Ohio Department of Transportation

Central Office • 1980 West Broad Street • Columbus, OH 43223

Mike DeWine, Governor • Pamela Boratyn, Director

Date: July 18, 2025

To: All Current Holders of the Location and Design Manual, Volume 2

Subject: Location and Design Manual, Volume Two Revisions

The following revisions have been made to the July 2025 publication of the LD2:

- **Revisions / Additions** Highlighted
- **General Information: Glossary of Terms – Added** definition for Bankfull Width
- **General Information: Abbreviations – Added** AOP; Aquatic Organism Passage, HSR; Hard Shoulder Running, LD4; Location & Design Manual 4 and LRW; Limited Resource Waters
- **General Information: References – Added** Corrugated Steel Pipe Design Manual
- **C1002.3.1 – Updated** commentary on upsizing conduits
- **1002.3.1 – Updated** guidance on when corrugated metal conduit field paving is required and the minimum size from 60" to 54"
- **C1009.1 – Added** commentary to include contacting the Office of Roadway Engineering if MOT design criteria cannot be met
- **C1010.1 – Added** commentary on 2D models for TAFs
- **1103.2 – Added** guidance on allowable pavement spread on HSR lanes
- **C1103.2 – Added** commentary on pavement spread within roundabouts
- **1103.4 – Updated** gutter flow capacity equations
- **1104.2.1 – Updated** guideline C.
- **1105.2.1/C1105.2.1 – Deleted** Bankfull Discharge Design, **Added** guidance and commentary for Culvert Aquatic Organism Passage
- **1105.2.1.1/C1105.2.1.1 – Added** new section guidance and commentary for **Aquatic Organism Passage for New Culvert Crossings**
- **1105.2.1.2/C1105.2.1.2 – Added** new section guidance and commentary for **Aquatic Organism Passage for Culvert Replacements**
- **1105.2.1.3/C1105.2.1.3 – Added** new section guidance and commentary for **Aquatic Organism Passage for Culvert Rehabilitation Projects**
- **1105.2.2/C1105.2.2 – Updated Table 1105-1** by changing minimum pipe size from 36 inches to 54 inches. Added commentary about placement of material in culverts
- **1105.2.4/C1105.4 – Deleted** entire section **Flood Plain Culverts**
- **1105.2.5/C1105.5 – Renumbered** section **Outlet Velocity Control** to **1105.2.4**
- **1105.5.5/C1105.5.5 – Added** guidance and commentary for the Manning's n value in certain types of field paved corrugated metal pipe
- **C1107.2.1 – Added** commentary verifying lateral mesh limits in 2D models and on model terrain data sources
- **C1111.7 – Added** commentary clarifying that BMP treatment credit is allowed for undisturbed areas and areas outside of what is included under a project's coverage

under the Construction General Permit if the area drains to an appropriately sized BMP
- **1113.2.1/C1113.2.1 – Added** guidance and commentary for the requirement to coordinate with District Maintenance department for any VFS proposed behind guard rail and to ensure mower access to any VFS. **Clarified** that topsoil and slope erosion control are only required for disturbed portions of a VFS
- **1113.2.2/C1113.2.2 – Added** guidance and commentary for the requirement to coordinate with District Maintenance department for any VBF proposed behind guard rail and to ensure mower access to any VBF
- **Appendix A – Figure 1105-2: Converted** pipe diameter from foot to inch. **Added** Manning's n value for field paved pipe with 1" corrugations
- **Appendix A – Figure 1113-2: Updated** figure in its entirety

https://www.transportation.ohio.gov/working/engineering/hydraulic

Technical questions or recommended changes should be directed to Jeff Syar (614) 275-1373 or Kyle Brandon (614) 466-5199.

Respectfully,

Jeff Syar, P.E.
Office Administrator, Office of Hydraulic Engineering

OHIO DEPARTMENT OF TRANSPORTATION




LOCATION & DESIGN MANUAL

VOLUME 2
DRAINAGE DESIGN

JULY 2025

Table of Contents

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General Information

General Information - Table of Contents

Purpose

This Drainage Design Manual has been prepared as a guide for the hydraulic design of highway drainage facilities.

Drainage criteria and design outlined in this manual reflect the maximum standard achievable that is based on new project development for traditional design, bid, and build projects. Existing conditions represent the minimum standard, which should always be evaluated against the cost of achieving the maximum standard and the purpose and need of the project. The goal is to make improvements proportionate with the purpose and need of the project at minimized project costs without negative impacts to safety. Coordinate any proposed deviations from the maximum standard with the Department prior to incorporation into the design.

Drainage facilities account for approximately one quarter of the total construction cost for most roadway projects. This cost justifies a careful and scientific hydraulic analysis.

Application

Design drainage facilities following the recommended design procedures noted in this manual to minimize the following:

- Damage of private property due to flooding
- Inconvenience to the motorist during moderate to heavy rainfall
- Disturbance to the environment

Drainage Design Aid Charts have been assembled to assist the Drainage Design Engineer with the hydraulic analysis. Other design charts are available in Hydraulic Engineering Circulars and Hydraulic Design Series prepared by the Federal Highway Administration. Reference is made to those charts as required.

This manual is not a substitute for engineering knowledge, experience, or judgment. Its purpose is to provide uniform procedures for implementing drainage design decisions and assure quality and continuity in drainage of highways in Ohio. Although the manual is considered the primary source of reference for drainage design in Ohio, some of the suggested practices may be inappropriate for projects because of fiscal limitations or other justifiable reasons.

Consideration must also be given to reasonable hydraulic design standards adopted by city, county, or other local governments when designing facilities under their jurisdiction.

Format

Sections 1000 and 1100 of the LD2 are written in a two-column format. The left column represents ODOT drainage design specifications, and the right column represents commentary. The commentary may include background information, design guidance or other supplemental information related to a corresponding specification.

Preparation

The Drainage Design Manual has been developed by the Office of Hydraulic Engineering. Errors or omissions should be reported to the Administrator, Office of Hydraulic Engineering. A list of contacts can be found on the OHE website.

Revisions

Updating the manual is intended to be a continuous process. Revisions are issued periodically by OHE and will be available at the ODOT Publications Webpage.

All revisions are shown in highlighted text.

The date of the revision is shown in the document header.

Map of Districts

District 1
1885 N. McCullough St.
Lima, OH 45801-0040
419-222-9055
fax: 419-222-0438

District 2
317 East Poe Rd.
Bowling Green, OH 43402-1330
419-353-8131
fax: 419-353-1468

District 3
906 Clark Ave.
Ashland, OH 44805-1989
800-276-4188 or 419-281-0513
fax: 419-281-0874

District 4
2088 S. Arlington Rd.
Akron, OH 44306
330-786-3100
fax: 330-786-2232

District 5
9600 Jacksontown Rd.
Jacksontown, OH 43030
740-323-4400
fax: 740-323-3715

District 6
400 East William St.
Delaware, OH 43015
740-833-8000
fax: 740-833-8100

District 7
1001 St. Marys Ave.
Sidney, OH 45365-0969
888-200-9919 or 937-492-1141
fax: 937-497-9734

District 8
505 S. State Route 741
Lebanon, OH 45036-9518
800-831-2142 or 513-932-3030
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1980 W. Broad Street
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District 9
650 Eastern Ave. PO Box 467
Chillicothe, OH 45601
888-819-8501 or 740-773-2691
fax: 740-775-4889

District 10
338 Muskingum Dr. PO Box 658
Marietta, OH 45750
800-845-0226 or 740-568-3900
fax: 740-373-7317

District 11
2201 Reiser Ave.
New Philadelphia, OH 44663
330-339-6633
fax: 330-308-3942

District 12
5500 Transportation Blvd.
Garfield Heights, OH 44125-5396
800-732-4896 or 216-581-2100
fax: 216-584-2274

OHIO Counties

County	Code	District	County	Code	District
Adams	ADA	9	Licking	LIC	5
Allen	ALL	1	Logan	LOG	7
Ashland	ASD	3	Lorain	LOR	3
Ashtabula	ATB	4	Lucas	LUC	2
Athens	ATH	10	Madison	MAD	6
Auglaize	AUG	7	Mahoning	MAH	4
Belmont	BEL	11	Marion	MAR	6
Brown	BRO	9	Medina	MED	3
Butler	BUT	8	Meigs	MEG	10
Carroll	CAR	11	Mercer	MER	7
Champaign	CHP	7	Miami	MIA	7
Clark	CLA	7	Monroe	MOE	10
Clermont	CLE	8	Montgomery	MOT	7
Clinton	CLI	8	Morgan	MRG	10
Columbiana	COL	11	Morrow	MRW	6
Coshocton	COS	5	Muskingum	MUS	5
Crawford	CRA	3	Noble	NOB	10
Cuyahoga	CUY	12	Ottawa	OTT	2
Darke	DAR	7	Paulding	PAU	1
Defiance	DEF	1	Perry	PER	5
Delaware	DEL	6	Pickaway	PIC	6
Erie	ERI	3	Pike	PIK	9
Fairfield	FAI	5	Portage	POR	4
Fayette	FAY	6	Preble	PRE	8
Franklin	FRA	6	Putnam	PUT	1
Fulton	FUL	2	Richland	RIC	3
Gallia	GAL	10	Ross	ROS	9
Geauga	GEA	12	Sandusky	SAN	2
Greene	GRE	8	Scioto	SCI	9
Guernsey	GUE	5	Seneca	SEN	2
Hamilton	HAM	8	Shelby	SHE	7
Hancock	HAN	1	Stark	STA	4
Hardin	HAR	1	Summit	SUM	4
Harrison	HAS	11	Trumbull	TRU	4
Henry	HEN	2	Tuscarawas	TUS	11
Highland	HIG	9	Union	UNI	6
Hocking	HOC	10	Van Wert	VAN	1
Holmes	HOL	11	Vinton	VIN	10
Huron	HUR	3	Warren	WAR	8
Jackson	JAC	9	Washington	WAS	10
Jefferson	JEF	11	Wayne	WAY	3
Knox	KNO	5	Williams	WIL	2
Lake	LAK	12	Wood	WOO	2
Lawrence	LAW	9	Wyandot	WYA	1

Glossary of Terms

Aggregate Drain – A trench filled with granular material extending laterally from the pavement base or subbase layer to an outlet on the roadway foreslope with the intent of draining surface and/or ground water away from the pavement base and/or subbase.

Annual Exceedance Probability (AEP) – The probability that an event will occur, or be exceeded, in any given year, normally given in percentage.

Anti-seep Collar – Device that prevents the flow of water through the surrounding soil around a conduit that is used as an outlet for an infiltration, retention, or detention basin.

Apron – Paving at a pipe inlet or outlet, or upstream of a catch basin, constructed along the channel bottom to prevent scour.

Backwater Analysis – The determination of water surface profiles measured at specific locations upstream from a constriction causing an increased flow depth upstream.

Bankfull Discharge – The flow or stage of a stream corresponding to the highest level of active deposition. It is the discharge that, on average, fills a main channel to the point of overflowing. For simplicity, it is generally considered to be approximately the 50% AEP discharge.

Bankfull Width – The width of a stream or river channel at the elevation where it typically overflows into the floodplain, also known as the channel-forming flow

Base Flood – (FEMA) The flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood" or the “1% AEP flood.” The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all Federal agencies for the purposes of requiring the purchase of flood insurance and regulating new development. Base Flood Elevations (BFEs) are typically shown on Flood Insurance Rate Maps (FIRMs)

Base Flood Elevation – (FEMA) The computed elevation to which floodwater is anticipated to rise during the base flood. Base Flood Elevations (BFEs) are shown on Flood Insurance Rate Maps (FIRMs) and on the flood profiles.

Body of Water – A body of water is any significant accumulation of water, generally on a planet's surface. The term most often refers to large rivers, and lakes, but it includes smaller pools of water such as ponds, or wetlands.

Bridge – Structure that has a span greater than or equal to 10 feet as measured in a parallel direction to the roadway centerline.

Camber – A slight convex curve constructed into the bottom of a pipe to overcome anticipated settlement problems.

Cast-in-place Structure – A concrete drainage structure which is placed in forms and cured at its final location. Precast beams on cast-in-place foundations are considered cast-in-place structures.

Catch Basin – A structure for intercepting flow from a gutter or ditch and discharging the water through a conduit.

Channel – The bed and banks that confine the surface flow of a waterway under normal flow conditions.

Coefficient of Runoff (C) – A value, varying with the ground and ground cover, which is used in the Rational formula to determine the amount of a rainfall which is directed to streams and not absorbed into the ground.

Conduit – A closed structure such as a pipe that has a span less than 10 feet as measured in a parallel direction to the roadway centerline.

Corner Bearing Pressure – The pressure generated at the corners of pipe arch structures.

Cover – Distance measured from the top of the conduit vertically upward.

Culvert – A structure used to convey surface runoff through embankments, typically designed hydraulically to take advantage of submergence at the inlet to increase hydraulic capacity. A structure, as distinguished from a bridge, which is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on footings with the stream bed serving as the bottom.

Cutoff Wall – A wall that extends downward from the end of a structure to below the expected scour depth, or to a scour-resistant material.

Design Discharge (Q) – The peak rate of flow for which a drainage facility is designed. Usually given in cubic feet per second (cfs).

Design Service Life – The average usable life of a pipe or structure. A conduit is conserved to have reached the end of its service life when the General Appraisal rating is equal to 4.

Design Storm – A given rainfall amount, areal distribution, and a time distribution, used to estimate runoff. The rainfall amount is either a given storm (10% AEP, 4% AEP, 2% AEP, etc.) or a specific large value.

Detention Basin – A structure that holds water for a short period of time before releasing it to the natural water course.

Discharge – The volume of water that passes through a given cross-section per unit time; commonly measured in cubic feet per second (cfs).

Diversion Dike – An embankment to control or to deflect water away from a soil bank.

Drainage Area – The total surface area contributing discharge to a channel or catchment at a given point.

Drainage Basin – See Watershed.

Drop-down Entrance (Drop inlet) – A type of inlet which conveys the water from a higher elevation to a lower elevation smoothly without a free fall at the inlet.

Elliptical Pipe – Pipe which is manufactured with a span greater than rise to be utilized in shallow cover situations.

Ephemeral Stream – A stream or reach of stream that does not flow for parts of the year. As used here, the term includes intermittent streams with flow less than perennial. It is located above the water table year-round. Ground water is not a source of water supply.

Feasible – Term used to define BMP practicability. A BMP must be: technically feasible, implemented within the procured highway right-of-way, safe for the traveling public and ODOT maintenance personnel, cost effective as compared to the benefit, and will be legal at the State, Federal, and Local levels.

Flood Fringe or Floodway Fringe – The portion of the floodplain outside of the floodway.

Flood Hazard Evaluation – The act of determining if flood levels within a watercourse for a 100-year flood, or other recurrence interval floods have a significantly increased detrimental impact on upstream property.

Flood Insurance Rate Map (FIRM) – The official map of a community on which FEMA has delineated both the special hazard areas and the risk premium zones applicable to the community.

Flood Insurance Study (FIS) – A book with information regarding flooding in a community that is developed in conjunction with the FIRM. It discusses the engineering methods used to develop the FIRMs.

Floodplain – An area of land adjacent to a watercourse which experiences flooding during periods of high discharge.

Floodplain Culverts – Relief culverts that are placed in addition to a bankfull culvert at a higher elevation across the floodplain to allow multiple outlets for floodwaters.

Floodplain Study – A more extensive analysis of the effects of flood levels on upstream property than the Flood Hazard Evaluation. This analysis is to be used when upstream properties appear to have been subjected to a significantly increased detrimental effect from the flood flows.

Floodway – The channel and portion of the floodplain, which is effective in carrying flow, within which this carrying capacity must be preserved and where the flood hazard is generally highest.

Flowline – see Thalweg

Forebay – Depressed area that offers pretreatment of sediment laden storm water prior to a retention, detention, or infiltration basin.

Freeboard – the vertical clearance of the lowest structural member of a bridge superstructure above the water surface elevation.

Friction Slope – The slope of the energy grade line.

Granular Material – A term relating to the uniform size of grains or crystals in rock, larger than sand or pea gravel.

Grate – A type of screen made from sets of bars used to allow the interception of flow and to cover an area for pedestrian or vehicular traffic.

Headwall – The structural appurtenance placed at the open end of a pipe to control an adjacent highway embankment and protect the pipe end from undercutting.

Headwater – That depth of water impounded upstream of a culvert due to the influence of the culvert constriction, friction, and configuration.

Height of Cover – Distance measured from the top of the conduit vertically upward to the pavement surface or finished grade for conduits not under pavement.

Highest Known Water Elevation – The highest known flood water in record.

Hydraulic Grade Line – A line coinciding with the level of flowing water in an open channel. In a closed conduit operating under pressure, a line representing the distance water would rise in a pitot tube at any point along a pipe. The hydraulic grade line is equal to the pressure head (P/γ) along the pipe.

Hydraulic Gradient – The slope of the hydraulic grade line for a storm sewer or culvert.

Hydraulics – The science concerned with the behavior and flow of liquids, especially in conduits and open channels.

Hydrology – The science concerned with the occurrence, distribution and circulation of water on the earth, including precipitation, runoff and groundwater.

Idealized Channel Geometry – Physical, geometric, and hydraulic characteristics of a channel determined from empirical relationships.

Impervious Surface – Hardened pavement surface.

Infiltration Rate – The rate at which water penetrates the surface of the soil at any given instant. The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied.

Inlet – A structure for capturing concentrated surface flow. May be located along the roadway, in a gutter, in the highway median, or in the field.

Inlet Control – The situation where the culvert hydraulic performance is controlled by the entrance geometry only.

Intermittent Stream – A stream that is dry for part of the year, ordinarily more than 3 months.

Manhole – A structure by which one may access a closed drainage system.

Micropool –Depressed area providing a settling pool located at the water quality outlet structure of a detention basin.

MS4 Phase II Regulated Area – Area that has been designated by the Ohio EPA that requires a storm water management plan to discharge storm water.

Multiple Cell Culvert – A culvert with more than one barrel.

New Development Project – Projects that change the land use of a site from undeveloped to developed characteristics.

Ordinary High Water Mark – The line on the shore established by the fluctuation of water and indicated by physical characteristics such as: a clear natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, or other appropriate means that consider the characteristics of the surrounding areas. This elevation is lower than the highest known water.

Outlet Control – The situation where the culvert hydraulic performance is determined by the controlling water surface elevation at the outlet, the slope, length and roughness of the culvert barrel, as well as the entrance geometry.

Overland Flow – Water which travels over a surface and reaches a stream.

Perennial Stream – A stream that flows continuously for all or most of the year. The water table is located above the stream bed for most of the year.

Permeability – The quality of the soil that enables water to move downward through the soil profile. It is measured in units of inches per hour.

pH – The reciprocal of the negative logarithm of the Hydrogen ion concentration. Neutral water has a pH value of 7. A measure of the acidity of a substance, if less than 7; alkalinity if greater than 7.

Pipe Arch – Pipe which is manufactured with a span greater than rise (semicircular crown, small-radius corners, and large radius invert) to be utilized in shallow cover situations.

Pipe Underdrain – A longitudinal subsurface drainage system composed of a perforated pipe at the bottom of a narrow trench filled with permeable material and lined with a geotextile in erodible soils, with the intent of draining surface and/or ground waters away from the pavement base and/or subbase.

Porosity – The volume of voids divided by the total volume and multiplied by 100.

Prefabricated Edge Drain – A longitudinal underdrain system utilizing a narrow trench and a vertically elongated, perforated water carrier with the intent of draining surface and/or ground water away from the pavement base and/or subbase.

Prefabricated Structure – Any drainage structure which is manufactured off site and transported to the location of intended use. It may be of various materials, including concrete, clay, metal, thermoplastics, etc. It may be of various shapes including circular, elliptical, rectangular, arched, etc.

Premium Joints – Watertight joints.

Pretreatment – Preliminary filtering of sediment laden storm water prior to secondary treatment through a structural best management practice.

Rainfall Intensity (i) – The amount of rainfall occurring in a unit of time, normally given in inches per hour.

Reference Reach – A length of channel with stable geometric, physical, and hydraulic characteristics. A representation of the desired outcome of a restored channel.

Regulatory Floodway – (FEMA) The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Retention Basin – A structure that holds water on a permanent basis.

Roughness Coefficient (n) – The measure of texture on the surface of channels and conduits. Usually represented by the n-value coefficient used in Manning's open channel flow equation.

Runoff – That part of the precipitation which runs off the surface of a drainage area after all abstractions are accounted for.

Sanitary Sewer – A conduit or pipe system which carries household and/or industrial wastes. Sanitary sewers do not convey storm water.

Scupper – A device used to drain water through a bridge deck, parapet or barrier.

Sediment Basin – A basin or tank in which stormwater containing settleable solids is retained, to remove by gravity or filtration a part of the suspended matter.

Sediment Dam – A dam that is designed to allow suspended sediment to settle out of flowing water in a controlled area.

Short-circuiting – The act of storm water bypassing the intended route.

Soil Bioengineering – The use of live and dead plant materials, in combination with natural and synthetic support materials, for slope stabilization, erosion reduction, and vegetative establishment.

Spring Line – The locus of the horizontal extremities of a transverse section of a conduit.

Standard Temporary Discharge (STD) – The flow corresponding to twice the maximum mean monthly flow. The rate of flow for which a TAF facility is designed. Usually given in cubic feet per second (cfs).

Step Backwater or Standard Step Method – An iterative use of the energy equation for determining the water surface profile of an open channel.

Storm Sewer – A conduit or pipe drainage system that conveys storm water, subsurface water, condensate, or similar discharge, but not household or industrial wastes.

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.

Tailwater – The depth of flow in the stream directly downstream of a drainage facility, measured from the invert at the culvert outlet. Often calculated for the discharge flowing in the natural stream without the highway constriction. Term is usually used in culvert design and is the depth measured from the downstream flow line of the culvert to the water surface.

Temporary Access Fill (TAF) –A structure or earth fill that allows a contractor access to work on roads or bridges located within or over bodies of water.

Time of Concentration (t_c) – Time required for water to flow from the most distant point on a drainage area to the measurement or collection point.

TMDL (Total Maximum Daily Load) Regulated Stream – An Impaired water body as defined by the Ohio EPA that can still meet water quality standards if the daily maximum pollutant load is regulated.

Two Stage Channel – A channel that contains a cross sectional area for low and high discharges.

Water of The United States – Water bodies subject to Army Corps of Engineers jurisdiction through Section 404 of the Clean Water Act. They include all interstate waters such as lakes, rivers, streams (including intermittent streams) and wetlands. Ephemeral streams are included if they have a clearly defined channel.

Watershed – An area confined by drainage divides, and often having only one outlet for discharge.

Waterway – Any stream, river, pond, or lake. (See Channel)

Waterway Opening – Area of a bridge or drainage structure opening measured normal to the principal flow direction.

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
AEP	Annual Exceedance Probability
AOP	Aquatic Organism Passage
ASTM	American Society for Testing and Materials
AVFS	Amended Vegetated Filter Strip
AWWA	American Water Works Association
BDM	Bridge Design Manual (ODOT)
BFE	Base Flood Elevation
BMP	Best Management Practice
C&MS	Construction and Material Specifications (ODOT)

CB	Catch Basin
CDSS	Drainage Design Software for Culverts Ditches and Storm Sewers (ODOT)
CIPP	Cured-In-Place Pipe
CFN	Culvert File Number (ODOT)
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second (ft^3/s)
CLOMR	Conditional Letter Of Map Revision
CMM	Conduit Management Manual (ODOT)
CMP	Corrugated Metal Pipe
DEC	District Environmental Coordinator (ODOT)
EBW	Enhanced Bankfull Width
EDA	Earth Disturbing Activity
ED_v	Extended Detention Volume
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration, Department of Transportation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMP	Floodplain Management Program
fps	Feet per Second
GIS	Geographic Information Systems
GDM	Geotechnical Design Manual
HDPE	High Density Polyethylene
HDS	Hydraulic Design Series
HEC	Hydraulic Engineering Circular
HEC-RAS	Hydrologic Engineering Center-River Analysis System
H&H	Hydrology and Hydraulic (Report)(ODOT)
HSG	Hydrologic Soil Group
HSR	Hard Shoulder Running (lanes)
HUC	Hydraulic Unit Code
HW	Headwater or Headwall
HWI	Headwater Inlet Control
HWO	Headwater Outlet Control
LD1	Location & Design Manual, Volume 1 – Roadway Design (ODOT)
LD2	Location & Design Manual, Volume 2 – Drainage Design (ODOT)
LD3	Location & Design Manual, Volume 3 – Highway Plans (ODOT)
LD4	Location & Design Manual, Volume 4 – Survey, Mapping & Subsurface Utility Location Services Specifications (ODOT)
LFE	Limiting Flow Elevation

LOMR	Letter Of Map Revision
LPA	Local Public Agency
LRFD	Load and Resistance Factor Design
LRW	Limited Resource Waters
MH	Manhole
MOT	Maintenance Of Traffic
MS4	Municipal Separate Storm Sewer System Program
MSE	Mechanically Stabilized Earth (Retaining Wall)
NFIP	National Flood Insurance Program
NOI	Notice Of Intent
NPDES	National Pollutant Discharge Elimination System
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OES	Office of Environmental Services (ODOT)
OGE	Office of Geotechnical Engineering (ODOT)
OHE	Office of Hydraulic Engineering (ODOT)
OHWM	Ordinary High Water Mark
OMM	Office of Material Management (ODOT)
ORC	Ohio Revised Code
OSE	Office of Structural Engineering (ODOT)
OSIP	Ohio Statewide Imagery Program
PBPD	Performance Based Practical Design
PDP	Project Development Process
PE	Polyethylene
PDR	Permit Determination Request
RCP	Rock Channel Protection
R/W	Right-of-Way
SAPL	Spray Applied Pipe Liner
SCD	Standard Construction Drawing (ODOT)
SFE	Structure Foundation Exploration (Report)(ODOT)
SFHA	Special Flood Hazard Area
SFN	Structure File Number
SGE	Specifications for Geotechnical Exploration (ODOT)
SIR	Scientific Investigations Report (USGS Report)
STD	Standard Temporary Discharge
STS	Structure Type Study
SWPPP	Storm Water Pollution Prevention Plan
SS###	Supplemental Specification

TAF	Temporary Access Fill
TMDL	Total Maximum Daily Load
TIMS	Transportation Information Mapping System
TRB	Transportation Research Board
TSEC	Temporary Sediment and Erosion Control
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USGS	United States Geological Survey
VBF	Vegetated Bio Filter
VFS	Vegetated Filter Strip
WRI	Water Resources Investigation (USGS Report)
WQ_F	Water Quality Flow
WQ_V	Water Quality Volume
WSE	Water Surface Elevation

References

Code of Federal Regulations

23 CFR 650A - Location and Hydraulic Design of Encroachments on Flood Plains. Code of Federal Regulations: Title 23 - Highways; Chapter I - Federal Highway Administration, Department of Transportation; Subchapter G - Engineering and Traffic Operations; Part 650 - Bridges, Structures, and Hydraulics; Subpart A - Location and Hydraulic Design of Encroachments on Flood Plains.

40 CFR 122.26(b)(15)(i) - Storm water discharges (applicable to State NPDES programs, see § 123.25). Code of Federal Regulations: Title 40 - Protection of Environment; Chapter I - Environmental protection Agency (continued); Subchapter D - Water Programs; Part 122 - EPA Administered Permit Programs: The National Pollutant Discharge Elimination System; Subpart B - Permit Application and Special NPDES Program Requirements; Section 122.26 - Storm water discharges (applicable to State NPDES programs, see § 123.25); (b) Definitions; (15)(i)

Publications

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Manuals, Standards & Specifications

ODOT Bridge Maintenance Manual

ODOT Conduit Management Manual

ODOT Construction and Material Specifications

ODOT Geotechnical Design Manual

ODOT Location & Design Manual Volume 1

ODOT Location & Design Manual Volume 3

ODOT Location & Design Manual Volume 4

ODOT Ordinary High Water Mark Identification Manual

ODOT Standard Construction Drawings

Websites

FHWA Ultra Urban BMP webpage

USEPA National Pollutant Discharge webpage

Ohio EPA

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1000 Drainage Design Criteria

1000 Drainage Design Criteria – Table of Contents

1001 Hydraulic Design Criteria

1001.1 Responsibilities

The Office of Hydraulic Engineering is responsible for the hydraulic design standards for all surface drainage systems and bridge structures owned and maintained by the Department.

Additional responsibilities include conduit durability, culvert inspection and inventory, post construction storm water Best Management Practices, and the Department's Municipal Separate Storm Sewer System program (MS4).

1001.2 Floodplain Encroachments

Encroachments on floodplains for transportation projects are controlled in part by the Code of Federal Regulations 23 CFR 650A.

C1001.2

See section 1005.1 for guidance on floodplain encroachments.

1001.3 Highway Use Permits Design Considerations

The owner or developer of land adjacent to ODOT R/W proposing to route site drainage into the highway drainage system is responsible for:

1. No diversion of flow to the highway R/W.
2. Maintaining peak flows from areas contributing to the highway drainage system at pre-development levels. Provide onsite detention when required to meet this condition.
3. Prior to the start of construction, submit drainage plans and calculations for review to the Department.

Use facility design storms described in this Manual when determining flow peaks and impacts on the highway drainage system.

Private drainage structures, excluding conduits under driveways, are not permitted within ODOT R/W. Submit exception requests to OHE for approval.

Common methods for determining flow generated from developed land other than those shown herein are permitted.

C1001.3

Contact the local District Permit Office for further information on the permit process.

This criteria is intended for structures such as headwalls at the outlet of systems not owned or maintained by the Department. Perpetuate drainage patterns with a ditch from the system outlet to the roadside ditch or a conduit connection to the ODOT storm sewer. The placement of private drainage structures within ODOT R/W requires approval from OHE for all facility types.

1002 Pipe Criteria

1002.1 Introduction

The Department's pipe criteria is used to determine the type of pipe specified or permitted for the various items of highway drainage financed totally or in part with state or federal funds.

Include alternative pipe materials in plans for Type A conduits. Deviations specifying only one type of pipe material, where special conditions prevail, must include sound engineering judgment. Acceptable special conditions include:

- Where excessive cover requires a special design for rigid pipe verses a flexible alternate.
- Where minimum cover requirements inhibit the use of a flexible pipe.
- Where a metal pipe arch would be required as an alternate to a round rigid pipe.
- The outfall velocity would require an energy dissipater.
- Site conditions prevented the existing conduit material from meeting design service life.
- If a structure type study is performed and the cost analysis indicates a lower cost.

The use of a single material type is subject to the approval of OHE.

C1002.1

The Department's pipe criteria promotes open competition during the bidding process across various pipe materials that meet the hydraulic, structural and service life, requirements for the site.

While the contractor and pipe manufacturer are responsible for the final material selected from the pipe alternatives and the subsequent structural design, the designer needs to verify appropriate alternatives are listed which are not precluded due to excessive cover, minimum cover, or other special conditions.

1002.1.1 Deviation by ODOT Districts

Provide a written request for deviation from these criteria. Include documentation that justifies the request along with the completed Ohio Drainage Design Criteria Form, Appendix B – Reproducible Forms. Submit the documentation to the Administrator of OHE.

C1002.1.1

Written requests may be in the form of an email or a mailed document.

1002.1.2 Deviation by Local

Proposed deviations from these criteria and/or construction specifications by local political subdivisions or agencies will be considered for all portions of the project that are maintained by the political subdivision or agency.

ODOT Districts may permit a deviation from these criteria provided the local political subdivision or agency agrees to fund any additional costs incurred due to the conduit material selection or local construction requirement. The deviation requires alternate bid items, per Section 1307.2.7 of LD3, to determine the additional costs. The alternatives include the Department's pipe criteria/construction methods and the local's material selection/construction methods. Add additional notes or details as required by the local.

1002.2 General Requirements

1002.2.1 Pipe Materials

The pipe materials listed under the various conduit types in Section 611.02 of the C&MS are considered acceptable within their size, structural limitations and material durability limitations.

C1002.2.1

Refer to the CMM for pictures of the various pipe materials.

1002.2.2 Conduit Durability and Service Life

Perform conduit durability design for Type A, B, C, and D conduits when required per 1002.3. The required minimum service life for conduit material is 75 years.

Measure the pH of the normal stream flow in the field using a calibrated pH meter capable of measuring to a tenth. Field measurement of pH is required.

Use Figures 1002-2 and 1002-3 if flow is not present during the site visit.

Determine if the streambed material is abrasive by observation of the presence of material in the conduit, upstream of the conduit, and downstream of the conduit. An abrasive condition is defined as the presence of granular material with a stream gradient or flow sufficient to cause movement of the material. Granular material is defined as material the size of pea gravel or larger. Assign an abrasion level to the stream on a scale of 1-6 according to the descriptions below. Use Level 1 if non-abrasive.

Level 1: Bed loads of silts and clays or clean water with virtually no abrasive bed load. Non-Abrasive Material.

Level 2: Moderate bed loads of sand or gravel.

Level 3: Moderate bed load volumes of sand, gravels, and small cobbles.

Level 4: Moderate bed load volumes of angular sands, gravels, and cobbles/rocks.

C1002.2.2

The pH of the normal stream flow and the presence of abrasive flow conditions are the factors that influence the conduit material durability.

Field visits are required to determine the water pH and abrasiveness of the site.

The tabulations in the Durability Design spreadsheet are based on research report FHWA/OH-2016/16 [Sargand, 2016].

A conduit is considered to have reached the end of its service life when the General Appraisal rating is equal to 4. When this occurs, begin planning for rehabilitation or replacement.

Level 5: Moderate bed load volumes of angular sands and gravel or rock.

Level 6: Moderate bed load volumes of angular sands and gravel or rock OR Heavy bed load volumes of angular sands and gravel or rock.

Perform durability design using the OHE Durability Design spreadsheet. Obtain the spreadsheet from the OHE Design Resources web page.

Include the pH and abrasiveness level in the plans.

Additional abrasion level information and abrasion level site photos are available in the reference data tab of the Durability Design spreadsheet.

1002.2.3 Energy Control Structures

Provide Energy Control Structures for velocity control at culvert and storm sewer outlets and for storm sewers with steep slopes or high velocities.

Use the following options for energy control structures:

- Rock Channel Protection
- Broken-Back Pipe
- Riprap Basin
- Drop Structure
- Ring Chambers

When permissible pipe alternates have different velocity characteristics, the design specified for erosion control must satisfy the most severe velocity condition of the permissible alternates. Use Figure 1002-4 to determine the length, width and RCP type required.

C1002.2.3

Erosion control refers to controls placed in the stream channel at the outlet end of the pipe, such as rock channel protection, and does not refer to energy dissipaters. Energy dissipators include broken-back pipes, riprap basins, drop structures and ring chambers.

In general, the smooth pipe alternate will have the larger velocity as compared to the corrugated pipe alternate.

RCP is used to control erosion and as a scour countermeasure. It is placed at the outlet of culverts and storm sewers, or for lining ditches on steep grades. It is used as a scour countermeasure at wingwalls of full-height headwalls, along footings of 3-sided structures, corner cones, and under bridges. Avoid placing RCP where bedrock is present, other erosion control measures should be investigated.

Energy dissipaters create a forced hydraulic jump within the structure or immediately downstream of the structure, thus reducing the flow velocity. FHWA Hydraulic Engineering Circular No. 14 provides design guidance and procedures for various energy dissipators.

The design of internal energy dissipator ring chambers is provided in report FHWA/OH-84/007 [Simon, 1984]. This report and Ring Chamber Plan Insert Sheets are available on the OHE website.

1002.2.4 Special Shapes

Special shaped conduits are generally limited for use under shallow cover installations or extremely low or restrictive headwater control otherwise requiring multiple circular conduits to satisfy

C1002.2.4

Special shapes include: elliptical concrete, corrugated metal arch or pipe arch, prefabricated box or three-sided structures.

allowable headwater conditions.

Special shaped conduits may be provided to conform to the cross-sectional geometry of sensitive streams identified in the environmental documentation.

Where corrugated metal and structural plate pipe arches are specified or permitted, submit a foundation investigation as required by Section 1008.1.5.

1002.2.5 Structure File Number / Culvert File Number

Structures having an opening measured along the centerline of roadways of 10’ or greater require a Structure File Number. Multiple openings where the extreme ends of the openings are 10’ or greater also require an SFN when the clear distance between openings is less than half of the smaller contiguous opening.

Culverts (Type A) and Storm Sewers (Type B) having an opening measured along the centerline of roadway 12 inches or greater, but less than 120 inches require a Culvert File Number.

Include the CFN in the plans in accordance with LD3.

C1002.2.5

A new SFN is generated by the OSE Bridge Management Section.

Reference the CMM for additional guidance on determination of multi-cell culverts designation as a single unit or multiple structures.

A new CFN is generated by the Culvert Collector application or the Culvert Web application by the District.

Reference the CMM for instructions on obtaining a CFN.

1002.3 Conduit Types

1002.3.1 Type A Conduits

Specify Type A conduits for soil-tight, sealed-joint, open-ended cross drains under pavements and paved shoulders. Base the minimum size culvert to be specified on the roadway type and depth of fill from the flowline to roadway surface.

The minimum required round, or equivalent deformed pipe sizes are listed in Figure 1002-1.

For culverts under Interstates, Freeways & Expressways, or fills 16 feet or greater, increase the size by one pipe size over that required. In the plans, list the headwater and velocity for the culvert size that meets the design criteria and note that the culvert size shown has been increased for future rehabilitation.

The design service life for all Type A conduits is 75 years. Perform durability design using the OHE Durability Design Spreadsheet on all Type A

C1002.3.1

Conduits under Interstates, Freeways & Expressways, and fill of 16 feet or more are increased in size to allow for future relining without a reduction in design hydraulic capacity. Conduits under ramps do not require upsizing unless located under major interchanges such as system interchange ramps connecting two or more freeways. Conduits already upsized to meet minimum pipe sizes or Aquatic Organism Passage requirements do not require additional upsizing. Using trenchless rehabilitation techniques reduces impacts on high traffic facilities and eliminates the need to open cut. See section 1002.3.7 for culvert rehabilitation methods approved for use by the Department.

Once the minimum thickness and/or level of protection required to meet the design service life is determined for each material category of pipe alternates, it is not necessary to list additional options. If all options are eliminated from a conduits in accordance with 1002.2.2.

Show hydraulically adequate pipe alternates which provide the required service life on the plans and listed in the pertinent pay item. Include a minimum of one alternate from each of the following categories: concrete, plastic, and corrugated steel/aluminum. List the corrugation profile which requires the thinnest metal for corrugated metal pipe.

If the alternates listed in the plan are different sizes, show the pipe length associated with the smallest pipe size. Show the hydraulic design data associated with this conduit in the plans.

Provide concrete field paving on corrugated metal conduits 54 inch or larger where the invert is always submerged due to tailwater conditions from a body of water and where depressed or buried inverts are used to provide a natural stream bottom.

When extending existing Type A conduits, match the existing material in kind.

material category, inclusion in the alternates is not expected. Special conditions per 1002.1 may also eliminate all options from a material category.

The smallest pipe size will normally have the longest length. The designer needs to verify that the headwaters for all the pipe alternates meet the headwater controls.

1002.3.2 Type B and C Conduits

Specify Type B conduits for soil-tight, sealed joint storm sewers under pavements, paved shoulders, and commercial or industrial drives.

Specify Type C conduits for soil-tight, sealed joint storm sewers not under pavements, paved shoulders, and commercial or industrial drives.

Specify Type C conduits for soil-tight, sealed joint storm sewers under driveways and bikeways.

Provide premium joints in areas where the 10-foot separation required by the Great Lakes - Upper Mississippi River Board [GLUMRB) 10 State Standards cannot be achieved and in areas where tufa precipitate is present as identified by the Department.

For conduit placed through MSE walls or in the fill of MSE walls refer to the BDM Section 310.4.

The design service life for all Type B and C conduit is 75 years. The assumed flow conditions for new storm sewer are abrasion level equal to 1 and pH equal to 7 unless site conditions indicate otherwise. It is not required to perform durability design under the assumed flow conditions. When replacing Type B and C conduits, verify that the

C1002.3.2

Premium joints are watertight. The pressure testing of the joints is not necessary for storm sewer applications in most cases.

Pipe alternates are not normally specified for Type B and C conduits. If durability design is performed and the results require specifying alternates meeting the required design service life or due to special conditions listed in 1002.1, specify as Type B or C, As Per Plan, to list alternates. Reference 1002.3.1 for additional information on specifying alternates.

Providing one spreadsheet for each storm sewer system is sufficient.

It is encouraged to perform a site review during design for all new Type B and C conduits and for any existing conduit that has experienced premature wear.

existing conduit material was performing as intended. If the existing conduit material indicates premature wear, or site conditions vary from the assumed flow conditions, perform durability design using the OHE Durability Design Spreadsheet in accordance with 1002.2.2.

1002.3.3 Type D Conduits

Specify Type D conduits for pipes under driveways and bikeways. The minimum size required is 12 inches. For sizes 24 inches and larger submit calculations with the drainage review plan that specify the pipe sizing required to satisfy the hydraulic controls. The design storm used to analyze the hydraulic performance of the Type D conduit is the same as that used for the flow capacity of the connected ditch or channel. The allowable headwater elevation is 1 foot below the edge of the pavement of the adjacent roadway. If potential exists for the drive pipe headwater to encroach on the adjacent roadway, size the drive pipe utilizing a design storm per 1004.2.

Generally, the pipe alternates listed in 611.02 of the Construction and Material Specifications are applicable, except that equal size corrugated pipe will provide satisfactory alternates for sizes smaller than 24 inches. If the control is critical, a hydraulic analysis will be required to determine the proper size of pipe alternates.

Design drive pipes under commercial or industrial drives for material durability using the OHE Durability Design Spreadsheet per 1002.2.2. Additional protection for residential driveways, field drives, and bikeways may be specified if conditions warrant.

C1002.3.3

For new driveway and bikeway conduits, a calculation will be necessary to determine an initial size. A formal submission of the calculations is only necessary for 24 inch or larger conduits. Existing conduits less than 24 inches are generally replaced with the same size conduit if flooding has not been an issue.

The designer should give durability consideration when these conduits are under high fills or other conditions that make replacement an issue.

1002.3.4 Type E Conduits

Specify Type E conduits for farm drain headers.

C1002.3.4

Headers are ordinarily provided to intercept small, closely spaced lines in a tiled field, preventing the need for numerous field tile outlets through the backslope of the highway ditch.

1002.3.5 Type F Conduits

Specify Type F conduits where a butt joint or a short length jointed pipe would be undesirable as noted below:

A. For the steep portion of a median outlet under an embankment slope 4:1 or steeper, including any necessary pipe bends.

B. For the outlets of underdrains or farm drains through the slope or connecting to a drainage structure. When used for underdrain outlets, specify the following: Item 611, ____" Conduit, Type F for Underdrain Outlets. Provide 10 feet of conduit at each outlet into a drainage structure.

