USER MANUAL

COST ESTIMATOR FOR MASTER PLANNING (UD-MP Cost)

Version 1.1

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Acknowledgements

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1 INTRODUCTION

1.1 Background

Development of capital improvement costs for master planning projects has long been a subjective process. Many talented engineers have developed their own tools, primarily spreadsheets, to capture the costs of planned drainageway and storm drain improvements. Unfortunately, each of these tools was either developed independently, or was loosely based on a number of previous estimating procedures. In addition, master planning costs were generally underestimating construction improvement costs. In 2008, the master planning staff at UDFCD decided that development of cost estimating tool for master planning projects was a worthwhile investment and would solve many of the inconsistency problems experienced in the past. The overall concept for the tool was as follows:

- Develop Master Planning Cost Estimate Spreadsheet for Use on All Master Planning Projects,
- Develop Comprehensive Cost Data,
- Provide Support for Streamlined Table Creation for Master Plan Reports,
- Create a Flexible Tool For All Consultants.

With these concepts as a foundation, UDFCD began development of the Cost Estimator for Master Planning (UD-MP Cost) in 2009.

1.2 Purpose

The UD-MP Cost tool serves multiple purposes, as listed here:

- To provide consistency in cost estimates for all master plans,
- To eliminate differences in estimating procedures between consultants,
- To streamlines cost estimating processes during planning,
    - Reducing consultant costs and accelerating the estimating process,
- To provide consistency from Phase A Estimates to Phase B Estimates,
- To allows for annual updating of all existing master plans for more accurate CIP estimates, and
- To create a foundational database for cost estimating that could become part of GIS master plan layer that can be updated on annual basis and shown on maps for Board Meetings or for budgeting purposes

1.3 Tool Components

The UD-MP Cost tool is relatively simple and is made up of four major components as described below:

Project Information: All project related data is entered into this area including drainageway names, jurisdictions, and sheet information.

Cost Data Sheet: The cost data sheet provides all of the unit costs for pay items used in the UD-MP Cost tool.

Costs by Sheet: UDFCD master plans typically consist of plan and profile sheets accompanied by narratives and cost estimates. The Cost by Sheet portion of the UD-MP Cost tool allows the user to enter the proposed improvements on a sheet by sheet basis, thereby obtaining the costs for all improvements on the sheet as well as a summary of the total costs.

Master Plan Tables: These are the summary tables which are input directly into the drainageway master plans and outfall systems plan reports. Included in these tables are the:

- Cost Summary by P&P Sheet;
- Cost Summary by Reach; and
- Cost Summary by Jurisdiction.

GIS Integration: GIS integration is not a part of this first release of the UD-MP Cost tool. However, it is hoped that in future years, the cost data and calculation methodologies can be integrated into a single cost database that can be intersected with GIS master planning data, thereby creating the ability to create GIS maps showing cost data on the fly.

1.3.1 UD-MP Cost Lite

During the development of UD-MP Cost, it was decided that, in some cases, users might want to use a simplified cost estimating spreadsheet which excludes the summary tables. This version, called UD-MP Cost Lite eliminates the Project Information Tab, Sheet Index, Summary Tables, and duplicate Sheet Cost tabs. Calculations for costs are performed exactly the same as in the full version.

1.4 Development Process

In developing the UD-MP Cost tool, the following development process has been followed:

- Step 1 – Develop Pay Item List
- Step 2 – Develop Standardized Tables
- Step 3 – Develop Estimating Tools
- Step 4 – Develop Benefit-Cost Tool
- Step 5 – Use on Recent Master Plans
- Step 6 – Perform QA/QC
- Step 7 – Perform Alpha/Beta Testing
- Step 8 – Finalize Spreadsheet
- Step 9 – Update Costs on Annual Basis
- Step 10 – Consider GIS Integration

1.5 Unit Rate Development

A comprehensive list of items and unit rates was developed for use in the UD-MP Cost tool. The list used in UD-MP Cost is meant to provide a consistent approach to cost estimating for master planning projects. The user should note that the list does not include all possible improvement items. For example, circular pipe costs are based solely on using concrete circular pipe. This provides a conservative cost estimate for master planning purposes without being overly detailed. In some cases, user input is allowed to provide flexibility within the UD-MP Cost Tool.

Costs were developed based on numerous sources, including the UDFCD Bid Tabs Program (2008), the Colorado of Transportation's Cost Data Book (2005, 2006, 2007, and 2008), bid tab data from the City and County of Denver, and the City and County of Denver's Storm Drainage Master Plan (2009). Cost data reflects 2009 dollars. The tool is equipped with a user input inflation index to account for inflation in future years.

The following narrative describes the unit costs development for the UD-MP Cost tool.

Pipe Culverts and Storm Drains

This section of the cost data and cost estimate worksheet is meant to cover all items related to culverts and storm drain systems, including inlets, manholes, headwalls, and wingwalls. Subheadings in the UD-MP Cost Tool include:

- Circular Pipes
- Flared End Sections
- Headwalls
- Wingwalls
- Manholes and Inlets

Circular Pipes

Cost data for pipe culverts and storm drains assumes the use of circular reinforced concrete pipe. Based on discussions with the development team, it was thought that using concrete pipe as the basis of cost would provide a conservative estimate for master plans. After review of various cost data, it was decided to use the City and County of Denver's 2009 Storm Drainage Master Plan costing methodology for all pipes. Costing is based on the following:

Table 1 : Unit Rates for Pipe Culverts and Storm Drains

Item	Unit Cost Basis
Circular Pipe (66 in. and smaller)	$3.50 per inch diameter per lineal foot
Circular Pipe (72 in. to 96 in.)	$5.00 per inch diameter per lineal foot
Circular Pipe (> 96 in. to 120 in.)	$7.00 per inch diameter per lineal foot

These unit costs are complete-in-place and include all associated costs for excavation, bedding, placement, and backfill.

Flared End Sections

Costs for flared end sections have been provided in sizes from 12-inches to 48-inches. All costs assume concrete flared end sections to provide a conservative cost estimate. While flared end sections are available in sizes larger than 48-inches it was decided to specify headwalls for sizes 54-inches and larger. Costs are based on cost data from UDFCD, CDOT and CCD. A summary of FES costs by size is provided in Appendix A

Headwalls

Headwalls will be used for all pipe outlets with sizes of 54-inches and larger. Costs within the UD-MP Cost tool are based on CDOT Standard Detail M-601-10, Headwalls for Pipe Culverts. Costs are developed on an each basis and include concrete and steel pricing. Excavation costs for headwall structures are assumed to be included in the overall contingency for the project. For the UD-MP Cost tool, concrete costs are estimated at $700 per cubic yard and the steel costs are estimated at $0.80 per lb. of steel.

Wingwalls

Wingwalls will be used for all circular pipe headwalls and all box culverts. Costs within the UD-MP Cost tool are based on CDOT Standard Detail M-601-20. Lengths of the wingwalls are based on CDOT Design Aid #50, Selection of Culvert Wingwall Geometries and Quantity Calculations. To provide a simplistic approach, an embankment slope of 3:1 and a skew angle of 90^{o} have been assumed. Steel and concrete quantities are based on an average wall height using the Design

Table on Standard Plan M-601-20. A concrete reinforced apron is also assumed. Concrete and steel costs are estimated at $684 per cubic yard and steel costs are estimated at $0.80 per lb.

Manholes and Inlets

To provide some flexibility, 5 different manhole sizes are provided in the UD-MP Cost tool; three circular manhole types and two structural box types. Costs were evaluated based on CDOT cost data, UDFCD cost data, and CCD data. A summary of items and costs is provided in Appendix A.

For purposes of estimating costs for storm inlets, only a typical 5-foot Type R is shown. When lengths greater than 5-feet are required, the user will enter multiples of the 5-foot length.

Concrete Box Culverts

This section of the cost data and cost estimate worksheet is meant to cover all items related to concrete box culverts including box culvert pipe, headwalls, and wingwalls.

Box Culvert Pipe

Box culverts are based on CDOT Standard Plan M-601-1, Single Box Culvert. To simplify the assumptions for the box culvert design, 8-feet of cover was assumed. In addition, for box culverts smaller than the CDOT standard sizes a 10-inch wall thickness was assumed with 200 lbs of steel per cubic yard of concrete. Concrete and steel costs are estimated at $684 per cubic yard and steel costs are estimated at $0.80 per lb.

Headwalls and Toewalls

Headwall and toewall quantities are based on CDOT Standard Plan M-601-2. The total span of the headwall/toewall is based on a 10-inch wall thickness. For simplification, the headwall skew angle is assumed at $90^{o.}$ Concrete and steel costs are estimated at $684 per cubic yard and steel costs are estimated at $0.80 per lb.

Wingwalls

Wingwalls will be used for all box culverts. Costs within the UD-MP Cost tool are based on CDOT Standard Detail M-601-20. Lengths of the wingwalls are based on CDOT Design Aid #50, Selection of Culvert Wingwall Geometries and Quantity Calculations. To provide a simplistic approach, an embankment slope of 3:1 and a skew angle of 90^{o} have been assumed. Steel and concrete quantities are based on an average wall height using the Design Table on Standard Plan M-601-20. A concrete reinforced apron is also assumed. Concrete and steel costs are estimated at $684 per cubic yard and steel costs are estimated at $0.80 per lb.

Hydraulic Structures

This section of the cost data and cost estimate worksheet is meant to cover all items related to grade control structures.

Sloping Drop Structure

There are several drop structure alternatives available to engineers for channel stabilization. For purposes of simplifying the master planning cost estimate process, UD-MP Cost assumes a grouted sloping boulder drop, using 36-inch boulders. The dimensions of the drop are based on Figure HS-7A from UDFCD's Drainage Criteria Manual. The user must enter a height and width based on the drop location and the hydraulics, i.e. flow rate and channel shape. The spreadsheet estimates a drop length assuming a 4:1 drop face and a 2-foot deep stilling basin. The width of the grouted boulder basin is also estimated using a 4:1 side slope. The drop structure line item in UD-MP Cost has a unit of each, but is based on a per square foot cost and includes costs for grouted boulders, riprap, excavation, granular bedding, and a grout cutoff. Costs for the weep drain system are

considered incidental and are covered by the costs involved in each drop structure. Unit costs for each component of the drop structure are shown in Table 2.

Table 2 : Unit Rates for Sloping Drop Strucutres

Item	Unit Cost	Unit
Grouted Boulders, 36-inch	$160.00	C.Y.
Riprap, Type M	$60.00	C.Y.
Soil Riprap, Type M	$65.00	C.Y.
Excavation, Complete-in-Place	$12.00	C.Y.
Bedding, Granular Type II	$50.00	C.Y.
Grout	$275.00	C.Y.

Check Structures

For purposes of UD-MP Cost, a simple check structure detail is assumed. This section consists of a 1-foot wide x 6-foot tall concrete wall with soil riprap extending 10-feet upstream and 10-feet downstream at a thickness of 27 inches. Concrete costs for the check structure is assumed at $400/cy. Riprap is assumed to be Type M Soil Riprap with a unit cost of $65/cy. An excavation quantity is also provided to account for the displaced soil material for riprap installation and has been shown with a unit cost of $12/cy. Quantities are based on the lineal foot (see Table 2).

Channel Improvements

This section of the cost data and cost estimate worksheet is meant to cover all items related to channel improvements including low flow improvements, riprap stabilization and grading. A comprehensive list of items is provided for the user to choose from based on the projects individual needs. Unit costs for this portion of UD-MP Cost are included in Appendix A. These costs are primarily based on the UDFCD Bid Tabs program. As part of preparing the UD-MP Cost tool, the engineering team reviewed previous master plans for cost data and pay items. It was noted that many times, channel improvements are shown by the lineal foot. This is still something the planning engineer can do using the Special Items (User Defined) section of UD-MP Cost. However, it is preferred that the engineer would develop a typical section for the improvement and develop quantities based on that section to input into the Channel Improvements Section.

Detention/Water Quality Facilities

This section covers water quality and detention facilities. During the master planning phase, few details are known about the facility other than total desired storage volume and that there will be an outlet control structure or other appurtenances as necessary. Because of this, only a few items have been provided in the cost data. All available items are shown in Appendix A. The user must define the unit cost for Outlet Works. This provides flexibility in sizing as some ponds have very small outlets, and some have significant outlets with very high costs. Water Quality Appurtenances is a user defined item.

The user can also choose a Complete-in-Place option. This option includes all excavation costs and appurtenance costs related to the pond. These costs are based on previous construction costs on detention ponds in the Denver Metro area.

Removals

This section covers removal of culvert and storm drain pipe. Special removals would be included under the Special Items section of the tool. The focus of the removals section on the UD-MP Cost tool is for pipes and box culverts. Available items and unit rates are shown in Appendix A.

Landscaping and Maintenance Access

Landscaping and maintenance access are commonly included in drainageway master planning projects. This section is provided to cover common improvements including seeding and trail improvements. In regards to revegetation, the user can choose from wetlands plantings or simple reclamation using native seeding. Wetlands planting is meant to cover a variety of items including wetlands seeding, plug planting, shrubs, and wet tolerant trees. Available pay items and unit costs are shown in Appendix A.

Special Items

While the purpose of the UD-MP Cost tool is to provide consistency in cost estimating for master planning projects, it is understood that there is no exhaustive list of infrastructure improvements which will meet the needs of every project. To account for this, the special items section of the estimation tool allows for complete user defined input including the item, the quantity, the unit, and the unit costs.

Land Acquisition

Due to the variability of costs for land acquisition and easements, this section allows user input for unit costs. Temporary easements have a quantity of each, while Easement/ROW acquisition has a unit of acres.

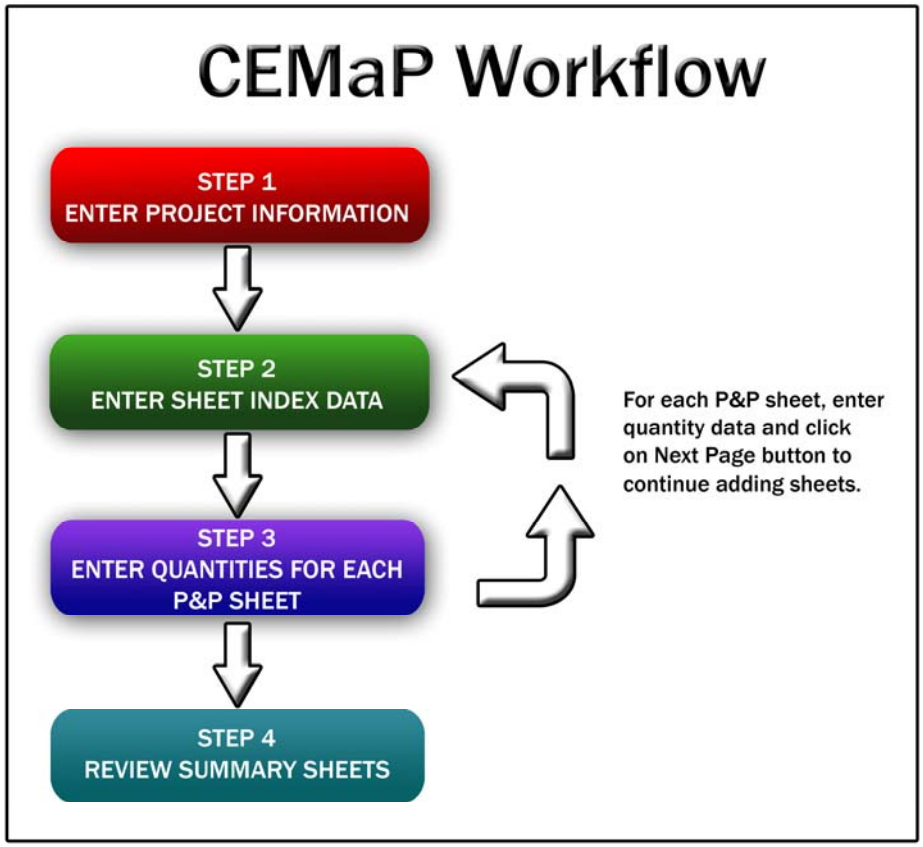
2 UD-MP COST USER GUIDE

2.1 UD-MP Cost Tool Components Overview

The UD-MP Cost Tool is composed of four types of worksheets; project data, cost summaries, individual cost worksheets, and backup cost data. The development of unit costs was discussed in Chapter 1 of this User's Guide and is located on the backup cost data tabs within the spreadsheet. The backup data tabs included in the spreadsheet are summarized below:

- Cost Data – Primary location of construction cost data.
- Headwall Table – Tabulation of quantities for CDOT pipe headwalls.
- Wingwall Table – Tabulation of quantities for CDOT wingwalls.
- Box Culvert Table – Tabulation of quantities and costs for box culverts.
- Research Data – Reference data on miscellaneous cost development.

