QUEWZ program is not properly estimating the full amount of diverting mainline traffic.

Experience has shown that additional detour user cost calculations should be conducted for the following:

1. Where exit ramps are closed. Experience has shown that most or all of this traffic will divert from the mainline before the construction zone. Therefore, the exit ramp volumes should be deleted from the input mainline volumes before using QUEWZ and appropriate detour calculations performed.
2. Closed entrance ramps may or may not lead to changes in the input values for QUEWZ. Additional detour calculations will be required for any expected diversions.

Temporary Traffic Control Devices Final Rule

Background

The Federal Highway Administration (FHWA) published the Final Rule on Temporary Traffic Control Devices, 23 CFR 630 Subpart K in December 2007. This rule applies to State and local governments that receive Federal-aid highway funding. All transportation agencies are required to comply with the provisions of the Rule. This rule supplements the Work Zone Safety and Mobility Final Rule – Subpart J and applies to all Federal Aid highway projects to include highway construction, maintenance, and utility projects.

Requirements

- Use of positive protection devices to prevent intrusions.
- Exposure control measures to avoid or minimize exposure of workers and road users.
- A Uniformed Law Enforcement policy.
- Guidance for the safe entry and exit of work vehicles and equipment.
- Guidance for payment for traffic control features and operations
- Guidance to help maintain the quality and adequacy of the temporary traffic control devices for the duration of a project.

For additional information on the Final Rule on Temporary Traffic Control Devices – Subpart K, follow this link: http://ops.fhwa.dot.gov/wz/resources/policy.htm

The WVDOT is extending this requirement to all highway projects, regardless of the funding source.

These guidelines should be applied to all projects; with the exception to work related to emergency repairs.

Positive Separation Devices

As part of the development of a Traffic Control Plan (TCP), the need for and usefulness of temporary traffic barrier protection should be evaluated throughout the project development process. In general, temporary traffic control barriers should only be installed if it is determined that the barrier offers the least hazard potential.

Installations and determination of Temporary Traffic Barriers are described per sections F.81 and F.82 and Figures 10 (Detail C) and 11 (Detail D) from the *West Virginia Division of Highways Temporary Traffic Control Manual – latest edition* and as described in Design Directive 685. These items can be found by the following links: https://transportation.wv.gov/highways/traffic/Documents/TemporaryTrafficControlManual2006.pdf~~http://www.transportation.wv.gov/highways/engineering/Manuals/Traffic/TCM_06L.pdf~~
https://webapps.transportation.wv.gov/TWS/Engineering/2014DDManualMasterrev20250402.pdf~~http://www.transportation.wv.gov/highways/engineering/DD/2006%20DD%20Manual%20MAS TER%2006112013.pdf~~

In addition to the above, the following should be performed during design of the TCP:

Preliminary Plan: Frequently during preliminary design, the TCP has not been developed to the point where an adequate assessment of the use of temporary traffic barrier can be made; however, available data should be used to make an initial determination regarding whether temporary traffic barrier is warranted and whether exposure control measures should be considered.

Final Plan: During detailed design, as the TCP is developed further, an evaluation shall be performed to determine whether temporary traffic barrier is required and the most appropriate application of barrier (e.g., standard concrete traffic barrier, moveable concrete barrier, etc.). Factors to be considered in the evaluation include, but are not limited to, the following:

- Project scope and duration
- Anticipated travel speeds through work zone
- Traffic volumes
- Time of day (e.g., night work)
- Vehicle mix
- Pedestrian/bicycle exposure
- Type of work (as related to worker exposure and crash risks)
- Impacts on project cost and duration
- Distance between traffic and workers and the extent of worker exposure
- Escape paths available for workers to avoid a vehicle intrusion into the work space
- Work area restrictions (including impact on worker exposure)
- Consequences from/to road users resulting from roadway departure (e.g., severity of hazard, obstacle, or drop-off/slope)
- Potential hazard to workers and road users presented by device itself and during device placement and removal (e.g., clear zone, barrier end protection, barrier deflection distance)
- Geometrics that may increase crash risks (e.g., poor sight distance, sharp curves)
- Access to/from work space

Exposure Control Measures

The appropriate measures should be taken to limit the exposure of a worker to motorized traffic and exposure of motorists to work zone activities, while also providing adequate consideration to the potential impacts on mobility. A wide range of Temporary Traffic Control Strategies that may be appropriate for a individual project basis to limit these exposures can be found listed in the Appendices of this Design Directive.

Law Enforcement Implementation

The West Virginia Division of Highways has implemented a directive for the use of a Traffic Director as part of a highway project based the following criteria as described in Traffic Engineering Directive 604. This policy reads as follows:

A traffic director shall be a uniformed off-duty law enforcement official with a properly identified police vehicle that displays blue flashing lights. The intent of a traffic director is to enforce the posted speed limit and to increase safety for motorists and workers.

A traffic director shall be included within a traffic control plan when one or more of the conditions noted below exist in a work zone:

1. Nighttime paving operations, nighttime resurfacing operations, or nighttime pavement repair:
    a. On any Interstate or Expressway facility with an ADT greater than 25,000, or
    b. On any non-Expressway facility with an ADT greater than 15,000.
2. Pouring and curing of concrete, day or night, during the overlay of a bridge deck:
    a. On any Interstate or Expressway facility, or
    b. On any non-Expressway facility while maintaining two-way traffic with an ADT greater than 3,000, or
    c. On any one-way non-Expressway facility.
3. Removing or setting of bridge beams:
    a. Over any Interstate or Expressway facility, or
    b. Over any non-Expressway facility with an ADT greater than 10,000.
4. Installation or removal of full span or half span sign structures:
    a. On any Interstate or Expressway facility, or
    b. On any multilane Non-Expressway facility.
    c. A Traffic Director may be used under other circumstances, as approved by the Traffic Engineering Division.

https://transportation.wv.gov/highways/traffic/Pages/TrafficEngineeringDirectives.aspx~~http://www.transportation.wv.gov/highways/traffic/Pages/TrafficEngineeringDirectives.aspx~~

Guidance for the Safe Entry and Exit of Work Vehicles and Equipment

The TTC plan should consider the need for a work area access plan. This is a constructability issue in which the designer addresses the question of how the contractor is to get materials and equipment into the work area safely. This is a particularly critical issue on high speed facilities (such as the Interstate) where barrier wall is used to protect median work areas. Some consideration may be given to the design and construction of temporary acceleration and deceleration lanes for the construction equipment. The following should be considered in the design, planning and operation of work zones.

1. Anticipate types of work zones likely to create ingress/egress problems. Examples are median work spaces requiring work vehicles to merge into/out of high-speed traffic and work activities that will generate frequent delivery of materials such as paving projects and the delivery of fill material.
2. Access into/out of the work space should be included in TCP. When operations require access and it is not addressed in the plan the project engineer must address the issue within the limits of their authority.
3. Adequate acceleration/deceleration space for work vehicles should be provided.
4. The location of access openings should provide good sight distance for oncoming traffic.
5. In extreme conditions lane closures may need to be considered.
6. Openings in barrier walls should be planned to ensure that ends are properly protected and that the walls do not create sight problems.
7. Ingress/egress condition may justify lowering the speed limit.
8. Warning signs (W21-10) are available for ingress/egress conditions and should be used when appropriate. Special warning signs may be necessary.
9. The use of Changeable Message Signs and/or Traffic Directors should be considered.
10. Vehicles entering/leaving a work space should use flashing amber lights for improved visibility by oncoming traffic.
11. Drivers and operators should be trained on safe operation and must be supervised and corrections made when unsafe actions occur.

Guidance for Payment for Traffic Control Features, Operations, and Guidelines for Maintaining the Quality of Temporary Traffic Control Devices

The guidance for the payment of operations and maintenance of the traffic control devices implemented for the use on a West Virginia highway construction project is listed under Section 636 of the latest adopted edition of *The West Virginia Division of Highways Standard Specifications for Roads and Bridges,*, as amended by the latest adopted issue of the *West Virginia Division of Highways Supplemental Specifications*.

The guidelines set forth to maintain the quality and adequacy of temporary traffic control devices for the duration of a project will follow the latest adopted edition of *The West Virginia Division of Highways Standard Specifications for Roads and Bridges* as amended by the latest adopted issue of the *West Virginia Division of Highways Supplemental Specifications*, and supplemented with the latest edition of the *Quality Guidelines for Temporary Traffic Control Devices* issued by the American Traffic Safety Services Association (ATTSA). The application of the Standard Specifications and Quality Guidelines will help field personnel to evaluate the condition of devices and assure continued effectiveness.

References

1. The West Virginia Department of Transportation, Division of Highways, *Standard Specifications, Roads and Bridges, as amended by the supplemental specifications*.

2. The West Virginia Department of Transportation, Division of Highways, Engineering Division, *Design Directives*.

3. The West Virginia Department of Transportation, Division of Highways, Traffic Engineering Division, *Manual on Temporary Traffic Control for Streets and Highways, Latest Edition*.

4. The West Virginia Department of Transportation, Division of Highways, Traffic Engineering Division, *Traffic Engineering Directives.*

5. FHWA Final Rule Website
http://www.ops.fhwa.dot.gov/wz/resources/final_rule.htm

6. 23 CFR Section 630 (Final Rule Language)
http://www.ops.fhwa.dot.gov/wz/docs/wz_final_rule.pdf

7. FHWA Work Zone Mobility and Safety Web Site
http://www.fhwa.dot.gov/workzones

8. FHWA Safety Web Site http://www.safety.fhwa.dot.gov

9. WVDOH Permitted Lane Closure Map
http://www.transportation.wv.gov/highways/traffic/Documents/permitted-lane-closure.pdf

Appendix A

** - The strategies listed below are a minimum requirement for a TMP

Work Zone Management Strategies Temporary Traffic Control (TTC)		
Control Strategies	**Traffic Control Devices**	**Project Coordination, Contracting, and Innovative Construction Strategies**
• Construction phasing/staging • Full roadway closures • Lane shifts or closures Reduced lane widths to maintain number of lanes Lane closures to provide worker safety Reduced shoulder width to maintain number of lanes Shoulder closures to provide worker safety Lane shift to shoulder/median to maintain number of lanes • One-lane, two-way operation • Two-way traffic on one side of divided facility	• Temporary signs Warning Regulatory Guide/ information • Changeable message signs (CMS) • Arrow panels • Channelizing devices • Temporary pavement markings • Flaggers and uniformed traffic control officers • Temporary traffic signals • Temporary Lighting • Warning Lights	• Project coordination Coordination with other projects Utilities coordination Right-of-way coordination Coordination with other transportation infrastructure • Contracting strategies Design-build A+B bidding Incentive/disincentive clauses Lane rental • Innovative construction techniques (precast members, rapid cure materials)

• Reversible lanes • Ramp closures/relocation • Night work • Weekend work • Work hour restrictions for peak travel • Pedestrian/bicycle access improvements • Business access improvements • Off-site detours/use of alternate routes		

Work Zone Management Strategies Public Information (PI)	
Public Awareness Strategies	**Motorist Information Strategies**
Press releases/media alerts Planned lane closure web site Project web site Public meetings/hearings Community task forces Coordination with media/schools/businesses/ emergency services Work zone safety highway signs	Changeable message signs (CMS) Temporary motorist information signs Dynamic speed message sign Freight travel information Transportation Management Center (TMC)

Work Zone Management Strategies - Transportation Operations (TO)			
Demand Management Strategies	**Corridor/Network Management Strategies**	**Work Zone Safety Management Strategies**	**Traffic/Incident Management and Enforcement Strategies**
Shuttle services	Signal timing/coordination improvements	Speed limit reduction/variable speed limits	ITS for traffic monitoring/management
Ridesharing/carpooling	Temporary traffic signals	Temporary traffic signals	Transportation Management Center (TMC)
Park-and-ride promotion	Street/intersection improvements	Temporary traffic barrier	Surveillance (ClosedCircuit Television (CCTV)
Variable work hours	Turn restrictions	Movable traffic barrier systems	Mile-post markers
	Parking restrictions	Crash-cushions	Tow/freeway service patrol
	Truck/heavy vehicle restrictions	Temporary rumble strips	Total station units
	Reversible lanes	Warning lights	Photogrammetry
	Ramp closures	Automated Flagger Assistance Devices (AFADs)	Coordination with media
	Railroad crossings controls	Project task force/committee	Local detour routes
	Coordination with adjacent construction site(s)	Construction safety supervisors/inspectors	Incident/emergency response plan
		Road safety audits	Dedicated (paid) police enforcement
		TMP monitor/inspection team	Cooperative police enforcement
		Safety awards/ incentives	Increased penalties for work zone violations
		Windshield surveys	

Appendix B

Stakeholders. Stakeholders are individuals, groups and organizations who have a "stake" in a particular highway improvement project. They may be immediately affected by the project because they must travel through the construction work zone. They may be more indirectly involved because of their position in the community or their job responsibilities are affected.

The traveling public is of course the important stakeholder. Motorists are most affected by highway improvement. They enjoy the new highway or the resurfaced highway once the project is completed and they are the ones inconvenienced when caught in the construction zone. They are by far, the largest and most important group a highway improvement project communication plan needs to target.

Major businesses in and around a project work zone are traffic generators. Employees going to and from work may travel through the zone daily. Deliveries to the businesses can create slower moving truck traffic and the timely arrival of some deliveries can be critical to some operations. Informing the businesses before construction starts not only builds good will, but enables them to inform employees and adjust delivery and transport schedules.

Other businesses located in the immediate area of a construction project may not be major employers, but may be traffic generators. The proprietors may be concerned about the construction project interfering or limiting customer access and the resulting loss of business. Being in the communication loop will reassure them and allow them to let their customers and employees know what to expect.

There are other stakeholders or stakeholder groups who may not be directly affected by highway improvement, but who should be considered when doing the construction project's communication plan. The stakeholders may not be located near the work zone. They may not be traffic generators. As individuals, they may not even travel through the work zone or in anyway be inconvenienced. However, because of their position, they need to be informed. It may be as simple as sending them copies of news releases or composing a letter.

Local government officials, such as mayors, city managers, city council members, and county commissioners need to be informed in order to deflect complaints and feel part of the project.

Emergency services and law enforcement agencies have a 'need to know" about highway improvement in their service areas. Often it is a matter of sending news releases to law enforcement headquarters and emergency 911 operations centers.

Legislators at both the state and federal level often have an interest in highway projects in their respective districts. In some cases they have been involved with project funding or they have helped promote the need for projects. State legislators, using the legislative process, develop the state's transportation budget. At the national level, members of congress help decide funding and national transportation policy. An informed legislator is much more likely to answer a constituent's complaint about highway improvement in a positive tone.

Utility companies are another stakeholder that is often contacted during the design process if necessary. But keeping appropriate utility company personnel up to date on the highway improvement project will help promote the image for all parties.

Keep in mind that construction may create some special needs to contact specific individuals or organizations. The **postmaster** may need to reroute mail delivery due to a road closure or inability to access rural mail boxes. **Convention and visitor's bureaus** should have construction information to pass on to meeting planners. **Promoters and managers of special events** (local festivals, street fairs, county fairs, etc.), **entertainment venues and amusement parks** need to understand that construction could affect customer access. Look for opportunities to share construction information with **travel clubs**, such as the American Automobile Association.

Developing an all-inclusive list of stakeholders who have a need to know about any given highway improvement project is dependent on the type of construction, the extent of construction, the length of the construction zone and how long the construction is expected to take. When planning communication for a construction project, consider the construction zone's geography, business and residential environment in order to begin the development of a specific list of stakeholders who need information on the construction project. Remember, an informed group of stakeholders not only builds good will and lessens the complaints, but the stakeholders in turn become communicators to their constituents. Well planned and targeted communication will ensure a positive message is forwarded.

Appendix C

Proposed Work Zone Training Requirements				
Staff	**Number of Individuals**	**Course**	**Time**	**Required**
Design	150	NHI	3 days	Every 5 years
Construction	200	ATSSA	1 -1.5 days	Every 5 years
Maintenance	100	LTAP/T2	1 day	Every 5 years
Programming Planning	15	Peer to Peer	1 day	Every 5 years

Design staff shall be from Traffic Engineering Division, Engineering Division, District Design, District Traffic.

Construction staff shall be from Central Office and District level Construction Engineers, Construction Supervisors, Construction Inspectors, and Utilities Supervisors and Inspectors.

Maintenance staff shall be from Central Office and District level Maintenance Engineers, Maintenance Assistants from the County and Expressway Headquarters.

Programming Division and Planning Division staff shall be from the Central Office.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 811
ACCESSIBILITY STANDARDS, CURB RAMPS AND SIDEWALKS
January 3, 2024
Supersedes November 1, 2023

This Design Directive defines the West Virginia Department of Transportation, Division of Highways' policy concerning curbs and sidewalks, and further compliance with the Americans with Disabilities Act of 1990 (ADA) and the U.S. Department of Justice (DOJ) 2010 ADA Standards. Other references will be given to assist the Designer/Project Manager during the assessment of a project for ADA requirements, as well as details and criteria that are to be used when ADA requirements must be met.

Attached to and made a part of this Design Directive is an ADA Exceptions Justification Form. See Section 50 of this DD for more information.

The policies described herein will apply to all projects, whether designed at the District level, in the Central Office, or the Special Projects Section.

10. General

In compliance with the Americans with Disabilities Act of 1990 and the U.S. Department of Justice 2010 ADA Standards for Accessible Design, curb ramps as per DOH Standard Details shall be provided at all existing marked and unmarked crosswalks for which the Division of Highways has responsibility. Existing ADA features that are within the limits and scope of work of the project are to be checked for conformity with the DOJ 2010 ADA Standards for Accessible Design and are to be reconstructed if they do not comply. All curb ramps are to have Detectable Warnings installed. In addition, the existing condition of a sidewalk will not affect the decision of whether to add a curb ramp or not.

The following information is to be used to determine, for ADA applicability purposes, whether a project is considered a "Maintenance Project" under which curb ramps are NOT required to be incorporated into the project, or an "Alteration Project" under which curb ramps MUST be incorporated into the project. See the following web page for a more precise definition of some of the terms in the lists below: https://highways.dot.gov/civil-rights/programs/ada/glossary-terms-dojfhwa-joint-technical-assistance-ada-title-ii~~www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta_glossary.cfm~~.

A. Roadway Maintenance
   1. Crack filling and sealing
   2. Surface sealing
   3. Chip, Slurry, and Fog seals
   4. Scrub sealing
   5. Joint crack seals
   6. Joint repairs
   7. Dowel bar retrofit
   8. Spot high-friction treatment
   9. Diamond grinding

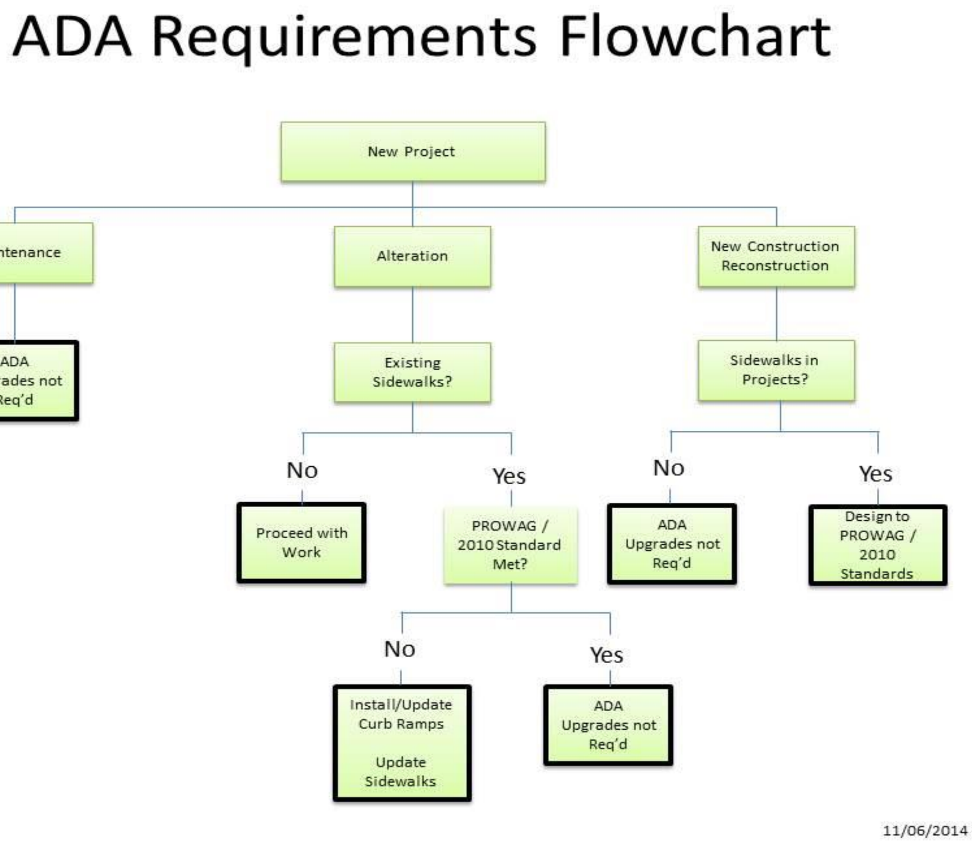
10. Pavement patching
11. Shoulder repairs
12. Pipe and inlet repairs
13. Pulling and restoration of ditches
14. Guardrail repair and installation
15. Re-striping

B. Roadway Alteration
1. Open-graded surface course
2. Cape seals
3. Mill and fill / Mill and overlay
4. Hot in-place recycling
5. Micro Surfacing / Thin-lift overlay
6. Addition of new layer of asphalt
7. Asphalt and concrete rehabilitation and reconstruction
8. New construction
9. Widening of the existing pavement typical section
10. Addition of turning lanes
11. Pavement rubblizing
12. Installation of new drainage structures to improve existing drainage characteristics

C. Bridge Maintenance
1. All painting of bridge members
2. Scour Countermeasure Activities
3. Expansion Joint Repairs and Replacement
4. Concrete Crack Repairs
5. Refurbishing or restoration of existing bridge bearings
6. Deck drainage system repairs
7. Seismic retrofit activities that do not include replacement of bearings or structural members

D. Bridge Alteration
1. Bridge deck overlay projects
2. Repairs to structural members for the purpose of restoring or enhancing structural capacity
3. Strength repairs to substructure elements
4. Bearing replacement
5. Bridge deck replacement
6. Superstructure replacement

Alteration projects administered by a municipality on WVDOH R/W, such as a streetscape, involve funds expended on a public right of way. The alteration requires the municipality and the WVDOH to meet full compliance with all federal laws and regulations during the development of plans and construction. As part of the development of plans for construction, where full design criteria for pedestrian access is not feasible, the designer (the municipality or their consultant) shall prepare an ADA Exception Justification Form, included in this DD, and submit with the plans for review and approval to the WVDOH. All exceptions approved by the Division shall be filed as required for all projects.



20. Existing Sidewalks

Projects considered an alteration by the Department of Justice (DOJ) as described in Section 10 of this DD will require all curb ramps within the project limits to meet the requirements of the Americans with Disabilities Act (ADA). This will also require installing curbs ramps where presently a curb ramp does not exist to make the sidewalk ADA accessible. Detectable warning systems will be required on all existing curb ramps that otherwise meet the ADA criteria. Existing sidewalks shall be evaluated for ADA Compliance using the DOJ 2010 ADA Standards for Accessible Design. These Standards are available at: www.ada.gov/regs2010/2010ADAStandards/2010ADAstandards.htm. The 2010 ADA Standards for Accessible Design consists of the U.S. DOJ TITLE 28 CFR Parts 35.151 from the Code of Federal Regulation combined with the 2004 ADA Accessibility Guidelines.

Within the project limits the evaluation of the sidewalks and any curb ramps which may exist within a project's limits is to be a field evaluation. An evaluation from remote sources such as Google Earth or the Division's pavement video records is not sufficient.

For sidewalks located outside of a municipality, the District/Division shall evaluate and fully document the entire sidewalk within the project limits for ADA Compliance. A cost estimate for the renovation and a copy of the ADA evaluation shall be forwarded for review to the District/Division ADA Coordinator. During project development, the District/Division shall consider incorporating side walk renovations into the project. If there is significant scope creep, the District/Division may request, through the District ADA Coordinator, that sidewalk renovations not be incorporated into the project, and be included in the WVDOH ADA Transition Plan. The ADA Coordinator shall obtain approval for this request from the State Highway Engineer ~~Deputy Commissioner of Highways~~. Regardless of when the sidewalks are renovated, curb ramp work to make the sidewalk ADA compliant must be incorporated into the alteration project, or completed prior to the alteration project.

For sidewalks located on the WVDOH Right of Way within a municipality where the municipality is responsible for the sidewalk maintenance, the District/Division ADA Coordinator shall contact the municipality to inform them that the existing sidewalks need to evaluated for ADA Compliance. Non-compliant sidewalks should be added to municipality's ADA Transition Plan. Regardless of sidewalk maintenance responsibility, curb ramp work must be incorporated into the project.

30. Curb Ramps on Resurfacing Projects in Urbanized Areas with Sidewalks

Alteration projects must include curb ramp installation if none previously existed where there is a pedestrian walkway with a prepared surface for pedestrian use within the scope of the project. Where a non-compliant curb exists within the pedestrian walkway, upgrading of the curb ramp to meet the Proposed Accessibility Guidelines for Pedestrian Facilities in the public Right-of-Way (PROWAG), dated July 26, 2011, is required.

When performing roadway activities at intersections and adjoining streets, the limits of resurfacing is to be the curb or gutter line of the street being altered.

The WVDOH recommends not paving to the end of the radius return on side street or alleys and impacting the existing curb ramps of the adjoining street. If flaring of the resurfacing project into an adjoining street is necessary, curb ramps shall be assessed for ADA compliance and addressed within the scope of the project.

Curb ramps are to be assessed for compliance with PROWAG, dated July 26, 2011, or constructed on resurfacing projects when:

A. Limits of the resurfacing project encroach into the boundary of the curb ramp detail;

B. Pedestrians may reasonably conclude that they would cross the resurfacing project from one curb ramp to another, even if the curb ramp is outside the limits of resurfacing;

C. Construction activities expand beyond the original limits and encroach into the curb ramp area; and

D. Curb ramps aren't present in sidewalks at signals, stop signs or yield signs (they must be constructed with the resurfacing project on each side of the pedestrian access route).

Additionally, when existing Type II (diagonal) curb ramps meet any of the above conditions, they must be assessed to determine if two separate ramps can be provided at the corner.

40. New Sidewalks and Replacement of Existing Sidewalks

The Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right of Way (PROWAG), dated July 26, 2011, should be considered as minimum criteria for the design of any new sidewalk or the replacement of an existing sidewalk. The complete PROWAG document is available at the following web address: https://www.access-board.gov/prowag/~~http://access-board.gov.~~ Certain sections will be referenced for the designer in Section 40 of this DD.

Currently, PROWAG is still in the rule making process and the 2010 ADA Standards for Accessible Design is being enforced by the Department of Justice. Therefore, new sidewalks shall also be checked for compliance with the 2010 ADA Standards for Accessible Design. If sidewalks do not meet the requirements of the 2010ADA Standards for Accessible Design an ADA Exception Justification Report (attached) shall be submitted to the District/Division ADA Coordinator for review and concurrence

50. Technical Guidance and References

2010 ADA Standards (Existing Sidewalks)

The 2010 ADA Standards are to be used to evaluate existing sidewalks for ADA compliance. If the existing sidewalk is to be replaced, The Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right of Way dated July 26, 2011 shall be used in the design of the new sidewalk.

A technical assistance "tool kit" which includes checklists and information on conducting assessments of existing facilities is available for use by Designers at the following web address: http://www.ada.gov/pcatoolkit/toolkitmain.htm. Chapter 6 of this resource provides the technical assistance, and Appendices 1 and 2 provide instructions and a survey form to use to analyze existing sidewalks.

A. In short, the above-mentioned checklist includes the following items (this listing is NOT all-inclusive).

B. Sidewalks shall be at least 3 ft. wide.

C. The cross slope shall not exceed 2%.

D. When sidewalks are less than 5 ft. in width, passing spaces with a minimum clear space of 5 ft. x 5 ft. shall be provided at intervals not to exceed 200'. Driveways, building entrances, and public sidewalk intersections may be used for passing spaces.

E. Where an obstacle (example: utility pole or fire hydrant) is considered immovable, a minimum 32" of sidewalk width (excluding curb width from measurement) must be provided for the pedestrian. Reduction of sidewalk width from 36" (3') due to an obstacle requires an ADA design exception. When developing sidewalk widths, the Roadside Design Guide (RDG) requirements of clear zone (RDG Section 3.1) and minimum lateral offset behind the curb (RDG Section 3.4.1) must also be considered.

F. Curb ramps shall not exceed a running slope of 1:12 (maximum 1:10 is permitted at existing sites where it is not feasible to provide the 1:12 requirement due to space limitations and the rise is less than 6 inches).

G. A level landing should be provided at the top of a perpendicular curb ramp.

H. The transition from curb ramp to gutter should be flush; lips are not permitted.

I. The foot of a curb ramp should be contained within the crosswalk markings.

J. Gratings such as tree well covers, valve boxes with vent holes, manhole covers, etc. in the path of travel may not have an opening with a dimension of greater than ½" in any direction. Drainage inlets or any other item with openings greater than ½" in any dimension shall be located out of the path of travel.

K. Drainage is to be provided upstream of the foot of the ramp to ensure flow depth is at a minimum.

The Designer is cautioned to fully review the requirements contained in the Guide and consult the Checklist for complete information.

Accessibility Guidelines for Pedestrian Facilities in the Public Right of Way (PROWAG) (New Designs)

These standards shall be used in the design of all new sidewalks and the replacement of any existing sidewalks:

A. The pedestrian access route shall have a minimum width of 4 ft. excluding the width of the curb.

B. A level landing shall be provided at the top of a perpendicular curb ramp. The landing at the top of the curb ramp shall be a minimum 4 ft. wide when no obstructions exist at the backside of the landing and a minimum 5 ft. wide when obstructions exist such as a building, pole etc.

C. All other requirements described for Existing Sidewalks above shall apply, noting that the list is NOT all-inclusive.

Additional guidance may be found at the following web site concerning Public Rights-of-Way Access from the United States Access Board (generally referring to facilities in public rights-of-way): https://www.access-board.gov/prowag/~~http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way~~. A manual entitled "Special Report: Accessible Public Rights-of-Way Planning and Design for Alterations", dated August 2007, is available for technical assistance to the Designer, generally providing guidance for alterations of existing facilities at https://www.access-board.gov/files/prowag/planning-and-design-for-alterations.pdf~~http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/guidance-and-research/accessible-public-rights-of-way-planning-and-design-for-alterations~~.

Technical guidance, including sample details, is available for the proposed DOJ rules at the address given heretofore in Section 20 of this Design Directive (the DOJ 2010 ADA Standards for Accessible Design (www.ada.gov/regs2010/2010ADAStandards/2010ADAstandards.htm.) Chapter 2 of this resource includes Scoping Requirements, while Chapter 4 "Accessible Routes", include requirements and sample details for sidewalks and curb cuts.

Where a sidewalk which is being constructed or reconstructed along a State highway is carried around a radius, and ended, the surface of the sidewalk will smoothly meet the existing ground or adjacent sidewalk where conditions permit. If the sidewalk being constructed or reconstructed extends through the crosswalk on the intersecting street, curb cuts or ramps shall be provided.

The Checklists found in Design Directive 202, *Field and Office Reviews for Initial Engineering, Preliminary Engineering and Final Design* include lines for the Designer/Consultant Project Manager to initial for compliance when submittals are made.

60. ADA Exception Justification Report

If a requirement of the DOJ 2010 ADA Standards is deemed technically infeasible, the reasons for the exception must be fully documented and approved. Some reasons why an ADA requirement cannot be implemented include historical considerations, limited right-of-way, or problems with geometry (both horizontal and vertical). It is up to the Designer to determine feasibility. If an ADA exception is granted for technically infeasibility, the Designer should make every effort to mitigate the requirement. Specifically, Sections 201, 202, and 206 of the adopted DOJ 2010 ADA Standards discuss scoping, structural impracticality and technical Section 406 discusses Curb Ramps.

Attached to and made a part of this Design Directive is an ADA Exceptions Justification Form which is to be completed by the Designer/Project Manager for all projects which have exceptions to any ADA requirements. A copy of the proposed ADA Exception Report with the recommended signatures shall be mailed to the EEO Division ADA Coordinator to be forwarded to the ADA Board for approval. The completed Form is to be included in the Final Office Review and PS&E submittals.

West Virginia Division of Highways
EEO Division ADA Coordinator
1900 Kanawha Boulevard, East
Building 5, Room 618
Charleston, West Virginia 25305-0430

The District/Division ADA Coordinator shall maintain a copy of all approved ADA Exception Justification Reports and Sidewalk Evaluations for future reference.

SHEET 1 OF _____

AMERICANS WITH DISABILITIES ACT EXCEPTIONS JUSTIFICATION REPORT

PROJECT DATA

State Project No. ______________________________ **Date:** ______________________

Federal Project No: ______________________________ **County:** ______________________

Project Name: ____

Project Description: ____

____

____

Special Project Sponsor Name and Address: ____

____

____

WVDOH Representative: ______________________________

FHWA Representative: ______________________________

(Note: Project Description in above table should be the complete scope of the project: i.e. major or minor construction, urban or rural, reconstruction, rehabilitation, pavement overlay, etc. using the descriptions given in DD-803 as a guide)

HIGHWAY ROUTE DATA

AASHTO Functional Classification

1. ☐ **Urban** ☐ **Rural**
2. ☐ **Arterial** ☐ **Collector** ☐ **Local Road**
3. ☐ **Freeway** ☐ **Divided/Arterial** ☐ **Two-Lane Arterial**
4. ☐ **Interstate**
5. ☐ **Other (i.e. school property)**

TERRAIN TYPE ☐ **Level** ☐ **Rolling** ☐ **Mountainous**

SHEET 2 OF _____

ADA REQUIREMENTS (Document Only Exceptions)

	ADA Requirements Triggered	Existing Condition	Design Criteria	Proposed Action	Criteria Source
1.	Sidewalk				
2.	Curb Ramps				
3.	Detectable Warnings				
4.	Accessible Signals				
5.	Accessible Parking				
6.	Van Accessible Spaces				
7.	Path of Travel				
8.	Bridge				
9.	Other				

(Note: references to the appropriate Section number of the 2010 ADA Standards for Accessible Design and proposed PROWAG Standards are to be used as the Design Criteria and the Criteria Source in the above table and in the Exception Report)

APPROVAL SIGNATURES

RECOMMENDED:

1. ______________________________
Consultant

2. ______________________________
Project Engineer

3. ______________________________
District/Division ADA Coordinator

APPROVED:

____
ADA Board Chairman

REVIEWED:

____
Federal Highway Administration

SHEET ____ OF _____

NARRATIVE DISCUSSION OF ADA EXCEPTION(S): Attach appropriate photos or other documentation as needed

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 813
BICYCLE/PEDESTRIAN ACCOMMODATION
September 6, 2023
Supersedes September 30, 2013

The goal of the West Virginia Division of Highways (WVDOH) is to plan, design, construct, maintain and operate a safe, efficient, and economical highway system for all users of the system. While motor vehicle traffic is the major concern in performing this task, bicyclists and pedestrians must also be given proper consideration.

In order to integrate the needs of the motorized and non-motorized users of our highway system, the WVDOH, in cooperation with the Federal Highway Administration (FHWA), adopted "The Statewide Plan for Accommodation of Bicycle Transportation and Pedestrian Walkways" dated September 1997. Based on this document it is the policy of the WVDOH that during the design of all highway construction projects, consideration will be given, as outlined herein, for the incorporation of facilities for the accommodation of bicyclists and pedestrians.

The designer's attention is directed to the following publication: "Guide For Development Of Bicycle Facilities 2012 (Fourth Edition)", AASHTO (hereinafter referred to as the 2012 AASHTO Bicycle Guide) or most current edition. Many of the definitions in this Design Directive are summarized from this resource, and it is the source of any design standards not described here in detail. It is to be used as a reference supplementing this Design Directive.

DEFINITIONS

Bicycle Facilities: A general term denoting improvements and provisions made by public agencies to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically defined for bicycle use. This includes new or improved lanes, paths, or shoulders for use by bicyclists as well as traffic control devices, shelters, and parking facilities for bicycles.

Bikeway: A generic term for any road, street, path, or way which in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes. **NOTE:** All public highways in West Virginia are open to bicycle traffic; however, on facilities such as Interstate Highways, bicycles are prohibited except in some very limited circumstances, such as when a fully controlled access highway is the only link between two separate bikeway segments.

Bicycle Boulevard: a local street or series of contiguous street segments that have been modified to function as a through street for bicyclists, while discouraging automobile through travel. Local access is maintained.

Bicycle Network: A system of bikeways designated by the jurisdiction having authority. This system may include bike lanes, bicycle routes, shared use paths, and other identifiable bicycle facilities.

Bicycle Lane: A portion of the roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane.

Bicycle Route: A roadway or bikeway designated by the jurisdiction having authority, either with a unique route designation or with Bike Route signs, along which bicycle guide signs may provide directional and distance information. Signs that provide directional, distance, and destination information for bicyclists do not necessarily establish a bicycle route.

Category I Roadways: Any highway facility that is a partially controlled access facility or any highway facility that contains four (4) or more travel lanes with design speeds greater than 40 mph.

Category II Roadways: Any non-controlled highway facility or street not defined as being a Category I Roadway.

Pedestrian Walkway Facilities: A general term denoting improvements and provisions made by public agencies to accommodate or encourage walking. This includes new or improved lanes, paths or sidewalks.

Combined Facilities: A combined facility, for the purpose of this directive, is a facility designated for use by bicyclists and pedestrians.
Rural Areas: All parts of the highway system NOT within an urban area as described in "Urbanized Areas" below.

Shared Lane: A lane of a traveled way that is open to both bicycle and motor vehicle travel.

Shared Use Path: A bikeway physically separated from motor vehicle traffic by an open space or barrier and either within the highway right of way or within an independent right of way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. Most shared use paths are designed for two way travel.

Trails: Facilities that may be used by, but not limited to, non-motorized vehicles, horseback riders, cross-country skiers, and pedestrians.

Urbanized Areas: All parts of the highway system within an urban area as shown on The West Virginia Urban Area maps maintained by the Planning Division. These maps are located on the Division's website at the following link: https://gis.transportation.wv.gov/ftp/Urban%20Area%20Maps/~~www.transportation.wv.gov/highways/programplanning/gti/GIS/MAPS/Pages/UrbanAreaMaps.aspx.~~

BICYCLES

During the environmental review and/or planning process, the WVDOH will assess the need and potential for the development of bicycle facilities as a part of the project. The criteria in the "Statewide Plan for Accommodation of Bicycle Transportation and Pedestrian Walkways", September 1997 will be considered. Reference is also made to the 2012 AASHTO Bicycle Guide or most current edition. It should be noted that the development of a bicycle facility may be combined with the development of a pedestrian walkway facility. The resulting combined facility would be designated for both bicycle and pedestrian use. The combined facility must meet the criteria for both bicycles and pedestrians while accounting for the required safe separation of these two transportation modes.

If it is determined that bicycle facilities are to be incorporated in the project, the environmental documents shall include recommendations as to the type of bicyclist(s), as well as the type of facility to be considered in the design process.

The designer shall use the following criteria when determining the need for bicycle facilities in new construction or reconstruction projects.

A. Urbanized Areas

- Bicycle facilities shall be established in all new construction or reconstruction projects that add a new highway or alter the functionality of an existing highway. Exceptions to this policy are described below.
- Bicycle facilities may not be required if one or more of the following conditions exist:
    - Bicycles are prohibited from using the roadway.
    - The cost of establishing a bikeway is greater than ten (10) percent of the estimated construction cost of the project.
    - Existing population conditions and other factors indicate an absence of need for bicycle facilities.
    - Development costs such as right-of-way, utility relocation, environmental mitigation, historical resource avoidance, and others may be considered when determining the need to establish a bicycle facility.

B. Rural Areas

- Designated bicycle facilities may be considered during the design phase of the project
- All new construction or reconstruction projects that add a new highway or alter the functionality of an existing highway, shall as a minimum, be designed as a Category II Roadway.
- The designer shall consider the continuity of bicycle facilities on highways where the classification of the highway changes from urban to rural in relatively short distances.

The final decision for inclusion of bicycle facilities in the project will be made during the design process utilizing the above criteria. If the designer proposes not to incorporate bicycle facilities in the proposed project, written approval must be obtained from theDeputy State Highway Engineer– Construction/Development or Operations, as applicable ~~Applicable Chief Engineer~~.

Bicycle facilities will be accommodated by one or more of the following methods:

- Designation of the project as a Bikeway or a Bicycle Route;
- Inclusion of a Bicycle Lane in the design of the project in urban areas; or

- Designation of or the inclusion of a Shared Use Path in the design of the project.

Sidewalks should not be designated for bicycle use. Bicyclists may be encouraged, with appropriate signing, to use short segments of sidewalks. One example of this would be a bridge structure that provides a safer environment to traverse the bridge. This would only be considered if the bridge sidewalk is wide enough to accommodate both pedestrians and bicyclists, in which case the criteria for a “Combined Facility” would be utilized (see the 2012 AASHTO Bicycle Guide or most current edition).

Design Bicyclist: To address the needs of bicyclists of various skill levels, the WVDOH shall use a classification of bicyclists. This system is a modification of the existing classification system used by AASHTO. This system is described as follows (taken from the 2012 AASHTO Bicycle Guide):

Experienced and Confident: This group includes bicyclists who are comfortable riding on most types of bicycle facilities, including roads without any special treatments for bicyclists. This group also includes utilitarian and recreational rider of many ages who are confident enough to ride on busy roads and navigate in traffic. Such bicyclists may deviate from the most direct route to travel in their preferred riding conditions. Experienced bicyclists may include commuters, long distance road bicyclists, racers, and those who participate in rides organized by bicycle clubs.

Most experienced riders are comfortable riding with vehicles on streets. Some prefer on-street bike lanes, paved shoulders, or shared use paths. They prefer a more direct route to their destination and avoid riding on sidewalks.

Casual and Less Confident: This group includes a majority of the population, and includes a wide range of people: (1) Those who ride frequently for multiple purposes; (2) those who enjoy bicycling occasionally but may only ride on paths or low-traffic and/or low-speed streets in favorable conditions; (3) those who ride for recreation, perhaps with children and; (4) those for whom the bicycle is a necessary mode of transportation.

Casual riders prefer shared use paths, bicycle boulevards, or bike lanes along low volume, low speed roads and streets. They may have difficulty gauging traffic and may be unfamiliar with the rules-of-the-road for bicyclists. They may use less direct routes to avoid heavy traffic volumes and are more likely to ride on sidewalks.

