

CHAPTER 4

OPEN CHANNELS AND ROADSIDE DITCHES



NOTE: For trunkline projects, direct questions and comments to the Hydraulic Unit Supervisor, Environmental Services Section.

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Table of Contents

4.1	INTRODUCTION/PURPOSE.....	4-5
4.2	DEFINITIONS.....	4-6
4.3	POLICY AND DESIGN CRITERIA	4-9
4.3.1	Federal Policy	4-9
4.3.2	State Policy	4-9
4.3.3	Roadside Ditches.....	4-9
4.3.4	Stream Channel Design.....	4-10
4.4	DESIGN GUIDANCE AND PROCEDURE.....	4-11
4.4.1	Hydraulic Analysis for Stream and Roadside Ditches	4-11
4.4.2	Roadside Ditches.....	4-11
4.4.2.1	Standard Ditch Types	4-12
4.4.2.2	Erosion Control in Ditches	4-12
4.4.3	Design Procedures	4-13
4.4.3.1	Cross-Sections	4-13
4.4.3.2	Terrain Development for Advanced Hydraulic Modeling (2D or CFD)	4-16
4.4.3.3	Manning's n-value Selection	4-17
4.4.3.4	Hydrologic and Hydraulic Calibration and Validation	4-20
4.4.3.5	Normal Depth Analysis	4-21
4.4.3.6	Example - Normal Depth Analysis for Culvert Tailwater Determination	4-24
4.4.3.7	Standard Step Analysis – Hand Calculation	4-27
4.4.3.8	Standard Step Analysis – HEC-RAS Model.....	4-28
4.4.3.9	HEC-RAS Standard Step Method.....	4-28
4.4.3.10	Profile Calculation Concepts.....	4-29
4.4.3.11	Switchback Phenomenon	4-31
4.4.3.12	Example: Calculation of Effect of Tailwater Condition on Channel Water Surface Profile	4-31
4.4.3.13	2D Hydraulic Modeling.....	4-37
4.4.4	Channel Design Procedure	4-37
4.4.4.1	Stream Channels	4-37
4.4.4.2	Stream Morphology	4-40
4.5	MAINTENANCE	4-41
4.5.1	Ditch Maintenance and Repairs.....	4-41

4.5.2 Erosion and Vegetation.....	4-41
References.....	4-42

Figures

Figure 4-1. Cross-Sections of Reaches, Segments and Subsections Used to Assign n-values (Arcement, 1989).....	4-14
Figure 4-2. Cross-Section Alignment to Flow Direction	4-15
Figure 4-3. Example Survey Cross-Section	4-16
Figure 4-4. Hydraulic Toolbox Input Data.....	4-22
Figure 4-5. Hydraulic Toolbox Cross-Section.....	4-23
Figure 4-6. Hydraulic Toolbox Stage Discharge Curve	4-23
Figure 4-7. Stream Profile	4-24
Figure 4-8. Cross-Section (Station 4+46).....	4-25
Figure 4-9. Stage Discharge Curve for Cross-Section 4+46	4-27
Figure 4-10. Backwater Profile Example	4-28
Figure 4-11. Profile Convergence Pattern Standard Step Computation (AASHTO Drainage Manual, 2014)	4-30
Figure 4-12. Profile Study Limits (HEC-RAS Reference Manual).....	4-30
Figure 4-13. Switchback Phenomenon.....	4-31
Figure 4-14. Cross-Section Examples.....	4-35
Figure 4-15. Channel Profile	4-36

Tables

Table 4-1. Roadway Ditch Design Criteria – AEP (ARI)	4-10
Table 4-2. Permanent Stabilization Treatments for Various Ditch Grades	4-12
Table 4-3. Values of Manning’s Roughness Coefficient n (Uniform Flow).....	4-17
Table 4-4. Cross-Section Data – Station 4+46.....	4-25
Table 4-5. Cross-Section Data for Sections A at Station 0.....	4-32
Table 4-6. Cross-Section Data for Cross-Section B at Station 6,600	4-33
Table 4-7. Cross-Section Data for Cross-Section C at Station 16,500	4-33
Table 4-8. Cross-Section Data for Cross-Section D at Station 24,000	4-34
Table 4-9. Cross-Section Data for Cross-Section E at Station 32,400	4-34
Table 4-10. Output Table from HEC-RAS for Figure 4-15 Profile.....	4-36

Appendices

Appendix 4-A Symbols and Acronyms

Appendix 4-B Open Channel Theory

If you require assistance accessing this information or require it in an alternative format, contact the Michigan Department of Transportation's (MDOT) Americans with disabilities Act (ADA) coordinator at Michigan.gov/MDOT-ADA.

4.1 INTRODUCTION/PURPOSE

Hydraulic design for natural channels and roadway ditches is the process used to evaluate design alternatives and select the final design according to established criteria. MDOT established criteria as the standards to ensure that a highway facility meets its intended purpose without endangering the structural integrity of the facility or adversely affecting the environment or public welfare.

While the principles of open channel flow are the same regardless of channel type, stream channels and artificial channels (primarily roadside ditches) are treated separately in this chapter as needed. The principles of open channel flow hydraulics are also applicable to all drainage facilities, including culverts and storm drains. Open channel theory is discussed in **Appendix 4-B**.

This chapter will:

- Discuss MDOT and federal policies
- Specify design criteria
- Review design philosophy
- Outline channel design procedures
- Demonstrate design techniques with example problems

Channel analysis is necessary for the design of transportation drainage systems to assess:

- Potential flooding caused by changes in water surface elevations
- Potential disturbance of the river system upstream or downstream of the highway right-of-way
- Changes in lateral flow distributions
- Changes in velocity or direction of flow
- Need for conveyance and disposal of excess runoff
- Need for bank protection to prevent erosion

Open channel types include:

- Stream channels
- Artificial channels
- Roadside ditches
- County drains

4.2 DEFINITIONS

Alluvial - Deposits of silts, sands, gravels, or similar detrital material that has been transported by running water.

Alluvial Channel - A channel that is formed wholly in alluvium with no bedrock exposed in the channel at low flow or likely to be exposed by erosion. A channel whose processes are controlled by flow and boundary interactions.

Annual Exceedance Probability (AEP) - The probability that the magnitude of the random variable (e.g., annual maximum flood peak) will be equaled or exceeded each year, often expressed as a percentage.

Annual Recurrence Interval (ARI) - The average time interval between occurrences of a hydrologic event of a given or greater magnitude, usually expressed in years. The ARI is the reciprocal of the AEP of a hydrologic event.

Artificial Channel - A roadside channel, irrigation channel, or county or agricultural drain that is:

- A constructed channel with regular geometric cross-sections.
- Unlined, or lined with artificial or natural material to protect against erosion.

Backwater - The increase in water surface elevation induced upstream from a bridge, culvert, dike, dam, another stream at a higher stage, or other similar structures or conditions that obstruct or constrict a channel relative to the elevation occurring under natural channel and floodplain conditions.

Boundary Condition - A boundary condition establishes the starting water surface elevation for the project study area. Under subcritical flow regime, only the downstream water surface elevation is needed. Under supercritical conditions, both upstream and downstream water surfaces are required.

Computational Fluid Dynamics (CFD) - Three-dimensional (3D) modeling software used to calculate fluid flow characteristics based on the conservation of mass, momentum, and energy.

Conveyance - A measure, K , of the ability of a stream, channel, or conduit to convey water. In Manning's formula, $K = (1.49/n) AR^{2/3}$.

County Drain - Michigan's Drain Code, MCL 280.3, provides that a drain "...shall include the main stream or trunk and all tributaries or branches of any creek or river, any watercourse or ditch, either open or closed, any covered drain, any sanitary or any combined sanitary and storm sewer, or storm sewer or conduit composed of tile, brick, concrete or other material, any structures or mechanical devices, ...pumping equipment...any levee, dike, barrier, or a combination of any or all of the same ...for the purpose of drainage..." Therefore, a "county drain" or "intercounty drain" can be a natural or artificially constructed water conveyance system, provided it was legally

established pursuant to the Michigan Drain Code (MCL 280) and falls under the jurisdiction of the County Drain office.

Energy Grade Line (EGL) - The plotted line that represents the total energy of flow at a location. It is the sum of the elevation head, the pressure head, and the velocity head.

Floodplain - Any land area susceptible to inundation by floodwaters.

Freeboard - The vertical distance between the design water surface elevation and a point of interest such as a low chord of a bridge beam, crown of a culvert, or specific location on the roadway grade, for example, the bottom of subbase grade.

Harmful Interference - Causing an increased stage or change in direction of flow of a river or stream that causes, or is likely to cause, any of the following: i) Damage to property, ii) A threat to life, iii) A threat of personal injury, iv) Pollution, impairment, or destruction of water or other natural resources. MCL 324.3103, R 323.1311g

Hydraulic Grade Line (HGL) - A plotted line coinciding with the level of flowing water in an open channel or conduit. In a closed conduit flowing under pressure, the HGL is the level to which water would rise in a vertical tube at any point along the pipe. It is equal to the EGL minus the velocity head ($V^2/2g$).

Normal Depth Analysis - Analysis that uses the Manning's equation to compute the normal depth of flow given the discharge and cross-section properties including geometry, channel, slope, and roughness.

n-values - Manning's roughness values used to calculate friction losses within channel sections.

Open Channel - A natural or constructed conveyance for water in which:

- The water surface is exposed to the atmosphere.
- The gravity force component in the direction of motion is the driving force.

Roadside Ditch - An artificial channel, smaller than a canal or stream, that conveys runoff from a road and adjacent drainage area.

Standard Step Method - An iterative use of the energy equation for determining the gradually varied water surface profile of an open channel.

Stream Channel - A natural conveyance for water with the following characteristics:

- Size and shape determined by natural forces.
- Compound in cross-section with a main channel for conveying low flows and a floodplain to transport flood flows.
- Shaped geomorphologically over time by sediment load and water discharge.

Thalweg - The lowest bed elevation in a natural channel cross-section. Also used in reference to the profile line extending down a channel along the lowest bed elevation.

Trunkline - Roadway (I, M, or US route) under MDOT jurisdiction.

Symbols and acronyms used in this chapter are listed in **Appendix 4-A**.

4.3 POLICY AND DESIGN CRITERIA

Design criteria establish the standards by which a policy is placed into action. They form the basis to select the final design configuration. Examples of policy and design criteria for channel design are listed in the following sections.

4.3.1 Federal Policy

For federal policy, refer to Chapter 2, Policy and Procedures.

4.3.2 State Policy

For state policy, refer to Chapter 2, Policy and Procedures.

4.3.3 Roadside Ditches

The following criteria apply to roadside ditches and may be revised as approved by the Hydraulic Unit Supervisor. Roadside ditches are further discussed in **Section 4.4.2**. Design criteria for open ditches are shown in **Table 4-1**. Also refer to MDOT Road Standard Plan R-105-Series for additional ditch grading design information.

- Design the channel side slopes to be 1V:3H or flatter ensuring the angle of repose of the soil and/or lining is not exceeded. However, in certain situations (high fills, deep cuts, limited ROW, physical obstructions, etc.), 1V:2H slopes may be used. Where roadside channels are within the clear zone, side slopes are required to adhere to appropriate safety standards.
- In the case of riprap-lined channels, design the side slopes to be 1V:3H or flatter.
- Set the design water surface elevation with at least 1.5 feet of freeboard below edge of shoulder.
- Ensure ditch depth will maintain positive drainage for pavement section and underdrains, as needed.
- If ditch is inside the clear zone, limit the design water depth to 2 feet.
- The desirable minimum grade for ditches is 0.3%. If site conditions prevent the desirable minimum grade, a 0.1% grade may be used.
- Refer to MDOT Road Design Manual Section 2.03 for additional grading requirements.
- For local agency projects with roadside ditches outside of MDOT's jurisdiction, 10% AEP (10-year) is the recommended minimum design unless the local agency has other published standards.