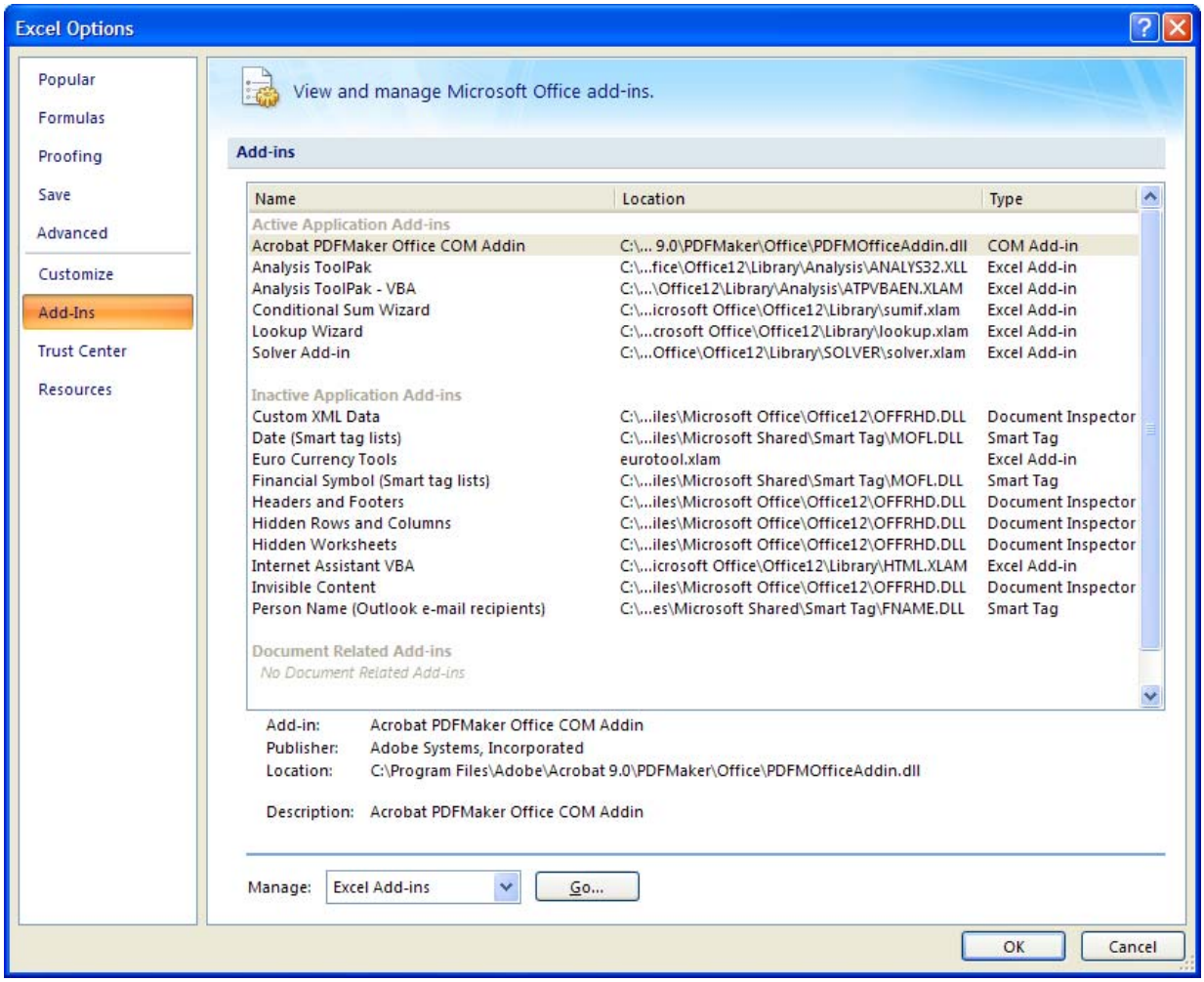
User interaction is constrained to the project data sheets and the individual cost worksheets. Cost summaries present a summary of user input only and are not editable. The figure below shows the workflow for a user of the UD-MP Cost program. Section 2.2 of the User's Guide explains the specific input requirements for each worksheet in the tool.



2.2 Before You Get Started

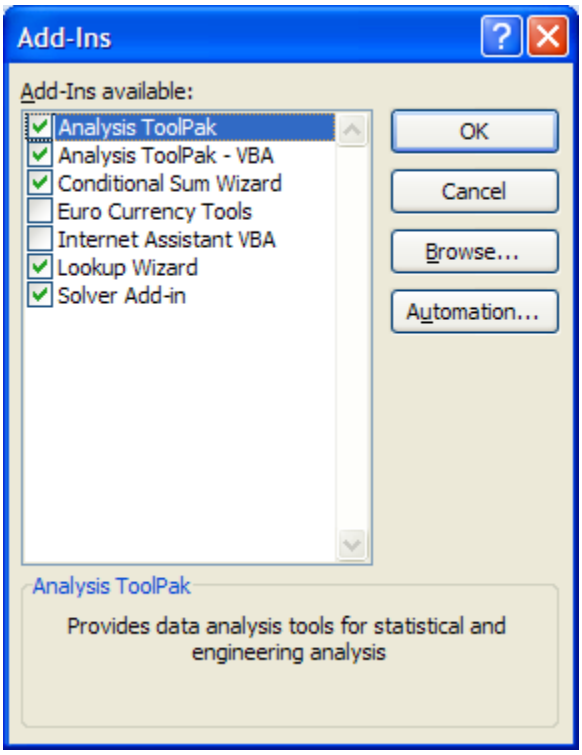
The UD-COST tool uses some of the advanced functionality of Excel. The user must have this advanced functionality active within the spreadsheet for all of the formulas to calculate correction. In general, if errors are shown in the calculation cells it is likely that the necessary add-ins are not loaded in Excel. To load these, the user must do the following in Excel:

1. Navigate to the “Excel Options” dialogue box. In Windows Office 2007 this can be found by clicking on the “Windows” icon in the upper left portion of Excel and clicking on the “Excel Options” button at the bottom of the dialogue box that appears.
2. Next, click on the “Add-Ins” option on the left side of the dialogue box. In this view you can see what add-ins are currently loaded in to Excel.



3. In the bottom of the screen is the “Manage” tool with a pulldown showing Excel Add-in and other program add-ins. With the Excel Add-ins pulldown option shown, click on the “Go…” button.

4. Make sure the Analysis ToolPak, Lookup Wizard, and Solver Add-in are checked.



Once these options are loaded, formula errors should be eliminated.

2.3 Entering Project Data Into UD-MP Cost

The UD-MP Cost tool is color coded throughout to provide general guidance for the user. These colors are based on typical UDFCD spreadsheet tool colors and have the following meanings:

- Yellow – Sheet titles and major headings
- Blue – User input fields
- Green – Calculated fields or fields populated by user entry from input fields.
- Grey – Sub-headings
- Peach – Used for subtotal summaries
- White – Standard fields, previously populated

Step 1 : Enter Project Information

Introduction

The first page the user will come to when opening the UD-MP Cost tool is the Intro page. This page summarize the purpose and function of the tool and provides links to the project data worksheets via buttons on the left hand side of the page.

Project Information

The UD-MP Cost tool is set up to minimize repetitive user entry. As the user moves forward through the tool, previous input is used for the header and other cells as appropriate. The Project Info tab is meant to collect the following information:

- Project Name
- Estimator (user entering the data)
- Date
- Drainageways being studied
- Number of project reaches
- Jurisdictions located within the project area (see note below)

Note: Per UDFCD guidelines, each reach must have a specific jurisdiction, i.e. reach breaks are to occur at jurisdictional boundaries.

The Length column is an optional summary tool and is populated based on data placed on the Sheet Index. This data is not necessary for the UD-MP Cost tool to operate properly.

The tool also has a built in inflation calculator. After entering the current year, the user may input an inflation index. If a number is entered here, the tool increases the present value of all cost data within the spreadsheet.

USER TIP :

Per UDFCD guidelines, user's should designate/define reaches considering the following items:

- Reaches should be broken at jurisdicitional boundaries
- Reaches should change when channel characteristics vary significantly, i.e. group similar stretches of drainageway together
- Reaches should end/start at confluences to other major drainageways
- Reach breaks should be considered at locations of significant changes in flow rates that may warrant larger improvements.

Step 2 : Enter Sheet Data

Sheet Index

The Sheet Index is meant to capture data regarding each plan and profile sheet including the reach, or reaches, on the sheet, jurisdictions, and upstream and downstream station limits (Note : Station limits are entered in feet – stationing format is handled by Excel formatting options). Station limits are used to calculate a length which then populates the length column on the Project Info tab. Stream stationing is an optional user input item. All of the data entered here is forwarded on to the Individual Cost Worksheets. In addition, hyperlinks are provided in the first column of the Index Sheet to take the user to the quantity/cost portion of the UD-MP Cost tool. Drainageway and Jurisdiction data is handled by pull-down menus populated by the Project Info tab.

USER TIP :

When P&P sheets have more than one reach, user must designate separate cost worksheets for each reach. For example, if P&P Sheet 1 has Reach 1 and Reach 2 within its boundaries, the user will input one row as P&P Sheet 1, Reach Number 1 and another row as P&P Sheet 1, Reach Number 2. Users should plan ahead accordingly when starting a cost estimate.

Step 3 : Entering Data on the Individual Cost Sheets

The following sections walk through, step-by-step, the user entry into the Individual Cost Sheets. Each major and minor heading is addressed.

Individual Sheet Costs

After populating the Sheet Index, the user will progress to placing quantities in the individual Sheet Cost worksheets. The user can hyperlink to these sheets from the Sheet Index and return to the Sheet Index via a button on the Individual Cost Sheet. There are several buttons provided at the top of the sheet to aid the user in use of the tool including a "Previous Page", "Next Page", "Return to Index", "Filter Summary", "Clear Filter", and "Reset" sheet button. A brief description of the button function is provided here:

Navigation Tools : The "Previous Page", "Next Page", and "Return to Index" buttons are meant for easing navigation through the tool itself.

Reset : The "Reset" button clears all unlocked, user input, cells.

Filter Summary : The "Filter Summary" button is meant to provide a summary that can be used for the plan and profile narratives in the drainageway master plans. Rows that have a zero dollar total cost are hidden as are some of the columns in the spreadsheet.

Undo Filter : The "Undo Filter" button returns the spreadsheet to its standard configuration, i.e. no filter applied and no hidden columns or rows.

The Individual Cost Sheets are broken down into major categories as follows:

- Pipe Culverts and Storm Drains
- Concrete Box Culverts
- Hydraulic Structures
- Channel Improvements
- Detention/Water Quality Facilities
- Removals
- Landscaping and Recreation Improvements
- Special Items (User Defined)
- Land Acquisition

At the bottom of the sheet is a cost summary that has three areas for user defined input for Dewatering, Traffic Control, and Utility Coordination/Relocation. For this version of UD-MP Cost, these items are identified as lump sum, allowing the user to determine if the items are needed and how much the cost of each item might be worth on the sheet.

Because all projects are different, it is understood that the UD-MP Cost tool is not going to have a pay item for every type of improvement that may be proposed on a master planning project. Because of this, a Special Items (User Defined) section has been provided that allows for definition of items, quantities, unit, and unit cost.

Pipe Culverts and Storm Drains

Items covered under this major heading include:

- Circular Pipes

- Flared End Sections
- Headwalls
- Wingwalls
- Manholes and Inlets

Circular Pipes

1. Circular pipes are entered by users selecting a pipe size with the pull-down menu under the Diameter column. Available pipe sizes range from 12-inches to 120-inches. When pipes larger than this are needed, the user should use a box culvert.
2. Once a pipe size is entered, the user must enter a total length of the pipe section.
3. User must enter number of barrel sections along the noted length.

   Example :

   Given : Roadway crossing shown on plan with 3 – 36” culverts with an upstream to downstream length of 100 feet.

   User Entry : Diameter = 36-inch

   Length = 100 ft

   No. of Barrels = 3

   Quantity : 300 lineal feet of 36-inch RCP

Flared End Sections

1. Pipe diameter and number of barrels are carried down to this section from the user’s Circular Pipe input. It is noted here that only pipes of 48-inches in diameter and smaller are allowed to use flared end sections. For purposes of this spreadsheet and UDFCD master planning, anything larger than 48-inches requires a headwall and wingwalls.
2. For pipes that are 48-inches in diameter and smaller, the user only has to enter two variables; whether flared end sections are needed on the upstream end and/or whether flared end sections are needed on the downstream end. These variables are input via pull-down by selecting either “Yes” or “No”. Quantities are estimated based on the number of barrels and the user specified end treatment.

   Example :

   Given : Using the previous example of 3- 36” culverts using flared end sections upstream and downstream.

   User Entry : U/S FES = Yes

   D/S FES = Yes

   Quantity : 3 x 36-inch flared end sections

Headwalls

1. Pipe diameter and number of barrels are carried down to this section from the user's Circular Pipe input. It is noted here that only pipes of 54-inches in diameter and larger are allowed to use headwall end treatments. For purposes of this spreadsheet and UDFCD master planning, anything smaller than 54-inches uses a flared end section.
2. For pipes that are 54-inches in diameter and larger, the user only has to enter two variables; whether a headwall is needed on the upstream end and/or whether a headwall is needed on the downstream end. These variables are input via pull-down by selecting either "Yes" or "No". Quantities are estimated based on the number of barrels and the user specified end treatment.

   Example :

   Given : Roadway crossing shown on plan using 2 – 54" culverts with upstream and downstream headwall treatments.

   User Entry : U/S FES = Yes

   D/S FES = Yes

   Quantity : 2 headwalls

Wingwalls

1. Pipe diameter, number of barrels, and quantity of wingwall treatments are all carried down to this section from the user's Circular Pipe input and Headwall input. For purposes of this spreadsheet, if the user intends to use a headwall, wingwalls are automatically assumed. The quantity shown represents a "pair" of wingwalls, i.e. a left and right wingwall.

   Example :

   Given : Using the previous example under Headwalls with 2 – 54" culverts with upstream and downstream headwall treatments.