PEDESTRIANS

During the environmental review and/or planning process, the WVDOH will assess the need and potential for the development of pedestrian walkway facilities as a part of the project. The criteria in the "Statewide Plan for Accommodation of Bicycle Transportation and Pedestrian Walkways", September 1997 will be considered. Reference is also made to the following publication: “Guide for the Planning, Design, and Operation of Pedestrian Facilities, July 2004, AASHTO. It should be noted that the development of a pedestrian walkway facility may be combined with the development of a bicycle facility. The resulting combined facility would be designated for both pedestrian and bicycle use. The combined facility must meet the criteria for both bicycles and pedestrians while accounting for the required safe separation of these two transportation modes.

If it is determined that pedestrian walkway facilities should be considered, the environmental documents would include recommendations as to the type of facility to be constructed. Facilities to be considered are sidewalks, shoulders and/or separate paths.

Any pedestrian accommodation on a project must be in accordance with DD-811 (Curb Ramps and Sidewalks) and be in accordance with the additional design standards noted below.

The designer shall use the following criteria when determining the need for pedestrian walkway facilities in new construction projects.

A. Urbanized Areas

- Pedestrian walkway facilities shall be established in all new construction or reconstruction projects that add a new highway or alter the functionality of an existing highway. Exceptions to this policy are described below.
- Pedestrian walkway facilities may not be required if one or more of the following conditions exist:
    - Pedestrians are prohibited by law from using the roadway.
    - The cost of establishing a pedestrian walkway is greater than ten (10) percent of the estimated construction cost of the project.
    - Existing population conditions and other factors indicate an absence of need for pedestrian walkway facilities. Development costs such as right-of-way, utility relocation, environmental mitigation, historical resource avoidance, and others may be considered when determining the need to establish a pedestrian walkway facility.

B. Rural Areas

- Designated pedestrian walkway facilities may be considered during the design phase of the project.
- All new construction or reconstruction projects that add a new highway or alter the functionality of an existing highway, shall as a minimum, be designed as a Category II Roadway.
- The designer shall consider the continuity of pedestrian walkway facilities on highways where the classification of the highway changes from urban to rural in relatively short distances.

On bridge construction projects, a sidewalk shall be designed as a part of the bridge if sufficient pedestrian activity exists and there is not a suitable pedestrian crossing reasonably close to the bridge. In the case of bridge replacement projects, a sidewalk shall be designed as a part of the bridge if the existing structure had a sidewalk or if sufficient pedestrian activity exists and there is not a suitable pedestrian crossing reasonably close to the bridge.

DESIGN STANDARDS

The following design standards have been developed for bicycle and pedestrian accommodation. These lists are not considered to be all-inclusive. The designer should consult the 2012 AASHTO Bicycle Guide (or most current edition) for further guidance, especially for design guidance for Shared Use Paths. The "Proposed Accessibility Guidelines for Pedestrian

Facilities in the Public Right of Way" (PROWAG), dated July 26, 2011, should be considered as minimum criteria for the design of any new or the replacement of any existing pedestrian facility.

A. General (Applicable to Pedestrian and Bicycle)

- The designer is cautioned to review sight distances carefully due to extra height of barriers as a design exception could be necessary for the extra height where a normal height barrier would not have needed one.
- All paved shoulders to accommodate both pedestrians and bicycles
- All structures shall have a combination of railings, fences or barriers with a minimum height of 42" for pedestrians and bicycles. A 48" railing shall be considered for the following conditions:
  - Where bicycle speeds are likely to be high (such as on a downgrade)
  - Where a bicycle could impact a barrier at a 25 degree angle or greater (such as in a curve)
  - Where significant bicycle traffic is anticipated
  - Where a bicycle falling over the rail could be catastrophic, such as a high drop off or into traffic.
- Drainage grates for bicycle routes shall be of a bicycle safe design.
- Reference is made to DD-645, Rumble Strips, to bicycle mitigation methods for rumble strips.

B. Category I Roadways

- Bicycle accommodations are to be designed for one way operation
- Bicycles to be encouraged to utilize right shoulder (with signing)
- Bicycles to be encouraged to use exit and entrance ramps shoulders (with signing)
- Minimum 5'-0" width of right shoulder (non-structure)* without rumble strip
- Minimum 6'-0"width of right shoulder (bridge structure)* without rumble strip
- Bridge expansion joints must be bicycle safe on the right shoulder (no exposed finger dams)

***NOTE:** The values for shoulder width shown in DD-601 shall supersede the values shown above if the values in DD-601 are greater.

C. Category II Roadways

- Bicycle accommodations are to be designed for one way operation
- When the ADT is greater than 1000 vpd, shoulders may be paved if bicycle and/or pedestrian walkway facilities are to be considered
- When the ADT is less than 1000 vpd, paved shoulder widths of 2'-0" should be considered; however, paved shoulder widths of 4'-0" or greater are encouraged. For pedestrian facilities, in absence of paved shoulders, a stabilized shoulder of 2'-0" minimum or 4'-0" preferred widths should be encouraged.
- All structures shall have a minimum shoulder width similar to the approach roadway shoulder width, but does not have to exceed 5'-0"
- Bridge expansion joints for bicycle facilities
  - If shoulder is 5'-0" or greater, no exposed finger dams on the right

shoulder

- If shoulder is less than 5'-0", no exposed finger dams on full roadway

- On curbed sections of roadways on bicycle routes, width of right lane shall be 14'-0", including the gutter pan.
- Structures without sidewalk shall have minimum shoulder widths of 4'-0"
- Structures with sidewalks shall have 4' minimum sidewalk widths and right lane/shoulder combined width of 14'-0" (12'-0" lane/2'-0" shoulder)

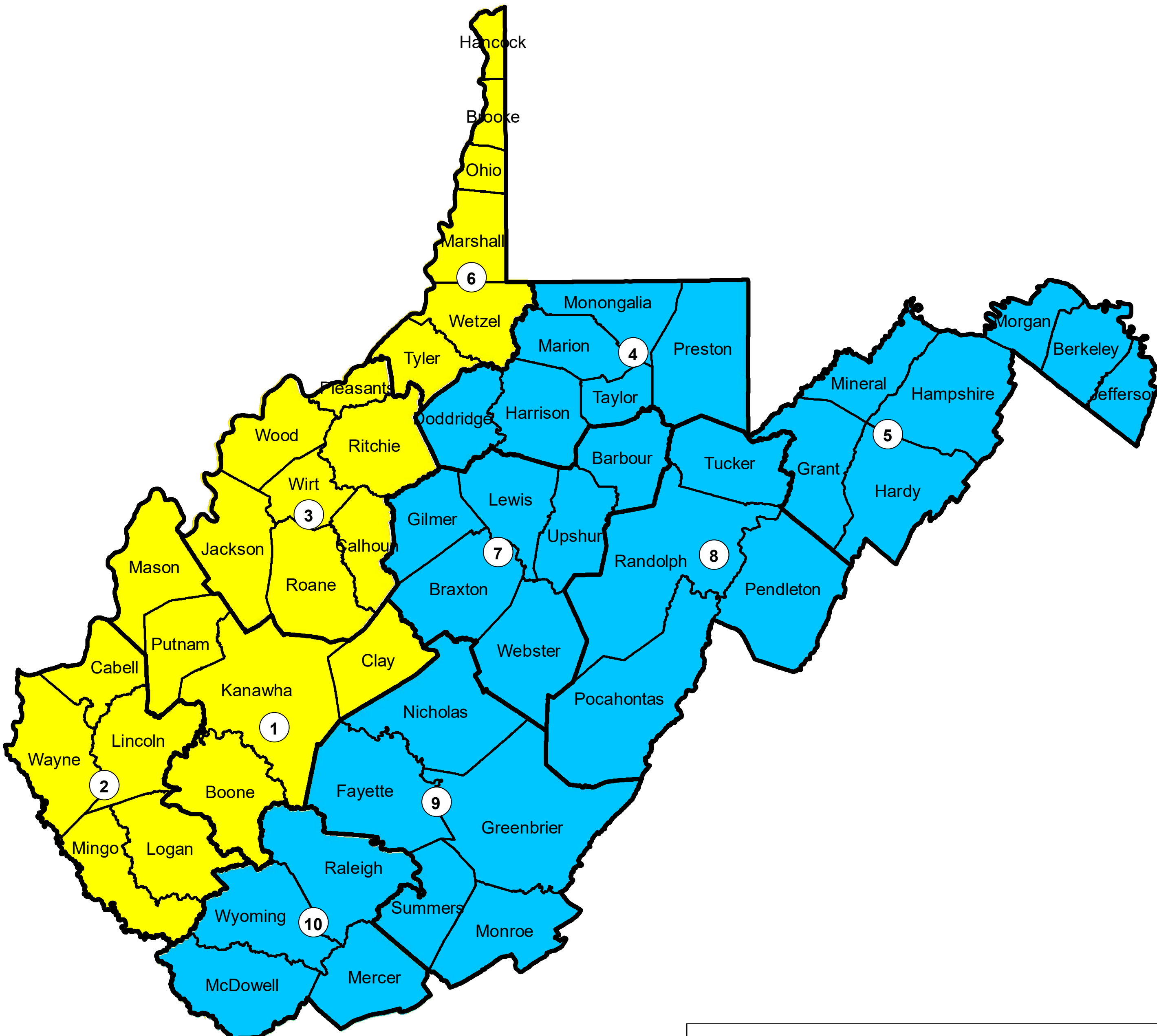
D. Shared Use Paths

- Designed for 2 way operation
- Minimum Travel Width - 10' with 2'-0" graded shoulders
- Reduced width of 8' in very rare circumstances or for short distances due to physical constraints.
- Structure railing/fence/barrier must be at least 5'-0" from the edge of shoulder of parallel roadway or separated by a combination of railings, fence or barrier with a height as described above.
- Superelevation 2% (no crown)

SECTION BREAK

NEW BUSINESS ITEMS

FHWA WV Division Area Engineer Assignments



A1 - Derrick Johnson
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(304) 347-5473

A2 - Hao Chen
Hao.Chen@dot.gov
(304) 347-5434

AREA ENGINEER ASSIGNMENTS 9/8/2025

COUNTY	CO. NO.	NAME	AREA	STATE DIST.
BARBOUR	1	HAO CHEN	A-2	7
BERKELEY	2	HAO CHEN	A-2	5
BOONE	3	DERRICK JOHNSON	A-1	1
BRAXTON	4	HAO CHEN	A-2	7
BROOKE	5	DERRICK JOHNSON	A-1	6
CABELL	6	DERRICK JOHNSON	A-1	2
CALHOUN	7	DERRICK JOHNSON	A-1	3
CLAY	8	DERRICK JOHNSON	A-1	1
DODDRIDGE	9	HAO CHEN	A-2	4
FAYETTE	10	HAO CHEN	A-2	9
GILMER	11	HAO CHEN	A-2	7
GRANT	12	HAO CHEN	A-2	5
GREENBRIER	13	HAO CHEN	A-2	9
HAMPSHIRE	14	HAO CHEN	A-2	5
HANCOCK	15	DERRICK JOHNSON	A-1	6
HARDY	16	HAO CHEN	A-2	5
HARRISON	17	HAO CHEN	A-2	4
JACKSON	18	DERRICK JOHNSON	A-1	3
JEFFERSON	19	HAO CHEN	A-2	5
KANAWHA	20	DERRICK JOHNSON	A-1	1
LEWIS	21	HAO CHEN	A-2	7
LINCOLN	22	DERRICK JOHNSON	A-1	2
LOGAN	23	DERRICK JOHNSON	A-1	2
MCDOWELL	24	HAO CHEN	A-2	10
MARION	25	HAO CHEN	A-2	4
MARSHALL	26	DERRICK JOHNSON	A-1	6
MASON	27	DERRICK JOHNSON	A-1	1
MERCER	28	HAO CHEN	A-2	10
MINERAL	29	HAO CHEN	A-2	5
MINGO	30	DERRICK JOHNSON	A-1	2
MONONGALIA	31	HAO CHEN	A-2	4
MONROE	32	HAO CHEN	A-2	9
MORGAN	33	HAO CHEN	A-2	5
NICHOLAS	34	HAO CHEN	A-2	9
OHIO	35	DERRICK JOHNSON	A-1	6
PENDLETON	36	HAO CHEN	A-2	8
PLEASANTS	37	DERRICK JOHNSON	A-1	3
POCAHONTAS	38	HAO CHEN	A-2	8
PRESTON	39	HAO CHEN	A-2	4
PUTNAM	40	DERRICK JOHNSON	A-1	1
RALEIGH	41	HAO CHEN	A-2	10
RANDOLPH	42	HAO CHEN	A-2	8
RITCHIE	43	DERRICK JOHNSON	A-1	3
ROANE	44	DERRICK JOHNSON	A-1	3
SUMMERS	45	HAO CHEN	A-2	9
TAYLOR	46	HAO CHEN	A-2	4
TUCKER	47	HAO CHEN	A-2	8
TYLER	48	DERRICK JOHNSON	A-1	6
UPSHUR	49	HAO CHEN	A-2	7
WAYNE	50	DERRICK JOHNSON	A-1	2
WEBSTER	51	HAO CHEN	A-2	7
WETZEL	52	DERRICK JOHNSON	A-1	6
WIRT	53	DERRICK JOHNSON	A-1	3
WOOD	54	DERRICK JOHNSON	A-1	3
WYOMING	55	HAO CHEN	A-2	10

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WVDOH Manuals Committee Meeting
Wednesday, October 1, 2025
Meeting Location: 1900 Kanawha Blvd. E., Building 5, Room 820, Charleston, WV

Also meeting virtually via Google Meet. Email distribution includes instruction.

Old Business:

ITEM	Champion
2nd time to Committee. Discussed in: August, October ***Drainage Manual – Chapter 8: Culverts*** ○ This is an update to Chapter 8 Culverts. The revision adds clarification to several subsections and makes grammatical and format changes throughout the chapter.	D. Holmes

New Business:

NONE

Next Meeting: The next meeting is on:

- **Wednesday, December 3,, 2025.**
- Deadline for submissions November 3, 2025.

Adjournment:

Chapter 8 Culverts

West Virginia
Department of Transportation
Division of Highways
Drainage Manual

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CHAPTER 8 CULVERTS

8.1 INTRODUCTION

Culverts are defined as hydraulic structures designed to convey surface water runoff under a highway embankment. This chapter outlines the policies, criteria, and guidelines for the hydraulic design of highway culverts. The information presented should enable the designer to select, plan, and design conventional highway culverts. This chapter does not cover all aspects of culvert design. The reference list at the end includes publications by the FHWA that should be consulted for additional information regarding specialized aspects of culvert design. Hydraulic Design Series 5 (HDS-5) is the primary FHWA reference for culvert design.

8.2 GENERAL DESIGN POLICY

The designer shall use the following general policies as a guide to select, plan, and design culverts placed beneath highways:

- Culverts shall be hydraulically designed.
- Culverts located in floodplains mapped by the Federal Emergency Management Agency shall satisfy the requirements of the National Flood Insurance Program.
- Culverts shall be designed to consider construction and maintenance costs, risk of failure, risk of property damage, traffic safety, and environmental considerations.
- Culverts shall be designed to be structurally stable and hydraulically efficient.
- The detail of documentation for each culvert site shall be commensurate with the risk and importance of the structure.

8.3 DESIGN CRITERIA

Culverts shall be designed with the following minimum design criteria to integrate hydraulics, economics, safety, environmental considerations, and maintenance.

8.3.1 STRUCTURE TYPE SELECTION

The choice between a culvert and a bridge at a given site shall be based on the following criteria:

Culverts are used:

- Where more economical than a bridge
- Where debris and ice are not significant
- Where bridges are not required to reduce backwater impacts
- Where environmentally acceptable

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This chapter outlines the policies, criteria, and guidelines for the hydraulic design of highway culverts. The information presented in this chapter should enable the designer to select, plan and design conventional highway culverts.

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8.2 GENERAL DESIGN POLICY

The designer shall use the following general policies as a guide to select, plan and design culverts placed beneath roadways and highways:

- Culverts shall be hydraulically designed;
- Culverts shall be located to present a minimum hazard to the public and the environment;
- Culverts shall be designed to be structurally stable and hydraulically efficient;
- Culverts shall be designed to consider construction and maintenance costs, risk of failure, risk of property damage, traffic safety and environmental considerations;
- The detail of documentation for each culvert site shall be commensurate with the risk and importance of the structure;
- Culverts located in floodplains mapped by the Federal Emergency Management Agency shall satisfy the requirements of the National Flood Insurance Program.

8.3 DESIGN CRITERIA

Culverts shall be designed with the following minimum design criteria to integrate hydraulics, economics, safety, environmental considerations, and maintenance.

8.3.1 STRUCTURE TYPE SELECTION

The choice between a culvert and a bridge at a given site shall be based on the following criteria:

- Where floodway encroachments are not critical
- Where overtopping potential and damage due to overtopping is low

Bridges are used:

- Where culverts cannot be used
- Where it is more economical than a culvert
- To avoid floodway encroachments
- To satisfy land use requirements
- To reduce environmental impacts caused by a culvert.
- To accommodate ice and large debris

8.3.2 LOCATION, ALIGNMENT AND GRADE

Culverts shall be in the existing channel to avoid major stream relocations beyond the roadway construction limits and to reduce environmental impacts. Where stream channel relocation is necessary, it shall be done without causing abrupt transitions of the stream at either end of the culvert. Consider the temporary diversion of the stream and constructability when locating a culvert.

Culverts shall be aligned with the direction of flow and with the natural grade of the stream. Improper selection of the alignment and grade can decrease hydraulic performance and increase sediment deposition, debris, and scour.

On steep terrain, long culverts under high fills should be designed to follow existing stream alignments with both horizontal and vertical bends. This will reduce trench excavation and possibly reduce outlet velocity.

8.3.3 MINIMUM SIZE

The minimum size of a culvert shall be determined based on the peak discharge of the design flow from the contributing drainage basin. Culverts in perennial streams shall span the bankfull channel if possible. In some instances, culverts may be oversized to limit upstream inundation due to headwater. Culverts may be sized to accommodate debris and to avoid maintenance problems due to sediment accumulation and clogging. Buoyancy issues should also be evaluated where they may be a concern. Table 8-1 denotes the minimum culvert diameter according to the type of roadway.

Driveway conduit is not classified as a culvert. For residential access it shall be a minimum of 15 inches in diameter for the case of single property access and 18 inches for single or multiple property access with more than 1 acre of contributory drainage area. For commercial or industrial

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Driveway conduit is not classified as a culvert. For residential access it shall be a minimum of 15 inches in diameter for the case of single property access and 18 inches for single or multiple property access with more than 1 acre of contributory drainage area. For commercial or industrial access it shall be a minimum of 18 inches. The placement of the driveway conduit shall not alter the natural water course. Driveways which cross a stream or natural water course have no allowable minimum size and shall be hydraulically designed. This criterion is presented in Section 6.3.11.

Storm drain conduit, which is also not classified as a culvert, shall be a minimum of 18 inches in diameter underneath of multi-lane or two-lane highways and a minimum of 24 inches in diameter when crossing multi-lane highways. The multi-lane crossing criteria is subject to the rule that conduit size shall not decrease in the downstream direction. This criterion is presented in Section 5.2.6.

8.3.3 MINIMUM SIZE

The minimum size of a culvert shall be determined based on the peak discharge of the design flood from the contributing drainage basin. In some instances culverts may be oversized to limit upstream inundation due to headwater. Culverts shall be sized to accommodate debris and avoid maintenance problems. The minimum culvert diameters based on the roadway classification shall be as shown in Table 8-1.

It should be noted that storm drain and median drain pipes, which are not classified as culverts, should be at least 18 inches in diameter and inlet drain pipes should be at least 12 inches in diameter.

access it shall be a minimum of 18 inches. The placement of the driveway conduit shall not alter the natural water course. Driveways which cross a stream or natural water course have no allowable minimum size and shall be hydraulically designed. This criterion is presented in Section 6.3.11.

Storm drain conduit, which is also not classified as a culvert, shall be a minimum of 18 inches in diameter underneath of multi-lane or two-lane highways and a minimum of 24 inches in diameter when crossing multi-lane highways. The multi-lane crossing criteria is subject to the rule that conduit size shall not decrease in the downstream direction. This criterion is presented in Section 5.2.6.

Table 8-1
Minimum Culvert Diameter

Multi-lane Highways	24 inches
Two-lane Highways	18 inches

8.3.4 STORM FREQUENCY

Highway culverts shall be designed for the storm criteria shown in Table 4-2 and shall be evaluated based on the check storm criteria in Section 4.3.2 of Chapter 4.

Temporary culverts used to maintain drainage during construction should be sized based on the expected duration of the project and shall be designed for a storm recurrence interval of no less than the 2-year event.

8.3.5 HYDROLOGY

A constant peak discharge shall be assumed for most culvert designs to size the structure conservatively. Culverts shall be designed for the peak flow calculated at the inlet end of the culvert. The design peak flow shall be determined by the methods outlined in Chapter 4, Section 4.4. Hydrograph and storage routing methods are generally not used for designing culverts unless unusual circumstances exist.

8.3.6 MAXIMUM ALLOWABLE HEADWATER

Allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design storm event. It will be based on the following requirements:

- Non-damaging to upstream property
- Below the roadway subgrade
- HW/D no greater than 1.2

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8.3.5 HYDROLOGY

A constant peak discharge shall be assumed for most culvert designs in order to size the structure conservatively. Culverts shall be designed for the peak flow calculated at the inlet end of the culvert. The design peak flow shall be determined by the methods outlined in Chapter 4.

Hydrograph and storage routing methods shall not be used for designing culverts unless unusual circumstances exist. An example would be the use of a smaller culvert for the purposes of inducing flow detention (increased headwater) behind it.

8.3.6 Maximum Allowable Headwater

Allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design storm event. It will be based on the following requirements:

- Non-damaging to upstream property
- Below the roadway subgrade
- HW/D no greater than 1.2
- Equal to the elevation where flow diverts around the culvert.
- For replacement culverts, no greater than the existing condition
- In compliance with FEMA and local floodplain regulations

A reduction in the HW/D ratio from 1.5 in the 2007 manual to the present 1.2 infers proper sizing of a culvert for the bankfull channel which reduces future maintenance and allows better aquatic organism passage. Culverts in perennial streams shall span the bankfull channel if possible. Major culvert installations where the headwater may affect insurable structures, developable property, or that are located within a FEMA designated flood zone may need to be analyzed using a backwater analysis program with the Engineering Division's approval.

8.3.6 Maximum Allowable Headwater

Allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design storm event. It will be based on the following requirements:

- Non-damaging to upstream property
- Below the roadway subgrade
- HW/D no greater than 1.5
- Equal to the elevation where flow diverts around the culvert
- For replacement culverts, no greater than the existing condition
- In compliance with FEMA and local floodplain regulations

Culverts shall be evaluated based on the check storm criteria in Section 4.3.2 of Chapter 4. Major culvert installations where the headwater may affect insurable structures, developable property, or that are located within a FEMA designated flood zone may need to be analyzed using a backwater analysis program with the Division's approval.

- Equal to the elevation where flow diverts around the culvert.
- For replacement culverts, no greater than the existing condition
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8.3.7 TAILWATER RELATIONSHIP

Tailwater is defined as the depth of water downstream of the culvert. It is measured from the outlet invert and is an important factor in determining the culvert capacity and headwater elevation under outlet control conditions. Tailwater may be caused by the hydraulic resistance (roughness) of the downstream channel or by obstructions such as a low water crossing, another culvert, or a reservoir. Tailwater in a tributary may also be controlled by backwater from a larger stream. For culverts operating in outlet control, tailwater depths shall be determined for a range of discharges. Depths are obtained from normal depth calculations, back water calculations for a receiving stream, or flood insurance study data.

The tailwater for a culvert located near the confluence with another stream or large water body shall be determined by a joint probability analysis (See Table 5-10 Section 5.3.6.5 of Chapter 5) or by a hydrograph analysis. If the design storm events occur concurrently (statistically dependent with coincident peaks), the high-water elevation that has the same frequency as the receiving stream or water body shall be used. If the events are statistically independent, the joint probability of the flood magnitudes shall be evaluated and a likely combination resulting in a greater tailwater depth shall be used. A hydrograph model at the confluence would account for the timing of the peak flow from each watershed to the confluence. Refer to Section 8.4.10 for more details regarding tailwater conditions.

8.3.8 END TREATMENTS (INLET OR OUTLET)

End treatments for culverts larger than 36 inches shall consist of headwalls or wingwalls at both ends as shown in the WVDOH Standard Drainage Details. Metal end sections or safety end sections for larger pipes may be used if approved by the engineer.

End treatments shall be located outside of the clear zone on high-speed roads to eliminate the possible hazard to an out-of-control vehicle. For culverts that are skewed to the roadway, headwalls shall be placed perpendicular to the culvert rather than parallel to the roadway. End

8.3.7 Tailwater Relationship

Tailwater is defined as the depth of water downstream of the culvert. It is measured from the outlet invert and is an important factor in determining the culvert capacity and headwater elevation under outlet control conditions. Tailwater may be caused by the hydraulic resistance (roughness) of the downstream channel or by obstructions such as a low water crossing, another culvert, or a reservoir. Tailwater in a tributary may also be controlled by backwater from a larger stream. For culverts operating in outlet control, tailwater depths shall be determined for a range of discharges. Depths are obtained from normal depth calculations, back water calculations for a receiving stream, or flood insurance study data.

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The tailwater relationship for a culvert located near the confluence with another channel or large water body shall be determined by a joint probability analysis (See Table 5-10 Section 5.3.6.5 of Chapter 5, Storm Drainage Systems). If the design storm events occur concurrently (statistically dependent with coincident peaks), the high water elevation that has the same frequency as the receiving channel or water body shall be used. If the events are statistically independent, the joint probability of the flood magnitudes shall be evaluated and a likely combination resulting in a greater tailwater depth shall be used. Refer to Section 8.4.10 for more details.

treatments on all culverts shall consider buoyancy protection. Refer to Section 8.4.12 for more details regarding end treatments.

8.3.9 MAXIMUM OUTLET VELOCITY AND SCOUR PROTECTION

The maximum velocity at the culvert outlet shall be determined by evaluating a range of discharges up to the design discharge. The need for scour protection shall be based on the maximum outlet velocity. Protection shall be provided by creating a stable discharge area that reduces the velocity to the pre culvert installation velocity. In other words, the culvert outlet velocity should be equal to or less than the velocity in the outlet channel before the installation. Allowable velocities of the stream bed material (Table 8-4) shall be used as a guide to determine the need for scour protection.

Outlet scour protection may consist of channel stabilization with rock lining or an equivalent material. On the plans, rock lining shall be designated as “Dumped Rock Gutter”, or “Select Embankment” as shown in the Standard Details. The use of rock-lined scour basins and energy dissipators shall be based on site-specific conditions and designed in accordance with the guidelines of HEC-14, published by the FHWA.

8.3.10 MINIMUM VELOCITY

The minimum velocity in the culvert shall be adequate to prevent sedimentation at low flow rates. Culverts shall be designed for a minimum velocity of 2 feet per second when the culvert is flowing at a depth equal to 15% of the diameter of the culvert.

8.3.11 DEBRIS CONTROL

Culverts at locations where excessive sedimentation and debris problems are expected (such as in steep streams that transport heavy bed load) shall be designed to accommodate debris or proper provisions shall be made for debris maintenance. Access to the culvert for maintenance, personnel, and equipment shall be provided. Debris control shall be designed using the guidelines of HEC-9, published by the FHWA.

8.3.12 PIPE MATERIAL SELECTION

Culvert material selection shall be based on Design Directive-503 (DD-503), Selection of Pipe Materials, published by the West Virginia Division of Highways.

Culvert material, gage, and corrugation shall be specified based on Design Directive-502 (DD-502), Maximum and Minimum Fill Height Tables for Drainage Pipe, published by the West Virginia Division of Highways.

8.3.13 MULTIPLE BARRELS

Multiple barrel culverts should generally be avoided. They refer to the use of more than one pipe of the same diameter with the same invert elevations. Multiple barrel culverts in an active stream natural channel will clog with debris and sediment. The clogging will cause flooding that could damage the highway, adjacent property, and endanger motorists. Where debris and sediment transport are a concern, a single cell culvert is recommended. If a special circumstance exists where multiple barrel culverts are considered, stream stability, fish passage, and sediment transport should be evaluated.

Locations where multiple barrel culverts are troublesome include:

- Where the approach flow is supercritical with high velocity. Such locations shall require a single barrel or special inlet treatment to avoid hydraulic jump effects.
- Where fish passage is required (see Section 8.4.15), except where special treatment is provided to ensure adequate low flow, such as lowering one barrel (becoming multiple cell culverts see Section 8.4.15).
- Where a meander bend is present immediately upstream

8.3.14 ENVIRONMENTAL CONSIDERATIONS

Culvert locations shall be selected to minimize impacts to the streams and wetlands whenever practical. Consideration shall be given to constructing culverts in the “dry” by using a temporary diversion channel. Aquatic life movement shall be accommodated when required by law or may be considered when it is beneficial as mitigation for stream impacts (see Section 8.4.17). If multiple barrels are used, special treatment shall be provided to ensure adequate low flow, such as lowering one barrel (becoming multiple cell culverts see Section 8.4.15).

8.4 DESIGN CONCEPTS AND GUIDELINES

8.4.1 CULVERT TYPES

Culverts are constructed of materials such as reinforced concrete, corrugated steel, polyvinyl chloride, polypropylene, and high-density polyethylene plastic. Common culvert shapes include circular, box, elliptical, arch, and pipe arch. The material and shape are selected based on factors such as roadway profile, channel characteristics, hydraulic performance, strength, construction methods, and corrosion and abrasion resistance.

Conventional culverts with uniform barrel cross-sections throughout their length are considered in this chapter. Culvert inlets and outlets may consist of the culvert barrel projecting from the roadway fill, mitered to the embankment slope, or with end treatments such as headwalls, wing-walls with apron slabs, or standard end sections of concrete or metal.

8.3.13 Multiple Barrels

Multiple barrel culverts should generally be avoided. They refer to the use of more than one pipe of the same diameter with the same invert elevations. Multiple barrel culverts in an active stream natural channel will clog with debris and sediment. The clogging will cause flooding that could damage the highway, adjacent property, and endanger motorists. Where debris and sediment transport are a concern, a single cell culvert is recommended. If a special circumstance exists where multiple barrel culverts are considered, stream stability, fish passage, and sediment transport should be evaluated.

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When considering multiple barrel culverts, stream stability and sediment transport must be evaluated. Where debris and sediment transport are a concerns, a single cell culvert is recommended.

Multiple barrel culverts shall be avoided:

- Where the approach flow is supercritical with high velocity. Such locations shall require a single barrel or special inlet treatment to avoid hydraulic jump effects;
- Where fish passage is required, except where special treatment is provided to ensure adequate low flow, such as lowering one barrel (see Section 8.4.15);
- Where a high potential exists for debris problems and clogging of the culvert;
- Where a meander bend is present immediately upstream.

8.4.2 CULVERT HYDRAULICS

An exact theoretical analysis of culvert hydraulics is extremely complex because the flow is usually non-uniform with regions of both gradually varying and rapidly varying flow. An exact analysis involves determining change in flow type for various flows and tailwater elevations, backwater and drawdown calculations, energy and momentum balance, application of hydraulic model studies, and determination of hydraulic jump locations.

8.4.3 CONTROL SECTION AND MINIMUM PERFORMANCE

The procedures in HDS-5 were developed to simplify culvert hydraulic calculations and systematically analyze culvert flow based on a “control section”. A control section is a location where there is a unique relationship between the flow rate and the upstream water surface elevation. Many different flow conditions exist over time but at a given time the flow is either governed by the inlet geometry (inlet control) or a combination of the inlet geometry, the culvert barrel characteristics, and the tailwater elevation (outlet control). Control may oscillate from inlet to outlet; however, the design method is based on a “minimum performance”. This means while the culvert may operate more efficiently at times (i.e., more flow for a given headwater level), it will never operate at a lower level of performance than the calculated minimum.

The HDS-5 design method uses equations, charts, and nomographs that were developed from numerous hydraulic laboratory tests and theoretical calculations. Due to the error introduced in the test data because of scatter, it should be assumed that culvert sizes calculated with this method are accurate to within plus or minus 10 percent, (HDS-5, Sept 2001, Chapter III, Section A, 3rd paragraph, page 23) in terms of head.

8.4.4 INLET AND OUTLET CONTROL

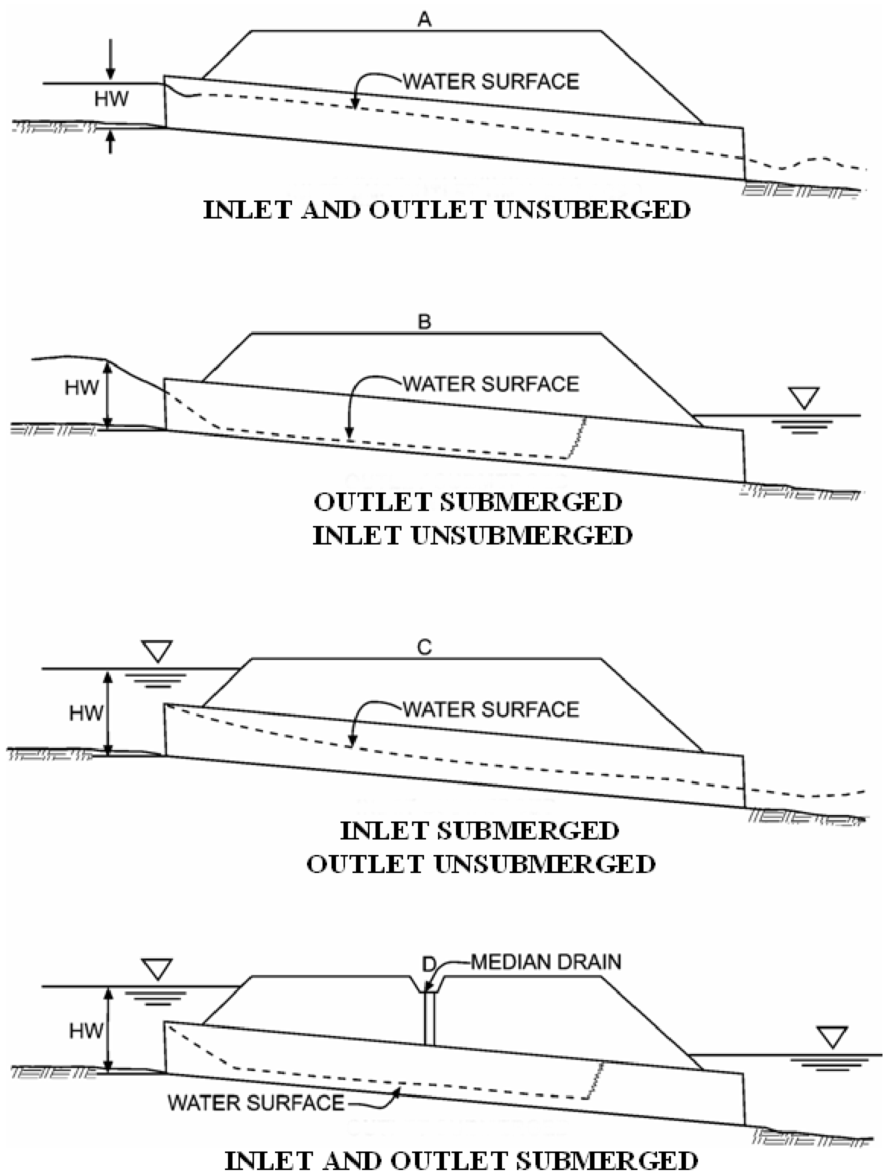
A culvert flowing in inlet control has shallow, high-velocity, supercritical flow with the control section located at the upstream end of the barrel. Inlet control is influenced by the headwater depth and inlet area, edge configuration, and shape. Figure 8-1 shows several examples of inlet control flow with either a submerged or unsubmerged inlet. The submerged inlet operates essentially as an orifice and an un-submerged inlet operates as a weir.

The inlet edge configuration is a major factor of inlet control performance, and it can be modified to improve performance. Modified inlets with beveled edges can reduce the flow contraction. This may decrease the headwater for a given barrel size or allow a smaller pipe for a given headwater.

A culvert flowing in outlet control will have a deep, low velocity, subcritical flow with the control section located at the downstream end of the culvert. The factors influencing outlet control are barrel roughness, tailwater elevation, headwater, edge configuration, barrel area, shape, length, and slope. The greater depth of the tailwater or downstream channel, whichever is greater, is the control at the outlet. Figure 8-2 shows several examples of outlet control flow.

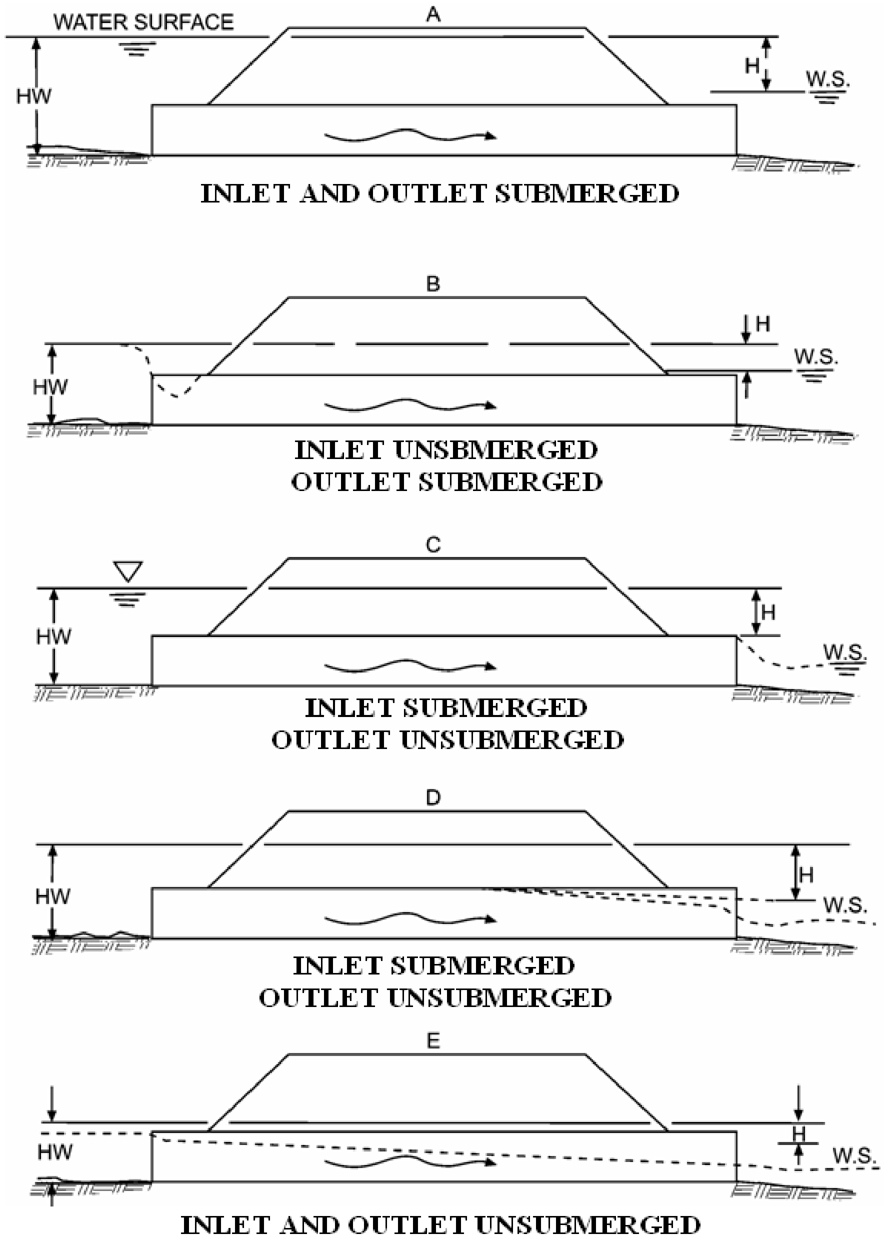
Figure 8-1

Types of Inlet Control



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Figure 8-2
Types of Outlet Control



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

8.4.5 Inlet and Outlet Control Equations

The two conditions of inlet control depend upon whether the inlet end of the culvert is submerged by the upstream headwater. If the inlet is not submerged, the inlet performs as a weir. If the inlet is submerged, the inlet performs as an orifice.

The unsubmerged and submerged inlet control headwater design equations are provided below. Note that there are two forms of the unsubmerged equation. Form (1) is based on the specific head at the critical depth adjusted with two correction factors. Form (2) is an exponential equation similar in form to a weir equation. Form (1) is preferable from a theoretical standpoint, but Form (2) is easier to apply and is the only documented equation for some of the inlet control nomographs. A constant slope value of 2 percent was used for the development of the nomographs. This is due to the small effect of the slope and the conservatively high resultant headwater value for sites with slopes exceeding 2 percent.

UNSUBMERGED

Form (1) $$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{K_u Q}{AD^{0.5}}\right]^M - 0.5S$$

Note: For mitered inlets, the slope correction factor is +0.7S instead of -0.5S as shown in the equation below. Note: For mitered inlets the slope correction factor is $+0.7S^2$ instead of $-0.5S^2$ as shown in the equation below.