Table 4-1. Roadway Ditch Design Criteria – AEP (ARI)

Roadway Classification	Design	Harmful Interference
MDOT: Interstate, Freeways (Urban / Rural)	2% (50-year)	1% (100-year)
MDOT: Principal Arterial	2% (50-year)	1% (100-year)
MDOT: Minor Arterial	2% (50-year)	1% (100-year)
Local: Minor Arterial	2% (50-year)	1% (100-year)
Local: Collector System	2% (50-year)	1% (100-year)
Local Road System	10% (10-year)	1% (100-year)

4.3.4 Stream Channel Design

The following criteria apply to natural channels and may be revised as approved by the Hydraulic Unit Supervisor.

- Evaluate the hydraulic effects of encroachments on the floodplain over a range of peak discharges from the 10% AEP (10-year) up to and including the 1% AEP (100-year) event for harmful interference.
- Avoid work that would require stream mitigation as much as possible. For trunkline projects requiring stream mitigation, contact the Region Resource Specialist, the Hydraulic Unit Supervisor, and the Compliance and Mitigation Unit Supervisor. Additional information on stream mitigation can be found on [EGLE's website](#).
- If a stream channel must be relocated, the cross-sectional shape, meander, pattern, roughness, sediment transport, entrenchment ratio, and slope must conform to the existing conditions as practical. Some means of energy dissipation is necessary when existing conditions cannot be duplicated. Match the energy grade line (EGL) elevations at the upstream and downstream ends of the project.
- Stabilize streambanks, as necessary, to address any streambank disturbance.

4.4 DESIGN GUIDANCE AND PROCEDURE

4.4.1 Hydraulic Analysis for Stream and Roadside Ditches

The hydraulic analysis of a channel determines the depth and velocity at which a given discharge will flow in a channel of known geometry, roughness, and slope. The depth and velocity of flow are necessary for the design or analysis of channel linings and highway drainage structures. Open channel flow theory is discussed in **Appendix 4-B**.

The two methods commonly used in hydraulic analysis of open channels are normal depth and standard step. The normal depth method (**Section 4.4.3.5**) is a simple application of Manning's equation. This method determines tailwater rating curves for culverts in which uniform or nearly uniform flow conditions exist. Manning's equation estimates high-water elevations for bridges that do not constrict the flow. The standard step method (**Section 4.4.3.7**) computes the complete water surface profile in a stream reach to evaluate the unrestricted water surface elevations for bridge hydraulic design or to analyze other gradually varied flow conditions in streams.

The normal depth method yields less reliable results because it requires more judgment and assumptions than the standard step method. In many situations, however, the normal depth method is sufficient (e.g., standard roadway ditch or tailwater for culverts and storm drain outfalls).

Open channel flow analysis requires a more detailed method of analysis for gradually varied flow profiles. Use computer models, such as USACE's Hydraulic Engineering Center's - River Analysis System (HEC-RAS), in these instances.

For complex situations, additional analysis techniques including 2D and 3D analysis, may be required. This level of analysis addresses hydraulic conditions with highly stratified flow, water and sediment routing, and unsteady flow. A 2D analysis addresses situations where flow varies horizontally across the stream cross-section. 3D analysis, also referred to as computational fluid dynamics (CFD) modeling, addresses situations where flow varies horizontally and vertically across the cross-section.

4.4.2 Roadside Ditches

Roadside ditches are open channels that usually flow parallel to the highway embankment and are located within the limits of the highway right-of-way. These ditches typically have a trapezoidal or V-shaped cross-section and are lined with grass or a protective material.

Refer to the [MDOT Stormwater Treatment Manual](#) for designing ditches for water quality treatment.

The primary function of roadside ditches is to collect surface runoff from the highway and areas that drain to the right-of-way and convey the accumulated runoff to acceptable outlet points. A secondary function is to drain subsurface water from the

pavement section to prevent saturation and loss of support for the pavement or to provide a positive outlet for subsurface drainage systems such as underdrains.

The project's geometric and safety standards constrain the alignment, cross-section, and grade of roadside ditches. Runoff is accommodated to promote motorist safety and minimize future maintenance, damage to adjacent properties, and adverse environmental or aesthetic impacts.

4.4.2.1 Standard Ditch Types

Standard ditch types are shown on MDOT Road Standard Plan R-105-Series. Many factors influence the type, width, depth, and backslope of a ditch including soil, depth of subbase, surface drainage, built-up conditions along the roadside, excavation requirements, roadside safety, and snow conditions. Address variations from standard ditch types with a note or sketch on the typical cross-section.

4.4.2.2 Erosion Control in Ditches

Erosion control measures for roadside ditches are needed for permanent and temporary durations. **Table 4-2** provides the recommended permanent ditch treatment for various ditch grades. Permanent ditch stabilization treatment is required to the top width of the design flow. Additional information is found in the following documents:

- MDOT Road Standard Plan R-100-Series
- MDOT Road Design Manual, Section 2.05
- MDOT Soil Erosion and Sedimentation Control Manual
- MDOT Road Standard Plan R-96-Series

Table 4-2. Permanent Stabilization Treatments for Various Ditch Grades

Ditch Bottom Treatment	Maximum Ditch Side Slope	Ditch Grades
Standard Mulch Blanket	1H:3V	<1.5%
High Velocity Mulch Blanket	1H:2V	1.5% to 3.0%
Turf Reinforcement Mat or Cobble Ditch	1H:2V	3.0% to 6.0%
Special Design Required		6.0% +

Additional ditch treatment requirements include:

- Refer to the [MDOT Stormwater Treatment Manual](#) for water quality treatment standard for ditches discharging to waters of the state.
- Avoid using paved sections of channel, except for spillways. When retrofitting an existing channel with excessive erosion or other special situations, additional erosion control measures are required.

- If the ditch slope is greater than 6.0%, use a drop manhole or series of drop manholes to drain the ditch. Additional energy dissipation is required when the outlet velocity is greater than or equal to 6 fps. For trunkline projects, consult the Hydraulic Unit Supervisor with additional questions.
- If the lateral inflow velocities are greater than 6 fps, energy dissipation is required. Refer to FHWA HEC-14 (2005) for energy dissipation guidance. For trunkline projects, consult the Hydraulic Unit Supervisor with additional questions.

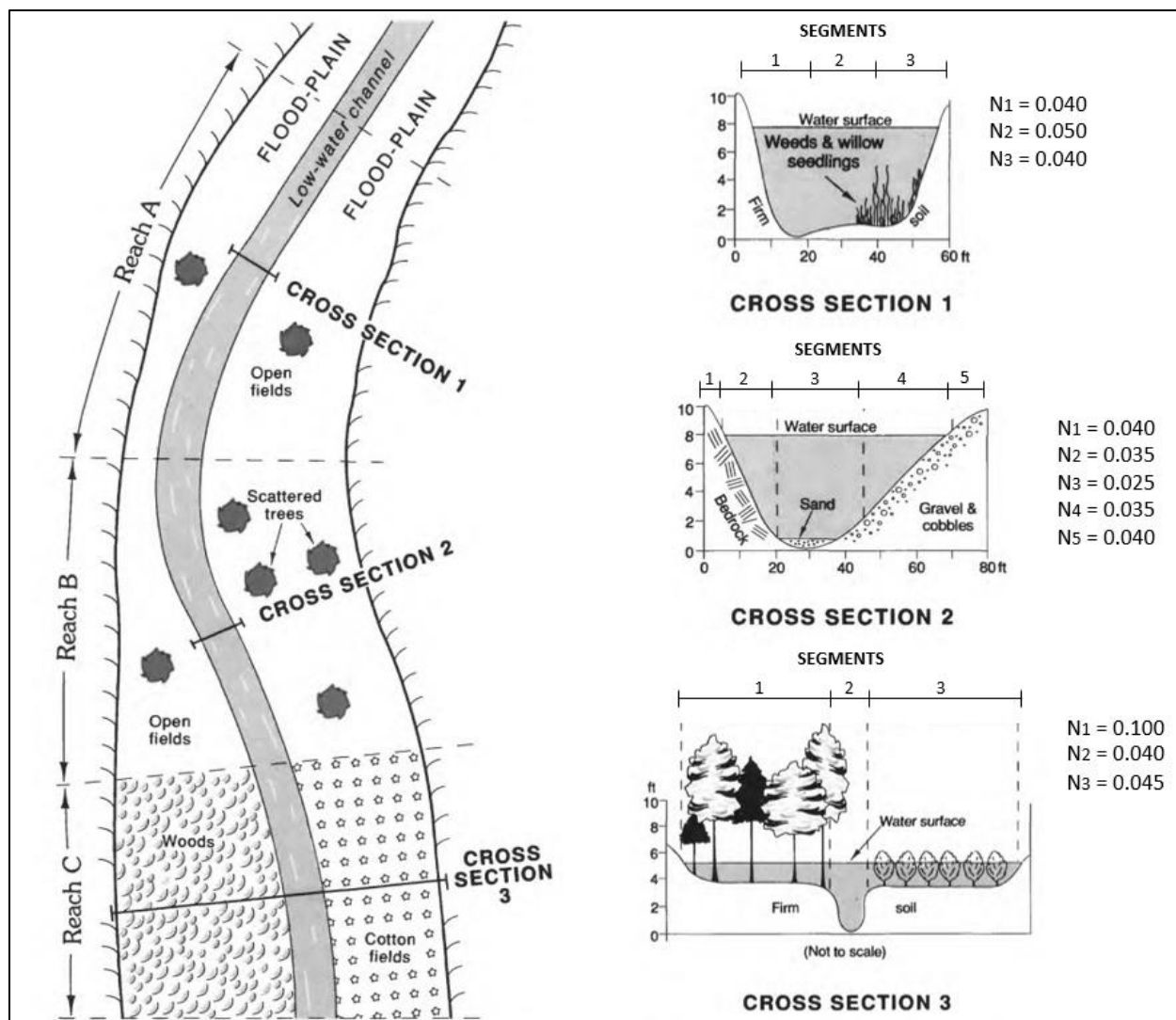
4.4.3 Design Procedures

The following sections describe the methods for collecting data and performing hand and computer model analysis for open channel and ditch design.

4.4.3.1 Cross-Sections

Cross-sections of the stream are needed for all water surface profile calculations (refer to **Figure 4-1** for example locations of cross-sections). Cross-sectional geometry of streams is defined by coordinates of lateral distance (offsets) and ground elevation, which locate individual ground points. The cross-section is taken normal (perpendicular) to the flow direction along a single straight line where possible. In wide floodplains or bends, a section is needed along intersecting straight lines (i.e., a bend section). Plotting the cross-section reveals inconsistencies or errors. The cross-section represents the typical shape of the reach. Cross-section stationing convention is looking downstream to establish left and right orientation.

Figure 4-1. Cross-Sections of Reaches, Segments and Subsections Used to Assign n-values (Arcement, 1989)



The number of and distance between cross-sections varies with stream size and slope and the type of work being proposed at the crossing. Because the required cross-sections vary from site to site, the MDOT Hydraulic Unit makes all requests for trunkline hydraulic surveys.