   User Entry : None

   Quantity : 2 wingwalls

   (assumes left and right wingwalls at either end of culvert)

Manholes and Inlets

1. User input for manholes is limited to the quantity estimate only. The user need only identify which type of manhole that is shown or required on the plan and input the total number. All manhole costs are based on a 15-foot average depth. This provides a consistent and conservative cost basis for manholes. If the user has a unique manhole condition then a user defined pay item may be used in the Special Items (User Defined) portion of the spreadsheet. A brief explanation of proper manhole selection is provided below:
   a. Manhole, 4'Dia. (Pipe Dia. < 36"): This manhole type should be used when the upstream and downstream pipe sections are smaller than 36-inches.
   b. Manhole, 5' Dia. (Pipe Dia. 36" – 42"): This manhole type should be used when the upstream and downstream pipe sections are between 36-inches and 42-inches.

c. Manhole, 6' Dia. (Pipe Dia. = 48"): As an alternative to the Denver Type B or Type P, the user may elect to use this manhole for locations when the upstream and downstream pipe sections are no larger than 48-inches.

d. Type-B Manhole (Pipe Dia. 48" and larger, deflection < 10 degrees) : This manhole type should be used when upstream and downstream pipe segments are 48-inches or larger. The Type-B manholes are generally a "straight run" manhole and should only be used if the deflection at the manhole is less than 10 degrees.

e. Type-P Manhole (Pipe Dia. 48" and larger, deflection > 10 degrees) : This manhole type should be used when upstream and downstream pipe segments are 48-inches or larger. The Type-P are for system deflection points and should be used if the deflection at the manhole is greater than 10 degrees.

2. User input for inlets is also limited to the number of inlets. A standard 5-foot Type-R (Denver Type-14) with a 10-foot average depth is assumed for planning purposes. If a user requires a 10-foot inlet to intercept flows they need only input 2 inlets to represent the longer section or 3 inlets for a 15-foot inlet.

Concrete Box Culverts

Items covered under this major heading include:

- Box Culvert Pipe
- Headwalls and Toewalls
- Wingwalls

Box Culvert Pipe

1. Users must input box span, box height, and number of box barrels to populate the UD-MP Cost tool. Both box span and box height are pull-down menus. Materials are based on CDOT M&S Standard Details. In some cases, the box and height combination does not exist and the user will get an error on the Unit Cost and Total Cost Column. To fix this problem, the user must select a box size that has cost data associated with it based on the standard details and available data. Table 3 shows the list of available box sizes (green (solid) cells are available in UD-MP Cost; cross hatched cells are not available).

Table 3 : Available Box Culvert Sizes

Span (feet)	Rise (feet)								
	2	3	4	5	6	7	8	9	10
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
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16									
17									
18									
19									
20									

Headwalls and Toewalls

1. Box spans are carried to this section from the Box Culvert Pipe input. To complete this section the user only need enter two variables; whether a headwall is needed on the upstream end and/or whether a headwall is needed on the downstream end. These variables are input via pull-down by selecting either “Yes” or “No”. Quantities are estimated based on the number of barrels and the user specified end treatment as shown in the CDOT M&S Standards.

Wingwalls

1. Box span, rise, number of barrels, and whether the upstream and downstream ends of the culvert receive headwalls and wingwalls are all carried down to this section from the user’s Box Culvert Pipe input and Headwall input. For purposes of this spreadsheet, if the user intends to use a headwall, wingwalls are automatically assumed. The quantity shown represents a “pair” of wingwalls, i.e. a left and right wingwalls.

Hydraulic Structures

Items covered under this major heading include:

- Sloping Drop Structures
- Check Structures

Sloping Drop Structures

1. Sloping Drop Structures require three user inputs; height, bottom width, and normal depth (See Figure HS-7A in the UDFCD Drainage Criteria Manual Volume 2).
    a. Drop height refers to the height from the drop crest to the top of the downstream sill.
    b. Bottom width refers to the upstream trapezoidal bottom width.
    c. The normal depth refers to the normal depth in the upstream section before entering the drop.
    d. The quantities assume use of 36-inch boulders.

Check Structures

1. Check structures are input into UD-MP Cost by the linear foot. The user must determine a total quantity by linear feet for each sheet and input the data here. No other input is needed.

Channel Improvements

Items covered under this major heading include all items related to channel rehabilitation, reconstruction, or repair. Items are accesses via a pull-down menu. UD-MP Cost provides coinciding units and unit costs based on the user's selection. Once the user has chosen an item, the tool requires that a quantity be input on the right hand side of the spreadsheet. Costs are then automatically calculated.

Detention/Water Quality Facilities

For detention, items are limited to excavation, outlet works, and water quality appurtenances. Users may also select a complete-in-place option that includes all associated costs and is based on an acre-foot unit cost. If that item is not used, the user must specify the estimated amount of excavation based on whether the excavation costs will be high, moderate or low.

Selection of an excavation item is primarily based on whether excavation conditions will require substantial dewatering, muck excavation, rock excavation, or waste materials and if a potential waste site or fill site is available nearby. For example, a detention for a site development would likely use a low range excavation cost as excavated material could likely be placed nearby on-site. Any site requiring long distance hauling would likely fall under the high range excavation quantity. This choice is left to the user.

Users must also specify unit costs for outlet works and water quality appurtenances based on their experience and knowledge.

Removals

User input for removals is limited to quantity, in linear feet, of pipe removal based on size. User's simply input the total lineal feet of pipe to be removed on the row corresponding to the pipe size to be removed. Each barrel is counted separately for these quantities:

Example :

Given : Roadway crossing shown on plan removing 2 – 54" culverts with a total length from upstream to downstream of 200 linear feet.

User Entry : 400 linear feet of "Removal of Culvert Pipe (48"<D<84")

Landscaping and Maintenance Access

Items provided for this section are limited to wetlands planting, seeding, and trails. More specific items must be entered under the "Special Items" section of UD-MP Cost. For this section, users need only input quantities based on the units supplied in the spreadsheet. Specifically, the user should consider the following when inputting items in this category:

- Wetlands Plantings cover costs associated with wetland shrubs, willow staking, plugs, and seeding. This item would only be used in areas where a wetland zone is desired.
- Reclamation & Seeding is meant to cover all uplands type seeding and restorative seeding from temporary construction impacts.
- Trails are broken up into concrete and crusher fines based on the desires of the project sponsors.

Special Items (User Defined)

The user is urged to use the items on the UD-MP Cost tool, but it is understood that in some circumstances, special items will be required. For items that are not covered elsewhere the Special Items section allows users to input item a description, quantity, units, and unit cost. A good example of items that might be shown here include pedestrian bridges and/or vehicular bridges over drainageways.

An example of what not to use the Special Items (User Defined) portion of the spreadsheet is a scenario where the user may want to specify a specific channel improvement using a linear foot cost. This item might include items such as a low flow channel, excavation, planting, riprap, etc. It is desired that the user should provide a typical channel detail and determine quantities and use the Channel Improvements portion of the UD-MP Cost tool.

Land Acquisition

Land acquisition costs will depend greatly on the location and existing land use of the property to be acquired. For this purpose, the user is allowed to input unit costs for Temporary Easements and Easement/ROW Acquisition. Planners should consult ROW experts when preparing these costs.

Master Plan Improvement Cost Summary

The Master Plan Improvement Summary provides a summary of all proposed capital improvements, land acquisition costs, additional capital construction costs and contingency items.

Additional Capital Construction Cost

There are three optional items that allow for user input in the Master Plan Improvement Cost Summary. These include dewatering, traffic control, and utility coordination/relocation.

Dewatering : The dewatering item should be used on streams with perennial flows or in locations that are extremely wet. This may include rehabilitation or construction of detention facilities. In general, when it is anticipated that significant dewatering is to be required a cost of 5-10% of the construction costs should be used for this item.

Mobilization : Mobilization includes all contractor costs to get equipment to the construction site, delivery of materials, and creation of the staging area including wash-outs and tracking control. For this tool, mobilization is assumed to be 5% of construction costs.

Traffic Control : When roadway crossings are being replaced or constructed, this item should be used. Costs can have significant variability based on the type of roadway, i.e. local, collector, or major arterial. In general, it is recommended that the user look at the cost of the improvements at the roadway crossing and the roadway classification and develop a cost based on a percent of construction. For example, a roadway crossing for a local road might use a 5% of construction cost for traffic control whereas a roadway crossing for a major arterial could be up to or more than 10% of construction.

Utility Coordination/Relocation : Utility relocation may not be required on projects, but sometimes can be a significant cost item. When a clear utility conflict is identified, this item is provided so that the user can provide a reasonable cost estimate for the work.

Stormwater Management/Erosion Control : This item includes preparation of a SWMP plan and all associated erosion control items and BMP's necessary during construction to control sediment and pollutant discharges. For this spreadsheet the amount is estimated at 5% of improvement costs.

Other Costs

Other costs, i.e. contingencies shown on the Master Plan Improvement Cost Summary include the following:

Engineering : Engineering is defined as the professional engineering services required to design the proposed capital improvements. Costs include preparation of construction plans, specifications, and all associated administrative services from notice-to-proceed to bidding assistance. For UD-MP Cost, this amount is estimated at 15% of the improvement costs.

Legal/Administrative : Legal/Administrative costs are provided to cover the costs of legal fees for land acquisition, general contracting administration, and other support services. For UD-MP Cost, this amount is estimated as 5% of the improvement costs.

Contract Admin/Construction Management : This item includes all professional services required for construction observation, review of shop drawings and technical submittals, requests for information, preparation of pay estimates, etc. For UD-MP Cost, this amount is estimated at 10% of the improvement costs.

Contingency : UD-MP Cost is meant to cover the "major" items shown on a drainageway master plan or outfall systems plan. To account for all additional items and unknowns, the contingency factor is applied to the total costs of improvement. This percentage is set at 25% in UD-MP Cost.

Step 4 : Review Summary Sheets

Four summary tabulations are provided by the UD-MP Cost Tool; Totals by Cost Sheet, Totals by Plan and Profiles Sheet, Jurisdiction Summary, and Reach Summary. These summaries are meant to aid the user in preparing master plan and outfall systems plans reports. They serve as a basic foundation, allowing the user to cut and paste data into the report itself and modify the table as necessary to convey pertinent information.

Total by Sheet : This summary table tabulates all of the Sheet Cost tabs for which the user input data. Blank worksheets are not tabulated. This summary is fully populated by the tool and does not require user input. The summary breaks down costs for each reach for Capital Improvements, Easements/ROW, Engineering fees, Legal Administrative Fees, Contract Administration/Construction Management, Contingency, and Total Sheet Cost.

Total by Plan and Profile Sheet : The Total by Plan and Profile Sheet summarizes the costs by individual plan and profile sheets.

Jurisdiction Summary : The jurisdiction summary breaks down the costs in a similar fashion to the Total by Sheet tab, but separates cost by the jurisdiction where they are proposed. This table is typically used in UDFCD master plans.

Reach Summary : The reach summary also breaks down costs for each reach. This table is typically provided in UDFCD master plans.

3 REFERENCES

1. Colorado Department of Transportation. Cost Data Book, 2005, 2006, 2007, 2008.

2. Colorado Department of Transportation. Standard Plans, M&S Standards, 2000.

3. Urban Drainage and Flood Control District. Bid Tabs Program, 2007.

4. City and County of Denver. Denver Storm Drainage Master Plan, 2009.

5. City and County of Denver. Standard Details, 1995.

4 APPENDIX

APPENDIX A – Unit Cost Data Summary

APPENDIX B – Standard Details

APPENDIX C – Calculation Design Aids

APPENDIX A

COST DATA

Cost Data

Item	Unit	Unit Cost 2009	Unit Cost Current Yr.
Circular Pipes			
12-inch	L.F.	$42.00	$42.00
18-inch	L.F.	$63.00	$63.00
24-inch	L.F.	$84.00	$84.00
30-inch	L.F.	$105.00	$105.00
36-inch	L.F.	$126.00	$126.00
42-inch	L.F.	$147.00	$147.00
48-inch	L.F.	$168.00	$168.00
54-inch	L.F.	$189.00	$189.00
60-inch	L.F.	$210.00	$210.00
66-inch	L.F.	$231.00	$231.00
72-inch	L.F.	$360.00	$360.00
78-inch	L.F.	$390.00	$390.00
84-inch	L.F.	$420.00	$420.00
90-inch	L.F.	$450.00	$450.00
96-inch	L.F.	$480.00	$480.00
102-inch	L.F.	$714.00	$714.00
108-inch	L.F.	$756.00	$756.00
120-inch	L.F.	$840.00	$840.00
Flared End Sections			
12-inch	EA	$650.00	$650.00
18-inch	EA	$750.00	$750.00
24-inch	EA	$850.00	$850.00
30-inch	EA	$1,050.00	$1,050.00
36-inch	EA	$1,500.00	$1,500.00
42-inch	EA	$1,950.00	$1,950.00
48-inch	EA	$2,000.00	$2,000.00
Manholes and Inlets			
Manhole, 4' Dia. (Pipe Dia. < 36"), Depth > 15-feet)	EA	$3,000.00	$3,000.00
Manhole, 5' Dia. (Pipe Dia. 36" - 42"), Depth > 15-feet)	EA	$4,500.00	$4,500.00
Manhole, 6' Dia. (Pipe Dia. , Depth > 15-feet)	EA	$5,250.00	$5,250.00
Type B Manhole (Pipe Dia. 48" and larger, deflection < 10 degrees)	EA	$10,000.00	$10,000.00
Type P Manhole (Pipe Dia. 48" and larger, deflection > 10 degrees)	EA	$15,000.00	$15,000.00
Storm Inlet, Type R/Type 14, 5-foot, 10-foot deep avg.	EA	$3,500.00	$3,500.00
Headwalls for Circular Pipes			
See Headwall Table			
Wingwalls for Circular Pipes			
See Wingwall Table			
Hydraulic Structures			
Grouted Boulders, 36-inch	C.Y.	$250.00	$250.00
Riprap, Type M	C.Y.	$60.00	$60.00
Soil Riprap, Type M	C.Y.	$65.00	$65.00
Excavation, Complete-in-Place	C.Y.	$12.00	$12.00
Bedding, Granular Type II	C.Y.	$50.00	$50.00
Grout	C.Y.	$275.00	$275.00
Check Structure, Concrete	L.F.	$220.00	$340.00
Channel Improvements			
Boulder Edging, 12" High	L.F.	$75.00	$75.00
Boulder Edging, 24" High	L.F.	$80.00	$80.00
Boulder Edging, 36" High	L.F.	$90.00	$90.00
Concrete Low Flow Channel	L.F.	$45.00	$45.00
Grouted Boulders, 12"	S.Y.	$100.00	$100.00
Grouted Boulders, 18"	S.Y.	$150.00	$150.00
Grouted Boulders, 24"	S.Y.	$200.00	$200.00
Grouted Boulders, 36"	S.Y.	$250.00	$250.00
Grouted Boulders, 48"	S.Y.	$300.00	$300.00
6-inch Riprap, Type VL	C.Y.	$45.00	$45.00
9-inch Riprap, Type L	C.Y.	$50.00	$50.00
12-inch Riprap, Type M	C.Y.	$55.00	$55.00
18-inch Riprap, Type H	C.Y.	$65.00	$65.00
24-inch Riprap, Type VH	C.Y.	$80.00	$80.00
Soil Riprap, Type VL	C.Y.	$50.00	$50.00
Soil Riprap, Type L	C.Y.	$55.00	$55.00
Soil Riprap, Type M	C.Y.	$60.00	$60.00
Soil Riprap, Type H	C.Y.	$70.00	$70.00
Soil Riprap, Type VH	C.Y.	$85.00	$85.00
Excavation, Low Range	C.Y.	$12.00	$12.00
Excavation, Mid Range	C.Y.	$15.00	$15.00
Excavation, High Range	C.Y.	$25.00	$25.00
Detention/Water Quality Facilities			
Excavation, Low Range	C.Y.	$12.00	$12.00
Excavation, Mid Range	C.Y.	$15.00	$15.00
Excavation, High Range	C.Y.	$25.00	$25.00
Outlet Works	EA		
Water Quality Appurtenances	EA		
Detention (Complete-in-Place)	AC-FT	$45,600.00	$45,600.00
Landscaping and Recreation Improvements			
Wetlands Plantings	ACRE	$25,000.00	$25,000.00
Reclamation & seeding (native grasses)	ACRE	$1,000.00	$1,000.00
Trail/Path, Concrete (10' Width)	L.F.	$40.00	$40.00
Trail/Path, Crusher Fines (10' Width)	L.F.	$10.00	$10.00
Removals			
Removal of culvert pipe (D<48")	LF	$30.00	$30.00
Removal of culvert pipe (48"<D<84")	LF	$50.00	$50.00
Removal of culvert pipe (D>84")	LF	$75.00	$75.00
Concrete Box Culvert	LF/CELL	$100.00	$100.00
Land Acquisition			
Temporary Easements	EA	$5,000.00	$5,000.00
Easement/ROW Acquisition	ACRE	$35,000.00	$35,000.00
Concrete and Steel			
Concrete	C.Y.	$700.00	$700.00
Steel	LB.	$0.80	$0.80