The following equations are applicable up to $\frac{Q}{AD^{0.5}} = 3.5$

Form (1) $$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{K_u Q}{AD^{0.5}}\right]^M + 0.7S$$

Form (2) $$\frac{HW_i}{D} = K\left[\frac{K_u Q}{AD^{0.5}}\right]^M$$

SUBMERGED

$$\frac{HW_i}{D} = c\left[\frac{K_u Q}{AD^{0.5}}\right]^2 + Y - 0.5S$$

The above equation applies above about $\frac{Q}{AD^{0.5}} = 4.0$

HW_i= Headwater depth above inlet control section invert (ft)

D = Interior height of culvert barrel (ft)

H_c = Specific head at critical depth ($d_c+V_c^2/2g$) (ft)

Q = Discharge (ft^3/s)

A = Cross-sectional area of the barrel (ft^2)

K,M,c,Y Constants from Table 8-2

K_u = 1.0 for English units

S = Culvert barrel slope (ft/ft) = 0.02

Outlet control flow conditions are calculated based on energy balance. In its most basic form, the head loss H_L (total energy required to pass flow through a culvert with the barrel flowing full throughout its length) is made up of three major parts: an entrance loss (H_e), the friction loss through the culvert (H_f), and the exit loss (H_o).

$$H_L = H_e + H_f + H_o$$

The culvert barrel velocity is calculated as: $V = \frac{Q}{A}$

V = average velocity in the culvert barrel (ft/s)

Q = flow rate (ft^3/s)

A = full cross-sectional area of flow (ft^2)

The velocity head is expressed as: $H_v = \frac{V^2}{2g}$

g = acceleration due to gravity (32.2 ft/s^2)

The entrance loss (H_e) is expressed as a coefficient times the velocity head:

$$H_e = K_e\left(\frac{V^2}{2g}\right)$$

Table 8-2
Constants for Inlet Control Design Equations

CONDUIT	CHART	INLET EDGE TYPE	UNSUBMERGED K	UNSUBMERGED M	SUBMERGED c	SUBMERGED Y
CORRUGATED METAL PIPE	Chart 8-1	HEADWALL	0.0078	2.00	0.0379	0.69
		MITERED TO SLOPE	0.0210	1.33	0.0463	0.75
		PROJECTING	0.0340	1.50	0.0553	0.54
CONCRETE PIPE	Chart 8-4	SQUARE EDGE WITH HEADWALL	0.0098	2.00	0.0398	0.67
		GROOVE END WITH HEADWALL	0.0018	2.00	0.0292	0.74
		GROOVE END PROJECTING	0.0045	2.00	0.0317	0.69
HIGH DENSITY POLYETHYLENE PLASTIC PIPE	Chart 8-6	HEADWALL	0.0078	2.00	0.0379	0.69
		MITERED TO SLOPE	0.0210	1.33	0.0463	0.75
		PROJECTING	0.0340	1.50	0.0553	0.54
CONCRETE BOX CULVERTS	Chart 8-14	30° TO 75° WINGWALL FLARE	0.026	1.00	0.0347	0.81
		90° AND 15° WINGWALL FLARE	0.061	0.75	0.0400	0.80
		0° FLARE OR SIDE EXTENSION	0.061	0.75	0.0423	0.82
CORRUGATED METAL PIPE ARCH STANDARD SIZES	Chart 8-19	90° HEADWALL	0.0083	2.0	0.0379	0.69
		MITERED TO SLOPE	0.0300	1.0	0.0463	0.75
		PROJECTING	0.0340	1.5	0.0496	0.57
STRUCTURAL PLATE CORR. METAL PIPE ARCH 18 INCH CORNER RADIUS	Chart 8-21	90° HEADWALL	0.0083	2.0	0.0379	0.69
		MITERED TO SLOPE	0.0300	1.0	0.0463	0.75
		PROJECTING	0.0340	1.5	0.0496	0.57
HORIZONTAL ELLIPTICAL CONCRETE PIPE	Chart 8-32	SQUARE EDGE WITH HEADWALL	0.0100	2.0	0.0398	0.67
		GROOVE END WITH HEADWALL	0.0018	2.5	0.0292	0.74
		GROOVE END PROJECTING	0.0045	2.0	0.0317	0.69

Table 8-3

Entrance Loss Coefficients K_e

Outlet Control, Full or Partly Full Entrance Head Loss

$$H_e = K_e\left[\frac{V^2}{2g}\right]$$

Type of Structure and Design of Entrance	Coefficient K_e
• Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end	0.2
Square-edge	0.5
Rounded (radius = D/12	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2
• Pipe. or Pipe-Arch. Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2
• Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of D/12 or B/12 or beveled edges on 3 sides	0.2
Wingwalls at 30^0 to 75^0 to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of D/12 or beveled top edge	0.2
Wingwall at 10^0 to 25^0 to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

*Note: "End Sections conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

The friction loss in the barrel (H_f) can be expressed as:

$$H_f = \left[\frac{29 n^2 L}{R^{1.33}}\right] \frac{V^2}{2g}$$

n = Manning's Roughness Coefficient

L = Length of the culvert barrel (ft)

R = Hydraulic radius of the full culvert barrel = A / P (ft)

A = Cross-sectional area of the barrel (ft^2)

P = Perimeter of the barrel (ft)

V = Velocity in the full barrel (ft/s)

Refer to Table 1-2 of Section 1.4 for Manning's Roughness Values for pipes.

The exit loss (H_o) for sudden expansion such as an endwall is:

$$H_o = 1.0\left[\frac{V^2}{2g} - \frac{V_d^{\,2}}{2g}\right]$$

V_d = channel velocity downstream of the culvert (ft/s)

Since the downstream velocity is usually neglected, the exit loss becomes equal to the full flow velocity head in the culvert barrel.

$$H_o = H_v = \frac{V^2}{2g}$$

Inserting the above relationships for entrance loss, friction loss, and exit loss into energy or head loss equation, the following equation for total head loss is obtained:

$$H_L = \left[1 + k_e + \frac{29\, n^2\, L}{R^{1.33}}\right] \frac{V^2}{2\, g}$$

The outlet control headwater design equation:

$$HW_o = H_L + h_o - L S_o$$

Minor losses such as bend losses (H_b), junction losses (H_j), and losses at grates (H_g) should be included in energy or head loss equation if appropriate. See Chapter 5 section 5.3.6.8 for information on minor losses.

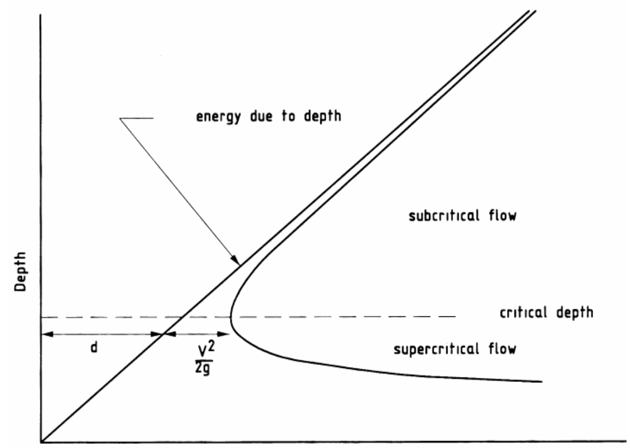
8.4.5.1 KEY PARAMETERS FOR CULVERT FLOW

Specific Energy

Specific energy (E) is the energy or head relative to the channel bottom. For a mild sloped channel with uniform flow (velocity and depth remain constant) the specific energy is defined as the depth plus the velocity head. If you look at the graph for depth vs. specific energy there is one depth at which the specific energy is at a minimum. This depth is the critical depth for the amount of flow or discharge.

$$E = \frac{V^2}{2g} + d$$

$$Q = V\,A \quad or \quad V = \frac{Q}{A}$$



The continuity equation transforms the specific energy equation in terms of depth, flow, and flow area.

$$E = \frac{Q^2}{2gA^2} + d$$

(see Section 8.4.5 and this entire section for term explanations)

It is important to define and distinguish between three important flow depths and how they pertain to a hydraulic pipe design.

Normal Depth

Normal depth is defined as the depth of uniform, steady flow under a constant discharge. In a uniform flow regime, the losses due to boundary friction are balanced by the force of gravity in the direction of the flow. In other words, friction and gravity forces in the direction of flow are equal but act in opposite directions. This creates a hydraulic condition where the discharge, cross-sectional area and velocity are constant throughout the length of the channel or pipe. The slope of the pipe invert, the slope of the water surface, and the slope of the energy grade line are equal and parallel to each other in this hydraulic condition.

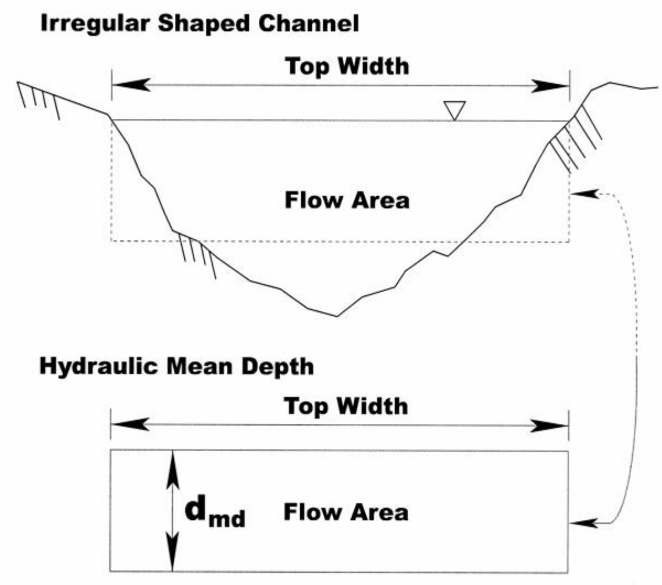
Normal depth is a function of discharge, size of channel, shape of channel, slope of channel, and frictional resistance to flow. It can be calculated using the familiar Manning's Equation.

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \qquad Q = VA = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

Hydraulic Mean Depth

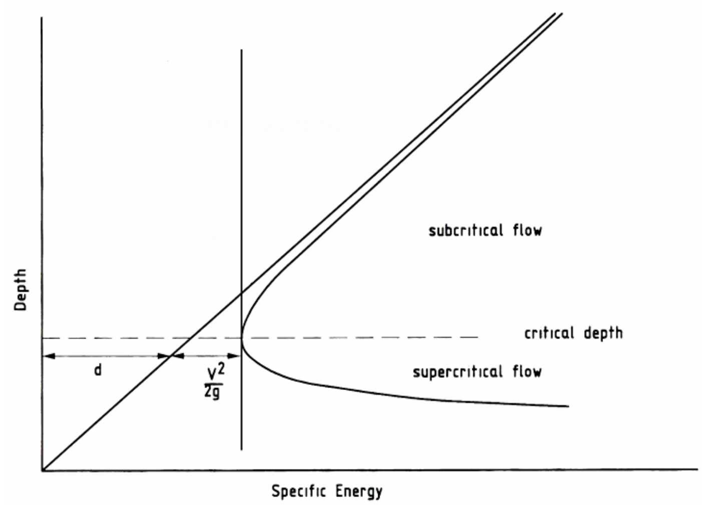
The hydraulic mean depth is defined as the area of the flow cross section divided by the water surface top width. It is a method of characterizing an irregular shaped channel in terms of a rectangular shaped channel.

$$d_{md} = \frac{A}{T}$$



Critical Depth

The critical depth is defined as the depth at the point of minimum specific energy for a constant discharge. In most cases the occurrence of critical flow determines the location of the control point within that flow. The equation for determining critical depth is reached by taking the 1st derivative of the energy equation with respect to depth and setting it equal to zero (finding the point of zero slope with respect to the y axis).

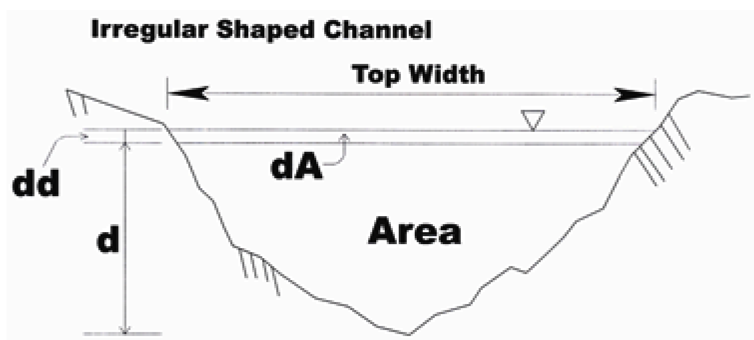


$$E = \frac{Q^2}{2gA^2} + d$$

$$E = \frac{Q^2}{2g}\frac{1}{A^2} + d$$

$$\frac{dE}{dd} = \frac{Q^2}{2g}\frac{-2}{A^3}\frac{dA}{dd} + 1$$

If we take small enough slices of our channel, the change in area with respect to the change in depth is equal to the water surface top width:



$$\frac{dA}{dd} = T$$

$$\frac{dE}{dd} = 1 - \frac{Q^2}{g}\frac{T}{A^3}$$

$$-\frac{Q^2}{g}\frac{T}{A^3} = -1$$

$$\frac{Q^2}{g} = \frac{A^3}{T}$$

Depth of flow determines the flow area (A) and the flow top width (T). To solve for critical depth, find the flow (Q) and its corresponding depth (d) that create the equality for this equation.

This equation applies to all sizes and shapes of pipe and is the source for the critical depth charts in this chapter. The calculation for determining the critical depth curves end at 94% of the diameter for the case of circular pipes since this depth gives the maximum amount of discharge. The depth yielding the maximum amount of discharge will vary for arch pipes due to the many differences in cross sectional geometry. The same limit was used for the calculation of the critical depth curves for arch pipes to preserve consistency. Determining the critical depth beyond this 94% limit shall be taken from a “sketched” continuation of the calculated curve up to the diameter or rise of the pipe.

Critical Slope

Each culvert flow rate has a critical slope that corresponds to the critical depth.

$$S_C = \frac{14.56\, n^2\, d_{md}}{R^{\frac{4}{3}}}$$

The value of the critical slope can be compared against the slope of the culvert invert to determine the state of flow (see Chapter 5 Section 5.3.6.9). If S_c is greater than the slope of the culvert invert, then the flow is subcritical, and the control section is the outlet. If S_c is equal to the slope of the culvert invert, then the flow is critical inside of the culvert, and the control section is at the inlet.

Froude Number

When the flow is at critical depth, the specific energy is at a minimum and the Froude Number is equal to one. A detailed discussion of the Froude Number is provided in Chapter 5, Section 5.3.6.9. The derivation is provided here.

$$\frac{Q^2}{g} = \frac{A^3}{T} \qquad Q = V\,A \qquad \frac{V^2 A^2}{g} = \frac{A^3}{T}$$

$$\frac{V^2}{g} = d_{md}$$

The Froude Number: $\frac{V^2}{g\, d_{md}} = 1$ or $\frac{V}{\sqrt{g\, d_{md}}} = 1$

8.4.5.2 HIGH DENSITY POLYETHYLENE PLASTIC PIPE

The inlet and outlet control equations and their corresponding nomographs do not address the subject of designing a culvert using High density polyethylene plastic pipe (HDPE). This type has a smooth interior with a corrugated exterior. It was determined in the development of design directive 503 (Design of Alternate Pipe Materials) that HDPE should be treated as a corrugated metal pipe in an inlet control situation. The constants K and M in an unsubmerged situation and c and Y in a submerged situation for circular corrugated metal pipe shall apply for HDPE in determining inlet control. This application shall be used for the headwall, mitered to slope, and projecting inlet edge description.

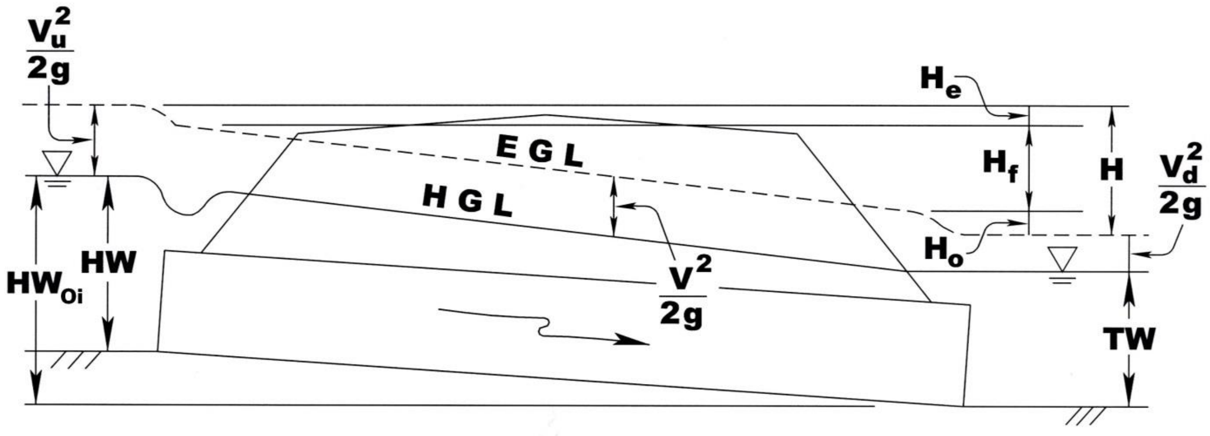
In an outlet control situation, the entrance loss coefficient K_e shall be the same as that for a concrete pipe. This application shall be valid for projecting from fill and headwall and wingwalls for a square or cut end, mitered to conform to fill slope, and an end section conforming to fill slope.

The roughness of the interior of the pipe varies with the type of backfill. When the non-compacted cementitious material, referred to as controlled low-strength material (see DOH specification 219) is used as backfill (type F trench see WVDOH Typical Sections and Related Details) the interior of the pipe remains smooth and the Manning's roughness coefficient is 0.013. When any other type of backfill is used the exterior corrugations tend to protrude into the interior and the roughness coefficient is 0.015. Since the nomographs for total head loss (H_L) use different roughness coefficients, only the equations on the nomographs can be used to determine total head loss for HDPEPP pipe in determining an outlet control headwater.

8.4.6 Full Flow Energy and Hydraulic Grade lines

Figure 8–3 shows the energy grade line (EGL) and the hydraulic grade line (HGL) for full flow in a culvert barrel. The EGL represents the total energy at any point along the culvert barrel. The HGL is the water surface and the depth to which water would rise in vertical tubes connected to the sides of the barrel. The headwater (HW) and tailwater (TW) conditions as well as the entrance (H_e), friction (H_f), and exit (H_o) losses are also shown. HW is the depth from the inlet invert to the hydraulic grade line and HW_{oi} is the headwater depth above the outlet invert. V_u is the approach velocity and V_d is the downstream velocity.

Figure 8-3
Full Flow Energy and Hydraulic Grade Lines



8.4.7 Roadway Overtopping

Roadway overtopping begins when the headwater rises to the elevation of the roadway. The overtopping will usually occur at the low point of a sag vertical curve resulting in flow that is equivalent to flow over a broad-crested weir. This overtopping flow is calculated using the weir equation:

$$Q = k\ C_d\ L\ H_w^{\ 1.5}$$

Q = Overtopping flow rate (ft^3/s)

C_d = Overtopping discharge coefficient (weir coefficient)

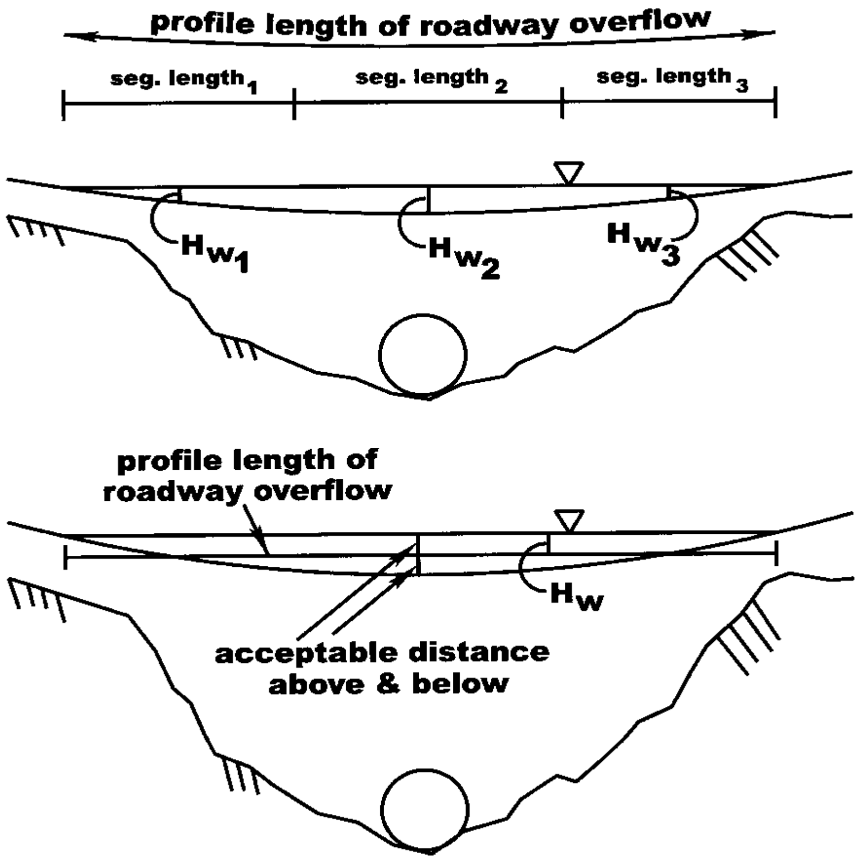
k = over-embankment flow adjustment factor

L = Profile length of the roadway overflow (ft)

H_W = Headwater depth measured above the roadway (ft)

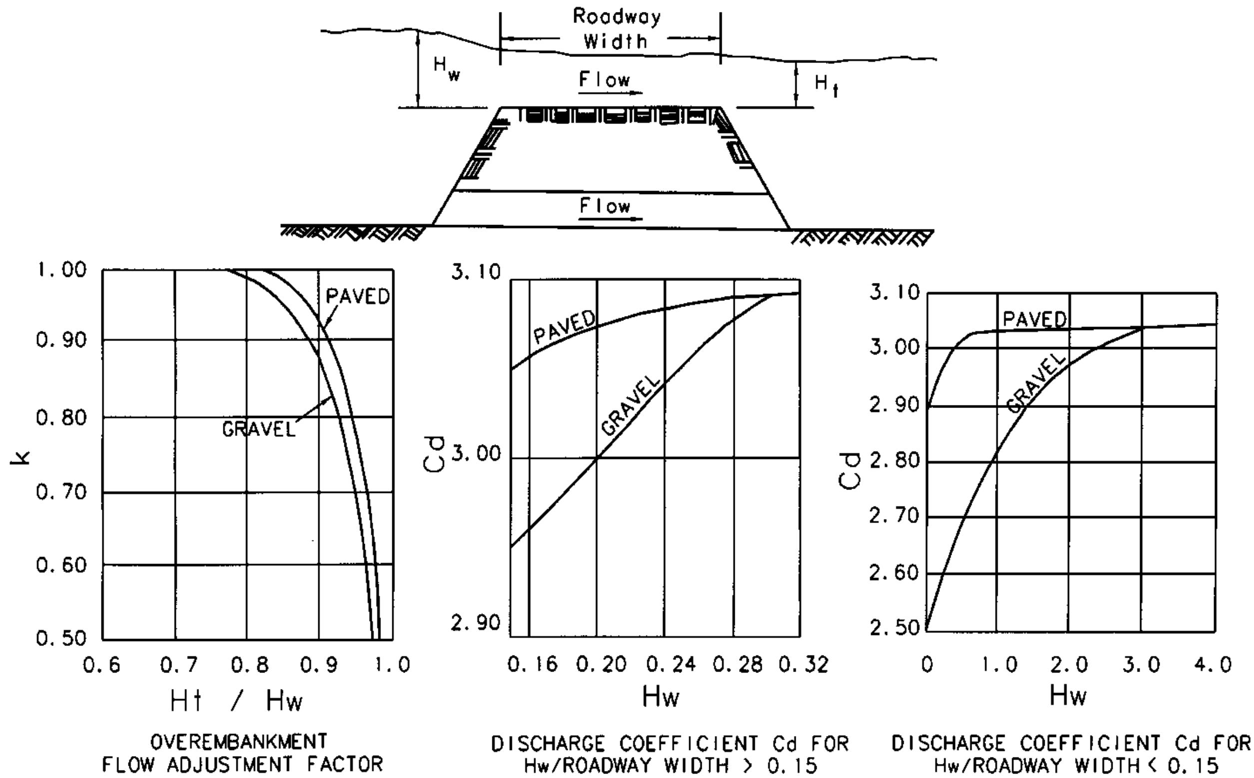
The length of overflow and the headwater depth along the roadway are difficult to determine when the overflow is defined by a sag vertical curve. The sag vertical curve can be broken into a series of horizontal segments and the flow over each segment is calculated for a given headwater using the weir equation (Figure 8–4). The given headwater is determined at the elevation along the vertical curve in the center of the horizontal segment. The overtopping flow rates for each segment are then added together, resulting in the total flow over the roadway.

Figure 8-4
Roadway Overtopping



The sag vertical curve can also be adequately represented by a single horizontal line with an acceptable variation above and below the line. The length of the overflow can be taken as this segment length or it can be based on the roadway profile. In effect, this method utilizes an average depth of the upstream pool above the roadway for the overflow calculation. Values of the weir coefficient (C_d in English Units) can be found in Figure 8–5 (Chart 60B from HDS-5). The roadway overflow plus the culvert flow must equal the design flow. A trial-and-error process are necessary to determine the amount of total flow passing through the culvert and the amount of flow over the roadway. Programs such as HY-8 are recommended when evaluating roadway overtopping.

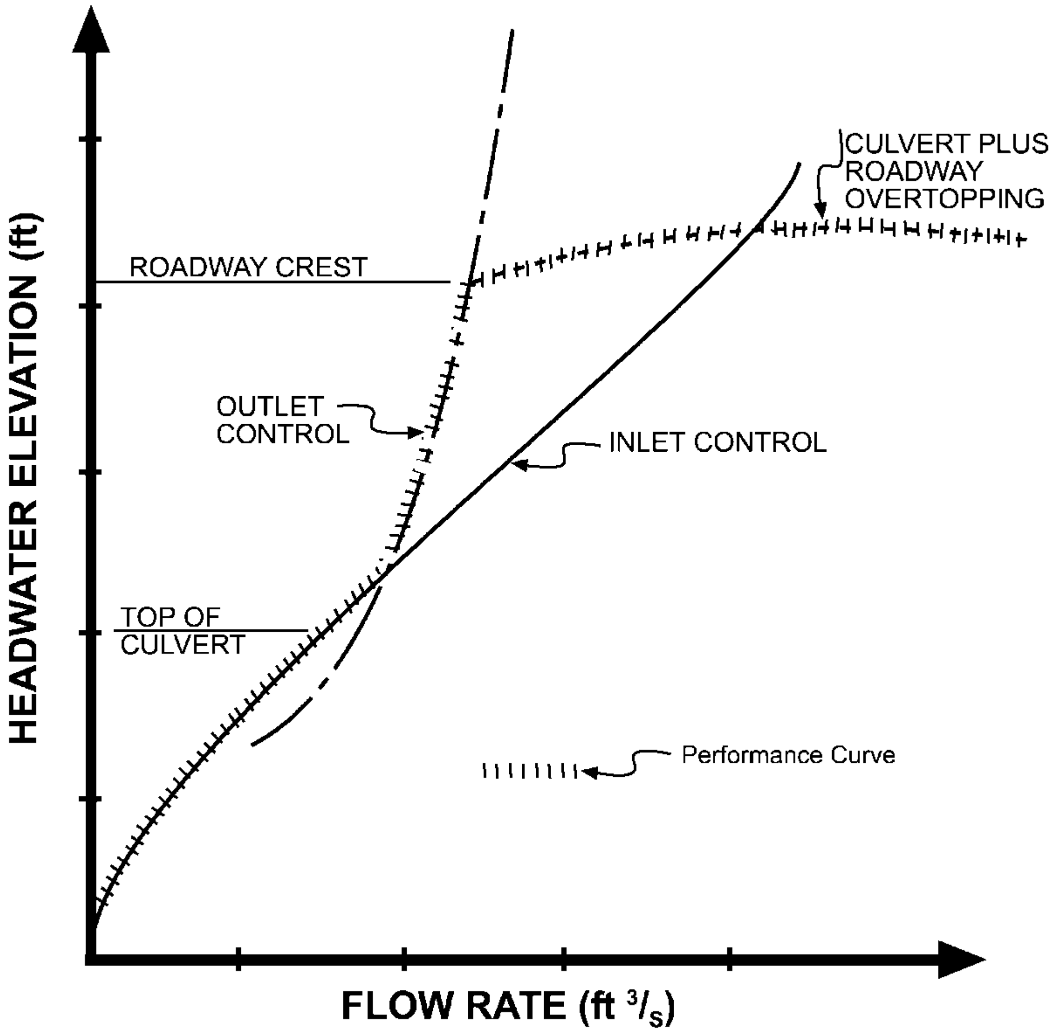
Figure 8-5
Roadway Overtopping / Discharge Coefficient



8.4.8 PERFORMANCE CURVES

Performance curves are plots of flow rate versus headwater depth or headwater elevation. Since the control section can exist at the inlet, outlet, or the throat of the culvert, a performance curve is possible for each control section including roadway overtopping. The overall performance curve is made up of the controlling portions of the individual curves for each control section. It can be used to determine the headwater depth or elevation for any flow rate, or to examine the performance of the culvert over a range of flow rates. Figure 8–6 depicts a typical culvert performance curve.

Figure 8-6
Overall Culvert Performance Curve



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

An overall performance curve can be developed as follows:

1. Select a range of flows falling above and below the design discharge and calculate the corresponding inlet and outlet control headwater elevations.
2. Plot and combine the inlet and outlet control performance curves to define a single curve for the culvert.
3. For culvert headwaters that overtop the roadway crest elevation, use the weir equation (see Section 8.4.7) to calculate flow rates over the roadway.
4. Add the culvert flow and the roadway overtopping flow at the corresponding headwater elevations to obtain the overall performance curve.

8.4.9 ALLOWABLE HEADWATER

The economic design of culverts requires that consideration be given to the following effects:

- Hydraulic uplift or buoyancy, which is especially significant in permeable soils, and/or pipes with no headwalls. The possibility of uplift is increased when the culvert entrance becomes blocked with debris.
- Exfiltration in pipes due to pressure
- Erosion of the embankment due to falling headwater.
- Danger to fills due to seepage especially in hillside locations.
- Debris protection
- Maintenance
- Damage to upstream and downstream property
- Hazards to life
- Public image
- Acquisition of land affected by headwater. Areas inundated beyond levels of former flooding may need to be acquired.
- Possible future development of the land upstream

Allowable headwater depth criteria are provided in Section 8.3.6. The check storm should be evaluated in accordance with Section 4.3.2 (see Chapter 4).

The area upstream of a culvert where ponding might occur can impact the design of the culvert. If the upstream ponding area is limited, the allowable headwater may need to be reduced. Conversely, if the upstream area has a large storage capacity, the allowable headwater elevation could be increased thus reducing the required culvert size. In the latter case, the Division of Highways shall acquire the right to pond water on the affected area to prevent future development and maintain the area for ponding. This will require the purchase of right of way, permanent ponding easement, or permanent drainage easement. The delineation of the ponding area will require mapping with at least 2-foot interval contours.

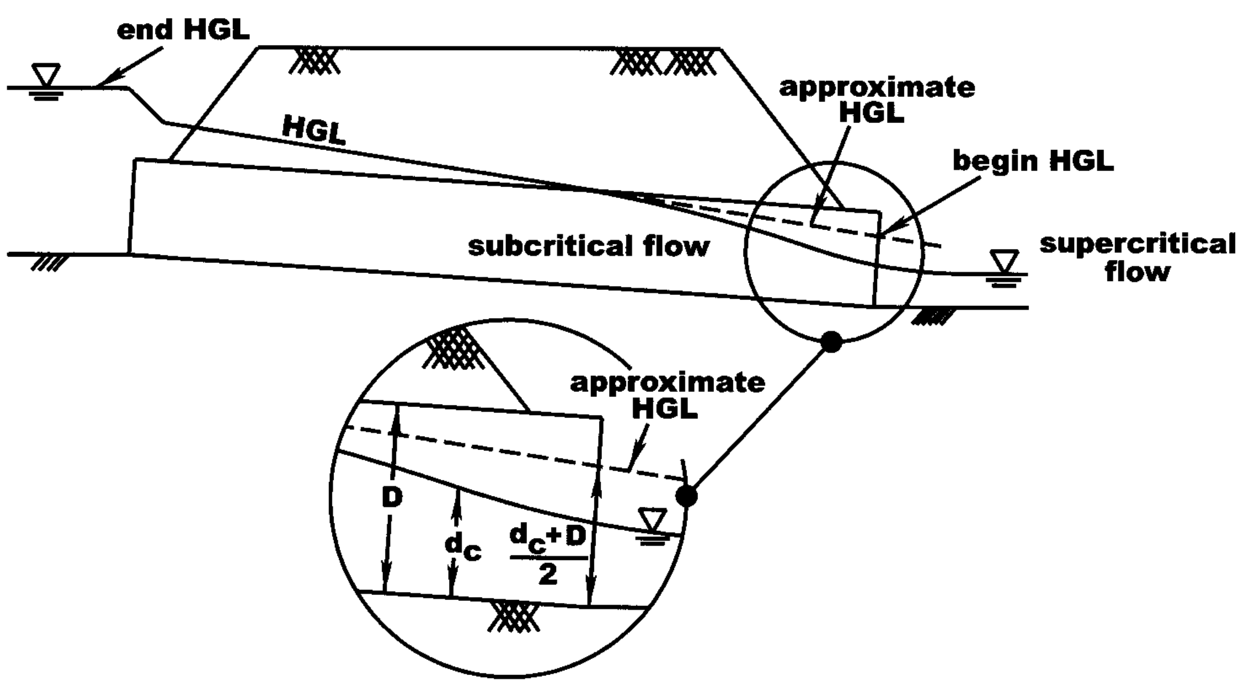
8.4.10 TAILWATER CONDITIONS

The tailwater elevation above the outlet invert at the design flow rate may be obtained from backwater calculations, normal depth calculations, or from field observations. A field inspection and a review of flood insurance studies should be made to check the effect of downstream controls on tailwater conditions at the outlet. Backwater computations from a downstream control point can be tedious and may require additional survey of the area. Normal depth computations utilize Manning's Equation and the geometric properties of the outlet channel to determine a tailwater elevation, (assuming the channel is reasonably uniform in cross section) slope, and roughness. Once this elevation is determined, it is compared to the critical depth of flow for the culvert.

The critical depth of flow is a computable occurrence in the flow regime. Where this depth occurs, it influences the tailwater condition for a culvert. In the case of a hydraulic drop, flow changes from a subcritical state (slow, deep flow) to a supercritical state (shallow, fast flow). The depth of flow must pass through the critical depth to make this change in flow state.

In the case of the culvert flowing full at the outlet (as in Figure 8–3), the tailwater elevation is simple to determine. In the case of the culvert flowing partly full at the outlet, the tailwater is determined by comparing the observed or computed tailwater (from backwater or normal depth methods) with the critical depth. Based on numerous backwater calculations by the FHWA, it was determined that for partly-full flow, a downstream extension of the full-flow hydraulic grade line pierces the vertical plane of the culvert outlet at a point halfway between critical depth (d_C) and the top of the barrel (culvert diameter, D). This means the change in the flow state occurs within the culvert and the tailwater elevation at the culvert outlet is $(d_C + D)/2$ above the outlet invert (Figure 8–7). This is the value used to set the beginning of the hydraulic grade line at the outlet for the calculation of headwater in an outlet control situation.

Figure 8-7
Hydraulic Grade Line Approximation



If the observed or computed tailwater elevation exceeds $(d_C + D)/2$, then it is used to set the beginning of hydraulic grade line. The headwater elevation (or end of the hydraulic grade line) is then determined by adding the exit loss, the head due to friction losses through the culvert barrel, the head due to entrance losses, and subtracting the change in the invert elevation (slope of culvert x length of the culvert) to (d_C +D)/2 or the tailwater, whichever is greater (see Section 8.5).

This approximate method by the FHWA works best when the barrel flows full over at least part of its length. When the barrel is partly full over its entire length, the method becomes increasingly inaccurate as the headwater falls further below the crown of the culvert. Adequate results are obtained down to a headwater of 0.75D. For lower headwater, backwater calculations are required to obtain accurate headwater elevations. Programs such as HEC-2 or HEC-RAS should be utilized.

8.4.11 CULVERT SLOPE

The culvert length and longitudinal slope should be based on existing site conditions and topography. The flow characteristics of the existing channel at the proposed culvert should be examined to properly position the culvert vertically. The culvert invert should be as near as possible to the existing channel bottom and follow the existing stream bed alignment as close as is practical.

Where extremely steep grades are encountered, vertical breaks in grade can be introduced to reduce outlet velocities and minimize outlet protection requirements. The use of grade breaks in culverts should be coordinated with the WVDOH Engineering Division.

8.4.12 END TREATMENTS

Design of the inlet and outlet is a very important aspect of the overall design of a culvert. End treatments such as headwalls, wingwalls, end sections, and improved inlets can increase hydraulic efficiency, prevent buoyancy effects, and reduce erosion. Culvert outlets are also important because of the potential for erosion caused by the increased flow velocity through the culvert. Other types of end treatments include scour protection with rock lining and energy dissipators.

8.4.12.1 HEADWALLS OR WINGWALLS

Safety of the road user is an important consideration in the design and location of drainage structures. It is important to locate the headwall, wingwall, or end section outside the clear zone on high-speed roads to eliminate the possible hazard to an errant vehicle. Where end treatments must be within the clear zone, they should be designed or modified to be traversable or present a minimal obstruction to an errant vehicle where debris is not a concern. The end section can be made traversable by using sloped grates or safety slope end sections. If a major drainage feature cannot effectively be redesigned or relocated, shield it using a suitable traffic barrier. Refer to the AASHTO Roadside Design Guide for further information on traffic safety issues associated with drainage features. See Section 8.3.8 for guidelines on where to use headwalls, wingwalls or other end sections.

Wingwalls retain the roadway embankment and improve the hydraulic efficiency by reducing the inlet and outlet loss coefficients. Cut-off walls at the entrance or outlet of a culvert are used to prevent piping and subsequent undermining along the culvert barrel.

8.4.12.2 IMPROVED CULVERT INLETS

Improved inlets are refinements to the geometry of the culvert entrance to increase the hydraulic performance. These types of inlets should be considered for exceptionally long culverts operating under inlet control or when an existing culvert operating under inlet control is lengthened and hydraulic performance needs to be increased. There are three types of improved inlets:

- Beveled-Edge
- Side-Tapered
- Slope-Tapered

The bevel-edged inlet acts to decrease the flow contraction at the inlet and generally increases the culvert capacity by 5 to 20 percent depending on the type of entrance edge, wingwalls, and depth of headwater.

The side-tapered inlet has an enlarged face area with tapered sidewalls that transition to the culvert barrel. This type of inlet provides an increase in flow capacity of 25 to 40 percent over that of a conventional culvert with a square edged inlet.

The slope-tapered inlet incorporates a steeper slope or fall in the enclosed entrance portion of the culvert. The increase in capacity with this inlet depends on the amount of fall available, but up to a 100 percent increase in capacity can be achieved over a conventional culvert with a square edged inlet.

The designer should refer to HDS-5 for detailed guidance on the design of improved inlets.

8.4.12.3 SCOUR PROTECTION AND ENERGY DISSIPATORS

A pre-formed basin lined with rock is called a scour basin. The geometry of a rock lined scour basin can be determined using the Energy Dissipator Module of HY-8, which is based on the methods presented in HEC-14 published by the FHWA.

High velocity culverts or culverts where a hydraulic jump cannot be avoided at the outlet may require an energy dissipator device to reduce the velocity. Energy dissipators work on the principle of inducing a hydraulic jump, controlling it within a stilling basin, and transitioning the reduced velocity flow to the downstream channel. HEC-14 presents a variety of energy dissipator designs including the CSU basin, USBR impact basin, SAF stilling basin, rock lined scour basin, and the VPI tumbling flow dissipator. The need for maintenance is an important consideration for such energy dissipators. The design should be based on HEC-14.

The following guide should be used for selecting the most appropriate outlet protection. It is based on a comparison of the pre-existing stream velocity, culvert outlet velocity, and the maximum allowable velocity for the soil. The allowable velocities of the channel bed material are listed in Table 8-4. V_o is the culvert outlet velocity in feet/second.

- If V_o < allowable streambed material velocity, no protection is needed.
- If V_o > allowable streambed material velocity, use dumped rock gutter or select embankment.
- If V_o > 15fps, use rock lined basin or energy dissipator
- If V_o > 20 fps, use tied concrete block mattress, rock lined basin, or energy dissipator.

Table 8-4

Allowable Velocities of Streambed Material

SOIL TEXTURE	ALLOWABLE VELOCITIES (ft/sec)
Fine sand and sandy loam (A-3)	2.5
Silt soils (A-4, A-5, A-6)	3.0
Silt or clayey gravel and sand (A-2)	3.5
Clayey soils (A-6, A-7)	4.0
Clay, fine gravel	5.0
Cobbles	5.5
Shale	6.0

8.4.13 SEDIMENT/BEDLOAD

A major concern with culverts involves the adverse effects of sediment and bedload deposition. Excessive deposition can partially block the culvert inlet, the barrel itself, or the outlet and reduce the flow carrying capacity of the culvert. This can also result in a potential flood hazard or develop into a costly maintenance problem.

Culvert locations where potential sediment problems are anticipated require a sediment transport analysis. Whether sediment will be deposited or be scoured will depend on the ability of the upstream channel and the culvert to transport sediment under varying hydraulic conditions. There are four types of methods to evaluate sediment deposition and scour in a culvert: statistical, simplistic, complex, and tractive shear. A description of these methods can be found in the 2005 AASHTO Model Drainage Manual, Chapter 9, Appendix C. These methods estimate the rate of sediment deposition versus the rate of scour or clean out under varying hydraulic conditions. This estimate predicts the potential for problems caused by sediment.

In most cases, a simplistic method of assessment will be adequate unless there are extenuating circumstances that dictate a more complex study. The simple method is based on extreme conditions, and it assumes the culvert barrel will fill more than the stream bed if the culvert where not present. The existing channel flow line is assumed to be the limit of deposition except for aggrading channels. This method results in a ratio that describes the sediment movement. This ratio is the sediment transport ratio and is determined by the following equation:

$$R_G = \left(\frac{V_1}{V_2}\right)^3 \left(\frac{n_1}{n_2}\right)^4 \left(\frac{y_2}{y_1}\right)^{\frac{5}{3}}$$

$V_{1,2}$ = Average velocity in uniform flow (ft/s)

$n_{1,2}$ = Manning's roughness value

$y_{1,2}$ = Average depth of uniform flow (ft)

In this expression the subscript 1 refers to the reach upstream of the culvert and the subscript 2 refers to a location within the culvert. If this ratio is greater than 1 the deposition will occur in the vicinity of section 2. If this ratio is much greater than 1 expect nearly all the sediment carried by the stream to be deposited in the vicinity of section 2. Since V_2 is within the culvert and an average velocity is taken throughout the length of the culvert. The location of section 2 can be taken at any point within the culvert.

In some instances, environmental considerations may require countersinking one or more culvert barrels. The purpose of countersinking a culvert is to allow the pipe barrel to fill with streambed material up to the profile of the streambed that existed prior to the culvert's installation. This is done to accommodate the passage of fish and other stream biota (see Section 8.4.17). Sediment transport calculations will be required to ensure that the desired depth of streambed material will be maintained in the culvert. Baffles may be required to hold the streambed material in the culvert during the design flow.

8.4.14 DEBRIS

Debris is defined as any natural or manmade material in the stream that has the potential to block the culvert opening and prevent it from performing its function. Debris potential at a site is dependent on the land use in the contributing watershed and the floodplain characteristics upstream of the culvert. A field reconnaissance of the upstream watershed may be conducted with particular attention given to the presence of shrubs and trees on eroded banks, stream susceptibility to flash floods and storage of manmade debris in the floodplain.

Accumulation of debris at a culvert's inlet or within the barrel could cause failure. The result would be increased headwater depths, flooding which can cause damage to upstream property, and possible roadway overtopping. Possible accumulation of debris can be reduced by avoiding skewed culverts and providing a well-designed inlet.