C. For farm drains that outlet through slopes flatter than 4:1, provide 20 feet of conduit.

D. For pipe underdrains that span the trench of a lower conduit, unless the crossing is more than 12 inches above the granular backfill of the lower conduit, provide a minimum length of 10 feet of conduit.

Type F conduits may be used beyond the paved shoulder to eliminate a ditch in front of a yard where such ditch elimination can be justified.

1002.3.6 Subsurface Pavement Drainage

Refer to the Pavement Design Manual, Section 205 Subsurface Pavement Drainage for guidance.

See 1002.3.5 B and D above for underdrain outlet and lower conduit crossing criteria.

1002.3.7 Culvert Rehabilitation

The following specifications or methods are available for culvert rehabilitation:

- C&MS 611.11 – Field Paving of Existing Pipe
- Supplemental Specifications:

  SS833 – Conduit Renewal Using Spray Applied Structural Liner

  SS837 – Liner Pipe

  SS841 – Conduit Renewal Using Spiral Wound Liner

  SS899 – Cured-In-Place Pipe Liner

Evaluate field paving as the first option. Perform a structural analysis of the existing conduit to determine if the addition of rebar to the field paving is necessary. Perform the analysis using the OHE Field Paving of Pipe spreadsheet .

Show all available Liner Pipe materials in SS837 in the plans if they satisfy the hydraulic conditions. Evaluate the hydraulic calculations for the alternative slip-line materials. Submit Liner Pipe projects to OHE for review and approval if one material alternative is specified in the plans. Provide a cost analysis verifying the use of a single

C1002.3.7

A range of material applications and solutions are available for culvert rehabilitation. These solutions are used to extend the service life of existing conduits by adding durability or in some cases structural strength.

Field paving of existing conduits has been used to add durability to conduits for many years. This solution is a cost-effective way to add service life to an existing conduit provided the culvert has a good structural shape and is structurally sound.

The Field Paving of Pipe spreadsheet is based on the research report FHWA/OH-2017/21 [Masada, 2017].

Supplemental Specification 833 – Conduit Renewal Using Spray Applied Structural Liner is a solution that provides structural rehabilitation to existing conduits via a spray application. The interior of the conduit is spray lined with a factory blended cementitious geopolymer or resin-based material.

Supplemental Specification 837- Liner Pipe offers a solution that lines an existing conduit with another conduit. This specification requires the slip-lined conduit to be grouted in-place and in some cases material option. Verify that the material will satisfy a 75 year design service life.

Design the culvert rehabilitation to match existing headwater conditions. If the proposed design does not meet these conditions, contact OHE for approval.

Design appropriate erosion control measures for increased outlet velocities.

Additional information and guidance for culvert rehabilitation can be found on the OHE website.

would be considered a structural solution if the slip-lining material is designed accordingly.

Supplemental Specification 841 – Conduit Renewal Using Spiral Wound Liner is a unique solution that may be used to line various shaped conduits such as: Round, Elliptical, Box, or Pipe Arch. This solution custom manufactures the conduit on site from polyvinyl chloride material with either a special machine or by manual labor. The manufactured conduit is placed into the existing conduit and the void is filled with grout. This solution adds durability to the existing host conduit. Use of this solution requires approval from OHE.

Supplemental Specification 899 – Cured-In-Place Pipe Liner (CIPP) offers a structural rehabilitation solution that lines an existing conduit with a form fitting liner. The resin saturated liner is inserted into the conduit. Once in place the liner is expanded and cured to mold itself to the host conduit. While CIPP can be used for culvert rehabilitation, explore other techniques in this section first. CIPP is best suited for closed systems such as storm sewers.

1003 Hydrology

1003.1 Estimation of Magnitude and Frequency of Floods on Ohio Streams

1003.1.1 General

Use the USGS web-based application StreamStats to determine the design peak discharge for hydraulic structures designated by or for ODOT.

Use USGS WRI Report 93-4080 [Sherwood, 1993] to determine flood volumes and hydrographs for rural areas within the limits prescribed in the report. When applying this technique, consider the tributary with the largest contributing drainage area, not the longest reach.

C1003.1.1

USGS SIR 2006-5312 [Koltun et al., 2006] is a USGS web-based application for estimating stream flow statistics and basin characteristics on unregulated streams. USGS WRI Report 2019-5018 [Koltun, 2019] supersedes USGS SIR 2006-5312.

USGS WRI Report 89-4126 [Koltun & Roberts, 1990] was developed cooperatively by the United States Geological Survey and the State of Ohio. This bulletin is an update of Bulletin 32 (1959), Bulletin 43 (1969), and Bulletin 45 (1977). This report provides the latest hydrologic information for determining the magnitude and frequency of floods for rural streams in Ohio.

The USGS WRI Reports from 1993 and prior are based upon the use of USGS 7.5-minute topographic quadrangle maps to estimate flood-peak discharges. The USGS WRI Report 2003-4164 [Koltun, 2003] has two sets of equations that use GIS data or USGS 7.5-minute topographic quadrangle maps to estimate flood-peak discharges. All subsequent reports are strictly a GIS format which is the basis for the StreamStats web application. StreamStats delineates the drainage basin boundary for a selected site by use of an evenly spaced grid of land-surface elevations, known as a Digital Elevation Model or DEM.

Caution and further investigation is required for determining discharges of regulated streams.

1003.1.2 Alternate Discharge Sources for Bridges

Discharge estimates may be calculated by other methods for comparisons against verified flood elevations and other known river data to ensure that the most realistic discharge for the area is used for the design of the waterway opening. Submit calculations and comparisons to OHE for review.

Flood Insurance Studies; U.S. Corps of Engineer Flood Studies; U.S. Soils Conservation Studies; U.S. Water Resources Data and other reliable sources may be used as reference information in estimating discharges and flood elevations. However, for waterway crossings located in a FIS area, the base discharge $Q_{1\%}$ from the FIS takes precedence over all other calculated discharges.

Where a U.S. Geological Survey estimate conflicts with that of another agency, contact the agency in order to resolve the discrepancy. In general, the U.S. Geological Survey estimate is given preference.

Design proposed structures upstream or downstream from a flood control facility for discharges as supplied by the U.S. Corps of Engineers, Ohio Department of Natural Resources or the agency responsible for the flood control facility.

1003.1.3 Limitations

Specific limitations on the use of the USGS regression equations can be found in each report.

USGS Water-Supply Paper 2432 [Sherwood, 1994] may be used in the design of culverts, detention basins, large storm sewers, and large open channels with urban drainage areas within the limits set in the report.

C1003.1.3

For additional guidance on the proper use of USGS regression equations see TRB Transportation Research Record No. 1319, p.126-130 [Hurd, 1991]

1004 Flood Clearance

1004.1 General

Where a new highway crosses a floodplain, set the highway grade such that the low edge of the traveled way will clear the design water surface profile for existing conditions by 3 feet, and bridges low chord clear the water surface profile of the flood produced by the design AEP storm discharge. These clearances may be reduced where a cost comparison of alternatives shows that a reduction in clearance will result in significant savings. Consider future flood related costs relative to highway operation, maintenance, and repair; highway-aggravated flood damage to other property; and for additional or interrupted highway travel.

Flood clearances may also be reduced to protect important ecological resources as identified in the environmental documentation.

C1004.1

Storm/flood events that were referred to by a yearly Recurrence Interval in the past are now a percentage Annual Exceedance Probability event. Equivalence between the two can be seen below.

AEP	Recurrence Interval
50%	2 year
20%	5 year
10%	10 year
4%	25 year
2%	50 year
1%	100 year
0.2%	500 year

See Glossary of Terms for the definition of AEP.

1004.2 Design AEP Storm

Use the AEP storm for the design as specified below:

- Interstates, Freeways & Expressways...2% AEP
- Other Highways (3000 ADT and over) and Freeway Ramps.......................................4% AEP
- Other Highways (under 3000 ADT)....10% AEP
- *Bicycle Pathway..................................20% AEP

* Unless otherwise approved by OHE.

C1004.2

Code of Federal Regulations 23 CFR 650.115(a)(2) requires interstate highways to be provided with protection from the 2% AEP flood event.

Other roadway design AEP floods are based on the class of highway, or the level of urbanization and development.

1005 Highway Encroachments on Floodplains

1005.1 General

Design all highways that encroach on floodplains, bodies of water or streams to allow conveyance of the 1% AEP storm discharge without causing significant damage to the highway, watercourse, body of water or other property.

Hydraulically design structures and/or channels to carry the design AEP storm discharge. Confirm the structure and/or channel will carry the 1% AEP check storm discharge without causing property damage. Inundation of the highway is acceptable for the 1% AEP discharge, but it is not permitted for the design AEP discharge. Water surface elevations caused by existing structures do not have to be lowered to meet the 1% AEP discharge.

1005.1.1 Flood Data and Flood Insurance Study

Special consideration must be given when designing a structure located within a reach of channel that is part of an FIS. Perform a step backwater analysis of the floodplain to the extent required by the Federal Emergency Management Agency.

The allowable surcharge for the National Flood Insurance Program is set at one (1) foot, however local jurisdictions may reduce the allowable surcharge below the one-foot criteria.

SFHAs are labeled as different Zones. Flood Insurance Zone designations may be accessed at the FEMA Flood Map Service Center.

C1005.1.1

The floodway is the channel of a watercourse and the adjacent land areas that must be reserved in order to discharge the 1% AEP flood, or base flood, without cumulatively increasing the water surface elevation more than a designated height. The flood fringe is the portion of the floodplain, outside of the floodway, that contains slow-moving or standing water. See Figure 1006-1.

The limits of the floodway are created by a computer model that conveys the base flood discharge within artificial encroachments placed within the floodplain until an allowable water surface surcharge is established.

The more common FIS risk zones:

Zone	Description
A	Areas subject to inundation by the 1-percent-annual-chance flood. Detailed hydraulic analyses have not been performed, no BFE or flood depth is shown. Use hydrology methods outlined in 1003.
AE A1-A30	Areas subject to inundation by the 1-percent-annual-chance flood determined by detailed study methods. BFEs are shown within these zones. Zone AE is used on new and revised maps in place of Zones A1-A30. An existing hydraulic model should be available from FEMA. Use the 1% AEP discharge found in the FIS model for the analysis.
	AE (BFEs WITH Floodway): BFEs and floodways have been determined and depicted on the FIRM.
	AE (BFEs WITHOUT Floodway): BFEs have been determined, but no floodway has been generated and is not delineated on the FIRM. In SFHAs with BFEs, but no floodway, a hydrologic and hydraulic analysis is required demonstrating that the cumulative effect of proposed development, when combined with all other existing and anticipated development will not increase the water surface elevation of the base flood by more than the allowable surcharge.

1005.1.2 Proposed Construction in FEMA Zones

Construction within FEMA Zone A requires documentation through the ODOT self-compliance process and coordination with the Local Floodplain Coordinator. A BFE has not been established. Limit the allowable water surface surcharge to the requirements from the Local Floodplain

C1005.1.2

The Ohio Department of Natural Resources Floodplain Management Program coordinates the NFIP throughout the State of Ohio as specified in Section 1521 of the Ohio Revised Code. The FMP works as a liaison between communities that participate in the NFIP and FEMA, who administers

Coordinator or one (1) foot, whichever is less. Contact OHE if the allowable surcharge required by the Local Floodplain Coordinator is not feasible.

Construction within FEMA Zones AE or A1-A30 requires documentation through the ODOT self-compliance process, coordination with FEMA, ODNR, and the Local Floodplain Coordinator. Where a floodway is established, span the floodway with the proposed construction if feasible. A No-Rise condition is preferred if construction is performed within the floodway. If proposed construction within the floodway creates any increase in the water surface elevation above the BFE, a variance is required and approval through the appropriate FEMA map revision processes will be necessary. Where no floodway is established and the proposed construction creates any increase in the water surface elevation above the BFE + Allowable Surcharge, a variance is required and approval through the appropriate FEMA map revision processes will be necessary.

Locally administered projects are required to obtain a permit from the Local Floodplain Coordinator for proposed work within a FEMA SFHA.

the program nationally. Additional information can be found at the ODNR FMP web site: ODNR Floodplain Management

1005.1.3 Exceptions

ODOT has determined that the following types of projects will have no impact upon the BFE, and no hydraulic analysis for FEMA coordination is required:

1. Bridge Painting
2. Bridge maintenance such as bridge deck or superstructure replacement that is performed where the existing low chord of the bridge has freeboard over the BFE, including the allowable surcharge.
3. Any bridge or culvert maintenance that does not change the alignment, grade, or hydraulic capacity of the existing structure as determined by the District Hydraulic Engineer.

For exempt projects located within a Special Flood Hazard Area Zone A or AE, provide a Letter of Notification of SFHA Exemption LD-53 to the Local Floodplain coordinator and copy to the project file.

C1005.1.3

Most work involving a pole or post such as signal and utility poles, sign and mailbox posts are accepted as insignificant as they will not block flood flows. A hydraulic analysis is not required.

When utilizing a Temporary Access Fill, refer to the Waterway Permits Special Provisions for any specific exceptions.

1005.1.4 ODOT Self Compliance Process

Compliance with federal, state and local floodplain standards is required; however, obtaining a permit from the Local Floodplain Coordinator is not required for work administered by or for the Department (ORC 1521.13 D). The Department will self-comply with Local Floodplain standards under this process. In order to maintain and verify compliance, thorough documentation is necessary.

The Local floodplain coordinator must be contacted early in the process to obtain any local standards that may be more restrictive than FEMA requirements. Keep all documentation requesting Local requirements in the project file.

For construction within the following FEMA Zones, provide a copy of the following documentation to the Local Floodplain Coordinator and the project file.

Zone A:

1. Letter of Notification LD-52
2. Letter of Compliance LD-51, note if a variance requesting relief from local standards is required.
3. Calculations demonstrating the carrying capacity of the stream is maintained.
4. If a variance is requested for relief from local standards, further coordination is required between ODOT, the Local Floodplain Coordinator, ODNR and FEMA. Contact OHE if a variance is required.

Zone AE, without Floodway:

1. Letter of Notification LD-52
2. Letter of Compliance LD-51, note if a variance requesting relief from local standards is required.
3. Hydrologic and Hydraulic calculations.
4. If a variance is requested for relief from local standards, further coordination is required between ODOT, the Local Floodplain Coordinator, ODNR and FEMA. Contact OHE if a variance is required.

Zone AE, with Floodway:

1. Letter of Notification LD-52
2. Letter of Compliance LD-51, note if a variance requesting relief from local standards is required.
3. Hydrologic and Hydraulic calculations.
4. No-Rise Certification LD-50, if applicable.

5. If a variance is requested for relief from local standards, further coordination is required between ODOT, the Local Floodplain Coordinator, ODNR and FEMA. Contact OHE if a variance is required.

1005.2 Type of Studies

1005.2.1 Hazard Evaluation for Watercourses W/O A Defined FEMA SFHA

A Flood Hazard Evaluation is required for all watercourse involvements except for FEMA Zones A, AE and A1-A30, or where roadway culverts are provided to satisfy minimum size requirements. Perform the following for a flood hazard evaluation:

1. Determine the water surface elevation of the design AEP and 1% AEP flood.
2. Delineate the inundation area for the peak water surface elevation for the design AEP and 1% AEP flood on a topographic map or a digital map.
3. Evaluate the impacts of any increase in the flooding limits.

C1005.2.1

A Flood Hazard Evaluation is a condition statement regarding the nature of the upstream area, the extent of upstream flooding, and whether buildings are in the 1% AEP floodplain.

1005.2.2 Detailed Study

If the Hazard Evaluation indicates a significant increase in the flooding of upstream property, a Detailed Study is required. Furnish a Detailed Study in highly urbanized areas where the potential for flooding cannot be accurately assessed without an analysis of the entire floodplain. For prefabricated structures, the Detailed Study, including a step-backwater analysis, will be authorized after review of the Hazard Evaluation by OHE.

1006 Allowable Headwater

1006.1 Design AEP Storm

Use the design AEP storm as shown in Section 1004.2.

1006.2 Culvert Headwater Controls

1006.2.1 Design Storm Controls

Headwater depth for all culverts (Type A Conduits) must not exceed any of the following controls for the design storm:

A. 2 feet below the near, low edge of the pavement for drainage areas 1000 acres or greater and 1 foot below for culverts draining less than 1000 acres.

B. 2 feet above the inlet crown of the culvert or above a tailwater elevation that submerges the inlet crown in flat terrain.

C. 4 feet above the inlet crown of a culvert in a deep ravine.

D. 1 foot below the near edge of pavement for bicycle pathways.

1006.2.2 Check Storm Controls

Headwater depth for all culverts (Type A Conduits) must not exceed any of the following controls for the applicable check storm.

A. 2 feet below the lowest ground elevation adjacent to an occupied building for a 2% AEP storm. This is not intended to lower existing high-water elevations around buildings.

B. Limit the maximum 1% AEP storm headwater depth to twice the diameter or rise of the culvert.

C. Size a replacement structure to prevent overtopping by the 1% AEP storm where overtopping would not occur with the existing structure.

D. Size a replacement structure so that flooding of upstream land is not increased for the 1% AEP storm when compared to the existing structure. Before implementing this criteria consider the type of upstream property and land use.

E. Controls Specific to an FIS. See section 1006.4.

1006.2.3 Limitations

1006.2.1 A is typically the primary headwater control. 1006.2.1 B and C are secondary headwater controls.

The near low edge of the traveled way is the lowest edge of the traveled way elevation located within the drainage divide. This may or may not be located directly over the culvert. If the overtopping elevation point on the roadway is outside the drainage divide, use the ditch break elevation as a headwater control in lieu of 1006.2.1 A.

Use smooth pipe when 1006.2.1 B is applicable to establish the allowable headwater. Use corrugated

C1006.2.3

In general, a reduction in waterway opening from existing to proposed is discouraged. Consideration can be given to reducing the waterway opening if it does not cause flooding damage upstream or excessive outlet velocity. There are times the hydrology can be questionable so maintaining the same waterway opening as the existing is recommended.

A culvert on a flat grade or one that acts as an equalizer pipe that experiences frequent tailwater conditions may fit the criteria of 1006.2.1 C for determining allowable headwaters.

pipe when 1006.2.1 C is applicable to establish the allowable headwater. Use these established headwater elevations in the design of conduit alternates.

Provide a free water surface through structures with a span greater than or equal to 10 feet for the design storm, unless tailwater controls.

1006.3 Bridge Headwater Control

Evaluate the headwater generated by a bridge in accordance to a flood hazard evaluation. Meet the following:

A. Match the existing headwater for a bridge replacement for the design storm and the 1% AEP check storm to the maximum extent practicable. If there is an increase in headwater, determine the upstream impacts.

B. The design storm does not contact the low chord for new structures on new alignment.

C. Regulations from the local Conservancy Districts apply if they are more restrictive than the Department's.

D. Controls specific to an FIS. See section 1006.4.

1006.4 Controls Specific to Flood Insurance Studies

When making an encroachment on a NFIP designated floodplain in the floodway fringe, the rise in the water surface above the natural 1% AEP flood elevation is limited by the community. Contact the Local Floodplain Coordinator early in the design process to determine the allowable headwater increase. A current list of Floodplain Coordinators may be found here: Floodplain Coordinator List

No increase in the Base Flood Elevation is preferred when encroaching on a NFIP designated floodway. When an increase is necessary, approval from the Department, coordination with the Locals/FEMA and a NFIP FIRM revision are required.

C1006.4

Initiate the flood map revision process as soon as possible if changes to the NFIP FIRM will occur because of an encroachment on the floodway or floodway fringe. Submit a CLOMR to FEMA for approval. After construction, a LOMR officially revises the FIRM. The most common cause of change is an increase in the BFE from fill or obstructions added to the floodplain.

FEMA provides guidance on the Flood Map Revision Process.

A decrease to the BFE may require submission of a LOMR application following construction, however, a CLOMR submission is not required. Obtain guidance from the Local Floodplain Coordinator when there is a decrease in the BFE. Reference the Code of Federal Regulations 44 CFR 65.3.

1007 Pipe Removal Criteria

1007.1 General

Use the following guidelines to determine whether an existing pipe, regardless of type, being taken out of service is to be abandoned, filled and plugged, or removed.

A. Pipes less than 4 inches in diameter may be abandoned in place when below the pavement subgrade.

B. Remove or fill and plug pipes 4 inches through less than 12 inches in span or rise with less than 8 feet of final cover. Those with more than 8 feet of final cover may be abandoned in place.

C. Remove or fill and plug all pipes 12 inches or larger in span or rise.

When fill and plug is specified, add Plan Note D103, to the General Notes.

C1007.1

Use discretion in removing:

- Small pipes based on roadway importance, pipe material longevity and if the pipe is under existing rigid pavement or base which is to remain in place.
- Any size pipe with more than 10 feet of cover.

1007.2 Asbestos Pipe

Asbestos pipe is a regulated material. Make reasonable efforts to identify existing asbestos pipes in the plans and, when necessary, provide appropriate removal quantities.

In the past, pipe containing asbestos was allowed on ODOT, LPA and utility projects under the following specifications:

- ASTM C663 Asbestos-Cement Storm Drain Pipe
- AASHTO M217
- AWWA C400
- AWWA C603
- ASTM C296 Asbestos-Cement Pressure Pipe
- ODOT C&MS 707.09 Asbestos Bonded Bituminous Corrugated Steel Pipe and Pipe Arches (Circa 1983)
- ODOT C&MS 706.15 Asbestos Cement Perforated Underdrain Pipe (Circa. 1973)

Reasonable efforts to identify asbestos pipes would include the following:

A. Examination of original construction plans and specifications.

B. Contact with the owner of the pipe (e.g., utility company or LPA).

C1007.2

Transite is a common brand name for a type of asbestos pipe. Asbestos can also be found in insulation wrapped around water pipes.

Not all asbestos pipes will be identified by a records search. If asbestos pipe is identified during construction, the contractor will be compensated by change order.

C. Inspection of the pipe for markings when the pipe is exposed during routine maintenance operations.

Asbestos is a hazard only when it becomes airborne. Pipes that are otherwise unaffected by ODOT work are not required to be removed simply because they contain asbestos.

1008 Pipe Design Criteria

1008.1 Corrugated and Spiral Rib Steel and Aluminum Pipes, Corrugated Steel and Aluminum Pipe Arches

1008.1.1 Material Durability

Follow the criteria outlined in Section 1002.2.2 specifying types of protective coatings and/or extra metal thickness.

C1008.1.1

The maximum available sheet thickness for aluminum coated corrugated steel pipe (707.01, 707.02, 707.05, 707.07; all with aluminum coating) or polymer coated corrugated steel pipe (707.04) is 0.138.

1008.1.2 Designation and Thickness

The corrugation profile and required metal thickness for structural strength is furnished by the Manufacturer in accordance to C&MS 611.

1008.1.3 Cambered Flow Line

Provide a cambered flow line where soil conditions at the site indicate that significant settlement is expected. Show the cambered flow line as a vertical curve following the manufacturer's recommendations.

1008.1.4 Height of Cover

The maximum height of cover is measured from the top of the pipe or pipe-arch to the top of the wearing surface or finished grade.

The minimum height of cover is measured from the top of the pipe or pipe-arch to the top of subgrade.

See Figures 1008-1 through 1008-11 for minimum height of cover. Provide a minimum height of cover to the top of the wearing surface or finished grade not less than the figure values plus 6 inches.

C1008.1.4

See Glossary of Terms for the definition of cover and height of cover.

1008.1.5 Foundation Reports

Perform an exploration of the supporting foundation material and submit a Structure

Foundation Exploration report in accordance with the SGE. Perform analysis in accordance with the BDM and GDM.

1008.2 Rigid Pipes

1008.2.1 Cambered Flow Line

Provide a cambered flow line where soil conditions at the site indicate that significant settlement is expected. Show the cambered flow line as a vertical curve following the manufacturer's recommendations.

1008.2.2 Height of Cover

Provide a minimum height of cover of 15 inches to the pavement surface including a minimum cover of 9 inches to top of the subgrade. Where the pipe is not under pavement, provide a minimum height of cover of 9 inches to the finished grade.

C1008.2.2

See Glossary of Terms for the definition of cover and height of cover.

1008.2.3 Reinforced Concrete Radius Pipe

Specify a minimum radius of 100 feet.

C1008.2.3

The radius was chosen to comply with the capabilities of manufacturers to provide satisfactory and economical radius pipe sections.

The method of manufacturing pipe sections is at the discretion of the producer, subject to inspection and approval by OMM.

1008.3 Thermoplastic Pipe

1008.3.1 Height of Cover

Provide a minimum height of cover of 18 inches to the pavement surface including a minimum cover of 12 inches to top of the subgrade. Where the pipe is not under pavement, provide a minimum height of cover of 18 inches to the finished grade.

C1008.3.1

See Glossary of Terms for the definition of cover and height of cover.

1008.4 Corrugated Steel and Aluminum Box Culverts, Corrugated Steel Long Span Culverts

1008.4.1 Designation and Thickness

Follow the corrugation profile and metal thickness requirements of the AASHTO LRFD Bridge Design Specifications. Structural strength design is furnished by the Manufacturer in accordance with C&MS 611.

Designate the skew of the structure relative to the roadway in 1° increments. Limit the skew to 15°. If this cannot be achieved, contact OHE.

1008.4.2 Height of Cover

Provide a minimum height of cover, measured from the trough of the corrugation profile to the pavement surface, of 18 inches. Locate the rib stiffeners of corrugated steel and aluminum box culverts completely within the subgrade.

C1008.4.2

See Glossary of Terms for the definition of cover and height of cover. Cover, in this case, is not measured from the crest of the corrugation of the pipe.

1008.4.3 Foundation Reports

Per 1008.1.5.

1008.5 Precast Reinforced Concrete Box Culverts

1008.5.1 Designation

The allowable sizes of precast reinforced concrete box culverts are given in Figure 1008-14. Include the height of cover rounded to the highest 1 foot in the pay item description.

Do not skew ends of box culverts.

C1008.5.1

Height of cover may be referred to as design earth cover.

ASTM C1577 is used to design structures with a span of 12 feet or less.

Structures with spans 14 feet or greater require a special design. C&MS 706.05 refers to SS940 which lists the design for each span and fill height.

1008.5.2 Height of Cover

The maximum height of cover is 10 feet. Greater covers may be provided contingent upon the approval of the Manufacturer. A special design is required.

C1008.5.2

See Glossary of Terms for the definition of cover and height of cover.

1008.5.3 Radius Box Sections

Specify a minimum radius of 100 feet.

C1008.5.3

The radius was chosen to comply with the capabilities of manufacturers to provide satisfactory and economical radius box sections.

The method of manufacturing box sections is at the discretion of the producer, subject to inspection and approval by OMM.

1008.6 Precast Reinforced Concrete Three-Sided Flat-Topped Culverts

1008.6.1 Designation

Precast reinforced concrete three-sided, flat-topped culverts have a clear span of 14 through 34 feet with an opening rise of 4 feet through 10 feet.

The individual culvert units may be skewed in 5° increments with a maximum skew of 30°. Designate the skew of the structure relative to the roadway in 1° increments with a maximum skew of 45°.

The minimum deck thickness for the culvert unit is 12 inches and the minimum leg thickness for the culvert unit is 10 inches. Base the design on these dimensions.

1008.6.2 Height of Cover

The maximum height of cover is 5 feet.

Greater covers may be provided contingent upon the approval of the Manufacturer. A special design is required.

C1008.6.2

See Glossary of Terms for the definition of cover and height of cover.

1008.6.3 Foundation Reports

Per 1008.1.5.

1008.7 Precast Reinforced Concrete Arch Sections

1008.7.1 Designation

Precast reinforced concrete arch sections have a clear span of 12 to 34, 36, 42, 48, 54 and 60 feet with an opening rise of 4 feet through 13 feet. Use of other sizes requires that a Proprietary Product Approval Request be completed and signed by the contracting agency.

Designate the skew of the structure relative to the roadway in 1° increments up to 45°. Where skews exceed 45°, analyze traffic loading for the most critical case. Individual culvert sections may only be skewed with written permission from OSE.

Obtain the deck thickness and leg thickness for the culvert units from the manufacturer. Show the maximum and minimum height of cover on the plans. Design the footing keyway based on the leg thickness plus 6 inches. Design the guardrail post length based on the deck thickness and cover.

Precast reinforced concrete arch sections may only be used for roadway grade separation structures with written approval from the OSE. Standard design modifications, including but not limited to increased concrete thickness, concrete admixtures, epoxy coating of concrete surfaces and epoxy coating of reinforcing steel may be required for approval for use as roadway grade separation structures.

1008.7.2 Height of Cover

The maximum height of cover is 12 feet. Cover greater than 12 feet may be provided contingent upon the approval of the Manufacturer. A special design is required.

The minimum height of cover to the top of the pavement surface is 12 inches with no portion of the arch extending beyond the subgrade.

C1008.7.2

See Glossary of Terms for the definition of cover and height of cover.

1008.7.3 Foundation Reports

Per 1008.1.5.

1008.8 Precast Reinforced Concrete Round Sections

1008.8.1 Designation

Precast reinforced concrete round sections are one or two piece structures with a clear span of 12, 16, 20, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78 and 84 feet available in various rises and shapes Use of other sizes requires that a Proprietary Product Approval Request be completed and signed by the contracting agency.

Designate the skew of the structure relative to the roadway in 1° increments with a maximum skew of 30°. Individual culvert sections may only be skewed with written permission from OSE.

Obtain the section thickness for the sections from the manufacturer. Show the maximum and minimum cover on the plans. Design the footing keyway based on the section thickness plus 8 inches. Design the guardrail post length based on the section thickness and cover.

Precast reinforced concrete round sections may only be used for roadway grade separation structures with written approval from OSE.

C1008.8.1

Standard design modifications, including but not limited to increased concrete thickness, concrete admixtures, epoxy coating of concrete surfaces and epoxy coating of reinforcing steel may be required for approval for use as roadway grade separation structures.

1008.8.2 Height of Cover

The maximum height of cover is limited to 12 feet. Cover greater than 12 feet may be provided contingent upon the approval of the Manufacturer. A special design is required.

The minimum height of cover to the top of the pavement surface is 12 inches with no portion of the round section extending beyond the subgrade.

C1008.8.2

See Glossary of Terms for the definition of cover and height of cover.

1008.8.3 Foundation Reports

Per 1008.1.5.

1008.9 Arch or Flat Slab Top Culvert Foundations

Use Table 1008-1 to determine the flood used for scour evaluation.

For three-sided structures with no wingwall, or with a 90-degree turn-back angle, calculate the local scour depth at the upstream corners of the culvert entrance using the "without wing wall case" using HEC-18 [Arneson et al., 2012] Equations 6.12 and 6.13. For three-sided structures with a turn-back wingwall with an angle of 60 degrees or less, calculate the local scour depth at the upstream corners of the culvert entrance using the "with wing wall case" using HEC-18 [Arneson et al., 2012] Equations 6.10 and 6.11. For three-sided structures with a turn-back wingwall with an angle between 90 and 60 degrees, calculate the local scour depth at the upstream corners of the culvert entrance using both above methods, and linearly interpolate between the results based on the turn-back angle of the wall between these two limits. Otherwise, for the remainder of the three-sided structure, and for three-sided structures with straight wingwalls, calculate the local scour depth as for an abutment, in accordance with Section 1008.10.

When using a spread footing foundation, provide stone armoring at the footer per HEC-23 [Lagasse et al., 2009], Volume 2, Section 6, Design Guideline 18 (DG-18). Determine the stone armoring median diameter D_{50} using DG-18 with the minimum size at 12 inches of Type C RCP per C&MS 703.19. Use a Kr of 0.38, for the riprap sizing equation (18.1). Set the top of the spread footing at a depth equal to or exceeding the calculated scour depth elevation.

Where lateral stream stability is in question assume the scour design elevation based on the

C1008.9

The local scour depth calculated by the equations in HEC-18 [Arneson et al., 2012] Section 6.9 is inclusive of contraction scour. The research for scour at three-sided culvert structures was performed on models with wingwalls at a 90-degree turn-back angle for the "without wing wall case," and on models with wingwalls at a 45-degree turn-back angle for the "with wing wall case." Scour results using the equations in HEC-18 [Arneson et al., 2012] Section 6.9 may be inapplicable for configurations of culvert and wingwalls other than those used in the research.

See section C1008.10.4 for commentary on stream thalweg as the datum.

Access and/or download the HEC-23 [Lagasse et al., 2009] publication from the FHWA Hydraulics Library .

stability.

1008.10 Bridge Scour

1008.10.1 General

Evaluate the estimated scour that will occur at each pier and abutment using the FHWA Hydraulic Toolbox.

Provide Toolbox Input and output data including electronic program files.

Adjust the pier design in coordination with the geotechnical and structural engineers to minimize scour for new bridges.

See Figure 1008-15 for scour evaluation workflow.

C1008.10.1

FHWA produces the Hydraulic Toolbox software to aid with scour analysis using the HEC-18 [Arneson et al., 2012] equations.

Scour evaluations require an interdisciplinary approach. The interdisciplinary team consist of Structural Engineers, Hydraulic Engineers, and Geotechnical Engineers.

Structural Engineers perform or have oversight in routine bridge inspections that identify concerns due to scour, stream degradation/aggradation, meandering, and prior use of scour countermeasures.

Hydraulic Engineers provide the hydraulic loading applied to the bridge foundation created by the stream or channel flow. Shear forces are generated based on equations in HEC-18 [Arneson et al., 2012].

Geotechnical Engineers evaluate the resistance to the hydraulic loading based on streambed soil or rock properties.

The scour design engineer may be from any of the contributing disciplines provided the engineer has experience in performing this analysis.

Contact OHE for guidance regarding hydraulic modelling and the resulting shear forces or questions regarding scour calculations.

Contact OGE for guidance regarding the determination of the streambed soil or rock properties required for the scour analysis.

In general, circular piers or elongated piers with circular noses and an alignment parallel to the flood-flow direction help minimize scour.

Figure 1008-15 was developed for the designer to better understand the process steps commonly used to perform a thorough scour evaluation and confirm structural capacity is acceptable.

1008.10.2 Scour Types

Estimate scour depths due to the following scour types: long-term degradation, contraction scour, and local scour which occurs at piers and abutments.

Long-term degradation is added to the other forms of scour to obtain the total scour.

Contraction scour evaluates where the flow is most contracted at the bridge. The contracted width represents the main channel and is either the toe of slope to the toe of slope or the top of bank to top of bank.

Include pressure flow scour where overtopping occurs. When feasible, avoid pressure flow by increasing the hydraulic opening of the bridge.

C1008.10.2

Long-term profile changes can occur from aggradation or degradation, or both. Aggradation is the deposition of bed load due to a decrease in stream sediment transport capacity that results from a reduction in the energy gradient or an increase in the sediment load. Aggradation also frequently occurs in reservoirs. Degradation is the scouring of bed material due to increased stream sediment transport capacity that results from an increase in the energy gradient or a decrease in the sediment load. For most bridges, this determination will be made as a part of the stream stability assessment.

Contraction scour results from a constriction of the flow area caused by approach fills in the floodplain or, to a lesser extent, by bridge piers in the waterway. A common mistake is to use the width of abutment to abutment in lieu of the main channel.

All abutments and piers located within the flood-flow prism increase the potential scour hazard at a bridge site. The amount of scour caused by these features is a function of the geometry of the piers and abutments as they relate to the flow geometry. Additionally, review any history of documented debris accumulations. This type of scour is termed local scour.

Pressure flow, which is also known as orifice flow, occurs when the water surface elevation at the upstream face of the bridge is greater than or equal to the low chord of the bridge superstructure. Pressure flow under the bridge results from a buildup of water on the upstream bridge face and a plunging of the flow downward and under the bridge.

At higher approach flow depths, the bridge can be entirely submerged with the resulting flow being a complex combination of the plunging flow under the bridge and the flow over the bridge.

With pressure flow, the local scour depths at piers or abutments is larger than for free surface flow with similar depths and approach velocities. The increase in local scour at a pier that is subject to pressure flow results from the flow being directed downwards, toward the bed, by the superstructure and by increasing the intensity of the horseshoe vortex. The vertical contraction of the flow is a more significant cause of the increase in scour depth. However, in many cases, when a bridge becomes submerged, the average velocity under it is reduced due to a reduction of discharge that must pass under the bridge as a result of weir flow over the bridge and approach embankments. Consequently, increases in local scour attributed to pressure-flow scour at a particular site may be offset to a degree. The effects of this type of condition should be reflected in the design process. Refer to HEC-18 [Arneson et al., 2012] for more information pertaining to pressure flow scour.

Reference the AASHTO Drainage Manual [AASHTO, 2014] Sections 17.4.4 & 17.4.8.

1008.10.3 Total Scour

Use the following steps to determine total scour:

1. Determine the fixed-bed channel hydraulics.
2. Estimate the aggradation or degradation.
3. Adjust the fixed-bed hydraulics to reflect these changes.
4. Compute the bridge hydraulics.
5. Determine the Contraction Scour.
6. Determine the Local Scour at piers and abutments.

To obtain total scour, the potential local scour is added to the contraction scour without considering the effects of contraction scour on the channel and bridge hydraulics.

C1008.10.3

This is considered a conservative practice because it assumes that the scour components develop independently.

Reference the AASHTO Drainage Manual [AASHTO, 2014] Section 17.4.7.

1008.10.4 Scour Evaluation

Perform a scour evaluation for all structures within the scour design flood boundary. Assess rock scour resistance according to BDM Section 305.2.1.2.b(B). Compute scour depth for all bridge foundations except for spread footings founded on scour resistant bedrock. When evaluating scour for a replacement structure, review all inspection reports for evidence of stream degradation, scour or previous scour countermeasures.

Use evidence of past degradation to estimate future degradation.

Provide a scour plot showing the structure along with all components of the predicted scour. Include the scour design elevation at piers and abutments. See Figure 1008-19.

Locate the scour analysis at the point of scour.

C1008.10.4

Compare the predicted scour depth to historical site conditions. If the predicted depth does not match historical site conditions, consult with the interdisciplinary team to choose the appropriate action.

When scour projections on the scour plot overlap between piers, or piers and abutments, increase the span of the bridge to eliminate the overlap if feasible.

The soil profile used for the scour analysis begins at the point of scour.

Point of scour location:

Contraction and Degradation; on the channel bottom at the thalweg.

Abutments; at the toe of the embankment for spill-through type or the bottom of the wall for vertical-wall type.

Piers; ground surface at the location of the pier.

Take lateral channel stability into consideration when performing a scour evaluation. Where stability is in question assume the scour design elevation at local scour points based on the thalweg as the datum. See Figure 1008-19.

Naturally occurring lateral migration of the main channel of a stream within a floodplain may affect the stability of piers in a floodplain, erode abutments or the approach roadway, or change the total scour by changing the flow angle of attack at piers and abutments and the point of scour. Factors that affect lateral stream movement also affect the stability of the bridge foundation. These factors are the geomorphology of the stream, location of the crossing on the stream, flood characteristics, and the characteristics of the bed and bank materials. Refer to HEC-20 [Lagasse et al., 2012] for stream stability analysis and methods to determine stability.

Use the average D_{50} for the scour analysis for non-cohesive soils or perform a layer-by-layer scour analysis if there is a wide variability in the soil profile D_{50}.

If the scour depth exceeds the layer thickness, use the next layer D_{50} in the analysis. The next layer persists to the surface, keeping the same velocity and depth as the first layer. Repeat the process until a layer is not predicted to be fully scoured.

Use the critical shear stress from laboratory testing for cohesive soils if available.

Use 657450 hours for Duration of Flow. This represents the 75-year service life of the bridge.

No method exists to predict velocity due to scour decay. FHWA recommends that each layer be evaluated until the predicted scour is less than the layer thickness when performing layer-by-layer analysis assuming the next lower soil layer persists to the surface.

Methods to calculate critical shear stress for soils and bedrock can be found in the GDM Section 1302. Contact OGE for information regarding laboratory testing.

Where cohesive soil is present and the allowable soil shear force is not available, perform the scour calculations using a granular soil with a D_{50} value of 0.2mm

The FHWA Hydraulic Toolbox has a lower limit of 0.2mm for the D_{50} when calculating contraction and local abutment scour.

The only reliable method of determining critical shear for silt and clay particles is to perform laboratory testing. Consult with OGE for guidance on whether to pursue soil testing as opposed to using the assumed D_{50}.

For local pier scour, use the HEC-18 [Arneson et al., 2012] method for soils with a D_{50} less than or equal to 20mm. Use the Coarse Bed method when soils

The Geotechnical Engineer will provide a D_{84} value for use in the Coarse Bed method if the soils are have a D_{50} greater than 20mm. The Coarse Bed method requires a D_{50} and D_{84} of the granular soil.

deemed coarse granular.

Use the hydraulic parameters from just upstream and outside of the influence of the pier.

Estimate local abutment scour by using the NCHRP method. Use the appropriate hydraulic parameters based on the abutment location relative to the channel.

FHWA recommends the NCHRP method. The abutment scour depth calculated by the NCHRP method is inclusive of contraction scour.

FHWA defines two abutment scour scenarios as Condition A and B.

Scour Condition A: The abutment is located near the channel bank or the channel may migrate into the abutment over the life of the bridge. Use main channel hydraulics to compute abutment scour.

Scour Condition B: The abutment is set back from the channel bank far enough that it will not be in contact with the channel over the life of the bridge. Use overbank hydraulics to compute abutment scour.

1008.10.4.1 Rehabilitation Work

Perform a scour evaluation for all rehabilitated structures that require a hydraulic analysis or when otherwise required by BDM section 405.15.3. Provide calculations along with a narrative of findings and recommended scour countermeasures in the STS. Ignore scour countermeasures in the prediction of scour depths. Include a statement regarding the susceptibility of the stream banks and flow line to scour, and the susceptibility of the piers and abutments to scour.

C1008.10.4.1

For existing bridges, the scour evaluation may consist of determining what the bridge is founded on. For example, with bridge rehabilitation, noting that the bridge is founded on spread footings on scour resistant bedrock would constitute the scour evaluation.

1008.10.5 Scour Design Flood

Bridge foundations are designed to withstand the effects of scour caused by hydraulic conditions from floods larger than the design flood. The scour design flood and the scour check flood are determined by the hydraulic design flood used to hydraulically size the bridge. Use Table 1008-1 to determine the flood used for scour evaluation.

Table 1008-1

Hydraulic Design Flood	Scour Design Flood	Scour Check Flood
Q10%	Q4%	Q2%
Q4%	Q2%	Q1%
Q2%	Q1%	Q0.2%

C1008.10.5

The Scour Design Flood will typically produce the greatest scour for that design condition and the Scour Check Flood will typically produce the greatest scour for the check condition. However, instances can occur due to the hydraulic conditions at a particular site, such as pressure flow and/or overtopping, where flood magnitudes less than either of these floods will cause a greater amount of scour. If there is a flood magnitude less than the Scour Design Flood that causes greater scour at the bridge, it should be used as the Scour Design Flood. Similarly, if there is a flood event less than the Scour Check Flood that causes greater scour at the bridge, it should be used as the Scour Check Flood.