APPENDIX B

STANDARD DETAILS

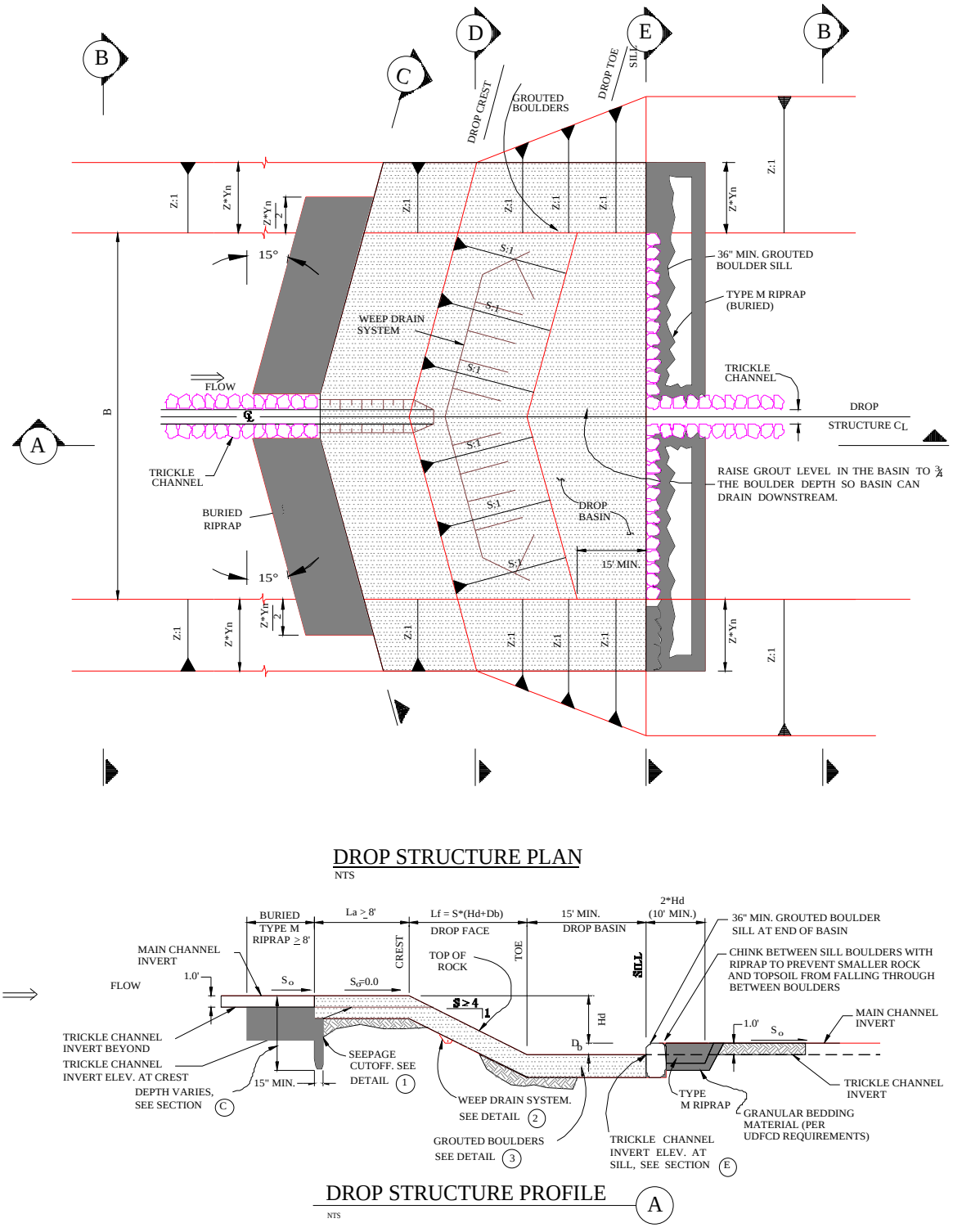


Figure HS-7A—Grouted Sloping Boulder Drop with Trickle Channel for Stabilized Channels in Erosion Resistant Soils (Figure 1 of 2)

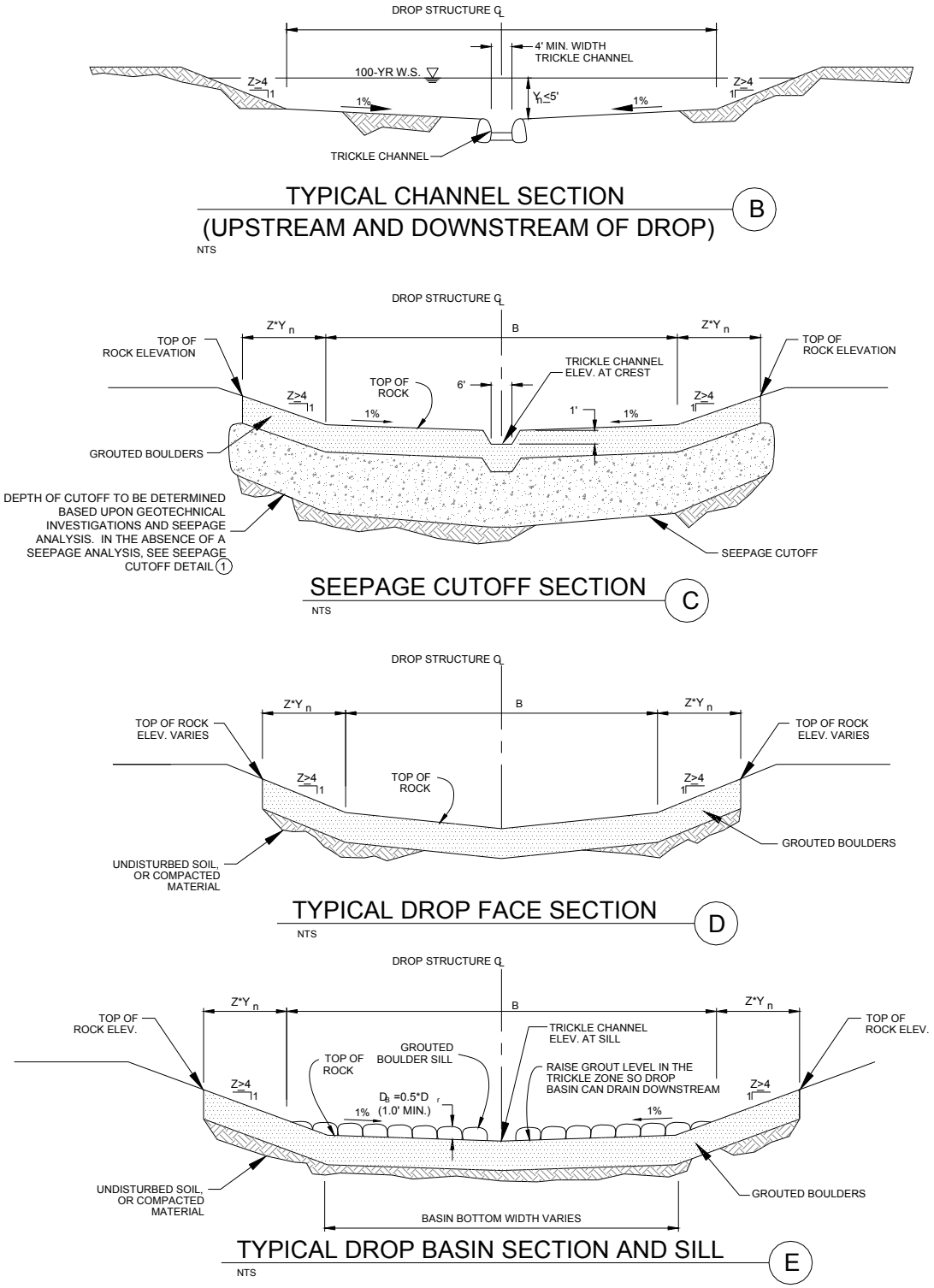


Figure HS-7A— Grouted Sloping Boulder Drop with Trickle Channel for Stabilized Channels and Erosion Resistant Soils (Figure 2 of 2)

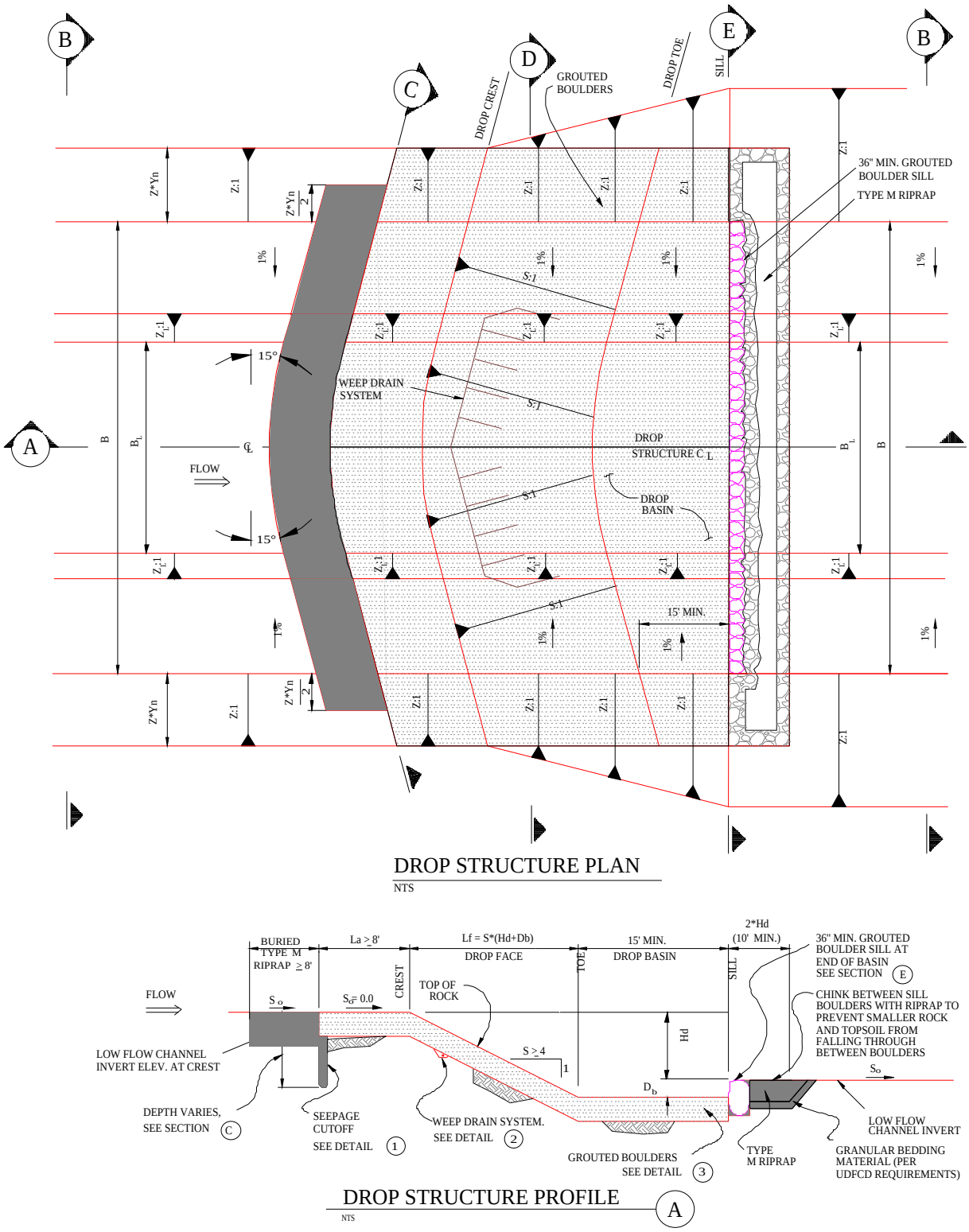
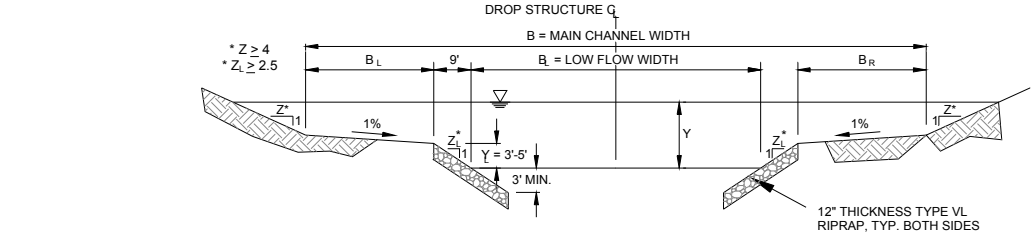
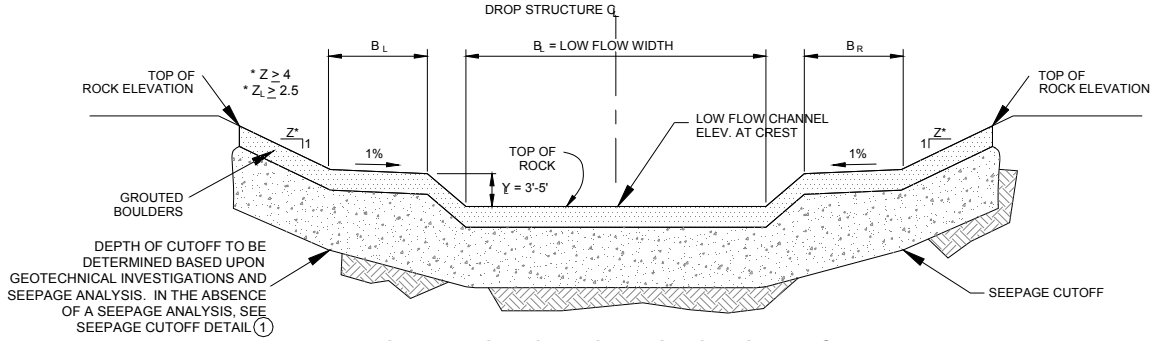