The hydraulic design engineer accompanies the survey crew when selecting cross-sections. The computation of water surface profiles requires cross-sections at representative locations throughout the river reach. When a river reach is fairly straight and uniform, cross-sections may be taken at regular intervals. However, most river reaches are not uniform and require cross-sections at specific locations to define transitional elements of a stream such as the cross-sectional area increasing or decreasing, channel or overbank roughness changes, or marked breaks in channel bottom slope. When an abrupt change in cross-section occurs, such as at bridges, dams, or other manmade or natural restrictions, several cross-sections are necessary to

represent the change, regardless of the distance. Establishing the prevailing slope of the channel is critical for setting normal depth boundary conditions. To establish these levels, survey crews collect stream bottom and water surface elevations that extend at least 300 feet upstream and 500 feet downstream of the project area.

Cross-sections are taken perpendicular to the direction of the estimated center of mass of the flood flow as shown in **Figure 4-2**. In some instances, this direction may differ from the direction of normal flow in the channel. Changes in flow direction can occur when high flow conditions shortcut the low flow stream path. Enough points are needed to represent the shape of the channel and overbanks. Locate points at each change in topography or vegetation and include the full floodplain width as shown in **Figure 4-3**.

Figure 4-2. Cross-Section Alignment to Flow Direction

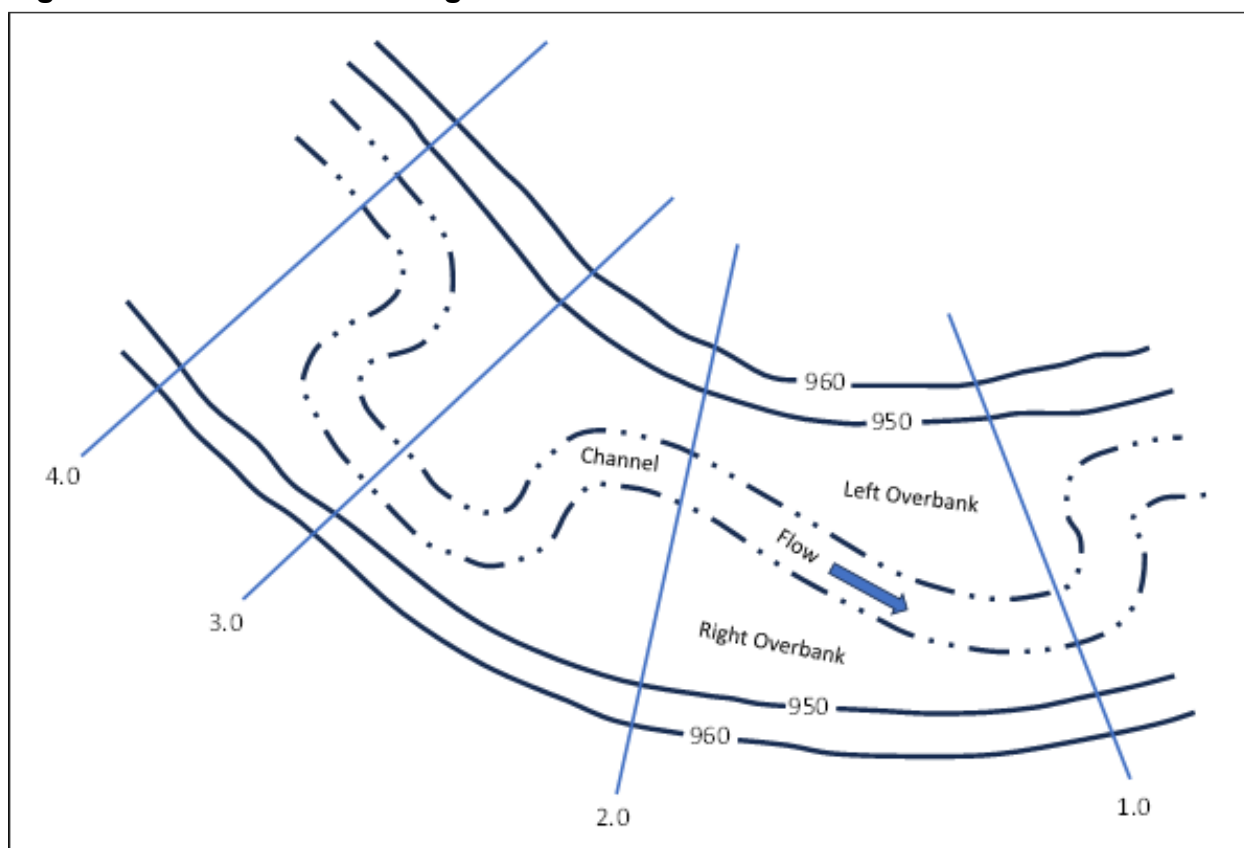
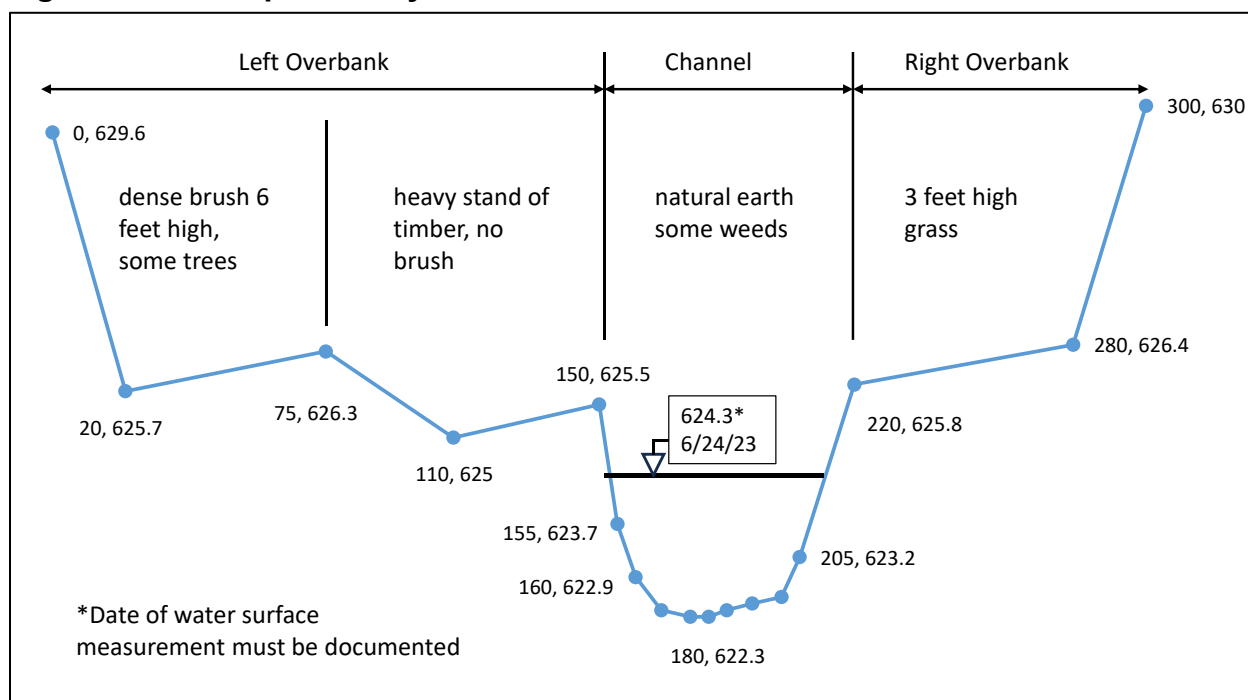


Figure 4-3. Example Survey Cross-Section

4.4.3.2 Terrain Development for Advanced Hydraulic Modeling (2D or CFD)

For advanced hydraulic modeling, a 3D terrain surface is required. The terrain surface includes the waterway/channel bathymetry and overbank topography for the entire width of the floodplain. Reasonable survey limits extend approximately two floodplain widths upstream and downstream of the bridge crossing. This terrain surface can be developed in various ways. Contact the Hydraulic Unit Supervisor to determine the level of data necessary for trunkline projects.

Bathymetric data is collected as cross-sections or full channel bathymetry. For cross-section bathymetric data, provide breaklines running along various features in the channel to ensure accuracy of the terrain triangulation. Provide breaklines at the channel thalweg, left bank, right bank, bottom (toe) of banks, top of banks, and at any other defining grade break features between cross-sections. If the channel's full bathymetric data is collected, breaklines are not necessary.

Collect overbank topography and combine it with the channel bathymetry to create one complete terrain model of the area. Include the overbank area/extents, roadway embankment, and road surface in the topography. Overbank data is collected by traditional survey methods or by utilizing USGS 1-meter digital elevation models (DEM). Compare elevations of the 1-meter DEM to actual survey ground measurements. If the 1-meter DEM data vertical accuracy is acceptable, use it for overbank topography. Inaccuracies in the DEM data may negatively affect hydraulic modeling and require additional data collection. If the 1-meter DEM vertical accuracy is not acceptable or available, collect additional topographic data by traditional or aerial methods. Perform aerial surveys when vegetation is limited and there is no snow cover.

Further guidance for the development and use of 2D modeling is included in *Two-Dimensional Hydraulic Modeling for Highways in the River Environment* (FHWA-HIF-19-061, 2019).

4.4.3.3 Manning's n-value Selection

Manning's n-value is influenced by many factors and its selection in natural channels depends heavily on engineering experience. Photos of reference channels and floodplains with measured discharge and Manning's calculations are very useful for selecting n-values. An example of this method is shown in Arcement (1989) and Barnes (1978). Select initial Manning's n-values and verify or calibrate the n-values to historical high-water marks and/or gaged stream flow data.

Manning's n-values are more easily defined for artificial channels than natural stream channels. **Table 4-3** for typical n-values for both channel types from the USACE *HEC-RAS Reference Manual*. For trunkline projects, contact the Hydraulic Unit Supervisor prior to use if a Manning's n-value recommended is different than **Table 4-3**.

Table 4-3. Values of Manning's Roughness Coefficient n (Uniform Flow)

Type of Channel and Description	Minimum	Normal	Maximum
A. Natural Streams	-	-	-
1. Main Channels	-	-	-
a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. Floodplains	-	-	-
a. Pasture no brush	-	-	-
i. Short grass	0.025	0.030	0.035
ii. High grass	0.030	0.035	0.050
b. Cultivated areas	-	-	-

Type of Channel and Description	Minimum	Normal	Maximum
i. No crop	0.020	0.030	0.040
ii. Mature row crops	0.025	0.035	0.045
iii. Mature field crops	0.030	0.040	0.050
c. Brush	-	-	-
i. Scattered brush, heavy weeds	0.035	0.050	0.070
ii. Light brush and trees, in winter	0.035	0.050	0.060
iii. Light brush and trees, in summer	0.040	0.060	0.080
iv. Medium to dense brush, in winter	0.045	0.070	0.110
v. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees	-	-	-
i. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
ii. Same as above, but heavy sprouts	0.050	0.060	0.080
iii. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
iv. Same as above, but with flow into branches	0.100	0.120	0.160
v. Dense willows in summer, straight	0.110	0.150	0.200
3. Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged	-	-	-
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070
B. Lined or Built-Up Channels	-	-	-
1. Concrete	-	-	-
a. Trowel finish	0.011	0.013	0.015
b. Float finish	0.013	0.015	0.016
c. Finished, with gravel bottom	0.015	0.017	0.020
d. Unfinished	0.014	0.017	0.020
e. Gunite, good section	0.016	0.019	0.023
f. Gunite, wavy section	0.018	0.022	0.025
g. On good excavated rock	0.017	0.020	-