When a high potential for debris accumulation exists, the culvert entrance should be designed using HEC 9 published by the FHWA. Protection should be provided where experience or field observations indicate that the natural water course will transport a heavy volume of controllable debris. Debris protection design may be submitted as a part of the culvert design.

The type of debris protection will depend on the location. Debris interceptors can be placed at the entrance to the culvert or upstream of the culvert. Upstream interceptors come in the form of debris racks, floating drift booms, and debris basins. Culvert entrance interceptors include debris risers and cribs. Normally debris protection will not be considered necessary for culverts that carry runoff from natural watersheds, but it may be provided in areas where debris is a known problem. Example problem areas are where timbering or strip-mining operations exist upstream, locations in mountainous or steep regions where the culvert is under high fill, and where clean out access is limited. Maintenance access must be provided to the debris control device to allow for cleaning.

8.4.15 MULTIPLE CELL CULVERTS

Traditional culverts are sized to carry a low-frequency design discharge and are usually accompanied by channel modification that results in localized channel instability. The more common high-frequency events will flow with high-velocity, shallow flow through the culvert which can hinder fish passage. Traditional culverts on roadway embankments also block the floodplain and result in high-velocity flow concentration through the culvert, which can scour the outlet channel and cause “perching” of the culvert. Perched culverts can also impede fish passage.

Multiple cell culverts improve channel stability as well as facilitate fish passage. They should not be confused with adjacent multiple-barrel culverts. Multiple cell culverts consist of one cell which spans the bankfull channel (conveys the channel forming discharge) and one or more cells positioned in the floodplain to convey overbank flow. This arrangement reduces the flow concentration through the culvert, which reduces channel scour. The entire arrangement of cells shall follow the requirements of Section 8.3.6.

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Accumulation of debris at a culvert's inlet or within the barrel can cause failure. The result will be increased headwater depths and flooding which can cause damage to upstream property and possible roadway overtopping. Accumulation can be reduced by avoiding skewed culverts and providing a smooth and well-designed inlet.

When a high potential for debris accumulation exists, the culvert entrance protection should be designed using the Federal Highway Administration's Hydraulic Engineering Circular No. 9, "Debris-Control Structures". Protection should be provided where experience or field observations indicate that the watercourse will transport a heavy volume of controllable debris. Debris protection design should be submitted as a part of the culvert design.

The type of debris protection will depend on the individual location. Debris interceptors can be placed at the entrance to the culvert or upstream of the culvert. Upstream interceptors come in the form of debris racks, floating drift booms and debris basins. Culvert entrance interceptors include debris risers and debris cribs. Normally debris protection will not be considered necessary for culverts that carry runoff from natural watersheds but it should be provided in areas where debris is a known problem. Problem areas could be where timbering or strip mining operations exist upstream, locations in mountainous or steep regions where the culvert is under high fill and where clean out access is limited. Maintenance access must be provided to allow for clean out of the debris control device.

8.4.15 Multiple Cell Culverts

Traditional culverts are sized to carry a low-frequency design discharge and are usually accompanied by channel modification that results in localized channel instability. The more common high-frequency events will flow with high-velocity, shallow flow through the culvert which can hinder fish passage. Traditional culverts on roadway embankments also block the floodplain and result in high-velocity flow concentration through the culvert, which can scour the outlet channel and cause "perching" of the culvert. Perched culverts can also impede fish passage.

Multiple cell culverts improve channel stability as well as facilitate fish passage. They should not be confused with adjacent multiple-barrel culverts. Multiple cell culverts consist of one cell which spans the bankfull channel (conveys the channel forming discharge) and one or more cells positioned in the floodplain to convey overbank flow. This arrangement reduces the flow concentration through the culvert, which reduces channel scour. The entire arrangement of cells shall follow the requirements of Section 8.3.6.

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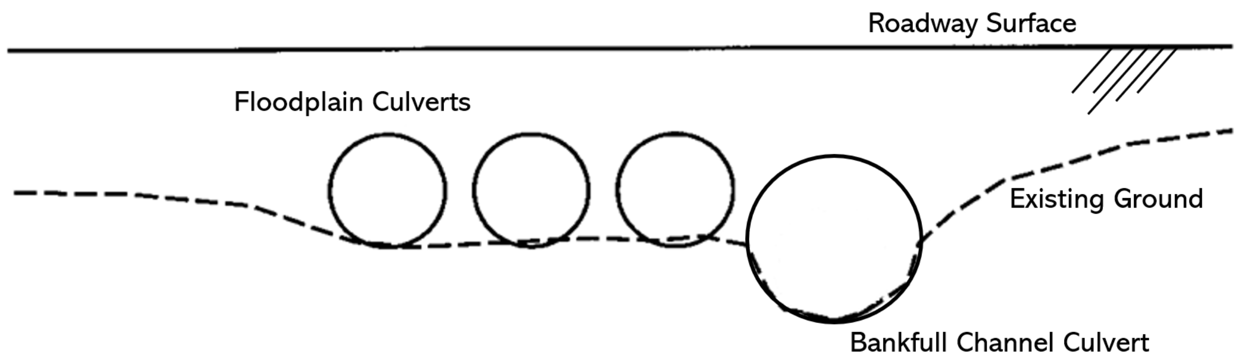
Multiple cell culverts were developed to improve channel stability as well as facilitate fish passage. They should not be confused with traditional multiple-barrel culverts. Multiple cell culverts consist of one or more cells placed in the channel to convey flows up to the dominant discharge (or channel forming discharge) and one or more cells positioned in the floodplain to convey overbank flow up to the design discharge without increasing the water surface elevation of the 100-year discharge. The width of the channel culvert or total width of the channel culverts shall be equal to the bankfull width of the channel. This arrangement reduces the flow concentration through the culvert, which reduces channel scour.

Figure 8-8

Multiple Cell Culverts



The designer is cautioned that multiple cell culverts are not appropriate for all streams. A stream stability assessment should be conducted to determine if they are appropriate. Multiple cell culverts should be considered only on stable streams that have active floodplains. A bridge is more appropriate for an unstable stream or a stream with no floodplain.

Scour protection of the floodplain cell outlets should be considered to prevent head cuts or erosion.

8.4.16 COMPUTATIONAL METHODS

Culverts can be designed using the design charts and nomographs from HDS-5 or with various programs. The FHWA HY-8 culvert analysis program is based on the methods presented in HDS-5. The results of computer applications should be spot-checked for accuracy using the design charts or equations.

8.4.17 ACCOMMODATING AQUATIC LIFE MOVEMENTS

Culverts have been determined to be barriers to passage of aquatic organisms in three ways:

- A high drop-off at the downstream end of the culvert keeps fish from entering. With a few exceptions, culverts are generally installed so that the invert of the pipe matches the bottom of the stream elevation. The high drop-off condition develops over time because of two possible causes. First, the streambed elevation downstream of the culvert has been lowered due to erosion after the culvert was installed. Second, the water velocities are high enough to cause a scour hole at the outlet end of the culvert.
- Steep, smooth culverts have flow that is too shallow and too swift for fish to swim through.
- Long culverts exceed the endurance limit of the fish by not providing pools for fish to rest in.

Research and regulation began in the 1970's. Most of the research in the U.S. has been focused along the northern Pacific coast, but efforts are increasing in the northeast and mid-Atlantic regions.

Legal basis

USACE Section 404 National Permit General Conditions, part C. 4. – Aquatic Life Movements:

"No activity may substantially disrupt the necessary life-cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water. Culverts placed in streams must be installed to maintain low flow conditions."

West Virginia 401 Water Quality Certifications Special Conditions for Nationwide 14 Linear Transportation Projects states that:

"The culvert barrel must be properly countersunk at the outlet."

Reference is also made to "Appendix A for recommendations on proper culvert installation."

These recommendations are from Oregon and Washington, and they have not been widely accepted or implemented in West Virginia.

Proposed Design Methods and Policy

The WVDOH has established a goal to accommodate aquatic life movements (ALM) where it is beneficial, practical, and feasible. In working toward this goal over the last few years, WVDOH has installed few experimental culverts which have yielded mixed results. The following design method and policy is proposed to implement ALM on a limited basis.

Step 1: Determine the culvert size based on WVDOH Drainage Manual to ensure that hydraulic design requirements are met. Remember to consider FEMA requirements if the stream crossing is in a mapped flood zone.

Step 2: Collect field data at the site to determine whether ALM is applicable.

- List aquatic organisms present at site. Note State and Federal Rare, Threatened and Endangered (RTE) species in conjunction with the Environmental Section of the Engineering Division's environmental document for the project.
- Consider whether the stream is perennial, intermittent, or ephemeral.
- Determine whether the stream is listed as a mussel stream.
- Determine whether the stream is a trout stream or an intermittent tributary of a trout stream.
- Measure bankfull width, bankfull maximum depth, and channel slope.

Step 3: Based on the data collected in step 2, determine whether ALM is appropriate.

- If the stream supports aquatic life, then ALM should be considered. Regulation of this issue is still developing. Building a stream crossing to accommodate ALM may be required, or it may be considered as mitigation of stream impacts.
- If ALM is not appropriate, then size the stream crossing based on the hydraulic culvert design performed in step 1.

Step 4: Determine whether the stream crossing should have an open bottom structure such as a bridge, 3-sided structure, or a closed cell culvert with natural stream bed material. Based on WVDOH calculations and current practice of other agencies, a stream slope of 5% is the upper limit for closed cell culverts with natural stream bed material. If the channel slope is less than 5%, follow steps 5 through 10 for closed cell culvert design. If the channel slope is greater than 5%, follow steps 11 through 14 for open bottom structure design.

Culverts

Step 5: Set the culvert width equal to the bankfull channel width. Investigate which structure types will be appropriate for this width.

Step 6: Determine what measures will be needed to ensure that the culvert will have adequate substrate and structure to allow ALM. Some culverts may be set at a low elevation and be expected fill in naturally over time. Others will require streambed material placement inside the culvert.

Step 7: For culverts that require streambed material placement inside the culvert, determine the size and thickness of the material to fill the bottom of the culvert. Based on current information:

$$D_{50} = 15.6dS$$

D_{50} = the median size of well graded stream bed material (ft)

d = bankfull maximum depth (ft)

S = channel slope (ft/ft)

The thickness of the stream bed material should be approximately $2D_{50}$.

Step 8: Determine the culvert height based on steam bed material thickness and bankfull maximum depth.

Step 9: Determine which structure sizes and types are acceptable based on fill heights and hydraulic requirements in step 1.

Step 10: Complete final design of culvert.

Bridges and three-sided structures

Step 11: Set the structure width equal to or greater than the bankfull channel width. Investigate which structure types will be appropriate for this width.

Step 12: Perform bridge scour analysis.

Step 13: Obtain core borings.

Step 14: Design the structure and foundations.

All stream crossings

Step 15: Prepare drawings and quantity tables for the permit applications.

8.5 CULVERT DESIGN PROCEDURE

The following is a step-by-step procedure to determine the minimum size of a culvert. While it is possible to follow the design method without an understanding of culvert hydraulics, it is not recommended as it can result in an inadequate and possibly unsafe structure. Therefore, the designer is advised to become familiar with the detailed procedures here. More information is provided in HDS-5.

Step 1: Assemble site data and culvert project file.

a. Minimum data are:
   - USGS site and location maps
   - Embankment cross sections
   - Roadway profile
   - Existing channel profile
   - Photographs
   - Field visit (check for downstream controls, sediment, debris, erosion, high water marks, etc.)
   - Surveyed elevations of nearby structures and design data of nearby hydraulic structures

b. Studies by other agencies including:
   - Small dams (NRCS, USGS, etc.)
   - Floodplain (NRCS, FEMA, USGS, NOAA, USACE, etc.)
   - Storm drain (local or private)

c. Environmental constraints including:

- Commitments contained in Environmental documents
- Environmental mitigation
- Aquatic life movement, see Section 8.4.17

d. Review Design Criteria in Section 8.3, and the design directives

Step 2: Calculate design discharge (Q):

a. Determine design frequency based on the design criteria for the roadway classification.

b. Determine Q from Form 4-1 or Form 4-2 (Chapter 4)

c. Divide Q by the total number of barrels, if more than one barrel is used.

Step 3: Determine tailwater conditions based on the downstream channel and stream flow:

a. Review Chapter 7

b. Minimum data are cross sections, an estimate of Manning's roughness coefficient for stream, geometry of channel and investigation of downstream controls.

Step 4: Summarize data on Form 8-1 (see Section 8.6):

a. Fill in data from step 2.

b. Fill in all other information including station, location, description, project number, etc.

c. Determine maximum allowable headwater (in feet), which is the vertical distance from the culvert inlet invert (flow line) to the allowable water surface elevation in the headwater pool or approach channel upstream of the culvert.

Step 5: Select the design alternative.

a. Choose culvert material, shape, entrance type, and trial size (for example, using inlet control nomographs, assume HW/D = 1.2 with the design discharge and determine a preliminary size). If the trial size is too large in dimension because of limited height of embankment or availability of size, multiple culverts may be considered by dividing the discharge equally between the number of barrels. Consider raising the embankment height or the use of a pipe arch or box culvert with a width greater than the height. Final selection should be based on an economic analysis of the alternatives.

b. Review the West Virginia Standard Specifications and Standard Details to ensure compliance and evaluate the need for special details or special provisions.

Step 6: Determine inlet control headwater depth (HW_i)

Use the inlet control nomographs in Section 8.6 for the selected culvert shape and material.

a. Locate the size or height on the scale.

b. Locate the discharge.

- For a circular or arch shape use discharge
- For a box shape use Q per foot of width

c. Locate HW/D ratio

- Use a straight edge.
- Extend a straight line from the culvert size through the flow rate.
- Mark the first HW/D scale. Extend a horizontal line to the scale for the end treatment to be used and read HW/D and note it on Form 8-1.

d. Calculate headwater depth (HW_i)

- Multiply HW/D by D (pipe diameter if circular shape, height of culvert if box shape or arch shape is used) to obtain HW.
- Neglecting the approach velocity HW_i = HW
- Including the approach velocity HW_i = HW - approach velocity head.

Step 7: Determine outlet control headwater depth at inlet (HW_O)

a. Calculate the normal depth (d_n) in feet above the outlet invert using the design flow rate (single section) or using a backwater profile for the downstream channel. A measurable tailwater (TW) should also be noted here.

b. Calculate critical depth (d_C) using appropriate charts in Section 8.6.

- Locate flow rate and read d_C (A is the area of flow)
- d_C cannot exceed D

c. Calculate (d_C + D)/2

d. Determine (h_o)

h_O = the larger of the measurable TW, normal depth, or (d_C + D) / 2

e. Determine the Entrance Loss Coefficient (k_e) used to determine the entrance head loss (H_e). Coefficient k_e is multiplied by the velocity head (V^2 / 2 g) to determine the head loss at the entrance to a culvert operating full or partially full with control at the outlet. Entrance loss coefficients for various inlet configurations are provided in Table 8-3.

f. Determine the total head losses (H_L).

- Use outlet control nomographs.
- Locate appropriate k_e scale.

- Locate culvert length (L) or (L1):
- Use (L) if Manning's n matches the n value of the culvert and use (L1) to adjust for a different culvert n value.
- $L1 = L (n_1 / n)^2$
- Mark point on turning line:
- Use a straight edge and connect culvert size with the length on the appropriate ke scale and mark a point on the turning line.
- Read (H_L).
- Use a straight edge,
- Connect discharge (Q) and mark on the turning line,
- Read (H_L) on Head Loss Scale.

g. Calculate outlet control headwater (HW_O).

$$HW_O = H_L + h_O - LS_O$$

S_O = slope of culvert (ft/ft)

L = length of culvert (ft)

Therefore, LS_O is the difference in elevation of the invert in and invert out of the culvert (fall through the culvert).

Step 8: Determine controlling headwater (HW).

a. Compare HW_i and HW_O. The higher headwater governs and indicates the flow control existing under the given conditions for the trial size selected.

b. If outlet control governs and the HW is higher than is acceptable, select a larger trial size and return to Step 7.

Step 9: Compute Outlet Velocity and Depth.

a. If inlet control governs, outlet velocity can be assumed to be equal to the mean velocity in open channel flow within the barrel as computed by Manning's equation for the rate of flow, barrel size, roughness, and slope of the selected culvert.

b. If outlet control governs:

- Use d_C if $d_C > TW$
- Use TW if $d_C < TW < D$
- Use D if $D < TW$

- Calculate flow area A
- Calculate exit velocity V = Q / A.

Step 10: Determine need for Culvert Outlet Protection.

a. Determine mean and maximum allowable flow velocities for the natural stream.

b. Design protection based on Section 8.4.12.3.

Step 11: Review Results:

Analyze the design alternative constraints and assumptions made in the design process. If any of the following constraints are not met, repeat steps 5 through 10 with another alternative design:

a. Allowable headwater is not exceeded.

b. Check storm criteria in Chapter 4 are met.

c. Culvert barrel material has adequate cover.

d. Actual length of the culvert is close to the approximated length.

e. Culvert end treatments can be accommodated by site conditions.

f. Allowable velocity is not exceeded.

If the above constraints are satisfied:

- Record final selection of culvert with size, type, required headwater, outlet velocity, and economic justification under recommendation on Form 8-1.

Step 12: Prepare a report if needed and file with the background information.

8.6 COMPUTATION FORMS AND DESIGN CHARTS

Nomographs, charts, computation forms, step-by-step procedures, and example problems pertaining to all aspects of hydraulic design of highway culverts can be found in HDS-5. Refer to the HDS-5 for complex situations not covered by the charts included in this section.

Form 8-1
Culvert Design Form

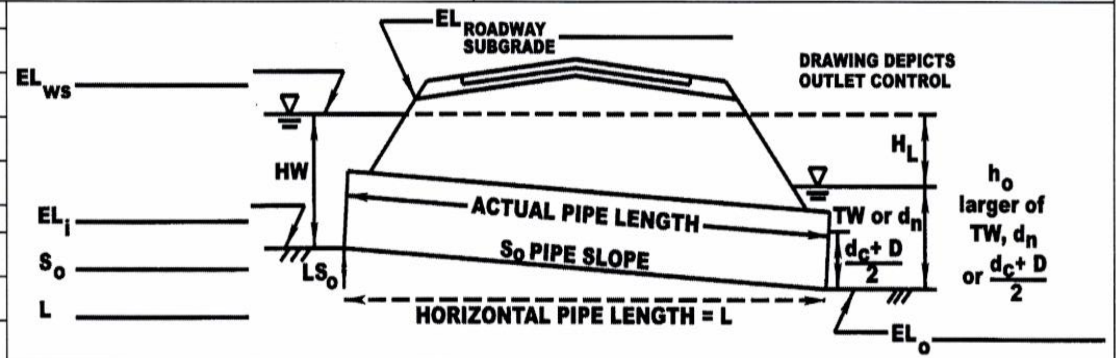
DRAINAGE COMPUTATION FORM 8 - 1
CULVERT DESIGN

PROJECT NAME ______________________
PROJECT NUMBER ______________________

STATION ______________________
DESIGNER __________ DATE __________
REVIEWER __________ DATE __________

OUTLET CHANNEL TAILWATER		
	RETURN PERIOD	TW OR NORMAL DEPTH
DESIGN STORM		
CHECK STORM		

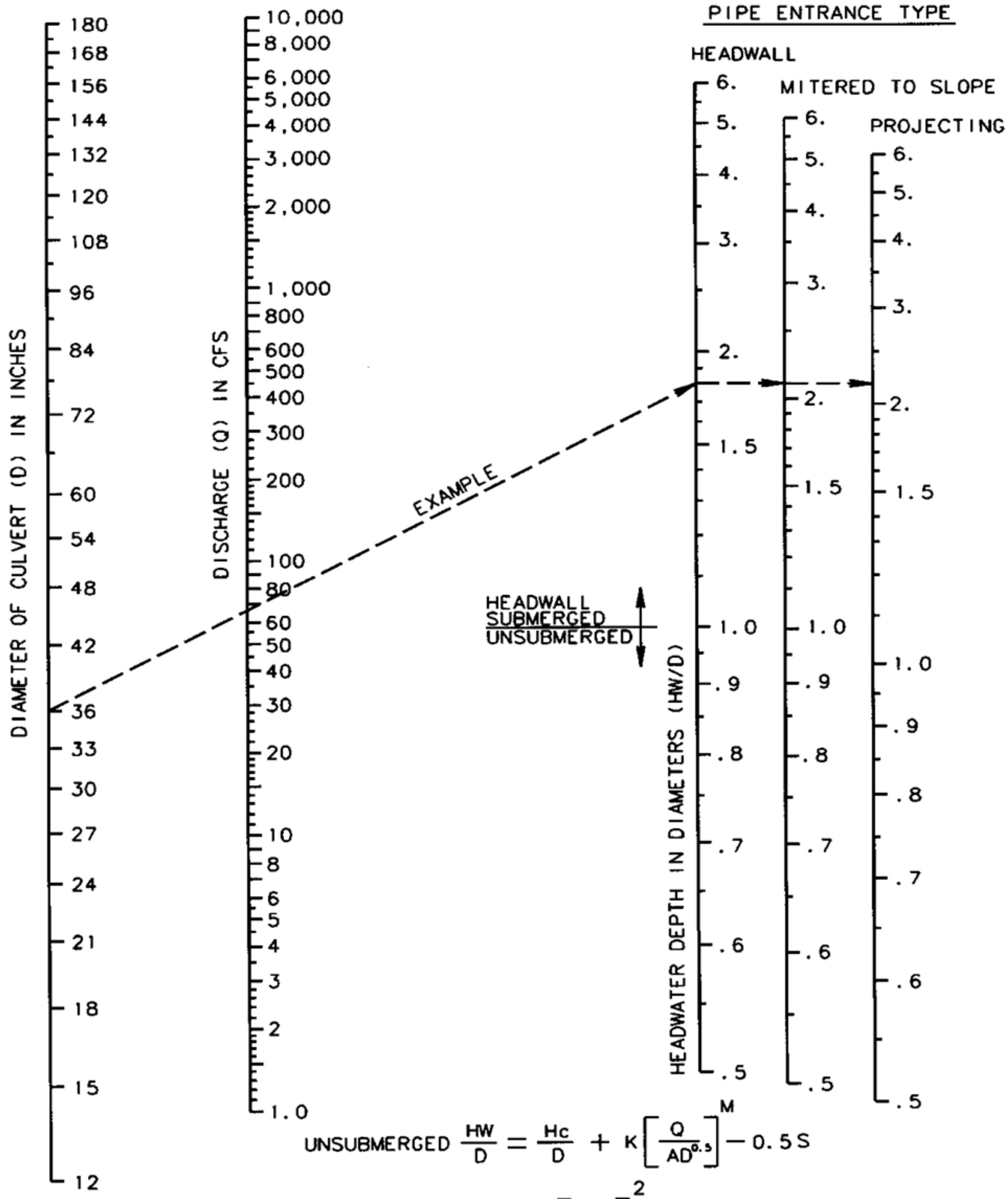
CULVERT FLOWS		
	RETURN PERIOD	FLOW
DESIGN STORM		
CHECK STORM		



CULVERT DESCRIPTION				INLET CONTROL		OUTLET CONTROL											
MATERIAL, ENTRANCE, ROUGHNESS	CULVERT DIAMETER OR SHAPE	TOTAL FLOW	MAX ALLOWABLE HEADWATER	HEADWATER TO DEPH RATIO	HW AT INLET DUE TO INLET CONTROL	TAILWATER OR NORMAL DEPTH IN CHANNEL	CRITICAL DEPTH IN PIPE	PIPE CRITICAL DEPTH & DIAMETER AVERAGE	WSEL AT THE PIPE OUTLET	ENTRANCE LOSS COEFFICIENT	HEAD LOSS DUE TO FLOW THROUGH THE CULVERT	FALL THROUGH THE CULVERT	HW AT INLET DUE TO OULET CONTROL	CONTROLLING HEADWATER	OUTLET VELOCITY	REMARKS
		Q	H_{MAX}	HW_i/D	HW_i	TW, d_n	d_c	$(d_c+D)/2$	h_o	k_e	H_L	LS_o	HW_o	HW	V	
		cfs	ft		ft	ft	ft	ft	ft		ft	ft	ft	ft	ft / s	

RECOMMENDATION:

Chart 8-1
C.M. Pipe Culverts with Inlet Control



UNSUBMERGED $\frac{HW}{D} = \frac{Hc}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^{M} - 0.5S$

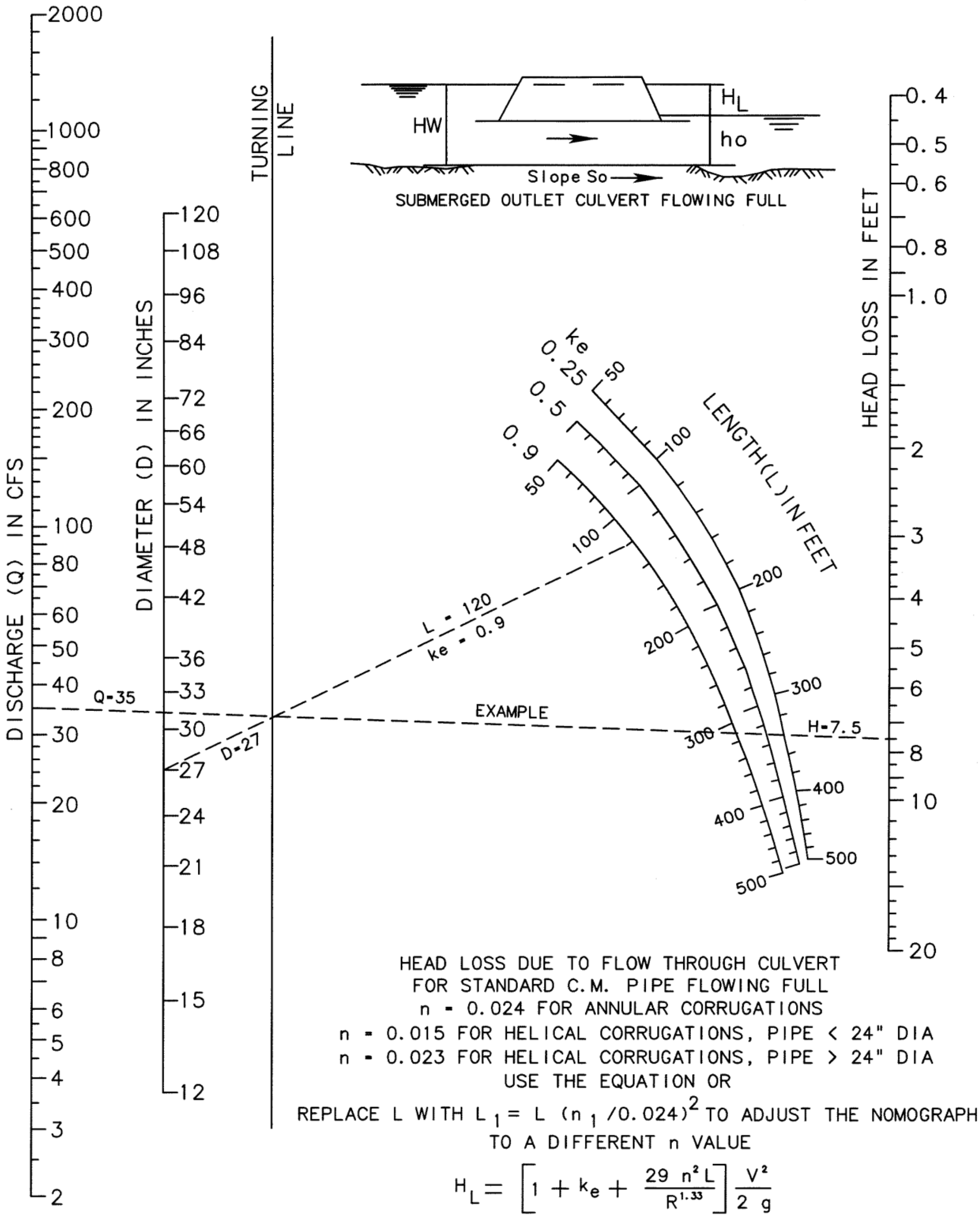
SUBMERGED $\frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^{2} + Y - 0.5S$

SEE TABLE 8-3 AND TABLE 8-4 FOR K, M, c, Y
REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-2

Standard C.M. Pipe Flowing Full



HEAD LOSS DUE TO FLOW THROUGH CULVERT
FOR STANDARD C.M. PIPE FLOWING FULL
n = 0.024 FOR ANNULAR CORRUGATIONS
n = 0.015 FOR HELICAL CORRUGATIONS, PIPE < 24" DIA
n = 0.023 FOR HELICAL CORRUGATIONS, PIPE > 24" DIA
USE THE EQUATION OR
REPLACE L WITH $L_1 = L\ (n_1/0.024)^2$ TO ADJUST THE NOMOGRAPH
TO A DIFFERENT n VALUE

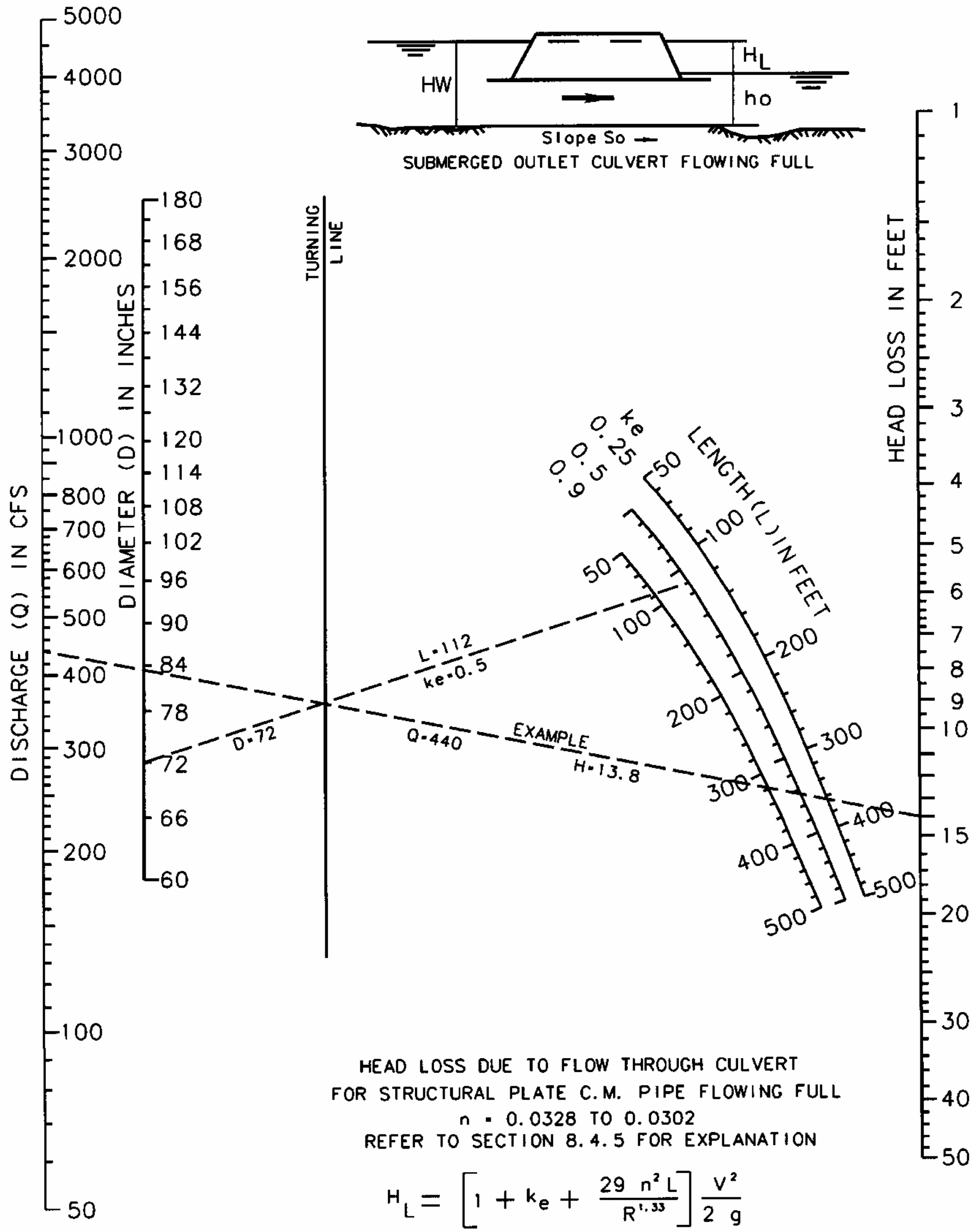
$$H_L = \left[1 + k_e + \frac{29\ n^2 L}{R^{1.33}}\right]\frac{V^2}{2g}$$

REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-3

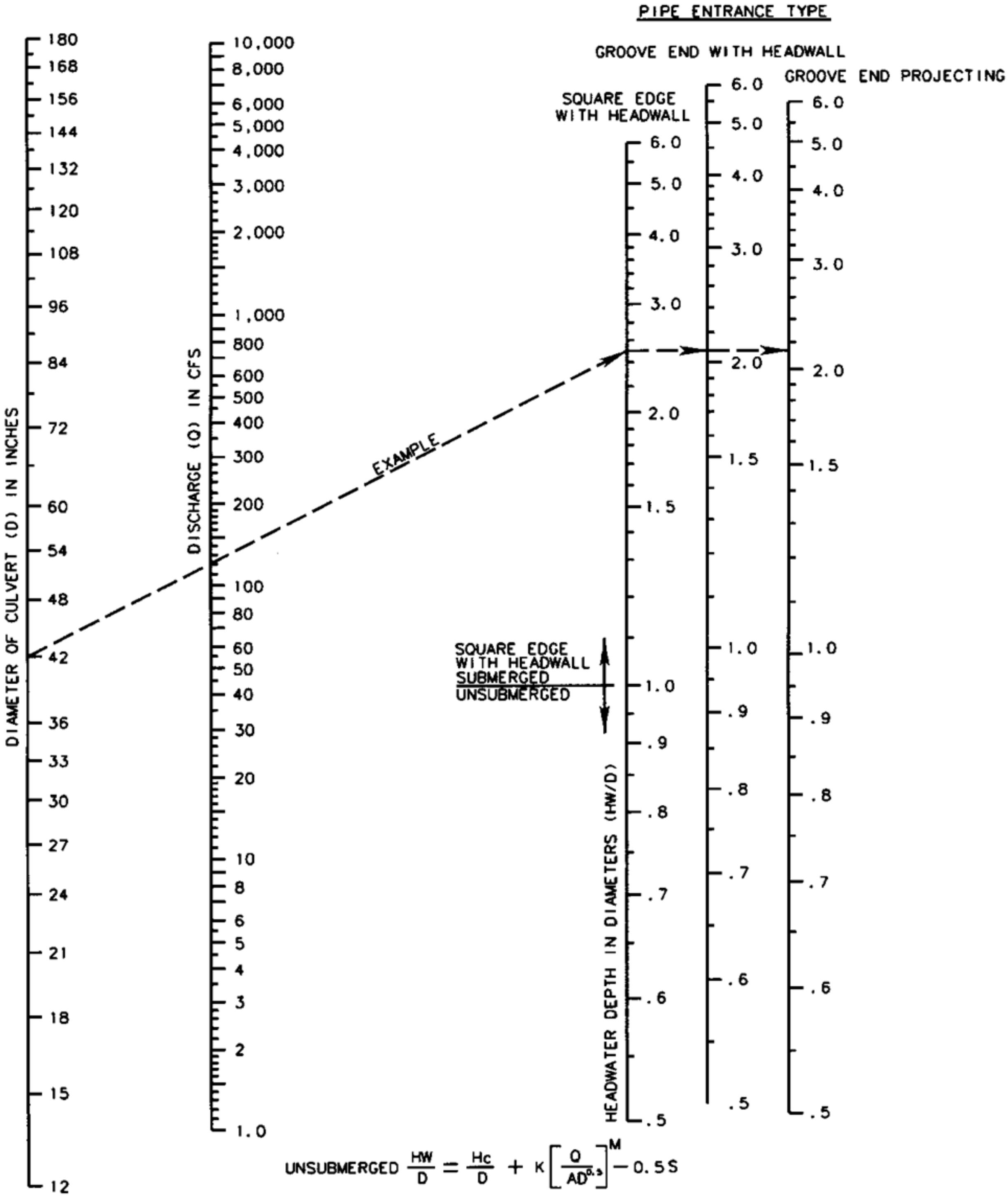
Structural Plate C.M. Pipe Flowing Full



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-4

Concrete Pipe Culverts with Inlet Control



UNSUBMERGED $\frac{HW}{D} = \frac{Hc}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^M - 0.5S$

SUBMERGED $\frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y - 0.5S$

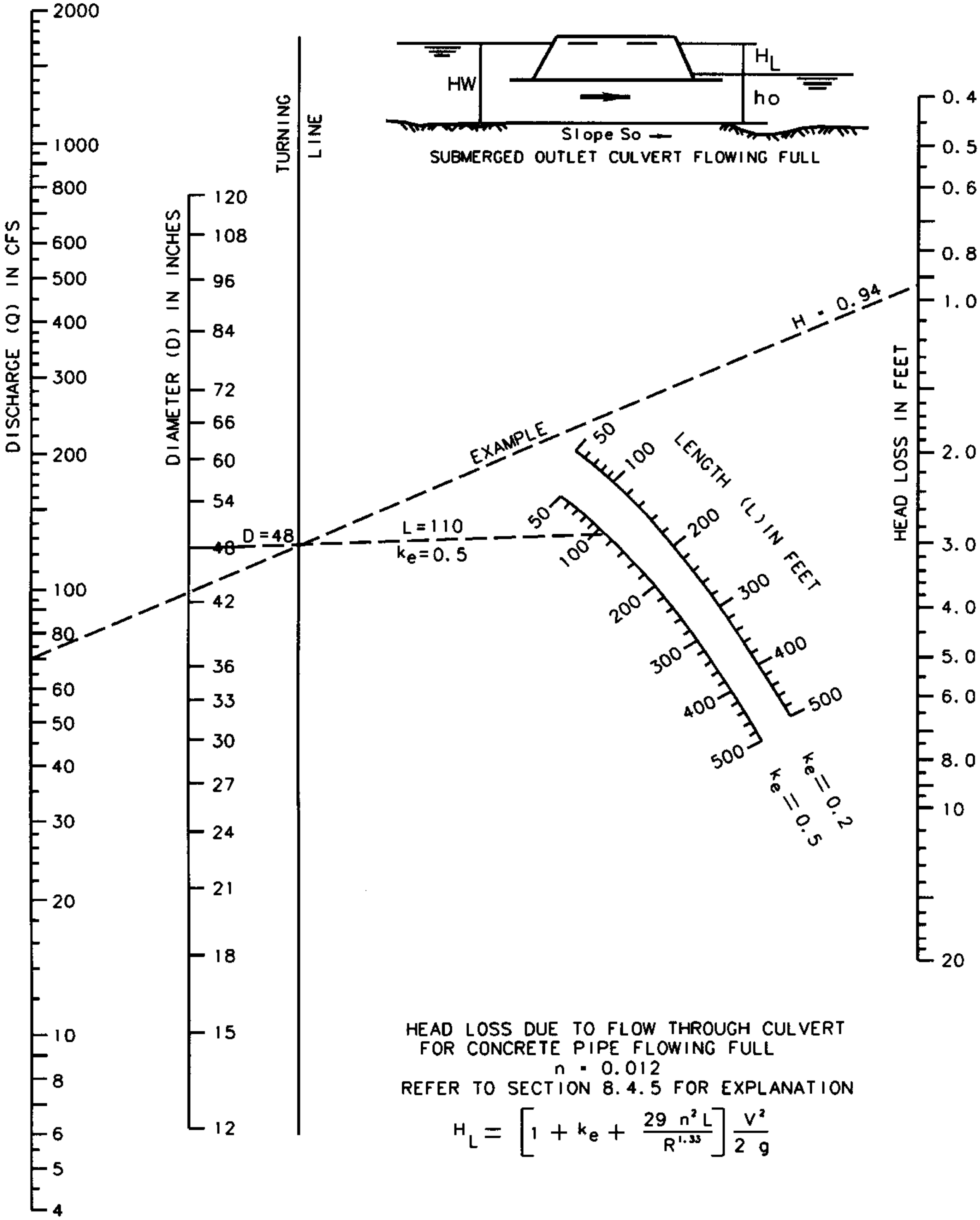
SEE TABLE 8-3 AND TABLE 8-4 FOR K, M, c, Y

REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-5

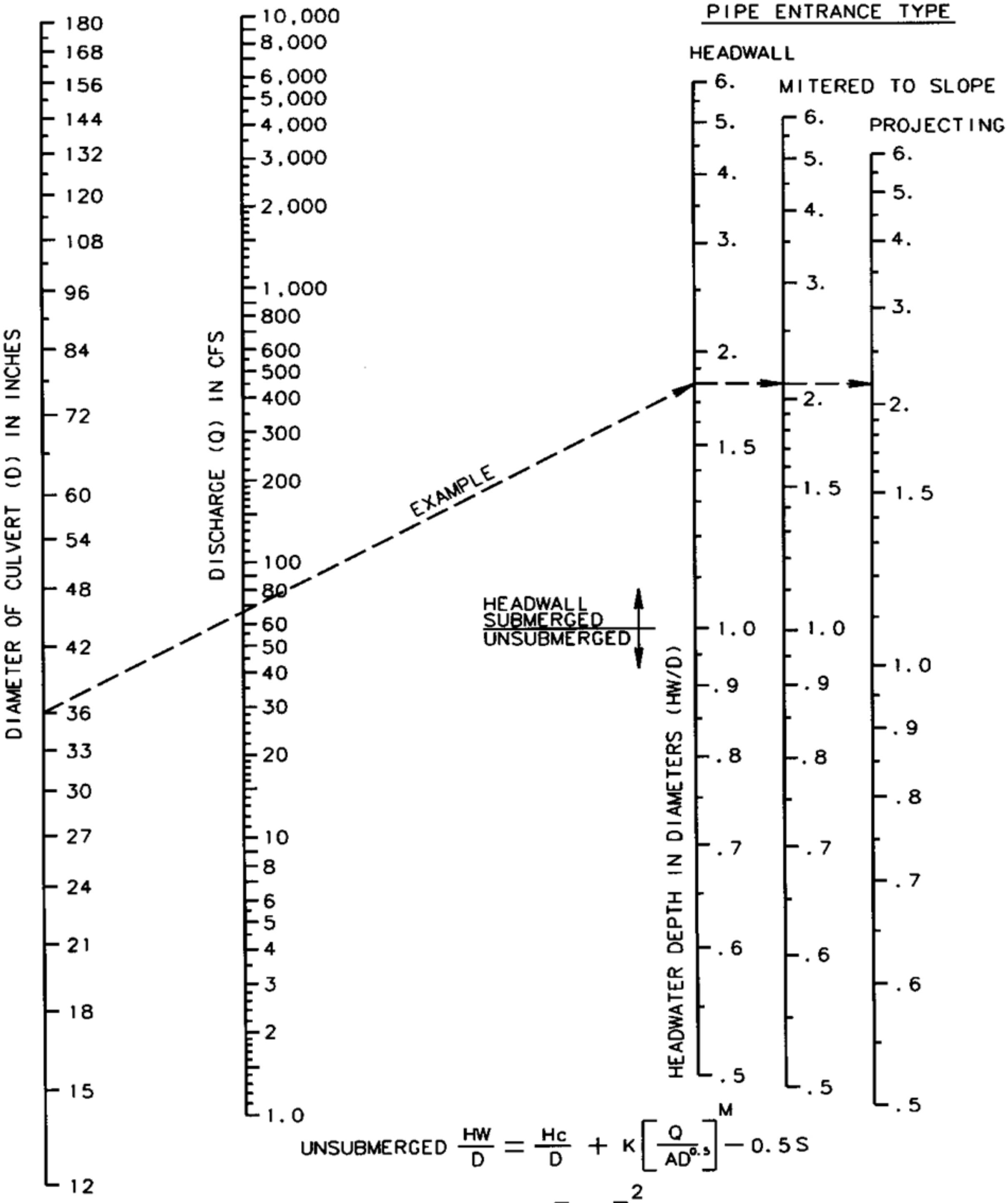
Concrete Pipe Flowing Full



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-6

HDPE Pipe Culverts with Inlet Control



UNSUBMERGED $\frac{HW}{D} = \frac{Hc}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^{M} - 0.5S$