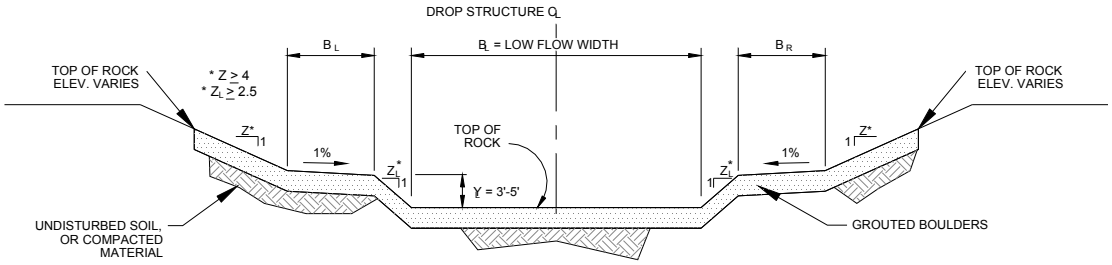
Figure HS-7B—Grouted Sloping Boulder Drop With Low-Flow Channel for Stabilized Channels in Erosion Resistant Soils (Figure 1 of 2)



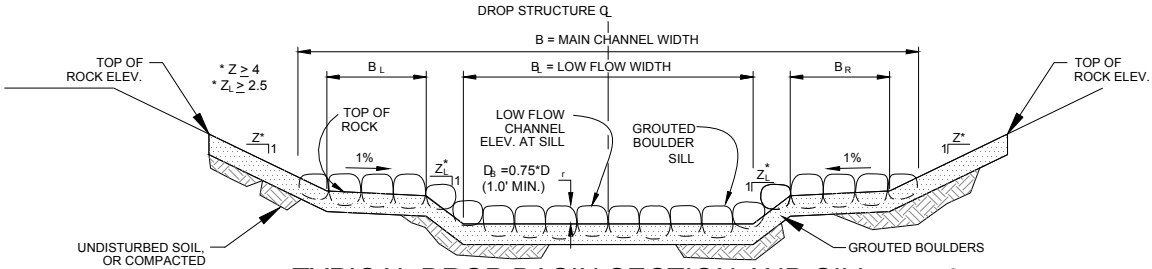
TYPICAL CHANNEL SECTION
(UPSTREAM AND DOWNSTREAM OF DROP
NTS
B



SEEPAGE CUTOFF SECTION
NTS
C



TYPICAL DROP FACE SECTION
NTS
D



TYPICAL DROP BASIN SECTION AND SILL
NTS
E

Figure HS-7B— Grouted Sloping Boulder Drop With Low-Flow Channel For Stabilized Channels and Erosion Resistant Soils (Figure 2 of 2)

SINGLE CONCRETE BOX CULVERT DIMENSIONS & QUANTITIES (EXCLUDING HEADWALLS & TOEWALLS)

BOX SIZE				FILL HEIGHT ALLOWED	SLAB & WALL THICKNESS (INCHES)			BAR SIZES						d_1▲	DIMENSIONS					QUANTITIES	
S	R	HT.	WIDTH		T_t	T_b	TW	t_1* & b_1	t_2	b_2	w_1* & w_2	c_1*	c_2		h_1	h_2	v_1	v_2	v_3	CONCRETE	REBAR STL
FT.	FT.	FT.-IN.	FT.-IN.	FT.-FT.				#	#	#	#	#	#	NO.	FT.-IN.	FT.-IN.	FT.-IN.	FT.-IN.	FT.-IN.	CU.YDS./LIN.FT	LBS./LIN.FT.
6	7	8-5	7-8	0 TO 10	8	9	10	4	5	5	4	4	4	48	2-7	2-11	7-6	2-3	2-3	0.834	153
		8-7	7-8	>10 TO 15	8.5	10.5	10	4	5	5	4	4	4		2-7	3-1	7-6	2-4	2-4	0.882	154
		8-10	7-8	>15 TO 20	10	12.0	10	4	5	5	4	4	4		2-7	3-3	7-9	2-6	2-6	0.953	156
8	6	7-7.5	9-8	0 TO 10	9	10.5	10	4	6	6	4	4	4	52	3-4	2-10	6-7	2-4	2-4	0.952	184
		7-11	9-8	>10 TO 15	10.5	12.5	10	4	6	6	4	4	4		3-0	2-10	6-8	2-6	2-6	1.057	184
		8-3	9-8	>15 TO 20	12.5	14.5	10	4	7	7	4	4	4		3-2	2-11	6-10	2-8	2-8	1.176	207
	8	9-7.5	9-8	0 TO 10	9.0	10.5	10	4	6	6	4	5	4	60	4-5	3-5	8-7	2-4	2-4	1.076	224
		9-11	9-8	>10 TO 15	10.5	12.5	10	4	6	6	4	5	4		2-9	3-7	8-8	2-6	2-6	1.180	218
		10-3	9-8	>15 TO 20	12.5	14.5	10	4	6	6	4	5	4		2-9	3-9	8-10	2-8	2-8	1.299	221
	10	11-8	9-8	0 TO 10	9	11	10	4	6	5	5	5	5	64	2-9	2-9	10-7	2-10	2-10	1.214	253
		11-11	9-8	>10 TO 15	10.5	12.5	10	4	6	6	5	5	5		2-9	2-9	10-8	2-11	2-11	1.303	267
		12-3	9-11	>15 TO 20	12.5	14.5	11.5	4	6	6	5	5	5		2-11	5-1	10-10	3-1	3-1	1.536	282
10	6	7-10.5	11-8	0 TO 10	10.5	12.0	10	4	6	7	4	5	5	56	3-4	3-0	6-8	2-11	2-6	1.181	243
		8-3	11-8	>10 TO 15	12.5	14.5	10	4	7	7	4	5	4		3-4	2-11	6-10	3-1	2-8	1.343	248
		8-10	11-8	>15 TO 20	15.5	18.5	10	4	7	7	4	4	5		3-1	2-9	7-1	3-5	3-0	1.395	244
	8	9-10.5	11-8	0 TO 10	10.5	12.0	10	4	6	7	4	5	5	64	3-11	3-5	8-8	2-11	2-6	1.304	266
		10-3.5	11-8	>10 TO 15	13	14.5	10	4	7	7	4	5	5		4-1	3-6	8-11	3-1	2-8	1.484	282
		10-9	11-8	>15 TO 20	15.5	17.5	10	4	7	7	4	5	5		3-6	2-11	9-1	3-4	2-11	1.682	280
	10	11-11	11-8	0 TO 10	10.5	12.5	10	4	6	6	4	5	5		2-11	4-6	10-8	2-11	2-6	1.445	270
		12-3.5	11-8	>10 TO 15	12.5	15.0	10	4	7	7	5	6	5	68	3-4	4-10	10-10	3-7	3-2	1.608	354
		12-8	11-11	>15 TO 20	15.0	17.5	11.5	4	7	7	5	5	5		3-8	3-4	11-1	3-4	3-4	1.905	328
12	6	7-11	13-8	0 TO 8	10.5	12.5	10	4	7	7	4	6	5	60	3-11	3-8	6-8	3-4	2-6	1.341	306
		8-4	13-8	>8 TO 12	13	15	10	4	8	8	4	5	5		2-10	2-9	6-11	3-2	2-9	1.551	313
		8-9.5	13-8	>12 TO 16	15.5	18	10	4	8	8	4	5	5		3-6	2-9	7-1	3-5	3-0	1.783	319
		9-3.5	13-8	>16 TO 20	19.0	20.5	10	4	8	9	4	5	5		3-6	2-9	7-5	3-7	3-2	2.037	341
	8	9-11	13-8	0 TO 8	10.5	12.5	10	4	7	7	5	6	5	68	4-1	3-9	8-8	3-4	2-11	1.464	351
		10-4	13-8	>8 TO 12	13	15	10	4	8	8	4	6	5		3-4	2-9	8-11	3-6	2-9	1.675	358
		10-9.5	13-8	>12 TO 16	15.5	18	10	4	8	8	4	5	5		3-6	2-10	9-1	3-5	3-0	1.907	338
		11-3.5	13-8	>16 TO 20	18.5	21	10	4	8	8	4	5	5		3-6	3-0	9-4	3-8	3-3	2.160	342
	10	12-0	13-8	0 TO 8	11	13	10	4	7	7	4	6	5	72	5-3	4-4	10-8	3-5	2-7	1.630	360
		12-4.5	13-8	>8 TO 12	13	15.5	10	4	8	8	4	6	6		3-4	3-4	10-11	3-7	2-9	1.819	393
		12-9.5	13-9	>12 TO 16	15.5	18	10.5	4	8	8	4	6	5		4-3	3-2	11-1	3-10	3-0	2 070	390
		13-2	13-11	>16 TO 20	18	20	11.5	4	8	8	4	6	5		4-4	3-5	11-4	4-0	3-2	2.342	396
14	6	7-11.5	15-8	0 TO 6	11	12.5	10	4	8	8	5	6	6	68	4-3	4-0	6-9	3-4	2-11	1.507	408
		8-2	15-8	>6 TO 8	12	14	10	4	8	8	4	6	6		4-1	3-4	6-10	3-6	2-8	1.628	386
		8-5	15-8	>8 TO 10	13.5	15.5	10	4	8	8	4	6	5		3-4	2-9	6-11	3-7	2-9	1.773	368
		8-9	15-8	>10 TO 12	15.5	17.5	10	4	9	9	4	6	5		4-3	2-10	7-1	3-9	2-11	1.966	421
		9-4.5	15-8	>12 TO 16	19.5	21	10	4	9	9	4	5	5		3-6	2-10	7-5	3-8	3-3	2.329	400
		9-7.5	15-8	>16 TO 18	21	22.5	10	4	9	9	4	5	5		3-6	2-11	7-7	3-9	3-4	2.474	402
	8	10-0	15-8	0 TO 6	11	13	10	4	8	8	5	6	6	76	4-4	4-1	8-9	3-5	3-0	1.654	435
		10-2	15-8	>6 TO 8	12	14	10	4	8	8	4	6	6		4-2	3-7	8-10	3-6	2-8	1.751	410
		10-5.5	15-8	>8 TO 10	13.5	16	10	4	8	8	4	6	5		3-4	2-11	8-11	3-8	2-10	1.920	394
		10-10	15-8	>10 TO 12	15.5	18.5	10	4	9	9	4	6	5		4-3	2-11	9-1	3-10	3-0	2.138	444
		11-3.5	15-9	>12 TO 16	18.5	21	10.5	4	9	9	4	5	5		3-7	3-1	9-4	3-8	3-3	2.439	421
		11-6.5	15-8	>16 TO 18	20	22.5	10	4	9	9	4	5	5		3-6	3-1	9-6	3-9	3-4	2.549	419
	10	12-0	15-8	0 TO 6	11	13	10	4	8	8	5	6	6	80	4-10	4-4	10-9	3-5	3-0	1.778	455
		12-2.5	15-8	>6 TO 8	12	14.5	10	4	8	8	4	6	6		4-10	4-3	10-10	3-6	2-8	1.899	439
		12-5.5	15-9	>8 TO 10	13.5	16	10.5	4	8	8	4	6	6		3-4	3-5	10-11	3-8	2-10	2.082	426
		12-9.5	15-9	>10 TO 12	15.5	18	10.5	4	8	8	4	6	6		4-3	3-4	11-1	3-10	3-0	2.277	436
		13-4	15-10	>12 TO 16	18.5	21.5	11	4	9	9	4	6	5		4-4	3-5	11-4	4-1	3-3	2.634	443
		13-6.5	15-11	>16 TO 18	20	22.5	11.5	4	9	9	4	6	5		4-4	3-6	11-6	4-2	3-4	2.798	477
16	6	8-2.5	17-9	0 TO 6	12.5	14	10.5	4	8	8	4	7	6	72	4-7	3-11	6-10	3-6	2-8	1.841	452
		8-5.5	17-11	>6 TO 8	13.5	16	11.5	4	8	8	5	7	6		3-10	3-5	6-11	3-8	3-3	2.057	463
		8-9	17-10	>8 TO 10	15.5	17.5	11	4	9	9	5	7	6		4-10	3-5	7-1	3-9	3-4	2.242	524
	8	10-3.5	17-9	0 TO 6	12.5	15	10.5	4	8	8	5	7	6	80	4-7	3-10	8-10	3-7	3-2	2.025	497
		10-6.5	17-10	>6 TO 8	14.0	16.5	11.0	4	9	9	4	7	6		3-8	3-4	9-0	4-2	2-10	2.189	522
		10-11	17-9	>8 TO 10	16.5	18.5	10.5	4	9	9	4	6	5		4-3	3-2	9-2	3-10	3-0	2.436	484
	10	12-4.5	17-8	0 TO 6	13.5	15	10	4	8	9	5	7	6	84	4-9	4-3	10-11	3-7	3-2	2.171	554
		12-8	17-9	>6 TO 8	15	17	10.5	4	9	9	4	6	6		4-3	3-4	11-1	3-9	2-11	2.401	515
		12-11	17-9	>8 TO 10	16.5	18.5	10.5	4	9	9	4	6	6		4-3	3-4	11-2	3-10	3-0	2.566	516
18	8	10-5	19-11	0 TO 5	13.5	15.5	11.5	4	8	9	5	7	7	84	5-2	4-5	8-11	4-1	3-2	2.351	588
		10-9	19-10	>5 TO 7	15.5	17.7	11	4	9	9	4	7	6		4-10	3-11	9-1	3-9	2-11	2.563	565
	10	12-6	19-10	0 TO 5	14	16	11	4	9	9	4	7	6	88	5-1	4-6	11-0	3-8	2-10	2.515	598
		12-9	19-11	>5 TO 7	15.5	17.5	11.5	4	9	9	4	7	6		5-0	4-5	11-1	3-10	2-11	2.738	597
20	8	10-3.5	22-0	0 TO 3	13.5	15	12	5	9	9	5	7	8	92	5-9	5-2	8-11	4-1	3-2	2.528	700
		10-9.5	22-2	>3 TO 6	16	17.5	13	4	9	9	4	7	7		5-5	4-9	9-2	4-3	2-11	2.934	646
		11-0.5	22-3	>6 TO 8	17	19.5	13.5	4	9	10	4	8	7		5-8	4-7	9-3	4-5	3-1	3.173	727
		11-5.5	22-2	>8 TO 10	19.5	22	13	4	10	10	4	7	6		5-0	4-4	9-4	4-2	3-4	3.481	702
	10	12-5.5	21-11	0 TO 3	15	15.5	11.5	4	9	9	5	7	7	96	5-4	4-11	11-1	4-1	3-2	2.773	692
		12-9	22-1	>3 TO 6	15	18	12.5	4	9	10	4	8	7		5-8	4-9	11-1	4-4	3-0	3.021	751
		13-0.5	22-1	>6 TO 8	17	19.5	12.5	4	10	10	4	8	7		5-7	4-7	11-3	4-5	3-1	3.259	792
		13-5.5	22-2	>8 TO 10	19.5	22	13	4	10	10	4	7	6		5-1	4-7	11-5	4-2	3-4	3.642	728

HEADWALL AND TOEWALL QUANTITIES

HEADWALL SKEW ANGLE	90% TO 75%			74% TO 60%			59% TO 45%		
SPAN - S	Z	STIRRUPS	REBAR QUANT.	Z	STIRRUPS	REBAR QUANT.	Z	STIRRUPS	REBAR QUANT.
	#	#	LBS./LIN.FT.	#	#	LBS./LIN.FT.	#	#	LBS./LIN.FT.
6	4	4	22.1	4	4	21.9	4	4	21.3
8	4	4	22.5	4	4	22.3	5	4	28.0
10	5	4	28.2	5	4	27.9	7	4	43.2
12	5	4	27.6	6	4	34.5	8	5	56.4
14	6	4	34.0	7	4	41.9	10	5	81.5
16	6	4	32.3	8	5	53.3	✱	✱	✱
18	7	4	39.0	9	5	62.6	✱	✱	✱
20	7	4	38.6	11	6	96.9	✱	✱	✱
CONCRETE QUANTITY = 0.085 CU.YDS./LIN.FT.									