1008.10.6 Scour Countermeasures

Provide hydraulic modelling of existing bridges when it is anticipated that the scour countermeasures will impact the flow parameters through the bridge opening or increase the backwater created by the bridge.

Armoring scour countermeasures are not accounted for in the scour depth calculations and are considered a factor of safety.

Incorporate scour countermeasures into the hydraulic model of new bridges.

Example scour countermeasures for existing bridges can be found in the ODOT Bridge Maintenance Manual.

C1008.10.6

Scour countermeasures may consist of structural devices to modify stream alignment through the bridge or placement of structural armoring at piers or abutments.

Selection of scour countermeasures requires an interdisciplinary approach in a similar manner to the scour evaluation.

For existing bridges, the structural engineer will propose countermeasures and consult with the hydraulic and geotechnical engineers for concurrence. If deemed necessary by the interdisciplinary team, the hydraulic engineer performs hydraulic calculations to evaluate impacts to the hydraulic aspects of the bridge such as headwater elevation, velocities, resulting shear forces, etc. The geotechnical engineer in collaboration with the structural engineer will evaluate the resisting forces provided by the scour countermeasure to ensure stability.

1008.11 Waterproofing Membrane

Apply an external waterproofing membrane to all precast reinforced concrete box culverts, three-sided flat-topped culverts, arch culverts and round sections. Use Item 512, Waterproofing, Type 2, along the vertical sides and Type 2 or 3 across the top of the structure. Use Type 3 waterproofing if pavement is to be used directly on top of the structure. Provide an overlap of a minimum of 12 inches of the top membrane over the vertical membrane.

C1008.11

Waterproofing based on recommendations from TRB Transportation Research Record No. 1315, p. 53-57. [Hurd, 1991].

1008.12 Precast Reinforced Concrete Flat Slab Tops, Catch Basin Tops and Inlet Tops

Design Precast Reinforced Concrete Flat Slab Tops, Catch Basin Tops, and Inlet Tops in accordance with ASTM C478.

Use a design loading of HL-93 when the structure is under pavement and the span is greater than 10 feet.

1008.13 Wingwall Design

When not using the standard construction drawings or design data sheets, design wingwalls as retaining walls in accordance with the BDM and

C1008.13

The channel bottom is normally the span of the structure opening.

the current AASHTO LRFD Bridge Design Specifications.

All precast/prefabricated wall systems require submission and approval from OGE according to the following: Approval Process of Prefabricated Retaining Wall Systems. Approved vendors can be found here: PRWS Approved List

1009 Maintenance of Traffic Drainage

1009.1 General

Evaluate MOT drainage for projects on Interstates, Freeways & Expressways that have one or more of the following or as directed by the District:

A. Multi-phased MOT operations.

B. Profile changes in the roadway that temporarily create a sag point different than the final design.

C. Traffic maintained adjacent to concrete barrier with 2 feet or less clear distance from the edge of lane to the edge of barrier.

Provide a minimum dry lane width of 10 feet for each traveled lane. Determine the spread of water on the pavement using a 50% AEP design storm unless a different recurrence interval is specified by the District.

Provide MOT drainage by utilizing permanent drainage items for final design and temporary drainage items. Temporary drainage items may include items such as inlets, storm sewers, culverts, ditches, perforated conduits, catch basins, conduits bored or jacked, opening cuts in concrete barrier, French drains, pavement saw cut openings, etcetera. These drainage items could conflict with future MOT phases and may require removal quantities in subsequent MOT phases.

Use permanent drainage items for final design where feasible. Provide a minimum diameter of 12 inches for temporary storm sewers and 18 inches for temporary culverts.

Provide temporary drainage items on the MOT plan per Plan Note D124.

C1009.1

Positive drainage during Maintenance of Traffic operations is provided under Items 614 and 615 of the C&MS for most projects.

Consider MOT phasing and potential traffic impacts when utilizing permanent drainage items during MOT operations. Avoid placement of drainage items such as barrier inlet or catch basin grates in vehicle wheel-paths where a roadway hazard may be created.

Criteria used for MOT drainage may be modified by the District as warranted by practicable design with consideration to limitations of site conditions, risk to the travelling public, and the length of time of the MOT. Examples include a modification of the AEP design storm or a reduction to the minimum dry lane width. Contact the Office of Roadway Engineering if the MOT design criteria cannot be met.

1009.2 Structures for Maintaining Traffic

The design AEP and other hydraulic requirements for temporary structures are defined in C&MS 502.02.

Show the water surface elevation and velocity for the design AEP discharge on the temporary structure plans. Confirm the design AEP discharge does not contact the lowest portion of the superstructure of a temporary bridge.

Culvert pipes may be used in place of a bridge structure provided controls specified in Section 1006 are not exceeded for the design AEP discharge.

Refer to Section 500 of the BDM for other details regarding temporary structures.

1009.3 Temporary Excavation Support for Maintenance of Traffic

When support of excavation is required per BDM Section 310.1.1, include Item 503 Cofferdams and Excavation Bracing in the plans. Provide a plan design for the temporary excavation support per section 310.1.1.2 of the BDM.

1010 Waterway Permit Hydraulic Analysis

1010.1 General

Follow the procedure below for establishing the hydraulic and construction contract requirements for Temporary Access Fills in the Waterway Permits Special Provisions. Perform a hydraulic analysis based on the maximum permitted extents of the TAF as per the BDM Section 201.3. Do not include this information in the project plan set. Perform the following:

1. Determine the maximum mean monthly flow from USGS StreamStats (i.e.: largest of Q1, Q2, Q3...Q12). If a delineation is not feasible in USGS StreamStats and the basin area is known, use the following equation:

   $$\overline{Q_{Mar}} = 2.01A^{1.01}$$

   Where: $\overline{Q_{Mar}}$ is the mean monthly flow for March in cfs. **A** is the basin or drainage area in square miles.

2. Multiply the maximum mean monthly flow

C1010.1

A hydraulic analysis is required when a Temporary Access Fill (causeways and partial width cofferdams) is proposed in a waterway that has a Standard Temporary Discharge of 10 cfs or greater. Reference the TAF Design Process Flowchart and TAF Design Worksheet linked below for the analysis and suggested scoping requirements. A 2-Dimensional hydraulic analysis is suggested for TAF locations with drainage areas greater than 100 sq. mi. and where the stream's flow is influenced by hydraulic controlling features (i.e., dams). See section 1107.2 for more information on 2-Dimensional hydraulic modeling. The majority of projects will meet the standard hydraulic and construction conditions with a Tier 1 design analysis as described in steps 1-10.

Reference Research [Che et al., 2022] Efficient and Effective Ways to Manage Water through ODOT's occurring in a 12-month period by 2 to determine the project's Standard Temporary Discharge.

3. Calculate the water surface elevation from the STD in the channel cross-section when no TAF is installed. Use the design hydraulic model if a model was required for hydraulic design. If no hydraulic design model was created, use the Manning's open channel equation, solving for depth.
4. Calculate the back water surface elevation from the 50% AEP design storm event flow when no TAF is installed.
5. Calculate the corresponding channel flow rate from the OHWM elevation with no TAF installed.
6. Record the undeveloped channel characteristics, calculated water surface elevations from the STD, 50% AEP storm event, and OHWM flow on the TAF Design Worksheet.
7. Coordinate with the ODOT Project Manager whether a full width or partial width TAF will be utilized for the project.
8. Provide a hydraulic analysis of the maximum permitted extents of the TAF constructed to 1-foot above the OHWM elevation. Submit to the ODOT Project Manager. Design the required Hydraulic Opening necessary to provide a backwater equal to or less than the OHWM elevation. The Hydraulic Opening as defined in the Waterway Permits Special Provisions is "The cross-sectional area allowing an unimpeded discharge equal to twice the highest monthly flow without producing a rise Temporary Fills during Construction.

Reference the TAF Design Process flowchart for steps and a workflow summary related to this activity.

This information is intended to verify the standard hydraulic and construction contract requirements or establish modified hydraulic and construction contract requirements of the Waterway Permits Special Provisions. Environmental professionals will utilize the analysis information to complete the Permit Determination Request.

Utilize the TAF Design Worksheet for identifying stream flow characteristics and verifying the TAF hydraulic and construction requirements. If the standard hydraulic and construction requirements cannot be achieved, utilize the TAF Design Worksheet for providing a Tier 2 or Tier 3 design analysis.

The Temporary Construction Access and Dewatering Activities Checklist is required when a TAF is proposed in a waterway. The Checklist is available from OES-Waterway Permits Unit.

Special consideration is given to structures over controlled bodies of water such as lakes or reservoirs. Refer to the BDM for further design guidance.

The OHWM is determined in the field by an individual trained in identifying the OHWM. Refer to the Ordinary High Water Mark Identification Manual published by OES.

in backwater above the OHWM." The Hydraulic Opening may be culverts and/or channel opening that facilitates construction of the project.

9. Verify whether the standard TAF construction and hydraulic conditions can be achieved.
10. If the standard TAF construction and hydraulic conditions can be met, record this information on the TAF Checklist of the Permit Determination Request.

Standard TAF construction and hydraulic conditions are where the TAF is constructed to 1-foot above OHWM with a Hydraulic Opening capable of passing the STD without producing a rise in backwater above the OHWM elevation.

11. If the standard hydraulic conditions cannot be achieved after verification of the OHWM with the ODOT Waterway Permits Unit, utilize the TAF Design Worksheet Tier 2 Analysis to determine a modified TAF construction height and backwater elevation.
12. Coordinate the modified TAF construction height and backwater conditions with the ODOT Project Manager. Verify that the modified TAF height will facilitate construction of the project. Assess if the TAF height may result in any adverse flooding impacts and/or be cost prohibitive. If the Tier 2 TAF design is accepted, record this information on the TAF Checklist of the Permit Determination Request.

The OHWM is verified with the ODOT Waterway Permits Unit prior to advancing to a Tier 2 analysis.

Tier 2 TAF Analysis is a simple iterative approach where the designer will raise the required height of the TAF and adjust the Hydraulic Opening until a backwater condition can be achieved providing sufficient freeboard between 0.5-1.0 foot. Refer to the TAF Design Worksheet. Ensure the increased height of the causeway does not create any adverse flooding potential by verifying the backwater condition is below the 2-yr storm event water surface elevation or top of bank elevation.

13. If a Tier 2 solution cannot be achieved, complete the Tier 3 TAF Analysis section of the TAF Design Worksheet. Contact the ODOT Project Manager prior to beginning the Tier 3 TAF Analysis.
14. Complete the TAF Design Worksheet TAF Stability section. Use the 20% AEP design storm event flow and identify the maximum velocities through or adjacent to the TAF.
15. Include the hydraulic analysis, TAF Design Worksheet, TAF Checklist with submittal of the Permit Determination Request.

Boater safety should be considered in the TAF design in recreational waters to avoid entrapment, adverse hydraulic conditions, or unexpected barriers.

Tier 3 TAF Analysis is a more complex iterative approach to determining modified construction and hydraulic requirements for the TAF design. This iterative approach requires the evaluation of risks of water inundating the TAF and thus preventing the contractor from accessing the waterway. Tier 3 analysis requires lowering the Standard Temporary Discharge (2xMMF) to a flow resulting in a backwater equal to the height of the TAF. The TAF height may also need to be raised from the standard 1' above the OHWM elevation. Tier 3 analysis will generally be necessary in tailwater controlled waterways. For these waterways, the water surface elevation can significantly rise with respect to relatively low river flows. The designer should consider that TAFs in these waterways may be inundated by water for extended periods thus rendering them inaccessible. Ensure that critical work dates are not planned during periods when high probability rainfall events may inundate the TAF. Tier 3 TAF Analysis should be coordinated with ODOT to identify contract risks, project schedules, potential environmental impacts, etc.

The goal of the Tier 3 analysis approach is to provide a TAF that can pass a flow rate without overtopping while facilitating the construction schedule. Determining an appropriate flow for the STD begins by obtaining historical waterway flows from the closest USGS Gage for the past 10-years if available. Flows at the project location can be directly proportionate to the decrease or increase in watershed size. If no gage data is available for the waterway, coordinate with ODOT for guidance. Identify a flow rate that can be passed through and/or around the TAF without producing a backwater exceeding the height of the TAF and will facilitate the anticipated construction schedule. Consider the probability of exceedance of the flow rate compared to the critical work times/durations when the contractor will need access to the TAF to progress the work. As an example, these critical work items may include demolition and/or construction of piers, setting bridge beams, pouring bridge decks, installation/removal of etc.

The designer may need to run multiple scenarios varying the STD, Hydraulic Opening and TAF height. The TAF height should be set as low as possible to prevent negative flooding impacts, but high enough to reduce delay risks and facilitate construction of the work items.

The TAF Stability analysis identifies whether high velocities may be experienced when the TAF is installed and approximates a minimal Dumped Rock Fill Type that would resist erosion from a specified channel velocity. Designers may need to apply a factor of safety appropriate for the hydraulic model that is being utilized for the analysis. Velocities may not be represented accurately using 1-dimensional hydraulic modeling. The factor of safety may vary depending on the unique waterway characteristics and anticipated TAF. i.e., TAFs in high velocity areas of the Maumee River where the TAF is obstructing a portion of the channel may experience increased velocities adjacent to the TAF as flow moves around the obstruction.

Reference the OES Recreational Boating Guidance document for additional guidance for work within recreational waters.

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1100 Drainage Design Procedures

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1101 Estimating Design Discharge

1101.1 General

The rational method and the USGS regression equations require the determination of drainage basin characteristics such as the contributing drainage area. Use a suitable topographic map or contours generated from LiDAR data collected through OSIP to develop the drainage area.

C1101.1

In order to design highway drainage facilities properly a reasonable estimate must be made of the required design and check storm discharges. Factors affecting discharge are duration, intensity and the AEP frequency of the rainfall as well as the contributing drainage area size, shape, slope and land use.

Historically, for drainage areas over 100 acres, 7.5-minute USGS Quadrangles were used. For smaller drainage areas, or where discharges were calculated using the rational method, lesser scale maps were utilized.

Other methods that use GIS such as USGS StreamStats are acceptable.

Verify drainage areas automatically delineated by software.

Make an evaluation of the land use throughout the drainage area. Consider changes in land use within the drainage area which will occur before the anticipated date of project construction.

Do not assume probable land use changes beyond the start of construction when determining design discharges. It is the responsibility of the local permitting/zoning agency to ensure proper land and water management techniques are utilized. These techniques will minimize the adverse effects of a change in land use.

1101.2 Procedures

1101.2.1 Rational Method

Use this method for drainage areas up to a maximum of 100 acres where no well-defined natural channel exists, and sheet flow prevails.

The design discharge **Q** is obtained from the Rational Equation:

$$Q = CiA$$

Where:

Q = Discharge (cfs)

C = Coefficient of runoff

i = Average rainfall intensity in inches per hour, for a given AEP storm and for a duration equal to the time of concentration.

A = Drainage area (acres)

C1101.2.1

The rational method is an empirical approach used for estimating the discharge at a point of concentration for small drainage areas. It assumes that the storm duration equals the time of concentration. The time of concentration is used with the appropriate IDF curve to find the design intensity.

The time of concentration is the time for the runoff to flow from the most remote point of the drainage area to a point of concentration.

The point of concentration could be a catch basin, inlet or a location in a roadway ditch when checking for shear protection and depth of flow.

Time of concentration is designated by $\mathbf{t_c}$ and is the summation of the time of overland flow $\mathbf{t_o}$, the time of shallow concentrated flow $\mathbf{t_s}$ and the time of pipe or open channel flow $\mathbf{t_d}$.

$$t_c = t_o + t_s + t_d$$

The time of overland flow may be obtained from Figure 1101-1 a similar overland flow chart, or from the equation:

$$t_o \approx \frac{1.8(1.1 - C)L^{1/2}}{S^{1/3}}$$

Where:

t_o = Time of overland flow (minutes)

C = Runoff coefficient

L = Distance to most remote location in drainage area (ft)

S = Overland slope (percent)

This equation and Figure 1101-1 assume a homogeneous drainage area. Where the overland flow area is composed of segments with varying cover and/or slopes, the summation of the time of concentration for each segment will tend to over-estimate the overland flow time, $\mathbf{t_o}$. In this case it may be more appropriate to use an average runoff coefficient **C** and an average ground slope in the Overland Flow Chart.

The overland flow equation is from the U.S. Department of Transportation publication, FAA: Advisory Circular 150/5320-5B [FAA, 1970]. The equation was developed from airport drainage data collected by the U.S. Army Corps of Engineers and is best suited for small drainage areas with fairly homogeneous surfaces.

Overland flow maintains a uniform depth across the sloping surface. It is often referred to as sheet flow.

The velocity of shallow concentrated flow can be estimated using the following relationship:

$$V = 3.3ks^{1/2}$$

Where:

V = Velocity (fps)

k = Intercept coefficient (see Table 1101-1)

s = Overland slope (percent)

Sheet flow is assumed to occur for no more than 300 feet after which water tends to concentrate in rills and then gullies of increasing proportion. This type of flow is classified as shallow concentrated flow. For 300 feet assume a homogeneous drainage area.

Table 1101-1

Types of Surface	k
Forest with heavy ground litter	0.076
Min. tillage cultivated; woodland	0.152
Short grass pasture	0.213
Cultivated straight row	0.274
Poor grass; untilled	0.305
Grassed waterways	0.457
Unpaved area; bare soil	0.491
Paved area	0.619

Shallow concentrated flow velocity equation and Table 1101-1 are referenced from HDS-2 [McCuen et al., 2002] section 2.6.2.2

Shallow concentrated flow generally empties into pipe systems, drainage ditches, or natural channels. The velocity of flow in an open channel or pipe can be estimated using the Manning's equation.

The travel time for both shallow concentrated flow and open channel or pipe flow is calculated as follows:

$$t_s \text{ or } t_d = \frac{L}{60V}$$

Where:

t_s = Travel time for shallow concentrated flow (minutes)

t_d = Travel time for open channel or pipe flow (minutes)

L = Flow length (ft)

V = Velocity (fps)

Where a contributing drainage area has its steepest slope and/or highest **C** value in the sub-area nearest the point of concentration, the rational method discharge for this sub-area may be greater than if the entire contributing drainage area is considered. Consider the maximum runoff rate for a sub-area only if it is greater than that for the entire area.

1101.2.2 Runoff Coefficient

The recommended values for the runoff coefficient **C** for various contributing surfaces are shown in Table 1101-2. Where two values are shown, the higher value ordinarily applies to the steeper slopes.

C1101.2.2

The runoff coefficient is a dimensionless decimal value that estimates the percentage of rainfall that becomes runoff.

Table 1101-2

Types of Surface	C
Pavement & paved shoulders	0.9
Berms and slopes 4:1 or flatter	0.5
Berms and slopes steeper than 4:1	0.7
Contributing areas	
Residential (single family)	0.3-0.5
Residential (multi-family)	0.4-0.7
Woods	0.3
Cultivated	0.3-0.6

See HDS-2 [McCuen et al., 2002] section 5.3.3 for additional runoff coefficient values.

The total area contributing flow to a given point usually consists of surfaces having varying land cover and therefore requires a weighted runoff coefficient.

See HDS-2 [McCuen et al., 2002] section 5.3.2 for weighted runoff coefficient determination.

1101.2.3 Rainfall Intensity

The average rainfall intensity **i** in inches per hour may be obtained from the Intensity-Duration-Frequency curves shown on Figure 1101-2. Each set of curves applies to a specific geographic area, A, B, C, or D as shown on the Rainfall Intensity Zone Map. Some political subdivisions may have developed curves for their specific area similar to Figure 1101-2. These curves may be based on a much longer period of record and provide more reliable information. Any local curves proposed by the designer require approval from OHE prior to incorporating that information in the drainage calculations.

C1101.2.3

The geographic areas were established from an analysis of rainfall records obtained from Weather Bureau stations in Ohio.

1102 Open Water Carriers

1102.1 General

Design open water carriers with a minimum slope of 0.50% with a recommended absolute minimum of 0.25%. Lesser slopes can be used on large width open water carriers.

Maintain a constant slope wherever possible and provide an adequate outfall with positive drainage. Perpetuate existing drainage patterns as much as practicable.

Avoid capturing an existing stream with the roadside ditch. If this is necessary, design the ditch

C1102.1

Open water carriers generally provide the most economical means for collecting and conveying surface water from the roadway. The required capacity of a water carrier involves a determination of the velocity and depth of flow for a given discharge.

Standard ditches are open water carriers. Large width open water carriers are channels.

in accordance to Section 1102.2.4.

1102.2 Types of Open Water Carriers

1102.2.1 Normal Ditches

A ditch is normal when:

A. The centerline is parallel to the edge of the pavement.

B. The flowline is a uniform distance below the edge of the pavement.

Refer to LD1, Section 307 for more information on normal ditch shape, size and placement for common, safety, clear zone and barrier grading.

1102.2.2 Special Ditches

Refer to LD1, Section 307 for more information on where special ditches are required.

1102.2.3 Median Ditches

A median ditch is defined by location and have the same shape and capacity features as normal ditches.

1102.2.4 Channel Relocations

Design Channel relocations or ditch stream captures as follows:

A. Use the design AEP storm specified in Section 1004.2.

B. Design all channel relocations to prevent erosion.

C. Whenever possible, limit channel relocations to the downstream end of the proposed culverts.

D. Perpetuate the existing cross section including a two-stage channel if evident. See Figure 1101-2 for a graphical representation of the major channel features.

E. Perpetuate the existing channel as closely as possible in regard to existing geomorphic conditions; channel slope and length, velocity, depth of flow, channel sinuosity, energy dissipation, etc.

F. Duplicate the existing hydraulic properties for the bankfull design AEP storm. Meet the flood clearance criteria given in Section 1005.

C1102.2.4

Avoid major channel relocations.

Information on the design of relocated channels can be found in the USDA National Engineering Handbook 653 [FISRWG, 1995]. The principles given in this publication utilize idealized channel geometry.

A two-stage channel is comprised of two distinct areas. The first of these is a meandering bankfull width that carries the channel-forming discharge. The second area is the flood plain width.

Establish the existing channel geometry and physical characteristics from reference reaches and idealized geometry. Select the reference reaches from stable channel reaches close to the relocated section or in locations with similar watershed and valley conditions.

1102.2.5 Channel Linings and Bank Stabilization

Use soil bioengineering to stabilize banks for channel relocations or ditch stream captures.

Specify native plant species.

C1102.2.5

Bank stabilization using bioengineering is covered in the previously referenced USDA publication as well as the AASHTO Model Drainage Manual [AASHTO, 2005] and the USDA Engineering Field Handbook, Chapter 16 [USDA, 1996], part 650. The design procedures and methods for determining the effectiveness of the traditional channel linings are covered in HEC-15 [Kilgore & Cotton, 2005].

1102.3 Ditch Design Criteria

1102.3.1 Design AEP Storm

Determine the depth of flow and the shear stress based on the following recurrence interval:

ADT	Depth of Flow Design AEP	Shear Stress Design AEP
<3000	20%	50%
≥3000	10%	20%

Use a minimum time of concentration of 15 minutes for analyzing the first ditch section.

Where a flexible ditch lining is required for calculated stresses exceeding the allowable for seed, the minimum width of the lining is 4 feet. Additional required width is in increments of 3.5 feet. The installed width of all ditch linings is centered on the flow line of the ditch.

The depth of flow is limited to an elevation 1 foot below the edge of pavement for the design discharge. The depth of flow in toe of slope ditches is further limited such that the design AEP discharge does not overtop the ditch bank.

C1102.3.1

If erosion has been an issue or the time calculated is significantly less, then a minimum time of 10 minutes can be assumed.

4 feet is a common commercially available width for flexible ditch lining. Additional width is achieved with a minimum 0.5 foot overlap.

1102.3.2 Ditch Protection

The shear stress for the Design AEP storm cannot exceed the values shown in Table 1102-1 for the various flexible linings.

Table 1102-1

Permanent Protection	
Protective Lining	**Allowable Shear Stress (lbs./ft^2)**
Seed (659)	0.40
Sodding, Ditch Protection (660)	1.0
Temporary Protection	
Item 670 Ditch Erosion Protection Mat Type __	
B	1.50
C	2.0
E	2.25
G	1.75

The temporary linings will reach a value of 1.0 lbs./ft^2 upon vegetation establishment. Use the temporary lining shear stress values in Table 1102-1 on a temporary basis of 6 months or less.

Calculate the actual shear stress by the following equation:

$$\tau_{ac} = 62.4DS$$

Where:

D = Water surface depth (ft)

S = Channel slope (ft/ft)

τ_{ac} = Actual shear stress (lbs./ft^2)

If the calculated shear stress exceeds that shown in table 1102-1 then use the following permanent shear stress values within the stated limitations:

A. Seeding and Erosion Control with Turf Reinforcing Mat, SS836, where the ditch slope is 10% or less. Allowable shear stress for each type is as follows:

Turf Reinforcing Mat Shear Stress	
Type	**Allowable Shear Stress (lbs./ft^2)**
1	3
2	4
3	5
4	6

B. Type B, C or D Rock Channel Protection may be used to line the ditch if the nearest point of the lining is outside the design clear zone or located behind guardrail or barrier. The actual shear stress is based upon the parameters of the channel slope and depth of flow for the 20% AEP discharge. The shear equation is valid for discharges less than 50 cfs with slopes less than 10%. Allowable shear stress for each type is as follows:

Rock Channel Protection Shear Stress	
Type	**Allowable Shear Stress (lbs./ft^2)**
B	6
C	4
D	2

C. Type B or C RCP may be utilized for lining ditches on profile grades from 10%- 25% that carry flow from the end of a cut section down to the valley floor. Use HEC-15 [Kilgore & Cotton, 2005] procedures with a safety factor of 1.5 for steep gradient channels. Contact OHE for further guidance of RCP usage for 20% AEP discharges greater than or equal to 50 cfs.

D. Tied concrete block mat protection, Item 601, may be used for slopes and channels. Provide for slopes that are 2:1 or flatter. Provide for channels when side slopes are 2:1 or flatter and profile grades are 25% or less. The matting may be used within the clear zone when the top of the blocks are flush with the finished grade. Install per the manufacturer recommendations. The allowable shear stress for each type is 12 lbs/ft^2. Specify Type 1 underlayment as the standard option. Provide Type 2 Underlayment in areas where establishing vegetation is difficult, such as, areas with poor soils, flumes on steep slopes, or areas subjected to constant flow.

E. Articulating concrete block revetment system, Item 601, may be used for slopes and channels with 2:1 or flatter side slopes. The revetment may be used within the clear zone when the top of the blocks are flush with the finished grade. Install per the manufacturer recommendations. The allowable shear stress for each type is as follows:

Articulating Concrete Block Revetment System Shear Stress	
Type	**Allowable Shear Stress (lbs./ft²)**
1	17
2	20
3	23

F. Consider a concrete lining only as a last resort. Contact OHE, before using a concrete lining.

1102.3.3 Roughness

Suggested values for Manning's Roughness Coefficient **n** for the hydraulic analysis of various types of open water carrier linings are listed in Table 1102-2.

Table 1102-2

Manning's Roughness Coefficient	
Type of Lining	**n**
Bare Earth	0.02
Seeded	0.03
Sod	0.04
Turf Reinforcing Mat	0.04
Item 670	0.04
Concrete	0.015
Bituminous	0.015
Grouted Riprap	0.02
Tied Concrete Block	0.03
Rock Channel Protection	0.06 for ditches 0.04 for large channels

1102.3.4 Catch Basin Types

CB-4, CB-5 and CB-8 basins are suitable for the standard roadside designs covered in LD1. The bases can be expanded to accommodate larger diameter conduits by specifying SCD CB-4A , 5A, 8A.

The bar spacing can be decreased for safety reasons, by specifying Grate **E** for CB-4 and Grate **B** for CB-5. Provide 150 feet of Item 670, Ditch Erosion Protection, upstream of all CB-4, CB-5 and CB-8 basins, regardless of velocity.

The following catch basin types are generally recommended based on the size and shape of the ditch.

C1102.3.4

The tilt built into the basin top provides a self-cleaning feature when the basins are used on continuous grades. The wide bar spacing minimizes the possibility of clogging, resulting in an efficient design.

A. CB-4 for depressed medians wider than 40 feet.

B. CB-5 for 40-foot radius roadside or median ditches. Use Grate **B** where pedestrian traffic may be expected.

C. CB-8 for 20-foot radius roadside or depressed medians 40 feet or less in width.

D. CB-2-2-A in trapezoidal ditches where the basin is in a rural area. Locate the basin outside of the design clear zone or behind guardrail. The capacity of the side inlet window, for unsubmerged conditions, may be determined by the standard weir equation:

$$Q = CLH^{3/2}$$

Where **C** is a weir coefficient, generally 3.0, L is the length of opening in feet, **H** is the distance from the bottom of the window to the surface of the design flow in feet. The catch basin grate is considered as an access point for the storm sewer and its capacity to admit flow is ignored for continuous grades.

E. Use a CB-2-2-B basin where minor, non-clogging flows are involved such as yard sections and the small triangular area created by the guardrail treatment for a depressed median at bridge terminals. Provide CB-2-3 through CB-2-6 basins where a larger base is required to accommodate conduits greater than 21 inches in span or sewer junctions, or where a CB-2-2-B will not provide adequate access to the sewer.

F. In urban areas use Standard Side Ditch Inlets to drain small areas of trapped water behind curbs and/or between driveways.

For lower ADT highways consider using CB-5, CB-2-2-A, within the safety limitations as discussed in Section D above, and CB-2-2-B. Where additional capacity is required use CB-4.

For catch basin details refer to the Hydraulic SCDs.

1102.3.5 Calculated Catch Basin Spacing

Provide catch basins to intercept flow from open water carriers when the depth of flow or shear exceeds the maximum allowable for the design storm for all highway classifications.

When the calculated depth of flow or shear exceeds the maximum allowable at the checkpoint in the ditch, a catch basin or ditch lining will be required. However, the capacity of the catch basin may be

C1102.3.5

CB-4, CB-5 and CB-8, include an earth dike. The dike is approximately 12 inches above the flowline of the grate, immediately downstream from the catch basin and serves to block the flow on continuous grades and create a sump condition.

less than the capacity of the ditch and thereby control the catch basin spacing. Figure 1102-1 is used to check the capacity of a catch basin grate in a sump. To use Figure 1102-1, double the calculated discharge at the ditch checkpoint to compensate for possible partial clogging of the grate.

In cut sections, carry the accumulated ditch flow as far as the capacity, allowable depth, or shear of flow will permit. The first catch basin in the roadside or median ditch will determine the need for a storm sewer system required for the remainder of the cut. Extend shear control as far as inexpensive flexible ditch linings will permit.

When locating ditch catch basins, provide positive outlets for underdrains and access to longitudinal sewer systems.

1102.3.6 Arbitrary Maximum Catch Basin Spacing

Catch basins are required at the low point of all sags. Omit the earth dike shown on the standard construction drawings when used in a sag. The maximum distance between catch basins in depressed medians in fill sections is as follows:

Depressed Median Catch Basin Spacing (Fill Sections)		
Median Width (ft)	**Desirable Spacing (ft)**	**Maximum Spacing (ft)**
84	1250	1500
60	1000	1250
40	800	1000

Where underdrains are utilized, place catch basins at a maximum spacing of 1000 feet to provide a positive outlet for the underdrains.

1103 Pavement Drainage

1103.1 General

Refer to the LD1 for pavement cross-slope design criteria.

When curb or barrier is provided, determine the proper type of pavement inlet or catch basin to control the spread of water into the traveled lane. Maximize the allowable spread without exceeding the allowable depth of flow at the face of curb or barrier.

C1103.1

When paved shoulders are provided, the drainage cost can be decreased due to the large volume of flow that can be carried on the pavement shoulder.

Additional information concerning pavement drainage can be obtained from HEC-22 [Brown et al., 2009].

Reduce the need for bridge scuppers by intercepting the flow prior to the bridge.

1103.2 Design AEP Storm

Locate pavement inlets or catch basins to limit the spread of flow on the traveled lane to those shown in Table 1103-1. Base the design on the following recurrence interval:

Facility	Design (AEP)
Interstates, Freeways & Expressways	10%
High Volume Highways (Over 6000 ADT)	20%
All other Highways	50%

For underpasses or other depressed roadways where ponded water can be removed only through the storm sewer system, check the spread for a 2% AEP storm on Interstates, Freeways & Expressways, and other High-Volume highways as defined above. Use a 4% AEP storm on other multiple lane highways. Ponding is permitted to cover all but one through lane of a multiple lane roadway or one-half of a lane on a 2-lane highway. No ponding is permitted into the traveled lanes of an interstate highway for the 2% AEP sag check.

The depth of flow or ponding at the curb cannot exceed 1 inch below the top of the curb for the design storm discharge regardless of the type of highway. A maximum depth of 6 inches is permitted where a barrier is provided.

Table 1103-1

Facility	Allowable Pavement Spread* (ft)
Interstates, Freeways & Expressways	0
High Volume Highways (Over 6000 ADT)	
≥ 45 mph	4
< 45 mph 2 lanes	6
4 lanes	8
All other Highways	
2 lanes	6
≥4 lanes	8

* Pavement spread applies only to the through lane and assumes a 12 ft. lane width.

The speeds listed in the manual are design speeds.

C1103.2

These criteria are intended for sag locations with no outlet except through the storm sewer system. Examples include sag locations with barrier wall, underpasses, or other depressed cut sections without an alternative outlet. Typically, these criteria do not apply to 2-lane or other curbed roadway facilities where water can overtop the curb. Contact OHE if encountered.

The criteria for interstate sags are based on Code of Federal Regulation 23 CFR 650.115 requirements.

Where lanes are less than the standard 12 ft. lane width, reduce the allowable spread an equal amount. Therefore, 11 ft. lanes on All other Highways with 2 lanes will have an allowable spread of 5 ft. instead of 6 ft.

Allowable spread may be increased proportionally within roundabouts to account for the wider lanes and reduced speeds.

For flow less than 0.75 cfs, the use of curb cuts with a flume may be considered in lieu of inlets along the legs of roundabouts in rural areas.

In some instances, using the legal speed instead of the design speed will result in a more practical pavement spread design. Contact OHE if encountered.

Provide a minimum 10 ft dry lane width HSR lane.

If design requirements cannot be met, contact OHE for guidance in a Performance Based Practical Design.

PBPD focuses on performance improvements that benefit both project and system needs rather than strict adherence to published standards. Standards are not abandoned but all factors are considered to produce a balanced decision that does not compromise safety.

1103.3 Estimating Design Discharge

Estimate runoff contributing to curbed pavements by the rational method, as explained in Sections 1101.2.1, 1101.2.2 and 1101.2.3.

The time of concentration $\mathbf{t_c}$ is the actual time of concentration calculated according to Section 1101.2.2 with an absolute minimum time of 10 minutes.

Contact OHE when the contributing drainage area is difficult to determine, and the calculations indicate the need for more basins than existing or the required spacing between basins is less than or equal to 100 feet.

C1103.3

The profile and cross section of the roadway may need to be modified to obtain a reasonable basin spacing by using a rolling gutter profile. If the geometrics cannot be revised, a contributing drainage area will need to be assumed. Use the entire contributing drainage area for the storm sewer design.

1103.4 Capacity of Pavement Gutters

Use the following equation to determine flow capacity for a standard curb and straight pavement slope:

$$Q = \frac{0.56ZS^{1/2}Y^{8/3}}{n}$$

Where:

Q = Discharge (cfs)

Z = $1/S_x$

n = Manning's Coefficient of Roughness (Table 1102-2)

S = Longitudinal pavement slope (ft/ft)

Y = Depth of flow in gutter section at curb (ft)

Use the following equations to determine flow capacity for a composite gutter section:

$$Q_1 = (0.56ZS^{1/2}Y^{8/3})/n_{(1)}$$

C1103.4

The longitudinal slope can vary on the approach to the inlet or catch basin, especially in a sag. When flatter grades are located at a sump, using the flatter slope will underestimate the overall gutter capacity and result in overestimated spread values. Examine the approach lengths of the grades to determine an average slope. If one of the grades has a much longer approach length, use this most predominant slope.

On curbed facilities, design sag vertical curves to prevent inadequate drainage near the bottom. This can be achieved by providing a minimum longitudinal slope of 0.3 percent at the two points 50 ft. from the bottom. This yields a maximum value of K = 167 for the vertical curve, which is typically called the drainage maximum.

Composite Gutter Section: In most cases, the top width of the water surface in a pavement gutter far exceeds the height of the curb. The hydraulic radius does not accurately describe the gutter cross section in this situation, thereby requiring a modification to the Manning's equation to analyze

$$Q_2 = (0.56ZS^{1/2}Y_1^{8/3})/n_{(1)}$$

$$Q_3 = (0.56ZS^{1/2}Y_1^{8/3})/n_{(2)}$$

$$Q_{Total} = Q_1 - Q_2 + Q_3$$

Where:

Q_1,Q_2, Q_3 = Discharge in each triangular segment (cfs)

Z = $1/S_x$, use $S_{x(1)}$ for Q_1 and Q_2, use $S_{x(2)}$ for Q_3

$n_{(1)}$ & $n_{(2)}$ = Manning's Roughness Coefficient (Table 1102-2)

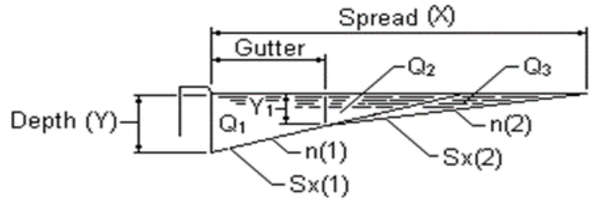
S = Longitudinal pavement slope (ft/ft)

Y = Depth of flow in gutter section at curb (ft)

Y_1= Depth of flow at gutter/pavement interface (point of slope change) (ft)

When the longitudinal slope varies along the gutter, use the average or most prominent slope for the analysis.

the gutter flow.



1103.5 Bypass for Continuous Pavement Grades

Add the flow bypassing an inlet or catch basin to the total flow of the adjacent downstream gutter section.

C1103.5

Flow bypasses inlets and catch basins as inflow capacity is exceeded. Capacity depends on geometry and catchment characteristics.

CB-3A and CB-3 catch basins generally provide the most economical inlet spacing design. Investigate the use of I-2A and I-2 inlets when the catch basin bypass becomes excessive on continuous grades. This is especially the case when a CB-3 is investigated with little reduction in the bypass. An inlet can reduce the amount of bypass thus reducing the number of catch basins necessary. Size the inlet window length to bypass 10% to 15% of the design discharge. It is not intended to establish the required spacing. The use of inlets is limited to sections without a gutter. The most efficient design maintains the allowable spread on continuous grades and at the sag.

1103.5.1 Curb and Barrier Opening Inlets

Avoid the use of curb opening inlets where bicycle traffic is anticipated.

Provide barrier inlets with a grate on one side unless placement is not feasible. Approval from the District is required when using barrier inlets

C1103.5.1

Grates allow easier access for future maintenance.

without a grate.

Where barrier inlets are placed on continuous grades, the window opening is the primary design feature with the grate considered as a factor of safety only. Locate the grate on the side of the barrier with the largest flow.

1103.5.2 Grate or Combination Grate and Curb Opening Catch Basin

Calculate flow intercepted over the outside edge of the grate using the following equations:

$$Q_a/L_a = 0.7(A + Y_2)^{3/2}\left(1 - \left(1 - \frac{Y_2}{A + Y_2}\right)^{5/2}\right)$$

$$L_a = \frac{Q_a}{\frac{Q_a}{L_a}}$$

$$Q/Q_a = \frac{\left(\frac{A}{Y_2} + 1.0^{5/2}\right) - \left(\frac{A}{Y_2} + 1 - \frac{L}{La}\right)^{5/2}}{\left(\frac{A}{Y_2} + 1.0\right)^{5/2} - \left(\frac{A}{Y_2}\right)^{5/2}}$$

$$Q_i = Q_a\left(\frac{Q}{Q_a}\right)$$

Where:

Q_a= Flow outside the width of the grate (cfs); grate is assumed to capture 100% of flow within the grate width

L_a = Length required for 100% capture of flow bypassing grate (ft)

L = Length of grate (ft)

A = Depression at edge of grate edge nearest the pavement centerline (ft)

Y_2 = Depth at the edge of grate edge nearest the pavement based on the flow (without depression added) (ft)

Q = Total Flow in section just before the catchment (cfs)

Q_i = Flow intercepted over side of grate (cfs)

The total flow bypassing the catchment and efficiency is calculated using the following equations:

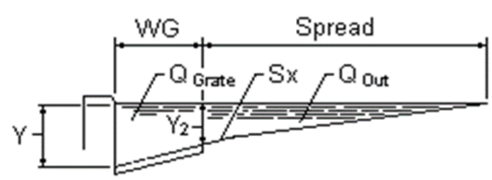
$$Q_b = Q - Q_i$$

C1103.5.2

Pavement catch basins in this category are considered to intercept all flow over the grate when used on continuous grades. The curb opening of a combination catch basin on a continuous grade will admit some flow; however, the additional capacity is not accounted for.

A portion of the flow outside of the edge of the grate will also be intercepted, the amount varying with the depth of flow Y2 along the edge of the grate. This flow is calculated as a window opening at the edge of the grate with an opening depth of Y2 with a length equal to the grate length.

Composite Gutter Section with Grate:



The same equations can be used for curb inlets to determine the required window opening length. Use Y in lieu of Y_2 in the equations, which is at the face of the curb.

Section 1103.9 Slotted Drains and Trench Drains are designed with the same equations.

$$E = \left(\frac{Q}{Q_a}\right)100$$

Where:

Q_b = Bypass Flow carried to next catchment (cfs)

E = Efficiency of catchment (%)

Curb opening inlets hydraulic capacity can be enhanced by using a local depression at the face of curb.

Likewise, grate hydraulic capacity can be increased by using a local depression at the face of the grate closest to the centerline of the roadway.

The local depression is not the same depression identified in the standard construction drawings for catch basin grates.

See Figure 1103-1 for local depression location and values for various pavement drainage structures.

For inlet and catch basin details refer to the Hydraulic SCDs.

1103.6 Grate Catch Basins and Curb / Barrier Opening Inlets in Pavement Sags

C1103.6

The spread in the sag is determined from the depth of flow at the edge of grate and includes the total flow contributed from each side of the sag vertical curve reaching the inlet or catch basin.

Flat profile grades in sags often lead to an excessive number of basins based on spread calculations. For this situation, consider PBPD where the spread is not checked any closer than 25 to 50 feet between basins leading up to the sag.

Provide a flanking inlet or catch basin on both sides of the pavement sag on Interstates, Freeways & Expressways. Place them where the grade elevation is approximately 0.20 feet higher than the low point. On barrier sections; place 3 barrier inlets. On curbed sections; place flanking 6 foot inlets or CB-3As with a CB-3 at the low point.

Three inlets or catch basins in a sag can only be justified on the basis of need for other highway classifications.