SUBMERGED $\frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^{2} + Y - 0.5S$

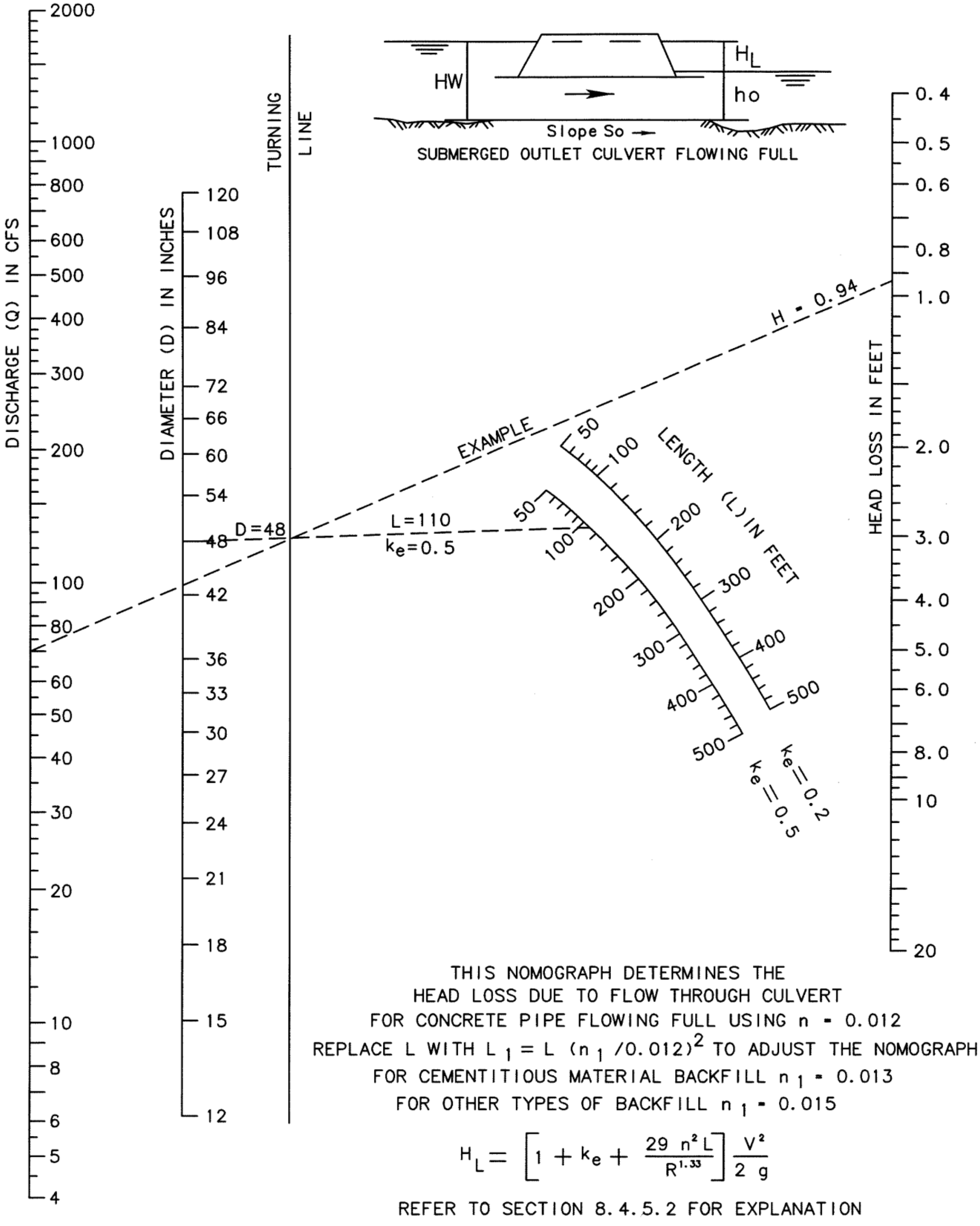
SEE TABLE 8-3 AND TABLE 8-4 FOR K, M, c, Y

REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-7

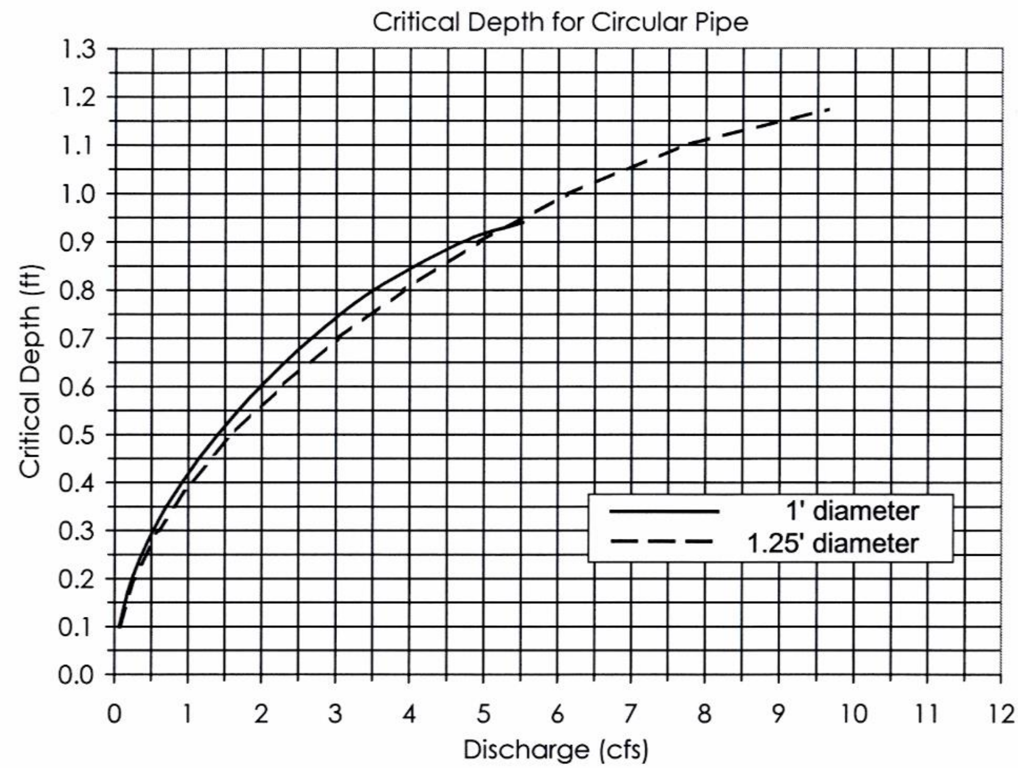
HDPE Pipe Flowing Full

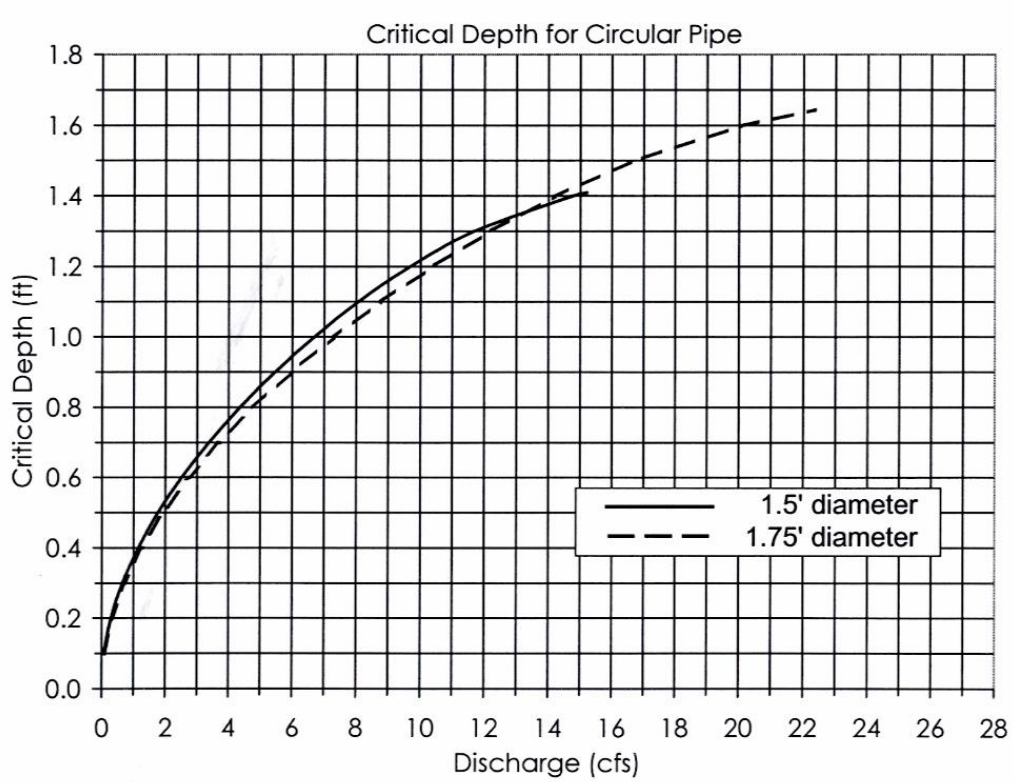


Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-8

Critical Depth for Circular Pipe

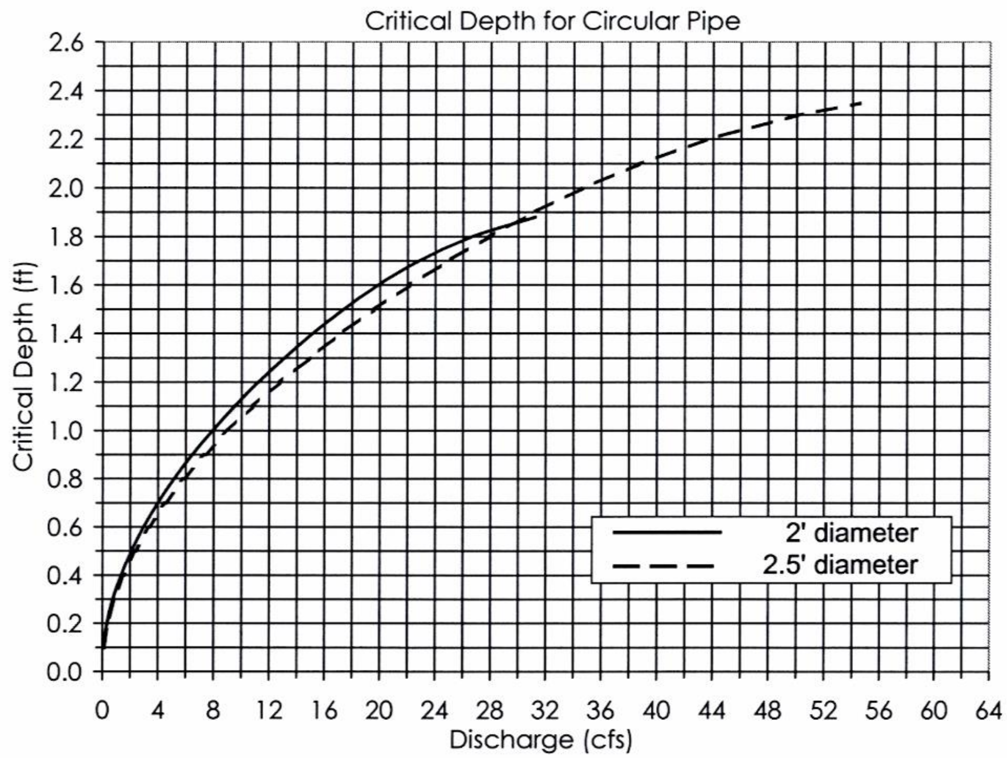


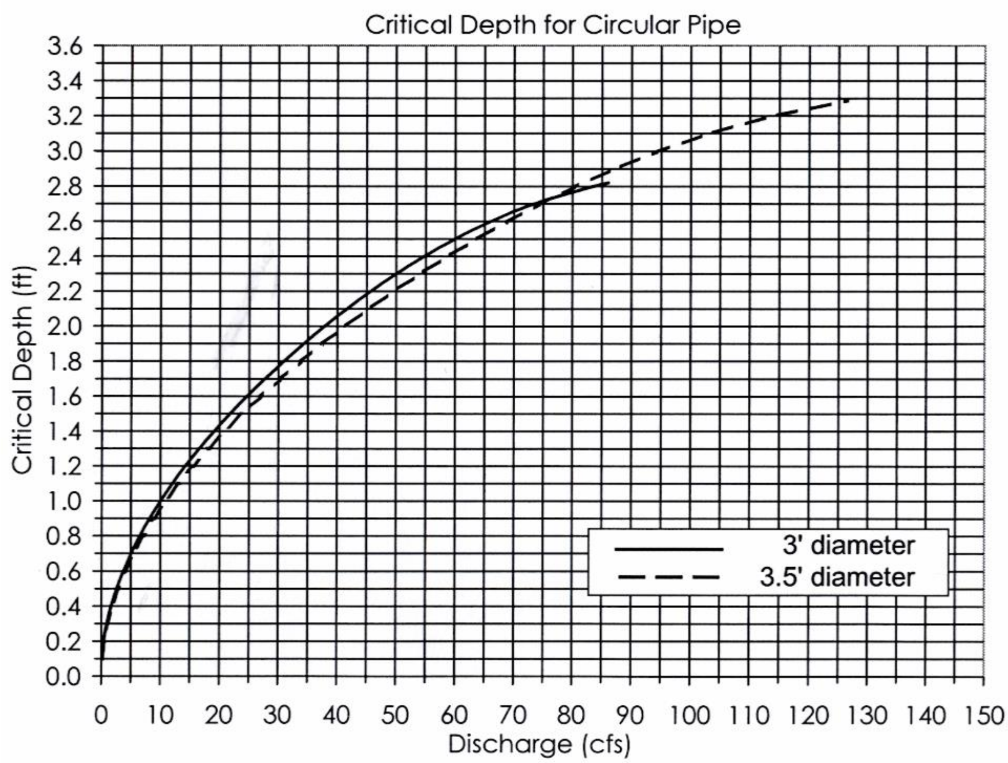


Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-9

Critical Depth for Circular Pipe

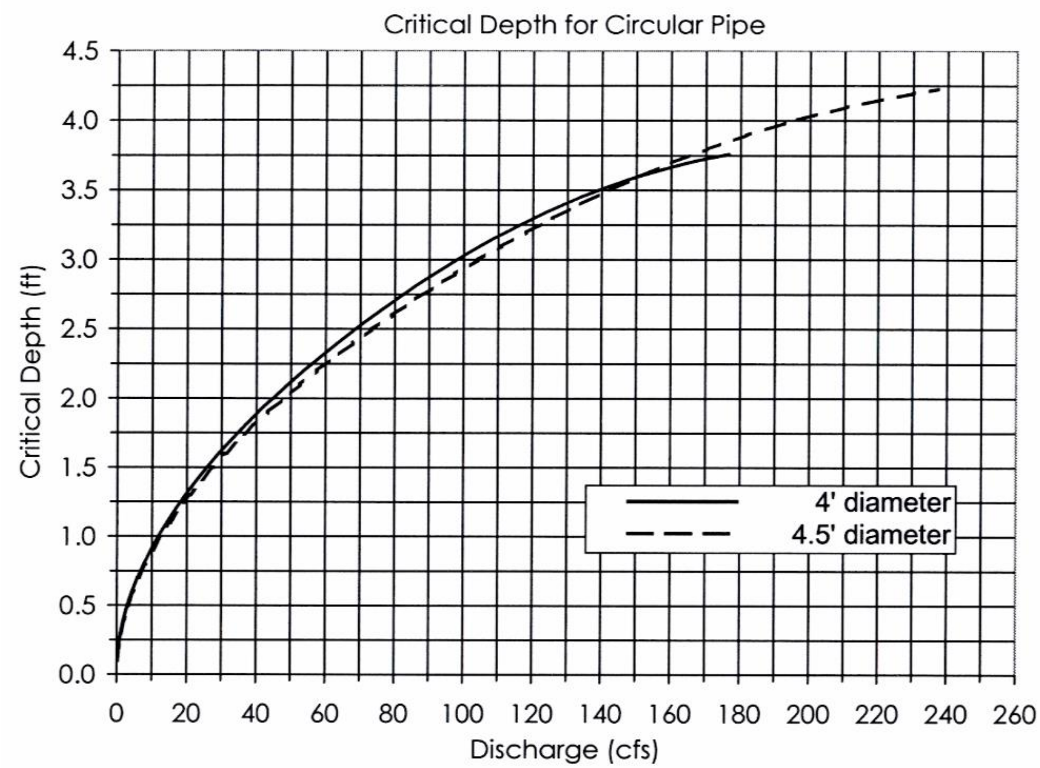


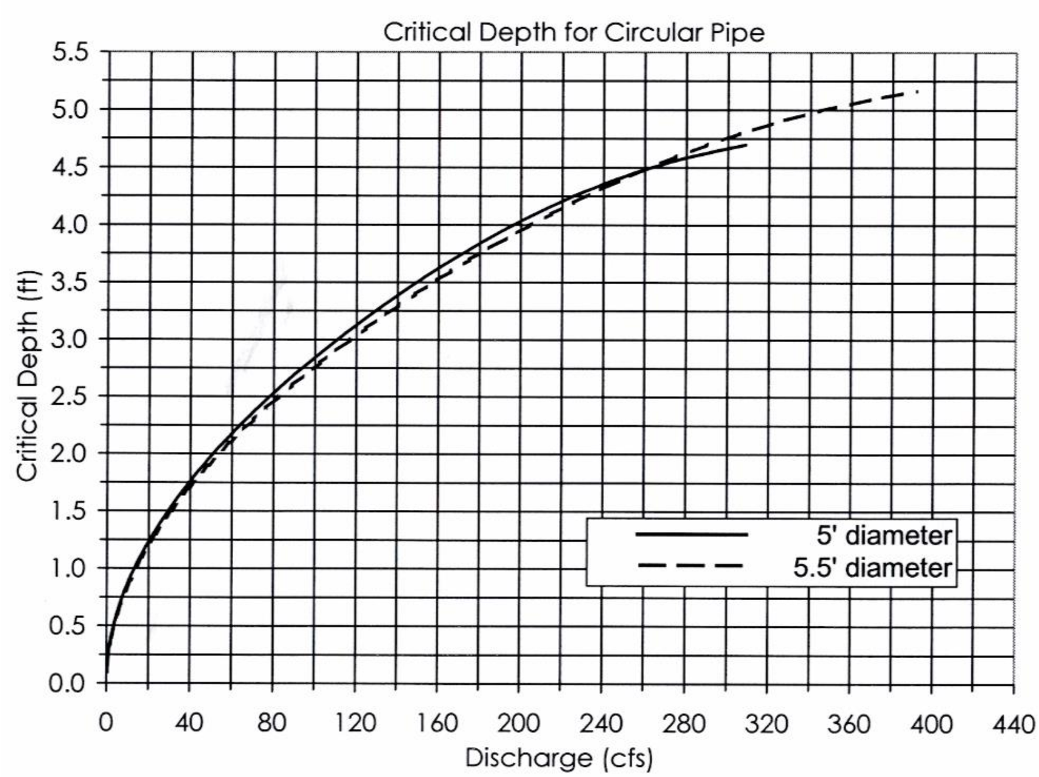


Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-10

Critical Depth for Circular Pipe

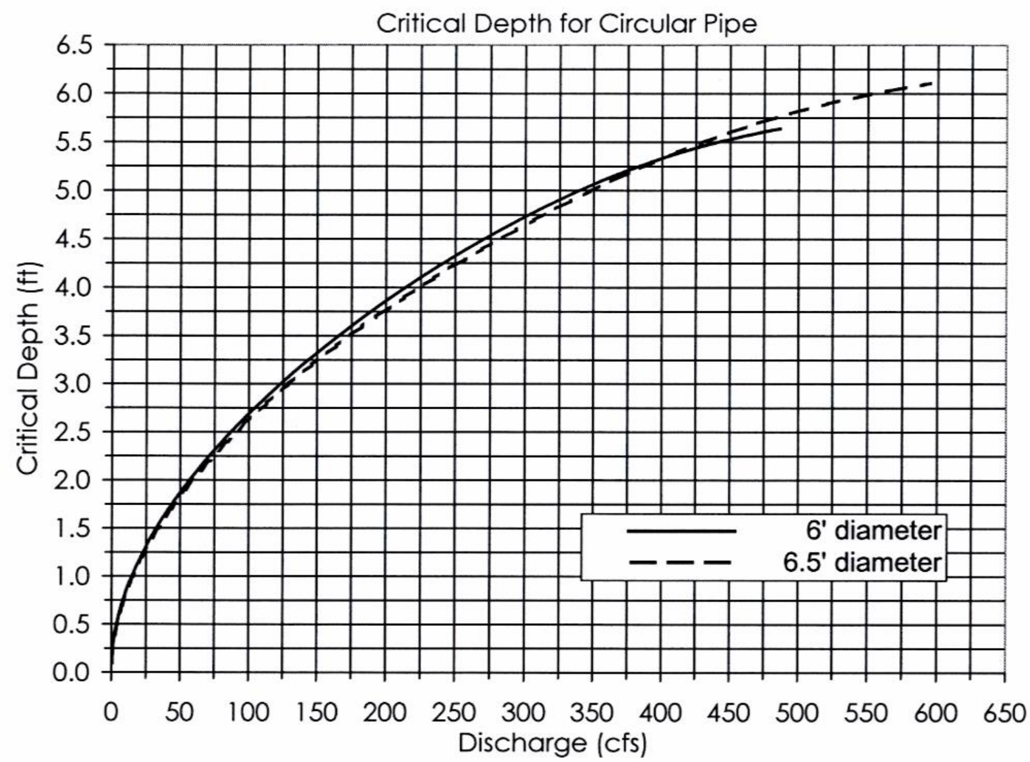


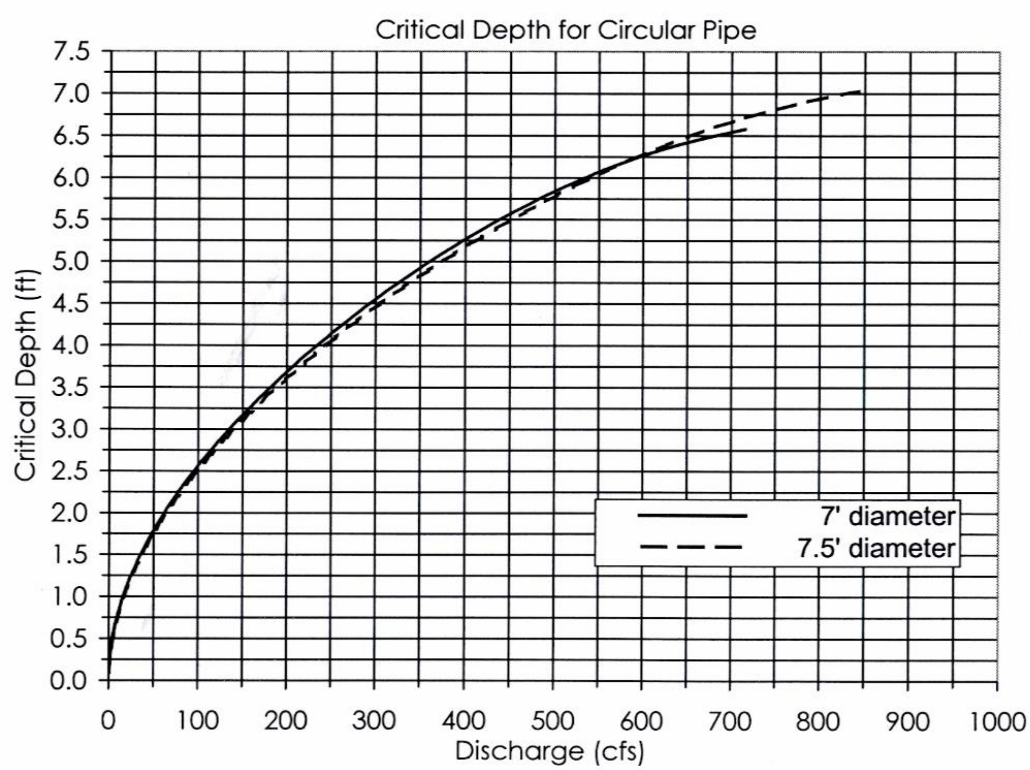


Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-11

Critical Depth for Circular Pipe

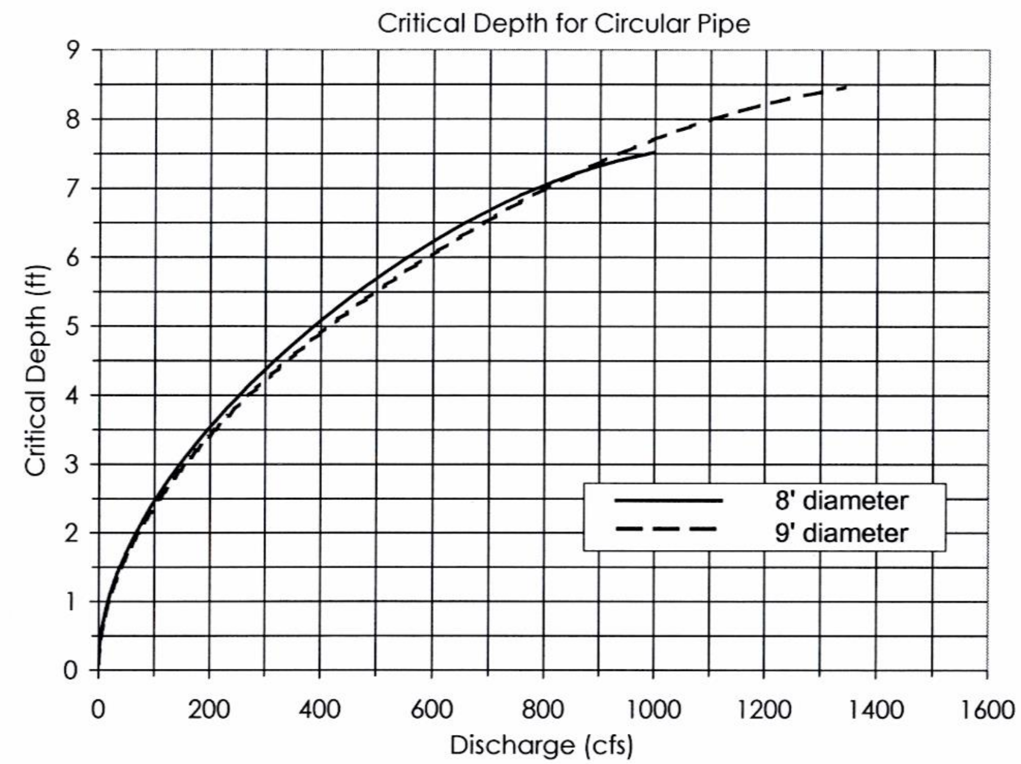


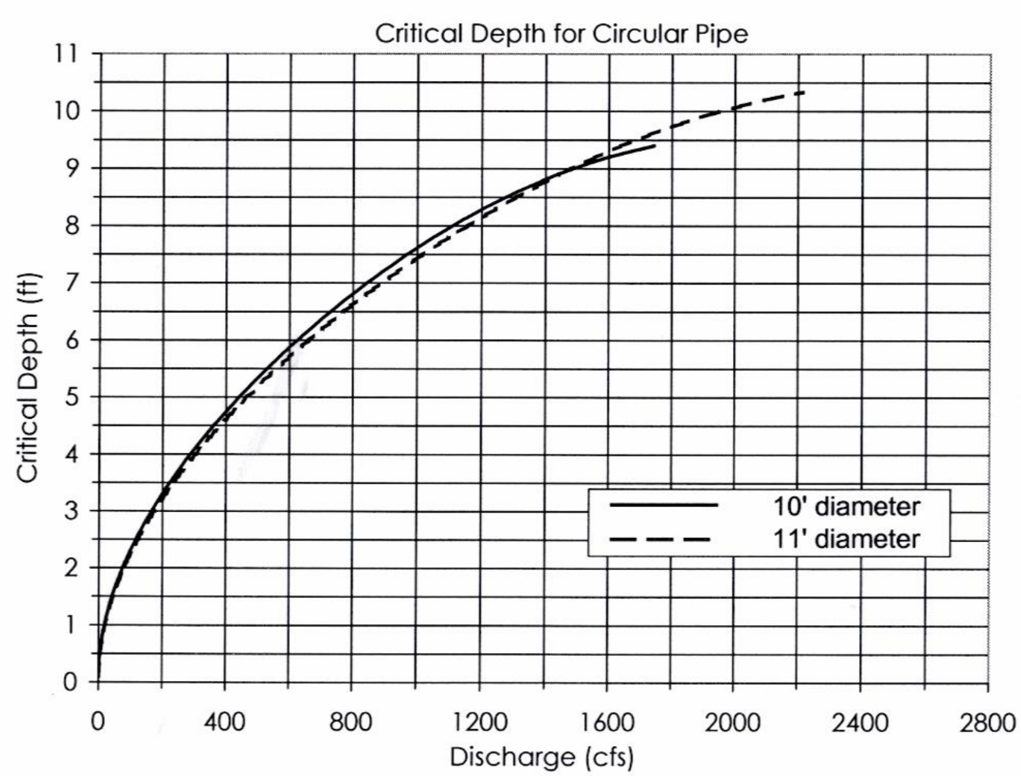


Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-12

Critical Depth for Circular Pipe

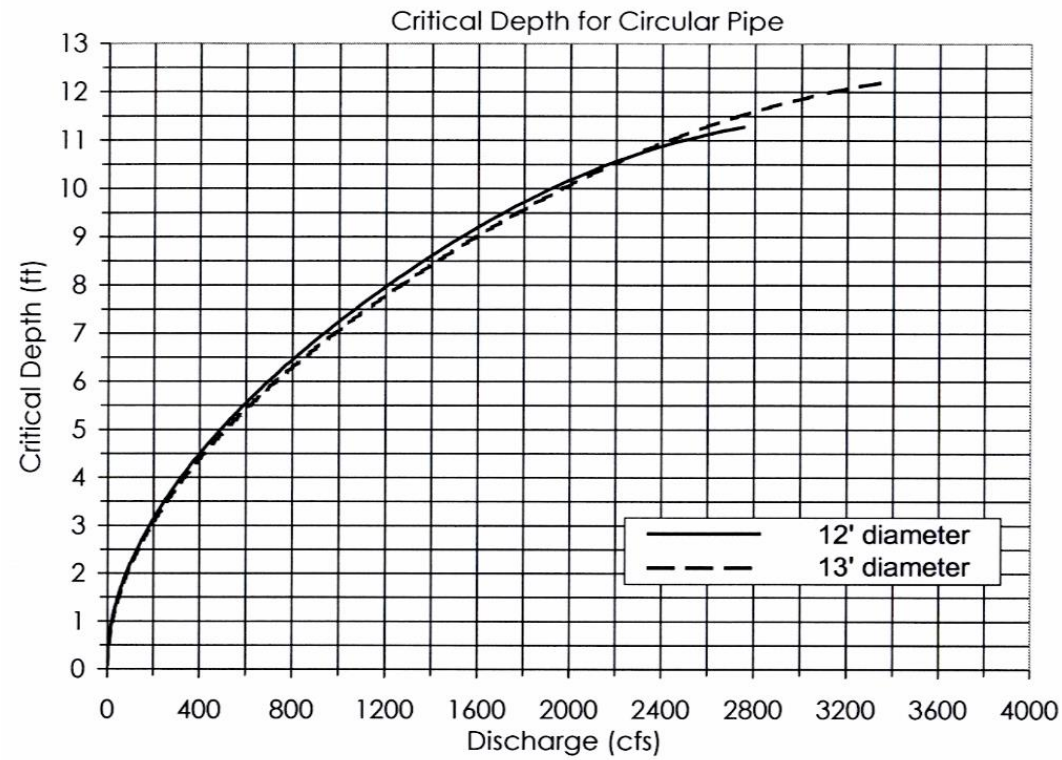


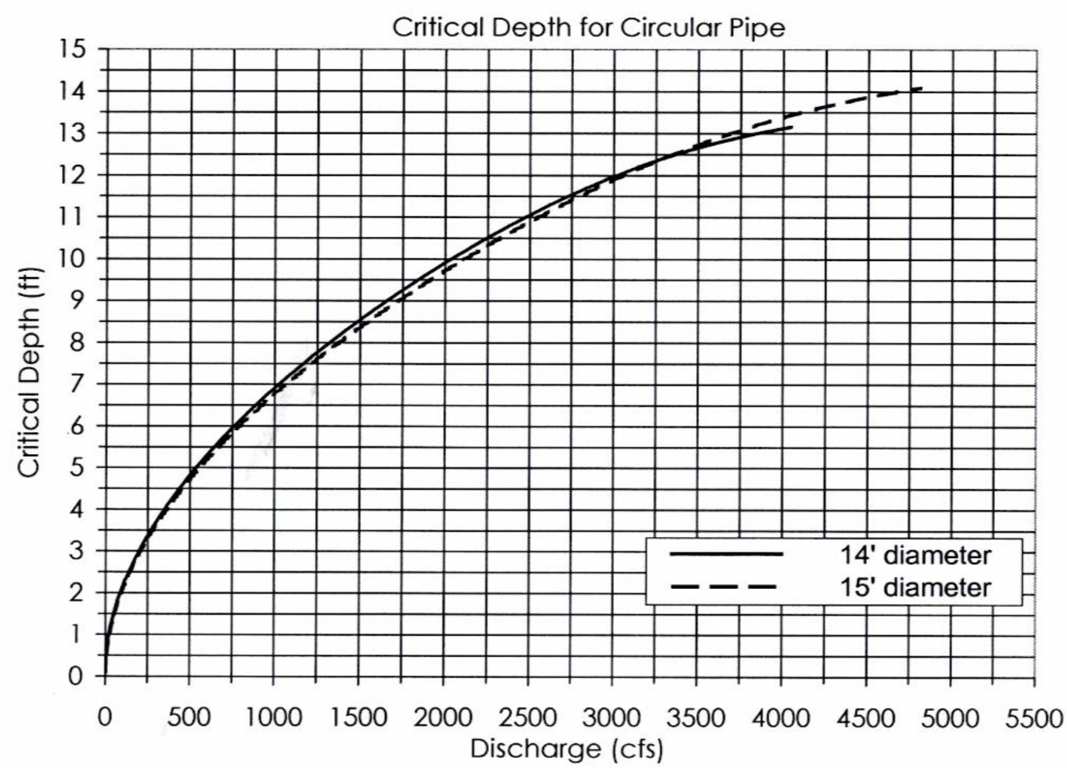


Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-13

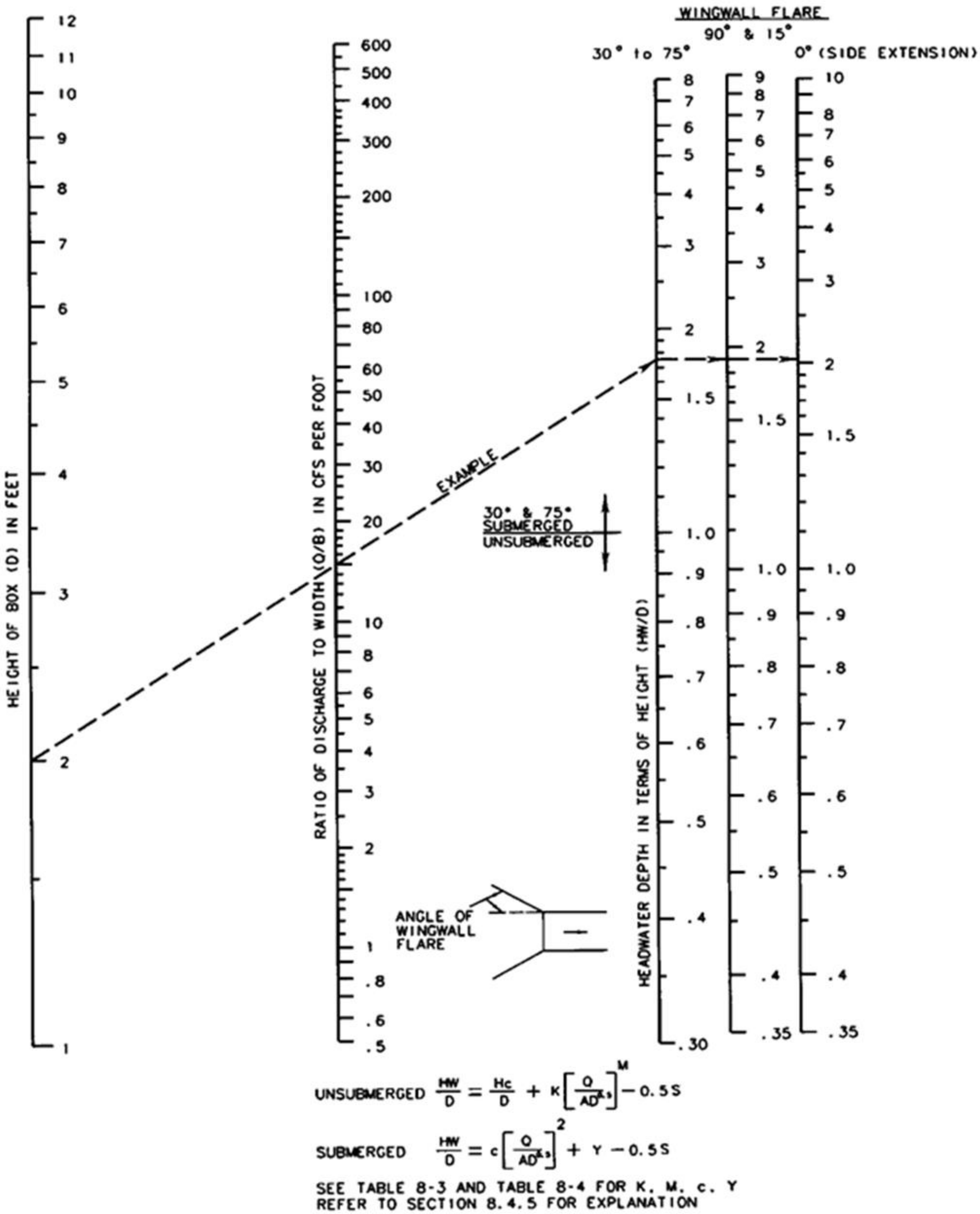
Critical Depth for Circular Pipe





Created by the WVDOH Hydraulic and Drainage Unit

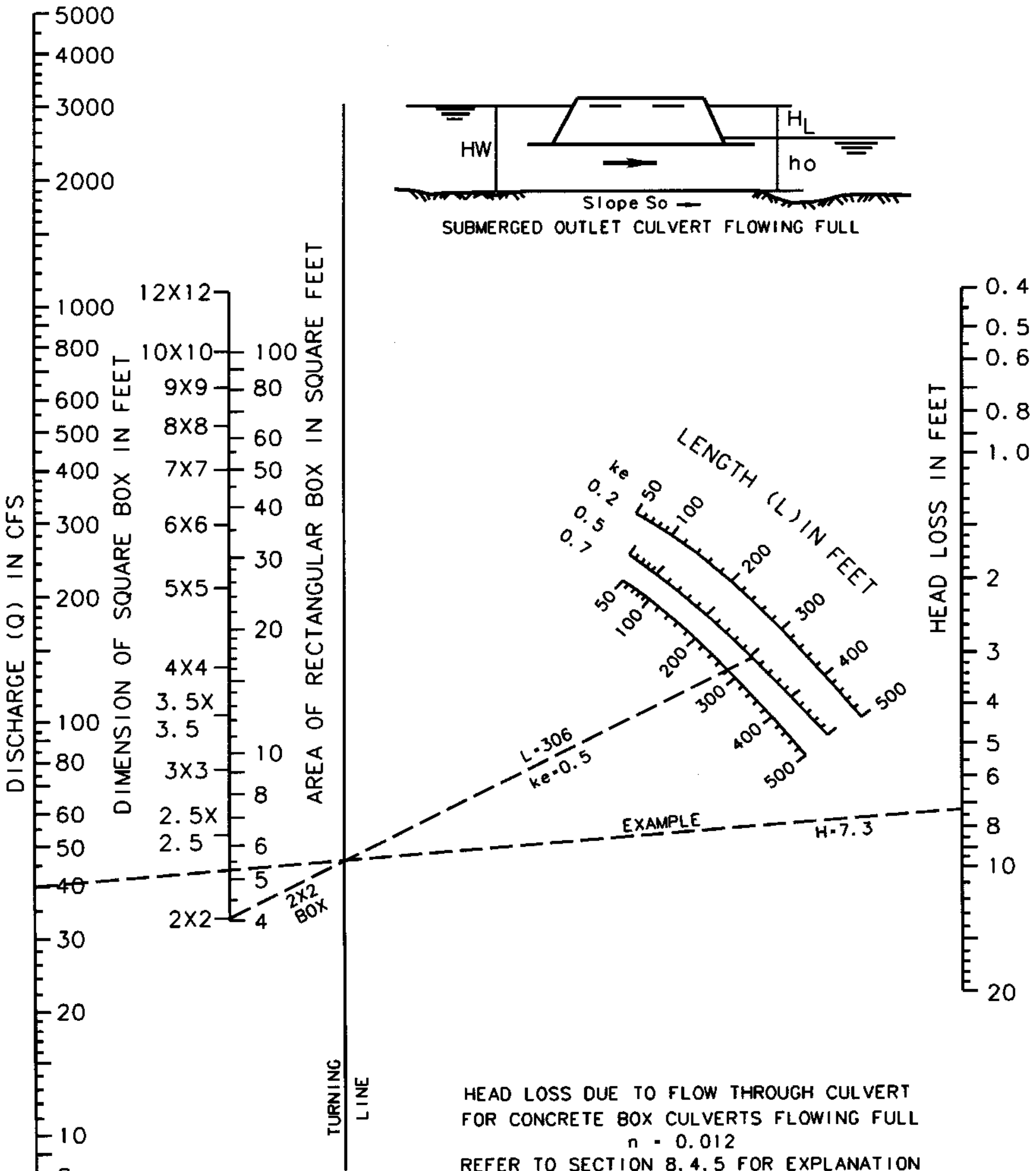
Chart 8-14
Box Culverts with Inlet Control