NOTES: QUANTITIES ARE PER LINEAR FOOT (OF HEADWALL) FOR ONE HEADWALL AND TOEWALL AND INCLUDE ALL HEADWALL AND TOEWALL REINFORCING STEEL.

✱ A SKEWED HEADWALL IS NOT RECOMMENDED FOR THESE SPANS. A SPECIAL DESIGN IS REQUIRED.

FOR HEADWALL AND TOEWALL DETAILS SEE PREVIOUS SHEET.

WHEN THE NOMINAL FILL HEIGHT FOR THE CONCRETE BOX CULVERT IS ≤ 2'-0", ALL REINFORCING STEEL IN THE HEADWALL SHALL BE EPOXY-COATED. ALSO, THOSE REINFORCING BARS DESIGNATED BY AN ASTERISK (*) AND THE d_1 BARS IN THE TOP MAT OF THE TOP SLAB SHALL BE EPOXY-COATED.

REINFORCING QUANTITIES INCLUDE BOTH EPOXY-COATED AND UNCOATED BARS.

WHEN AN R (RISE) OF LESS THAN SIX FEET IS REQUIRED, USE THE BAR SIZES AND THE SLAB AND WALL THICKNESSES FOR THE SIX FOOT RISE (IF AVAILABLE).

▲ THE SIZE OF d_1 BARS IS #4. THE NUMBER OF BARS REQUIRED IS LISTED.

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Drawing File Name: 601010202.dwg
Acad Version: R14 Scale: NA Units: English

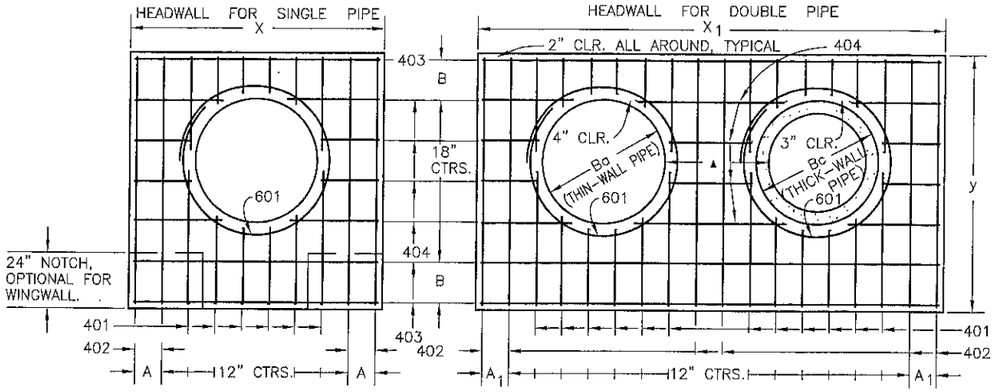
Standard Plan Revised

Date:	Comments:

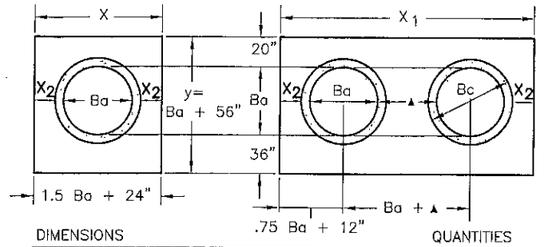
SINGLE CONCRETE BOX CULVERT

Issued By: Project Development Branch October 1, 2000

STANDARD PLAN NO.
M-601-1
Sheet No. 2 of 2



TYPICAL BAR LAYOUT FOR CONCRETE HEADWALLS



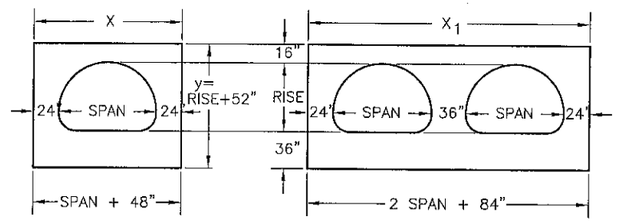
DIMENSIONS / QUANTITIES

Ba in.	Bc in.	X ft.-in.	A in.	X_1 ft.-in.	A_1 in.	y ft.-in.	B in.	X_2 in.	CONCRETE SGL cu.yd.	CONCRETE DBL cu.yd.	STEEL ■ SGL lbs.	STEEL ■ DBL lbs.
54	65	8-9	8½	15-6	7	9-2	17	20	2.12	3.55	209	364
60	72	9-6	7	17-0	10	9-8	11	21	2.35	3.99	236	414
66	79	10-3	11½	18-6	7	10-2	14	22	2.60	4.44	249	453
72	86	11-0	10	20-0	10	10-8	17	23	2.85	4.91	270	476
78	93	11-9	8½	21-3	11	11-2	11	24	3.11	5.29	306	527
84	100	12-6	7	22-6	7	11-8	14	25	3.38	5.68	333	572
90	107	13-3	11½	23-9	8½	12-2	17	26	3.66	6.08	335	593
96	114	14-0	10	25-0	10	12-8	11	27	3.94	6.48	379	649
102	121	14-9	8½	26-3	11½	13-2	14	28	4.24	6.89	400	664
108	128	15-6	7	27-6	7	13-8	17	29	4.54	7.30	424	707

HEADWALL FOR THICK - WALL ROUND PIPE

DIMENSIONS / QUANTITIES

EQUIV Ba in.	SPAN in.	RISE in.	X ft.-in.	A in.	X_1 ft.-in.	A_1 in.	y ft.-in.	B in.	CONCRETE SGL cu.yd.	CONCRETE DBL cu.yd.	STEEL ■ SGL lbs.	STEEL ■ DBL lbs.
72	81	59	10-9	8½	20-6	7	9-3	17½	2.72	5.10	250	467
78	87	63	11-3	11½	21-6	7	9-7	10½	2.85	5.34	275	531
84	95	67	11-9	8½	22-10	9	9-11	12½	3.08	5.79	290	547
90	103	71	12-7	7½	24-2	11	10-3	15	3.30	6.21	321	591
96	112	75	13-4	12	25-8	8	10-7	16½	3.52	6.65	314	606
102	117	79	13-9	8½	26-6	7	10-11	9½	3.63	6.86	356	672
108	128	83	14-8	8	28-4	12	11-3	11½	3.96	7.51	376	699

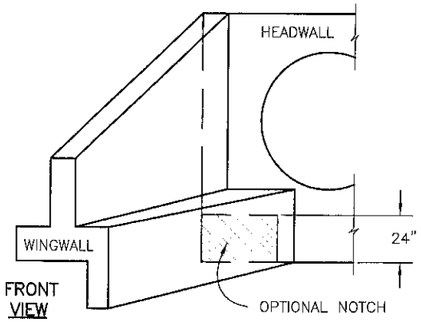


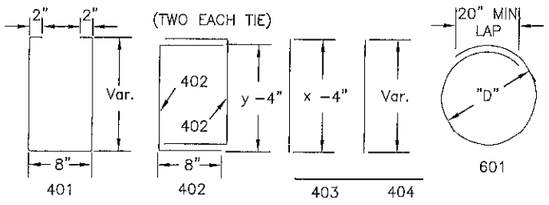
HEADWALL FOR THIN - WALL PIPE ARCH

DIMENSIONS / QUANTITIES

EQV. Ba in.	SPAN ft.-in.	RISE ft.-in.	X ft.-in.	A in.	X_1 ft.-in.	A_1 in.	y ft.-in.	B in.	CONCRETE SGL cu.yd.	CONCRETE DBL cu.yd.	STEEL ■ SGL lbs.	STEEL ■ DBL lbs.
66	6-1	4-7	10-1	10½	19-2	11	8-11	15½	2.52	4.70	232	424
75	7-0	5-1	11-0	10	21-0	10	9-5	9½	2.80	5.25	282	509
84	7-11	5-7	11-11	9½	22-10	9	9-11	12½	3.08	5.79	291	540
93	8-10	6-1	12-10	9	24-8	8	10-5	15½	3.36	6.33	309	622
102	9-9	6-7	13-9	8½	26-6	7	10-11	9½	3.63	6.86	379	673
111	10-11	7-1	14-11	9½	28-10	9	11-5	12½	4.05	7.67	377	711
120	11-10	7-7	15-10	9	30-8	8	11-11	15½	4.36	8.28	395	731
132	12-10	8-4	16-10	9	32-8	8	12-8	11	4.75	9.03	441	839
141	14-1	8-9	18-1	10½	35-2	11	13-1	13½	5.17	9.86	448	931
150	15-4	9-3	19-4	12	37-8	8	13-7	16½	5.69	10.88	490	953
159	15-10	9-10	19-10	9	38-8	8	14-2	11	5.89	11.25	534	1019

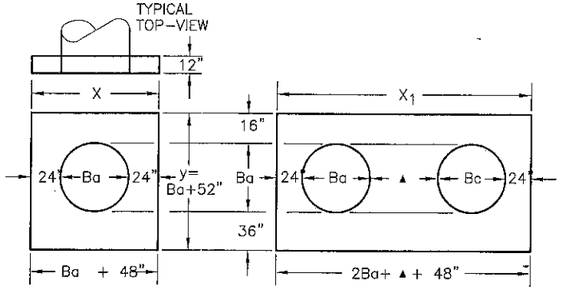
HEADWALL FOR STRUCTURAL PLATE ARCH





"D" FOR
THICK-WALL PIPE, = Bc + 6"
THIN-WALL PIPE, = Ba + 8"
THIN-WALL PIPE-ARCH = SPAN + 8"
STRUCTURAL PLATE-ARCH = RISE + 8"

BAR BENDING



DIMENSIONS / QUANTITIES

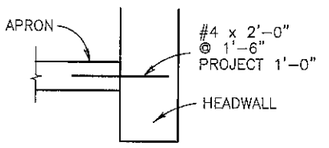
Ba in.	X ft.-in.	A in.	X_1 ft.-in.	A_1 in.	y ft.-in.	B in.	CONCRETE SGL cu.yd.	CONCRETE DBL cu.yd.	STEEL ■ SGL lbs.	STEEL ■ DBL lbs.
54	8-6	7	15-3	11½	8-10	15	2.19	3.81	211	358
60	9-0	10	16-6	7	9-4	18	2.38	4.25	217	396
66	9-6	7	17-9	8½	9-10	12	2.58	4.70	252	454
72	10-0	10	19-0	10	10-4	15	2.78	5.17	255	472
78	10-6	7	20-0	10	10-10	18	2.98	5.56	276	499
84	11-0	10	21-0	10	11-4	12	3.19	5.95	297	553
90	11-6	7	22-0	10	11-10	15	3.40	6.36	317	571
96	12-0	10	23-0	10	12-4	18	3.62	6.79	321	597
102	12-6	7	24-0	10	12-10	12	3.84	7.21	364	663
108	13-0	10	25-0	10	13-4	15	4.06	7.63	362	678

HEADWALL FOR THIN - WALL ROUND PIPE

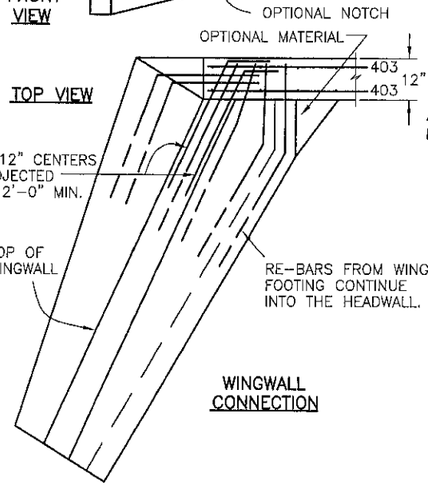
SKEW ANGLE A°	FACTOR (cosecA°)
90	1.000
85	1.004
80	1.015
75	1.035
70	1.064
65	1.103
60	1.155
55	1.221
50	1.305
45	1.414
40	1.556
35	1.743
30	2.000

SKEW FACTOR TABLE

HEADWALL SHALL BE PERPENDICULAR TO THE CULVERT CENTERLINE UNLESS OTHERWISE SPECIFIED. TABULATED DIMENSIONS AND QUANTITIES MUST BE ADJUSTED FOR SKEWED INSTALLATIONS.

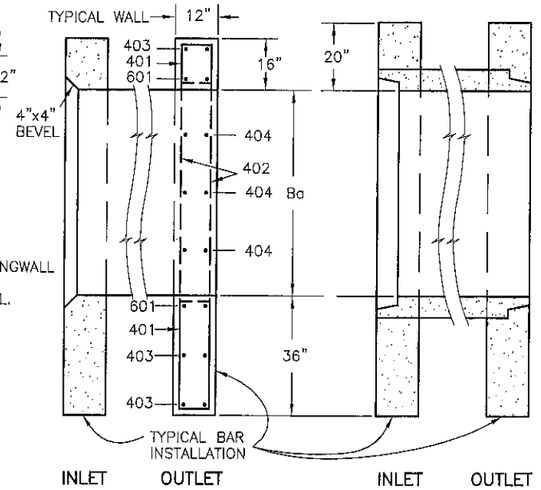


WHEN APRON IS REQUIRED



TOP VIEW

WINGWALL CONNECTION



INLET OUTLET

ENDS OF THIN-WALL PIPE

INLET OUTLET

ENDS OF THICK-WALL PIPE

GENERAL NOTES

1. CONCRETE SHALL BE CLASS B.
2. HEADWALL SHALL BE PERPENDICULAR TO THE CULVERT ℄ UNLESS OTHERWISE SHOWN ON THE PLANS. TABULATED DIMENSIONS AND QUANTITIES MUST BE ADJUSTED FOR SKEWED INSTALLATIONS.
3. FOR WINGWALL DETAILS, SEE STANDARD M-601-20.
4. VOLUME OCCUPIED BY PIPE HAS BEEN DEDUCTED FROM STEEL AND CONCRETE QUANTITIES.
5. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED ¾ ".
6. ALL BARS SHALL HAVE A 2" MINIMUM CLEARANCE.

▲ WHEN TWO OR MORE CONDUITS ARE LAID SIDE BY SIDE, THEY SHALL BE PLACED SO THAT THE ADJACENT PIPES WILL BE ½ INSIDE DIAMETER OR ½ INSIDE SPAN OR 3 FEET APART (INCLUDING WALL THICKNESS) WHICHEVER IS LESS.

■ ADD 0.89 x (X OR X_1) (LB.) WHEN APRON IS REQUIRED.