Type of Channel and Description	Minimum	Normal	Maximum
h. On irregular excavated rock	0.022	0.027	-
2. Concrete bottom float finished with sides of:	-	-	-
a. Dressed stone in mortar	0.015	0.017	0.020
b. Random stone in mortar	0.017	0.020	0.024
c. Cement rubble masonry, plastered	0.016	0.020	0.024
d. Cement rubble masonry	0.020	0.025	0.030
e. Dry rubble on riprap	0.020	0.030	0.035
3. Gravel bottom with sides of:	-	-	-
a. Formed concrete	0.017	0.020	0.025
b. Random stone in mortar	0.020	0.023	0.026
c. Dry rubble or riprap	0.023	0.033	0.036
4. Brick	-	-	-
a. Glazed	0.011	0.013	0.015
b. In cement mortar	0.012	0.015	0.018
5. Metal	-	-	-
a. Smooth steel surfaces	0.011	0.012	0.014
b. Corrugated metal	0.021	0.025	0.030
6. Asphalt	-	-	-
a. Smooth	0.013	0.013	-
b. Rough	0.016	0.016	-
7. Vegetal lining	0.030	NA	0.500
C. Excavated or Dredged Channels	-	-	-
1. Earth, straight and uniform	-	-	-
a. Clean, recently completed	0.016	0.018	0.020
b. Clean, after weathering	0.018	0.022	0.025
c. Gravel, uniform section, clean	0.022	0.025	0.030
d. With short grass, few weeds	0.022	0.027	0.033
2. Earth, winding and sluggish	-	-	-
a. No vegetation	0.023	0.025	0.030

Type of Channel and Description	Minimum	Normal	Maximum
b. Grass, some weeds	0.025	0.030	0.033
c. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
d. Earth bottom and rubble side	0.028	0.030	0.035
e. Stony bottom and weedy banks	0.025	0.035	0.040
f. Cobble bottom and clean sides	0.030	0.040	0.050
3. Dragline-excavated or dredged	-	-	-
a. No vegetation	0.025	0.028	0.033
b. Light brush on banks	0.035	0.050	0.060
4. Rock cuts	-	-	-
a. Smooth and uniform	0.025	0.035	0.040
b. Jagged and irregular	0.035	0.040	0.050
5. Channels not maintained, weeds and brush	-	-	-
a. Clean bottom, brush on sides	0.040	0.050	0.080
b. Same as above, highest stage of flow	0.045	0.070	0.110
c. Dense weeds, high as flow depth	0.050	0.080	0.120
d. Dense brush, high stage	0.080	0.100	0.140

4.4.3.4 Hydrologic and Hydraulic Calibration and Validation

Models are calibrated and validated to an observed condition. Calibration and validation are performed based on measured flow values if a stream gauge is nearby or field observations of high-water marks from historic flood events are available. Unfortunately, for most projects, sufficient observed data does not exist to calibrate models. However, calibration yields greater confidence in model results. A suggested calibration and validation procedure is described as follows:

Step 1 Obtain site hydrology (refer to Chapter 3, Hydrology).

Step 2 Develop hydraulic component of the model. Hydraulic model parameters include Manning's n , expansion losses, contraction losses, ineffective flow areas, etc. Values for these parameters are based on reference tables of values and engineering judgement.

Step 3 Compare model calculated water elevations to observed elevations using available historic event information (flow data, rainfall data, etc.).

- Step 4** Revise model parameters (hydrologic and/or hydraulic) in a systematic manner until model-predicted water elevations are within 6 inches of the observed water elevations. Do not adjust model parameters beyond a reasonable range of values to force the model to match observed elevations.
- Step 5** Repeat Step 4 with other flow rates, if available. Select a single set of model parameters that work well for all observations.
- Step 6** Validate the selected model parameters by re-running the model to simulate an observed condition not used as part of the calibration procedure.
- Step 7** Assuming the validation run is satisfactory, use the model to predict existing conditions for design storms.

4.4.3.5 Normal Depth Analysis

Normal depth is calculated using the Manning's equation. Normal depth is based on discharge and cross-section properties including geometry, channel, slope, and roughness. Normal depth assumes the slope of the hydraulic grade line (HGL) and energy grade line (EGL) are equal to the channel slope. This method assumes the existence of steady, uniform flow; however, uniform flow rarely exists in artificial and stream channels. Nevertheless, the normal depth method is often used to design artificial channels for uniform flow as a first approximation. Normal depth is determined by iterating the Manning's equation by varying depth until the desired flow rate is achieved.

The standard form of the Manning's equation is:

$$Q = \left(\frac{1.486}{n} \right) A R^{\frac{2}{3}} \sqrt{S} \quad (4.1)$$

Where:

- Q = discharge, cfs
- n = Manning's roughness coefficient
- A = flow area, sft
- R = hydraulic radius = A/P, ft
- P = wetted perimeter, ft
- S = hydraulic slope, ft/ft

Normal depth approximation establishes the tailwater elevation for the design of a culvert or storm drain outlet. The process of calculating normal depth in a stream channel is described as follows:

- Step 1** Select the typical cross-section at or near the location where normal depth is needed.

- Step 2** Subdivide cross-section and assign n-values to subsections as described in **Section 4.4.3.1**.
- Step 3** Estimate hydraulic slope based on multiple water surface survey points along the stream or in the LiDAR DEM. If the streambed is dry, use the average slope of the streambed.
- Step 4** Select a water surface elevation for the cross-section and calculate the discharge using Manning's equation for each subsection across the cross-section. Total the discharge from each subsection at the selected elevation. To determine the hydraulic radius, measure the wetted perimeter along the solid boundary of the cross-section. Do not measure along the vertical water interface between subsections.

A normal depth analysis can establish a stage-discharge curve. This curve is a graphical relationship of stream flow depth or elevation for a range of discharges at a specific point on a stream. Determine the stage-discharge curve by repeating steps 1 through 4 for a range of water surface elevations. The final rating curve covers a range of discharges up to the 1% AEP (100-year) peak discharge.

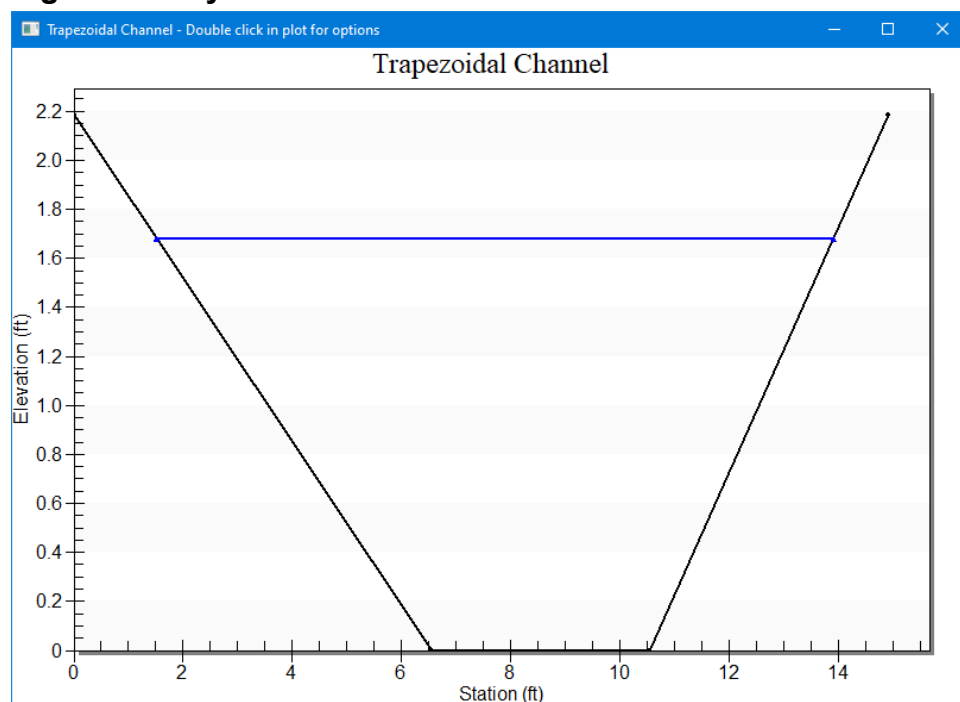
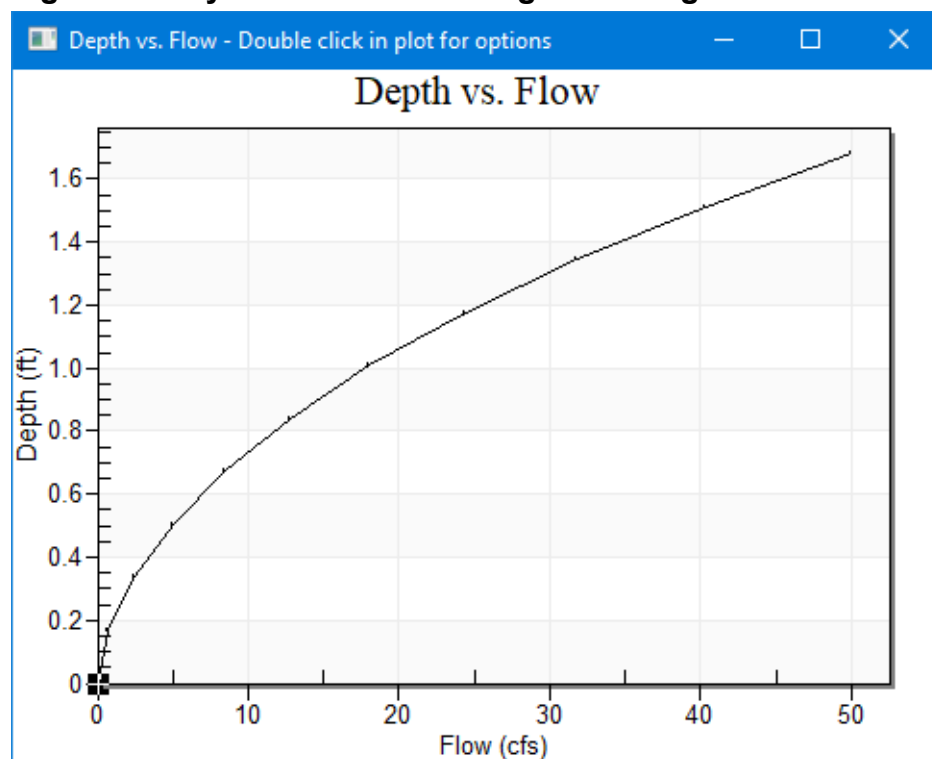
Alternatively, a stage discharge curve can be developed within FHWA Hydraulic Toolbox software. An example application for a trapezoidal channel using Hydraulic Toolbox is shown in **Figure 4-4** through **Figure 4-6**. Although this example is for a trapezoidal channel, an irregular cross-section uses a similar approach.

Figure 4-4. Hydraulic Toolbox Input Data

The screenshot shows the 'Channel Analysis' dialog box in the Hydraulic Toolbox software. The 'Type' is set to 'Trapezoidal'. The input parameters are as follows:

Parameter	Value	Units
Flow	50.000	cfs
Depth	1.680	ft
Area of Flow	13.781	sq ft
Wetted Perimeter	13.071	ft
Hydraulic Radius	1.054	ft
Average Velocity	3.628	fps
Top Width (T)	12.402	ft
Froude Number	0.607	
Critical Depth	1.291	ft
Critical Velocity	5.360	fps
Critical Slope	0.01453	ft/ft
Critical Top Width	10.454	ft
Max Shear Stress	0.524	lb/ft ²
Avg Shear Stress	0.329	lb/ft ²

The input fields on the left are: Type: Trapezoidal, Side Slope 1 (Z1): 3.0 H: 1V, Side Slope 2 (Z2): 2.0 H: 1V, Channel Width (B): 4.0 (ft), Pipe Diameter (D): 0.0 (ft), Longitudinal Slope: 0.005 (ft/ft), Manning's Roughness: 0.0300. The 'Enter Flow' radio button is selected with a value of 50.000 (cfs). The 'Enter Depth' radio button is also selected with a value of 1.680 (ft). Buttons for 'Calculate', 'Plot...', 'Compute Curves...', 'OK', and 'Cancel' are visible at the bottom.