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-15

Concrete Box Culverts Flowing Full

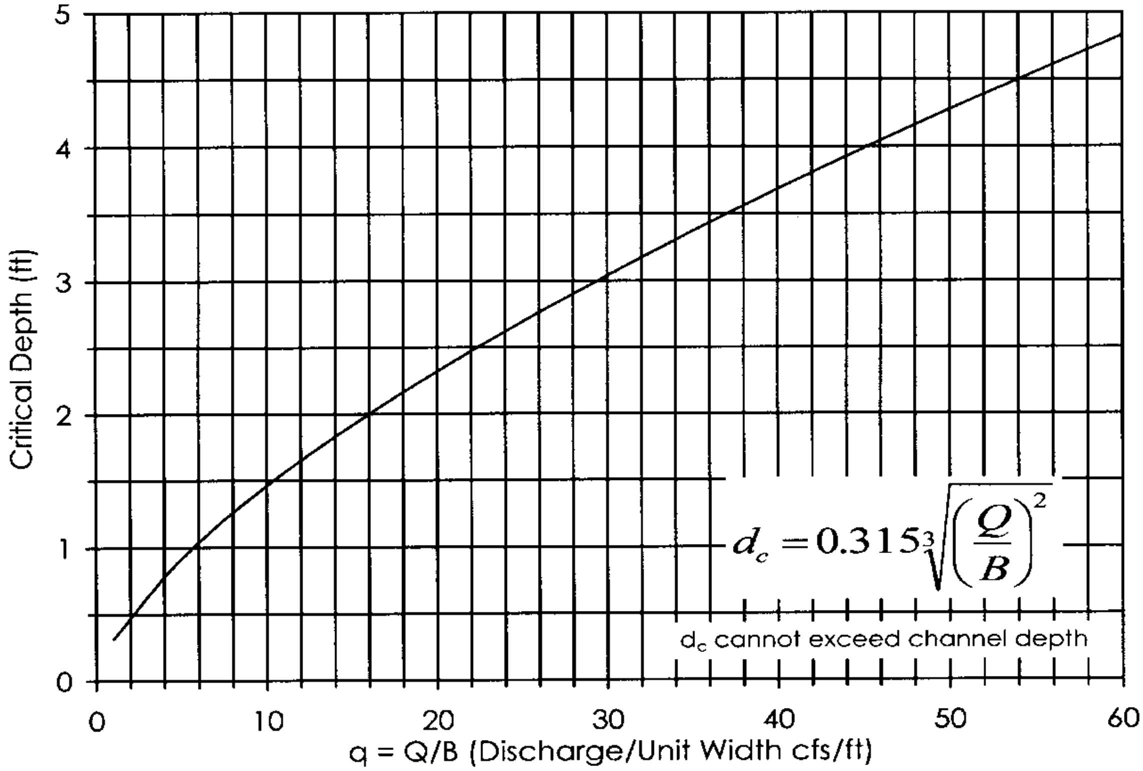


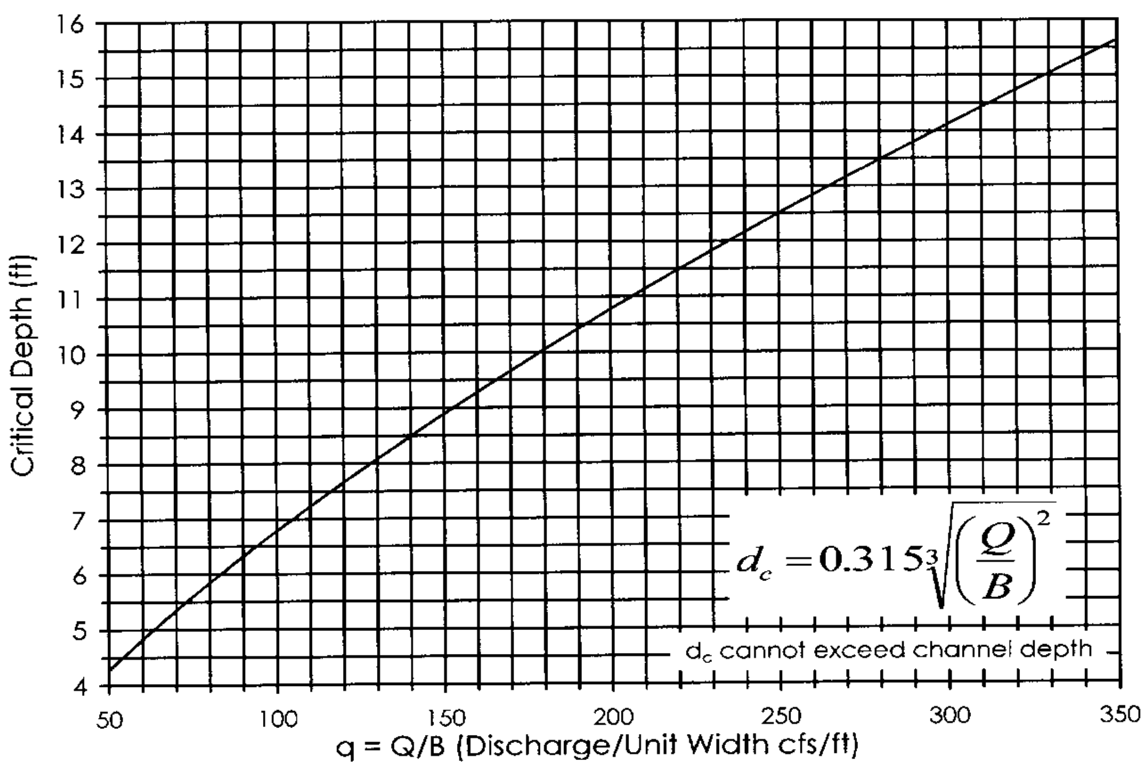
$$H_L = \left[1 + k_e + \frac{29\, n^2 L}{R^{1.33}}\right] \frac{V^2}{2g}$$

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-16

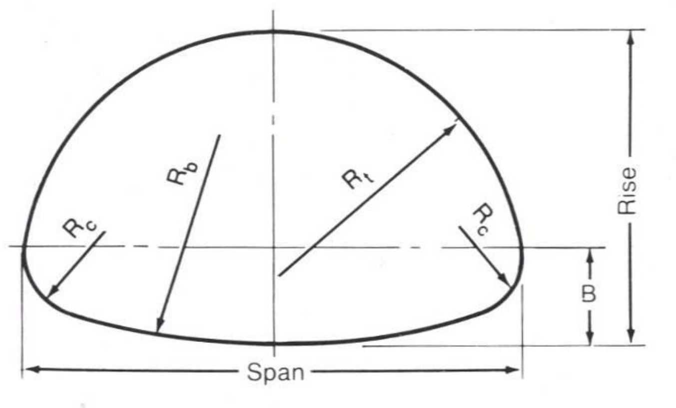
Critical Depth for Box Culverts





Created by the WVDOH Hydraulic and Drainage Unit

Chart 8-17
Standard Arch Pipe Details

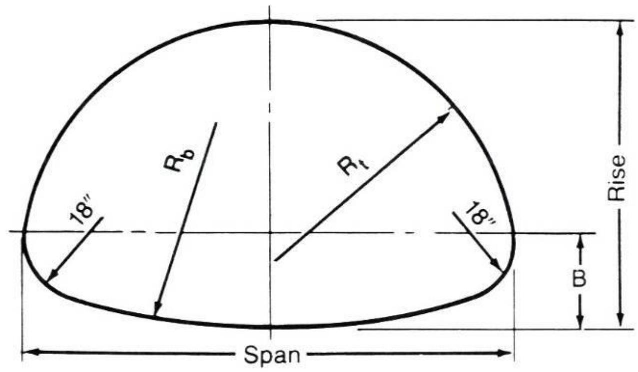


Corrugated Steel Pipe Arch												
NOMINAL SIZE	Rise			Span			Corrugation	Area	B	R_c	R_t	R_b
	in	ft	ft - in	in	ft	ft - in	in x in	ft^2	in	in	in	in
13 x 17	13	1.08	1 - 1.0	17	1.42	1 - 5.0	2 2/3 x 1/2	1.1	4 1/8	3 1/2	8 5/8	25 5/8
15 x 21	15	1.25	1 - 3.0	21	1.75	1 - 9.0	2 2/3 x 1/2	1.6	4 7/8	4 1/8	10 3/4	33 1/8
18 x 24	18	1.50	1 - 6.0	24	2.00	2 - 0.0	2 2/3 x 1/2	2.2	5 7/8	4 7/8	11 7/8	34 5/8
20 x 28	20	1.67	1 - 8.0	28	2.33	2 - 4.0	2 2/3 x 1/2	2.9	6 1/2	5 1/2	14	42 1/4
24 x 35	24	2.00	2 - 0.0	35	2.92	2 - 11.0	2 2/3 x 1/2	4.5	8 1/8	6 7/8	17 7/8	55 1/8
29 x 42	29	2.42	2 - 5.0	42	3.50	3 - 6.0	2 2/3 x 1/2	6.5	9 3/4	8 1/4	21 1/2	66 1/8
33 x 49	33	2.75	2 - 9.0	49	4.08	4 - 1.0	2 2/3 x 1/2	8.9	11 3/8	9 5/8	25 1/8	77 1/4
38 x 57	38	3.17	3 - 2.0	57	4.75	4 - 9.0	2 2/3 x 1/2	11.6	13	11	28 5/8	88 1/4
43 x 64	43	3.58	3 - 7.0	64	5.33	5 - 4.0	2 2/3 x 1/2	14.7	14 5/8	12 3/8	32 1/4	99 1/4
47 x 71	47	3.92	3 - 11.0	71	5.92	5 - 11.0	2 2/3 x 1/2	18.1	16 1/4	13 3/4	35 3/4	110 1/4
52 x 77	52	4.33	4 - 4.0	77	6.42	6 - 5.0	2 2/3 x 1/2	21.9	17 7/8	15 1/8	39 3/8	121 1/4
57 x 83	57	4.75	4 - 9.0	83	6.92	6 - 11.0	2 2/3 x 1/2	26.0	19 1/2	16 1/2	43	132 1/4
41 x 53	41	3.42	3 - 5	53	4.42	4 - 5	3 x 1 or 5 x 1	11.7	15 1/4	10 3/16	28 1/16	73 7/16
46 x 60	48 1/2	4.04	4 - 1/2	58 1/2	4.88	4 - 10 1/2	3 x 1 or 5 x 1	15.6	20 1/2	18 3/4	29 3/8	51 1/8
51 x 66	54	4.50	4 - 6	65	5.42	5 - 5	3 x 1 or 5 x 1	19.3	22 3/4	20 3/4	32 5/8	56 1/4
55 x 73	58 1/4	4.85	4 - 10 1/4	72 1/2	6.04	6 - 1/2	3 x 1 or 5 x 1	23.2	25 1/8	22 7/8	36 3/4	63 3/4
59 x 81	62 1/2	5.21	5 - 2 1/2	79	6.58	6 - 7	3 x 1 or 5 x 1	27.4	23 3/4	20 7/8	39 1/2	82 5/8
63 x 87	67 1/4	5.60	5 - 7 1/4	86 1/2	7.21	7 - 2 1/2	3 x 1 or 5 x 1	32.1	25 3/4	22 5/8	43 3/8	92 1/4
67 x 95	71 3/4	5.98	5 - 11 3/4	93 1/2	7.79	7 - 9 1/2	3 x 1 or 5 x 1	37.0	27 3/4	24 3/8	47	100 1/4
71 x 103	76	6.33	6 - 4	101 1/2	8.46	8 - 5 1/2	3 x 1 or 5 x 1	42.4	29 3/4	26 1/8	51 1/4	111 5/8
75 x 112	80 1/2	6.71	6 - 8 1/2	108 1/2	9.04	9 - 1/2	3 x 1 or 5 x 1	48.0	31 5/8	27 3/4	54 7/8	120 1/4
79 x 117	84 3/4	7.06	7 - 3/4	116 1/2	9.71	9 - 8 1/2	3 x 1 or 5 x 1	54.2	33 5/8	29 1/2	59 3/8	131 3/4
83 x 128	89 1/4	7.44	7 - 5 1/4	123 1/2	10.29	10 - 3 1/2	3 x 1 or 5 x 1	60.5	35 5/8	31 1/4	63 1/4	139 3/4
87 x 137	93 3/4	7.81	7 - 9 3/4	131	10.92	10 - 11	3 x 1 or 5 x 1	67.4	37 5/8	33	67 3/8	149 1/2
91 x 142	98	8.17	8 - 2	138 1/2	11.54	11 - 6 1/2	3 x 1 or 5 x 1	74.5	39 1/2	34 3/4	71 5/8	162 3/8
96 x 150	102	8.50	8 - 6	146	12.17	12 - 2	3 x 1 or 5 x 1	81.0	41	36	76	172
101 x 157	107	8.92	8 - 11	153	12.75	12 - 9	3 x 1 or 5 x 1	89.0	43	38	80	180
105 x 164	113	9.42	9 - 5	159	13.25	13 - 3	3 x 1 or 5 x 1	98.0	45	40	82	184
110 x 171	118 1/2	9.88	9 - 10 1/2	165	13.75	13 - 9	3 x 1 or 5 x 1	107.0	47	41	85	190

Source: Handbook of Steel Drainage Products, American Iron & Steel Inst., 1994

Chart 8-18

Arch Pipe with 18-inch Corner Radius Details

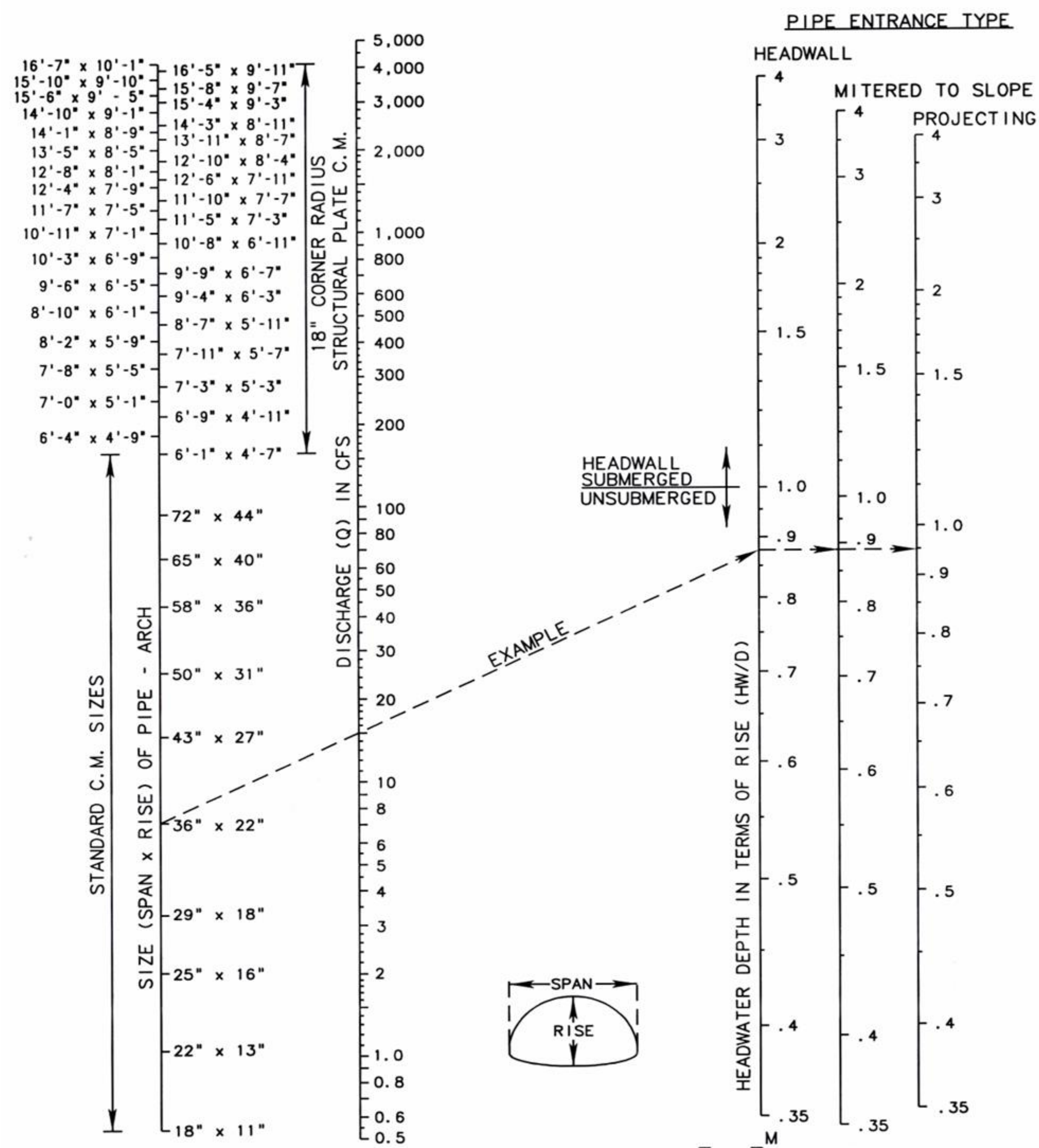


Corrugated Steel Pipe Arch 18 inch corner radius											
Rise			Span			Corrugation	Area	B	R_c	R_t	R_b
in	ft	ft - in	in	ft	ft - in	in x in	ft^2	in	in	ft	ft
55	4.58	4 - 7.0	73	6.08	6 - 1.0	6 x 2	22	21.0	18	3.07	6.36
57	4.75	4 - 9.0	76	6.33	6 - 4.0	6 x 2	24	20.5	18	3.18	8.22
59	4.92	4 - 11.0	81	6.75	6 - 9.0	6 x 2	26	22.0	18	3.42	6.96
61	5.08	5 - 1.0	84	7.00	7 - 0.0	6 x 2	28	21.4	18	3.53	8.68
63	5.25	5 - 3.0	87	7.25	7 - 3.0	6 x 2	31	20.8	18	3.63	11.35
65	5.42	5 - 5.0	92	7.67	7 - 8.0	6 x 2	33	22.4	18	3.88	9.15
67	5.58	5 - 7.0	95	7.92	7 - 11.0	6 x 2	35	21.7	18	3.98	11.49
69	5.75	5 - 9.0	98	8.17	8 - 2.0	6 x 2	38	20.9	18	4.08	15.24
71	5.92	5 - 11.0	103	8.58	8 - 7.0	6 x 2	40	22.7	18	4.33	11.75
73	6.08	6 - 1.0	106	8.83	8 - 10.0	6 x 2	43	21.8	18	4.42	14.89
75	6.25	6 - 3.0	112	9.33	9 - 4.0	6 x 2	46	23.8	18	4.68	12.05
77	6.42	6 - 5.0	114	9.50	9 - 6.0	6 x 2	49	22.9	18	4.78	14.79
79	6.58	6 7.0	117	9.75	9 9.0	6 x 2	52	21.9	18	4.86	18.98
81	6.75	6 - 9	123	10.25	10 - 3	6 x 2	55	23.9	18	5.13	14.86
83	6.92	6 - 11	128	10.67	10 - 8	6 x 2	58	26.1	18	5.41	12.77
85	7.08	7 - 1	131	10.92	10 - 11	6 x 2	61	25.1	18	5.49	15.03
87	7.25	7 - 3	137	11.42	11 - 5	6 x 2	64	27.4	18	5.78	13.16
89	7.42	7 - 5	139	11.58	11 - 7	6 x 2	67	26.3	18	5.85	15.27
91	7.58	7 - 7	142	11.83	11 - 10	6 x 2	71	25.2	18	5.93	18.03
93	7.75	7 - 9	148	12.33	12 - 4	6 x 2	74	27.5	18	6.23	15.54
95	7.92	7 - 11	150	12.50	12 - 6	6 x 2	78	26.4	18	6.29	18.07
97	8.08	8 - 1	152	12.67	12 - 8	6 x 2	81	25.2	18	6.37	21.45
100	8.33	8 - 4	154	12.83	12 - 10	6 x 2	85	24.0	18	6.44	26.23
101	8.42	8 - 5	161	13.42	13 - 5	6 x 2	89	26.3	18	6.73	21.23
103	8.58	8 - 7	167	13.92	13 - 11	6 x 2	93	28.9	18	7.03	18.39
105	8.75	8 - 9	169	14.08	14 - 1	6 x 2	97	27.6	18	7.09	21.18
107	8.92	8 - 11	171	14.25	14 - 3	6 x 2	101	26.3	18	7.16	24.80
109	9.08	9 - 1	178	14.83	14 - 10	6 x 2	105	28.9	18	7.47	21.19
111	9.25	9 - 3	184	15.33	15 - 4	6 x 2	109	31.6	18	7.78	18.90
113	9.42	9 - 5	186	15.50	15 - 6	6 x 2	113	30.2	18	7.83	21.31
115	9.58	9 7	188	15.67	15 8	6 x 2	118	28.8	18	7.89	24.29
118	9.83	9 10	190	15.83	15 10	6 x 2	122	27.4	18	7.96	28.18
119	9.92	9 11	197	16.42	16 5	6 x 2	126	30.1	18	8.27	24.24
121	10.08	10 1	199	16.58	16 7	6 x 2	131	28.7	18	8.33	27.73

Source: Handbook of Steel Drainage Products, American Iron & Steel Inst., 1994

Chart 8-19

Standard C.M. Pipe Arch Culverts with Inlet Control



UNSUBMERGED $\frac{HW}{D} = \frac{Hc}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^{M} - 0.5S$

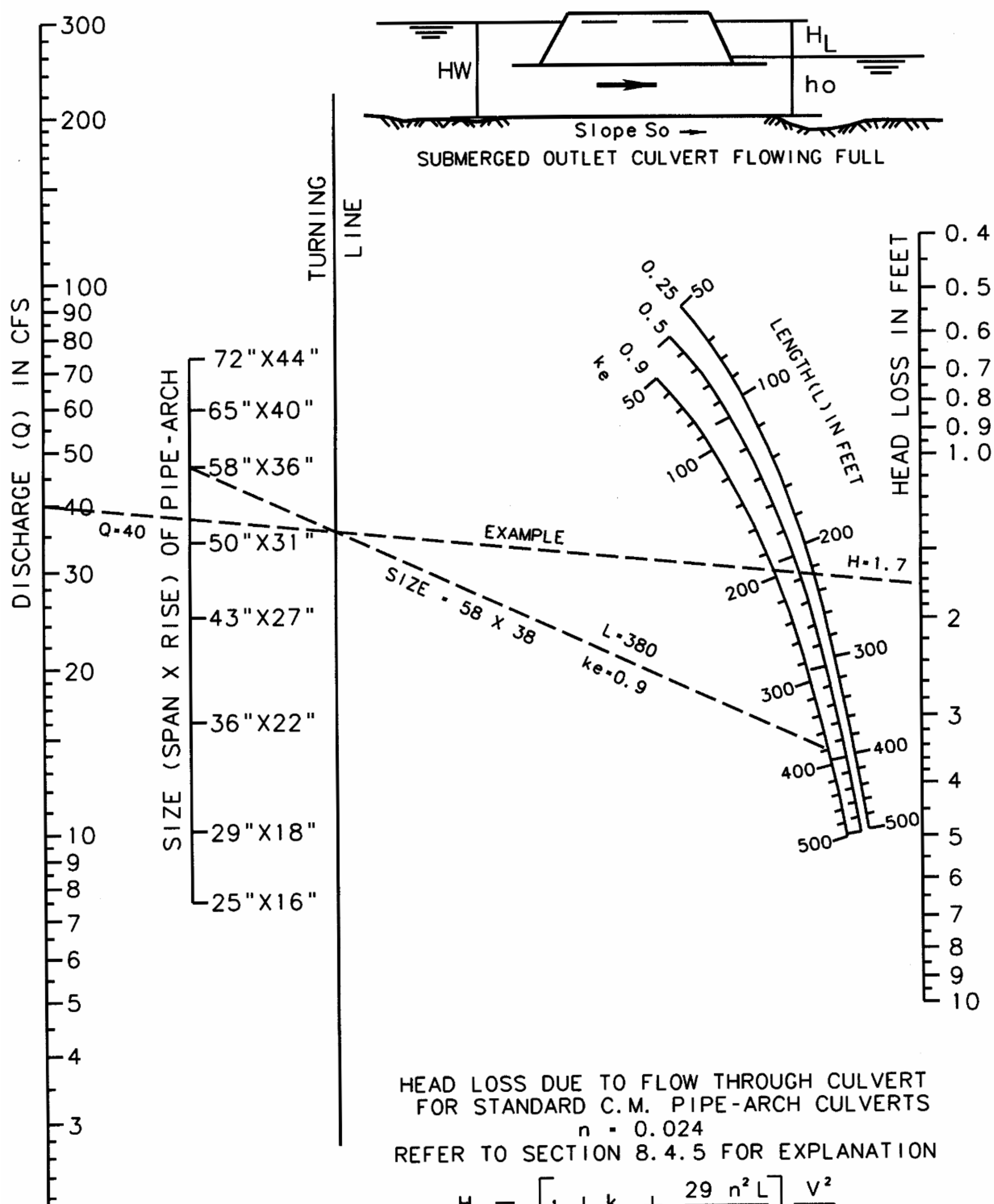
SUBMERGED $\frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^{2} + Y - 0.5S$

SEE TABLE 8-3 AND TABLE 8-4 FOR K, M, c, Y
REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-20

Standard C.M. Pipe Arch Flowing Full

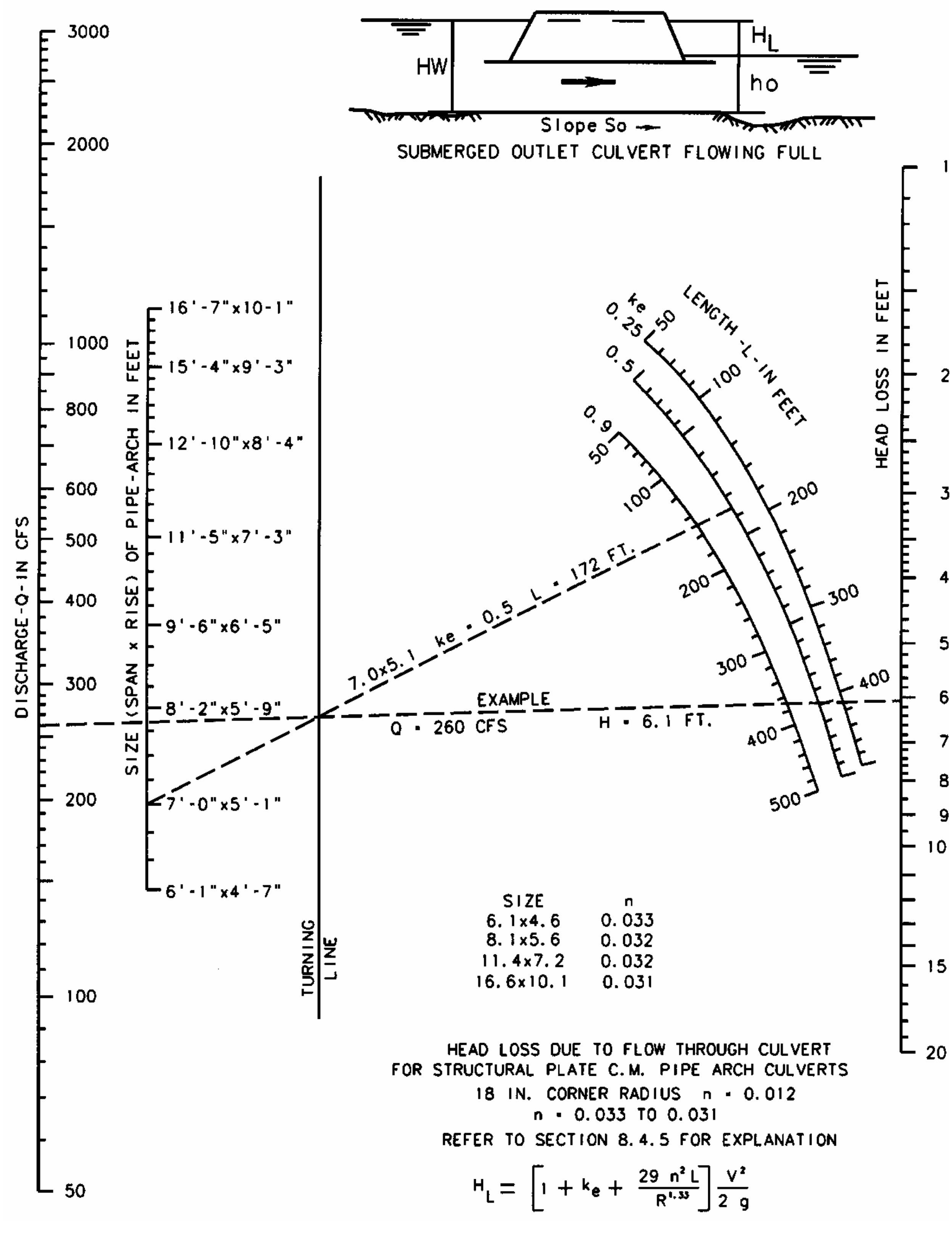


$$H_L = \left[1 + k_e + \frac{29\ n^2 L}{R^{1.33}}\right] \frac{V^2}{2g}$$

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-21

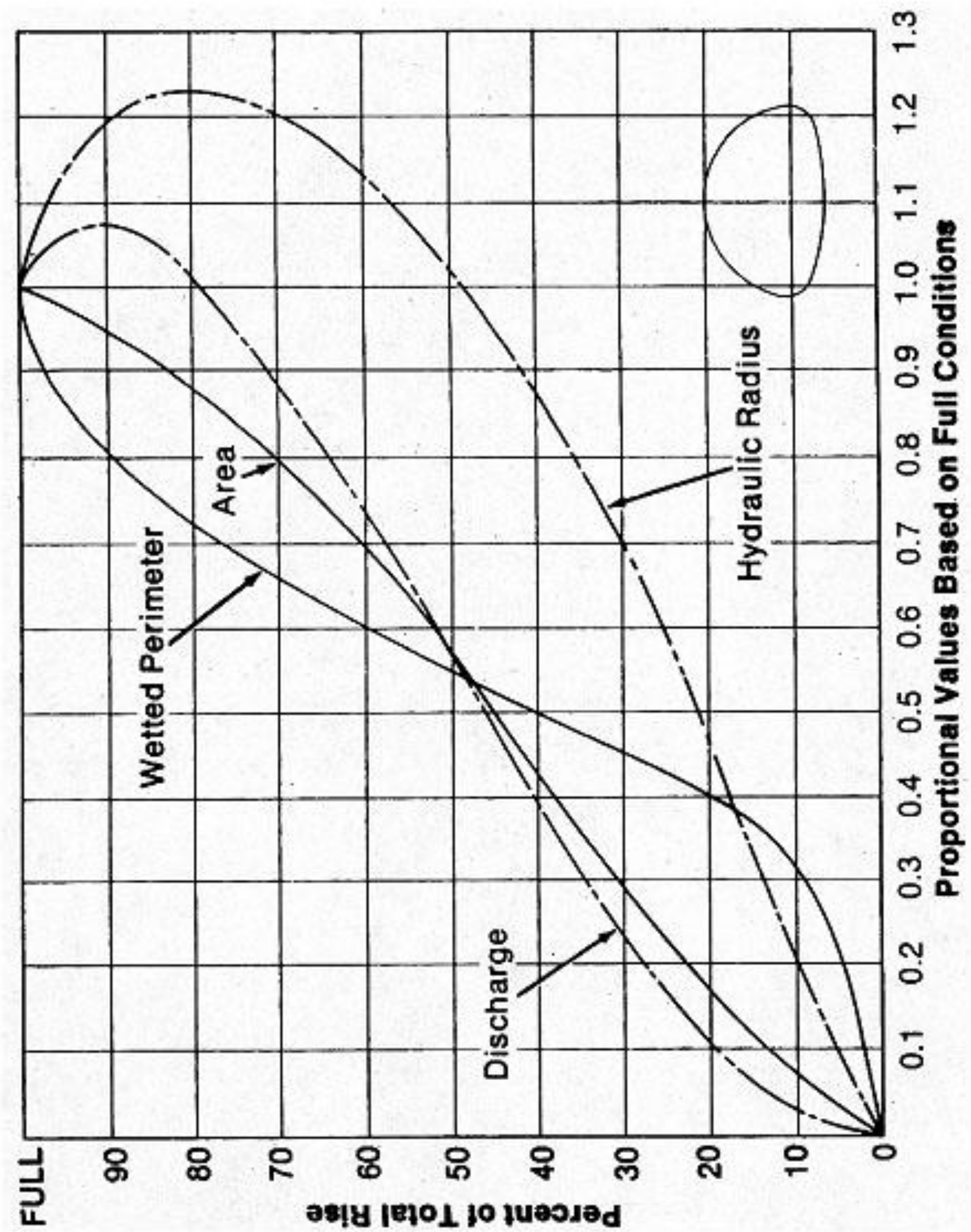
Str. Plate Pipe Arch (18” corner rad.) Flowing Full



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-22

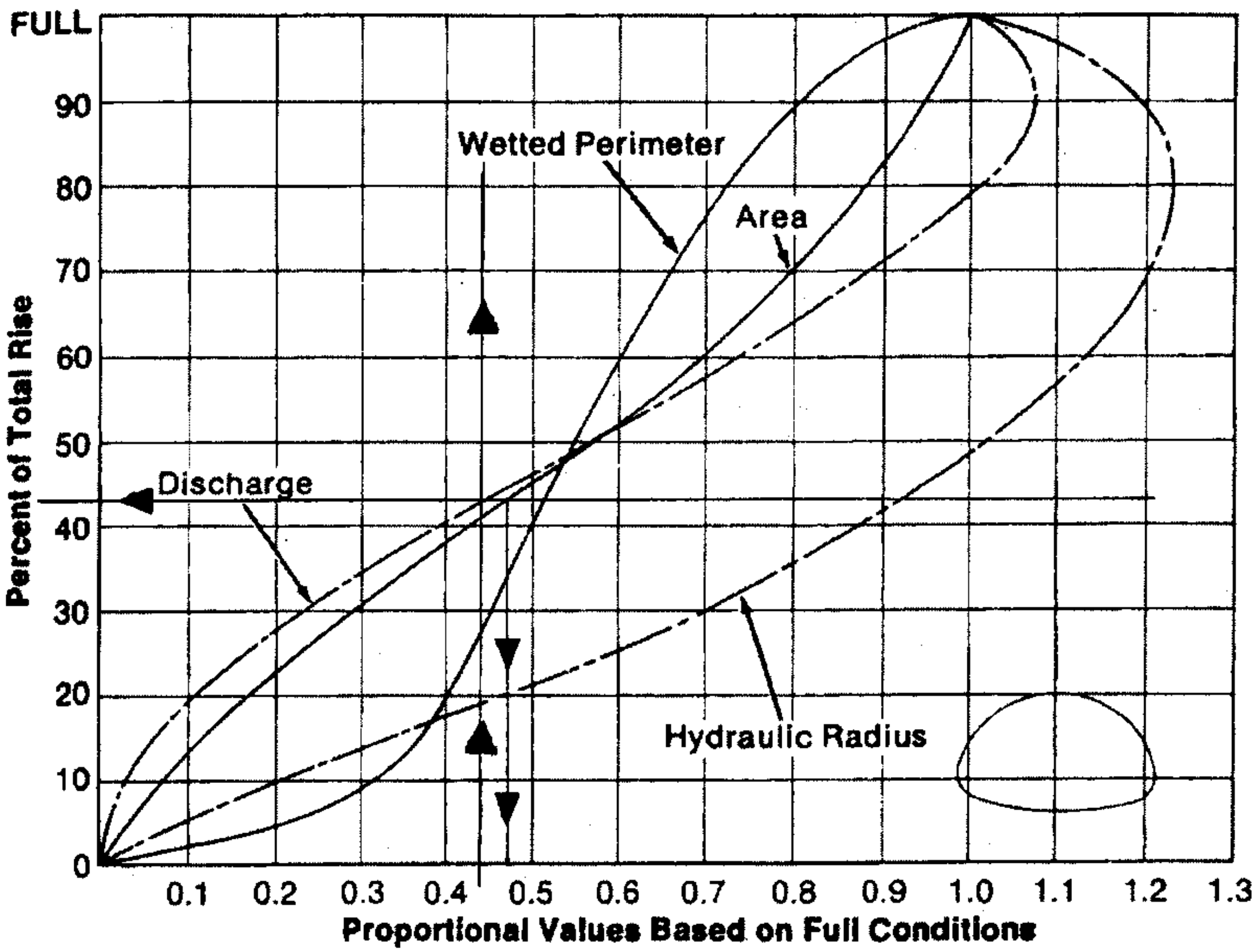
Hydraulic Elements for Partially Full C.M. Pipe Arch



Source: Handbook of Steel Drainage Products, American Iron & Steel Inst., 1994

Chart 8-23

Hydraulic Elements for Partially Full C.M. Pipe Arch Example



24 X 35 pipe, n = 0.024, Slope = 0.02, $Q_{full} / S^{0.5}$ = 192 (Table 8-5)

Given: D_{full} = 24 in, Q = 12 cfs

$Q_{full} = 192*(0.02)^{0.5} = 27.2$ cfs

Required: depth at Q, velocity at Q

Solution: $Q / Q_{full} = 12/27.2 = 0.44$

From figure for hydraulic elements, $d / d_{full} = 0.435$

$d = d_{full} \times 0.435 = 10.4$ in

From figure for hydraulic elements, $A / A_{full} = 0.465$ (A_{full} from Table 8-5)

$A = A_{full} \times 0.465 = 2.1$ ft^2

$V = Q / A = 12 / 2.1 = 5.7$ ft/s

Table 8-5

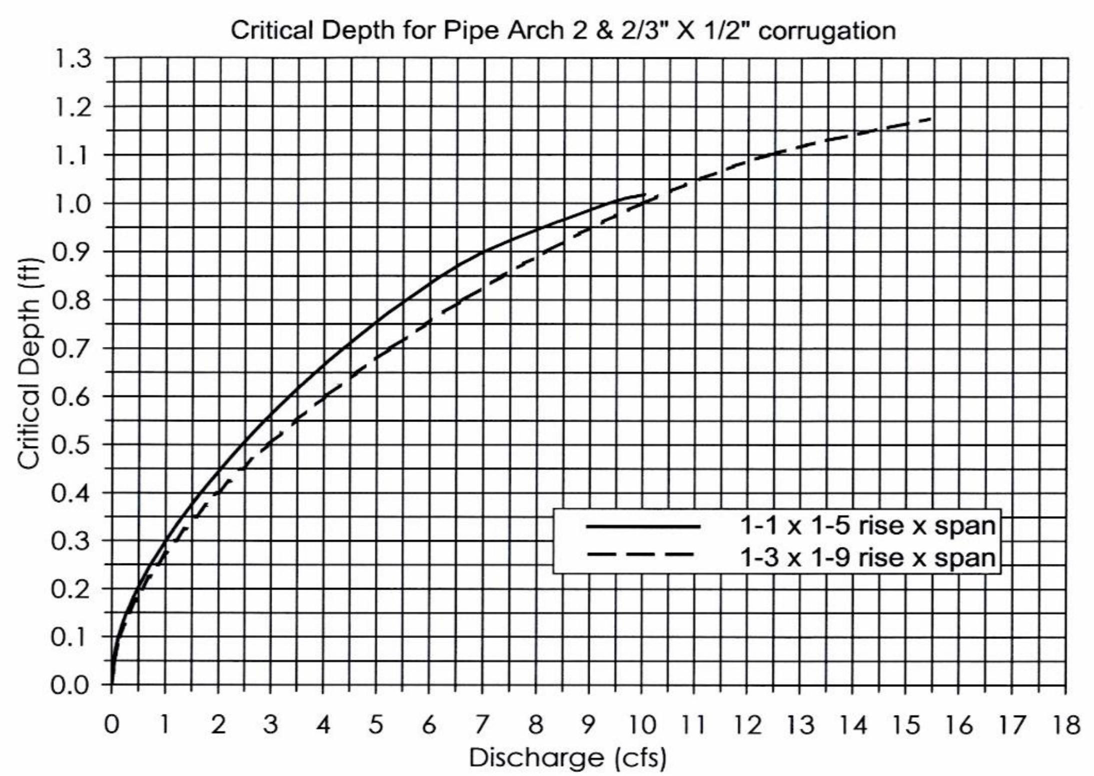
Full Flow Values for C.M. Pipe Arch

Pipe Size Rise X Span	Corrugations	Equivalent Full Flow Area for Circular Diameter inches	A Area ft^2	R Hydraulic Radius ft	Value of Full Flow Conveyance K $\frac{Q}{\sqrt{S}} = \frac{1.486}{n} A R^{\frac{2}{3}}$		
					n = 0.024	n = 0.027	n = 0.033
13" X 17"	2 2/3 X 1/2	15	1.1	0.280	29	26	21
15" X 21"	2 2/3 X 1/2	18	1.6	0.340	48	43	35
18" X 24"	2 2/3 X 1/2	21	2.2	0.400	74	66	54
20" X 28"	2 2/3 X 1/2	24	2.9	0.462	107	95	78
24" X 35"	2 2/3 X 1/2	30	4.5	0.573	192	171	140
29" X 42"	2 2/3 X 1/2	36	6.5	0.690	314	279	229
33" X 49"	2 2/3 X 1/2	42	8.9	0.810	479	426	348
38" X 57"	2 2/3 X 1/2	48	11.6	0.924	681	606	496
43" X 64"	2 2/3 X 1/2	54	14.7	1.040	934	830	679
46" X 60"	3 X 1	54	15.6	1.104	1032	917	750
51" X 66"	3 X 1	60	19.3	1.230	1372	1219	998
55" X 73"	3 X 1	66	23.2	1.343	1749	1554	1272
59" X 81"	3 X 1	72	27.4	1.454	2177	1935	1584
63" X 87"	3 X 1	78	32.1	1.573	2688	2390	1955
67" X 95"	3 X 1	84	37.0	1.683	3241	2881	2357
71" X 103"	3 X 1	90	42.4	1.800	3885	3453	2825
75" X 112"	3 X 1	96	48.0	1.911	4577	4068	3329
4'-7" X 6'-1"	6 X 2		22.1	1.298	1628	1447	1184
5'-1" X 7'-0"	6 X 2		28.4	1.463	2266	2014	1648
5'-5" X 7'-8"	6 X 2		32.9	1.565	2746	2441	1997
5'-9" X 8'-2"	6 X 2		37.7	1.670	3286	2921	2390
6'-1" X 8'-10"	6 X 2		42.9	1.776	3895	3463	2833
6'-5" X 9'-6"	6 X 2		48.5	1.881	4576	4067	3328
6'-7" X 9'-9"	6 X 2		51.2	1.930	4914	4368	3574
7'-3" X 11'-5"	6 X 2		64.0	2.145	6591	5859	4793
8'-1" X 12'-8"	6 X 2		81.0	2.390	8965	7969	6520
8'-4" X 12'-10"	6 X 2		85.5	2.465	9660	8587	7026