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Drawing File Name: 6060100101.dwg

Acad Version: R14 Scale: NA Units: English

Standard Plan Revised

Date:	Comments:

HEADWALLS FOR PIPE CULVERTS

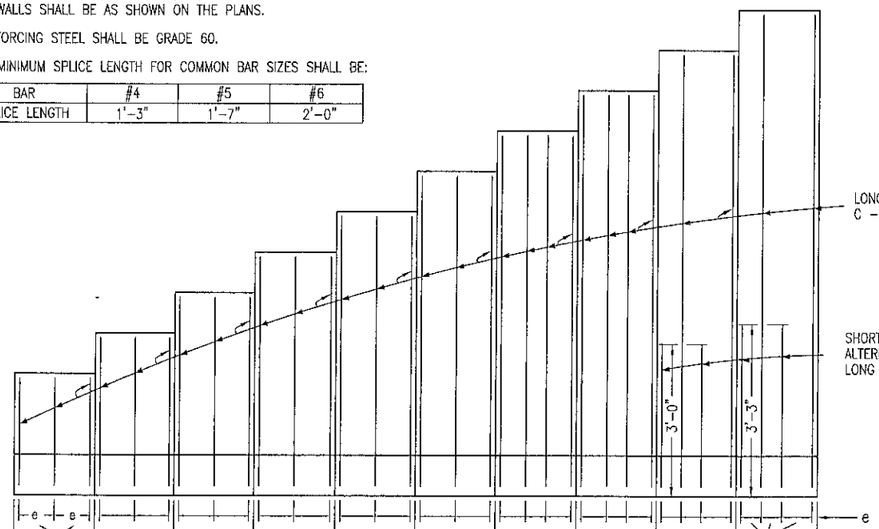
Issued By: Project Development Branch October 1, 2000

STANDARD PLAN NO.
M-601-10
Sheet No. 1 of 1

GENERAL NOTES

1. ALL EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED $^{3}/_{4}$".
2. WINGWALL FOOTINGS AND FLOOR OF BOX CULVERT SHALL BE PLACED MONOLITHICALLY.
3. DIMENSIONS "H", "Ba", "RISE", "k", "i", "m" AND ANGLES FOR WINGWALLS SHALL BE AS SHOWN ON THE PLANS.
4. REINFORCING STEEL SHALL BE GRADE 60.
5. THE MINIMUM SPLICE LENGTH FOR COMMON BAR SIZES SHALL BE:

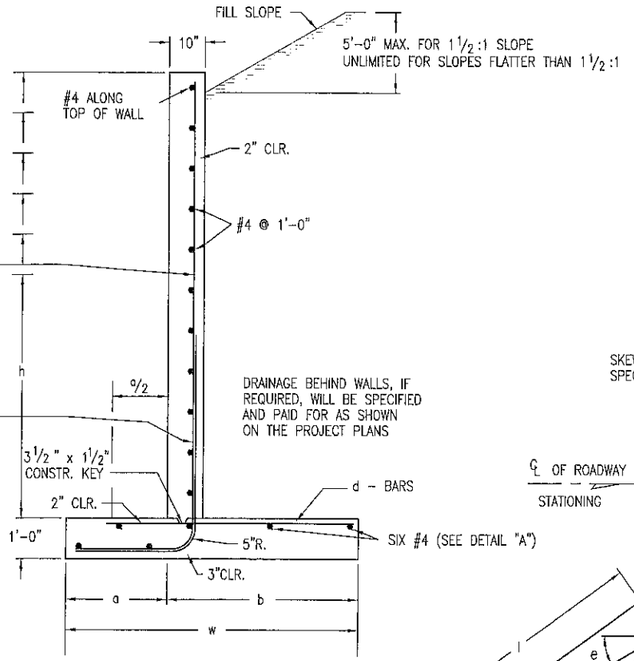
BAR	#4	#5	#6
SPLICE LENGTH	1'-3"	1'-7"	2'-0"



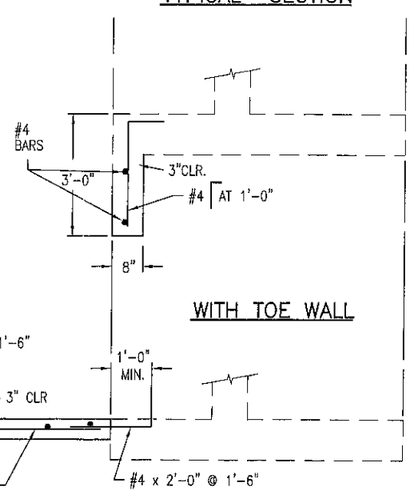
e =	1'-6"	1'-6"	1'-6"	1'-6"	1'-6"	1'-4"	1'-3"	11"	9"	7"	CTRS.
h =	2'	3'	4'	5'	6'	7'	8'	9'	10'	11'	
a =	1'-0"	1'-2"	1'-4"	1'-6"	1'-8"	1'-10"	2'-0"	2'-2"	2'-4"	2'-6"	
b =	1'-8"	2'-0"	2'-4"	2'-8"	3'-0"	3'-4"	3'-8"	4'-0"	4'-4"	4'-8"	
w =	2'-8"	3'-2"	3'-8"	4'-2"	4'-8"	5'-2"	5'-8"	6'-2"	6'-8"	7'-2"	
c & d BARS	#4@1'-6"	#4@1'-6"	#4@1'-6"	#4@1'-6"	#4@1'-6"	#4@1'-4"	#5@1'-3"	#5@11"	#6@9"	#6@7"	CTRS.
* CONC.CU.YD./L.F.	0.161	0.210	0.259	0.308	0.358	0.407	0.457	0.506	0.556	0.604	
* REINF. LB./L.F.	8.0	9.3	10.7	12.1	14.3	16.4	23.0	28.6	41.8	54.6	

* DOES NOT INCLUDE TOE WALL QUANTITIES

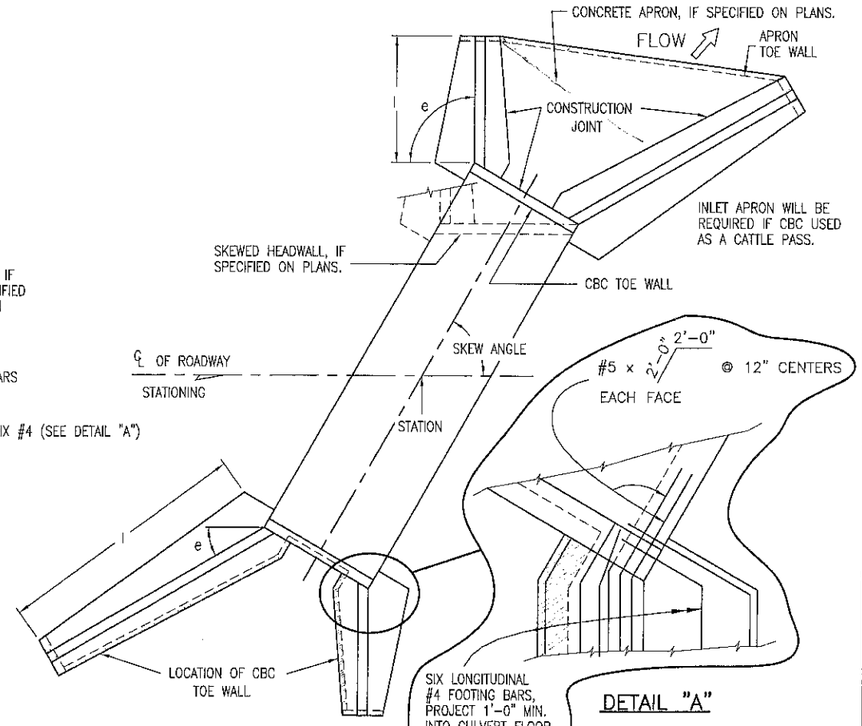
DESIGN TABLE



TYPICAL SECTION

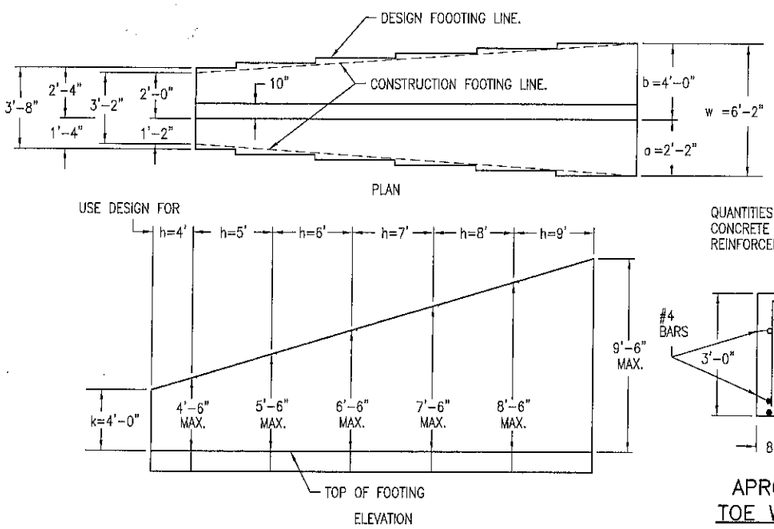


WITH TOE WALL

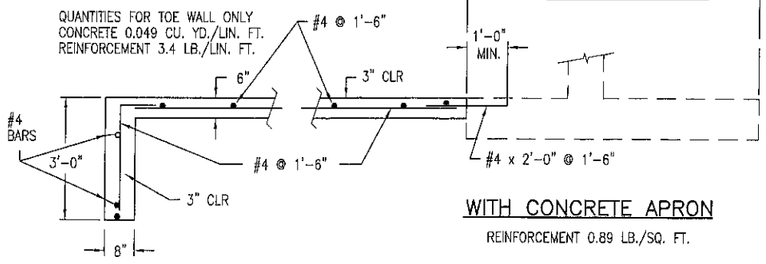


DETAIL "A"

TYPICAL CULVERT LAYOUT



DESIGN EXAMPLE



APRON TOE WALL

WITH CONCRETE APRON

REINFORCEMENT 0.89 LB./SQ. FT.

DESIGN DATA:
UNIT STRESSES: f_s = 24,000 PSI
f_c = 1,200 PSI
n = 9

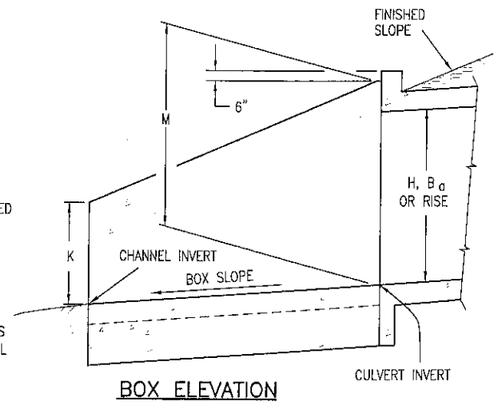
EQUIVALENT FLUID PRESSURE = 36 LBS./CU. FT.
MAXIMUM TOE PRESSURE = 1 TON/SQ. FT.

ALL CONSTRUCTION JOINTS SHALL BE THOROUGHLY CLEANED BEFORE CONCRETE IS POURED.

WINGWALL AND APRON CONCRETE SHALL BE:
CONCRETE CLASS B, OR D (BOX CULVERT) FOR CBC's.
CONCRETE CLASS B, OR D (WALL) FOR PIPES.

LIVE LOAD SURCHARGE HAS NOT BEEN CONSIDERED. WALLS WITHIN $^{h}/_{2}$ OF THE EDGE OF THE ROADWAY SHOULDER WILL REQUIRE A SPECIAL DESIGN IN ACCORDANCE WITH AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES.

APRON REQUIRED AT INLET OF THE CBC, IF USED FOR CATTLE PASSAGE.



BOX ELEVATION

M = H, Ba OR RISE + (1'-4")
UNLESS OTHERWISE SHOWN ON PLANS.

Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222
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Project Development Branch SD

Computer File Information	
Path: www.dot.state.co.us/DevelopProjects/DesignSupport/MStandards/	
Drawing File Name: 6010200101.dwg	
Acad Version: R14	Scale: NA Units: English

Standard Plan Revised	
Date:	Comments:

WINGWALLS FOR PIPE OR BOX CULVERTS

Issued By: Project Development Branch October 1, 2000

STANDARD PLAN NO.
M-601-20
Sheet No. 1 of 1

APPENDIX C

CALCULATION DESIGN AIDS

Design Aid #50
April, 1978

SELECTION OF CULVERT WINGWALL GEOMETRIES AND QUANTITY CALCULATIONS

WINGWALL GEOMETRY

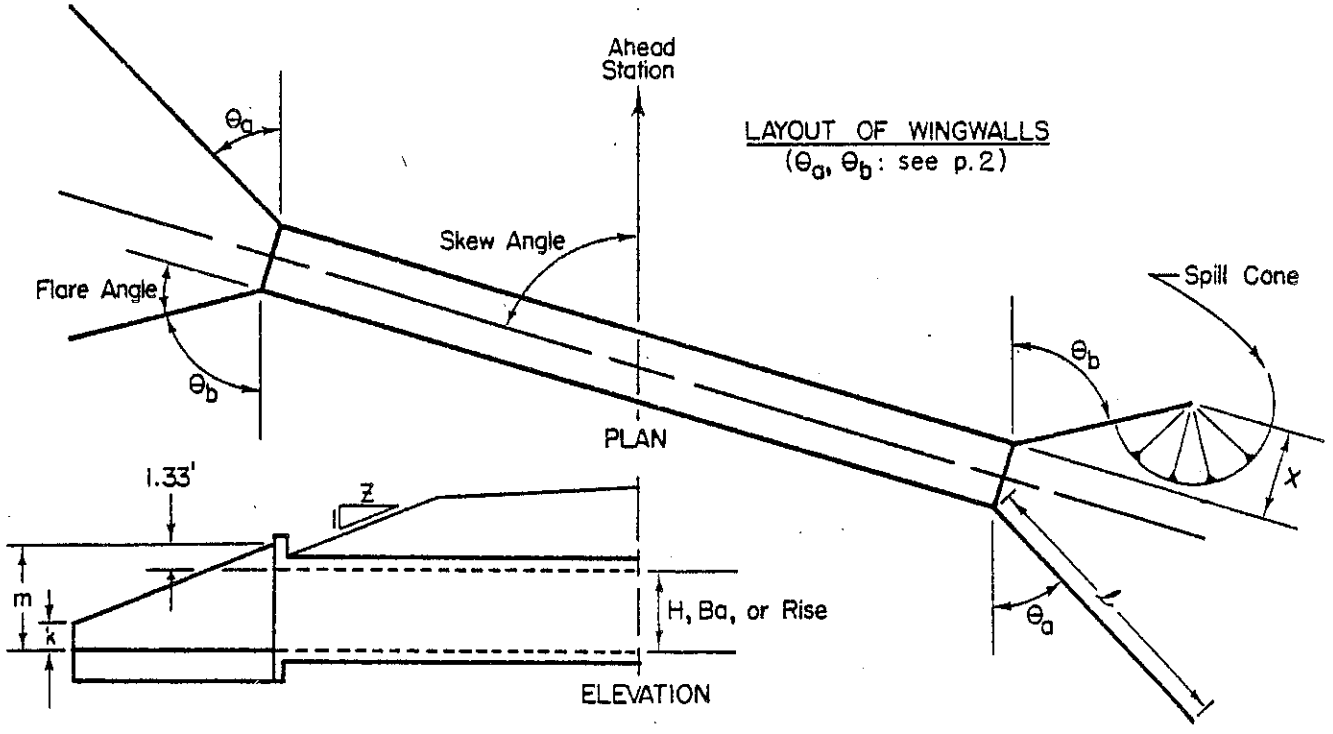
Wingwall geometry is determined by a combination of six parameters identified in the sketch below. Values for three of these parameters are fixed by the culvert design:

1. H, Ba, or Rise, the distance in feet from the flowline to the inside top of the culvert (in general , fixes the value of m, the height of the upper end of the wingwall) -
2. The skew angle of the culvert
3. Z, the roadway fill slope (that is, Z:1)

The designer must select values for three additional parameters:

1. k, the height in feet of the lower end of the wingwall
2. θ, the angle between the wingwall and a line parallel to the roadway
3. ℓ, the length of the wingwall

A schematic drawing of the culvert layout should be shown in the plans, identifying k, θ, and ℓ for each wingwall (m will also be shown, if other than standard).