When barrier inlets are placed in pavement sags, locate the grate on the side with the greatest flow. The grate is considered the primary design feature with the window as the factor of safety with the local depression at the front face of the grate per 1103.5.2.

The capacity of the grates is based on weir flow over the edge of the grate, up to a depth of 0.4 feet. For greater depths, the total area of grate opening is considered, with no deduction made for possible clogging. When evaluating the spread in a depressed sag for a 4% AEP or 2% AEP event, the capacity of the window is considered a factor of safety.

The capacity of the grates is based on the depth of ponding around the grates.

For inlet and catch basin details refer to the Hydraulic SCDs.

A CB-6 catch basin may be used along curbed roadways and medians provided that the grate capacity is not exceeded.

1103.7 Arbitrary Inlets and Basins

Place inlets or catch basins arbitrarily upstream of all intersections, bridges and pedestrian ramps. When justified, locate inlets or catch basins a minimum of 10 feet off drive aprons, intersection return radii, pedestrian ramps or curb termini.

C1103.7

Minimal flows at these locations do not justify arbitrary placement.

Consider grading out local minimal sag locations along curb radii at side roads to avoid ponding near curb ramps and reduce the number of inlets required.

1103.8 Bridge Drainage

1103.8.1 Bridge Deck Drainage

Design a minimum longitudinal grade of 0.3% for the bridge deck surface when using concrete parapets.

Minimize or eliminate the use of scuppers.

Calculate the allowable spread of flow using procedures described above.

The fraction of flow captured by the scupper can be determined by the following equation:

$$E = 1 - \left(1 - \frac{W}{T}\right)^{2.67}$$

Where:

E = Scupper efficiency

W = Width of scupper (ft)

T = Total width of spread (ft)

The scupper bypass flow can be determined by the following equation:

$$Q_b = Q(1 - E)$$

Where:

Q_b = Bypass discharge (cfs)

Q = Total discharge in gutter (cfs)

E = Scupper efficiency

Scupper bypass flow can also be determined with the spreadsheet found at the OHE Design Resources web page or similar.

Locate scuppers inside the fascia beam unless the parapet and beam spacing make this impractical. Design scuppers with vertical drops or nearly vertical drops when feasible. If a scupper pan is

C1103.8.1

On flatter longitudinal slopes, scuppers will intercept a portion of flow slightly wider than the width of the scupper (side flow), while on steeper longitudinal slopes, a portion of the flow in the gutter section occupied by the scupper (frontal flow) may splash over the grate. Assuming side capture and splash over are negligible, the frontal flow ratio is considered equal to the inlet efficiency.

Information concerning bridge deck drainage can be obtained from HEC-21 [Young et al., 1993]. Software utilizing methods outlined in HEC-21 are also acceptable for scupper analysis.

required, angle the pan as steeply as possible.

Design an uncollected / free fall per SCD GSD-1-19. When SCD GSD-1-19 will not physically fit due to the parapet, beam line or deck overhang, substitute heavy-duty cast iron deck drains as currently manufactured by Neenah or equal. If a drainage collection system is required. meet the following:

A. System is sloped greater than or equal to 15 degrees.

B. Bends have a minimum radius of 18 inches.

C. Bends have angles greater than 90 degrees.

D. Cleanout plugs are easily and safely accessible.

E. Include drainage collection when using finger joints or sliding plates. Provide a neoprene drainage trough under finger joints. Show the necessary deck drainage outlet locations on the preliminary structure site plan. Include this information in the STS.

Place scuppers with drainage collection systems close to the substructure unit which drains them. Place uncollected / free fall scupper downspouts as far from any part of the substructure as possible.

1103.8.2 Erosion Control at Bridge Ends

Provide curb from the end of the parapet to a basin or flume in order to collect and carry bridge deck drainage that flows off the ends of the bridge in accordance to the following:

A. Flow less than 0.75 cfs for bridges without MSE walls – Provide a flume, as shown on SCD DM-4.1. Locate the flume beyond the limits of the Bridge Terminal assembly.

B. Flow greater than 0.75 cfs for bridges without MSE walls - Provide a CB-3A Catch Basin located off the approach slab and outside the curb height taper length. Locate the basin beyond the limits of the Bridge Terminal assembly. Provide a Type F, broken back conduit per Figure 1104-1 for an outlet down the embankment slope and armor the outlet to prevent erosion.

   For bypass flow greater than 0.5 cfs, provide a flume downstream from the basin at the end of the curb per SCD DM-4.1.

C. Bridges with MSE Walls – Provide a barrier at the approach slab with a standard barrier inlet. Locate the inlet outside of the MSE wall soil reinforcement and the barrier transition.

C1103.8.2

For catch basin details refer to the Hydraulic SCDs.

The barrier inlet is placed outside of the MSE wall to protect against the loss of the MSE wall select granular backfill.

Place Item 670, Slope Erosion Protection, on all bridge approach embankment corner cones beginning at the edge of the crushed aggregate or concrete slope protection.

1103.9 Slotted Drains and Trench Drains

Slotted drains and trench drain systems are susceptible to clogging and are not recommended where significant sediment or debris load is present.

Locate slotted drains and trench drains longitudinally with the edge of pavement. Keep the drain and any surrounding concrete outside of the travelled way. Locate trench drains at the end of commercial drives to intercept large flows before entering the travelled way.

Outlet the slotted and trench drains to a CB-6 catch basin. Provide a CB-6 at a minimum 100 ft. interval for slotted drains and 200 ft. interval for trench drains.

Slotted drains and trench drains intercept flow capacity is best represented by HEC-22 [Brown et al., 2009] equations 4-22a, 4-32, and 4-33 for Curb-Opening Inlets.

On grade:

$$L_T = K_T\, Q^{0.42}\, S_L^{0.3}[1/(n\, S_x)]^{0.6} \qquad (4\text{-}22a)$$

Where:

L_T = Total length of drain required (ft)

K_T = 0.6 (unitless, US Customary)

Q = Total discharge in gutter (cfs)

S_L = Longitudinal slope (ft/ft)

S_x = Pavement cross slope (ft/ft)

n = Manning's coefficient (unitless)

In a Sag Condition*:

For a flow depth < .2 ft. (Weir Flow)

$$L_T = Q\,/2.48\, d^{1.5} \qquad (4\text{-}32)$$

For flow depth: d > .2 ft. (Orifice Flow)

$$L_T = Q\,/\,0.8\, W(2\, g\, d)^{0.5} \qquad (4\text{-}33)$$

C1103.9

Slotted and trench drains are used to capture sheet flow in areas where curb is not present. They collect and direct flow to a catch basin such as in a gore area.

For slotted drain and catch basin details refer to the Hydraulic SCDs.

Including CB-6 catch basins facilitates future cleanout of the slotted and trench drain systems.

Where:

d = Flow depth at edge of gutter (ft)

g = 32.2 (fps)

W = Width of drain (ft)

*Assuming 50% clogging, a safety factor of 2 times the Total Length of Drain Required is recommended.

Refer to SCD DM-1.3 for slotted drain details. Include Plan Note D120 when using slotted drain.

Specify SS839 and SS939 when using trench drain.

1104 Storm and Sanitary Sewers

1104.1 Storm Sewers

Size storm sewer systems to carry the current flow from areas naturally contributing to the highway or from intercepting existing storm sewers.

Following the local drainage criteria and standards is not required on ODOT owned and maintained drainage assets. Storm sewer systems may be oversized at the request of a local government entity to carry flow from areas beyond those considered highway responsibility or increased flows from anticipated development with the approval of OHE. The additional cost to construct the increased sized storm sewer system are the responsibility of the local government. The project funding participation is determined as a percentage of the total cost of the affected plan items.

Where proposed highway storm sewers or ditches interfere with existing private drains carrying treated or untreated sanitary flow, submit the names and addresses of the affected property owners to the District Right-of-Way permit office with the following:

1. PID
2. County - Route - Section
3. Latitude and Longitude
4. Size and pipe type or swell size carrying the discharge

The District Right-of-Way permit office will check if a permit has been issued. If a permit has been issued the designer will provide an unrestricted continuance of the discharge. An inspection well will be furnished at the Right-of-Way line for all

C1104.1

Storm sewer systems are designed to collect and carry storm water runoff from the first pavement or ditch inlet or catch basin to the predetermined outlet. Long cut sections often result in the need for longitudinal trunk sewers to accept the flow from a series of inlets or catch basins. Perpetuate existing drainage patterns as much as practical. Consider the possibility of actionable damage for the diversion of substantial volumes of flow. Long fill sections requiring median or pavement drains may best be served by transverse sewers that outlet independently at the toe of fill ditch.

For examples of storm sewer detail sheets, reference Sample Plan Sheets 1312-3 and 1312-4, maintained by the Office of CADD and Mapping. These provide a useful resource for preparation of hydraulic plans in terms of layout and content.

For inlet and catch basin details refer to the at Hydraulic SCDs.

pipe discharges. If a permit has not been issued, then the District Right-of-Way permit office will pursue a discharge permit. If a discharge permit cannot be granted, then add Plan Note D111 to the General Notes.

Do not change the type of conduit for a short run of which would ordinarily require a different type.

An example of varying conduit type conditions in a single run: Use Type B conduit for the entire transverse storm sewer run that is draining an earth median catch basin in an embankment section under the pavement and then to a ditch outlet.

On high fill embankment with transverse drainage, terminate the Type B conduit at a point approximately 10 feet from the embankment slope and a concrete collar provided, per SCD DM-1.1, to connect the Type B and a Type F conduit. Provide Type F conduit, 707.05 Type C, 707.21 or 707.33 for the pipe used for the bend at the top and bottom of the embankment. A detail is provided in Figure 1104-1.

The C&MS specifies the allowable pipe shape and material. Base storm sewer designs on smooth interior round pipe. The choice of the material type is determined by the designer based on durability requirements.

When extending existing Type B & C conduits, the extensions must match the existing material in kind unless the durability is not adequate to satisfy the 75-year service life.

The length of conduit paid for is the actual number of linear feet measured from center-to-center of small structures. No deduction is made for catch basins, inlets or manholes that are 6 feet or less across, measured in the direction of flow. Conduits placed on slopes steeper than 3:1 or with beveled or skewed ends are measured along the invert.

Changes to grade may occur at existing manholes due to proposed work. With a decrease in grade of not more than 6 inches or an increase in grade of not more than 12 inches, the existing structure should be Adjusted to Grade. Where grade elevation changes are greater, the existing structure should be Reconstructed to Grade.

1104.2 Storm Sewer Design Considerations

1104.2.1 Depth

Keep a storm sewer system as shallow as possible following these guidelines:

A. For rigid pipe; provide a minimum height of cover of 15 inches to the pavement surface

C1104.2.1

See Glossary of Terms for the definition of cover and height of cover.

including a minimum cover of 9 inches to the top of the subgrade. Where the pipe is not under pavement, provide a minimum height of cover of 18 inches to the finished grade.

B. For flexible pipe; provide a minimum height of cover of 24 inches to the pavement surface including a minimum cover of 12 inches to the top of the subgrade. Where the pipe is not under pavement, provide a minimum height of cover of 24 inches to the finished grade.

C. Higher strength concrete pipe may be specified where the minimum cover requirements of A. cannot be met; provide a minimum height of cover of 10 inches to the pavement surface including a minimum cover of 4 inches to the top of the subgrade. Where the pipe is not under pavement, provide a minimum height of cover of 4 inches to the finished grade. Check with OHE to determine the required D-Load.

D. Provide adequate depth to permit the use of precast inlets, catch basins and manholes. Refer to the Hydraulic SCDs for this information. Consider the sewer pipe thickness. No part of the pipe can extend into the precast top section.

E. Provide adequate depth to avoid interference with existing utilities.

F. Provide adequate depth to create a positive outlet for underdrains with the underdrain outlet generally 12 inches above the flow line of the outlet structure with 6 inches as a minimum.

G. Provide sufficient slope to maintain a recommended minimum velocity of 3 fps, for self-cleansing.

The cleanout velocity is a recommendation for both design and existing conditions. Avoid extensive alteration of the storm sewer to meet this recommendation.

H. Match the crown of a smaller upstream pipe in a longitudinal trunk sewer to the crown of the adjacent downstream pipe.

1104.2.2 Longitudinal Location

1104.2.2.1 Under Pavement

Longitudinal sewers are not permitted under the pavement of a limited or controlled access facility. Minimize the length of transverse sewers under pavements, with the objective of not placing manholes in the pavement.

For other facilities, locate storm sewers outside the limits of the pavement. However, in locations where this would create conflicts with existing

C1104.2.2.1

When placing manholes in the pavement of a limited access facility cannot be avoided; bury the frame and solid cover to the top of the (Item 304) aggregate base. Provide the Ohio State Plane Northing and Easting coordinates to the center of the manhole lid on the storm sewer profiles to aid in locating the structure in the future. This location is the coordinate in the CADD drawing when using utilities the storm sewer may be located under the pavement. Avoid placing manholes in vehicle wheel-paths or within an intersection. Place the center of the manhole in the center of the lane when feasible.

Provide premium joints on the storm sewer where an out-to-out clearance of 5 feet cannot be provided between parallel storm and sanitary sewers.

Submit exceptions to the above in the early stages of the design to OHE for review and approval.

ODOT Survey and Mapping Specifications.

1104.2.2.2 Under Paved Shoulder

The above applies to paved shoulder areas unless the cost of any other possible location is prohibitive.

1104.2.3 Access

For storm sewers under 36 inches in diameter located under or near the edge of pavement, provide access at intervals up to 300 feet maximum. For sewers sized 36 to 60 inches provide manholes spaced every 500 feet maximum and for larger sewers provide manholes spaced every 750 to 1000 feet maximum.

For manhole, inlet and catch basin details refer to the Hydraulic SCDs.

C1104.2.3

Most standard inlets and catch basins provide satisfactory access to small diameter shallow sewers. They can also be used where changes in pipe size or minor horizontal/vertical changes in alignment occur. Larger changes may require manholes.

It may be necessary to locate longitudinal trunk sewers away from the curb to provide for a utility strip between the curb and the sidewalk and to avoid a conflict with the underdrains. This will require properly spaced manholes in the sewer line.

1104.2.4 Rock Excavation

If it is known that bedrock will be encountered in the excavation for storm sewer installation, relocate the storm sewer. If bedrock cannot be avoided, separate the quantities of the storm sewer in rock and include Item 611, As Per Plan, in the plans.

1104.3 Storm Sewer Design Criteria

1104.3.1 Design AEP Storm

Size all storm sewers using open channel, just full capacity design to flow just full for a 10% AEP storm. The size is determined by working downstream from the first sewer run. It is acceptable to use a discharge of a more frequent occurrence if consistent with local criteria or to avoid extensive replacement of an existing

C1104.3.1

Just full is the depth of flow for maximum discharge. Just full capacity design assumes a free water surface at a depth of 93.8% of the pipe diameter for circular conduits. Maximum flow and velocity are considered to occur at this depth.

This design methodology provides a conservative downstream drainage system.

margin of safety by providing additional headroom due to increased pipe diameters.

1104.3.2 Hydraulic Grade Line

Determine the elevation of the hydraulic grade line at the upper end of each sewer run using a 4% AEP storm.

Start at the storm sewer system outlet and work upstream. It is acceptable to use a hydraulic grade line of a more frequent occurrence if consistent with local criteria and / or to avoid extensive replacement of an existing downstream drainage system.

The starting elevation for the hydraulic grade line determination is the higher of either: the downstream tailwater channel water surface elevation or (dc+D)/2 at the system outlet as explained in Section 1105.6.1.

Use the same intensity **i** in the Rational Equation Q = CiA to determine the check discharge for all sewer runs as that calculated for the last, or downstream run, in a continuous sewer system.

The hydraulic grade line must not exceed the following:

A. 12 inches below the near edge of pavement for sections without curb.

B. The elevation of a curb opening inlet or grate elevation of a pavement catch basin, as shown on the SCD.

For underpasses or other depressed roadway sags where ponded water can only be removed through the storm sewer system, check the HGL for a 2% AEP storm on Interstates, Freeways & Expressways, and other High-Volume Highways (over 6000 ADT). One directional lane of travel for a multiple lane highway or one-half of a lane on a 2-lane highway must be passable. No encroachment of ponded water is permitted into any traveled lanes on interstate sags for the 2% AEP HGL sag check.

C1104.3.2

Ordinarily, the hydraulic grade line is above the top of the pipe, causing the system to operate under pressure. If, however, any run in the system does not flow full, (pipe slope steeper than the friction slope) the hydraulic grade line will follow the friction slope until it reaches the normal depth of flow in the steep run. From that point, the hydraulic grade line will coincide with the normal depth of flow until it reaches a run flatter than the friction slope for that run.

These criteria are not intended to lower existing high-water elevations.

The check discharge is the 4% AEP event.

Hydraulic grade line requirement A is for ditch sections and B is for curbed sections.

These criteria are intended for sag locations with no outlet except through the storm sewer system. Examples include sag locations with barrier wall, underpasses, or other depressed cut sections without an alternative outlet.

Typically, these criteria do not apply to 2-lane or other curbed roadway facilities where water can overtop the curb. Contact OHE if encountered.

The criteria for interstate sags are based on Code of Federal Regulation 23 CFR 650.115 requirements.

1104.3.3 Runoff Coefficient

Determine the runoff coefficient per Section 1101.2.2.

1104.3.4 Time of Concentration

Determine the time of concentration as explained in Section 1101.2.1. Use a minimum time of concentration of 15 minutes to the first ditch catch basin and 10 minutes to the first pavement inlet. Use the actual calculated time of concentration when values greater than these minimums occur.

1104.3.5 Pipe Roughness Coefficient

Use a Manning's **n** of 0.015 for sewers 60 inches in diameter and under, and 0.013 for larger sewers. The typical **n** value for smooth pipe, concrete, vitrified clay, bituminous lined corrugated steel or thermoplastic is 0.012.

C1104.3.5

The increased **n** values are recommended to compensate for minor head losses incurred at catch basins, inlets and manholes located in a storm sewer system.

1104.3.6 Minimum Pipe Size

Use a minimum pipe diameter of 15 inches for Interstates, Freeways & Expressways, including ramps. Use 12 inches for other highways.

C1104.3.6

Where an existing storm sewer is to remain in service, it is not necessary to replace hydraulically adequate pipes to meet these criteria.

1104.3.7 Maximum Slope

The maximum slope is 4:1 H:V or the slope that produces a velocity exceeding 10 fps. Provide drop structures for energy dissipation when slopes or velocities exceed the allowable limits.

For storm sewers along embankment slopes that exceed 3:1 H:V, designate as Type F, Broken Back per Figure 1104-1.

C1104.3.7

A broken back is not intended for culverts or at the outlet of an extensive storm sewer network. Provide a manhole drop structure instead. Avoid having the flow impact the backside of the manhole due to the potential for the structure to erode or shift.

1104.3.8 Outlet Velocity Protection

Provide outlet velocity protection for all Storm Sewers with an outlet velocity greater than 5 fps.

Provide rock channel protection for erosion control per Figure 1002-4 using the 10% Design AEP Storm.

Provide a filter with the RCP. Use a geotextile fabric filter when not under water. Use an aggregate filter when the RCP is under water. The cost of the filter is included in the unit bid price for Item 601, Rock Channel Protection with Filter.

C1104.3.8

A filter is provided with the RCP to prevent soil piping through the rock. Aggregate filter is specified for placement under water as the fabric filter is buoyant and may cause difficulty during installation. Use aggregate filter for RCP placed under the OHWM.

1104.4 Storm Sewer Hydraulic Design Procedure

Provide storm sewer computations. Tabulate the calculations for lateral connections to the longitudinal trunk sewer separately from the trunk

C1104.4

With the layout suggested in Section 1104.3, start with the upper catch basin or inlet and determine the value of CA for the contributing flow (CA is the product of the weighted coefficient of runoff and sewer calculations.

Software is available at the OHE Hydraulic Software and Design Resources web page and can be used for these calculations. OpenRoads SUDA may also be used for these calculations. Other software packages may be utilized with approval from OHE.

the drainage area). Next, determine the time of concentration for the first area and the corresponding rainfall intensity **i** from the proper curve shown on Figure 1101-2. The design discharge **Q** to use to determine the required size of the first sewer from MH No. 1 to MH No. 2 is the product of CA x i. At manhole No. 2, determine the value of CA for the additional area contributing at that point and add to the CA for MH No. 1.

Compute the time of flow in the storm sewer from MH No.1 to MH No. 2 in minutes and add to the time of concentration at MH No. 1. Check the time of concentration for the area contributing to MH No. 2 and use the larger of the two as the duration for the new value of rainfall intensity for computing the design flow from MH No. 2 to MH No. 3.

1104.5 Combined Sanitary Sewer Separation

When the Combined Sanitary Authority is under court order to address frequent overflow of the sanitary system due to storm sewer impacts, when feasible, provide an exclusive outfall for the storm sewer. Coordination with the Local is required. While adherence to Local drainage standards is not applicable for ODOT owned and maintained drainage assets it may be possible for the Department to incorporate the needs of the local entity subject to review and approval of OHE.

The Department will fund storm sewer conduit and drainage structures to provide positive drainage of the roadway when a separation is feasible. Conduit and structures required for sanitary sewer are funded by the Local. All conduit located outside of the Department owned right-of-way is also funded by the Local.

1104.6 Sanitary Sewers

Specify joints in accordance with C&MS 706.11 for circular concrete pipe or 706.12 for clay pipe. Permissible thermoplastic pipe may also be specified.

Discharges of treated sanitary flow from abutting property into highway drainage systems are only permitted if the discharge is authorized by the Local Health Department and has a R/W permit.

C1104.6

Obtain and follow local sanitary sewer building codes.

1104.6.1 Manholes

Specify all new manholes for sanitary sewer lines per the Hydraulic SCDs.

1105 Roadway Culverts

1105.1 General

Check the design with a single cell round pipe as a first choice. In cases where the required cover or discharge rules out a round pipe, select a shape that reduces the vertical requirements while maintaining the hydraulic capacity. Consider the following shapes in order of minimum cost to increasing cost: single-cell elliptical concrete, metal pipe-arch, prefabricated box culvert or three-sided structure. For justification of multiple cell culverts, see Section 1105.6.2.

Do not place culverts on skews in excess of 45° or as further limited in Section 1008.

Do not locate the upstream invert below the natural channel unless the culvert has a depressed inlet, a paved depressed approach apron, or an improved inlet.

Maintain the existing upstream and downstream hydraulics for the design flows when replacing a culvert. In cases where these parameters must be modified, evaluate any upstream and downstream impacts.

Perpetuate existing drainage patterns such as: depth of flow, direction of flow and overbank flow to the maximum extent achievable. Diversion of substantial volumes of flow requires regulatory consideration and possible actionable damage.

Label the elevation of the OHWM for jurisdictional waterways on the Culvert Detail Sheet for all culverts.

Include Item 503 for cofferdams for jurisdictional waterway crossings or where the potential for dewatering exists.

C1105.1

A culvert generally carries a natural stream under the highway embankment. The culvert horizontal and vertical alignment should approximate that of the natural channel.

Culvert design with the best hydraulic performance and least environmental impacts occurs when the roadway alignment is normal to the flow in the channel and is located on a relatively straight and stable section of the channel.

Roadway alignment needs to be considered early in the design process to provide optimum culvert design.

For examples of culvert detail sheets, reference Sample Plan Sheets Section 1312 – Drainage Details, maintained by the Office of CADD and Mapping. These provide a useful resource for preparation of hydraulic plans in terms of layout and content.

1105.2 Stream Protection

Stream protection is provided using the following practices and is only applicable to culverts within the Waters of the United States:

- Bankfull discharge design
- Depressed culvert inverts
- Paved depressed approach aprons

C1105.2

Stream protection practices are provided to improve stream channel stability. Erosion of the stream channel can migrate upstream and downstream without proper protection at the structure.

The use of each stream protection practice is limited based on project specific conditions.

- Flood plain culverts

Water quantity treatment post construction BMP can be provided using stream grade control structures and is only applicable to culverts within the Waters of the United States. See Section 1111.1 and Section 1111.3.

For existing culvert replacements, inspect the channel for erosion that has caused undercutting or downcutting at the inlet of the culvert. At locations with evidence of undercutting or downcutting, provide a concrete apron according to Section 1106.3 at the inlet and outlet of the culvert to restore previous stream elevations and provide stream protection.

Culverts within the Waters of the United States require stream protection to meet waterway permit conditions. Only culverts within the Waters of the United States can also get credit for water quantity treatment post construction BMP's by use of grade control structures. The requirements for post construction BMP's are described in Section 1111.1. The need for water quantity treatment is described in Section 1111.3 along with the post construction BMP's that meet water quantity treatment.

Only the project areas that drain to a grade control structure will receive treatment credit. If the treatment provided by a grade control structure does not meet the required percentage of treatment, provide additional water quantity treatment in areas not draining to the grade control structure for the remaining amount required.

Other water quantity treatment post construction BMP's

- Extended Detention (Section 1113.3)
- Retention Basin (Section 1113.4)
- Bioretention Cell (Section 1113.5)
- Infiltration Methods (Section 1113.6)
- Constructed Wetlands (Section 1113.7)

See Sections 1111 through 1113 for further information concerning the above water quantity treatment post construction BMP's.

The above water quantity treatment post construction BMP's may be utilized within available right-of-way or right-of-way being obtained for roadway, however, project type, site constraints or limitations, will not exempt the project from providing water quantity treatment post construction BMP's.

1105.2.1 Culvert Aquatic Organism Passage

Design culverts to facilitate Aquatic Organism Passage when conveying intermittent and perennial streams with the following exceptions:

1. The culvert is located on bedrock
2. The culvert slope exceeds 1%
3. The culvert is 48" or less in span or diameter when hydraulically sized per 1105.5
4. Any culvert upsizing for AOP design would

C1105.2.1

In cases when an individual waterway permit is required, these requirements may be exceeded due to minimization or mitigation requirements from the regulatory agencies. OES will coordinate this need with the DEC or designer on a case-by-case basis.

Coordinate with OES waterway permits and the DEC regarding possible exceptions based on stream quality. Exceptions may include Limited cause downstream property damage from flooding as demonstrated by hydraulic calculations. Document justification in the drainage report.

See sections 1105.2.1.1, 1105.2.1.2 and 1105.2.1.3 for specific requirements regarding new culvert crossings, replacement culverts, and culvert rehabilitation projects.

When culverts are upsized to accommodate AOP, list the headwater and velocity in the plans for the culvert size that meets the design criteria with the invert filled by natural stream bottom for the burial depth. Note that the culvert size shown has been increased for AOP.

Resource Waters or other low-quality streams, such as acid mine drainage streams or concrete lined channels, that inhibit the effectiveness of AOP design. Refer to ODOT TIMS Map Viewer; Environmental; Beneficial Uses – Aquatic Life Use Designations to identify LRW.

1105.2.1.1 Aquatic Organism Passage for New Culvert Crossings

For new culverts that do not replace an existing culvert or bridge alignment meeting the requirements of 1105.2.1, size culverts to convey the stream bankfull width. Use the following design steps when performing AOP for new culvert crossings:

1. Determine the culvert size from traditional culvert hydraulic design criteria per 1105.5. For culverts sized 48" or less in span or diameter, no additional AOP considerations are required.
2. For culverts greater than 48" in span or diameter from step 1, determine the stream bankfull width from the StreamStats Bankfull Statistics or field collected information. Use the largest bankfull width value reported in StreamStats. Alternatively, the size required for AOP can be determined by another stream simulation method as approved by OHE and OES.
3. Increase the culvert size to accommodate the bankfull width or size to accommodate AOP with another approved stream simulation method from step 2.
4. Depress the culvert invert according to 1105.2.2

C1105.2.1.1

Roadway resurfacing, restoration, rehabilitation, and reconstruction projects, including changes in existing alignments, are not required to convey the bankfull width and are designed using 1105.2.1.2.

The bankfull width is determined from StreamStats or field collection in coordination with the DEC.

Culverts utilizing bankfull design are required to convey the bankfull width with minimum change in the stream energy for the adjoining channel sections when compared to the existing conditions.

The proposed culvert will minimize the impact to the stream channel by closely matching the existing depth of flow with the proposed depth of flow for the bankfull discharge in order to facilitate passage of aquatic organisms.

Information on stream flow regime can be found by contacting the DEC or consulting the Ecological Survey Report located on ODOT EnviroNet.

1105.2.1.2 Aquatic Organism Passage for Culvert Replacements

Use the following design steps when performing AOP design for culvert replacements:

1. Determine the culvert size from traditional

culvert hydraulic design criteria per 1105.5. For culverts 48” or less in span or diameter, no additional AOP considerations are required.

2. For culverts greater than 48” in span or diameter from step 1, upsize the culvert by one standard pipe size.
3. Depress the culvert invert according to 1105.2.2

1105.2.1.3 Aquatic Organism Passage for Culvert Rehabilitation Projects

For culvert rehabilitation projects per 1002.3.7, fill outlet scour holes and repair outlet rock channel protection to eliminate perched culvert conditions. Provide rock channel protection for outlet velocity control per 1105.2.4.

C1105.2.1.3

This requirement applies to culverts with outlet velocities less than 18 fps where a rip-rap basin or other energy dissipator are not required.

1105.2.2 Depressed Culvert Inverts

Provide depressed inverts when new and replacement culverts are designed for aquatic organism passage.

Provide concrete field paving on corrugated metal conduits 54 inches or larger with depressed culvert inlets. Additional depression depth is not required to account for the thickness of the field paving.

End treatments for culverts with depressed inverts consist of Item 601, Riprap, 6” Reinforced Concrete Slab, with a cutoff wall on both inlet and outlet ends. For details see Hydraulic SCD DM-1.1.

Depress the culvert invert per **Table 1105-1**:

Table 1105-1

Type A Conduit Invert	
Pipe Diameter or Rise (inches)	**Depression (inches)**
< 54	None
54- 60	6
66 - 120	12
126 - 180	18
186 - 252	24
> 252	30

Modifications to the standard headwalls are not necessary for the depression depths noted above.

C1105.2.2

Depressed culvert inverts will produce a natural channel bottom within the culvert. The natural channel bottom provides a substrate for passage of migratory species.

The depressed culvert is presumed to fill naturally, such that the channel bed in the culvert will be continuous with the adjacent channel sections. New culverts designed with stream simulation techniques, such as HEC-26, may require manual placement of material in the culvert during construction when culvert size allows. In some cases, when an individual waterway permit is required, manual placement of material in the culvert during construction when the culvert size allows may be necessary as a minimization or mitigation requirements from the regulatory agencies. OES will coordinate this need with the DEC or designer on a case-by-case basis.

When feasible, install culverts at the existing streambed slope to allow for the natural movement of bedload and aquatic organisms.

1105.2.3 Paved Depressed Approach Aprons

The dimensions of the slab are site specific. Limit

C1105.2.3

In many cases, the hydraulic operation of a culvert the downslope of the apron to a maximum of 2:1. Include a 3-foot length of paving along the natural channel slope prior to the drop-down. Provide a cut -off wall at the upstream end.

In general, limit drop-down entrances to 4 feet, or one pipe diameter or rise, whichever is greater.

can be improved by depressing the flowline at the entrance below the channel flowline. The drop-down will alleviate a minimum cover condition, provide for additional headwater depth, and decrease the culvert outlet velocity by reducing the culvert slope. The abrupt change in natural channel slope is affected with a short length of concrete paving to prevent downcutting of the stream.

The Federal Highway Administration has conducted extensive research and studies of paved depressed approach aprons, and recommended design procedures are included in HDS-5 [Schall et al., 2012].

1105.2.4 Outlet Velocity Control

Provide velocity control for all culverts with an outlet velocity greater than 5 fps.

Provide rock channel protection for erosion control per Figure 1002-4 using the Design AEP storm.

Provide a filter with the RCP. Use a geotextile fabric filter when not under water. Use an aggregate filter when the RCP is under water. The cost of the filter is included in the unit bid price for Item 601, Rock Channel Protection with Filter.

Provide the following energy dissipators when the velocity exceeds the limits for RCP per Figure 1002-4:

- Riprap Basin
- Ring Chambers

Contact OHE prior to using an energy dissipator.

Ring chambers may be specified at the outlet end of the pipe as an internal energy dissipator. If the outlet velocity for a corrugated pipe is less than 20 fps while the outlet velocity for a smooth pipe requires a ring chamber, the corrugated pipe may be specified exclusively.

C1105.2.4

The use of rock channel protection or energy dissipators does not constitute water quantity treatment for post-construction BMP purposes.

A filter is specified with RCP to prevent soil piping through the rock.

A riprap basin is the most cost-effective energy dissipator.

1105.3 Types of Culvert Flow

C1105.3

Laboratory tests sponsored by the FHWA have established two general types of culvert flow:

1. Flow with inlet control
2. Flow with outlet control

Under inlet control, the headwater HWI is directly related to the cross-sectional area of the culvert barrel and the inlet geometry. Under outlet control, the headwater HWO is further influenced by tailwater depth in the outlet channel and the slope, length and roughness of the culvert barrel. As shown in Figure 1105-1, culverts operate with a free water surface if the headwater is equal to or less than 1.2**D**, and with a submerged entrance if the headwater is greater than 1.2**D**, where **D** is the diameter or rise of the pipe.

1105.4 Design Procedure

1105.4.1 General

The design of a culvert involves a determination of the appropriate design and check discharges. The process begins with a delineation of the drainage area, in acres, on a suitable topographic map.

The design discharge **Q** for most culvert drainage areas is obtained by procedures described in Section 1003.1.2. Use the Rational method to obtain the discharge from small and other unusual drainage areas as noted in Section 1101.2.1.

A representative cross section of the embankment at the proposed culvert site, along with a profile of the natural stream or ground line, will be required to determine the approximate length and slope of the culvert.

1105.4.2 Hydraulic Analysis

Provide a culvert hydraulic analysis that determines the controlling headwater for each culvert type being considered for a given location. Include supporting data for the required review submissions.

Hydraulic analysis of culverts may be performed using the FHWA HDS-5 [Schall et al., 2012]. Computer programs such as FHWA HY-8 or software developed by ODOT, CDSS, is available at the OHE Hydraulic Software and Design Resources web page and can be used for these calculations.

For replacement projects, perform an analysis of the existing structure. Use the same analysis method when comparing the existing and proposed structures. For bridge replacements, the acceptable method of hydraulic analysis is HEC-RAS.

1105.5 Design Criteria

1105.5.1 Design AEP Storm

Use the design AEP storm as stated in Section 1004.2.

Perform a Flood Hazard Evaluation using a check discharge based on the 1% AEP flood for all culverts as noted in Section 1005.2.1.

1105.5.2 Maximum Allowable Headwater

See Section 1006.

1105.5.3 Method Used to Estimate Storm Discharge

See Sections 1003 and 1101

1105.5.4 Scale of Topographic Mapping Used to Delineate Contributing Drainage Areas

See Section 1101.1.

1105.5.5 Manning's Roughness Coefficient

The Manning's Roughness Coefficient **n** values for corrugated metal pipe are given in Figure 1105-2.

Field paving corrugated metal pipe will reduce the Manning's Roughness Coefficient. Use a value of 0.020 for 1-inch corrugations and 0.026 for all structural plate pipe.

The Manning's n value for field paved corrugated metal pipe with 1-inch corrugations is an average for all pipe diameters shown in the Corrugated Steel Pipe Design Manual (NCSPA, 2008).

The **n** value for all smooth flow pipe is 0.012. Use a weighted Manning's **n** for bankfull designed culverts.

1105.5.6 Entrance Loss Coefficient

Use the Entrance Loss Coefficient $\mathbf{k_e}$ found in Table 1105-2 or Appendix D of FHWA HDS-5 [Schall et al., 2012].

C1105.5.6

Table 1105-2

Type A Conduit Entrance Loss Coefficient k_e			
Type of Pipe	**Headwall Type**		
	Full	**Half**	**None**
Concrete, Vitrified (thick wall) *	0.2	0.2	0.2
Corrugated Metal (thin wall), Plastic	0.25**	0.9	0.9

* groove end entrance

** beveled entrance

1105.5.7 Pipe Design Criteria

See Sections 1002 and 1008

1105.5.8 Contacts with County Engineer

Contact the County Engineer at the beginning of the design process to review the proposed location, horizontal and vertical alignment and to determine ditch cleanout grades. Use the LD-33 County Engineer Approval Form to document the approval.

C1105.5.8

Ohio Revised Code, Section 6131.631.

The County Engineer is responsible to provide their concurrence with the proposed culvert elevations but not the size or type.

1105.6 Special Considerations

C1105.6

The following are special conditions that will be encountered in the hydraulic design of culverts that warrant clarification.

1105.6.1 Tailwater

When there is no downstream influence, calculate the tailwater by determining the normal depth of flow in the outlet channel when the culvert is discharging the design flow.

When there is influence from a backwater condition downstream, calculate the tailwater by the following:

Where the drainage areas of the culvert and receiving watercourse are nearly equal, assume concurrent flood peaks.

Where there is a significant, but not excessive, difference in the drainage area of the culvert and receiving stream, use the following design procedure and size the culvert using the combination that results in the highest headwater:

A. Compute the culvert headwater using the proper design AEP storm for the culvert and

C1105.6.1

Tailwater at a culvert outlet can greatly affect the size of culvert required at a specific site. A proper evaluation of the outlet channel must be made so that a reasonable estimate of the tailwater can be calculated.

A determination of the normal depth of flow in the outlet channel, when the culvert is discharging the design flow, normally establishes the culvert tailwater. An examination of the downstream channel may, make known a temporary or permanent obstruction that will control the operation of the culvert. In some cases, the culvert will outlet within the backwater of a river or other fluctuating water surface that could control the tailwater elevation.

the next lower AEP storm per 1004.2 for the receiving stream water surface elevation to determine the culvert tailwater elevation. For example, a 4% AEP culvert and a 10% AEP stream.

B. Use the lower AEP storm for the culvert and the proper design AEP storm for the receiving stream to determine the culvert tailwater elevation. For example, use 10% AEP for the culvert and 4% AEP for the stream.

Where the drainage area of a culvert is substantially less than the receiving watercourse, ~100 times, the effect of the receiving watercourse generally may be disregarded.

In some locations, a high tailwater will control the operation of a culvert to such an extent that a substantial increase in pipe size will be required for a negligible decrease in the headwater elevation. For this case, size the culvert based on a tailwater elevation using the equation:

$$TW = \frac{(dc + D)}{2}$$

Where:

TW = Tailwater (ft)

dc = Critical depth at culvert outlet (ft)

D = Rise of culvert (ft)

1105.6.2 Multiple Cell Culverts

A single-cell culvert is preferred, but at times site conditions or design considerations may create the need for multiple cells. For these cases, it is desirable to limit the number of cells to two.

C1105.6.2

When aligned with a relatively straight channel, multiple cells will operate satisfactory. However, a bend in the immediate upstream channel may cause the inside cell to collect debris during normal periods of flow and can substantially reduce the capacity of the culvert.

1105.6.3 Improved Side and Slope Taper Inlets

Consider improved inlets attached to the entrance end of the culvert to reduce headwater or culvert size. See section 1105.2.3. If additional improvement is needed.

Consider the following two general types of inlets in the following order:

A. Side-taper - A tapered end section from a round to an oval shape for a pipe, or a square to a rectangular shape for a prefabricated box. The length of the taper section is usually made

C1105.6.3

Culverts on relatively steep slopes and under inlet control can see a reduction in the culvert size by furnishing an improved inlet.

The improved inlet has the advantage of admitting more flow and thereby tending to fill the culvert barrel and reduce the culvert outlet velocity.

The Federal Highway Administration has conducted extensive research and studies of improved inlets, and recommended design procedures are included in HEC-13 [Harrison et al., 1.5 times the diameter or rise of the culvert.

B. Slope-taper - A combination of side-taper preceded by a drop in the culvert flow line. The drop can be similar to a paved drop-down entrance, see section 1105.2.3, or a more sophisticated reinforced concrete drop provided by a formed cast-in-place section with vertical sides.

The savings in culvert cost must justify the additional cost of the improved inlet.

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1106 End Treatments

1106.1 General

Provide headwalls, or other approved end finishes, at the open ends of all Type A, B and C conduits. Provided headwalls for Type D conduits greater than 24 inches in diameter or rise. Headwalls are not recommended for Type E and F conduits.

Figures 1106-2 and 1106-3 show typical end details for a concrete box culvert without guardrail attachment.

Special end treatments may be required per the LD1, Section 602.6. Details are available from the OHE. Justification for the use of this type of end treatment must accompany the request for details.

C1106.1

The selection of headwall type is based on safety and economics.

1106.1.1 End Treatment Grading

Project the prevailing embankment slope to the back edge of the top of the headwall to establish the required culvert length. When the roadway foreslopes are flatter than 2:1, provide a 2:1 slope from the back edge of the top of the headwall to a minimum of 1 foot, with 2 feet preferred, above the top of the culvert. See Figure 1106-1 for details. Warp the embankment slope on each side of the conduit to fit the prevailing slope. Unless guardrail is provided, maintain the design clear zone grading width, per LD1, Section 601, before the embankment slope changes to 2:1.

Provide clear zone grading at culverts only when the requirements of LD1, Section 307.2.1, are met.

Warp the prevailing embankment slope on either side of a skewed culvert to provide equivalent soil loading and proper side support of the pipe. This is especially true for flexible pipes with large skews and/or large diameters.

1106.2 Headwall Types

1106.2.1 Half-Height Headwalls

Use standard half-height headwalls HW-2.1 and HW-2.2 detailed in the Bridge SCDs for round, elliptical, or pipe arch culverts where clear zone grading is provided. Place half-height headwalls perpendicular to the end of the conduit to eliminate the need for a skew cut. Miter-cut the exposed half of conduits having a diameter or rise greater than or equal to 126 inches to fit the embankment slope. Show miter-cut end sections on the Culvert Detail Sheet.

Pay for half-height headwalls with Item 602, Concrete Masonry. Base the cubic yards of concrete masonry provided in the plans on the pipe alternate requiring the largest quantity of concrete masonry.

C1106.2.1

Masonry quantities for standard half-height headwalls may be obtained from the standard construction drawings.

The use of miter-cut end sections and other special slope tapered end treatments may be required for additional situations by LD1, Section 602.6. Contact OHE for guidance.

1106.2.2 Full-Height Headwalls

Use full-height headwall HW-1.1 detailed in the Bridge SCDs where a significant reduction in culvert length can be achieved with foreslopes flatter than 2:1, where right-of-way limits the culvert length and at the entrance end of round pipes when the savings in the reduced size and length of the conduit will offset the additional cost of the headwall.

Provide full-height headwalls for all prefabricated box culverts and three-sided structures. Design headwalls per Section 300 of the BDM. Refer to Bridge Plan Insert Sheet BCHW.

Include appropriate plan notes from Section 600 of the BDM in the project plans.

Perform an investigation of the supporting foundation material to estimate the bearing capacity of the material. Submit the foundation report with the Stage 1 review.