Source: American Concrete Pipe Association Publication

Chart 8-24

Critical Depth for Pipe Arch 2-2/3 x 1/2 in. Corrugation



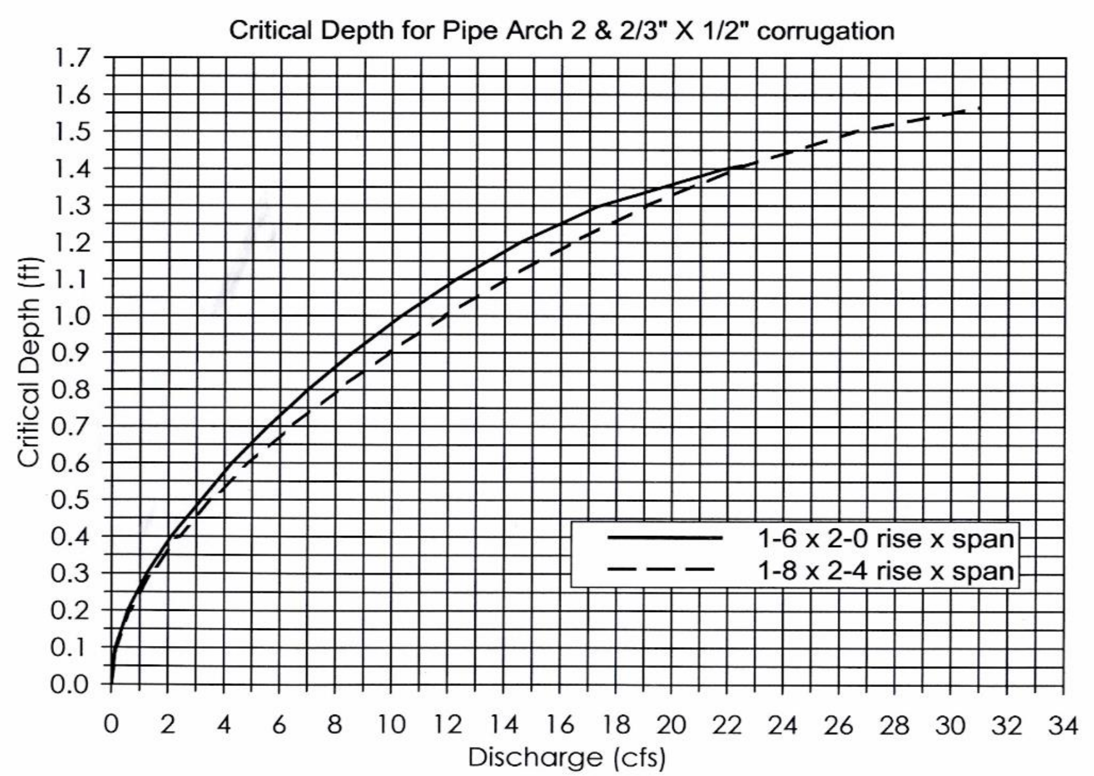


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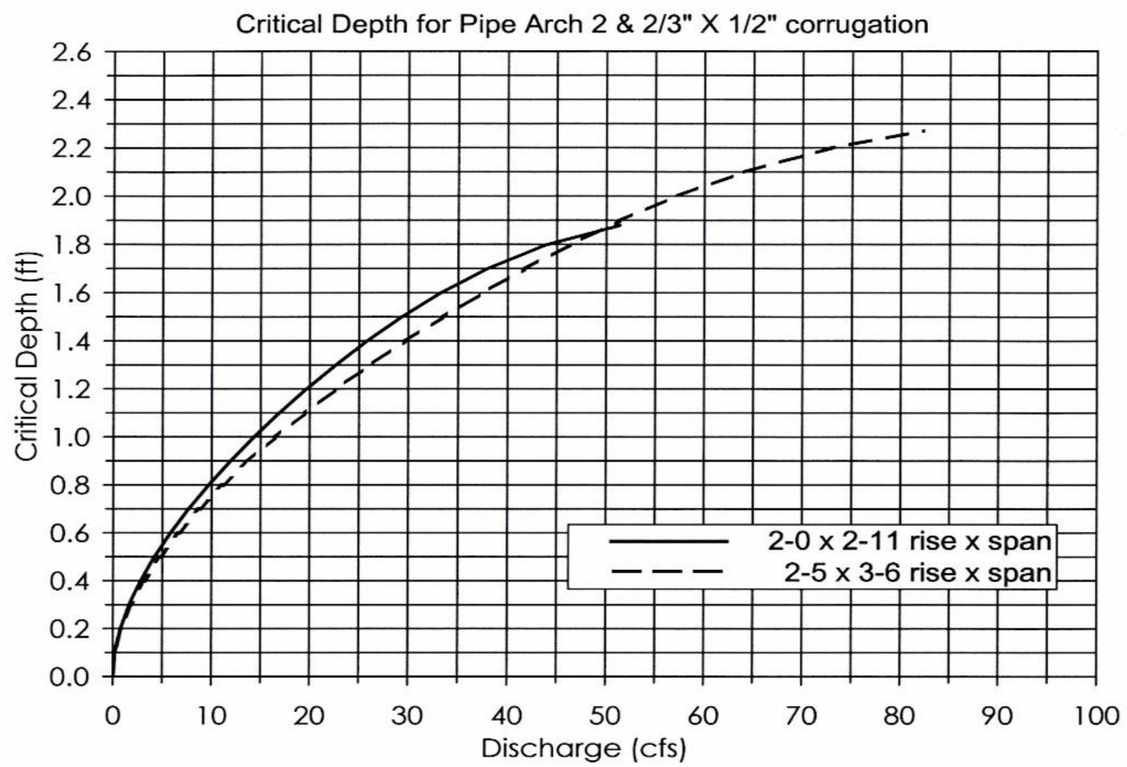
Chart 8-25

Critical Depth for Pipe Arch 2-2/3 x 1/2 in. Corrugation



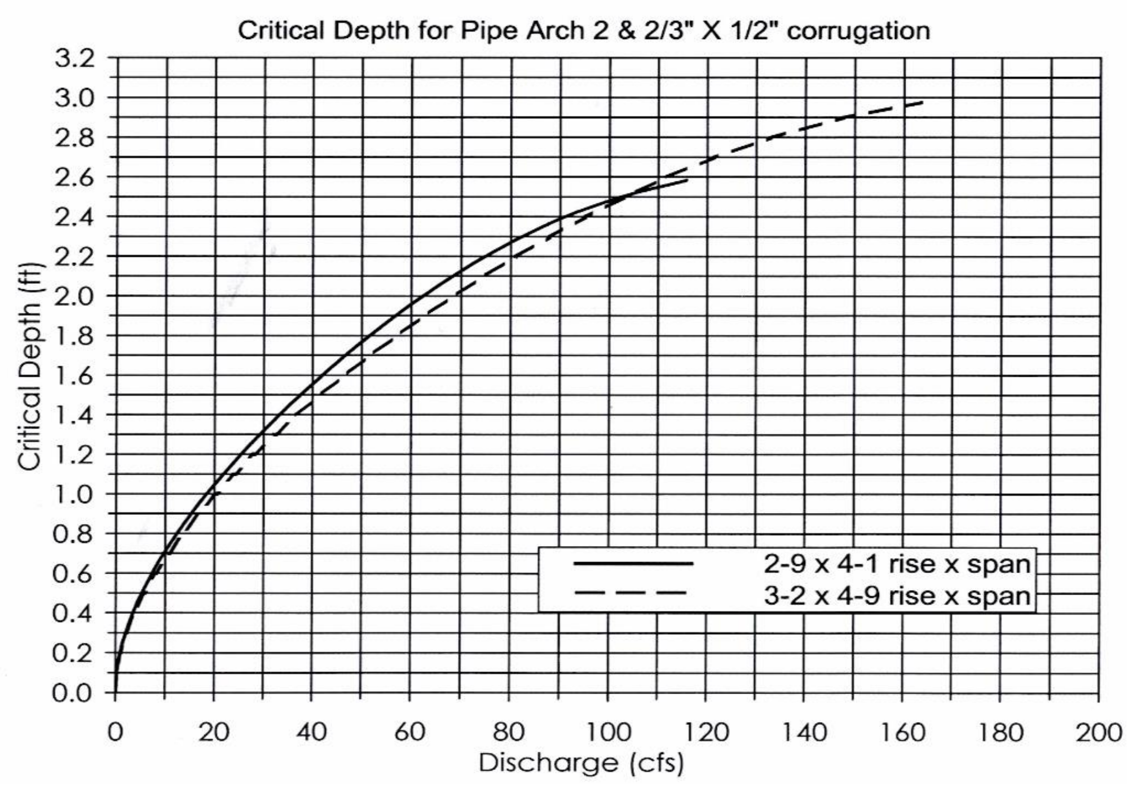


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Chart 8-26

Critical Depth for Pipe Arch 2-2/3 x 1/2 in. Corrugation

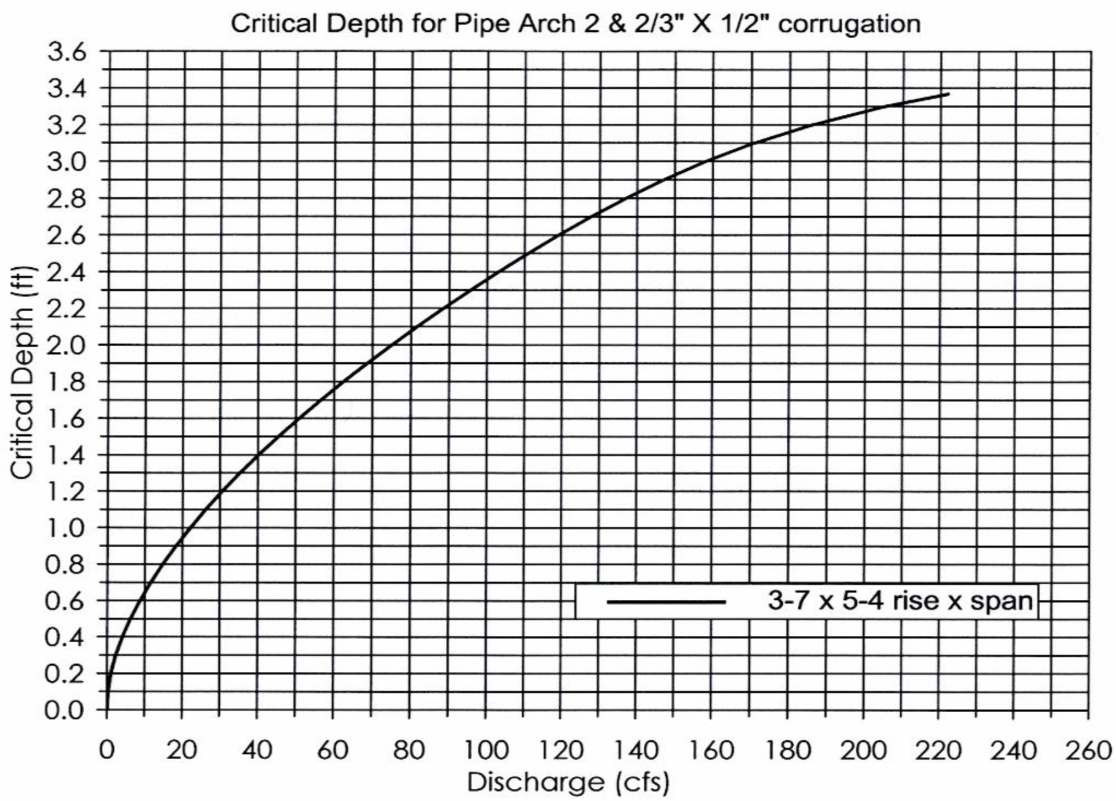

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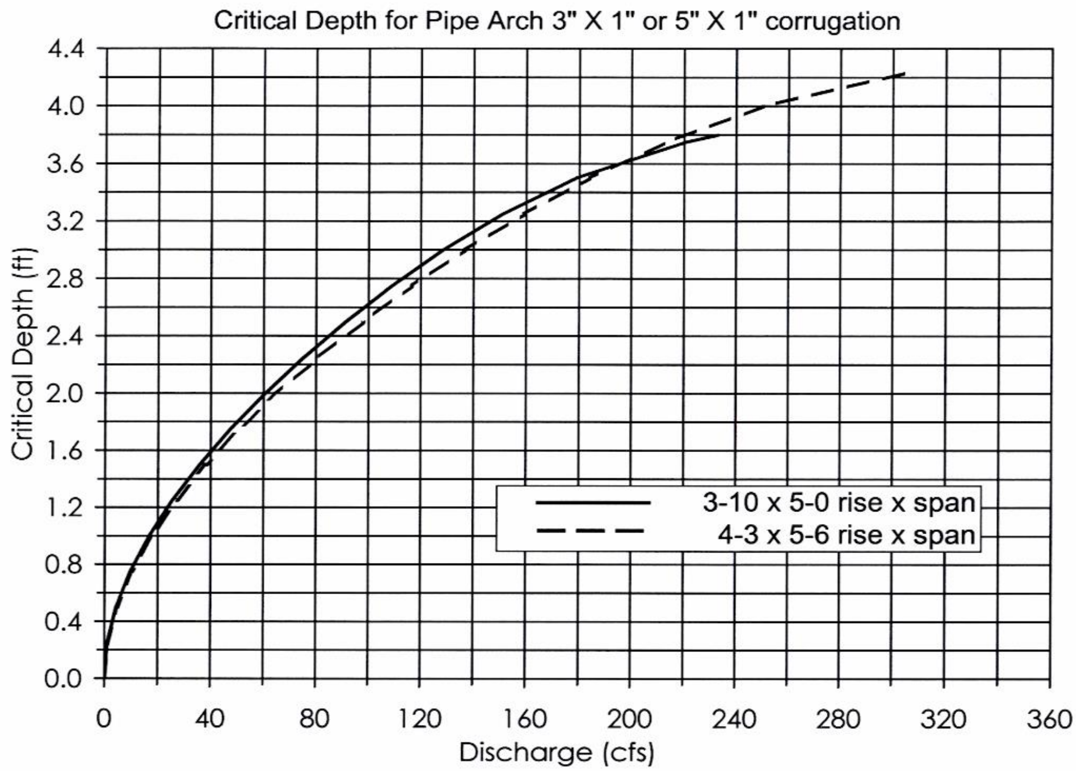
Chart 8-27

Critical Depth for Pipe Arch 3 x 1 or 5 x 1 in. Corrugation



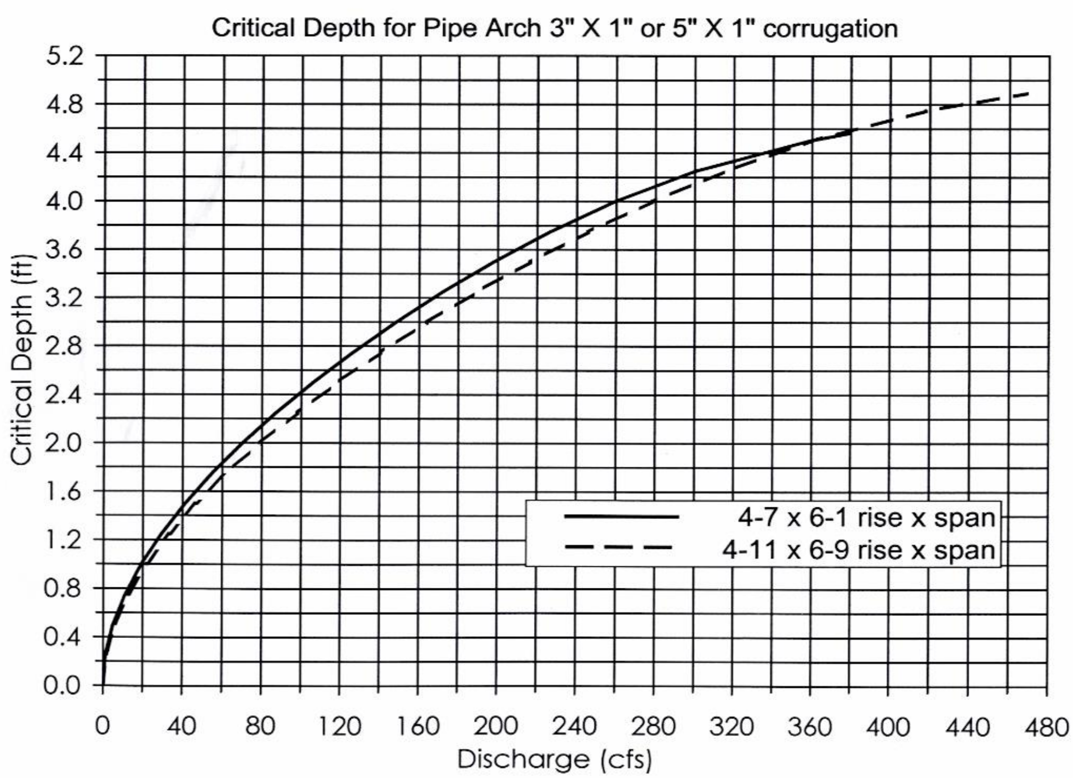


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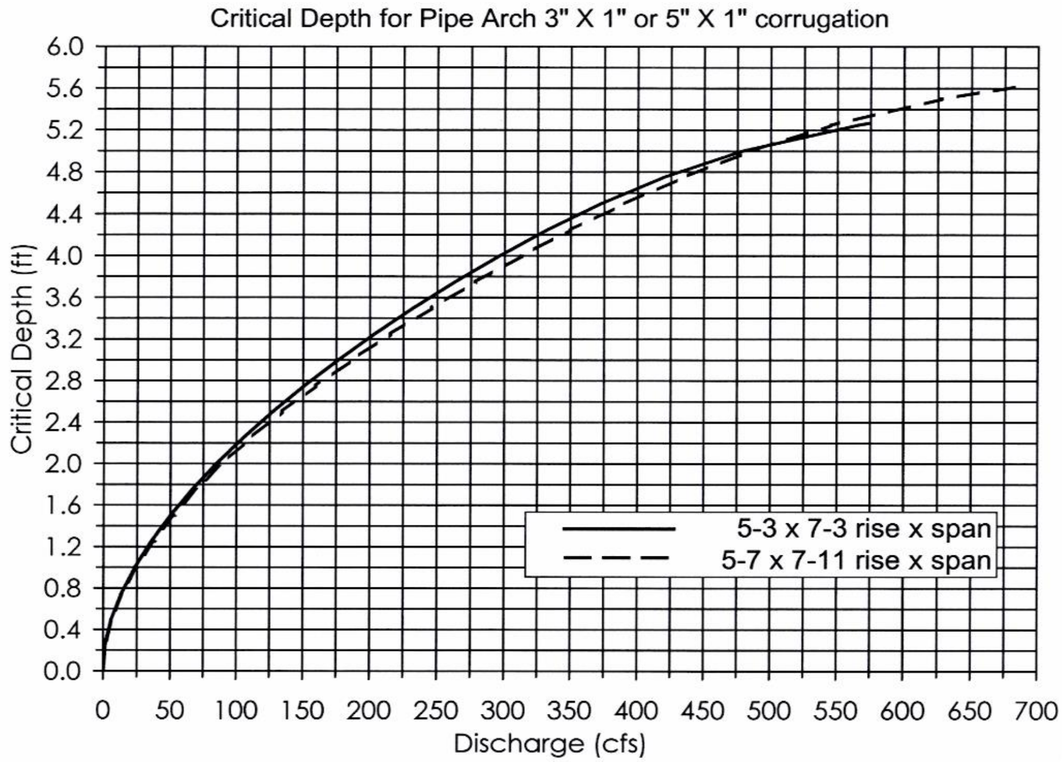
Chart 8-28

Critical Depth for Pipe Arch 3 x 1 or 5 x 1 in. Corrugation



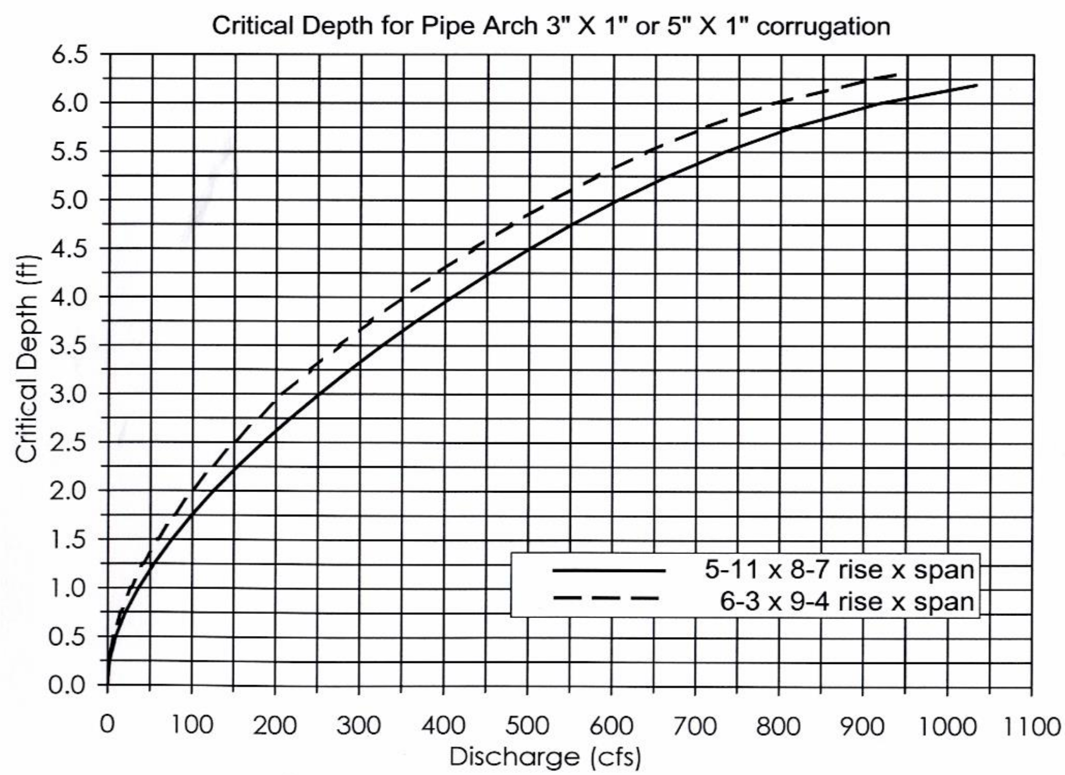


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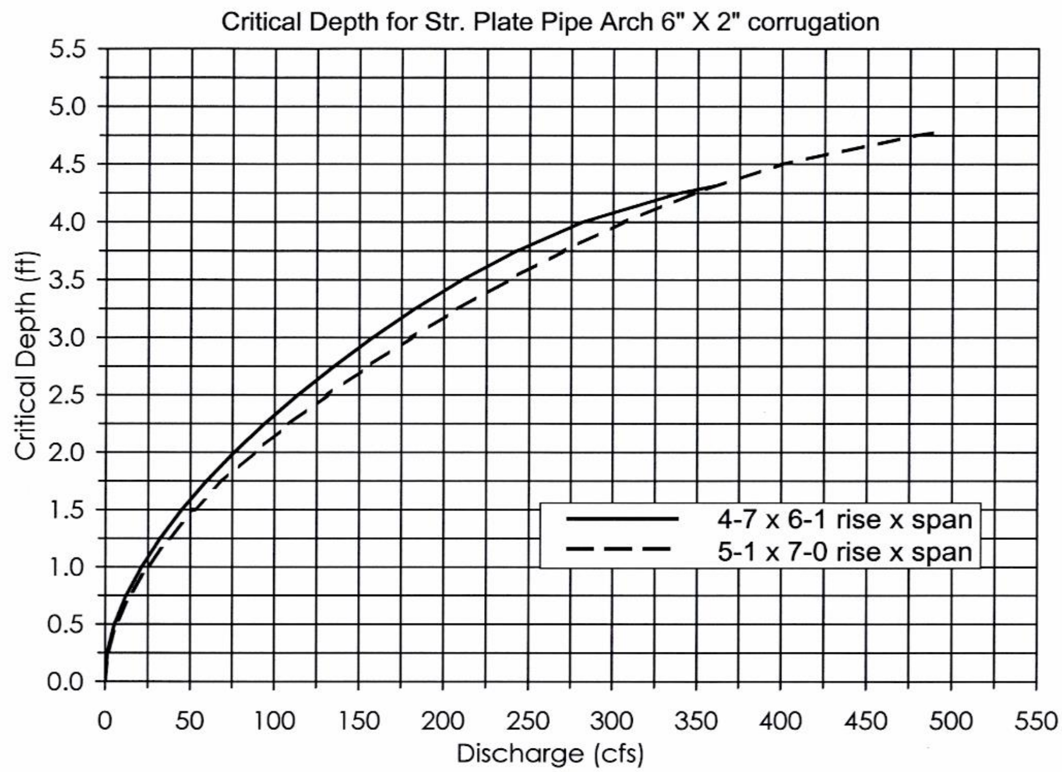
Chart 8-29

Critical Depth Str. Plate Pipe Arch 6 x 2 in. Corrugation



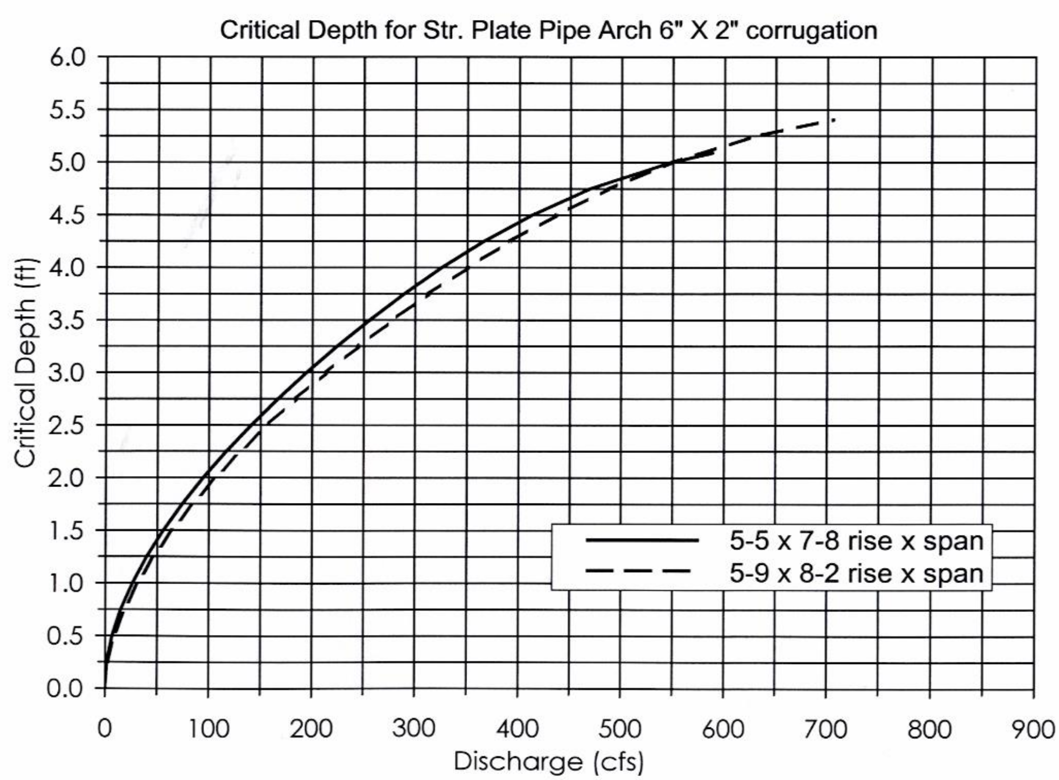


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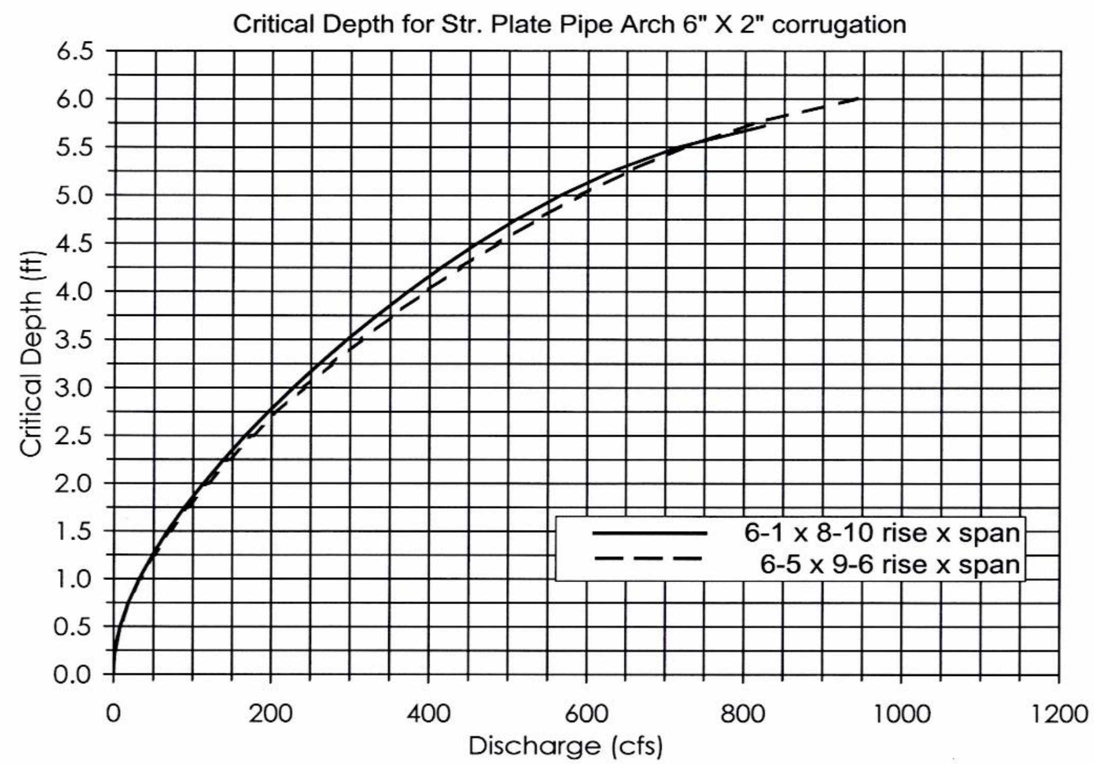
Chart 8-30

Critical Depth Str. Plate Pipe Arch 6 x 2 in. Corrugation



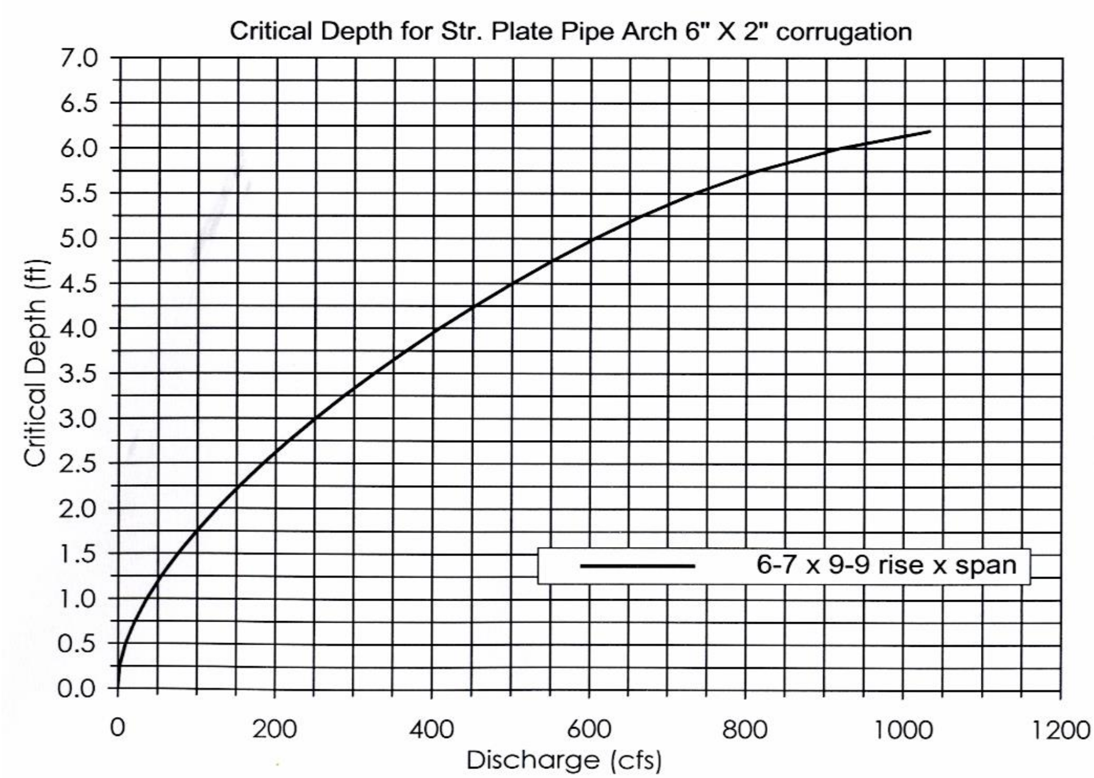


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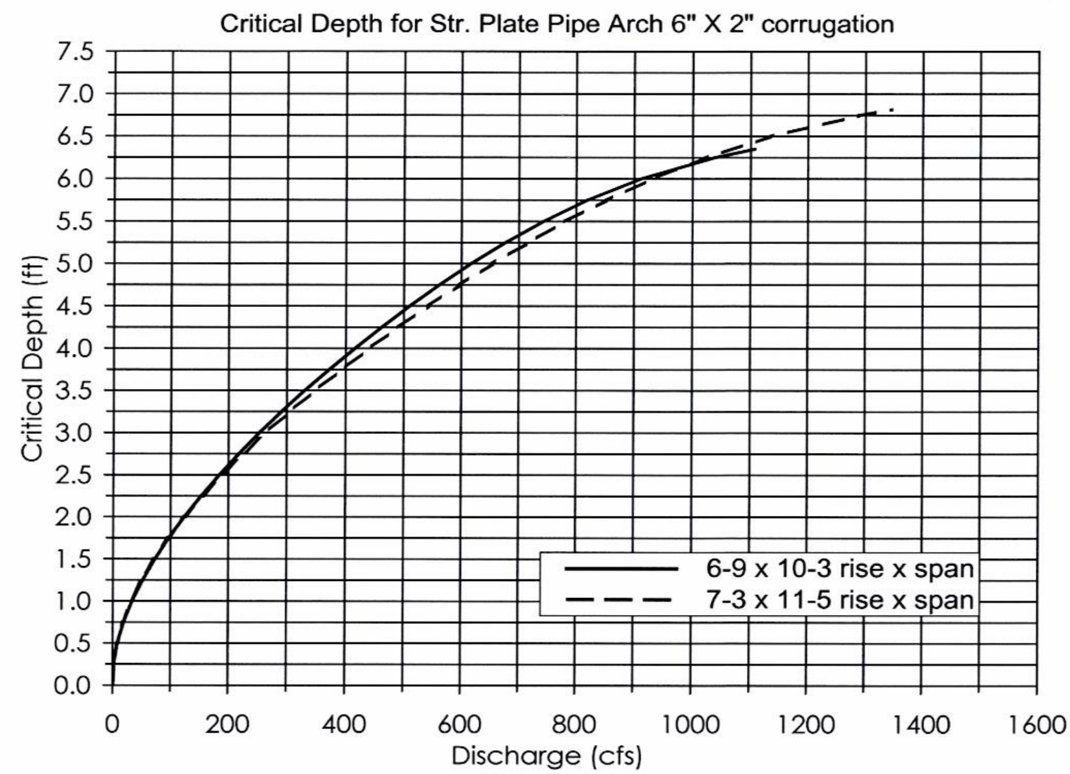
Chart 8-31

Critical Depth Str. Plate Pipe Arch 6 x 2 in. Corrugation



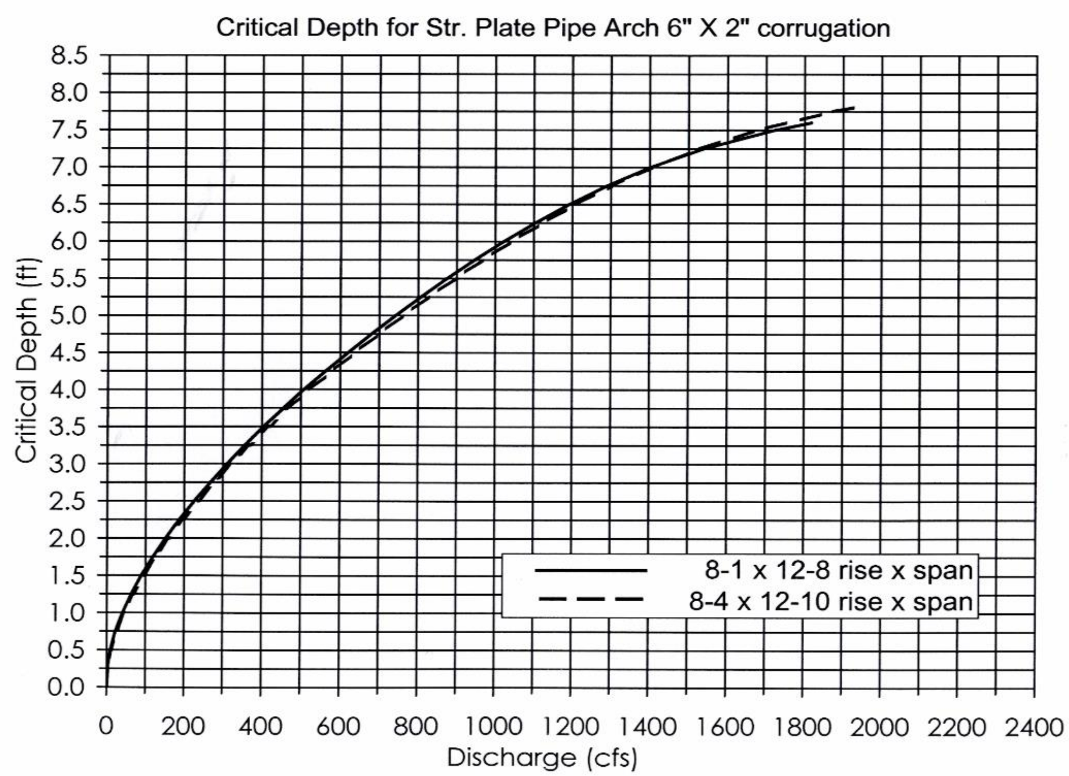


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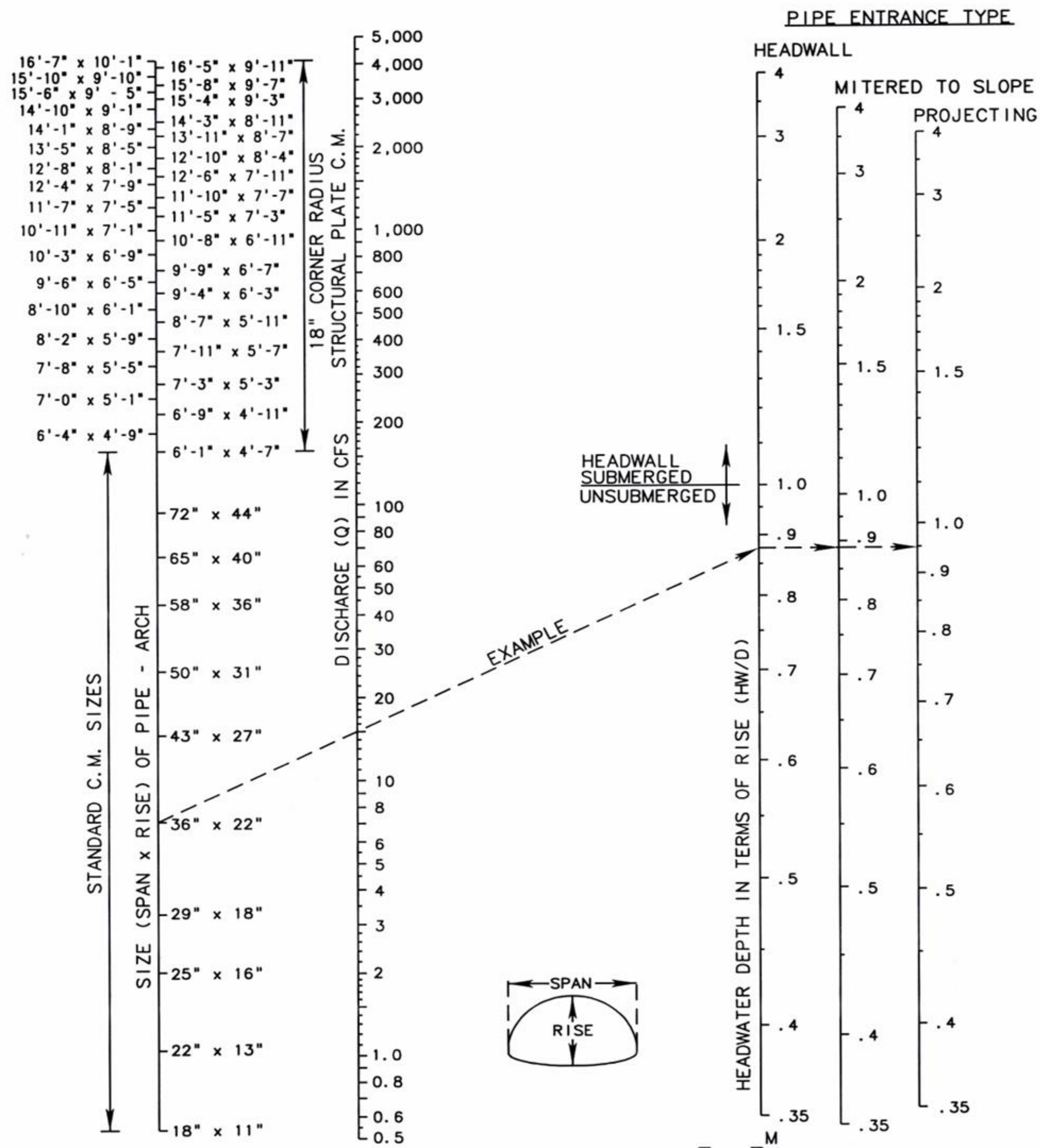
Chart 8-32
Horizontal Elliptical Concrete Pipe with Inlet Control



$$\text{UNSUBMERGED} \quad \frac{HW}{D} = \frac{Hc}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^{M} - 0.5S$$

$$\text{SUBMERGED} \quad \frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^{2} + Y - 0.5S$$