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DESIGN GUIDELINES

The following guidelines address various aspects of wingwall design. The general relationships will apply to most situations. However, the designer must set the wings to conform to the culvert site even though the geometry differs from these guidelines.

1. k = 1/2[H, Ba, or Rise] - 1'

   Values of k and θ must be chosen so that the spill cones do not obstruct the culvert inlet and outlet. Higher ends of wings may be used when the spill cone is not subject to erosion, e.g., stockpasses. The top of the wingwall should nearly match the final ground elevation.

2. A wingwall flare angle of from 20° - 40° normally provides a hydraulically efficient inlet condition for the culvert. Use of the recommended values for θ (given below) and k will in general effect a smooth flow transition from channel to culvert, and keep the spill cone out of the projected jet of flow.

SKEW ANGLE OF CULVERT	θ_a	θ_b	
90°	60°	60°	
80°	50°	70°	
70°	45°	80°	
60°	40°	90°	
50°	30°	90°	θ_a, θ_b
40°	20°	100°	identified
30°	15°	105°	in sketch
Less than 30°	Consult Hydraulics Unit		

3. m = [H, Ba, or Rise] + 1.33'

   Special headwall designs may dictate some other value for m.

4. $\ell = Z \frac{m-k}{\sin \theta}$

   The wingwall length is constrained by the selection of Z, m, k, and θ. Fill slopes (Z:1) flatter than 4:1 should be warped to 4:1 or steeper beyond the culvert headwall to reduce excessive wingwall length. Wingwall lengths should be rounded to the nearest foot for $\ell \leq 14'$; to the nearest even foot for $14' < \ell < 30'$; and to the nearest four-foot increment (30', 34', 38', etc.) for $\ell \geq 30'$.

   A plan showing site contours or spot elevations is often helpful when laying out final wingwall geometry, especially when the wingwalls must conform to a distinct channel (e.g. canals, gullies).

-continued-

5. $X \geq 1.5\ k$

   Allow a spill cone slope of 1-1/2:1 or flatter at the wingwall ends to assure that the main flow jet, roughly defined by the culvert width, does not impinge on the spill cone.

6. Culvert headwalls shall be perpendicular to the culvert centerline unless excessive cost or aesthetics favor a skewed headwall. A wide culvert with a small skew angle usually justifies the skewed headwall (See Design Manual Sec. 805).

7. If scour damage is anticipated, a concrete apron should be placed between the outlet wingwalls. An apron is not necessary at the inlet. Toe walls are required on all wingwalls except when a concrete apron is used. Toe walls are placed on the end of the apron as shown in Standard M-601-WW.

WINGWALL QUANTITY CALCULATIONS

Quantities for common wingwall sizes are tabulated on Page 7. For other wingwall sizes, use the unit quantities given in Standards M-601-WW (concrete, steel quantities) and M-206-AB (structure backfill), and the procedures discussed below.

Concrete and steel quantities are computed by first dividing the wingwall into trapezoidal blocks having average heights equal to the values of h shown in Standard M-601-WW. The end blocks will generally have odd average heights; the closest value of h will apply. Multiplying the individual block widths by the appropriate concrete and steel factors (per linear foot) shown in the Standard will give quantities for the vertical wall and footing. Toe wall quantities are computed by multiplying the factors given in Standard M-601-WW by the length of the wingwall plus the width of the footing at the outer end of the wingwall. Apron quantities are based on the surface area of the apron (does not include wingwall footings). Apron toe wall quantities are computed in the same manner as for wingwalls.

Structure backfill quantities are determined from the geometry shown in Standard M-206-AB. Fill quantities behind the vertical wall are computed by multiplying the wingwall length by the average of the fill cross sections at each end of the wingwall. Backfill along the toe wall is the product of the fill cross section and the wingwall length (or apron toe wall length).

The following equations were developed from the quantities in Standards M-206-AB and M-601-WW. Given the wingwall geometry, they allow direct computation of the component quantities.

-continued-

WINGWALL QUANTITIES

ℓ, k, m given in ft.

CONCRETE (cu. yd.)

Total concrete for one wing = $C_T = c_w + c_t$

c_w = concrete for wall and footing = $\ell[0.0247(m + k) + 0.0617]$

c_t = concrete for toe wall = $0.0494\ (\ell + \frac{k}{2} + 1)$

REINFORCING STEEL (lb.)

Total reinforcing steel for one wing = $S_T = s_w + s_t$

s_w = steel for wall and footing [Note: $\exp(X) = e^X$]

= [use quantities in Standard M-601-WW] $\underline{m = k}$

$= \frac{10.27\ell}{m-k}\left[\exp\left(\frac{m}{3.51}\right) - \exp\left(\frac{k}{3.51}\right)\right]$ $\underline{m > k \geq 5'}$

$= \frac{\ell}{m-k}\left[10.27\exp\left(\frac{m}{3.51}\right) + 0.57 - 5.23k - 0.68k^2\right]$ $\underline{m > 5',\ k \leq 5'}$

$= \ell\ [0.68\ (m+k) + 5.23\ ]$ $\underline{k < m \leq 5'}$

s_t = steel for toe wall

$= 3.4\ [\ell + \frac{k}{2} + 1\ ]$

STRUCTURE BACKFILL (cu. yd.)

Total structure backfill for one wing = $V_T = v_w + v_t$

v_w = fill vol. behind wall = $\ell[0.00412(m^2+mk+k^2) + 0.0309(m+k) + 0.0556]$

v_t = fill vol. along toe wall = 0.167ℓ

SAMPLE CALCULATION

Given: H = 6.0'; Culvert Skew = 85°; Fill Slope (Z:1) = 4:1

Compute Wingwall Geometry:

$k = \frac{H}{2} - 1 = \frac{6}{2} - 1 = 2'$

$m = H + 1.33' = 7.33'$

$\theta = 60°$

$\ell = Z\frac{m-k}{\sin\theta} = 4\ \frac{7.33-2}{\sin 60°} = 24.6'$, use 24'

-continued-

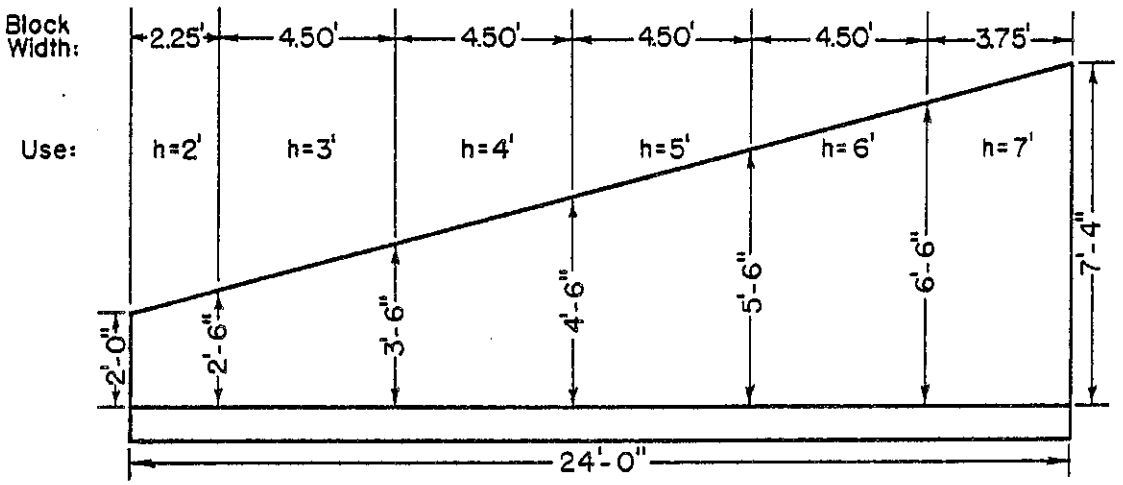
Compute Quantities (Refer to Standards M-206-AB, M-601-WW)

Wingwall Slope = $\frac{\ell}{m-k} = \frac{24'}{7.33'-2'} = 4.5$ ft/ft

Block Width = 4.5 ft/ft x 1 ft = 4.5 ft.

Lower End Block Width = 4.5 ft/ft x (2.5 ft. - 2.0 ft) = 2.25 ft.

Upper End Block Width = 4.5 ft/ft x (7.33 ft - 6.5 ft) = 3.75 ft.



Design h	Concrete (cu. yd.)	Reinforcing Steel (lb)	Backfill (cu. yd.)
2'	2.25' x 0.161 = 0.36	2.25' x 8.0 = 18.0	Behind wall and footing: 1/27 (24') 1/2 (6.2 ft^2 +30.8 ft^2) = 16.4▲
3'	4.50' x 0.210 = 0.94	4.50' x 9.3 = 41.8	
4'	4.50' x 0.259 = 1.16	4.50' x 10.7= 48.1	
5'	4.50' x 0.308 = 1.39	4.50' x 12.1= 54.4	
6'	4.50' x 0.358 = 1.61	4.50' x 16.2= 72.9	
7'	3.75' x 0.407 = 1.53	3.75' x 21.7= 81.4	
Toe Wall	(24'+2')*x0.049 = 1.27	(24'+2')* x 3.4 = 88.0	1/27(24' x 4.5 ft^2) = 4.0
Totals	8.26 cu. yd.	404.6 lb.	20.4 cu. yd.

* For toe wall at end of footing (w-8")

▲ Average end area method results in higher than actual value.

-continued-

Compute Quantities (equation method)

Given: $m = 7.33'$ $k = 2'$ $\ell = 24'$

Concrete: c_w (wall and footing) $= 24[0.0247(7.33+2) + 0.0617]$

$= 7.01$ cu. yd.

c_t (toe wall) $= 0.0494\ (24 + \frac{2}{2} + 1) = 1.28$ cu. yd.

Total Concrete $= C_T = c_w + c_t =$ 8.29 cu. yd.

Steel: $(m > 5', k \leq 5')$

s_w (wall and footing) $= \frac{24}{7.33-2}\ [10.27 \exp\left(\frac{7.33}{3.51}\right) + 0.57 - 5.23(2) - 0.68(2^2)] = 316.5$ lb.

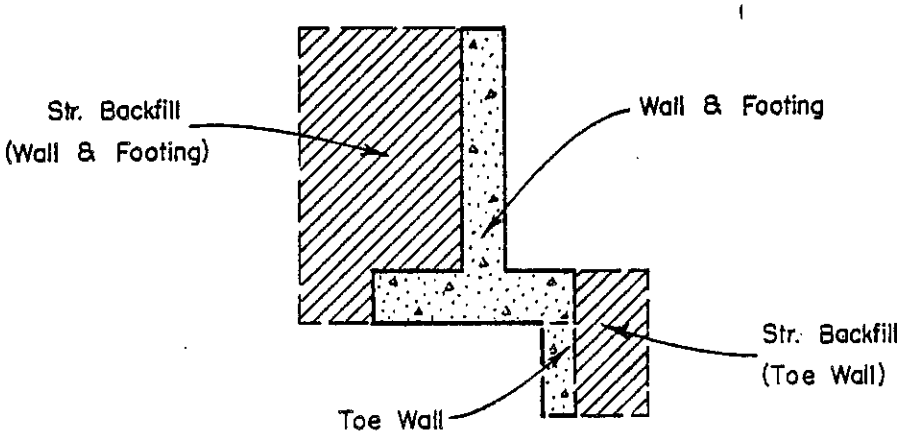
s_t (toe wall) $= 3.4\ [24 + \frac{2}{2} + 1] = 88.4$ lb.

Total Steel $= S_T = s_w + s_t =$ 404.9 lb.

Backfill: v_w (behind wall) $= 24\ [0.00412(7.33^2 + (7.33)(2) + 2^2) + 0.0309(7.33+2) + 0.0556] = 15.4$ cu. yd.

v_t (along toe wall) $= 0.167(24) = 4.0$ cu. yd.

Total Backfill $= V_T = v_w + v_t =$ 19.4 cu. yd.



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Design Aid #50
April, 1978

WINGWALL QUANTITIES
For Common Wingwalls

WINGWALL LENGTH, ℓ	QUANTITIES FOR WALL AND FOOTING H, Ba or Rise (HEIGHT OF CULVERT)						QUANTITIES TOE WALL ONLY°
	5' m=6.33' k = 1.5'	6' m=7.33' k = 2.0'	7' m=8.33' k = 2.5'	8' m=9.33' k = 3.0'	9' m=10.33' k = 3.5'	10' m=11.33' k = 4.0'	
10'	2.6 111 5.1	2.9 132 6.4					0.6 43 1.7
11'	2.8 122 5.6	3.2 145 7.1	←	Concrete- Cu.Yd. Rein.Steel- Lbs. Str.Backfill- Cu.Yd.		→	0.7 46 1.8
12'	3.1 133 6.1	3.5 158 7.7	4.0 194 9.5	4.4 238 11.4			0.7 49 2.0
13'	3.3 144 6.6	3.8 172 8.3	4.3 210 10.2	4.8 257 12.3			0.8 53 2.2
14'	3.6 155 7.2	4.1 185 9.0	4.6 226 11.0	5.1 277 13.3	5.7 347 15.7	6.2 436 18.4	0.8 56 2.3
16'	4.1 177 8.2	4.7 211 10.3	5.3 258 12.6	4.9 317 15.2	6.5 397 18.0	7.0 499 21.0	0.9 63 2.7
18'	4.6 200 9.2	5.3 237 11.6	5.9 290 14.2	6.6 356 17.1	7.3 446 20.2	7.9 561 23.6	1.0 70 3.0
20'	5.1 222 10.2	5.8 264 12.8	6.6 323 15.8	7.3 396 19.0	8.1 496 22.4	8.8 624 26.2	1.1 77 3.3
22'	5.6 244 11.2	6.4 290 14.1	7.3 355 17.3	8.0 436 20.8	8.9 545 24.7	9.7 686 28.8	1.2 83 3.7
24'	6.1 266 12.3	7.0 317 15.4	7.9 387 18.9	8.8 475 22.7	9.7 595 26.9	10.6 748 31.5	1.3 90 4.0
26'	6.6 288 13.3	7.6 343 16.7	8.6 420 20.5	9.5 515 24.6	10.5 645 29.2	11.4 811 34.1	1.4 97 4.3
28'	7.2 310 14.3	8.2 369 18.0	9.2 452 22.1	10.2 554 26.5	11.3 694 31.4	12.3 873 36.7	1.5 104 4.7
30'	7.7 352 15.3	8.7 396 19.3	9.9 484 23.6	11.0 594 28.4	12.1 743 33.7	13.2 935 39.3	1.6 111 5.0
34'	8.7 377 17.4	9.9 449 21.8	11.2 549 26.8	12.4 673 32.2	13.7 843 38.1	15.0 1060 44.6	1.8 124 5.7
38'	9.7 421 19.4	11.1 501 24.4	12.5 613 29.9	13.9 752 36.0	15.3 942 42.6	16.7 1185 49.8	2.0 138 6.4

°Include the quantity for the average (k = 3.0') length of Toe Wall at the end of the Wingwall.