Armor the inlet wingwall footings of full-height headwalls with Type B rock channel protection, with filter, to prevent scour.

C1106.2.2

The use of a full-height headwall will most likely apply where corrugated steel pipe is specified due to cover or size requirements and the bevel provided for the full-height headwall will substantially reduce the entrance loss.

1106.3 Concrete Apron

Provide a reinforced concrete riprap cutoff wall, as shown on Hydraulic SCD DM-1.1 when the depth of the rock channel protection, including the 6 inch granular filter, exceeds the depth of the headwall.

Provide concrete riprap per Section 1105.2.3, at the inlet end of the culvert where the existing culvert has been undercut. Concrete riprap is not necessary at the inlet of culverts with full height headwalls that have a footing toe extending 3.5 feet or more below proposed channel grade.

1107 Bridge Hydraulics

1107.1 General

Submit hydraulic design calculations, H&H reports, scour evaluations and flood hazard evaluations with the STS.

C1107.1

Bridge structural design requirements are found in the BDM.

1107.2 Hydrology and Hydraulics Report

Provide a plan view showing the waterway alignment with the location of all cross sections used for the hydraulic and scour analysis. Ensure the distances upstream and downstream meet those shown in Table 1107-1:

Table 1107-1

Model Type	Distance Upstream and Downstream (ft)
1-Dimensional	500
2-Dimensional	500 or 2 times the floodplain width, whichever is greater

Include the alignment of the proposed and existing roadways taken from ground survey.

Include a profile following the centerline of the roadway to compute the overflow section. Extend the profile along the approach fill to an elevation well above the high water elevation.

If bridges or large culverts are located within 1000 feet upstream or downstream of the proposed bridge, show additional stream cross sections which include the structure and roadway profile.

C1107.2

When convergence of the proposed and existing water surface profile does not occur within 500 feet, extend the waterway alignment if the channel is within a FEMA SFHA or the impacts of the water surface change to the surrounding properties is of concern.

The upstream and downstream structures may be used as a guide in establishing the waterway requirements of the proposed structure.

1107.2.1 Analysis

The H&H analysis is performed using the design AEP storm discharge as defined in section 1004.2 along with the 1% AEP and 0.2% AEP.

A 1D step backwater analysis software such as HEC-RAS-1D is adequate for crossings that are linear, without wide floodplains and without split flows. The simplified assumptions used in 1D models create limitations in complex hydraulic

C1107.2.1

2D models provide more realistic and detailed information on key variables such as velocity and water surface elevation. A 2D model is useful in locations where a 1D model cannot adequately describe the flow regime. Such locations may include wide floodplains with large flows into the overbanks, projects where bends and confluences are located near the area of interest, locations with situations where 2D modeling provides a more accurate analysis. A 1D analysis informed by a 2D analysis may be required if the crossing is within a FEMA SFHA.

Include the following items in the H&H analysis:

1. Hydrology calculations or source of the discharges used in the analysis. Include the drainage area in square miles.
2. Input and output data including electronic program files of computations for existing and proposed conditions. If using 1D HEC-RAS, refer to the HEC-RAS Help Applications Guide for the multiple plans file structure. If performing 2D modeling with SMS, refer to SRH-2D for providing the packaged project file.

multiple channels with split flows, multiple bridges and/or bridge openings, bridges with skewed abutments to the direction of flow, and bridges operating under pressure flow for the design AEP storm.

Many user assumptions that are made with a 1D model are calculated with a 2D model, providing a more consistent and accurate analysis.

FEMA Region 5 currently will not accept 2D hydraulic modelling for SFHA mapping revisions unless the current effective model was initially created in 2D. 2D hydraulic modelling creates a more accurate representation of water surface elevations, flow velocities, and flow direction, resulting in differences between modeled results and current effective FEMA models developed with 1D hydraulic modelling.

Aquaveo SMS SRH-2D is the preferred 2D hydraulic modeling software.

3. If performed, include a description of how the model was calibrated.

Best practice is to perform model calibration when observed or measured historical data is available. Examples include USGS Gauge Data, high-water mark photos, and first-person accounts of water-surface elevation.

Research [Che et al., 2022] suggests that for sites with a drainage area of more than 100 square miles, designers utilize 2D hydraulic models for design. According to the research, 2D models better depict the flow characteristics and offer a greater capability of more precisely capturing the shear and velocity at point locations, especially when designing a temporary access fill.

Consider the importance of the structure, based on roadway facility type and ADT, before 2D modeling is pursued.

When performing a step backwater analysis of the floodplain in a FEMA SFHA that has had a detailed hydraulic analysis; obtain the Current Effective FIS model to use as the basis of the model creation process.

4. Provide enough fully bounded cross sections to properly model the existing and proposed conditions if using a 1D model. A minimum of one cross section in close proximity to each face of the structure along with two additional cross sections upstream and downstream outside of the expansion/contraction zone are required.

Fully bounded cross sections provide sufficient width and elevation to contain all depths of flow produced in the 1D HEC-RAS analysis. Where the model produces a vertical wall to contain the flow, additional ground survey or LiDAR data may be used to supplement the cross section extents. Cross sections with expansive floodplains containing slow shallow flow may be truncated. Use

5. Color photographs of the bridge opening and the upstream and downstream channel.

engineering judgement to determine cross sectional widths. For 2D models, verify the lateral limits of the mesh extend beyond the limits of the floodplain.

Perform an evaluation of the channel stability for bridge replacements where the existing crossing exhibits continual maintenance issues with sediment aggradation, degradation, or debris accumulation. Maintain channel continuity to the upstream and downstream conditions through the structure by providing a channel similar to that which is naturally occurring. Design the channel cross section through the bridge to match the bankfull properties of the stream as much as practical. The use of a two-stage channel may be required to convey both the bankfull discharge and the design and check AEP discharges. Provide the same methodology for new bridges. Coordinate with OHE for additional guidance prior to design.

Multiple terrain data sources can be utilized when performing hydraulic modeling. LiDAR data can be used to supplement traditional ground survey for 1D models or as a primary data source for 2D models outside of the channel limits. Ohio Statewide LiDAR data may be used if accuracy is verified. Because LiDAR cannot penetrate water or some dense vegetation types, conventional topographic or hydrographic surveys are still required in most cases. Planning level accuracy is sufficient when acquiring terrain data for hydraulic modeling. See the LD4 for ODOT Survey and Mapping Specifications

Avoid over-widening the channel at the structure. This condition may reduce channel velocities leading to maintenance issues such as aggradation and debris accumulation where they had not occurred before.

1107.2.2 Narrative

Include the following in the narrative:

1. The rationale used to determine the proposed structure size and type by an analysis of design alternatives. Include a comparison of the existing and proposed design AEP storm and 1% AEP storm headwater elevations and velocities in tabular format noting differences.
2. Compare existing and proposed waterway opening along with the structure low cord elevations and design and check AEP flood clearances in tabular format.
3. A statement as to whether the structure is located within a FEMA SFHA. Identify the FIRM showing the project location. Include relevant excerpts from the FIS where applicable. If within an FIS, describe the hydraulic model creation process using standard FEMA naming terminology.
4. High water data from local residents and observed high water marks including their locations if available.
5. Approximate Flood Peak Discharge storm

C1107.2.2

The Narrative is a written discussion of the hydraulic adequacy for both the design AEP and 1% AEP storm discharges.

Take headwater elevations away from the face of the structure just beyond the effects of the contraction on the water surface profile.

Maintain the existing waterway opening size as much as possible. Limit reductions to 20 percent.

Standard FEMA model naming terminology includes: Current Effective, Duplicate Effective, Corrected Effective, Existing Conditions or Pre-project, Proposed Conditions or Post-project models.

event of roadway overtopping.

6. A Flood Hazard Evaluation per 1005.2.
7. Capital costs and risk as part of the discussion. Risk is defined as the consequences attributable to a flood plain encroachment.
8. Description of the bridge deck drainage. Indicate how the surface water will be collected and discharged. Include any scupper catch basin locations.

1107.3 Bridge Rock Channel Protection

Provide RCP for bridges over waterways at the following locations:

A. The entire spill-through slope

B. Front side of abutments and wingwalls

C. Corner cones

Use **Table 1008-1** to determine the Scour Design Flood used to calculate Channel Mean Velocity.

Use Table 1107-2 to determine the RCP Type:

Table 1107-2

Channel Mean Velocity (ft/s)	RCP Type	Thickness (inch)
0-8	C	24
8-10	B	30
Above 10	A	36

Contact OHE when Velocities exceed 12 fps.

Special circumstances such as protection on the stream bank located on the outside of a curve or where ice flow is problematic may require greater rock thickness.

Show the locations, length, and the top of slope elevations for the RCP on the Structure Site Plan. Show the RCP in greater detail in the roadway section in conjunction with the channel plans.

C1107.3

It is more economical to provide bank protection during the initial construction in order to minimize future maintenance.

Table 1107-1 is based on AASHTO Drainage Manual Volume 1 – Policy [AASHTO, 2014], Chapter 17 equations 17B-1 and 17B-2 to calculate the required RCP D_{50}. The D_{50} size corresponds to RCP Type A, B or C in the C&MS. The equations have average water velocity and depth as variables. For simplicity the table uses only velocity to provide RCP Type determination for most common water depths.

1107.4 Bridges Over Outlet Controlled Waterbodies

When replacing a bridge, match or exceed the hydraulic opening of the existing bridge. Maintain the roadway profile and low bridge cord elevation to existing as much as possible.

Where sizing of the bridge is controlled by navigational clearance, provide a cross sectional opening and low bridge chord elevation meeting

C1107.4

Bridges conveying waterbodies that have controlled outlets or spillways require a different design process due to the impacts of these downstream features. Use of USGS StreamStats to obtain discharge flow rates is not applicable due to the influence of the downstream structure. A hydrologic and hydraulic investigation is performed as part of the waterbody design to the navigational clearance requirements.

For new bridges on new alignments that do not require navigational sizing contact OHE for guidance.

develop stage, storage, discharge and water pool elevations created by the downstream structure. The water management data must be obtained from the owner to aid in the bridge design and the information must be shown on the structure site plans per the BDM.

The bridge opening serves as an equalizing connection between the two sides of the waterbody, which has a water pool elevation generated by the flow capacity of the downstream structure in combination with the topography of the reservoir.

1108 Miscellaneous Drainage

1108.1 Farm Drain Crossings

Where it is necessary to continue an existing farm drain crossing under the highway, use Type B Conduit, one size larger than the existing farm drain within the right-of-way limits.

1108.2 Farm Drain Outlets

Terminate existing farm drains that outlet through the backslope of the roadway ditch with a minimum length of 10 feet of equivalent size Type F Conduit. Use one size larger Type F Conduit when existing farm drains are plastic.

Place the outlet invert of the Type F Conduit a minimum of 6 inches, with 12 inches being desirable, above the ditch flow line.

Provide an Erosion Control Pad as shown on Hydraulic SCD DM-1.1.

C1108.2

To allow for possible sedimentation of the roadway ditch, the farm drain outlet is placed above the ditch invert.

The farm drain pipe can be place with a minimum slope of 0.

1109 Notice of Intent

1109.1 General

Submit a Notice of Intent for all projects where Total Earth Disturbing Activity is one acre or more, except Routine Maintenance Projects, as defined by Section 1109.2. The Total EDA acreage includes the combination of Project EDA and Contractor EDA.

EDA is defined as any activity that exposes bare ground or an erodible material to storm water as well as anywhere that Item 659, Seeding, or Item 660, Sodding, is being furnished. Project EDA is EDA that occurs within the project construction limits. Contractor EDA is EDA from support activity sources such as field offices, batch plants, borrow/waste pits, and temporary access routes.

C1109.1

An NOI is an application requesting coverage under Ohio EPA's National Pollutant Discharge Elimination System (NPDES) general permit for storm water discharges from construction activities (OHC000005). The applicant(s) must certify their intention to comply with the NPDES construction general permit by submitting an NOI. The construction general permit requires specific documentation of site conditions, temporary erosion and sediment controls, post-construction storm water best management practices (BMPs), good housekeeping practices, and other requirements depending on the site.

Project EDA is determined based on the project design, while Contractor EDA is estimated.

Non-contiguous portions of projects sold under one contract, such as multiple culvert replacements or Part1/Part 2 projects, may be treated as separate projects for the purposes of submitting an NOI if the project sites are located ¼ mile or more apart and the areas between the activities are not being disturbed. If each site is below the Total EDA threshold of one acre, no post-construction BMP or NOI is required. If one or more individual sites meet the Total EDA threshold, an NOI is required for those sites that meet or exceed the Total EDA threshold. The NOI application must reflect the Total EDA for all project sites that meet or exceed the threshold. Provide post-construction BMPs only at the individual project sites that exceed the Project EDA threshold as described in Section 1111.

Disturbed areas that drain into a combined sewer do not require coverage under Ohio EPA's construction general permit, and therefore are not included towards meeting the Total EDA threshold of one acre. If a project has some disturbed area that drains to a combined sewer system and some disturbed area that drains to a storm water system, only disturbed areas that drain to a storm water system are EDA when determining the need for coverage under the construction general permit or the need for a post-construction BMP. Coordinate with the agency responsible for the receiving treatment plant for construction activities that drain into a combined sewer. Consider the local agency's temporary erosion and sediment control requirements for construction activities that drain into a combined sewer.

Prepare a Project Site Plan as required by LD3, Section 1308 for all projects that require an NOI or post construction BMPs.

Examples for EDA: an area where pavement is being removed to the sub-grade **is** considered earth disturbing activity, but bridge deck construction or repair **is not** considered earth disturbing activity since there is no erodible material under the bridge deck. Pavement milling is not considered earth disturbing activity. Full depth pavement reclamation with cement stabilization and full depth pavement reclamation with emulsified asphalt stabilization are not considered earth disturbing activity because even though the sub-grade is being impacted, it is stabilized immediately in the reclamation process. ODOT Item 320 Rubblize and Roll is not considered earth disturbing activity because the rubblized concrete is considered stabilized.

The Contractor EDA can be estimated using the NOI Acreage Calculation Form Figure 1109-1.

When the combined Project EDA and estimated Contractor EDA are just less than one acre, the project designer may choose to increase the estimated Contractor EDA to avoid the possibility of the project disturbing one acre or more without coverage under Ohio EPA's construction general permit.

1109.2 Routine Maintenance Project

For the purposes of applying for coverage under Ohio EPA's construction general permit, submitting an NOI, a Routine Maintenance Project is one in which all of the Project Earth Disturbing Activities are routine maintenance activities that do not change the purpose, line and grade, or the hydraulic capacity of the facility and involve Total EDA of less than five acres. Routine Maintenance Projects do not require permit coverage and therefore do not require an NOI. If a project

C1109.2

40 CFR 122.26(b)(15)(i) indicates that "construction activities" (which require an NOI) do not include routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the facility. While the federal language does not include an acreage limitation on routine maintenance activities, Ohio EPA added the limitation that routine maintenance projects (that do not require an NOI) must be limited to projects that have a Total EDA of less

includes disturbance from both routine maintenance activities and construction activities, then the project, as a whole, cannot be considered a Routine Maintenance Project and all earth disturbed area must be included in determining the requirement for an NOI. Permanent erosion control items are included in the plans, if required.

Projects with five or more acres of Total EDA cannot be classified as Routine Maintenance Projects.

The following activities are considered routine maintenance activities:

- Bridge Repair and Replacement – repair or replace bridge abutments, approach, and deck and associated grading
- Fence Repair and Replacement – repairing or replacing existing fencing and/or posts
- Guardrail Repair and Replacement – repairing or replacing with minor grading work to create proper grade for end assemblies where previous guardrail existed
- Noise Wall Repair – repairing or replacing existing noise wall
- Sign Maintenance – repairing or replacing traffic signs and posts
- Lighting Maintenance
- Loop Detector Repairs – repairing loop detectors in existing pavement
- Signal Installation and Maintenance – installing, repairing, or replacing traffic signals and poles where previous signals existed
- Pothole Filling
- Tree/Brush Removal
- Linear Grading – reshaping of graded shoulders to establish proper drainage away from pavement
- Berm Repair or Topsoil placement along shoulders – placing berm material or topsoil on shoulders adjacent to pavement to eliminate drop-offs
- Ditch Cleanout – maintaining or restoring original flow line and cross section only
- Culvert Replacement – replacing a culvert with same line, grade and hydraulic capacity; must be within parameters of the USAC Nationwide Permit #3

than 5 acres.

Ohio EPA's routine maintenance exclusion for construction activity permitting can be found here: Storm Water Program

If EDA associated with routine maintenance activities are located ¼ mile or farther apart, they may be considered separately associated with the five-acre Total EDA limit.

- Culvert Repair or Lining – repairing or lining existing culvert maintaining same line, grade and hydraulic capacity, must be within parameters of the USAC Nationwide Permit #3
- Curb Repairs – repairing existing curbing along a roadway
- Utility Repairs – repairs to existing utilities, and associated grading or pavement replacement
- Sidewalk – replacement of existing sidewalk without other drainage or roadway improvements
- Land slide repairs – includes grading and repairing roadway features affected by the slide
- Unpaved/Gravel Roadway or Shoulder Maintenance – dragging, blading, grading, adding aggregate, etc. to an existing unpaved/gravel roadway. This includes paving of an existing gravel road or shoulder in order to stabilize the roadway surface
- Full Depth Pavement Repair or Replacement – repairs to existing roadway with no changes to the purpose, horizontal alignment, or hydraulic capacity of the roadway. Full depth pavement replacement is considered a routine maintenance activity if no additional impervious area is added outside of the existing edge of the paved roadway

Post-construction storm water best management practices are not required for Routine Maintenance Projects. For projects in which all of the Project EDA is associated with routine maintenance activities, but the Total EDA is equal to or greater than 5 acres, an NOI is required. However, for some of these projects, such as larger land slide repairs or linear grading, post-construction BMPs may not be necessary. Coordinate with OHE and Ohio EPA to determine whether post-construction BMPs will be required for these projects.

Submit an NOI for routine maintenance projects that have all the following criteria:

- Earth disturbance within 200 feet of Waters of the United States
- Earth disturbance associated with landslide repair, mitigation, bridge repair, or bridge replacement
- Total EDA is equal to or greater than 1 acre

Post-construction BMPs are not required for these

For all projects that submit an NOI with a Project EDA > 0, provide Item 832, Erosion Control, Item 832, Storm Water Pollution Prevention Plan, Item 832, Storm Water Pollution Prevention Inspections, and Item 832, Storm Water Pollution Prevention Inspection Software. See Section 1110.1 for more details.

routine maintenance projects that are within 200 feet of Waters of the United States.

1109.3 Watershed Specific NOI Requirements

Watershed-specific requirements exist for the Big Darby Creek watershed in Table 1109-1 and portions of the Olentangy River watershed in Table 1109-2. These watersheds are identified by their Hydrologic Unit Code. Coordinate projects in the following watersheds with OHE:

Table 1109-1

Big Darby Creek Watersheds with Additional Permit Requirements	
HUC-10	**Watershed Name**
0506000119	Headwaters Big Darby Creek
0506000120	Little Darby Creek
0506000121	Worthington Ditch-Big Darby Crk
0506000122	Hellbranch Run-Big Darby Creek

Table 1109-2

Olentangy River Watersheds with Additional Permit Requirements	
HUC-12	**Watershed Name**
050600010901	Shaw Creek
050600010902	Headwaters Whetstone Creek
050600010903	Claypool Run-Whetstone Creek
050600010904	Delaware Run-Olentangy River
050600010905	Deep Run-Olentangy River
050600010906	Rush Run-Olentangy River*

* only the portion north of IR-270

Projects located in the Big Darby Creek watershed must meet the standard permit requirements as well as the following additional requirements described in Appendix A of Ohio EPA's construction general permit:

- Sediment settling pond sizing, for temporary erosion and sediment control, that is larger than normally required
- Quarterly sampling of all concentrated runoff from active construction sites following a rainfall event, ensuring that the effluent TSS concentration is no greater than 45 mg/L
- Riparian setback mitigation for riparian zone impacts outside of the existing ODOT right-of-way
- Groundwater recharge mitigation for impacts

C1109.3

Ohio EPA's construction general permit includes additional requirements for projects located in certain designated watersheds.

A map of HUC boundaries can be found at ODOT's TIMS website. Click on **HUC – Stream Order** to view the boundaries.

outside of the existing ODOT right-of-way

See Ohio EPA's construction general permit for detailed requirements of the above bullets.

In the Big Darby Creek watershed, linear transportation projects which are caused solely by correcting safety related issues, mandates of modern design requirements and/or resulting from other mitigation activities are exempt from riparian setback mitigation and groundwater recharge mitigation if less than one acre of total new right-of-way is associated with the project.

Projects located in the portions of the Olentangy River watershed shown in Table 1109-2 must meet the standard permit requirements as well as the following additional requirement described in Appendix B of Ohio EPA's construction general permit.

- Riparian setback mitigation for riparian zone impacts outside of the existing ODOT right-of-way

For projects in the watersheds listed in Table 1109-1 and Table 1109-2, provide groundwater recharge calculations, riparian setback mitigation calculations, and temporary sediment basin sizing calculations and locations to OHE with the BMP submittals as outlined in Section 1112.2. Groundwater recharge calculations and riparian setback calculations are based on impacts outside the existing ODOT right-of-way. Determine the riparian setback limits according to Ohio EPA's construction general permit and identify the riparian setback limits on the Project Site Plan.

Determine mitigation for groundwater recharge and riparian setback through coordination between the District and OHE prior to the BMP submittal outlined in Section 1112.2. The District and OHE must coordinate with Ohio EPA as to any mitigation proposals prior to submittal of the NOI application.

Determine soil types required for groundwater recharge calculations using the NRCS Web Soil Survey website.

While sediment basin locations are typically provided by the Contractor, designers of projects being developed in the watersheds listed in Table 1109-1 and Table 1109-2 must identify locations of sediment basins with capacities required for these watersheds. Show the locations and calculations for sediment basins on the Project Site Plan.

Additional temporary erosion and sediment control features will be added to the Storm Water Pollution Prevention Plan by the Contractor.

Submit the NOI, Project Site Plan, proposed mitigation and supplemental calculations to the Ohio EPA at least two months prior to plan package submittal to ensure that there are no delays.

1110 Temporary Sediment and Erosion Control

1110.1 General

Provide temporary sediment and erosion control on all projects that have Earth Disturbing Activities. As outlined in SS832, projects fall into four different scenarios associated with temporary sediment and erosion controls.

Scenario A: No EDA, No NOI

Scenario B: EDA > 0, No NOI

Scenario D: NOI required due to contractor activities

Scenario F: EDA > 0, NOI required

Include SS832 on all projects.

Provide Item 832, Erosion Control, on all projects with EDA (Scenarios B, D, and F).

Provide Item 832, Storm Water Pollution Prevention Plan, Item 832, Storm Water Pollution Prevention Inspections, and Item 832, Storm Water Pollution Prevention Inspection Software, on projects with Project EDA > 0 that require an NOI, Scenario F.

Projects that have potential environmental impacts to habitat, species or with specific local requirements may also be required to submit an NOI and prepare a SWPPP as determined by the District Environmental Coordinator.

C1110.1

SWPPP requirements are outlined in SS832.

1110.2 Cost Estimate for Temporary Sediment and Erosion Control

For all projects that require Item 832, Erosion Control, furnish a dollar amount to be encumbered in the final plan package. Use the Item 832 Erosion Control Estimator spreadsheet to estimate this amount. The dollar amount for Item 832, Erosion Control, is used for both the **quantity** and the **total** fields.

The units for Item 832, Storm Water Pollution Prevention Plan, Item 832, Storm Water Pollution Prevention Inspections, and Item 832, Storm Water Pollution Prevention Inspection Software, are each lump sum.

1111 Post-Construction Storm Water Structural Best Management Practices

1111.1 General

For ODOT projects, submit any proposed alternative post-construction BMP designs that are not found in Section 1113 to OHE. A review and approval of the alternative BMP by OHE and Ohio EPA is required. Local-Let Local Public Agency projects may use an alternative post-construction BMP criterion with Ohio EPA approval.

Locate BMPs so that they are protected in accordance with the LD1.

C1111.1

Post-Construction Storm Water Best Management Practices (BMPs) are provided for long term management of storm water runoff quality and quantity so that a receiving stream's physical, chemical and biological characteristics are protected, and stream functions are maintained.

Ohio EPA's construction general permit includes requirements for post-construction BMPs on most projects that meet the disturbance threshold for an NOI. The construction general permit allows roadway projects administered by public entities, such as ODOT, to follow the criteria in this manual as an alternative to the specific post-construction BMP requirements in the permit. Many of the post-construction BMP design criteria in this manual are consistent with Ohio EPA's permit, but some criteria have been tailored to fit linear roadway construction as opposed to standard site development.

Local entities with local post-construction guidance may have more restrictive language regarding selection and use of BMPs as compared to the Department. Storm water discharge from ODOT right-of-way is not subject to local storm water requirements. While the local entity cannot force the Department to use their standards, it may be possible for the Department to incorporate the needs of the local entity subject to review and approval of OHE.

1111.2 Project Thresholds for Post-Construction BMP

Projects that do not require an NOI per Section 1109 do not require post-construction BMPs. Since Routine Maintenance Projects do not require an NOI, they do not require post-construction BMPs. For projects that do require an NOI, the requirement for post-construction BMPs is based on the Project EDA. While the requirement for an NOI is based on Total EDA, the requirement for

C1111.2

As described in Section 1109, EDA is defined as any activity that exposes bare ground or an erodible material to storm water as well as anywhere that Item 659, Seeding, or Item 660, Sodding, is being provided. Contractor EDA is generally outside of the ODOT right-of-way and therefore is unable to be addressed by post-construction BMPs.

post-construction BMP treatment is only based on Project EDA (Total EDA – Contractor EDA). Contractor EDA is stabilized after construction to match existing conditions.

The following types of projects do not require post-construction BMPs.

- Project EDA < 1 acre
- Routine Maintenance Projects as defined in Section 1109.2
- Projects including only earth disturbance from utility line, fence, guardrail, or noise wall installation

Provide post-construction BMPs for all projects with Project EDA ≥ 1 acre except those listed above.

For projects requiring post-construction BMPs, evaluate the following items:

- Need for Water Quantity and Quality Treatment vs. only Water Quality Treatment (Section 1111.3)
- Project Type – Redevelopment or New Construction (Section 1111.6)
- If New Construction, calculate the Treatment Percent (Section 1111.7)
- Applicable BMP to be implemented (Section 1113)

All projects, including Local Public Agency projects, ODOT-let and Local-Let, are required to provide post-construction BMPs as indicated in this section. Coordinate with the LPA when a project requires post-construction BMPs outside ODOT right-of-way. Inform the LPA of maintenance responsibilities associated with post-construction BMPs.

Projects may have a Total EDA ≥ 1 acre but a Project EDA < 1 acre. For these types of projects, an NOI is required because the Total EDA threshold is met, but a post-construction BMP is not required because the Project EDA threshold is not met.

Projects that include construction activities only associated with utility line, fence, guardrail, or noise wall installation do not require post construction BMPs. These types of projects may require an NOI if the Total EDA threshold is met, but not a post-construction BMP.

1111.3 Water Quality and Water Quantity Treatment

Post-construction storm water treatment is divided into two categories: water quality treatment and water quantity treatment. Projects exceeding the minimum thresholds in Section 1111.2 must address water quality and potentially water quantity treatment in the post-construction BMP.

BMPs to address water quantity are not required for projects that meet any of the following criteria:

- Redevelopment projects as defined in Section

C1111.3

Water quality treatment provides for reduction of pollutants from storm water runoff before leaving the site. Water quantity treatment is reducing the volume or peak flow rate of storm water runoff in order to protect the receiving stream’s physical characteristics.

1111.6.1.

- New Construction Projects as defined in Section 1111.6.2 where less than 1 acre of new impervious area is created in new permanent right-of-way area being acquired for the project.
- Portions of New Construction Projects, as defined in Section 1111.6.2, which discharge from ODOT right-of-way, directly to a large river or to a lake and where the development area is less than 5 percent of the watershed area upstream of the development site, unless known water quality problems exist in the receiving waters. Only the project areas that drain from ODOT right-of-way to a large river or lake will be excluded from the requirement to provide quantity treatment. If portions of a project discharge to smaller waterbodies, quantity treatment may still be required for those portions.

Do not subdivide projects into multiple NOIs for the sole purpose of attempting to reduce post-construction treatment requirements.

BMPs that treat water quality and water quantity include:

- Detention Basin
- Retention Basin, also called Wet Extended Detention Basin in Ohio EPA permit
- Bioretention Cell
- Infiltration Trench
- Infiltration Basin
- Constructed Wetlands
- Amended Vegetated Filter Strip

BMPs that treat only water quality include:

- Manufactured Systems
- Vegetated Biofilter
- Vegetated Filter Strip

BMPs that treat only water quantity and must be paired with a water quality BMP include:

- Stream grade control structures, within Waters of the U.S.
- Underground Extended Detention

If there is a question regarding the stream classification, contact OHE. A map of stream classifications can be found at ODOT's TIMS website. Click on the **HUC – Stream Order** tab to view the stream layers.

A large river has a drainage area >100 square miles or is fourth order or greater.

ODOT's BMPs are divided into two categories of treatment because Ohio EPA's General Construction Permit (OHC000005) states "Discharge rate is considered to have a negligible impact if the permittee can demonstrate that one of the following three conditions exist:

i. The entire WQ_V is recharge to groundwater;
ii. The larger common plan of development or sale will create less than one acre of impervious surface;
iii. The storm water drainage system of the development discharges directly into a large river with drainage area equal to 100 square miles or larger upstream of the development site or to a lake where the development area is less than 5 percent of the watershed area, unless a TMDL has identified water quality problems into the receiving surface waters of the state."

For ODOT projects, if discharge rate has a negligible impact (as defined in this document), then water quantity treatment is not required.

1111.4 Water Quality Volume

Use the water quality volume to determine sizing

C1111.4

The water quality volume calculation is used to for the following BMPs:

- Detention Basin
- Retention Basin
- Infiltration Trench
- Infiltration Basin
- Constructed Wetlands

Use the following equation to calculate the water quality volume:

$$WQ_V = \frac{R_V PA}{12}$$

Where:

WQ_V = Water Quality Volume (acre-feet)

R_V = Volumetric Runoff Coefficient: 0.05 + 0.9 * i

i = impervious area divided by the total area (within the BMP drainage area)

P = Precipitation (0.90 inches)

A = Contributing Drainage Area to the BMP (acre)

Treat all areas within existing ODOT right-of-way as impervious when determining the impervious area within the BMP drainage area.

define the amount of storm water runoff from any given storm that should be captured and treated in order to remove a majority of storm water pollutants on an average annual basis.

Ohio EPA determined that the WQ_V precipitation depth of 0.90 inches is the appropriate depth for sizing BMPs in order to achieve an estimated 80 percent reduction in total suspended solids (TSS) on an average annual basis based on long-term, historic Ohio rainfall data.

All areas within existing ODOT right-of-way are treated as impervious because ODOT and Ohio EPA acknowledged that roadway construction generally compacts soils, even outside of impervious areas. Therefore, Ohio EPA requires that ODOT consider existing right-of-way impervious in BMP design as a conservative approach to avoid under sizing BMPs.

While existing right-of-way is treated as impervious, pervious areas in newly acquired right-of-way for a project are not considered impervious for BMP calculations.

1111.5 Water Quality Flow

Use Water Quality Flow to determine sizing for manufactured systems and vegetated biofilters.

The WQ_F is calculated based on the rational method as described in Section 1101.2.2.

$$Q = CiA$$

Where:

Q = Discharge (cfs)

C = Coefficient of runoff

i = Average rainfall intensity in inches per hour, for a given AEP storm and for a duration equal to the time of concentration.

A = Drainage area (acre)

The **C** value used for the WQ_F calculation must be consistent with the rational method and Table 1101-2. Treat all areas within existing ODOT right-of-way as impervious with a **C** value of 0.90 when determining the appropriate **C** value.

The rainfall intensity **i** for the WQ_F calculation is

C1111.5

The coefficient of runoff **C** used in the WQ_F equation is not the same as the volumetric runoff coefficient **R_V** used in the WQ_V calculation.

different for the design of manufactured systems compared to vegetated biofilters.

1111.5.1 Rainfall Intensity for Manufactured Systems

The process for determining the rainfall intensity for manufactured systems is similar to the process in Section 1101.2.2. Calculate the time of concentration from the most remote point of the drainage area to the manufactured system. Then, use that time of concentration to determine the appropriate water quality intensity according to the Duration vs. Intensity Table in Figure 1111-2.

C1111.5.1

The Duration v. Intensity Table in Figure 1111-2 is taken from Ohio EPA's Construction General Permit (OHC000005)

1111.5.2 Rainfall Intensity for Vegetated Biofilters

Use the rainfall intensity of 0.65 in/hr for sizing of vegetated biofilters.

C1111.5.2

The typical length, percent of the drainage area that is grass-covered, and contribution from off-site runoff leads to high average time of concentrations. This, combined with conservative requirements in Section 1113.2.2 makes 0.65 in/hr an appropriate intensity for sizing of vegetated biofilters.

1111.6 Project Type - Redevelopment and New Construction

1111.6.1 Redevelopment Projects

Redevelopment projects include:

- Projects constrained entirely within existing right-of-way
- Projects that do not add new impervious area in new permanent right-of-way

While all areas within existing ODOT right-of-way may not be covered by impervious surfaces, the area within existing ODOT right-of-way is considered impervious area for the purpose of post-construction BMP design considerations. Therefore, consider all area within existing right-of-way to be impervious when performing post-construction BMP calculations.

1111.6.2 New Construction Projects

Projects that add new impervious area inside new permanent right-of-way are considered new construction projects.

New construction projects allow for the reduction of treatment requirements based on the amount of new impervious area relative to the existing impervious area within the Project EDA, see

Section 1111.7. Consider all area within existing ODOT right-of-way to be impervious for post construction BMP calculations.

1111.6.3 Pedestrian Facilities and Shared Use Paths

For Redevelopment Projects or New Construction Projects that include Project EDA only associated with pedestrian facilities and shared use paths, with no Project EDA from planned roadway improvements, narrow Vegetated Filter Strips are an acceptable post-construction BMP per Section 1113.2.1. For these projects, quantity treatment per Section 1111.3 is not required.

1111.7 Treatment Requirements for Projects

The amount of treatment required for a project to meet the post-construction BMP treatment requirements is based on the Project EDA and the weighted average for new and existing impervious area.

Use a Treatment Percentage (T%) of 20% for redevelopment projects.

Determine the Treatment Percent for New Construction projects using the following equation:

$$T\% = \frac{(Aix * 20) + (Ain * 100)}{(Aix + Ain)}$$

Where:

T% = Treatment percent (percentage)

Aix = Project EDA that is inside the existing right-of-way

Ain = The new impervious area inside new permanent right-of-way minus any impervious area that is removed inside new permanent right-of-way.

All Project EDA within existing ODOT right-of-way is included in the Aix value. All area within existing ODOT right-of-way, whether impervious or pervious, is considered to be impervious for post-construction BMP calculations.

Provide post-construction treatment area equal to: Project EDA * T%.

Area draining to a post-construction BMP will earn treatment credit equal to the amount of ODOT

C1111.7

All areas within existing ODOT right-of-way (Aix) are treated as impervious because ODOT and Ohio EPA acknowledged that roadway construction generally compacts soils, even outside of impervious areas. Therefore, Ohio EPA requires that ODOT consider existing right-of-way impervious in BMP design as a conservative approach to avoid under sizing BMPs.

While existing right-of-way is treated as impervious, pervious areas in newly acquired right-of-way for a project are not considered impervious for BMP calculations.

Example: A vegetated biofilter that has offsite contributing drainage area of one acre and on-site contributing drainage area of two acres (total drainage area of three acres) would result in a treatment credit of two acres. The vegetated biofilter must be sized for the total contributing drainage area of three acres. Multiple areas of a project may provide treatment to meet the treatment requirement. If the total area requiring treatment in this example was four acres, another vegetated biofilter with a minimum of two acres of on-site drainage area would be needed to meet the treatment requirements.

Example: A large new roadway project is constructed and 100% of the project EDA drains to a post-construction BMP. If a future portion of this roadway is redeveloped, and that area already drains to an existing BMP, no new BMPs would be required to meet post-construction treatment requirements.

Example: A large highway redevelopment project right-of-way area treated by the BMP.

The treatment credit, the ODOT right-of-way area treated by BMPs, must be equal to or greater than the treatment requirement (Project EDA * T%) for the project.

Size the BMP based on the entire contributing drainage area, offsite and on-site, to the BMP.

Credit for water quality and water quantity treatment is only applied to the portion of the contributing drainage area within ODOT right-of-way. Include any offsite contributing drainage area in the BMP calculations for sizing purposes. Do not include the offsite area in the determination of treatment credit.

For projects with multiple distinct stream crossings that do not immediately share a common confluence downstream, provide post-construction BMP treatment proportional to the amount of Project EDA tributary to each stream.

If there is an existing post-construction BMP that treats runoff from the project site, and the BMP is sized appropriately to manage runoff from T% of the Project EDA, then additional BMPs are not required to meet post-construction treatment requirements. Include the existing post-construction BMP in the Project Site Plan. Include calculations demonstrating the BMP's capacity to manage runoff from the project site as well as any other existing sources of runoff into the BMP in the BMP submittal described in Section 1112.2.

(100 acres) is constructed and 20% of the project EDA (20 acres) drains to various post-construction BMPs. A future redevelopment project has a project EDA of 10 acres within the original 100-acre project. The treatment requirement for the future project is 2 acres. If at least 2 acres of the future project drains to existing post-construction BMPs, then no new BMPs would be required to meet post-construction treatment requirements. If the future project is planned for a section of the roadway where BMPs were not implemented in the original project, then new BMPs are required that ensure a minimum of 2 acres of the future project drain to a BMP.

All roadway right-of-way areas draining to an appropriately sized BMP earn treatment credit. This includes areas that are not considered EDA and areas not covered in the project's Construction General Permit. Treatment credit for vegetated biofilters is determined differently as described in Section 1113.2.2.

1112 BMP Selection & Submittals

1112.1 BMP Selection

Base selection of BMP on providing maximum runoff treatment while minimizing impacts to the remaining project design features, including utilities and right-of-way. In addition, each BMP option comes with unique maintenance requirements.

Obtain approval from Ohio EPA to use alternative BMPs not listed in Section 1113. Alternative methods will be approved or denied on a case-by-case basis if the alternative methods are demonstrated to sufficiently protect the overall integrity of the receiving streams and the watershed. For curbed roadways, total contributing drainage areas to sumps or intersections that are less than or equal to 0.25

C1112.1

Contact the Office of Maintenance Administration for detailed BMP maintenance information.

acres as shown in Figure 1112-1 do not require a BMP. Note that these exceptions are unique circumstances. Provide BMP as necessary for all other project features.

For projects where the drainage sheet flows off the roadway and continues outside existing or proposed right-of-way, do not channelize flow for the sole purpose of providing a post-construction BMP. Treatment is not required for areas where sheet flow off the roadway continues to sheet flow outside ODOT right-of-way. Document areas where this occurs in the post-construction BMP calculations and identified on the Project Site Plan.

For projects where portions of the disturbed area sheet flows outside ODOT right-of-way, calculate the treatment requirement area as follows:

(Project EDA – Sheet Flow Area) * T%

Where:

Project EDA = as defined in Section 1109.1

Sheet Flow Area = Area within the Project EDA that sheet flows outside ODOT right-of-way (acre)

T% = Treatment percent as defined in Section 1111.7

If a BMP can fit in an area that sheet flows outside of ODOT right-of-way, such as a vegetated filter strip, the project may install a BMP in that area and receive treatment credit. However, if a BMP is installed in an area that sheet flows outside of ODOT right-of-way, that area must not be excluded from the Project EDA in determining the required treatment area.

Design criteria for all BMP are available in Section 1113. A flow chart to determine BMP treatment requirements is provided in Figure 1111-1.

1112.2 BMP Submittals

Consider BMPs early in the design process to allow for right-of-way and utility coordination as well as evaluation with respect to waterway permitting issues.

For PDP projects characterized as Paths 4 and 5, provide a description of the planned BMPs to be used for the project in the Preliminary Engineering Phase. Submit final BMP design during Stage 1 plan development as identified in later tasks of the Preliminary Engineering Phase. Further refinement may be needed within the

C1112.2

The following design resources are available on the OHE Post Construction Storm Water BMP web page.

- Post-Construction BMP Design Review Checklist
- BMP Calculation Spreadsheet
- Post-Construction BMP Design Examples
- Post-Construction BMP Training Workshop Slides

Environmental Engineering Phase.

For projects categorized as Paths 1-3, it is unlikely a conceptual BMP task will be needed. Include BMPs in the Environmental Engineering Phase and potentially the Final Engineering Phase of the PDP.

Submit the BMP final design during Stage 1 to OHE. Include the following information:

- Estimated Project Earth Disturbed Area
- Treatment Percent Calculation as well as Treatment Requirement Area
- BMPs selected for use
- Drainage area mapping for post-construction BMPs that show the total contributing drainage area and the amount of contributing drainage area within ODOT right-of-way.
- Plan sheets showing locations of post-construction BMPs
- Calculations for each BMP. See section BMP Toolbox
- Explanation for any area that is not treated such as environmental commitment, total parcel takes, environmental resource impact, sheet flow runoff, etc.

Identify the final locations and EDA treatment credit of each individual post-construction BMP in the Project Site Plan as described in Section 1308 of the LD3. If applicable, provide cross-references to sheets showing post-construction BMP details on the Project Site Plan.

1113 BMP Toolbox

1113.1 Manufactured Systems

Supplemental Specifications 895 and 995 cover the material and performance criteria for these devices. Place manufactured systems in an off-line configuration with manholes to allow for routine maintenance procedures. See Figure 1113-1.

Use the following procedure for design of manufactured systems:

1. Determine the total contributing drainage area.
2. Calculate the WQ_F according to Section 1111.5.
3. Provide a No. 3 Manhole, with ___” Base ID and ___” Weir where flow is to be diverted to the off-line manufactured system according to Table

C1113.1

Manufactured systems consist of underground structures that treat the WQF by removing particulate matter through settlement or filtration.

Figure 1113-1 shows the typical layout of a diversion manhole and the space reserved for a manufactured system. Figure 1113-9 illustrates an isometric rendering of a manufactured system.

1113-1 and 1113-2 and the calculated WQ_F.

Table 1113-1

Manufactured Systems			
Type	**WQ_F (cfs)**	**No. 3 Manhole Base ID (inches)**	**611-Type B Conduit Diameter (inches)**
1	1	84	12
2	2	90	15
3	3	96	18
4	6	108	24

Reserve an area, as measured from the centerline of the No. 3 Manhole, according to Table 1113-2:

Table 1113-2

Reserved Area for Manufactured System				
Type	**W (ft)**	**L (ft)**	**611-Type B Total Conduit Length (ft)**	**Weir Height (inches)**
1	15	30	20	6
2	20	32	30	8
3	25	33	40	9
4	25	37	40	12

4. Furnish two lengths of 611, Type B Conduit placed perpendicular to the inflowing sewer See Table 1113-2 for the total length required.
5. Reserve an area, as measured from the centerline of the No. 3 Manhole, according to Table 1113-2. If this area is not attainable, contact OHE for further guidance. Confirm the area is void of all utilities and is accessible for routine cleanout and maintenance.