Figure 4-5. Hydraulic Toolbox Cross-Section**Figure 4-6. Hydraulic Toolbox Stage Discharge Curve**

Some streams have permanent USGS stream gauges with established measured stage-discharge relationships for the channel. These measured stage-discharge curves yield more accurate estimates of water surface elevations and take precedence over the

analytical methods previously described. These curves are valid within the immediate vicinity of the stream gauge.

Alluvial channels are made up of loose sediments that erode or build up within the cross-section. It is challenging to establish stage-discharge relationships in a channel with changing geometry because the bed is deformable and has different geometry under different flow rates. For example, a stream bed may experience deposition and form ripples and dunes in lower flows, and experience erosion under higher flows. These bed forms are highly variable with the addition of form resistance. Selecting a standard cross-section and Manning's n -value is not straightforward. If measured stage-discharge relationship cannot be obtained, follow alternate methods outlined in *Sedimentation Engineering* (Vanoni, 1977).

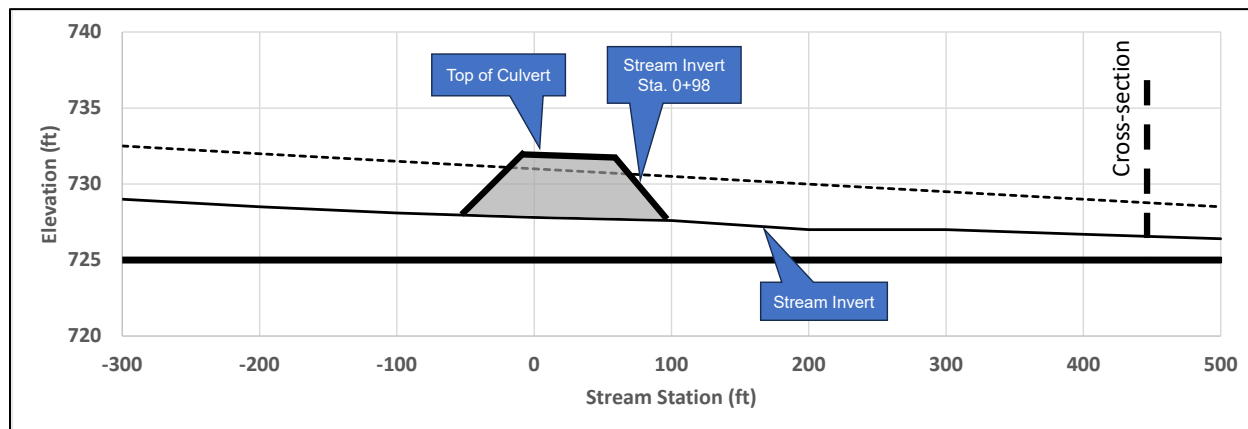
4.4.3.6 Example - Normal Depth Analysis for Culvert Tailwater Determination

Using Hydraulic Toolbox, determine the culvert tailwater elevation for specific design flow rates using downstream cross-section survey data.

Given:

The profile of a stream segment for analysis is shown in **Figure 4-7**. The 10% AEP (10-year) and 2% AEP (50-year) peak discharges equal $Q_{10\%} = 175$ cfs and $Q_{50\%} = 220$ cfs. Stream invert is 726.8 feet at Station 4+46 and 728.8 feet at Station -2+94.

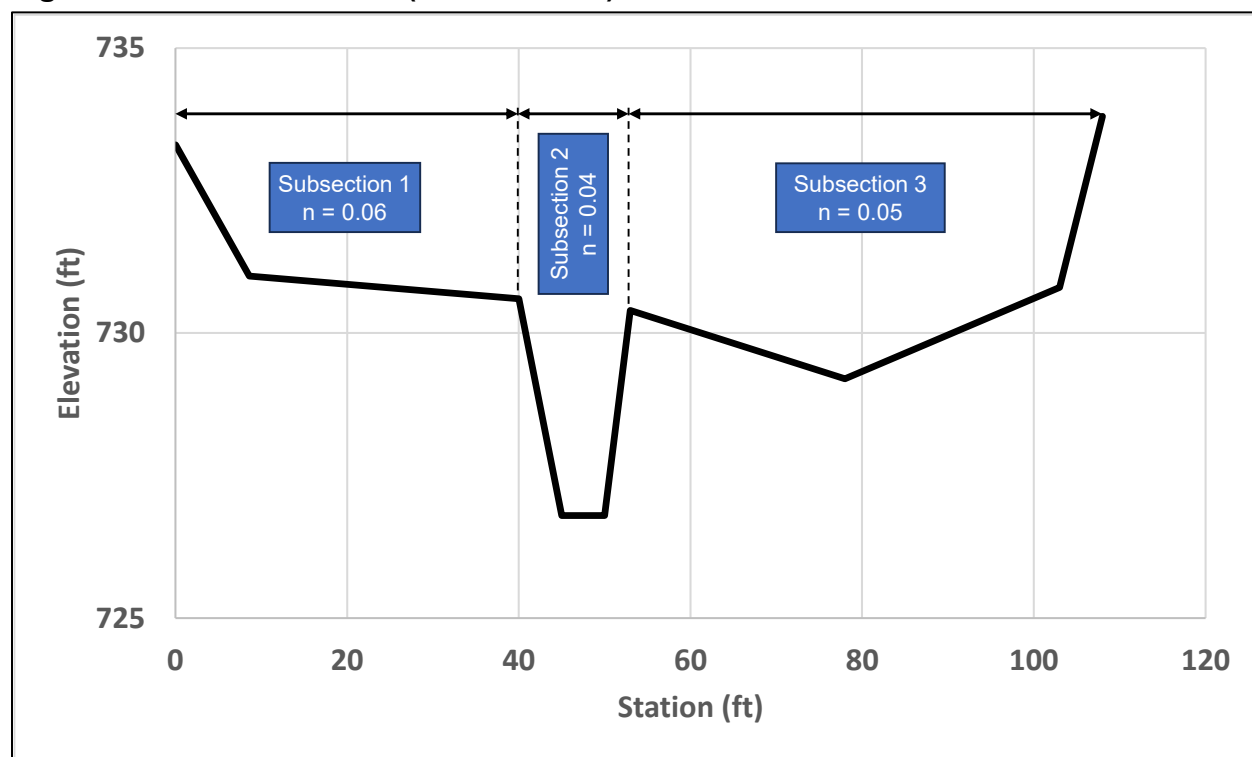
Figure 4-7. Stream Profile



Cross-section information for the downstream cross-section at Station 4+46 is provided in **Table 4-4**. A graphical representation of the cross-section is shown in **Figure 4-8**. Subsection 1 includes the left overbank area with light brush and trees. Subsection 2 includes the main channel of a clean and straight stream with a few weeds and rocks. Subsection 3 includes the right overbank area with some scattered brush and considerable weeds.

Table 4-4. Cross-Section Data – Station 4+46

Station along Cross-Section	Elevation (ft)	n-value
0.0	733.3	0.06
8.6	731.0	0.06
40.0	730.6	0.04
45.0	726.8	0.04
50.0	726.8	0.04
53.0	730.4	0.05
78.0	729.2	0.05
103.0	730.8	0.05
108.0	733.8	0.05

Figure 4-8. Cross-Section (Station 4+46)**Find:**

A stage-discharge curve for the typical channel cross-section at Station 4+46, which is located downstream from a highway culvert, using the Hydraulic Toolbox. Determine the tailwater elevation at the outlet of the culvert (assume channel Station 0+98) for the 10% AEP (10-year) and 2% AEP (50-year) floods.

Solution:

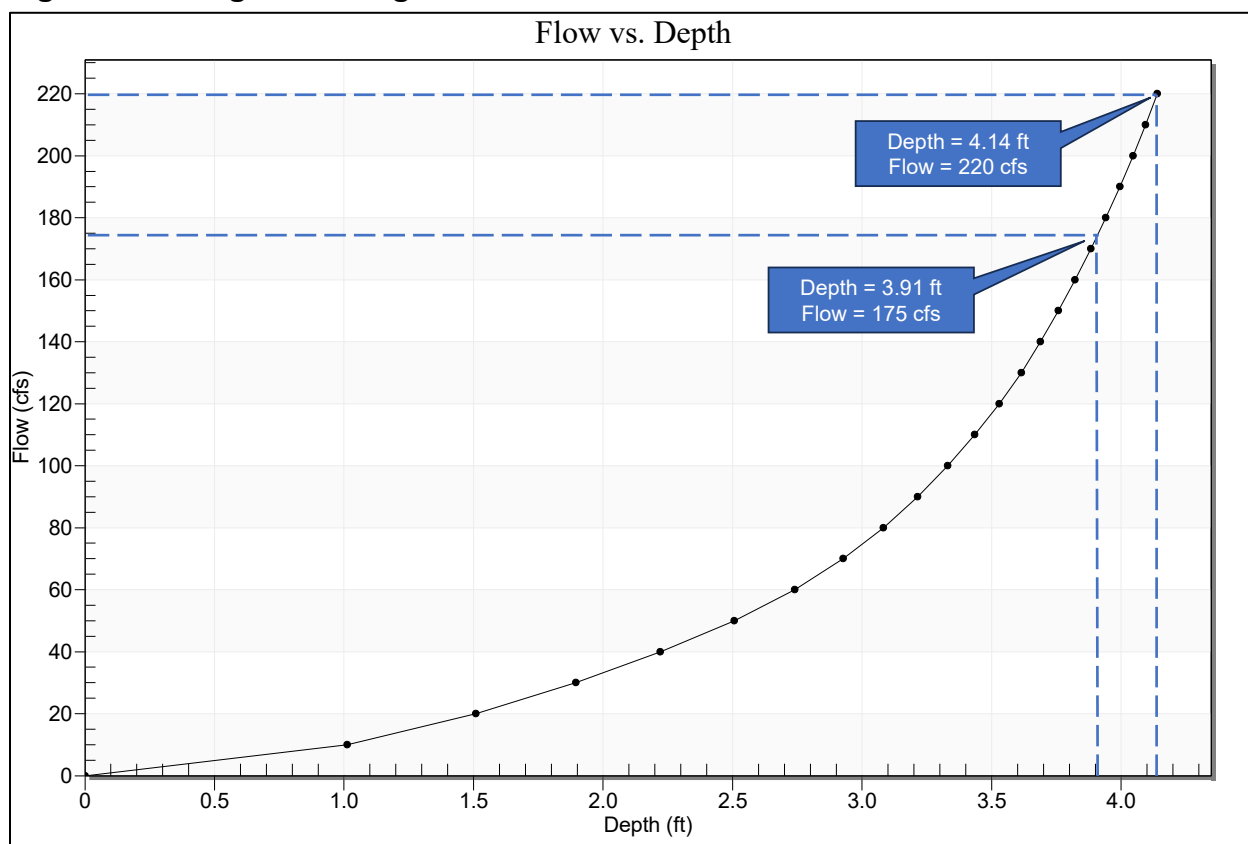
Examine the reach of the stream from Station -2+94 to the typical channel cross-section Station 4+46 to determine the slope of the stream. The channel bottom falls 2.0 feet along 740 feet of reach. Therefore, the slope is 0.0027 feet/foot. Under subcritical conditions and when available, it is best to use the slope of the channel downstream of the station in question (Station 4+46). In this application, the downstream channel is also sloped at 0.0027 feet/foot.