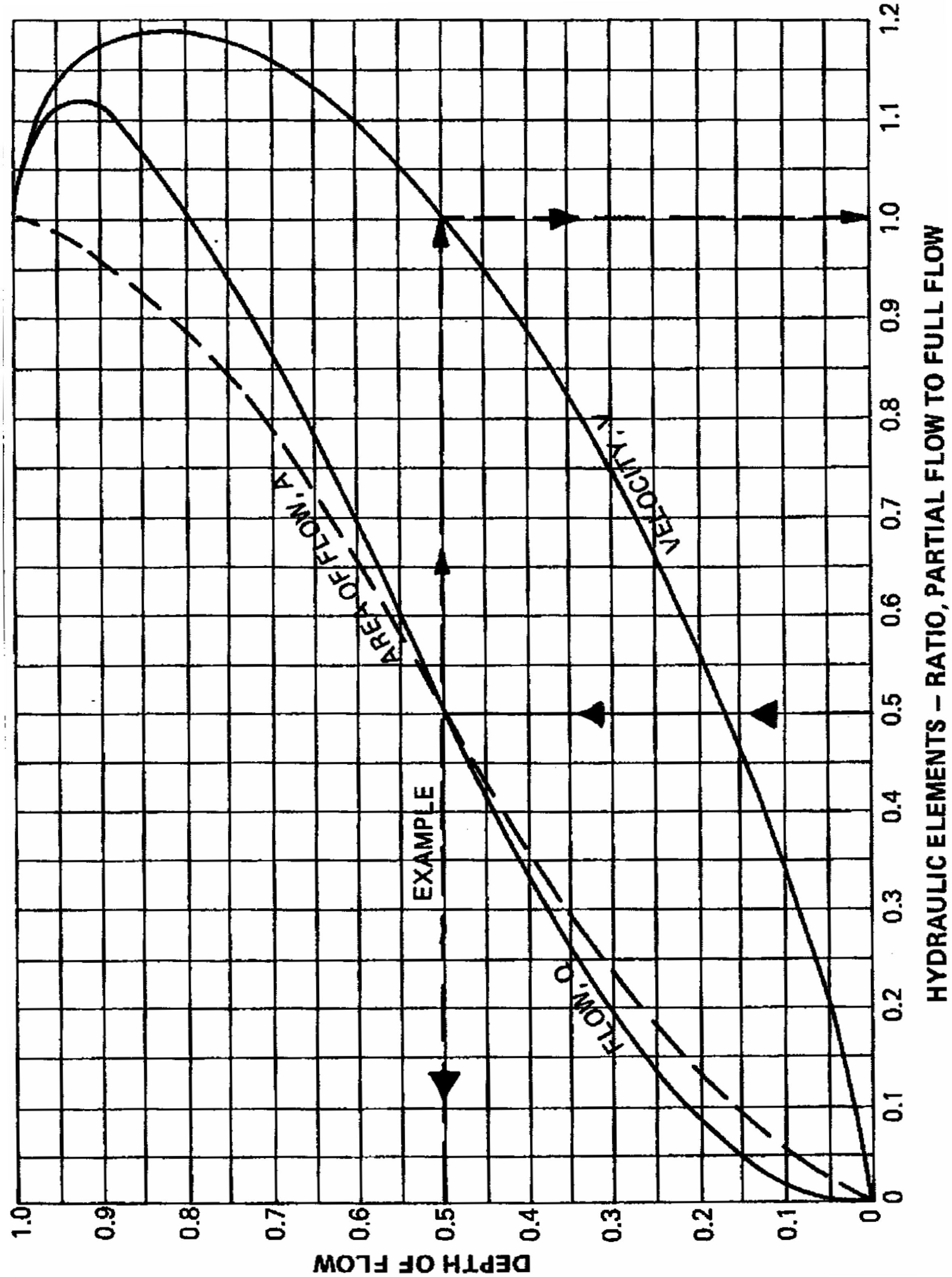
SEE TABLE 8-3 AND TABLE 8-4 FOR K, M, c, Y

REFER TO SECTION 8.4.5 FOR EXPLANATION

Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-33

Hydraulic Elements for Partially Full Horizontal Elliptical Concrete Pipe

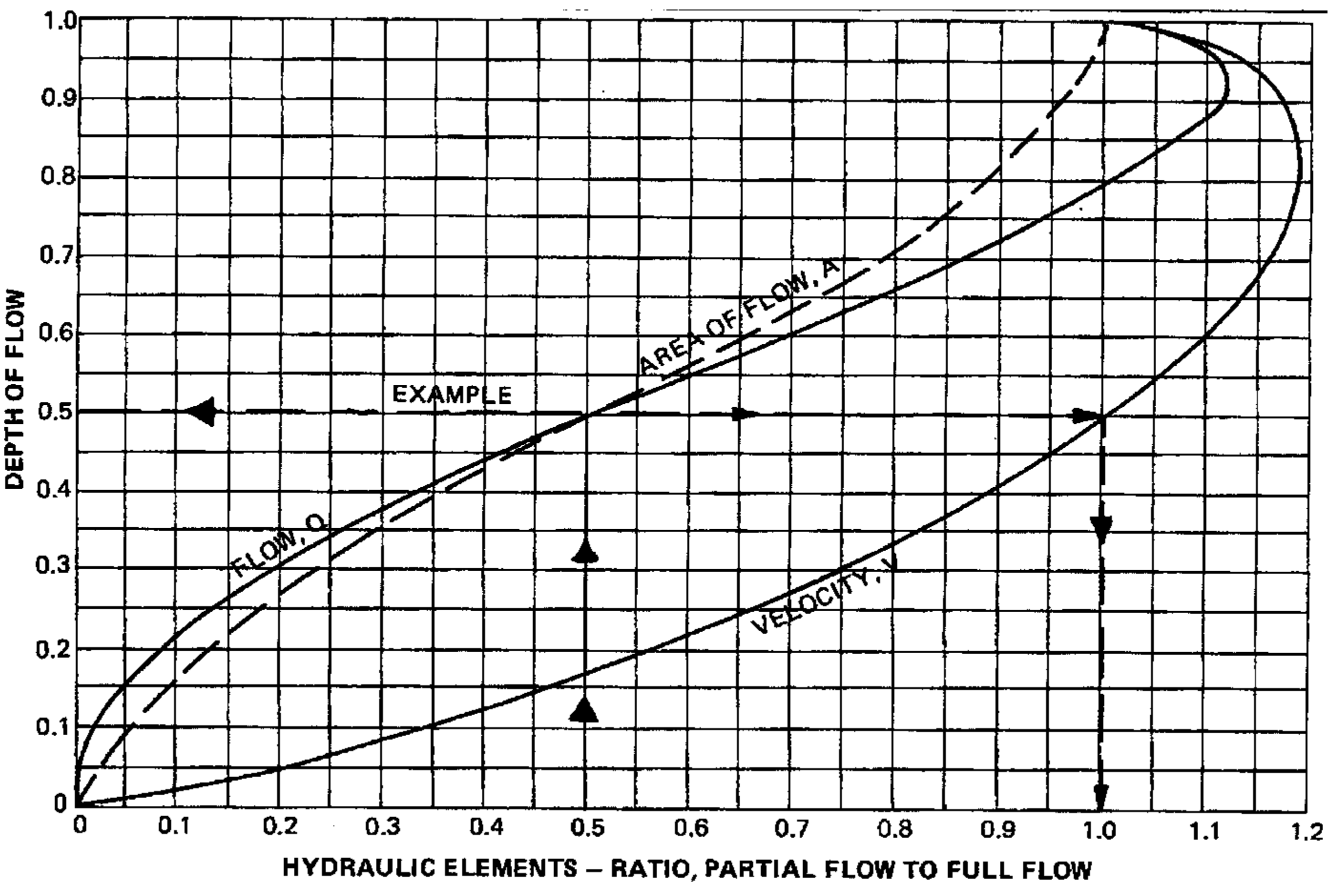


Source: Handbook of Steel Drainage Products, American Iron & Steel Inst., 1994

Chart 8-34

Hydraulic Elements for Partially Full Horizontal Elliptical Concrete Pipe

Example



24 X 38 pipe, n = 0.012, Slope = 0.02, Q_{full} / S $^{0.5}$ = 456 (from Table 8-6)

Given: D_{full} = 24 in, Q = 32.2 cfs

Q_{full} = 456*(0.02)$^{0.5}$ = 64.5 cfs

Required: depth at Q, velocity at Q

Solution: Q / Q_{full} = 32.2/64.5 = 0.5

From figure for hydraulic elements, d / d_{full} = 0.5

d = d_{full} x 0.5 = 12 in

V_{full} = Q_{full} / A_{full} = 64.5 / 5.1 = 12.6 (A_{full} from Table 8-7)

From figure for hydraulic elements, V / V_{full} = 1

V = V_{full} x 1 = 12.6 ft/s

Table 8-6

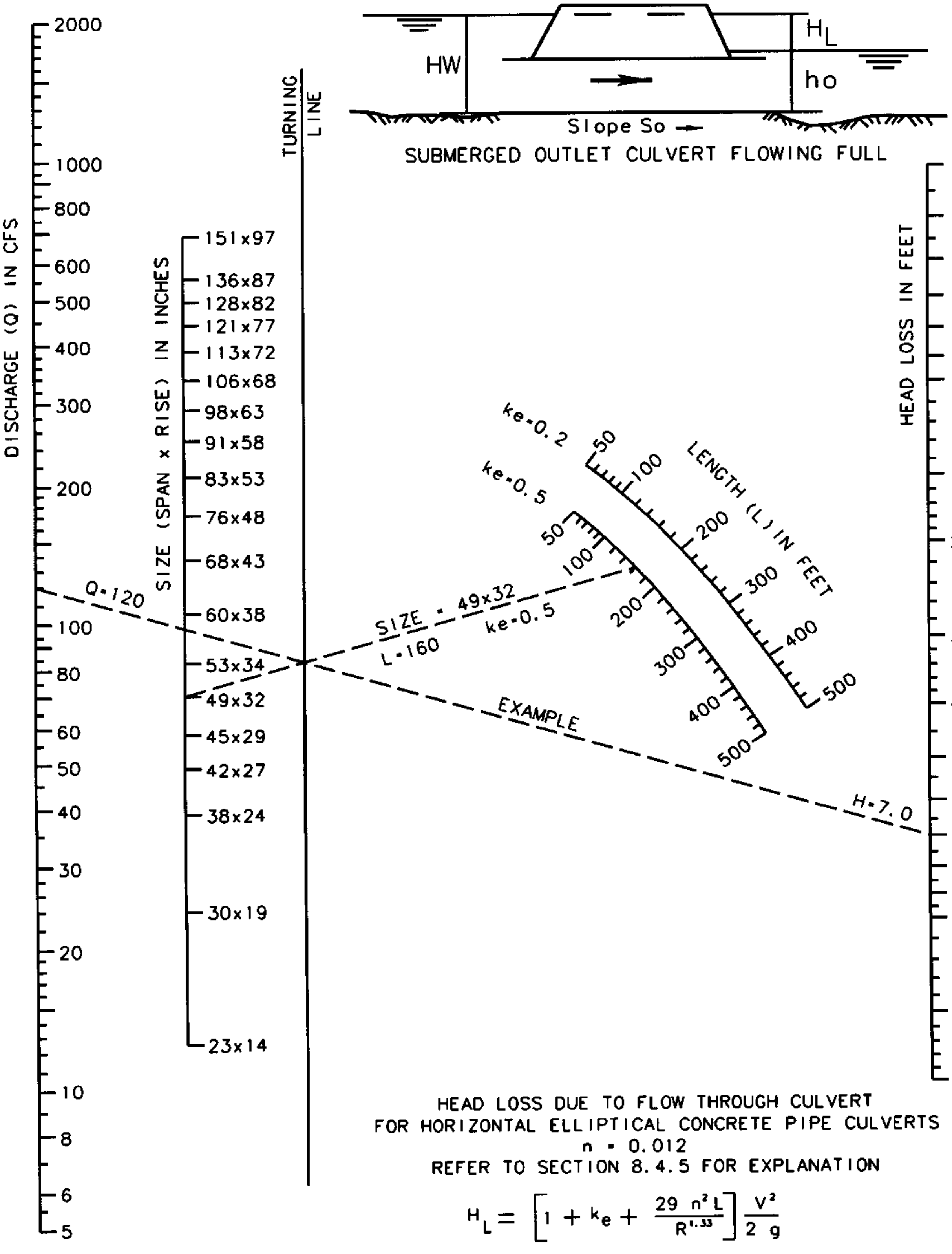
Full Flow Values for Horizontal Elliptical Concrete Pipe

Pipe Size Rise X Span inches	Equivalent Full Flow Area for Circular Diameter inches	A Area ft^2	R Hydraulic Radius ft	Value of Full Flow Conveyance K $\frac{Q}{\sqrt{S}} = \frac{1.486}{n} A R^{\frac{2}{3}}$			
				n = 0.010	n = 0.011	n = 0.012	n = 0.013
14 X 23	18	1.8	0.367	138	125	116	108
19 X 30	24	3.3	0.490	301	274	252	232
24 X 38	30	5.1	0.613	547	497	456	421
27 X 42	33	6.3	0.686	728	662	607	560
29 X 45	36	7.4	0.736	891	810	746	686
32 X 49	39	8.8	0.812	1140	1036	948	875
34 X 53	42	10.2	0.875	1386	1260	1156	1067
38 X 60	48	12.9	0.969	1878	1707	1565	1445
43 X 68	54	16.6	1.106	2635	2395	2196	2027
48 X 76	60	20.5	1.229	3491	3174	2910	2686
53 X 83	66	24.8	1.352	4503	4094	3753	3464
58 X 91	72	29.5	1.475	5680	5164	4734	4370
63 X 98	78	34.6	1.598	7027	6388	5856	5406
68 X 106	84	40.1	1.721	8560	7790	7140	6590
72 X 113	90	46.1	1.845	10300	9365	8584	7925
77 X 121	96	52.4	1.967	12220	11110	10190	9403
82 X 128	102	59.2	2.091	14380	13070	11980	11060
87 X 136	108	66.4	2.215	16770	15240	13970	12900
97 X 151	120	82.0	2.461	22190	20180	18490	17070

Source: Handbook of Steel Drainage Products, American Iron & Steel Inst., 1994

Chart 8-35

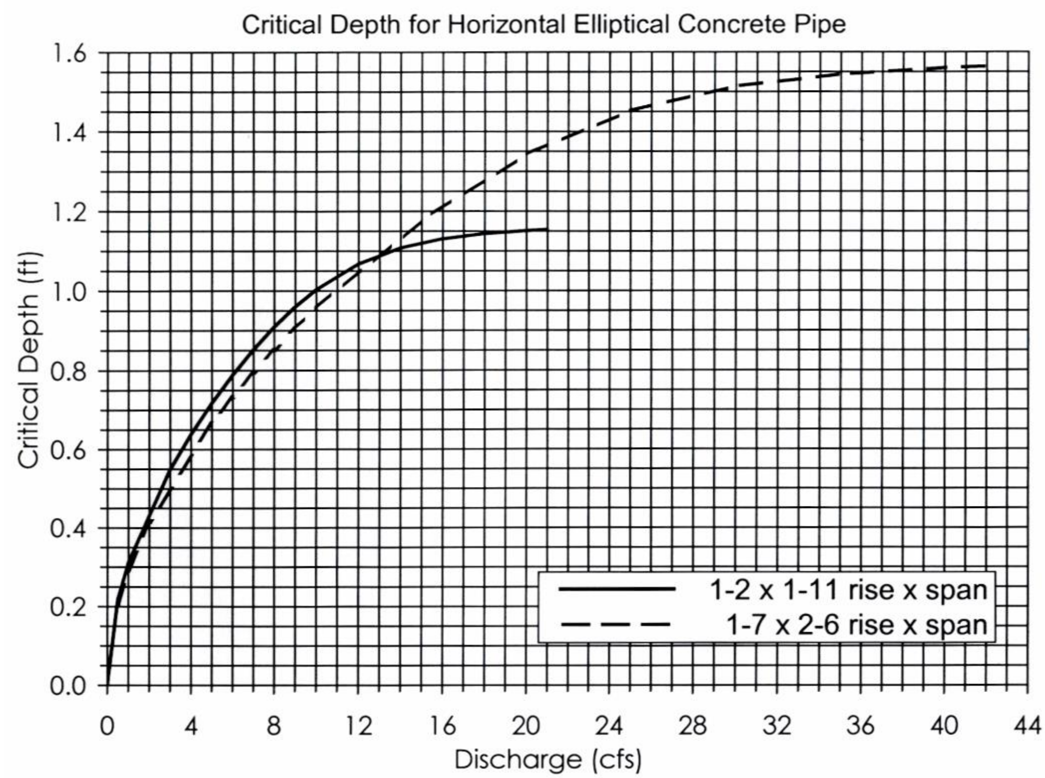
Horizontal Elliptical Concrete Pipe Flowing Full



Source: Hydraulic Design of Highway Culverts, HDS-5, FHWA, 2005

Chart 8-36

Critical Depth for Horizontal Elliptical Concrete Pipe



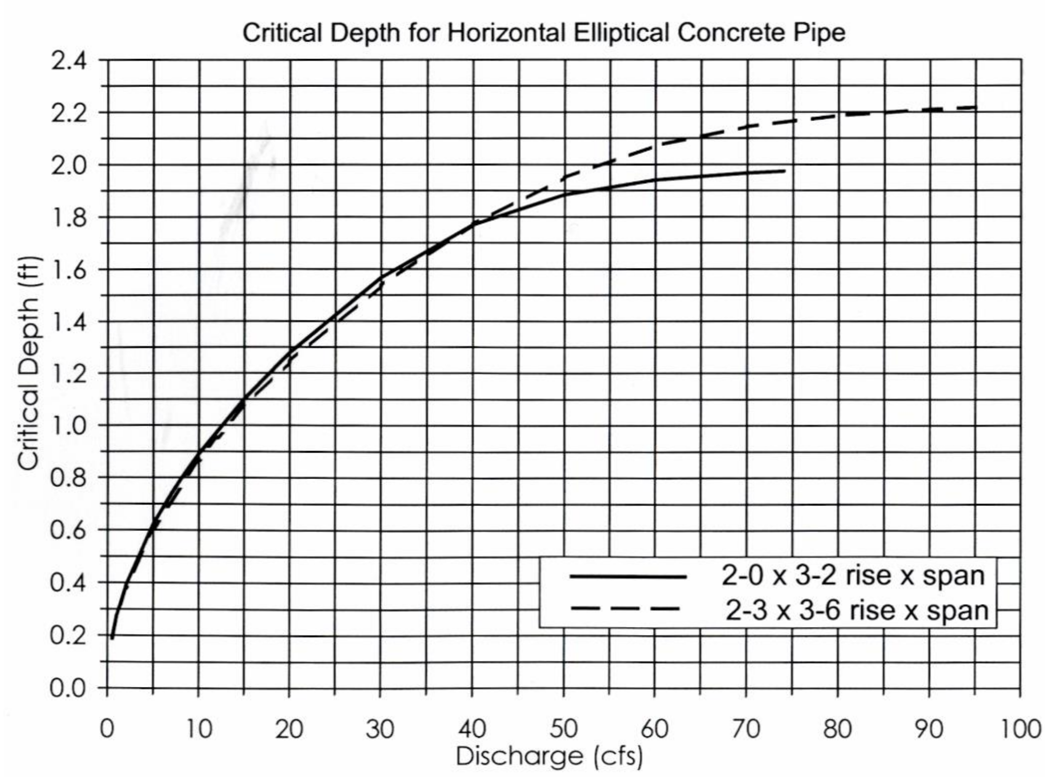


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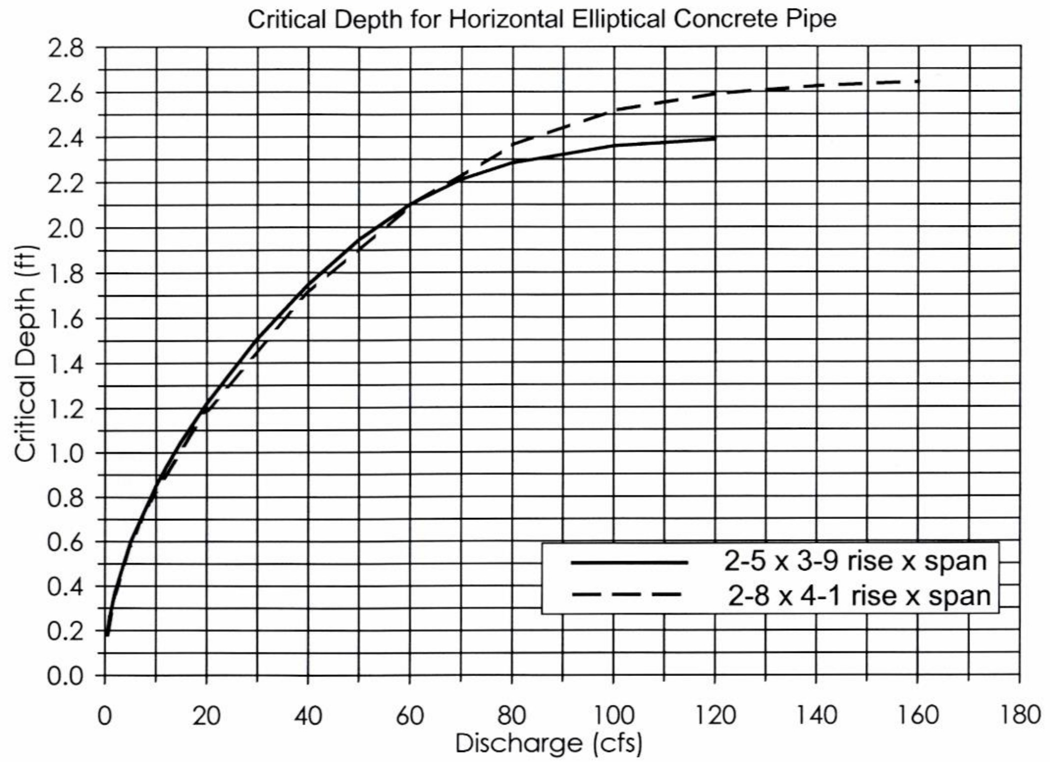
Chart 8-37

Critical Depth for Horizontal Elliptical Concrete Pipe



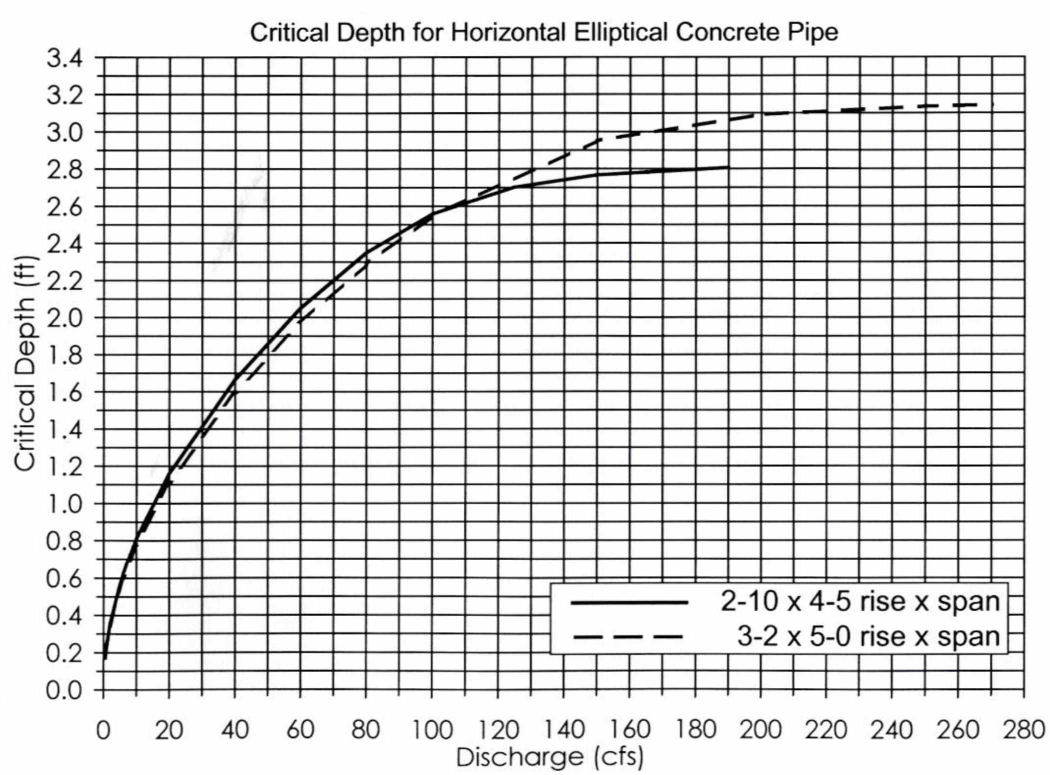


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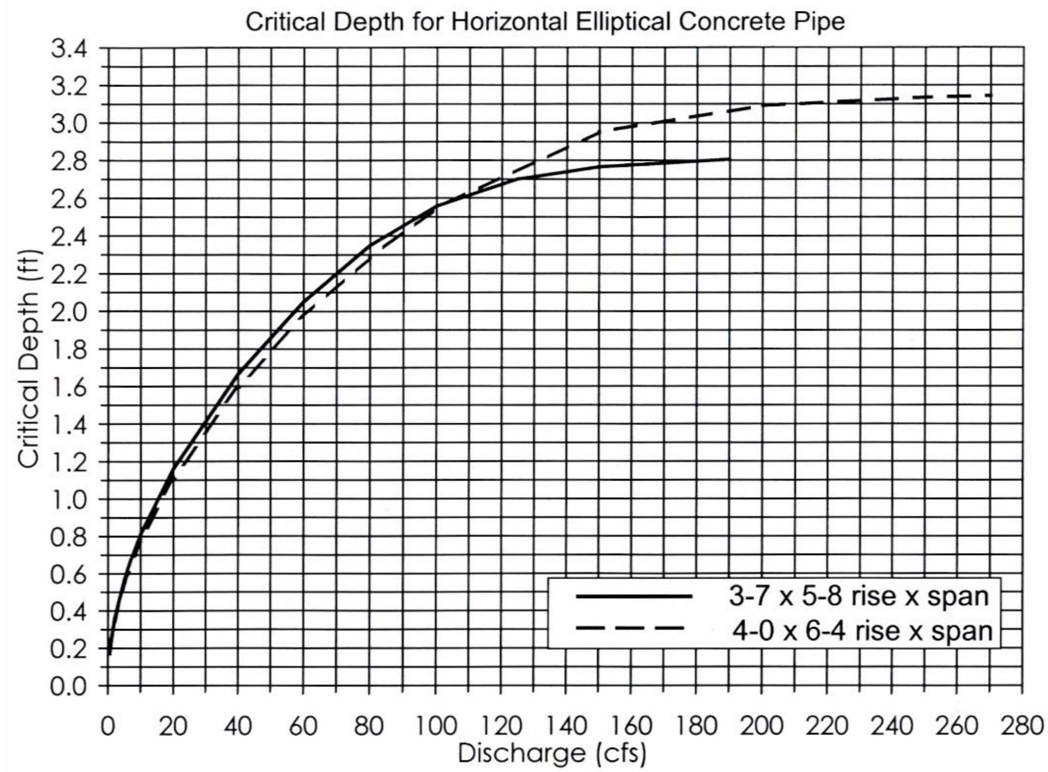
Chart 8-38

Critical Depth for Horizontal Elliptical Concrete Pipe



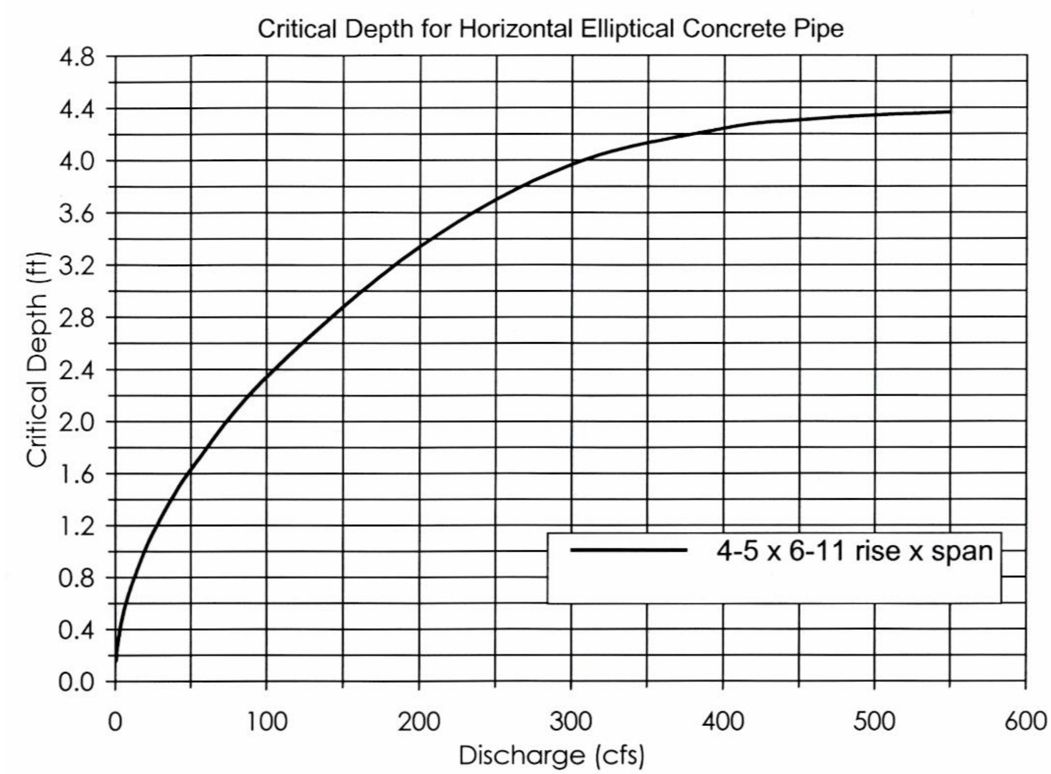


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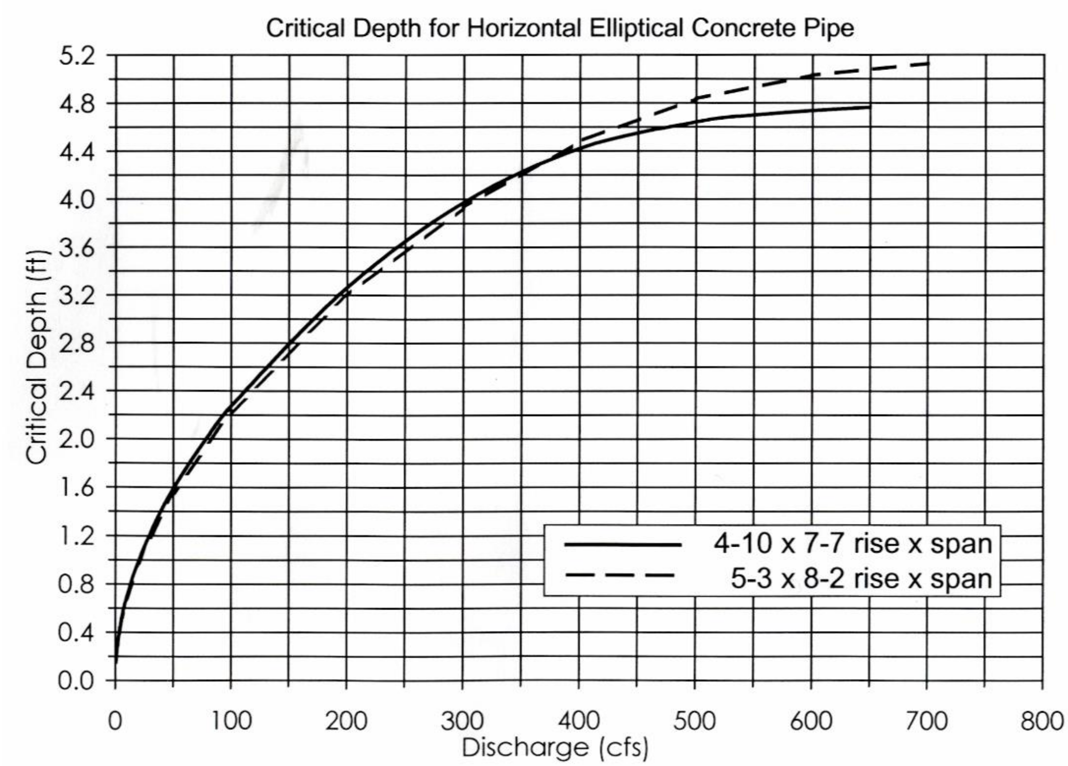
Chart 8-39

Critical Depth for Horizontal Elliptical Concrete Pipe



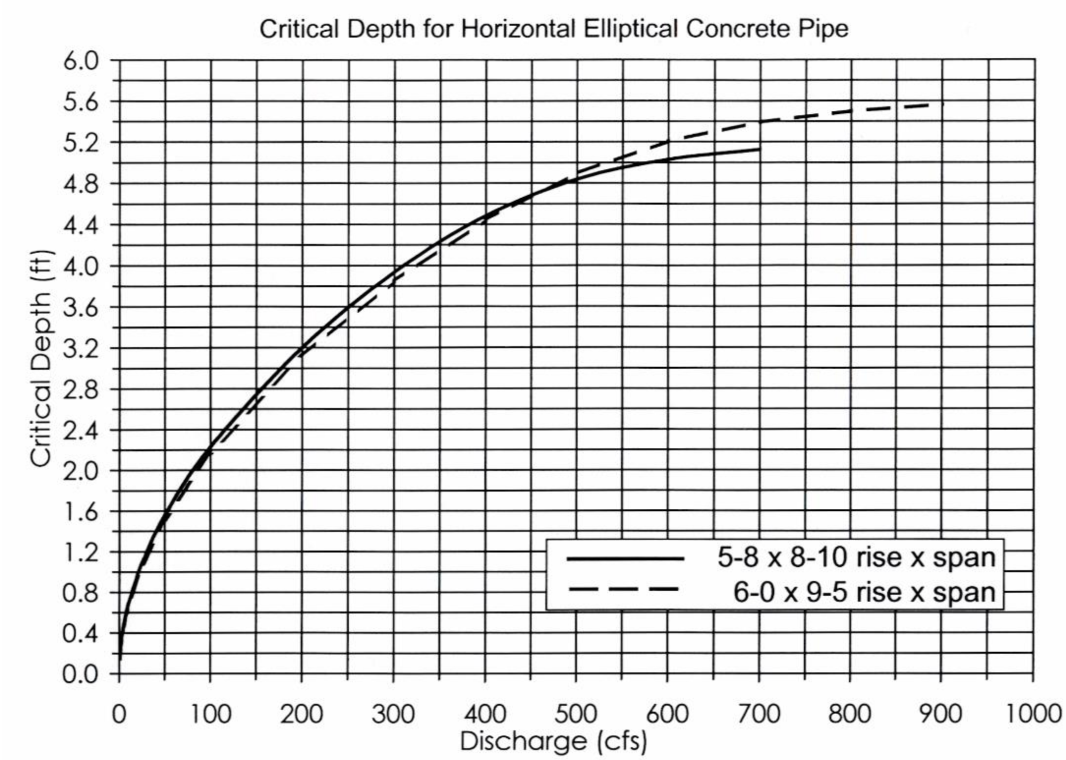


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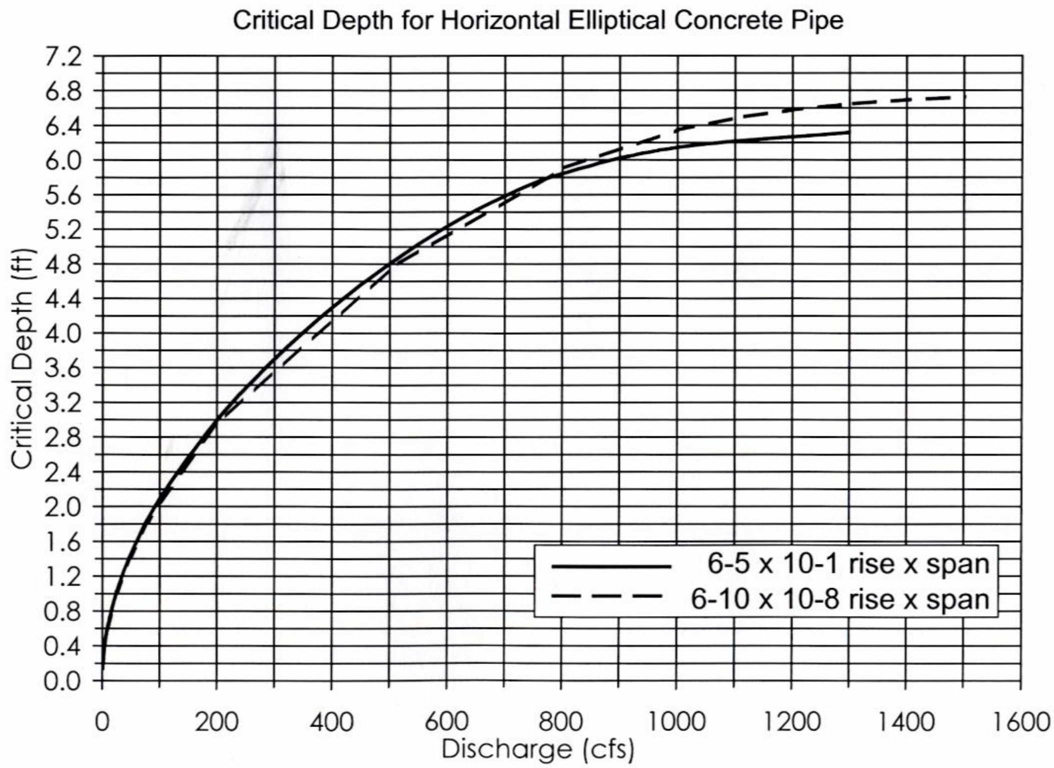
Chart 8-40

Critical Depth for Horizontal Elliptical Concrete Pipe



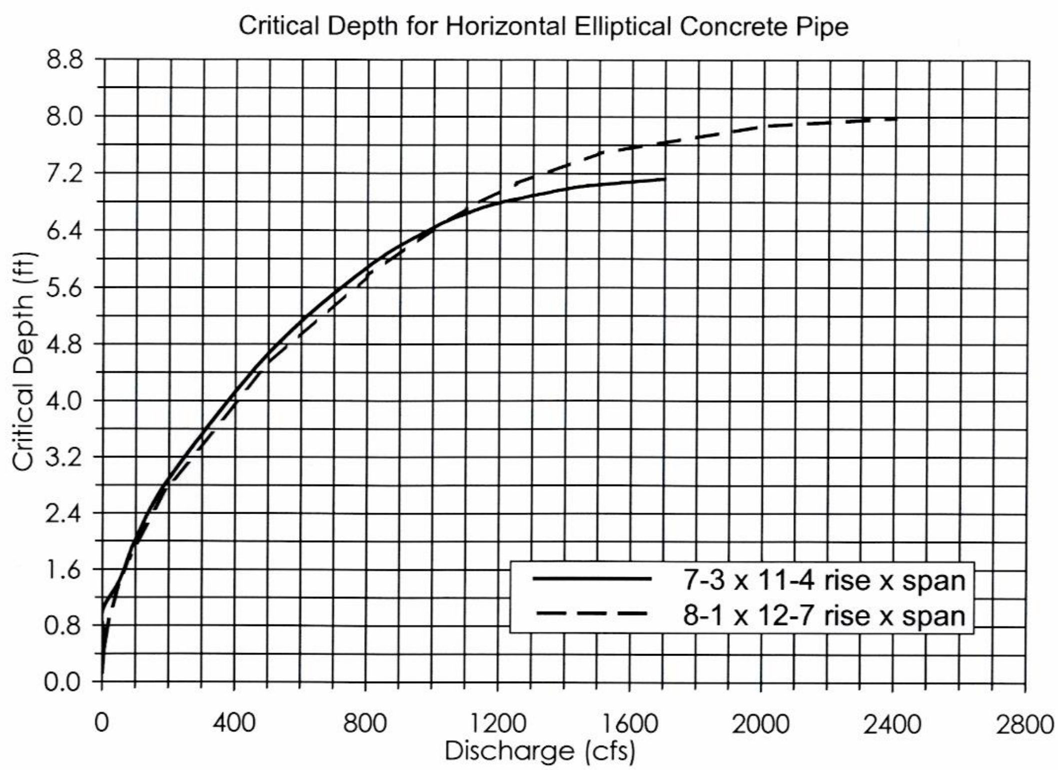


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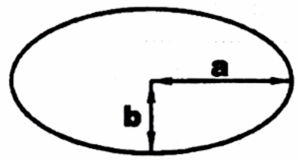
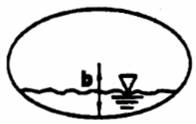
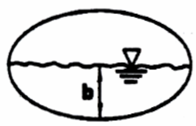
Figure 8-9
Elliptical Pipe Flow Area

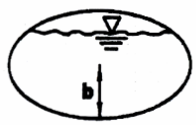




$$b - depth > 0 \quad A = a\,b\,\arccos\left(\frac{b - depth}{b}\right) - a\,(b - depth)\sqrt{1 - \left(\frac{b - depth}{b}\right)^2}$$



$$b - depth = 0 \quad A = \frac{\pi}{2}\,a\,b$$



$$b - depth < 0 \quad A = \pi\,a\,b - \left[a\,b\,\arccos\left(\frac{depth - b}{b}\right) - a\,(depth - b)\sqrt{1 - \left(\frac{depth - b}{b}\right)^2}\right]$$

This chart provides equations for calculating the flow area for any flow depth within an elliptical pipe. It can be useful for calculating the critical depth of flow using the critical depth equation (see Section 8.4.5.1).

8.7 REFERENCES

(1) Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular-15 (HEC-15), Federal Highway Administration, April 1988

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(5) AASHTO Drainage Manual, American Association of State Highway Transportation Officials (AASHTO), 2014

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(7) Culvert Design for Aquatic Organism Passage, Hydraulic Engineering Circular -26 (HEC-26), FWHA, October 2010

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