For manufactured systems located along a roadway with a legal speed limit over 45 mph, locate the area for the manufactured system outside all paved areas.

For manufactured systems located along a roadway with a legal speed limit of 45 mph and less, it is preferred to locate the area for the manufactured system outside paved areas. If it is not feasible to locate the area outside of the paved area, select another BMP or contact OHE for further coordination.

When a manufactured system is connected to a storm sewer with a depth exceeding 10 feet, contact OHE.

Manufactured systems are typically not suited for treatment of flows in large trunk sewers. As indicated in Table 1113-1, do not provide manufactured systems on sewers that are carrying a water quality flow greater than 6 cfs. The water quality flow calculation is based on the entire contributing drainage area to the storm sewer.

Add Item 895, Manufactured Water Quality Structure, Type__, to the plans when using a manufactured system.

Label the location and EDA treatment credit on the Project Site Plan for each manufactured system on the project.

1113.2 Vegetation Based BMP

1113.2.1 Vegetated Filter Strip

The Vegetated Filter Strip consists of the grassed portion of the graded shoulder and the grassed foreslope. The VFS must be void of gullies or concentrated flow. The water flow is characterized as overland flow throughout the grass.

The minimum VFS required is defined in Table 1113-3 below. The VFS can start at the end of the graded shoulder or at any point on the slope. Areas such as pavement, graded shoulder, or any grass slope that drain to a VFS receive treatment credit including the VFS area.

Table 1113-3

Maximum Pavement Width (ft)	Maximum Slope (H:V)	Minimum Filter Strip Width (ft)
22	3:1	15
24	3:1	17
26	3:1	18.5
28	3:1	20.5
30	3:1	22
32	3:1	24
34	3:1	25
48	6:1	25

Measure the VFS width down the grass slope starting at the grass and ending at the inside edge of the ditch bottom.

C1113.2.1

A Vegetated Filter Strip is a BMP that filters storm water through vegetation.

Figure 1113-10 illustrates an isometric rendering of a vegetated filter strip.

Vegetated filter strip performance and design criteria were supported by research conducted by Ohio University titled; Vegetated Biofilter for Post Construction Storm Water Management for Linear Transportation Projects (Mitchell, 2010). While the title reads “Vegetated Biofilter,” it in fact supports vegetated filter strips, and not the Department’s vegetated biofilter BMP.

Do not include any area associated with concentrated flows that outlet to a VFS in the treatment credit.

Use of VFS located behind guardrail must be coordinated with the District Maintenance department to confirm that maintenance is feasible. Ensure that mower access is provided to any VFS.

Maintaining grass may be difficult on slopes behind guardrail. Often, areas behind guard rail are allowed to grow brush instead of grass, which does not meet the grass requirement for a VBF. Also, some vegetation management practices associated with guard rail can lead to poor grass growth, such as spraying herbicide.

For projects that include EDA only associated with pedestrian facilities and shared use paths, with no EDA from planned roadway improvements, widths of the VFS can be narrower than those in Table 1113-3. Vegetated Filter Strips are an acceptable post-construction BMP for these projects when the following criteria are met:

- The minimum VFS width is equal to the width of the contributing impervious area
- The maximum slope of the VFS is 3:1
- All runoff must be sheet flow, with no concentrated flows to the VFS

Similarly, to standard VFS, treatment credit for narrow VFS is given to the impervious area draining to the filter strip as well as the area of the filter strip itself.

Projects that have EDA from a combination of pedestrian facilities or shared use path as well as roadway improvements may not utilize VFS narrower than those shown in Table 1113-3 without project-specific permission from Ohio EPA.

Narrow VFS Example 1: A project includes the addition of 4-foot wide sidewalk along a road to the extent that the project EDA is greater than 1 acre, but no roadway improvements are included. That project may incorporate 4-foot wide Vegetated Filter Strip collecting runoff from the sidewalk in order to meet its post-construction treatment requirements.

Narrow VFS Example 2: A project includes the addition of a 10-foot-wide bike path, but no roadway improvements are included in the project. The project may incorporate 10-foot wide Vegetated Filter Strip collecting runoff from the bike path in order to meet its post-construction treatment requirements.

Label the station range and location, the VFS width, and the EDA treatment credit on the Project Site Plan for each VFS provided on the project.

Add 4” of Item 659, Topsoil, to the disturbed portion of the grass shoulder and foreslope of the VFS.

Add Item 670, Slope Erosion Protection, to the disturbed portion of the grass shoulder and foreslope of the VFS.

VFSs may be used in areas where the existing grassed slope meets the conditions in Table 1113-3. The topsoil and slope erosion control is only required for disturbed areas of a VFS. The purpose of the topsoil and slope erosion control is to help establish good grass coverage. Do not disturb existing good grass coverage for the sole purpose of installing topsoil and slope erosion protection.

1113.2.2 Vegetated Biofilter

The Vegetated Biofilter consists of the grassed portion of the graded shoulder, grassed foreslope, and flat grassed ditch. The purpose of the VBF is to

C1113.2.2

If the Vegetated Filter Strips will not provide the required treatment, consider using a Vegetated allow runoff to spread out and move slowly through a shallow, flat, and grassed conveyance. VBF must be void of rills, gullies, or visible erosion on the grassed foreslope of the ditch as well as in the bottom of the ditch.

When widening existing ditches, consider the following before purchasing new right-of-way:

- A steeper ditch foreslope
- A steeper ditch backslope
- Reducing the bench width to a minimum of 4 ft.

Consider soil conditions and safety issues prior to making any of the above changes to the existing slopes or benches.

Changes to existing ditches may be regulated through waterway permits since ditches may be considered streams or wetlands. Avoid or minimize all impacts to existing streams and wetlands to the maximum extent practicable. To determine if the proposed ditch will impact an existing stream or wetland, contact the District Environmental Coordinator.

For projects utilizing the VBF, provide a ditch width using the Enhanced Bankfull Width or the standard ditch width to provide water quality treatment. Use the following steps to determine the ditch width:

1. Determine Enhanced Bankfull Width:

   The EBW is the width in a trapezoidal ditch for which the following criteria are met:

- The minimum EBW is 4 ft.
- The depth of flow for the water quality flow rate (WQ_F) is less than or equal to 4 inches
- The velocity of flow for the water quality flow rate (WQ_F) is less than or equal to 1 fps

   Use the water quality flow rate (WQ_F) per Section 1111.5.

   Use Manning's Equation to determine the depth and velocity of flow:

   Manning's Equation:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

   Where:

   Q = flow rate (cfs)

   n = Manning's Roughness Coefficient (0.15)

   A = Cross section area of flow (ft^2)

Biofilter.

A VBF is a BMP that filters storm water through vegetation and potential infiltration.

Figure 1113-2 shows isometric and cross section views of a vegetated biofilter. Figure 1113-11 illustrates an isometric rendering of a vegetated biofilter.

The minimum EBW width of 4 ft. is based on the ability to construct and maintain a flat bottom ditch. Narrower ditches are less likely to maintain a flat ditch bottom.

The 4-inch depth limitation is based on keeping the depth of flow within the height of grass to promote filtering.

The 1 fps velocity limitation is based on limiting the velocity to avoid grass bending over and reducing filtering capacity.

A value of 0.15 for the Manning's Roughness Coefficient is required because flow depths within the height of grass (4 inches or less) have

R = Hydraulic Radius (ft) (Area/Wetted Perimeter)

S = Longitudinal Slope of ditch (ft/ft)

There is not a direct calculation to determine EBW. Use a trial-and-error method to determine a width for which the depth and velocity criteria are met for the WQF, assuming open channel flow. The EBW is in whole numbers only, no half-foot increments.

The enhanced bankfull width corresponds to the dimension of the bottom width of the trapezoidal ditch.

2. Determine Standard Ditch Width:

   Determine the size of the trapezoidal ditch that would typically be specified for the project without accounting for water quality treatment using typical roadway design practices.

   Use the bottom width dimension of the trapezoidal ditch. Ignore any rounding lengths associated with the trapezoidal ditch.

3. Determine the VBF ditch width required for water quality treatment as described below:

A. If the EBW is less than or equal to the standard ditch width, use the standard ditch width.

B. If the EBW is greater than the standard ditch width, use the EBW.

The EBW can be calculated at multiple locations along its length. This would allow the width to be reduced where there is less tributary area, such as at the upstream end of the ditch. However, use the entire contributing drainage area to the location in the ditch being evaluated to determine the EBW.

Recalculate the EBW at points where concentrated offsite runoff is accepted.

Treatment credit for VBF is given to:

1. Areas within the project limits that sheet flow off the roadway into a grassed shoulder, grassed foreslope, and then into a grassed trapezoidal ditch sized as described above. Tributary areas to a VBF that do not meet this criterion, i.e. drainage from concentrated flow or outside project limits, must be included in the determination of the EBW, but do not receive treatment credit.

2. The area of the defined VBF including the shoulder, foreslope, ditch bottom, and

Manning's Roughness values more consistent with overland flow rather than open channel flow.

backslope within the permanent right-of-way.

Make sure that rock or other impervious soil layers will not prevent grass from being established at the invert of the flowline. A minimum of 1-foot separation is required between the invert of a VBF and bedrock. If the velocity is such that rock channel protection, reinforced concrete mats, or SS836 are required, that section of the ditch cannot be used as a VBF.

Bedrock is solid in-place rock typically underlying soil and exhibiting structure, such as bedding and jointing.

Use of VBF with grassed foreslopes steeper than 3:1 or located behind guard rail must be coordinated with the District Maintenance department to confirm that maintenance is feasible. Ensure that mower access is provided to any VBF.

Maintaining grass foreslopes and ditch bottoms may be difficult on steeper slopes, especially behind guard rail. Often, areas behind guard rail are allowed to grow brush instead of grass, which does not meet the grass requirement for a VBF. Also, some vegetation management practices associated with guard rail can lead to poor grass growth, such as spraying herbicide.

Constriction points in the enhanced bankfull width at drive pipes or other drainage related features are acceptable. Transition back to the calculated width immediately following the constriction point.

Label the station range and location, bottom width, and EDA treatment credit on the Project Site Plan for each VBF provided on the project.

Add 4” of Item 659, Topsoil, to the grass portion of the shoulder and foreslope of the VBF.

Add Item 670, Ditch Erosion Protection, to the plans when using VBF. Size the width of ditch erosion protection consistent with Section 1102.3.1, using the width for the 20% AEP storm. 4 feet is the minimum width of lining. Additional required width is in increments of 3.5 feet.

1113.2.3 Amended Vegetated Filter Strip

Amended vegetated filter strips consist of grassed slopes on top of amended soils. The AVFS must be void of gullies or concentrated flow. All runoff to an AVFS must be sheet flow. The flow is characterized as overland flow throughout the grass.

The width of an AVFS must meet the following criteria:

1. The minimum AVFS width is 4 feet.
2. The maximum AVFS width is equal to the width of the tributary area draining to the AVFS. This tributary width may include the roadway from the crown of pavement, paved or graded shoulders, and any grass slope that drains to the AFVS.

C1113.2.3

Amended vegetated filter strips are similar to vegetated filter strips, except that the soil is amended in increase infiltration. Also, the AVFS width requirements are different than VFS width requirements.

Figure 1113-12 illustrates an isometric rendering of an amended vegetated filter strip.

AVFS performance and design criteria were supported by research for the ODOT conducted by MS Consultants; FHWA/OH-2022-10 [Tangirala & Kerns, 2021]. Some design criteria from this research do not match those in this document due to input from Ohio EPA.

The AVFS width can be any width between the

3. The AVFS may not start at the edge of pavement. A minimum 2-foot separation must be left between the edge of pavement and the beginning of the AVFS.
4. The AVFS must end a minimum of 2 feet above the toe of slope or ditch bottom.
5. The AVFS may not extend to include any areas where concentrated flow conditions exist.

The maximum slope of an AVFS or any area draining to the AVFS is 3:1.

Amend the soil for an AVFS as shown in Figure 1113-8 and detailed here:

1. Soil Ripping: Use a solid-shank ripper with teeth, traversing the area with two passes in each direction to a depth of 12 inches. If the scarifier teeth are spaced greater than 12 inches perform additional passes such that the maximum furrow spacing is 6 inches. Perform soil ripping during dry conditions when soil is friable.
2. Excavation/Grading: Remove excess soil or grade such that the soil is 2 inches below the final grade before placing and incorporating the soil amendments. The AVFS will match final grade after soil amendments are incorporated.
3. Amendment Placement and Incorporation: Spread sand and soil amendment compost evenly across the AVFS area. Add 82 lb/sy (0.75 inches) sand and 73 lb/sy (1.25 inches) soil amendment compost that meets the specifications shown in Figure 1113-8. Incorporate the amendments into the existing soil to a depth of 6 inches using a rototiller or similar equipment. Incorporate amendments into the soil during dry conditions. Perform a minimum of 6 passes with a rototiller. Continue tilling until all soil clods are reduced to a maximum size of 1 inch and the mixture is uniform.
4. Fine Grading and Limited Compaction: Perform fine grading to achieve the slope geometry and elevations specified in the plans. Perform 1 pass with a rubber-tired or smooth drum roller to lightly compact the amended soil.
5. Compost Blanket: Evenly spread a 0.5-inch thick layer of soil amendment compost (17 lb/sy) over the ground surface.
6. Seeding and Watering: Install Class 1 – Lawn minimum and maximum allowable width; however, treatment credit will vary depending on the area of AVFS installed.

The AVFS can begin 2 feet from the edge of pavement or at any point further down the slope.

The tributary width draining to an AVFS can be larger than the AVFS width; however, treatment credit may vary depending on the site conditions as described below.

A Plan Insert Sheet is available that includes the content of Figure 1113-8.

Incorporation of soil amendments is meant to increase infiltration capacity compared to native soils. However, after the soil is ripped and the amendments are added, light compaction is required to increase safety associated with potential errant vehicles entering the AVFS. Compaction reduces the infiltration capacity of the amended soils. Do not over-compact the amended areas.

The soil amendment compost used for AVFS has more strict requirements than C&MS 659.06 compost. Soil amendment compost must be finer and more mature than Item 659.06 Compost. See Figure 1113-8 for soil amendment compost specifications.

Class 1 seed mixture per C&MS 659.09 is required for AVFS instead of Class 2 to promote thicker grass coverage over the BMP.

Mixture grass seed per C&MS 659.09. Rake seed into soil amendment compost blanket. Water per C&MS 659.17.

7. Fertilizer: Apply the following fertilizer at the rates shown. Follow C&MS 659.04 for application of fertilizer.

- 1.0 lb/1,000 ft^2 potassium
- 2.5 lb/1,000 ft^2 potash
- 1.0 lb/1,000 ft^2 magnesium

8. Erosion Control Matting: Install Item 712 Type A Temporary Erosion Control Mat per C&MS 671. Do not allow machinery/equipment over the amended soils during installation of the erosion control mat.

Pay for AVFS with Item 654, Renovating Existing Soil, As Per Plan and Item 671, Erosion Control Mats (sq yd).

Treatment credit for an AVFS is given as follows:

1. 100% of the AVFS area (amended area) is given treatment credit.
2. 45% of the tributary area to an AVFS is given treatment credit, but only for the width of the tributary area that does not exceed the width of the AVFS.

Tributary areas beyond the width of the AVFS do not receive treatment area credit.

The maximum AVFS width is equal to the tributary area; therefore, if an AVFS is installed wider than the tributary area, the excess width does not receive treatment area credit.

After installation, AVFSs should be maintained to ensure a minimum of 70% grass coverage, similar to a VFS BMP. Therefore, ensure that AVFSs are located in areas with access for mowing equipment.

For any ODOT-let project utilizing AVFS BMPs, contact OHE to obtain approval to use this BMP to meet post-construction BMP requirements.

Treatment credit for tributary areas to AVFSs is not given credit equal to 100% of that tributary area because the BMP is not able to fully infiltrate 90% of the average annual runoff. Based on research conducted by MS Consultants in 2021 [Tangirala & Kerns, 2021], AVFSs are expected to facilitate infiltration of approximately 75% of the average annual runoff of tributary area and BMP area combined. Since the AVFS improves infiltration, but not to a degree consistent with other infiltration BMPs (infiltration trench or infiltration basin), a reduced treatment credit is necessary (45% for the tributary area and 100% for the BMP area).

AVFS Treatment Credit Example 1:

An AVFS will be incorporated along a 1,000-foot section of roadway. The width from the crown of pavement to the edge of pavement draining to the AVFS is 18 feet (12-foot lane and 6-foot shoulder). A 2-foot grass strip will be installed at the edge of pavement, before the beginning of the AVFS. A 20-foot wide AVFS will be installed.

Treatment credit is given to the AVFS at 100%:

1,000’ x 20’ / 43,560sf/ac = 0.46 acres

Treatment credit is given to the tributary area at 45%:

1,000’ x (12’+6’+2’) / 43,560sf/ac x 45% = 0.21 acres

Total Treatment Credit = 0.67 acres (0.46 + 0.21)

AVFS Treatment Credit Example 2:

An AVFS will be incorporated along a 1,000-foot section of roadway. The width from the crown of pavement to the edge of pavement draining to the AVFS is 18 feet (12-foot lane and 6-foot shoulder). The inside edge of a ditch is 14 feet from the edge of pavement. A 2-foot grass strip will be installed at the edge of pavement, before the beginning of the AVFS. A 2-foot offset is required from the inside edge of the ditch. Therefore, a 10-foot wide portion of the foreslope is available and an AVFS will be installed at that 10-foot width.

Treatment credit is given to the AVFS at 100%:

1,000' x 10' / 43,560sf/ac = 0.23 acres

Treatment credit is given to the tributary area at 45%, but treatment credit is only given for tributary width that does not exceed the AVFS width (10 feet):

1,000' x 10' / 43,560sf/ac x 45% = 0.10 acres

Total Treatment Credit = 0.33 acres (0.23 + 0.10)

1113.3 Extended Detention

Extended detention is a method that captures storm water during rain events and slowly releases the captured volume over a period of time. The WQ_V is used to determine the storage volume of the detention basin. The WQ_V is discharged over a 48-hour time frame. Increase the WQ_V by 20% when sizing the BMP to allow for sediment storage. Detention can be either above or below ground. Use detention basins that are above ground when feasible. However, when project site parameters dictate, an underground system may be considered.

Due to the safety considerations and potential impacts to the drainage system, the use of extended detention BMPs requires approval from OHE. Provide submittals according to Section 1112.2. Do not locate extended detention BMPs with more than one foot of ponding water in the clear zone without prior approval from the Office of Roadway Engineering.

1113.3.1 Detention Basin

Use the following procedure for design of a detention basin:

1. Calculate the WQ_V per Section 1111.4.
2. Calculate the Design Check Discharge per Section 1113.3.3.
3. Increase the calculated WQ_V by 20% to determine the required size of the detention basin.
4. Provide a forebay that is 10% of the WQ_V, if feasible. Provide justification if no forebay is feasible. The forebay volume is part of the required volume and is not an additional volume requirement.
5. Provide a micropool that is 10% of the WQ_V, if feasible. Provide justification if no micropool is feasible. The micropool volume is part of the required volume and is not an additional volume requirement.
6. Connect the forebay to the micropool in the bottom of the detention basin with a low flow channel lined with tied concrete block or rock channel protection.
7. Size the water quality basin outlet structure for proper discharge of the WQ_V and for proper discharge of events up to the design check discharge according to Section 1113.3.1.1. Consider the water surface elevations created by the basin in the design of the upstream drainage system.
8. Provide anti-seep collars for the outlet pipe according to Section 1113.3.1.2.

The following criteria apply when designing a detention basin:

1. Use side slopes of 4:1 maximum.
2. Consider vehicle access to the basin for periodic maintenance.
3. Do not locate on uncompacted fill, steep slopes of 2:1 or more, or where infiltrating ground water could adversely impact slope stability.
4. Vegetate the sides of the basin with Item 670, Slope Erosion Protection.
5. Embankment work to create the impoundment will be constructed and paid for as Item 203, Embankment, Using Natural Soils, 703.16 A.
6. Provide gravel pack protection at the outlet

C1113.3.1

A detention basin is a partially dry pond that detains storm water for quality and quantity treatment.

Figure 1113-13 illustrates an isometric rendering of a detention basin.

In Ohio EPA's Technical Memo: Sediment Storage Design for Post-Construction Practices (OEPA, 2019), they state: "the purpose of the sediment storage volume is to avoid reduced treatment effectiveness and maintenance frequency as sediment accumulated within the practice (WEF/ASCE, 2012)".

Figure 1113-3 is an example detention basin design which includes sample plan and profile images of a detention basin showing the locations of the parts of a detention basin identified in this section.

structure. Refer to Hydraulic SCD WQ-1.1.

7. Place channel protection of RCP or Tied Concrete Block Mat at the entrance of the basin to minimize erosion and sediment resuspension.
8. Place a 6” thick layer of Item 601.10 Detention Basin Filter to all parts of the detention basin that are expected to be continually inundated with water (i.e. forebay and micropool).
9. Provide a Water Quality Basin, Detention per section 1113.3.1.1.
10. Provide a 6” diameter underdrain located with the crown a minimum of 6 inches below the bottom elevation of the micropool. Extend the underdrain from the location of the low flow channel, under the micropool, and connecting into the Water Quality Basin per Hydraulic SCD WQ-1.1. If the invert of the outlet conduit from the Water Quality Basin is equal to the orifice elevation, then do not include the 6” diameter underdrain.
11. Label the location and EDA treatment credit on the Project Site Plan for each extended detention basin on the project.

1113.3.1.1 Water Quality Basin and 4% AEP Overflow Weir

C1113.3.1.1

Provide an outlet structure that fully drains the WQ_V in 48 hours or more. No more than 50% of the WQ_V may be released from the detention basin in less than one-third the drain time, which is equal to 16 hours.

The outlet structure consists of a catch basin with a perforated conduit discharging through an orifice on the inlet side and a conduit on the outlet side. The orifice is used for flow control to achieve the required discharge time. A gravel envelope surrounds the horizontal perforated conduit at the inlet side of the catch basin to prevent blockage of the orifice. The catch basin and perforated conduit are paid for as Item 611, Water Quality Basin, Detention.

Details of the outlet structure can be found on Hydraulic SCD WQ-1.1.

The equation for a single orifice is:

$$Q = AC\sqrt{64.4H}$$

Where:

A = Area of orifice (ft^2)

H = Head on orifice as measured to the centerline of the orifice (ft)

C = Orifice coefficient

Table 1113-4

Orifice Coefficient Guidance	
C	**Description**
0.66	Use for thin materials where the thickness is equal to or less than the orifice diameter.
0.88	Use when the material is thicker than the orifice diameter.

Table 1113-4 Orifice Coefficient values from CALTRANS, Storm Water Quality Handbooks, Project Planning and Design Guide [CALTRANS, 2002].

The design check discharge must be able to bypass the orifice outlet and overflow through the catch basin grate into the discharge conduit. Convey the full design check discharge through the catch basin and discharge conduit without overtopping the detention basin. Determine the design check discharge per 1113.3.3.

In order to protect the detention basin from uncontrolled overtopping and berm erosion, provide an overflow weir sized to convey the 4% AEP design flow rate. Protect the weir from erosion.

A hydrograph curve for the orifice is required to calculate the discharge time of the WQ_V. Correspond the discharge time to the minimum drain time of 48 hours with no more than 50% of the WQ_V being released from the detention basin in less than one-third of that 48 hour drain time.

It is easier to model the outlet structure and discharge time using software such as Pond Pak or HydroCad to develop the hydrograph rather than producing the stage/storage/discharge calculations by hand.

1113.3.1.2 Anti-Seep Collar Design

Provide anti-seep collars on conduits through earth fills where water is being detained. The following criteria apply to anti-seep collars:

1. Provide a minimum of 2 collars per outlet conduit. Increase the seepage length along the conduit by a minimum of 15%. This percentage is based on the length of the pipe in the saturation zone.
2. Place anti-seep collars equally within the saturation zone. Place one collar at the end of the saturation zone. In cases where the spacing limit will not allow this, place at least one collar within the saturation zone.
3. Maximum collar spacing is 14 times the minimum projection above the pipe, but not

more than 25 feet. The minimum collar spacing is 5 times the minimum projection, but not less than 10 feet.

4. Extend the collar dimensions a minimum of 2 feet in all directions around the outside of the conduit, measured perpendicular to the conduit. Center the anti-seep collars around the conduit.
5. The top of collar must not be less than 6 inches below, measured normal to, the finished ground line.
6. All anti-seep collars and their connections must be watertight.
7. Minimum thickness is 6 inches.
8. Pay for the collar with Item 602, Concrete Masonry. Refer to Hydraulic SCD WQ-1.2.

The design procedure for anti-seep collars is as follows:

1. Determine the length of the conduit within the saturated zone. The assumed normal saturation zone can be determined by projecting a line through the embankment, with a 4:1 (H:V) slope, from the point where the water elevation at the 10% AEP design storm meets the upstream slope to a point where it intersects the invert of the conduit. This line, referred to as the "phreatic line", represents the upper surface of the zone of saturation within the embankment, see Figure 1113-7. The 10% AEP storm pool elevation is the phreatic line starting elevation.

$$L_S = Y(Z+4)\left(1+\frac{S}{0.25-S}\right)$$

Where:

Ls = Seepage Length: length of the conduit in the saturated zone (ft)

Y = Depth of the water at the spillway crest, 10% AEP storm water surface elevation (ft)

Z = Slope of the upstream face of the embankment (Z feet horizontal to 1 foot vertical)

S = Slope of the conduit (ft/ft)

2. Determine the required seepage length increase.

$$\Delta L_S = 0.15 L_S$$

3. Choose a collar height and width that is at least 4 feet larger than the outside diameter of the conduit (minimum projection of 2 feet from all

sides of the conduit). Give collar sizes in one foot increments.

$$P = W - D$$

Where:

P = Projection of collar (ft)

W = Height or width of collar (ft)

D = Inside diameter of conduit (ft)

4. Determine the total number of collars required. The collar size can be increased to reduce the number of collars. Alternatively, the collar size can be decreased by providing more collars. In any case, increase the seepage length by a minimum of 15%.

   Number of collars required $= \Delta L_S/P$

1113.3.2 Underground Detention

1. Confirm the Hydraulic Grade Line design of the storm sewer will pass through the structure and meet the requirements of Section 1104.3.2.
2. Provide an outlet structure that fully drains the WQ_V in 48 hours or more. Release no more than 50% of the WQ_V from the detention basin in less than one-third the drain time, which is equal to 16 hours.
3. Locate access to the conduits for periodic maintenance so that traffic impacts are minimized.
4. If practical, provide pretreatment of the storm water with vegetation.
5. Pay for the conduit with Item 611, ____” Conduit, Type____, for underground detention.
6. Label the location and EDA treatment credit on the Project Site Plan for each underground detention on the project.

C1113.3.2

Figure 1113-14 illustrates an isometric rendering of an underground detention BMP.

1113.3.3 Design Check Discharge

Use a design check discharge of a 10% AEP event. Use the entire drainage area that contributes to the BMP to calculate the design check discharge.

1113.4 Retention Basin

A retention basin is a *wet* pond that has a minimum water surface elevation between storms that is defined as the permanent pool. Above the permanent pool is a detention pool that provides storage for 100% of the WQ_V and drains in 24 hours or more. The detention volume above the

C1113.4

Figure 1113-15 illustrates an isometric rendering of a retention basin.

Figure 1113-4 is an example retention basin design.

permanent pool is called the Extended Detention Volume. The full storage water depth is typically between 3-6 feet and the volume is less than 15 Ac-ft. The permanent pool is sized to provide storage for 100% of the WQ_V. A retention basin may be considered for large tributaries, but it may require a large amount of space.

Use the following procedure for design of the retention basin:

1. Calculate the WQ_V per Section 1111.4.
2. Calculate the Design Check Discharge per Section 1113.3.3.
3. If feasible, provide a forebay that is 10% of the total storage volume. The forebay volume is part of the required volume and is not an additional volume requirement.
4. Size the water quality basin for proper discharge of the WQ_V and the 4% AEP overflow weir for proper discharge of events up to the 4% AEP storm according to Section 1113.4.1. Consider the water surface elevations created by the basin in the design of the upstream drainage system.
5. Provide anti-seep collars for the outlet pipe according to Section 1113.3.1.2.

The following criteria apply when designing a retention basin:

1. Place channel protection (RCP or Tied Concrete Block Mat) at the entrance of the basin to minimize erosion and sediment resuspension.
2. Use side slopes no steeper than 4:1.
3. Use a length to width ratio of at least 3:1 to prevent short-circuiting.
4. Compact the underlying soils to prevent infiltration of the permanent pool or use an impervious liner.
5. Consider vehicle access to the basin for periodic maintenance.
6. Retention basin must be greater than 10,000 feet from a municipal airport runway.
7. Vegetate the sides of the basin with Item 670, Slope Erosion Protection.
8. Embankment work to create the impoundment will be constructed and paid for as Item 203, Embankment, Using Natural Soils, 703.16.A.

09. Furnish a Water Quality Basin, Retention per

1113.4.1.

10. Label the location and EDA treatment credit on the Project Site Plan for each retention basin on the project.

1113.4.1 Water Quality Basin and 4% AEP Overflow Weir

A retention basin outlet structure is designed similar to the outlet structure for a detention basin. The difference is that the ED_V, which for a retention basin is equal to 100% of the WQ_V, must discharged out of the basin in 24 hours or more. No more than 50% of the ED_V can be released from the retention basin in less than one-third of that 24 hour drain time, which is equal to 8 hours. The outlet structures are of a similar type, except the openings will be set at a high enough elevation to maintain at least 100% of the WQ_V in the permanent pool. The catch basin and perforated conduit are paid for as Item 611, Water Quality Basin, Retention.

Details of the outlet structure can be found on Hydraulic SCD WQ-1.1.

The design check discharge must bypass the orifice outlet structure and overflow through the catch basin grate into the discharge conduit. Convey the full design check discharge through the catch basin and discharge conduit without overtopping the retention basin. Determine the design check discharge per 1113.3.3.

In order to protect the detention basin from uncontrolled overtopping and berm erosion, furnish an overflow weir sized to convey the 4% AEP design flow rate. Protect the weir from erosion.

A hydrograph curve for the orifice is required to calculate the discharge time of the WQ_V. The discharge time must correspond to the minimum drain time of 24 hours with no more than 50% of the ED_V being released from the retention basin in less than one-third of that 24 hour drain time.

C1113.4.1

Generally, it is easier to model the outlet structure and discharge time using software such as Pond Pak or HydroCAD to develop the hydrograph rather than producing the stage/storage/discharge calculations by hand.

1113.5 Bioretention Cell

Furnish Item 659 Seeding and Mulching for the vegetation of the Bioretention Cell. Cover this area with Item 671, Erosion Control Mat. Do not include any Item 659, Commercial Fertilizer, or Item 659, Lime, in the Bioretention Cell. Other shrubs or plantings may be provided in the Bioretention Cell with permission of OHE.

C1113.5

A Bioretention Cell consists of a depressed area that allows shallow ponding and treatment of storm water runoff by evapotranspiration and filtration through an engineered soil (bioretention planting soil). As storm water runoff percolates through the bioretention planting soil, sediment and other pollutants are filtered. An underlying perforated underdrain captures the treated storm

The water table or bedrock must be at least 1 foot below the invert of the bioretention cell, which is the excavated depth.

A bioretention cell is sized to treat the WQ_V by allowing that volume of runoff to percolate through the bioretention planting soil. Storm water runoff greater than the WQ_V is allowed to bypass treatment through an overflow structure. Treatment credit is given to the total area within the right-of-way draining to the most downstream part of the bioretention cell.

There are two configurations of bioretention cells:

- Level bioretention cell in an open area with grassed side slopes. See Figure 1113-5
- Sloped bioretention cell within a grassed ditch. See Figure 1113-5

1113.5.1 Level Bioretention Cell in an Open Area with Grassed Side Slopes

Pretreat the storm water prior to entering the bioretention cell by one of the following methods:

A. For sheet flows from impervious areas, the runoff must flow through a minimum of 5 feet, preferably 15 feet, of grassed filter strip with side slopes no steeper than 3:1.

B. For concentrated flows from a pipe, open channel, or curb cut, the runoff must flow through either a grassed swale at least 20 feet in length or a forebay sized to capture 10% of the WQ_V.

Provide a raised catch basin per Figure 1113-5 to allow the design check discharge to bypass the bioretention cell. Determine the design check discharge per Section 1113.3.3. Place the overflow outlet in the raised catch basin 12 inches above the surface elevation of the bioretention cell. Locate the raised catch basin outside of the clear zone.

1113.5.2 Sloped Bioretention Cell within a Grassed Ditch

Pretreat the storm water prior to entering the bioretention cell by one of the following methods:

A. For sheet flows from impervious areas, the runoff must flow through a minimum of 5 feet, preferably 15 feet of grassed filter strip with side slopes no steeper than 3:1.

water runoff and carries it to an outlet. Vegetation assists in maintaining ongoing performance of bioretention cells.

Figure 1113-16 illustrates an isometric rendering of a bioretention cell.

C1113.5.2

B. For concentrated flows from a pipe, open channel, or curb cut, the runoff must flow through either a grassed swale at least 20 feet in length or a forebay sized to capture 10% of the WQ_V.

Provide an earth dike covered with item 601 Tied Concrete Block Mat with Type 2 Underlayment per Figure 1113-5 to allow the design check discharge to bypass the bioretention cell. Determine the design check discharge per Section 1102 for the appropriate design storm of the ditch. The dike must be 1V:6H or flatter and pond water to a maximum depth of 12 inches.

Install a dike at every 1 foot of elevation drop along the longitudinal slope of a linear bioretention cell.

Example: If a ditch line is at a 1% slope, install a dike every 100 feet along its length to promote temporary ponding and filtration through the bioretention planting soil.

1113.5.3 Bioretention Cell Design Procedure

Use the following procedure for the design of a bioretention cell:

1. Determine the total impervious tributary area to the bioretention cell: $A_{TRIB,IMP}$. Include impervious area within and outside of the right-of-way; treatment credit is only given to the area within the right-of-way. Consider all area within existing right-of-way to be impervious, even if the area is grassed.
2. The minimum bioretention cell surface area is 5% of the total impervious tributary area.

   $A_{BIO} = A_{TRIB,IMP} \times 5\%$
3. Choose one of the two configurations of bioretention cells and follow the appropriate pretreatment and overflow requirements described in Section 1113.5.1 and 1113.5.2.
4. Limit the maximum depth to 12 inches measured from the final grade of the bioretention cell to the outlet riser pipe, raised catch basin, weir, or check dam.
5. In addition to the pretreatment required where concentrated flow enters the bioretention cell, limit the incoming velocity to 1 fps or less for the WQ_F to protect the bioretention cell from erosion. Assume an intensity of 0.65 in/hr and calculate the WQ_F per Section 1111.5 at the point of concentrated flow. Increase the pipe size, widen the open channel, increase the curb opening to the bioretention cell, or provide energy dissipation

C1113.5.3

The 5% sizing criterion and other design constraints are based on Ohio EPA's Technical Memo: Bioretention Filter Bed Area and Ponding Depth Revision [OEPA, 2019].

to limit the velocity to 1 fps or less. For Curb Cuts, assume all the WQ_V is captured by the curb opening and use the height of the curb and the opening width to calculate the area.

6. Do not place a bioretention cell where the required hydraulic design flows (i.e. 50% AEP event, 20% AEP event, 10% AEP event, or higher) have an Allowable Shear Stress higher than 1 psf or velocity higher than 5 fps

7. Provide the bioretention cell layers as shown in Figure 1113-5.

A. Bioretention Planting Soil Layer: Provide 30 inches of bioretention planting soil. See Plan Note W101. When planting shrubs or trees, extend the bioretention planting soil layer at least 4 inches below the lowest root ball.

B. Filter Layer: Provide 3 inches of Fine Aggregate per C&MS 703.20 directly below the bioretention planting soil layer. Provide 3 inches of Coarse Aggregate size No. 78 per C&MS 703.20 directly below the Fine Aggregate layer.

C. Gravel Layer for Underdrain: Provide 12 inches of Coarse Aggregate size No. 57 per C&MS 703.20 directly below the No. 78 aggregate layer. Provide a minimum of 3 inches of No. 57 aggregate above and below any underdrain pipes.

8. For the bioretention planting soil, specify 10% excess planting mix volume to account for expected settling of the uncompacted soil. Show final expected soil elevations on the plans but allow contractor to place bioretention planting soil 3 inches above elevations shown on plans, as described in Plan Note W101.

9. Provide one 4-inch diameter perforated PVC pipe underdrain per C&MS 605 along the length of the bioretention cell. Include one underdrain at the center for widths 20 feet or smaller. For all other widths calculate the number of underdrains required by dividing the width by 20 and rounding up to the next whole number. Space these underdrains equally around the center with a minimum distance of 5 feet from the outside edge.

10. Provide a 4-inch diameter PVC observation well/cleanout port in accordance to Figure 1113-5 for every run of underdrain at an interval of 100 feet.

11. Outlet the underdrain by combining all

underdrains into a single type C Item 611 pipe. Provide this pipe with a positive outlet either into a drainage structure that is part of the drainage design or on a slope with Item 611, Precast Concrete Outlet. Show underdrain connection to outlet in the plans. While the underdrains will likely be 3 feet, 9 inches below the surface of the bioretention cell, the designer may choose to raise the underdrain outlet at the point of discharge. The underdrain discharge invert must be a minimum of 2 feet below the final surface elevation of the bioretention planting soil to allow the top 2 feet of the bioretention cell to drain freely. The designer may choose to raise the underdrain at the point of discharge to either hold back internal water storage to increase potential pollutant treatment in the bioretention cell, or in order to allow positive discharge of the underdrain into a downstream catch basin or outlet that has a depth less than 3 feet, 9 inches.

12. For bioretention cells planted with grass, include temporary erosion control mat Type A, B, C, or E per C&MS 671 with either straw mulch or compost per plan over the surface of all bioretention planting soil. Specify the mat type on the plan sheets.
13. For non-grass bioretention cells that include shrubs or trees, include a 3-inch layer of wood fiber mulch per C&MS 659.15 above the bioretention planting soil.
14. Label the location and EDA treatment credit on the Project Site Plan for each bioretention cell on the project.
15. PAY ITEMS:

203, Excavation As Per Plan (cu yd)

601, Bioretention Cell (cu yd)

601, Tied Concrete Block Mat (sq yd)

605, Underdrain As Per Plan, (includes observation wells, fittings, and couplers as specified) (each)

611, Outlet Pipe (ft)

659, Seeding and Mulching (sq yd)

671, Erosion Control Mats As Per Plan (sq yd)

1113.6 Infiltration

Typically, infiltration practices are only suitable when Hydrologic Soil Group HGS Type A soils or, in some cases, HSG Type B soils exist.

Infiltration methods require an extensive

C1113.6

Infiltration techniques treat storm water through the interaction of a filtering substrate that consists of soil, sand, or gravel. This technique discharges the treated storm water into the ground water investigation of the existing soils and geology to guarantee success. Begin the investigation with a preliminary soil evaluation of the project site early in the design process. In-situ testing is not anticipated during the preliminary evaluation process.

Use available soil and geology data found in the Soil and Water Conservation maps, United States Geological Survey, adjacent projects, or estimations from a geotechnical engineer.

National Resources Conservation Service's Web Soil Survey website may also provide soil and geology information.

Material property tables for infiltration, permeability, and porosity have been provided for the preliminary evaluation. See Table 1113-5.

If the preliminary evaluation yields favorable results, perform a more detailed evaluation. The detailed evaluation will require a geotechnical investigation of the underlying soils and geology. Soil borings must be performed to a maximum depth of 20 feet, or refusal with samples taken every 5 feet for laboratory testing. The number and location of soil borings must correspond with the approximate size, as determined in the preliminary evaluation, of the infiltration BMP and should be recommended by the geotechnical engineer.

If the detailed evaluation yields favorable results, the ground water depth must be verified. The geotechnical engineer will provide the seasonal high ground water depth. In some cases, observation wells may be installed, and static water levels may be observed over a dry and wet season for verification.

Test the infiltration and permeability rate of the soil in the detailed soil evaluation at the discretion of the geotechnical engineer. In some cases, in-situ testing at the proposed location of the infiltration BMP may be required.

The following criteria apply to infiltration methods and must be met to be considered a feasible alternative:

1. Design using the WQ_V as per Section 1111.4.
2. Do not place infiltration BMP where snow may be stored.
3. The appropriate soil type must be present:

A. Infiltration, the rate at which water enters into rather than into surface waters.

the soil from the surface, must be greater than 0.50 in/hr and no greater than 2.4 in/hr.

B. Soils must have less than 30% clay or 40% of clay and silt combined.

4. The invert of the structure must be at least 4 feet above the seasonal high-water table and any impervious layer.
5. Infiltration techniques are not suitable on fill soil, compacted soil, or slopes steeper than 4:1. Consider the long-term impacts upon hillside stability if applicable.
6. Provide pretreatment to remove large debris, trash and suspended sediment to extend the service life. An example of pretreatment includes providing vegetated ditches prior to flow entering the infiltration facility.

1113.6.1 Infiltration Trench

The WQ_V must fully drain from the aggregate into the in-situ soil in 48 hours or less.

Design of an infiltration trench must follow the criteria in the Ohio EPA's Rainwater and Land Development Manual.

The following criteria apply when designing an infiltration trench:

1. Provide a 6 inch layer of Coarse Aggregate No. 57 or 67 conforming to C&MS 703.20 per C&MS 601.10 on the top of the trench.
2. Provide Coarse Aggregate No. 1 or 2 conforming to C&MS 703.20 within the infiltration trench.
3. Provide pretreatment using vegetation to safeguard the longevity of the infiltration trench.
4. Provide an observation well to facilitate ground water level inspection.
5. Locate the infiltration trench at least 1,000 feet from any municipal water supply well and at least 100 feet from any private well, septic tank, or field tile drains.
6. Keep the bottom of the trench below the frost line of 2.5 feet
7. Include an infiltration trench as Item 601 – Infiltration Trench.
8. Label the location and EDA treatment credit on the Project Site Plan for each infiltration trench on the project.

C1113.6.1

An infiltration trench is an excavated trench that has been lined with a geotextile fabric and backfilled with aggregate. The storm water is filtered through the aggregate and is stored within the pore volume of the backfill material. It is allowed to percolate through the sides and bottom of the trench.

Figure 1113-17 illustrates an isometric rendering of an infiltration trench.