Within Hydraulic Toolbox, select “New Channel Analysis” and change the type to “Cross-Section.” Enter the Longitudinal Slope, select Enter Flow. Click the “Define” button to enter the station, elevation, and Manning’s n-values to define the channel cross-section.

Hydraulic Toolbox will compute a depth for a given flow rate based on the inputs to the model. Alternatively, Hydraulic Toolbox will calculate a depth vs. flow rating curve ranging from zero flow up to the flow rate entered in the model by selecting the computer curves button. An example of the computed rating curve is shown in **Figure 4-9**. Data from the plot can be exported into Excel by double-clicking on the plot and using the export function. In this example, a depth of 3.91 feet corresponds to a flow rate of 175 cfs. Add the channel invert to the depth data to convert the depth to elevation.

The rating curve is developed for stream Station 4+46. This rating curve can be translated upstream to stream Station 0+98 by adding the product of the slope and distance to the upstream station. For example:

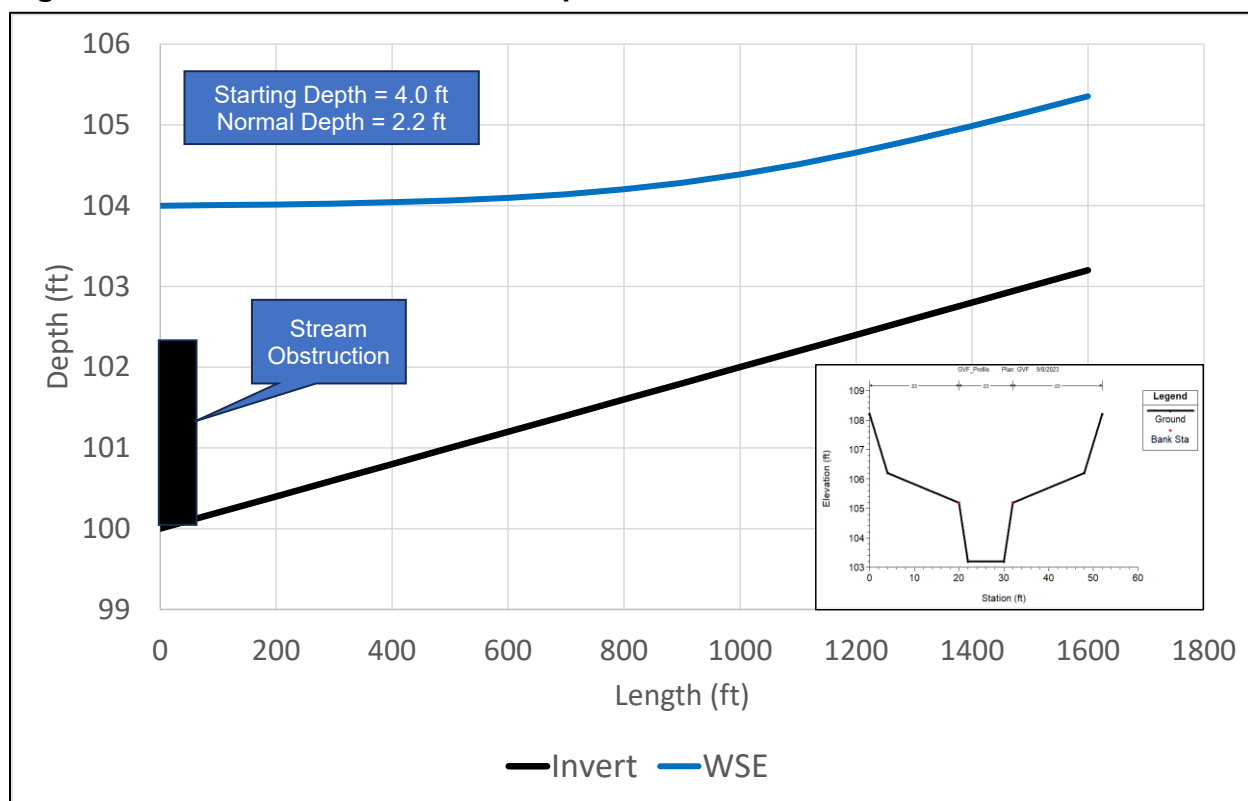
$$\text{Translation} = 0.0027(446 - 98) = 0.94 \text{ ft}$$

Figure 4-9. Stage Discharge Curve for Cross-Section 4+46

4.4.3.7 Standard Step Analysis – Hand Calculation

Standard step analysis is useful for determining the water surface profile for a gradually varied water surface. Generally, these profiles occur in locations that have an in-line restriction within the system that prevents the development of a normal water surface profile. Change in the slope of the streambed can induce a backwater condition. The gradually varied profile is used to assess how far upstream the water surface is affected by a culvert, bridge, or other situation that generates a backwater.

Standard step calculations can be performed by hand or in a spreadsheet following the calculation worksheet described in **Appendix 4-B**. Because these calculations are tedious and repetitive, a computer program, such as the HEC-RAS program, is recommended. An example of a backwater profile for a natural cross-section with an in-line obstruction is shown in **Figure 4-10**.

Figure 4-10. Backwater Profile Example

4.4.3.8 Standard Step Analysis – HEC-RAS Model

The HEC-RAS program is widely used for calculating water surface profiles for steady gradually varied flow (refer to **Section 4.4.3.1**) in natural or constructed channels. Subcritical and supercritical flow profiles can be calculated. The effects of bridges, culverts, weirs, and structures in the floodplain are considered in the computations. This program is designed for application in floodplain management and FEMA Flood Insurance Study (FIS).

If available, obtain flood flows from an FIS for initial model set up. However, flood flows requested from EGLE are required for final design for drainage areas greater than 2 square miles. If available, an FIS Flood Profile can be used to establish the downstream boundary conditions for a stream.

4.4.3.9 HEC-RAS Standard Step Method

HEC-RAS computes water surface profiles using the standard step method. Cross-sections are placed along the stream reach to divide it into subreaches with gradually varied flow. The energy equation is solved in a step-wise fashion to account for friction and minor losses for the stage at one cross-section based on the stage at the previous cross-section.

The geometry and roughness of each cross-section is defined as discussed in **Section 4.4.3.3**. Manning's n-values vary horizontally and vertically across the section. Expansion and contraction head loss coefficients, variable main channel and overbank flow lengths, and the method of averaging the slope of the energy grade line are specified. For more information on the standard step method, refer to **Appendix 4-B**.

4.4.3.10 Profile Calculation Concepts

Water surface profile computation requires a beginning value of elevation or depth (boundary condition) and proceeds upstream for subcritical flow and downstream for supercritical flow. For supercritical flow, critical depth is often the boundary condition at the control section. However, for subcritical flow, the boundary condition is the normal depth or a known backwater elevation based on a downstream condition. If downstream water bodies or hydraulic controls are present, consider the following:

- Use the high-water mark that has the same discharge as the design flood if events are known to occur concurrently (statistically dependent).
- At the confluence, if statistically independent, evaluate the joint probability of flood magnitudes and use a likely combination resulting in greater tailwater depth. Guidelines are provided in Chapter 7, Inlet and Enclosed Storm Drainage Systems, Table 7-7, Frequencies for Coincidental Occurrence – AEP (ARI).
- For outfalls to one of the Great Lakes, review relevant data including Section 324.32502 of the Michigan Natural Resources and Environmental Protection Act (EXCERPT) Act 451 of 1994. Historical Great Lakes elevation data is also available from the US Army Corps of Engineers (USACE) and/or the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory.
- High and low Great Lake levels can impact design (refer to Chapter 9, Coastal Engineering). Review both when performing scour calculations.

A sensitivity analysis on the starting water surface is recommended. The sensitivity analysis is performed by calculating water surface profiles with varying starting elevations to demonstrate that the profiles converge downstream of the project area. If the profiles do not converge, extend the stream reach downstream, use a shorter cross-section interval, or adjust the range of starting water surface elevations. A plot of the convergence profiles is a useful analysis tool. In **Figure 4-11**, a range of starting water surface elevations at Section 1 all converge to the same water level at the cross-section of interest at Section 6. Include enough cross-sections in the analysis so that the existing and proposed condition analyses also converge upstream of the project area as shown in **Figure 4-12**.

Figure 4-11. Profile Convergence Pattern Standard Step Computation (AASHTO Drainage Manual, 2014)

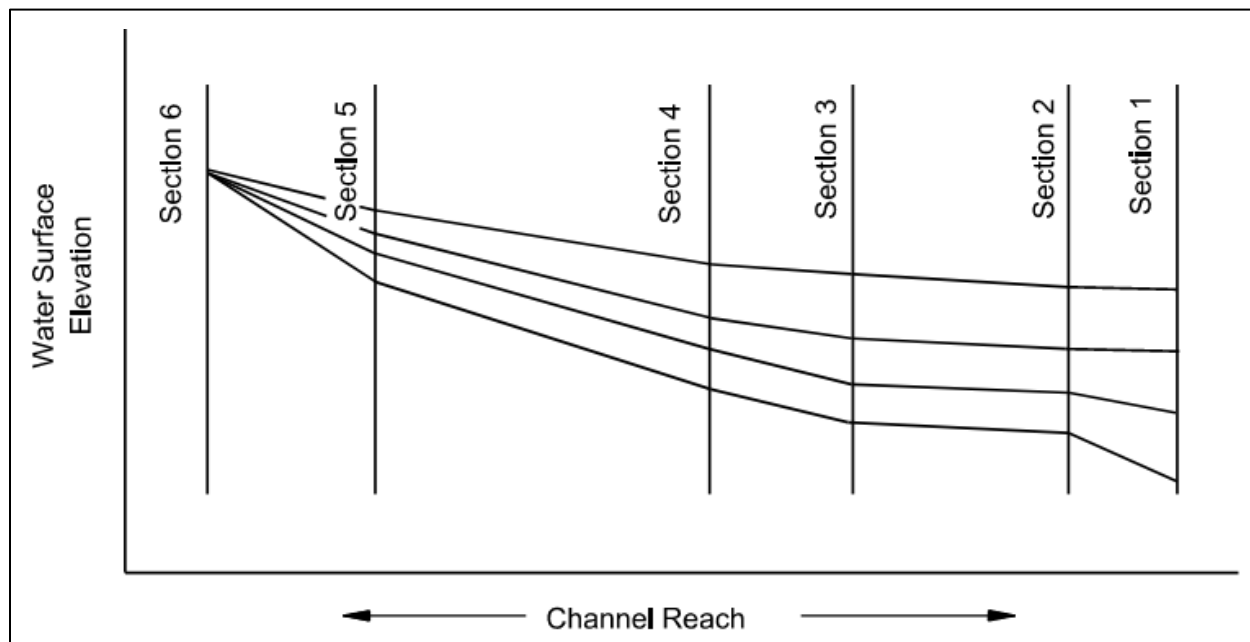
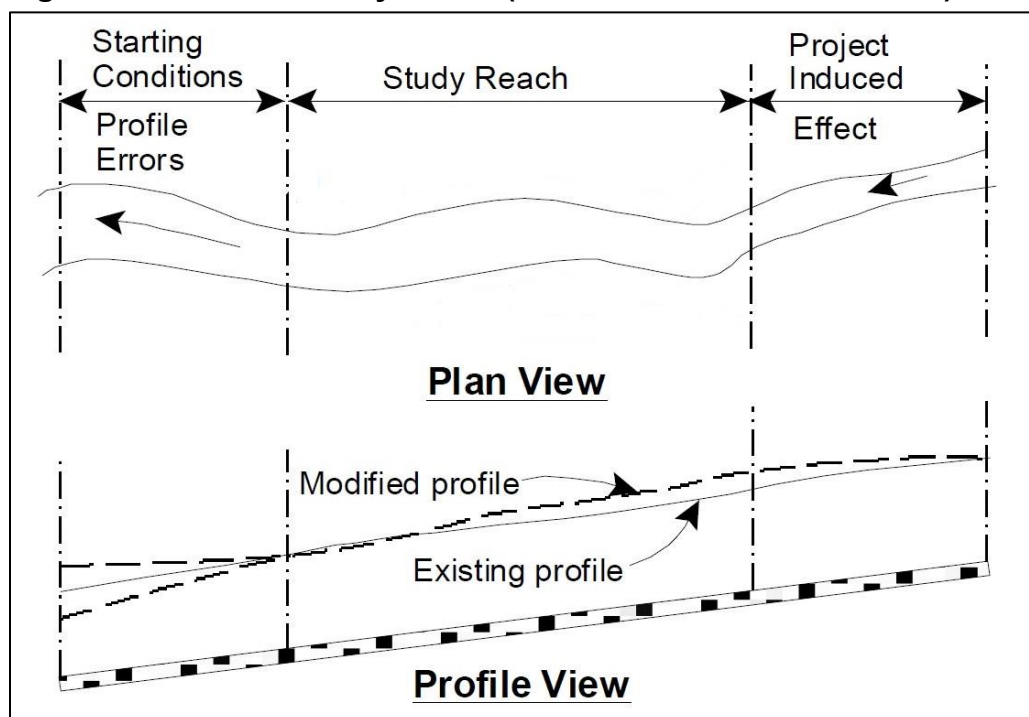