1113.6.2 Infiltration Basin

Design the Infiltration Basin to store the WQ_V. Depending on the soil permeability, an infiltration basin may be used to treat from 5 to 50 acres. The WQ_V must fully drain into the in-situ soil in 24 hours or less.

Use the following procedure for the design of an infiltration basin:

1. Calculate the WQ_V per Section 1111.4.
2. Determine the invert area of the infiltration basin using the following equation:

$$A = \frac{WQ_V(S.F.)(12)}{kt}$$

Where:

A = area of invert of the basin (acre)

WQ_V = Water Quality Volume (see section 1111.4) (acre-feet)

S.F. = Safety Factor of 1.5

k = Infiltration Rate (in/hr) (table 1113-5)

t = Drawdown time of 24 hours

Table1113-5

NRCS Soil Type (from soil maps)	HSG Class	Rate (k) (in/hr)
Sand	A	8.0
Loamy Sand	A	2.0
Sandy Loam	B	1.0
Loam	B	0.5
Silt Loam	C	0.25
Sandy Clay Loam	C	0.15
Clay Loam & Silty Clay Loam	D	<0.09
Clays	D	<0.05

Infiltration Rate (k): From Urban Runoff Quality Management WEF Manual of Practice No. 23, 1998, published jointly by the WEF and ASCE, chapter five.

3. Use a length to width ratio of 3:1.
4. Determine the required depth of the infiltration basin using following equation:

$$D = \frac{WQ_V}{A}$$

Where:

A = area of invert of the basin (acre)

C1113.6.2

An infiltration basin is an open surface pond that uses infiltration into the ground as the release mechanism.

Figure 1113-18 illustrates an isometric rendering of an infiltration basin.

Figure 1113-6 shows a design example of an infiltration basin.

WQ_V = Water Quality Volume (acre-feet)

D = Required depth of the basin (ft)

5. Allow for 1-foot minimum freeboard above the WQ_V.
6. Calculate the Design Check Discharge per Section 1113.3.3.
7. Provide bypass or overflow for the design check discharge.

The following criteria apply when designing an infiltration basin:

1. Use an energy dissipater at the inlet.
2. Vegetate the sides of the basin with Item 670, Slope Erosion Protection.
3. Provide a 6-inch layer of Coarse Aggregate No. 57 or 67 conforming to C&MS 703.20 per C&MS 601.10 on the bottom of the basin.
4. Use side slopes of 4:1 maximum.
5. Consider vehicle access to the basin for periodic maintenance.
6. Locate basin at least 1,000 feet from any municipal water supply well and at least 100 feet from any private well, septic tank, or drain field.
7. Provide 10 feet or less width between 4-inch underdrain laterals, if used in the design.
8. Do not locate the basin where infiltrating ground water may adversely impact slope stability.
9. Place the invert of underdrains in the basin below the frost line of 2.5 feet.
10. Embankment work to create the impoundment will be constructed and paid for as Item 203, Embankment, Using Natural Soils, 703.16.A.
11. Label the location and EDA treatment credit on the Project Site Plan for each infiltration basin on the project.

1113.7 Constructed Wetlands

Size the wetland to provide storage for the WQ_V for a time frame of at least 24 hours, above the permanent pool, while providing a bypass or overflow for larger design check discharge. See section 1113.3.3. Maintain the water depth by an outlet structure capable of providing the required water depth with the provision of a 1-foot freeboard.

C1113.7

Constructed Wetlands treat storm water through bio-retention. They are depressed, heavily planted areas that are designed to maintain a dry weather flow depth ranging between 0.5 to 2 feet. The surface area required for a wetland is usually quite large due to the limited allowable depth. The area is usually on the magnitude of 1% of the entire drainage area. They are designed in a similar

The following criteria apply when designing a Constructed Wetland:

1. Do not place on a steep or unstable slope or at a location, which could induce short-term or long-term instability.
2. Constructed Wetlands must be greater than 10,000 feet from a municipal airport runway.
3. Base flow must be present to maintain the constant water depth, such as ground water.
4. Provide a forebay that is 7% of the total required volume at a depth between 3-6 feet to settle out sediments.
5. Use side slopes of 4:1 (max).
6. Consider access for maintenance to the forebay and the outlet structure.
7. Vegetate the sides and bottom with grass
8. Provide an impervious liner. Use a compacted clay bottom or a geotextile fabric to prevent infiltration of the storm water.
9. Use a length to width ratio of 3:1 (min) to prevent short-circuiting.
10. Label the location and EDA treatment credit on the Project Site Plan for each constructed wetland on the project.

manner as a retention basin.

Figure 1113-19 illustration an isometric rendering of a constructed wetland.

1113.8 Stream Grade Control

Stream grade control structures are structures installed on the upstream and downstream end of a culvert at a stream crossing to promote stream protection. They provide a grade control in a stream to prevent downcutting of the stream bed.

The following are Stream Grade Control structures:

- Concrete aprons shown in Section 1106.3.
- Three sided culverts with paved Inverts
- Three sided culverts with bed rock inverts

Stream grade control structures provide quantity treatment, but not quality treatment. Therefore, pair stream grade control structures with a post-construction BMP that provides quality treatment. Only those portions of a project within existing and/or new permanent right-of-way that drain to a stream grade control structure receive quantity treatment credit. Stream grade control structures are only an appropriate post-construction BMP when installed within a Waters of the United States and associated with sites that acquire a permit from the Army Corps of Engineers for stream

C1113.8

Figure 1113-20 illustrates an isometric rendering of a stream grade control BMP.

impacts.

Label the location and EDA treatment credit on the Project Site Plan for each stream grade control structure on the project.

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Appendix A – Figures

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MINIMUM CULVERT SIZES	1002-1 REFERENCE SECTION 1002.3.1

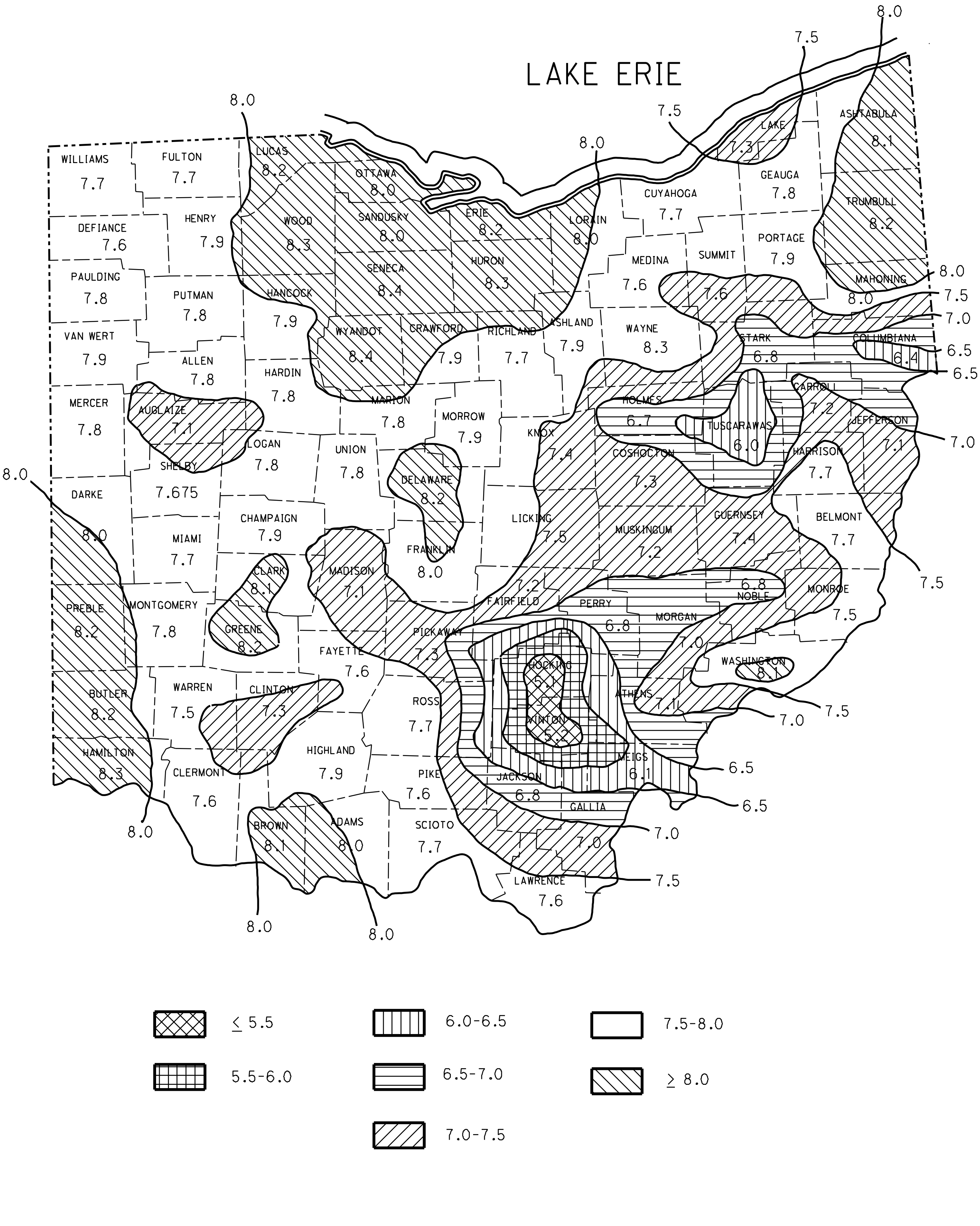
	Roadway Types	
	Interstates, Freeways, & Expressways	Other
Fill Depth (ft)	Minimum Size (inches)	Minimum Size (inches)
< 8	24	15
8 to < 16	30	24
16 to 32	36	30
> 32	42	36

WATER pH CONTOURS BASED ON AVE. pH FOR COUNTIES

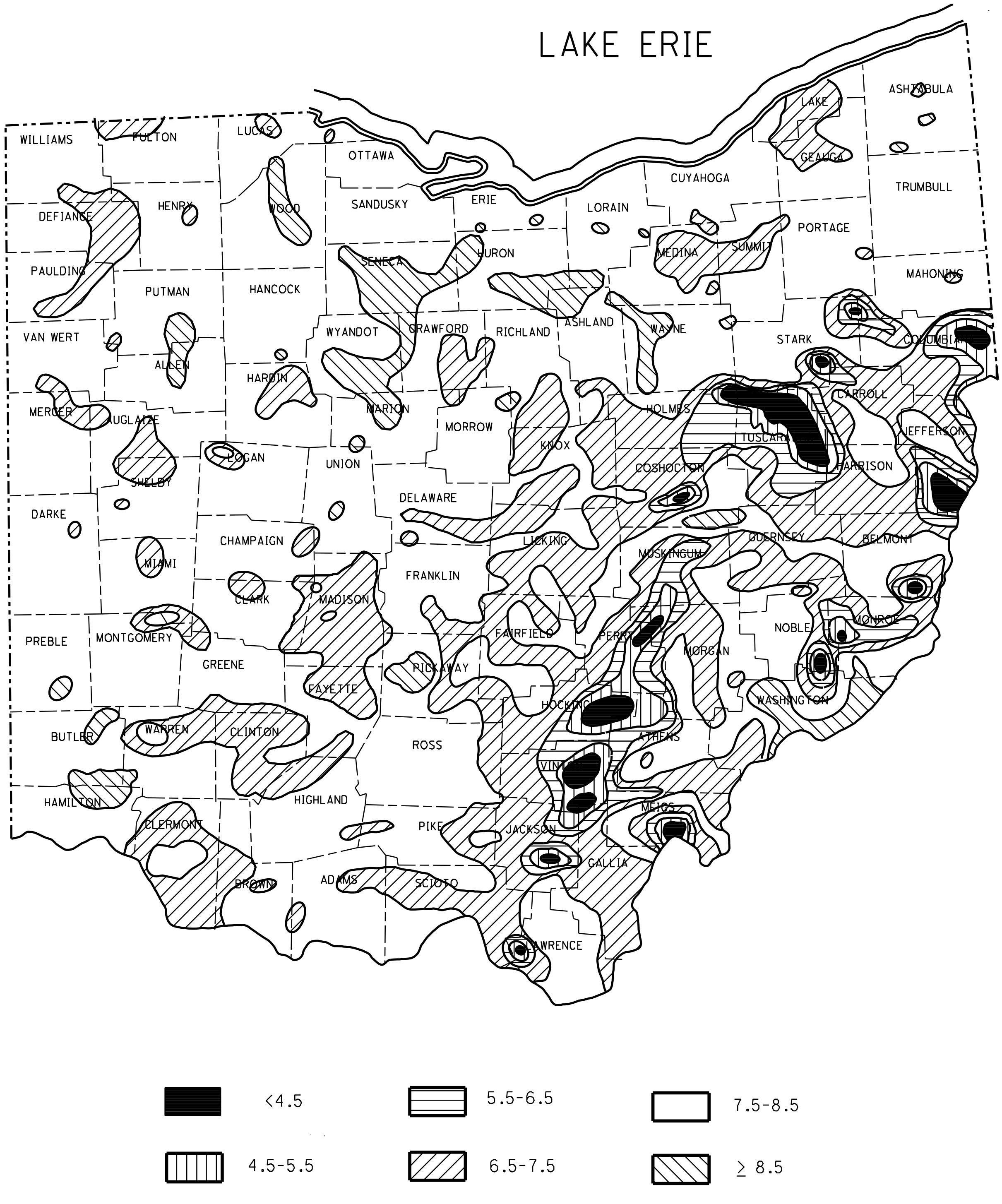
1002-2

REFERENCE SECTION

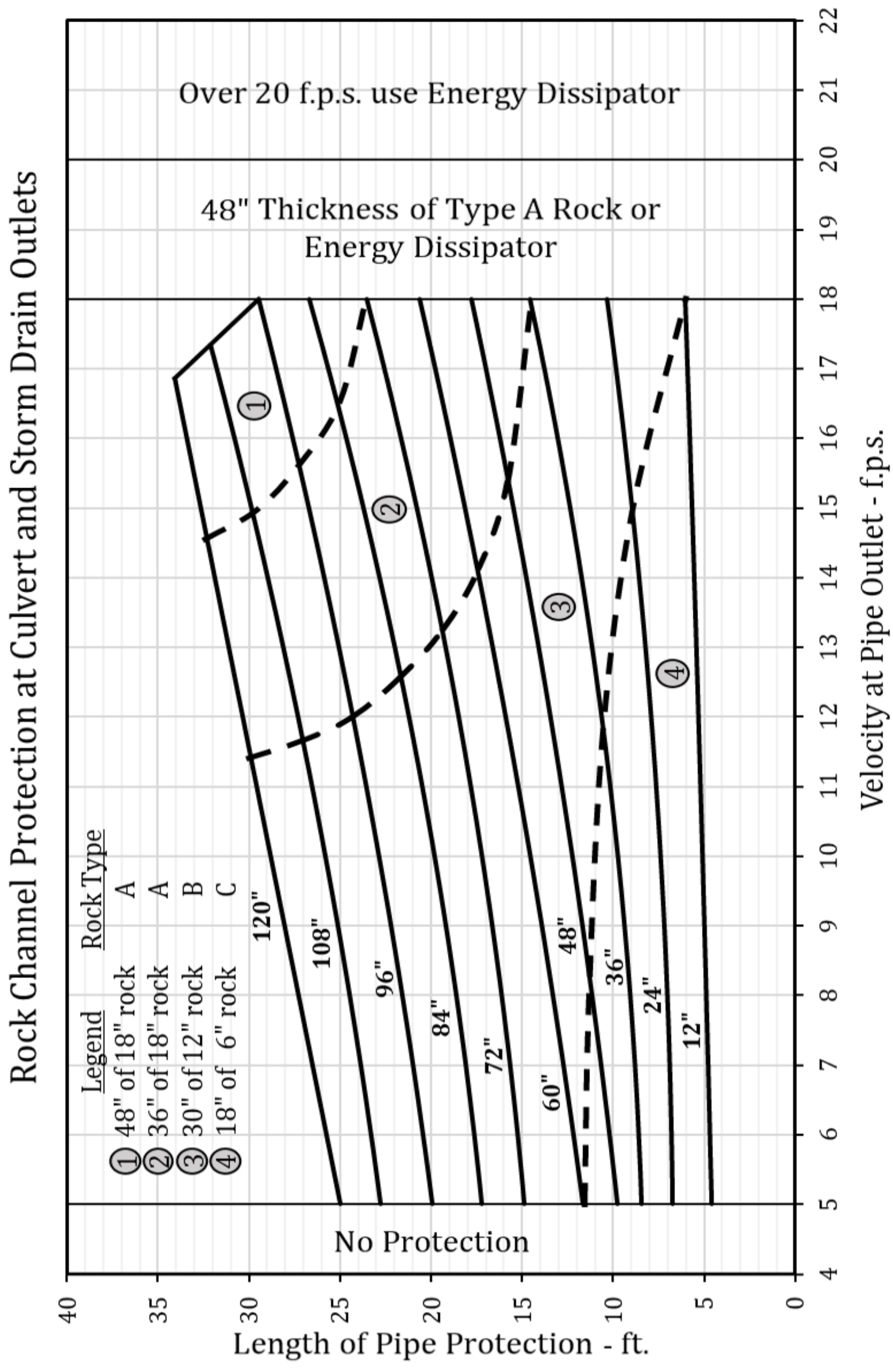
1002.3.1



WATER pH CONTOURS BASED ON pH VALUES OF INDIVIDUAL CULVERTS	1002-3
	REFERENCE SECTION 1002.3.1



ROCK CHANNEL PROTECTION AT CULVERT AND STORM SEWER OUTLETS	1002-4
	REFERENCE SECTION 1002.2.3



ROCK CHANNEL PROTECTION AT CULVERT AND STORM SEWER OUTLETS	1002-4
	REFERENCE SECTION 1002.2.3

Notes:

Rock size (6", 12", 18") indicates the square opening on which 85% of the material by weight is retained.

Provide rock channel protection the width of the headwall with a minimum of 4'.

No rock channel protection is required where the natural stream bed will withstand the calculated velocity without erosion.

Equations for length of protection:

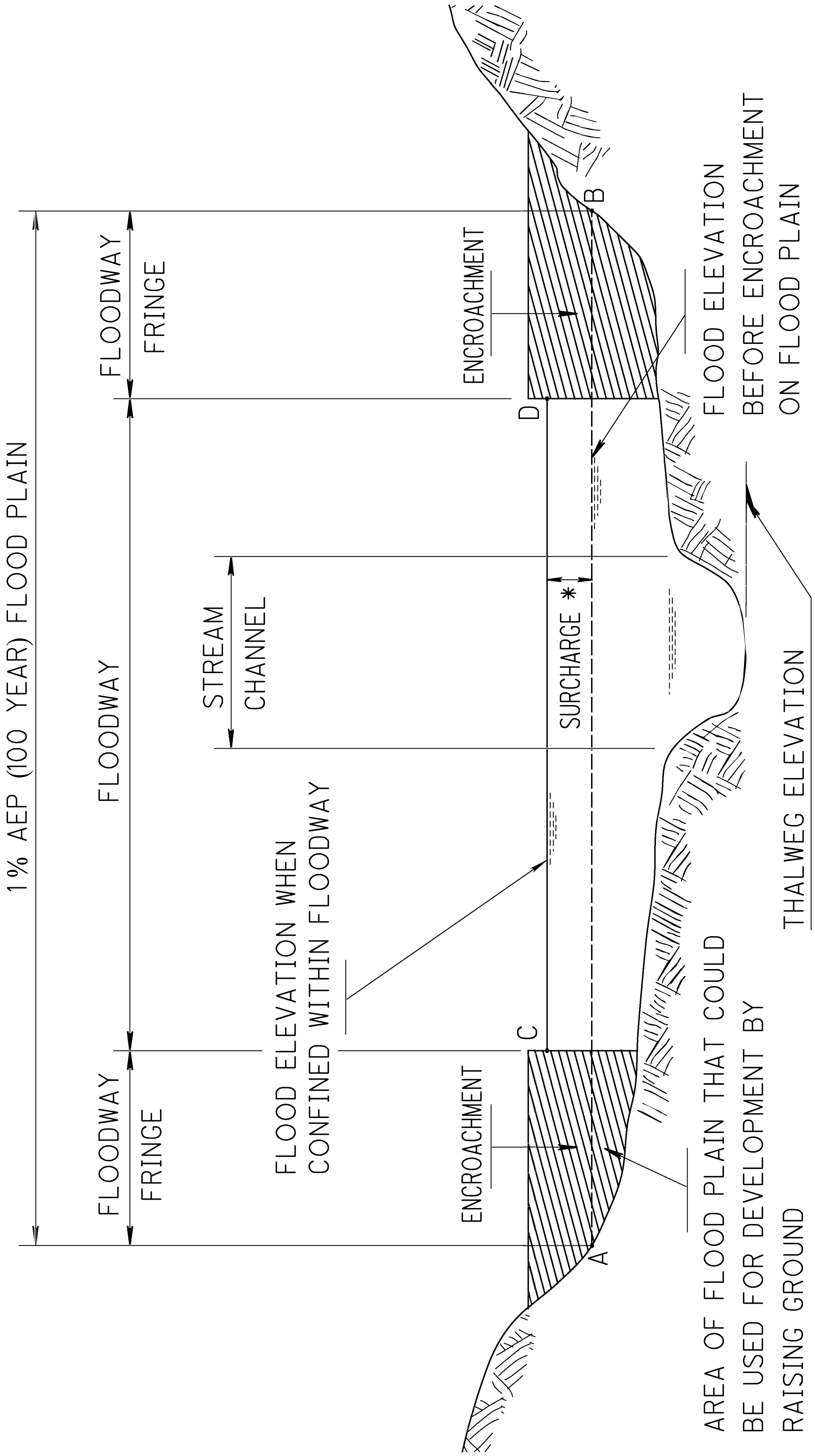
Rise	Length
120"	$L = 0.764996 * V + 21.17502$
108"	$L = 0.0203 * V^2 + 0.3004 * V + 20.765$
96"	$L = 0.0184 * V^2 + 0.3121 * V + 17.892$
84"	$L = 0.0261 * V^2 + 0.1234 * V + 15.970$
72"	$L = 0.0251 * V^2 + 0.0897 * V + 13.798$
60"	$L = 0.0139 * V^2 + 0.3683 * V + 9.4671$
48"	$L = 0.0151 * V^2 + 0.2661 * V + 8.0899$
36"	$L = 0.0262 * V^2 + 0.1341 * V + 8.4794$
24"	$L = 0.0182 * V^2 + 0.1404 * V + 6.983$
12"	$L = 0.0014 * V^2 + 0.0816 * V + 4.1255$

V=Velocity (f.p.s.)
L=Length of minimum Rock Channel Protection (ft.)

FLOODWAY SCHEMATIC

1006-1

REFERENCE SECTION 1006.4



LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT
* SURCHARGE IS NOT TO EXCEED 1.0 FOOT OR THAT ALLOWED BY OTHER REGULATORY AGENCIES IF MORE RESTRICTIVE.

FLOODWAY SCHEMATIC

MINIMUM HEIGHT OF COVER TABLE 1 CORRUGATED STEEL PIPE

1008-1

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 1 Corrugated Steel Pipe	
	Pipe Diameter (inches)	Minimum Cover (inches)
707.01, 707.04 and 707.05 (2 2/3" x 1/2" Corrugations)	12	12
	15	12
	18	12
	21	12
	24	12
	27	12
	30	12
	36	12
	42	12
	48	12
	54	12
	60	12
	66	12
	72	12
	78	12
	84	12
707.02, 707.04 and 707.07 (5" x 1" Corrugations)	36	12
	42	12
	48	12
	54	12
	60	12
	66	12
	72	12
	78	12
	84	12
	90	12
	96	12
	102	18
	108	18
	114	18
	120	18

MINIMUM HEIGHT OF COVER TABLE 2 CORRUGATED STEEL PIPE ARCHES

1008-2

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 2 Corrugated Steel Pipe Arches	
	Pipe Dimentions Span X Rise (inches)	Minimum Cover (inches)
707.01, 707.04 and 707.05 (2 2/3" x 1/2" Corrugations)	17 x 13	12
	21 x 15	12
	24 x 18	12
	28 x 20	12
	35 x 24	12
	42 x 29	12
	49 x 33	12
	57 x 38	12
	64 x 43	12
	71 x 47	12
	77 x 52	12
	83 x 57	12
707.02, 707.04 and 707.07 (5" x 1" Corrugations)	40 x 31	15
	46 x 36	15
	53 x 41	15
	60 x 46	15
	66 x 51	15
	73 x 55	18
	81 x 59	18
	87 x 63	18
	95 x 67	18
	103 x 71	18
	112 x 75	21
	117 x 79	21
	128 x 83	24
	137 x 87	24
	142 x 91	24

MINIMUM HEIGHT OF COVER TABLE 3 707.03 STRUCTURAL PLATE CORRUGATED STEEL PIPE

1008-3

REFERENCE SECTION 1008.1.4

HEIGHT OF COVER TABLE 3		
707.03 Structural Plate Corrugated Steel Pipe		
Pipe Diameter (inches)	Pipe Diameter (feet-inches)	Minimum Cover (inches)
60	5'0"	12
66	5'6"	12
72	6'0"	12
78	6'6"	12
84	7'0"	12
90	7'6"	12
96	8'0"	12
102	8'6"	18
108	9'0"	18
114	9'6"	18
120	10'0"	18
126	10'6"	18
132	11'0"	18
138	11'6"	18
144	12'0"	18
150	12'6"	24
156	13'0"	24
162	13'6"	24
168	14'0"	24
174	14'6"	24
180	15'0"	24
186	15'6"	24
192	16'0"	24
198	16'6"	30
204	17'0"	30
210	17'6"	30
216	18'0"	30
222	18'6"	30
228	19'0"	30
234	19'6"	30
240	20'0"	30
246	20'6"	36
252	21'0"	36
258	21' 6"	36
264	22' 0"	36
270	22' 6"	36
276	23' 0"	36
282	23' 6"	36
288	24' 0"	42
294	24' 6"	42
300	25' 0"	42
306	25' 6"	42
312	26' 0"	42

MINIMUM HEIGHT OF COVER TABLE 4 707.03 STRUCTURAL PLATE CORRUGATED STEEL PIPE ARCHES

1008-4

REFERENCE SECTION 1008.1.4

HEIGHT OF COVER TABLE 4	
707.03 Structural Plate Corrugated Steel Pipe (18-inch Corner Radius)	
Pipe Dimentions Span x Rise (feet-inches)	Minimum Cover (inches)
6'1" x 4'7"	18
6'4" x 4'9"	18
6'9 x 4'11"	18
7'0" x 5'1"	18
7'3" x 5'3"	18
7'8" x 5'5"	18
7'11" x 5'7"	18
8'2" x 5'9"	18
8'7" x 5'11"	18
8'10" x 6'1"	18
9'4" x 6'3"	18
9'6" x 6'5"	18
9'9" x 6'7"	18
10'3" x 6'9"	18
10'8" x 6'11"	18
10'11" x 7'1"	18
11'5" x 7'3"	18
11'7" x 7'5"	18
11'10" x 7'7"	18
12'4" x 7'9"	18
12'6" x 7'11"	18
12'8" x 8'1"	24
12'10" x 8'4"	24
13'5" x 8'5"	24
13'11" x 8'7"	24
14'1" x 8'9"	24
14'3" x 8'11"	24
14'10" x 9'1"	24
15'4" x 9'3"	24
15'6" x 9'5"	24
15'8" x 9'7"	24
15'10" x 9'10"	24
16'5" x 9'11"	36
16'7" x 10'1"	36

MINIMUM HEIGHT OF COVER TABLE 5 707.03 STRUCTURAL PLATE CORRUGATED STEEL PIPE ARCHES

HEIGHT OF COVER TABLE 5	
707.03 Structural Plate Corrugated Steel Pipe (31-inch Corner Radius)	
Pipe Dimentions Span x Rise (feet-inches)	Minimum Cover (inches)
13'3" x 9'4"	24
13'6" x 9'6"	24
14'0" x 9'8"	24
14'2" x 9'10"	24
14'5" x 10'0"	24
14'11" x 10'2"	24
15'4" x 10'4"	24
15'7" x 10'6"	24
15'10" x 10'8"	24
16'3" x 10'10"	36
16'6" x 11'0"	36
17'0" x 11'2"	36
17'2" x 11'4"	36
17'5" x 11'6"	36
17'11" x 11'8"	36
18'1" x 11'10"	36
18'7" x 12'0"	36
18'9" x 12'2"	36
19'3" x 12'4"	36
19'6" x 12'6"	36
19'8" x 12'8"	36
19'11" x 12'10"	36
20'5" x 13'0"	36
20'7" x 13'2"	36

MINIMUM HEIGHT OF COVER TABLE 6 CORRUGATED STEEL SPIRAL RIB PIPE

1008-6

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 6 Corrugated Steel Spiral Rib Pipe	
	Pipe Diameter (inches)	Minimum Cover (inches)
707.12 and 707.11 (3/4" x 7 1/2" Corrugations)	18	12
	21	12
	24	12
	30	12
	36	12
	42	15
	48	15
	54	15
	60	15
	66	18
	72	18
	78	18
	84	18
	90	18

MINIMUM HEIGHT OF COVER TABLE 7 CORRUGATED ALUMINUM PIPE

1008-7

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 7 Corrugated Aluminum Pipe	
	Pipe Diameter (inches)	Minimum Cover (inches)
707.21 (2 2/3" x 1/2" Corrugations)	12	12
	15	12
	18	12
	21	12
	24	12
	27	12
	30	12
	36	12
	42	12
	48	12
	54	18
	60	18
	66	18
	72	18
707.22 (3" x 1" Corrugations)	36	12
	42	12
	48	12
	54	18
	60	18
	66	18
	72	18
	78	24
	84	24
	90	24
	96	24
	102	30
	108	30
	114	30
	120	30

MINIMUM HEIGHT OF COVER TABLE 8 CORRUGATED ALUMINUM PIPE ARCHES

1008-8

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 8 Corrugated Aluminun Pipe Arches	
	Pipe Dimensions Span x Rise (inches)	Minimum Cover (inches)
707.21 (2 2/3" x 1/2" Corrugations)	17 x 13	12
	21 x 15	12
	24 x 18	12
	28 x 20	12
	35 x 24	12
	42 x 29	12
	49 x 33	12
	57 x 38	12
	64 x 43	12
	71 x 47	12
707.22 (3" x 1" Corrugations)	53 x 41	15
	60 x 46	15
	66 x 51	15
	73 x 55	18
	81 x 59	21
	87 x 63	21
	95 x 67	24
	103 x 71	24
	112 x 75	27
	117 x 79	27

MINIMUM HEIGHT OF COVER TABLE 9 707.23 STRUCTURAL PLATE CORRUGATED ALUMINUM PIPE

1008-9

REFERENCE SECTION 1008.1.4

HEIGHT OF COVER TABLE 9		
707.23 Structural Plate Corrugated Aluminum Pipe		
Pipe Diameter (inches)	Pipe Diameter (feet-inches)	Minimum Cover (inches)
60	5'0"	15
66	5'6"	18
72	6'0"	24
78	6'6"	24
84	7'0"	24
90	7'6"	24
96	8'0"	24
102	8'6"	30
108	9'0"	30
114	9'6"	30
120	10'0"	30
126	10'6"	30
132	11'0"	30
138	11'6"	30
144	12'0"	36
150	12'6"	36
156	13'0"	36
162	13'6"	36
168	14'0"	36
174	14'6"	36
180	15'0"	36
186	15'6"	36
192	16'0"	36
198	16'6"	36
204	17'0"	36
210	17'6"	36
216	18'0"	36
222	18'6"	36
228	19'0"	36

MINIMUM HEIGHT OF COVER TABLE 10 707.23 STRUCTURAL PLATE CORRUGATED ALUMINUM PIPE ARCHES

1008-10

REFERENCE SECTION 1008.1.4

HEIGHT OF COVER TABLE 10	
707.23 Structural Plate Corrugated Aluminum Pipe Arches	
Pipe Dimentions Span x Rise (feet-inches)	Minimum Cover (inches)
6'7" x 5'8"	21
6'11" x 5'9"	21
7'3 x 5'11"	21
7'9" x 6'0"	24
8'1" x 6'1"	24
8'5 x 6'3"	24
8'10" x 6'4"	27
9'3" x 6'5"	27
9'7" x 6'6"	27
9'11" x 6'8"	27
10'3" x 6'9"	27
10'9" x 6'10"	30
11'1" x 7'0"	30
11'5" x 7'1"	30
11'9" x 7'2"	33
12'3" x 7'3"	33
12'7" x 7'5"	33
12'11" x 7'6"	33
13'1" x 8'2"	33
13'1" x 8'4"	33
13'11" x 8'5"	33
14'0" x 8'7"	33
13'11" x 9'5"	33
14'3" x 9'7"	33
14'8" x 9'8"	33
14'11" x 9'10"	33
15'4" x 10'0"	33
15'7" x 10'2"	33
16'1" x 10'4"	33
16'4" x 10'6"	33

MINIMUM HEIGHT OF COVER TABLE 11 CORRUGATED ALUMINUM SPIRAL RIB PIPE

1008-11

REFERENCE SECTION 1008.1.4

Pipe Designation	HEIGHT OF COVER TABLE 11 — Corrugated Aluminum Spiral Rib Pipe	
	Pipe Diameter (inches)	Minimum Cover (inches)
707.24 (2 2/3" x 1/2" Corrugations)	18	12
	21	12
	24	12
	30	15
	36	15
	42	15
	48	18
	54	18
	60	18
	66	21

REINFORCED CONCRETE CIRCULAR PIPE

706.02 Reinforced Concrete Circular Pipe	
Pipe Diameter (inches)	Wall Thickness (inches)
12	2
15	2.25
18	2.5
21	2.75
24	3
27	3.25
30	3.5
36	4
42	4.5
48	5
54	5.5
60	6
66	6.5
72	7
78	7.5
84	8
90	8
96	8.5
102	8.5
108	9
114	9.5
120	10
126	10.5
132	11
144	12

REINFORCED CONCRETE ELLIPTICAL PIPE

1008-13

REFERENCE SECTION 1008.2

706.04 Reinforced Concrete Elliptical Pipe					
Equivalent Round Diameter (inches)	Pipe Rise X Span (inches)	Wall Thickness (inches)	Equivalent Round Diameter (inches)	Pipe Rise X Span (inches)	Wall Thickness (inches)
18	14x23	2.75	36	45x29	4.5
24	19x30	3.25	42	53x34	5
27	22x34	3.5	48	60x38	5.5
30	24x38	3.75	54	68x43	6
36	29x45	4.50	60	76x48	6.5
42	34x53	5	66	83x53	7
48	38x60	5.5	72	91x58	7.5
54	43x68	6	78	98x63	8
60	48x76	6.5	84	106x68	8.5
66	53x83	7	90	113x72	9
72	58x91	7.5	96	121x77	9.5
78	63x98	8	102	128x82	9.75
84	68x106	8.5	108	136x87	10
90	72x113	9	114	143x92	10.5
96	77x121	9.5	120	151x97	11
102	82x128	9.75	132	166x106	12
108	87x136	10	144	180x116	13
114	92x143	10.5			
120	97x151	11			
132	106x166	12			
144	116x180	13			

MAXIMUM ALLOWABLE HEIGHT OF COVER - REINFORCED CONCRETE BOX CULVERTS

1008-14

REFERENCE SECTION 1008.5

Box Span (ft)	706.05 Precast Reinforced Concrete Box Culverts								
	Box Rise (ft)								
	4	5	6	7	8	9	10	11	12
	Height of Fill (Maximum)								
6	10	10	10	-	-	-	-	-	-
7	10	10	10	10	-	-	-	-	-
8	10	10	10	10	10	-	-	-	-
9	10	10	10	10	10	10	-	-	-
10	10	10	10	10	10	10	10	-	-
11	10	10	10	10	10	10	10	10	-
12	10	10	10	10	10	10	10	10	10
14	10	10	10	10	10	10	10	-	-
16	10	10	10	10	10	10	10	-	-
18	10	10	10	10	10	10	10	-	-
20	10	10	10	10	10	10	10	-	-

Approval of OHE is required for sizes other than those listed above.

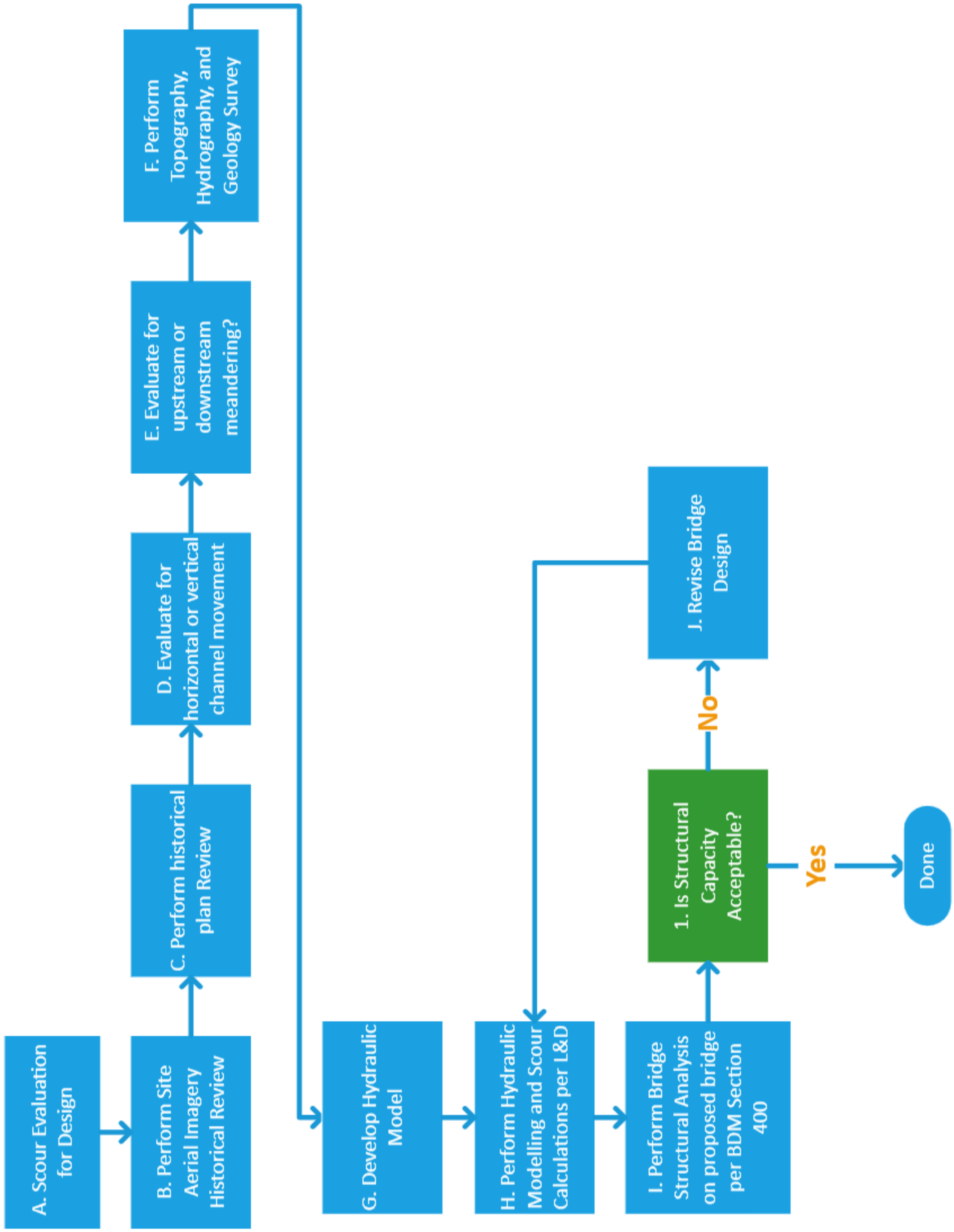
For fill heights in excess of 10 ft, a round alternate should be investigated.

Skewed box culvert end sections are not permitted without approval of OHE.

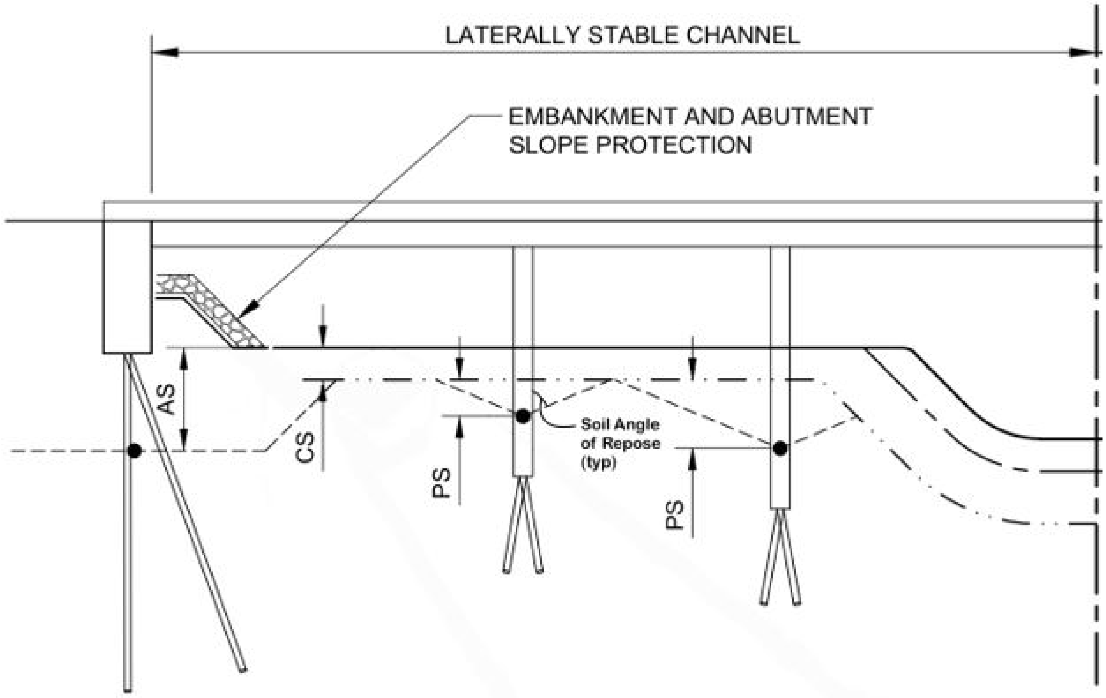
Design spans 14' or greater for HL93 live load with an additonal 60psf for a future wearing surface. Refer to SS940.