Figure 4-12. Profile Study Limits (HEC-RAS Reference Manual)



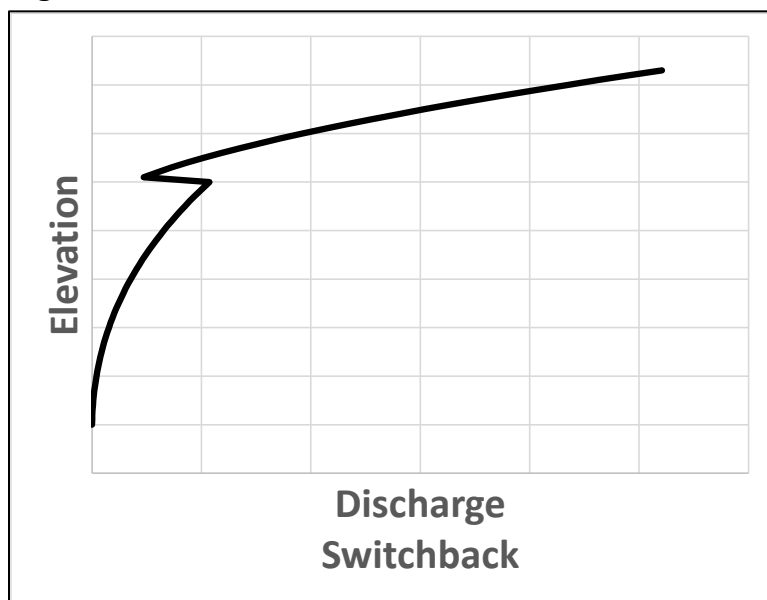
Davidian (1984) and USACE (1986) provide additional guidance on the practical application of the standard step method to highway drainage problems involving open channels. These references contain specific guidance on cross-section determination, location, spacing, and stream reach determination. USACE (1986) investigates the

accuracy and reliability of water surface profiles related to n -value determination and the survey or mapping technology used to determine the cross-section coordinate geometry.

4.4.3.11 Switchback Phenomenon

If the cross-section is improperly subdivided, the use of Manning's equation can result in a switchback caused by a decrease in calculated discharge with an associated increase in elevation. This occurs when a minor increase in water depth causes a large increase of wetted perimeter without a similar increase on cross-section area resulting in a net decrease in the hydraulic radius. When the lower hydraulic radius and the slightly larger cross-sectional area are combined, the computed discharge is lower than the discharge based upon the lower water depth. Use more subdivisions within such cross-sections to avoid the switchback. This switchback phenomenon is demonstrated in **Figure 4-13**.

Figure 4-13. Switchback Phenomenon



This phenomenon can occur in any type of conveyance computation, including the standard step method. The computer model may not run correctly if a switchback occurs in any cross-section being used in a standard step program. For this reason, subdivide the reach with cross-sections with respect to vegetation and geometric changes. Note that the actual n -value may be the same in adjacent subsections.

4.4.3.12 Example: Calculation of Effect of Tailwater Condition on Channel Water Surface Profile

Given:

A series of five cross-sections is available for a creek with a discharge of 9,990 cfs. The section station and elevation points (X, Y), distance upstream, and bank station locations are given in **Table 4-5** through **Table 4-9** for cross-sections A, B, C, D, and E.

Cross-sections are shown in **Figure 4-14**. The Manning's n is 0.027 in the center channel and 0.065 in the overbanks. Contraction and expansion losses are 0.1 and 0.3 respectively.

Find:

The water surface profile using HEC-RAS for three tailwater conditions: critical depth, normal depth, and a known water surface elevation of 801.25 feet. For the normal depth analysis, assume a downstream slope of 0.1%. Determine if enough cross-sections are taken downstream to allow for convergence within the study reach (Station 150+00 to 300+00).

Solution:

The water surface profile is shown in **Figure 4-15** and the HEC-RAS output data is presented in **Table 4-10**. The profiles converge at the most upstream station, Station 324+00. The most downstream cross-section, Station 0+00, is far enough downstream that the reach being analyzed from Station 150+00 to Station 300+00 is not sensitive to the tailwater conditions.

Table 4-5. Cross-Section Data for Sections A at Station 0

X (ft)	Y (ft)
106.9	822.6
131.9	810.9
169.9 (Left Bank Station)	801.6
189.9	793.8
248.0	790.3
270.9	790.3
292.9	789.9
310.0	790.3
317.8	792.9
337.8	795.7
350.0	800.3
368.0 (Right Bank Station)	803.6
379.8	804.8
399.8	805.0

Table 4-6. Cross-Section Data for Cross-Section B at Station 6,600

X (ft)	Y (ft)
144.0	821.9
182.0 (Left Bank Station)	805.3
205.0	795.3
218.8	793.4
222.1	793.5
274.9	789.7
296.8	789.6
315.9	789.8
345.1	790.4
356.9	793.5
383.8 (Right Bank Station)	803.9
384.7	805.0
399.8	805.4

Table 4-7. Cross-Section Data for Cross-Section C at Station 16,500

X (ft)	Y (ft)
196.8	819.2
224.0 (Left Bank Station)	808.2
247.0	795.8
273.9	791.3
275.8	789.3
293.9	789.1
305.0	788.3
316.8	787.9
327.0	788.3
352.9	789.5
354.9	792.4
373.9	796.0
392.9	803.2
396.9 (Right Bank Station)	804.4
399.8	804.5

Table 4-8. Cross-Section Data for Cross-Section D at Station 24,000

X (ft)	Y (ft)
220.1	818.9
239.8 (Left Bank Station)	803.5
252.9	793.3
272.9	793.0
275.8	790.6
294.9	790.4
311.9	790.4
314.9	788.8
328.0	788.9
339.8	789.0
340.8	790.6
372.0	794.6
389.0 (Right Bank Station)	803.2
399.8	803.5

Table 4-9. Cross-Section Data for Cross-Section E at Station 32,400

X (ft)	Y (ft)
204.0	818.8
239.8 (Left Bank Station)	792.9
257.8	793.0
275.8	792.1
292.9	791.9
310.9	791.9
329.0	791.6
347.0	792.8
364.7 (Right Bank Station)	792.6
383.8	800.8
399.8	801.8
400.8	807.8

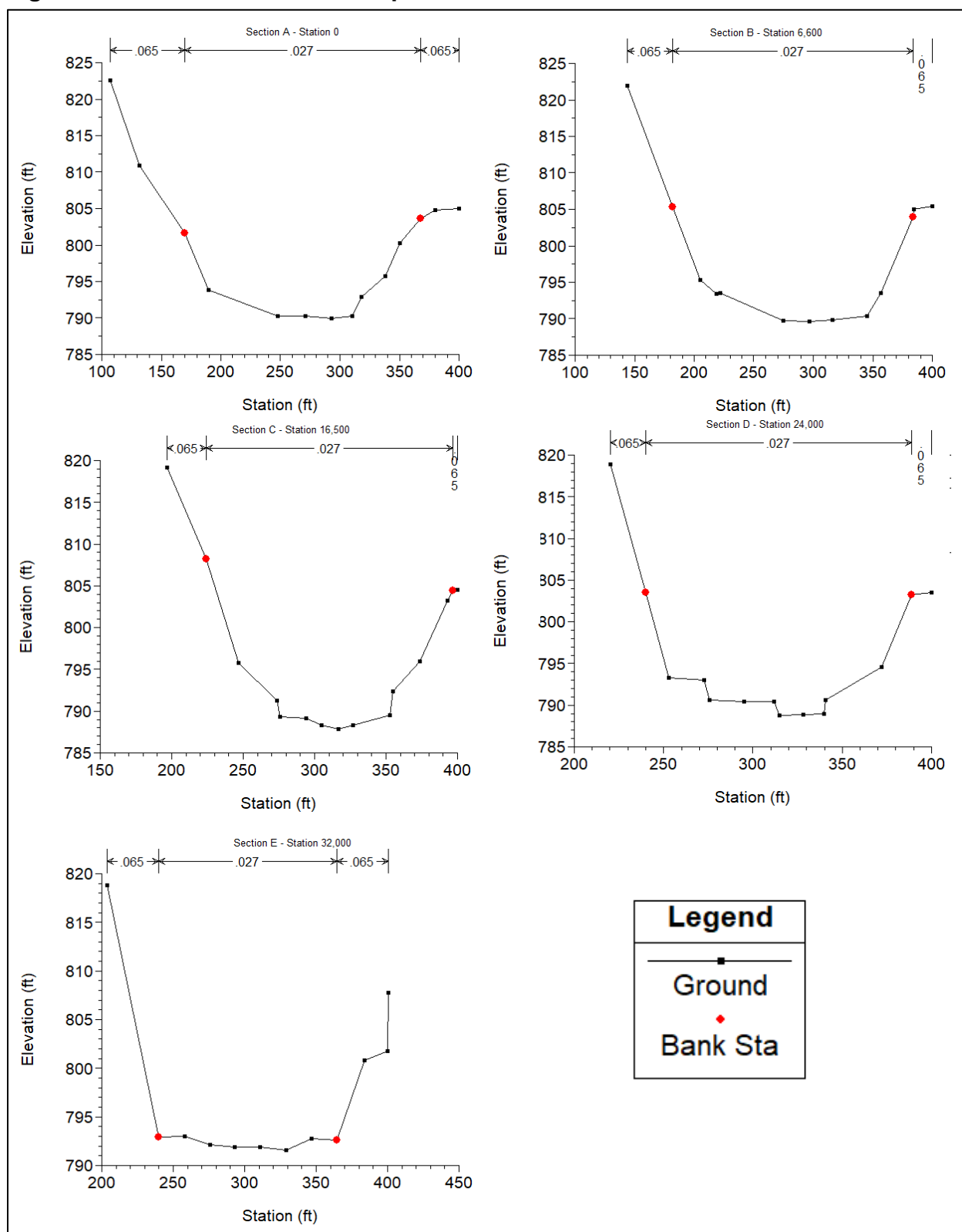
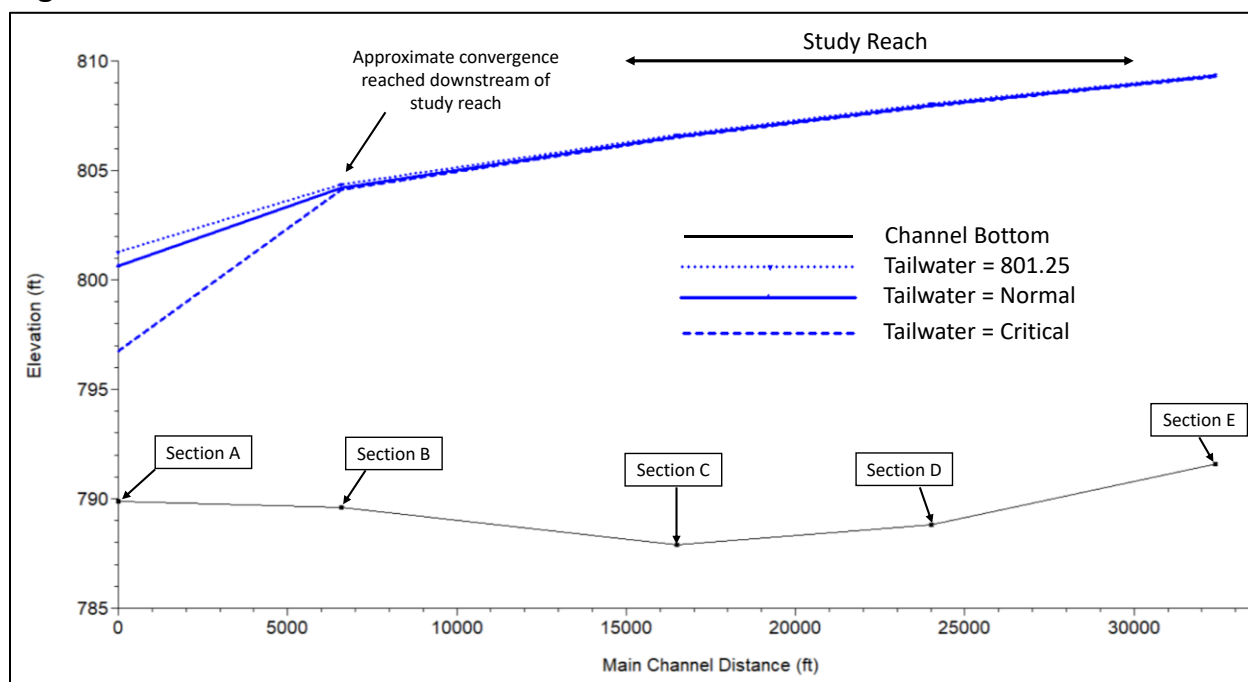
Figure 4-14. Cross-Section Examples

Figure 4-15. Channel Profile**Table 4-10. Output Table from HEC-RAS for Figure 4-15 Profile**

River Station	Profile I.D.	Min Channel Elev (ft)	W.S. Elev (ft)	E.G. Elev (ft)	Channel Velocity (fps)	Flow Area (sf)	Top Width (ft)
0	TW=801.25	789.90	801.25	801.88	6.39	1548.78	184.38
0	TW=Normal	789.90	800.63	801.37	6.89	1436.35	179.43
0	TW=Critical	789.90	796.75	799.24	12.69	779.86	158.16
6600	TW=801.25	789.60	804.38	804.68	4.37	2264.23	200.09
6600	TW=Normal	789.60	804.19	804.50	4.45	2225.61	199.48
6600	TW=Critical	789.60	804.12	804.43	4.48	2212.14	199.27
16500	TW=801.25	787.90	806.65	806.94	4.33	2294.44	172.92
16500	TW=Normal	787.90	806.55	806.84	4.36	2277.28	172.73
16500	TW=Critical	787.90	806.51	806.81	4.37	2270.91	172.66
24000	TW=801.25	788.80	808.05	808.33	4.30	2358.73	165.82
24000	TW=Normal	788.80	807.98	808.27	4.32	2347.05	165.73
24000	TW=Critical	788.80	807.95	808.24	4.32	2342.74	165.70
32400	TW=801.25	791.60	809.37	809.64	4.36	2695.41	183.76
32400	TW=Normal	791.60	809.31	809.59	4.37	2685.76	183.69
32400	TW=Critical	791.60	809.29	809.58	4.38	2682.22	183.66

4.4.3.13 2D Hydraulic Modeling

2D hydraulic models simulate flow in two directions, longitudinal and transverse, at a series of user-defined elements/cells/nodes. Flow in the vertical direction is assumed negligible. 2D models account for transverse flow due to lateral velocities and water surface gradients that are not accounted for with 1D models. Consider 2D models for projects with complex flow patterns that 1D models cannot adequately analyze. 2D models are recommended for:

- Bridges in wide floodplains
- Bridges in floodplains with highly variable roughness
- Bridges that have significant roadway overtopping
- Upstream controls (supercritical flow)
- Highly sinuous channels
- Skewed bridges (>20 degrees)
- Floodplain crossings with multiple openings
- Channel bifurcation
- Flow around channel bends
- Flow at confluences
- Flow around islands
- Sites where more accurate flow patterns and velocities are needed to design cost-effective countermeasures (e.g., riprap along embankments, abutments)
- High-risk or sensitive locations where losses and liability costs are high

Further guidance for 1D versus 2D modeling is provided in *Two-Dimensional Hydraulic Modeling for Highways in the River Environment* (FHWA-HIF-19-061, 2019). Contact the Hydraulic Unit Supervisor for approval of 2D modeling for trunkline projects.

4.4.4 Channel Design Procedure

The design procedure for all types of channels shares common elements and substantial differences. This section outlines a process for assessing a natural stream channel.

4.4.4.1 Stream Channels

Analysis of a stream channel is typically performed during the design of a highway hydraulic structure such as a culvert or bridge. The objective is to convey water along or under a highway without damaging the highway, stream, or adjacent property. Assess the existing channel for potential problems that may result from a proposed structure. The detail of study necessary correlates with the risk associated with the proposed structure and with the environmental sensitivity of the stream and adjoining floodplain (refer to **Section 4.4.4.2**). Information on erosion controls in channels can be found in FHWA HEC-23 (2009).

The following step-by-step procedure is appropriate for most applications.

Step 1 Assemble site data and project file:

- A. Data Collection:
 - a. Topography and bathymetry, site and location maps
 - b. Roadway profile
 - c. Photographs
 - d. Field reviews
 - e. Design data at nearby structures
 - f. Gaging records
 - g. Historic flood data and local knowledge
- B. Studies by other agencies:
 - a. Flood Insurance Studies (FIS)
 - b. Floodplain Studies (completed by NRCS, USACE)
- C. Environmental constraints (refer to Chapter 2, Policy and Procedures):
 - a. Floodplain encroachment (Part 31, NREPA)
 - b. Floodway designation
 - c. Fish and wildlife habitat
 - d. Environmental clearance documents (MDOT Form 1775)
- D. Design criteria (**Section 4.3**).

Step 2 Determine the project scope:

- A. Determine level of assessment:
 - a. Existing channel stability
 - b. Potential for damage
 - c. Stream sensitivity
 - d. Special analysis techniques
- B. Determine type of hydraulic analysis:
 - a. Normal depth analysis (**Section 4.4.3.5**)
 - b. Standard step method (HEC-RAS, **Section 4.4.3.9**)
 - c. 2D hydraulic modeling (with approval)
 - d. Special analysis techniques such as 3D hydraulic modeling (with approval)
- C. Determine hydraulic survey information:
 - a. Study limits (convergence downstream of study area)
 - b. Cross-section locations
 - c. Instream structures (bridges, culverts, weirs, etc.)
 - d. Flood-prone property elevations
 - e. Existing structure elevations
 - f. Soil properties of bed and bank materials

Step 3 Obtain hydrologic data (refer to Chapter 3, Hydrology).

Step 4 Perform hydraulic analysis:

- A. Determine if standard step method is appropriate (**Section 4.4.3.7**)
- B. Establish downstream boundary conditions
- C. Normal depth analysis (**Section 4.4.3.5**):
 - a. Select representative cross-section for stream reach (**Section 4.4.3.1**)
 - b. Select appropriate n-values (**Table 4-3**)
 - c. Compute stage-discharge relationship
- D. Perform standard step analysis
- E. Perform 2D hydraulic model analysis if standard step method is not appropriate (**Section 4.4.3.13**).
- F. Calibrate model with known high water and flow rate (**Section 4.4.3.4**)

Step 5 Perform stream stability analysis for:

- A. Bridge scour
- B. Stream mitigation
- C. Perched culverts
- D. Vertical or horizontal stream instability

Step 6 Design stream instability countermeasures:

- A. Criteria for selection:
 - a. Erosion mechanism
 - b. Stream characteristics
 - c. Construction and maintenance requirements
 - d. Vandalism considerations
 - e. Cost
- B. Types of countermeasures (FHWA HEC-23, 2009) for:
 - a. Meander migration
 - b. Channel bank stabilization
 - c. Bend control
 - d. Channel braiding
 - e. Degradation
 - f. Aggradation
- C. For additional information, refer to reference list.

Step 7 Documentation:

- A. Prepare report for MDOT project manager and file with background information. For streams under EGLE's floodplain regulatory authority, report guidelines are provided in Chapter 6, Bridge Hydraulic Design, Appendix 6-C.

4.4.4.2 Stream Morphology

A natural stream's form, which includes its cross-sectional shape and plan form, is a function of many variables for which cause-and-effect relationships are difficult to establish. The stream is in equilibrium over long time periods when it discharges the same amount of sediment that it receives. There may be short-term adjustments in its bed form in response to flood flows. Conversely, a stream reach may be aggrading or degrading due to deposition or scour in the reach, respectively. The plan form of the stream may be straight, braided, or meandering. The complexities of stream morphology are assessed by inspecting historic and current aerial photographs and topographic maps of the stream for changes in slope, width, depth, meander form, and bank erosion.

A qualitative assessment of the stream response to proposed highway facilities is possible based on knowledge of river mechanics and engineering experience. A natural stream channel assumes a geomorphological form that is compatible with its history of sediment load and discharge. When a highway structure disturbs this delicate balance by encroaching on the natural channel, flooding, erosion, and deposition can be significant and widespread. The hydraulic analysis of a proposed highway structure considers the extent of these consequences. The detailed calculation of sediment transport beyond scour analysis is outside the scope of this manual. For more information, refer to FHWA HEC-20 (2012).

4.5 MAINTENANCE

4.5.1 Ditch Maintenance and Repairs

Ditch maintenance follows the work methods described in the MDOT Maintenance Activity Guide. Activity 1230, Ditch Cleanout & Check Dam Maintenance, provides guidance for maintaining ditches. Contact the MDOT Maintenance Services Section Engineer for more information.

4.5.2 Erosion and Vegetation

Because erosion is a major problem that occurs in ditches, growth of vegetation is essential. The vegetation is occasionally maintained by adjoining property owners, but more often it is maintained by the roadway owner or designated personnel. Regular maintenance enables ditches to perform as designed.

If the hydraulic properties of the ditch are detrimentally impacted by growth of woody vegetation, mow or cut back the ditch banks as needed.

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References in bold type are recommended reading for the engineer's library. MDOT does not claim responsibility for the information at these links or their maintenance.

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