Scour Evaluation for Design	1008-15
	REFERENCE SECTION 1008.10

Scour Evaluation for Design Flowchart



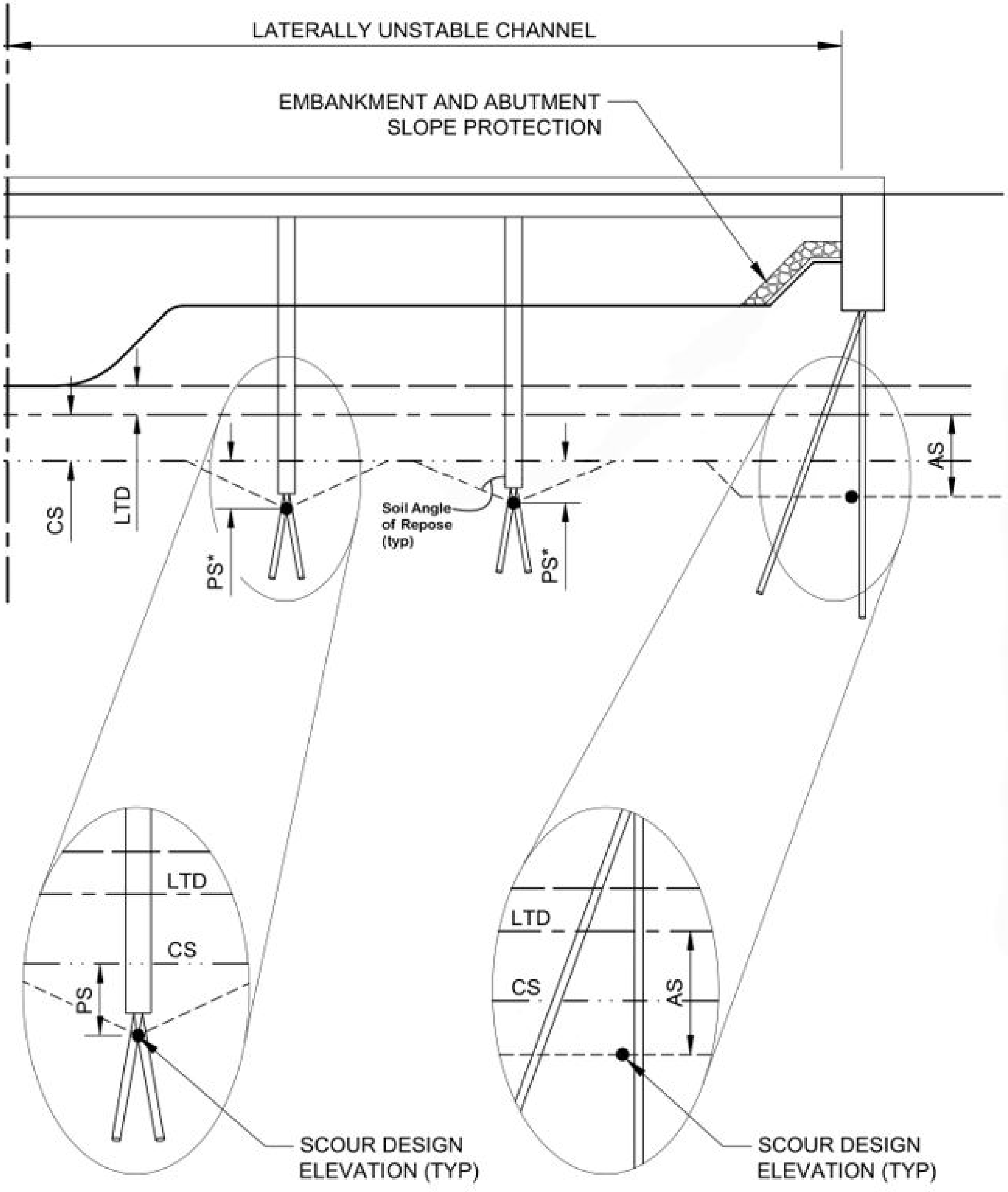
SCOUR PLOT EXAMPLE / LATERAL CHANNEL STABILITY	1008-19
	REFERENCE SECTION 1008.10.4



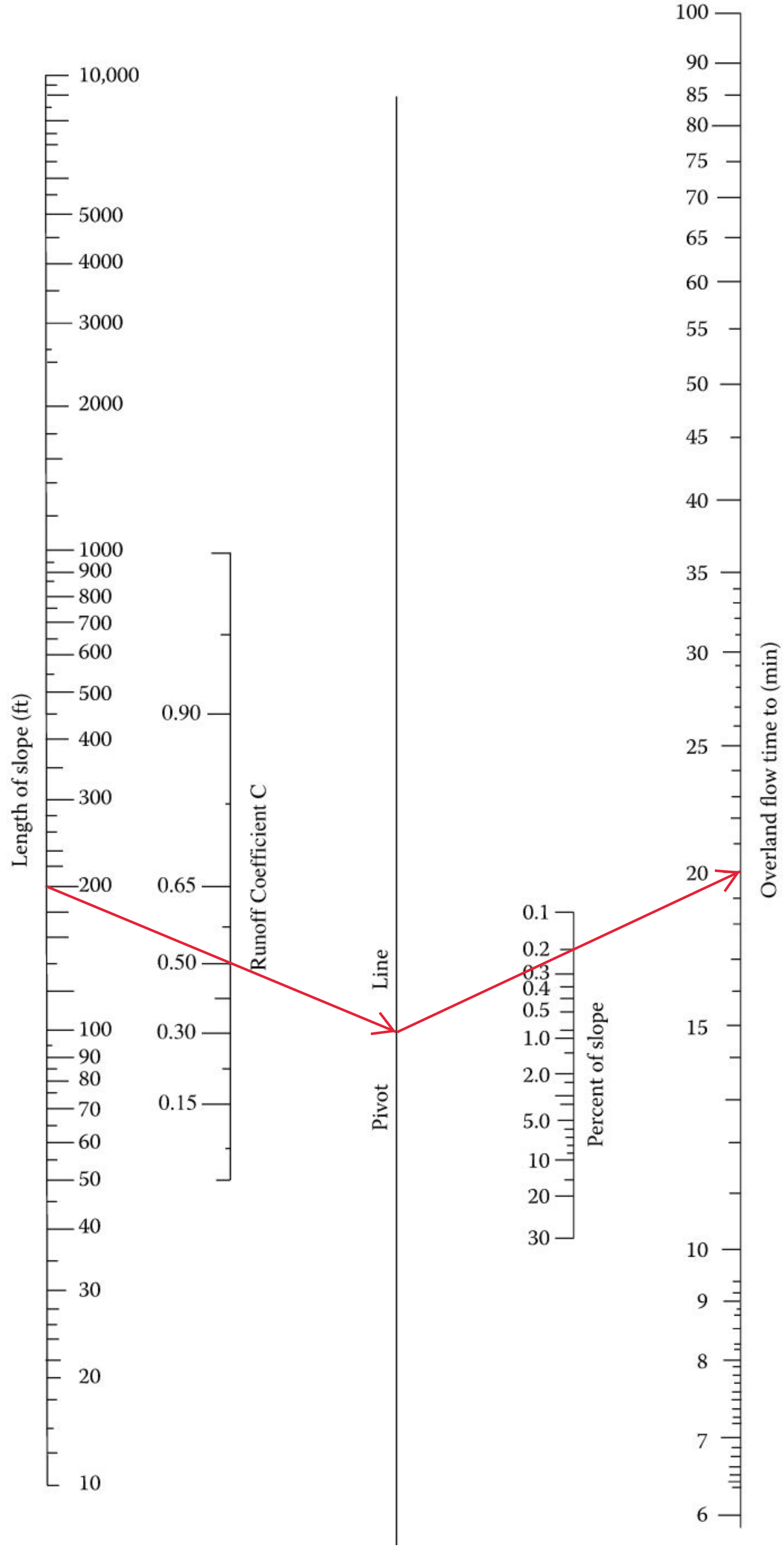
LEGEND

LTD	GENERAL SCOUR: LONG-TERM DEGRADATION
CS	CONTRACTION SCOUR
PS	PIER SCOUR
PS*	PIER SCOUR BASED ON MAIN CHANNEL HYDRAULICS
AS	ABUTMENT SCOUR (INCLUDES CONTRACTION SCOUR + LOCAL SCOUR)
●	SCOUR DESIGN ELEVATION
— —— —— —	STREAM THALWEG
—— · · —— · · ——	CONTRACTION SCOUR
—— – ——	LONG TERM DEGRADATION
- - - - - - - - - -	SCOUR EXTENTS

SCOUR PLOT EXAMPLE / LATERAL CHANNEL STABILITY	1008-19 REFERENCE SECTION 1008.10.4

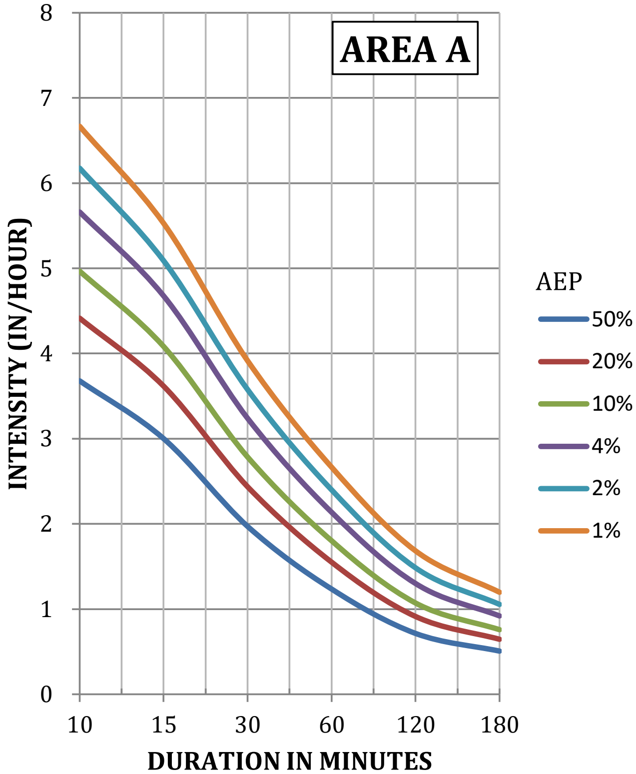


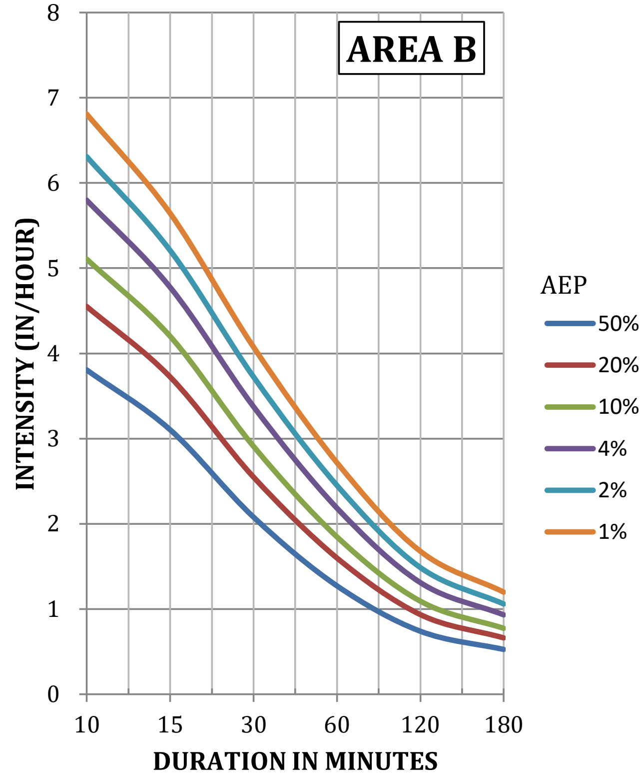
OVERLAND FLOW CHART	1101-1
	REFERENCE SECTION 1101.2.1

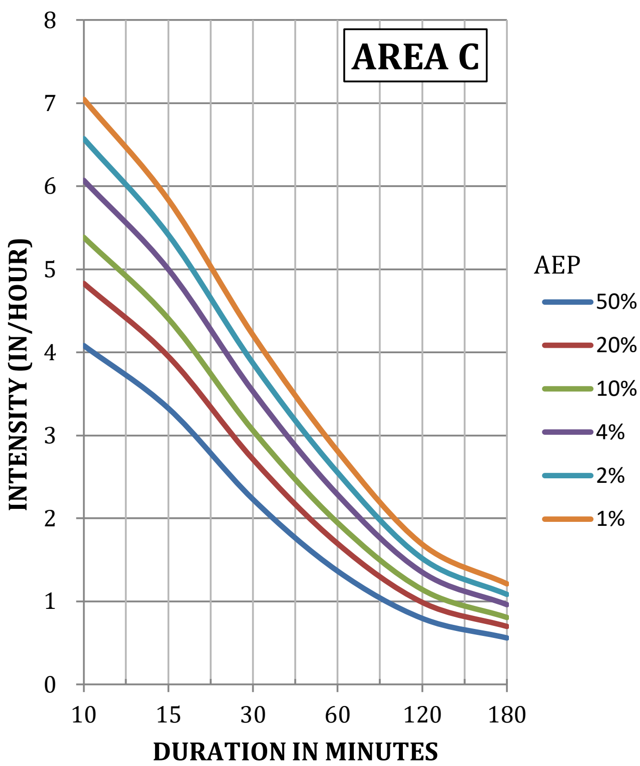


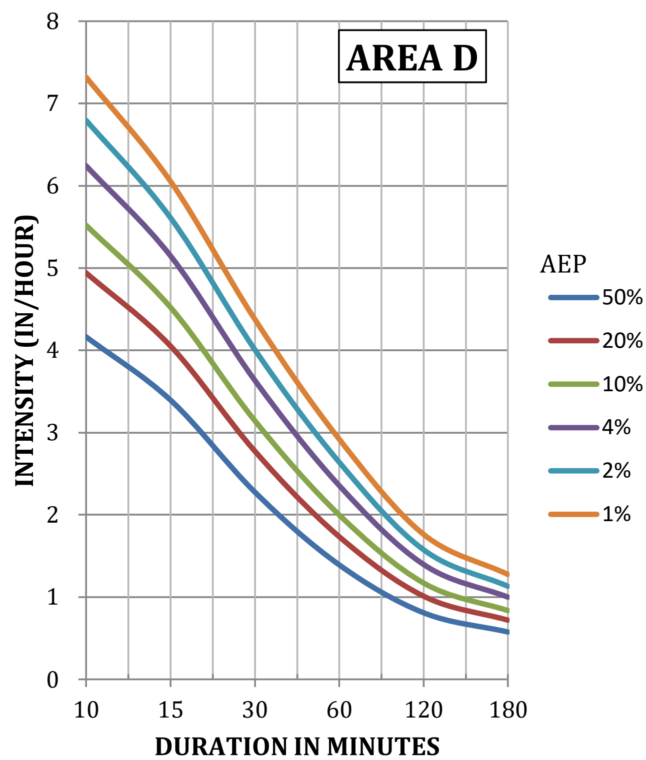
New Jersey Highway Authority—Garden State Parkway (1957). Time of concentration nomograph.

Rainfall Intensity-Frequency-Duration Curves	1101-2 REFERENCE SECTION 1101.2.3

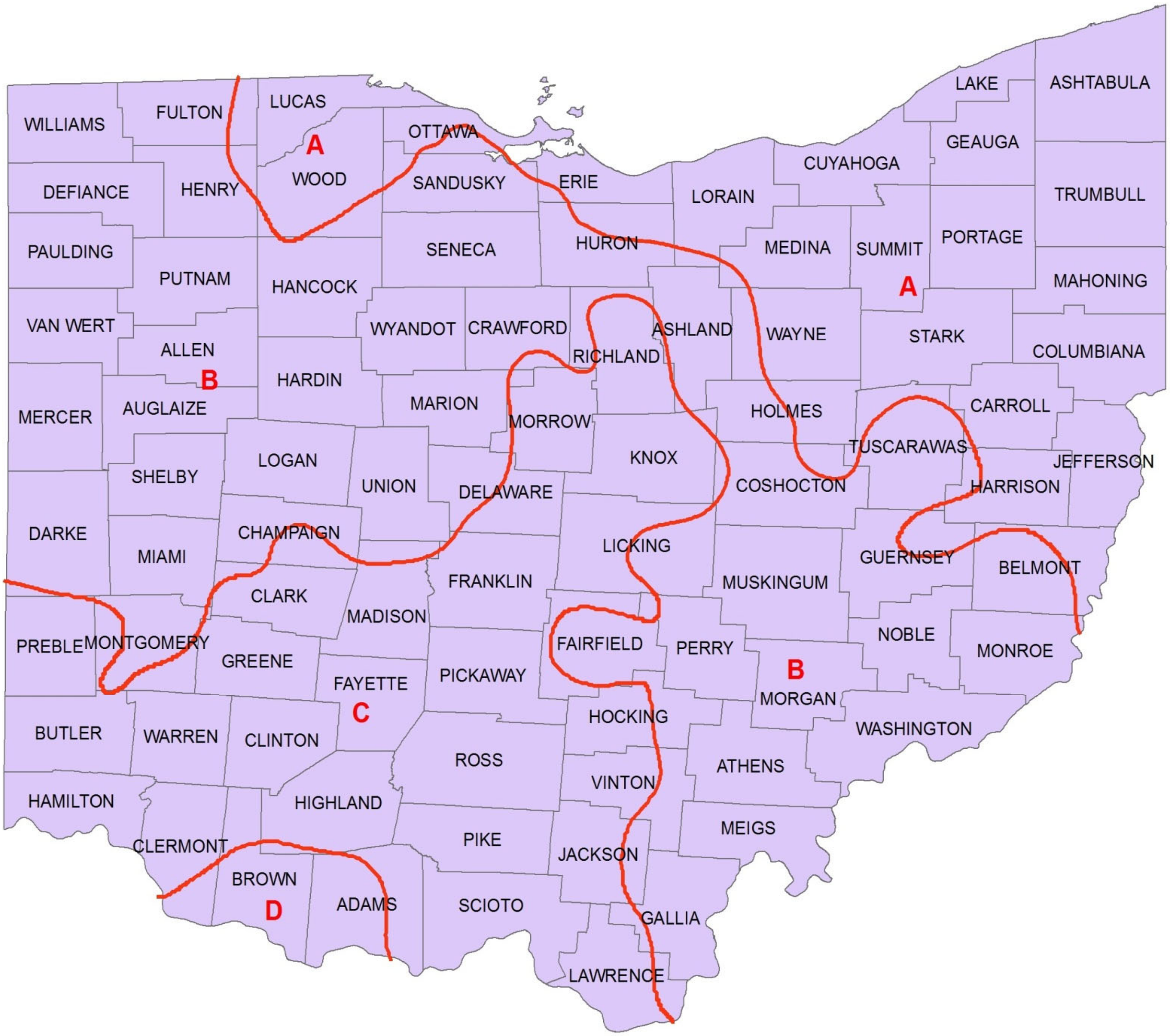








Rainfall Intensity-Frequency-Duration Curves	1101-2
	REFERENCE SECTION 1101.2.3



Rainfall Intensity Zone Map

Rainfall Intensity-Frequency-Duration Curves

1101-2

REFERENCE SECTION 1101.2.3

The Rainfall Intensity-Duration-Frequency (IDF) curves are based upon precipitation data obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14. The precipitation data was collected between 4/1863 to 12/2000.

Rainfall depth varies across the State with more rainfall depth present in the Southwest portion of the state and gradually decreaseing towards the Northeast. IDF curves were developed for 4 regions across the State to simplify hydraulic design. The regions were determined by normalizing contours created from NOAA precipitation GIS data from the 10% AEP, 60 minute duration.

Federal Highway Administration Hydraulic Engineering Circular No. 12 Appendix A offers a methodology for converting IDF data points to an equation of the general form:

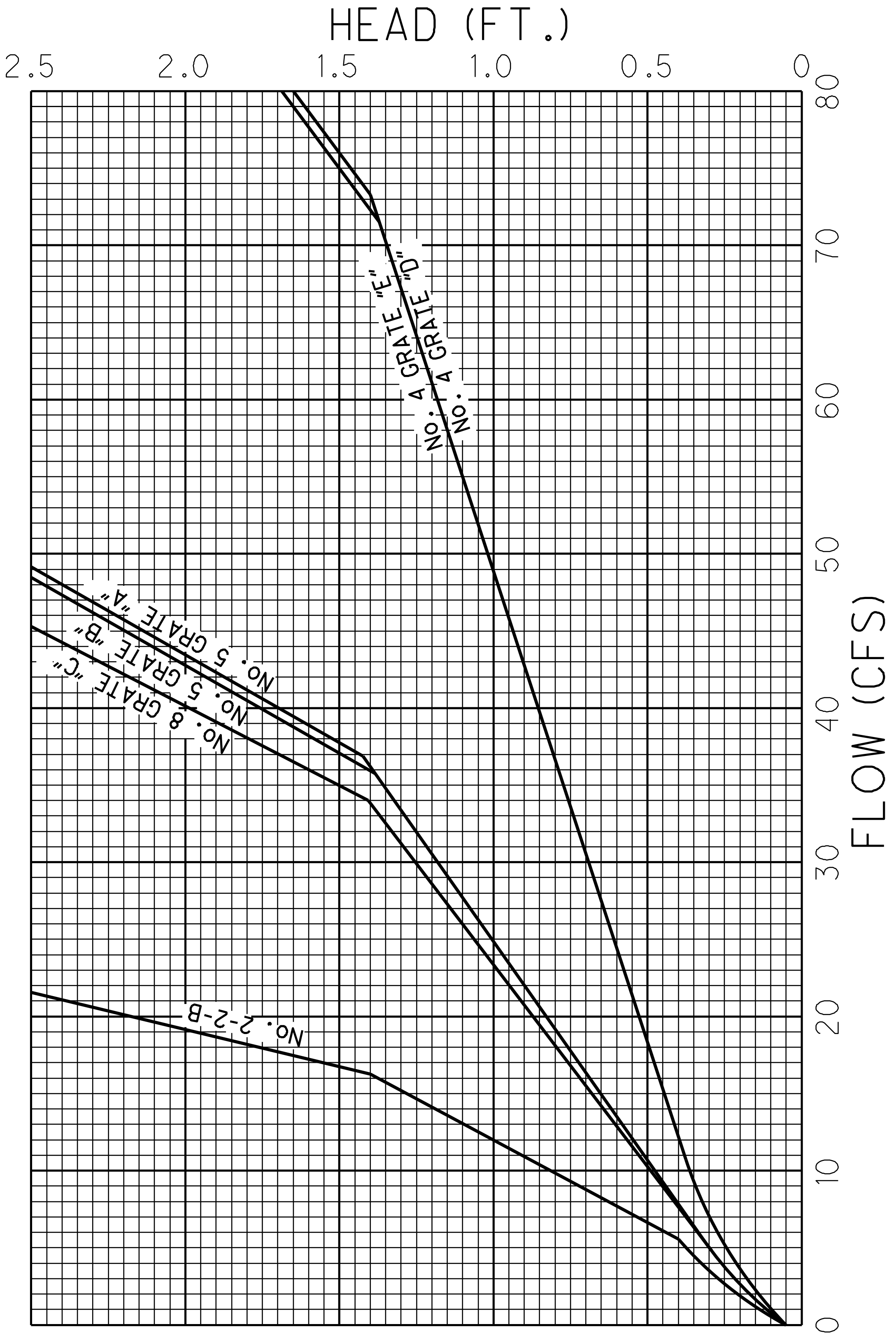
$i = a/(t+b)^c$

Where:
i = rainfall intensity (inches/hour)
t = time of concentration (minutes)
a = constant
b = constant
c = constant

The IDF Curves can be expressed using the above general equation utilizing the constants shown below.

Intensity Zone	AEP %	Constant **a**	Constant **b**	Constant **c**
A	50	46.184	9.000	0.859
	20	56.985	10.250	0.851
	10	64.167	11.000	0.842
	4	66.528	11.000	0.811
	2	65.702	10.750	0.782
	1	64.489	10.500	0.754
B	50	47.987	9.000	0.859
	20	60.684	10.500	0.858
	10	73.126	12.000	0.863
	4	75.841	12.000	0.833
	2	65.621	10.000	0.781
	1	85.047	13.250	0.806
C	50	56.299	10.000	0.876
	20	67.933	11.000	0.869
	10	84.550	13.000	0.882
	4	95.736	14.000	0.871
	2	96.783	14.000	0.850
	1	80.436	11.500	0.794
D	50	57.448	10.000	0.876
	20	67.933	11.000	0.869
	10	79.192	12.000	0.864
	4	87.886	12.750	0.849
	2	95.169	13.500	0.839
	1	91.982	13.000	0.810

CAPACITY OF A GRATE CATCH BASIN IN A SUMP	1102-1
	REFERENCE SECTION 1102.3.5



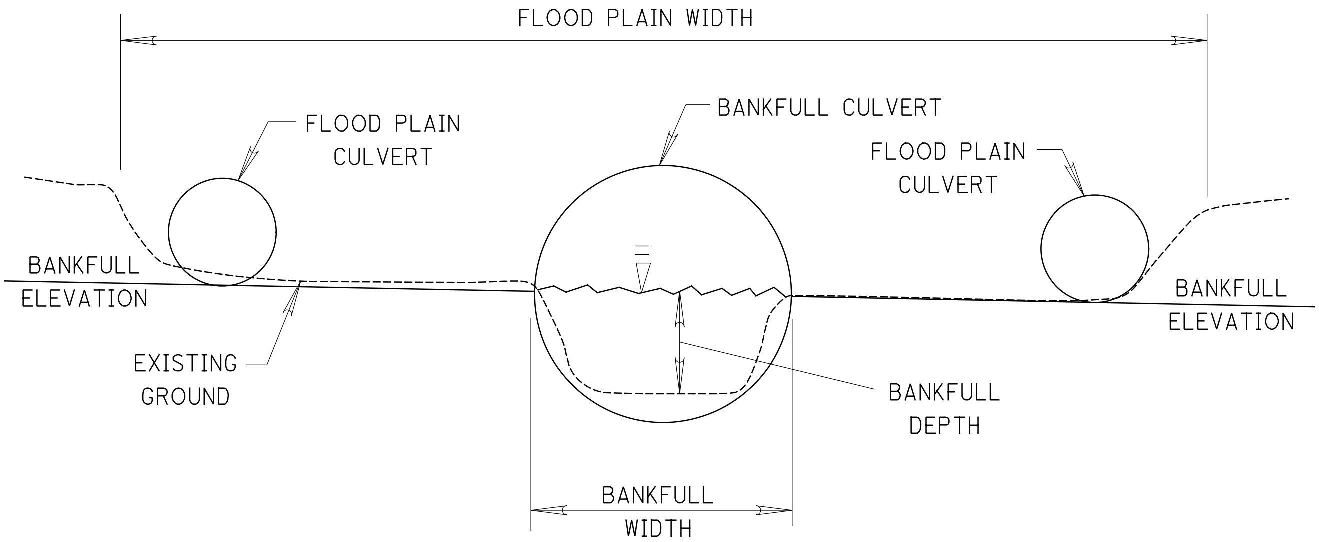
CAPACITY OF A GRATE CATCH BASIN IN A SUMP
(WATER PONDED ON THE GRATE)

CHANNEL FEATURES

1102-2

REFERENCE SECTION

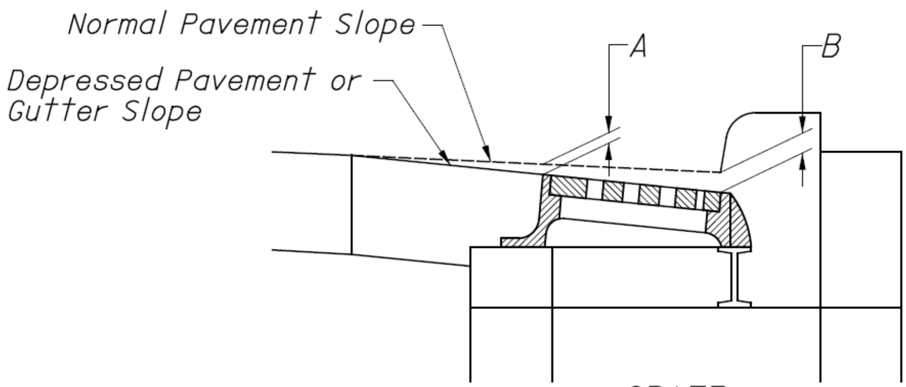
1102.2.4



LOCAL DEPRESSION LOCATION AND VALUES

1103-1

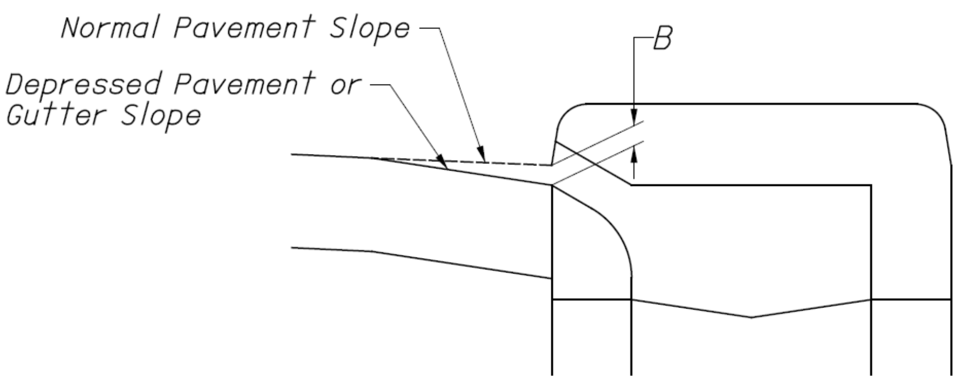
REFERENCE SECTION 1103.5.2



GRATE

A : Depression at Roadside Edge of Grate

B : Depression at Face of Curb or Barrier



INLET WINDOW

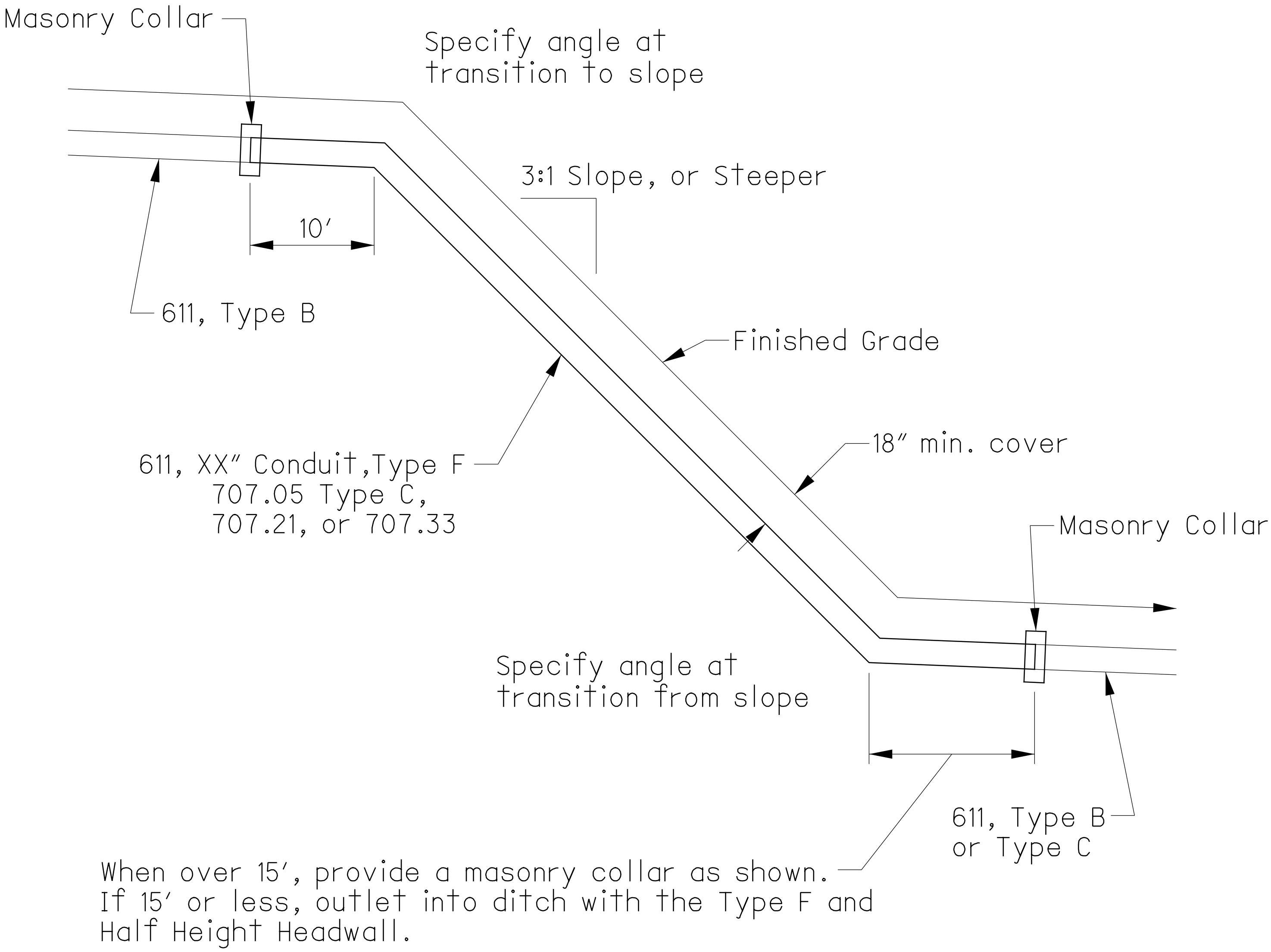
Basin/Inlet Type	Slope of Grate (ft/ft)	Normal Pavement Slope		Depressed Pavement or Gutter	
		A (inches)	B (inches)	A (inches)	B (inches)
CB-3/3A	0.1074	0.5*	2	0*	0.5
CB-6	0	1.25*	0.5	1.625*	0
I-2/2A	N/A	-	2*	-	2*
I-3B/3C/3D Grate	0.0833	0.75**	2*	-	-
I-3B/3C/I-4 Window	N/A	-	2*	-	-

***Local Depression Value for CDSS Calculations**

****Local Depression Value for CDSS Calculations in Sag Condition Only**

JULY 2022

TYPE F, BROKEN BACK DETAIL	1104-1
	REFERENCE SECTION 1104.1



BROKEN BACK DETAIL
(NTS)

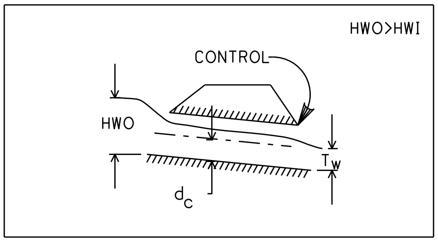
NOTE: THE LENGTH OF TYPE F CONDUIT IS MEASURED ALONG THE FLOWLINE OF THE PIPE.

CLASSIFICATION OF FLOW IN CULVERTS

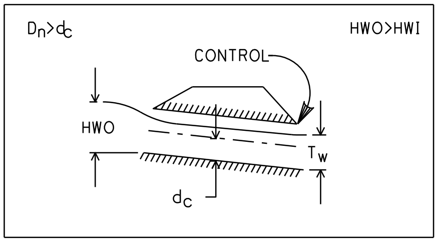
1105-1

REFERENCE SECTION
1105.2

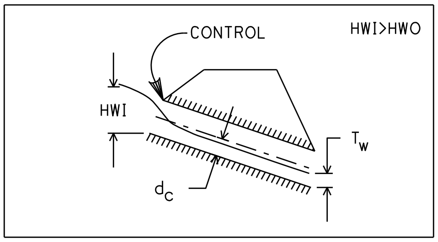
CLASS 1 OPERATION
FREE WATER SURFACE
HWI OR HWO ≦ 1.2D



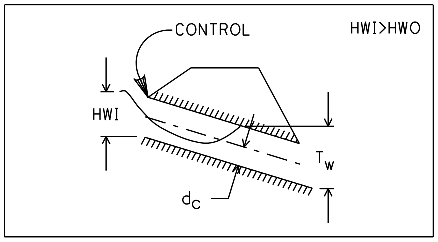
1A



1B

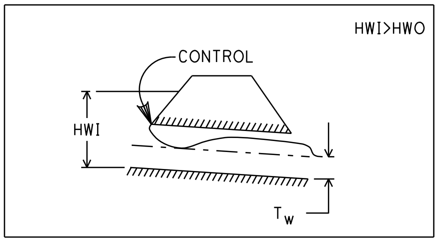


1C

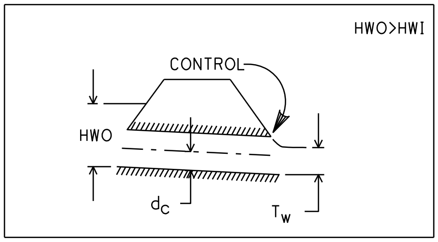


1D

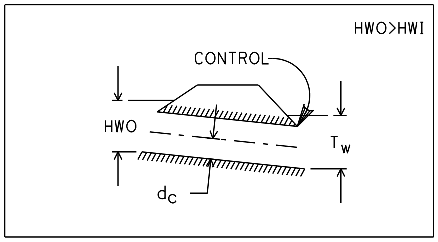
CLASS 2 OPERATION
SUBMERGED ENTRANCE
HWI OR HWO > 1.2D



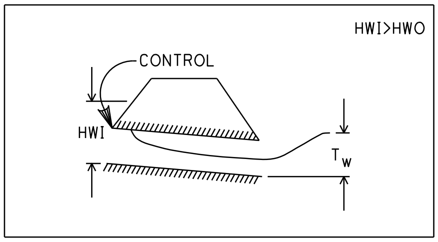
2E



2F



2G



2H

HWO indicates headwater based on outlet control
HWI indicates headwater based on inlet control
D = Height of culvert d = critical depth

MANNING'S "n" VALUES CORRUGATED METAL PIPE TYPE A CONDUIT

1105-2

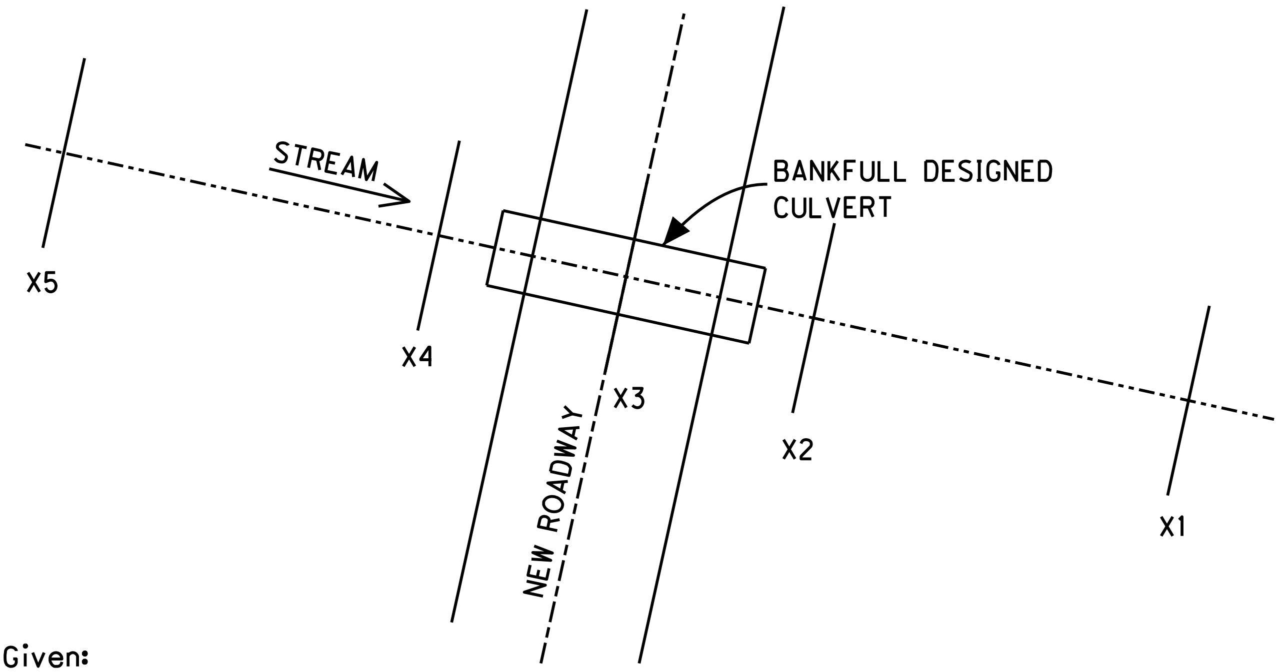
REFERENCE SECTION 1105.5.5

1/2" Corrugations		2" Corrugations		2 1/2" Corrugations	
Diameter (in)	Manning's n	Diameter (in)	Manning's n**	Diameter (in)	Manning's n**
15	0.0250	60	0.0332	60	0.035
18	0.0249	66	0.0330	66	0.035
21	0.0248	72	0.0327	72	0.034
24	0.0247	78	0.0325	78	0.034
30	0.0244	84	0.0323	84	0.034
36	0.0241	90	0.0321	90	0.034
42	0.0237	96	0.0320	96	0.034
48	0.0235	102	0.0318	102	0.034
54	0.0233	108	0.0317	108	0.033
60	0.0232	114	0.0315	114	0.033
66	0.0231	120	0.0314	120	0.033
72	0.0229	126	0.0313	126	0.033
78	0.0228	132	0.0312	132	0.033
84	0.0227	138	0.0311	138	0.033
90	0.0226	144	0.0310	144	0.033
96	0.0225	150	0.0309	150	0.033
1" Corrugations		156	0.0308	156	0.033
Diameter (in)	Manning's n*	162	0.0307	162	0.033
		168	0.0307	168	0.032
36	0.0281	174	0.0306	174	0.032
42	0.0278	180	0.0305	180	0.032
48	0.0275	186	0.0305	186	0.032
54	0.0273	192	0.0304	192	0.032
60	0.0271	198	0.0304	198	0.032
66	0.0269	204	0.0303	204	0.032
72	0.0267	210	0.0303	210	0.032
78	0.0266	216	0.0302	216	0.032
84	0.0265	222	0.0302	222	0.032
90	0.0263	228	0.0301	228	0.032
96	0.0263	234	0.0301	234	0.032
102	0.0262	240	0.0300	240	0.032
108	0.0261	246	0.0300	246	0.032
114	0.0260	252	0.0300	252	0.031
120	0.0260				

* 0.020 for all field paved 1" corrugations

** 0.026 for all field paved strutural plate pipe

EXAMPLE BANKFULL DISCHARGE CULVERT DESIGN



Given:

Use a Box Conduit
Max Height of Box = 8 feet

1. According to Table 1105-1, culvert invert is to be buried by 12 inches.

2. Use Hec-Ras to determine the following table:

2-Year Frequency Water Surface Elevations

	Existing	12′ x 8′ Box	14′ x 8′ Box	16′ x 8′ Box	20′ x 8′ Box
X1	790.67	790.67	790.67	790.67	790.67
X2	791.07	791.07	791.07	791.07	791.07
X3	791.27	791.47	791.42	791.39	791.32
X4	791.47	791.88	791.81	791.74	791.65
X5	791.87	791.98	791.94	791.91	791.88

3. Will provide a 20′ x 8′ box with a 12 ″ burial depth due to its smallest impact on the adjoining stream sections.

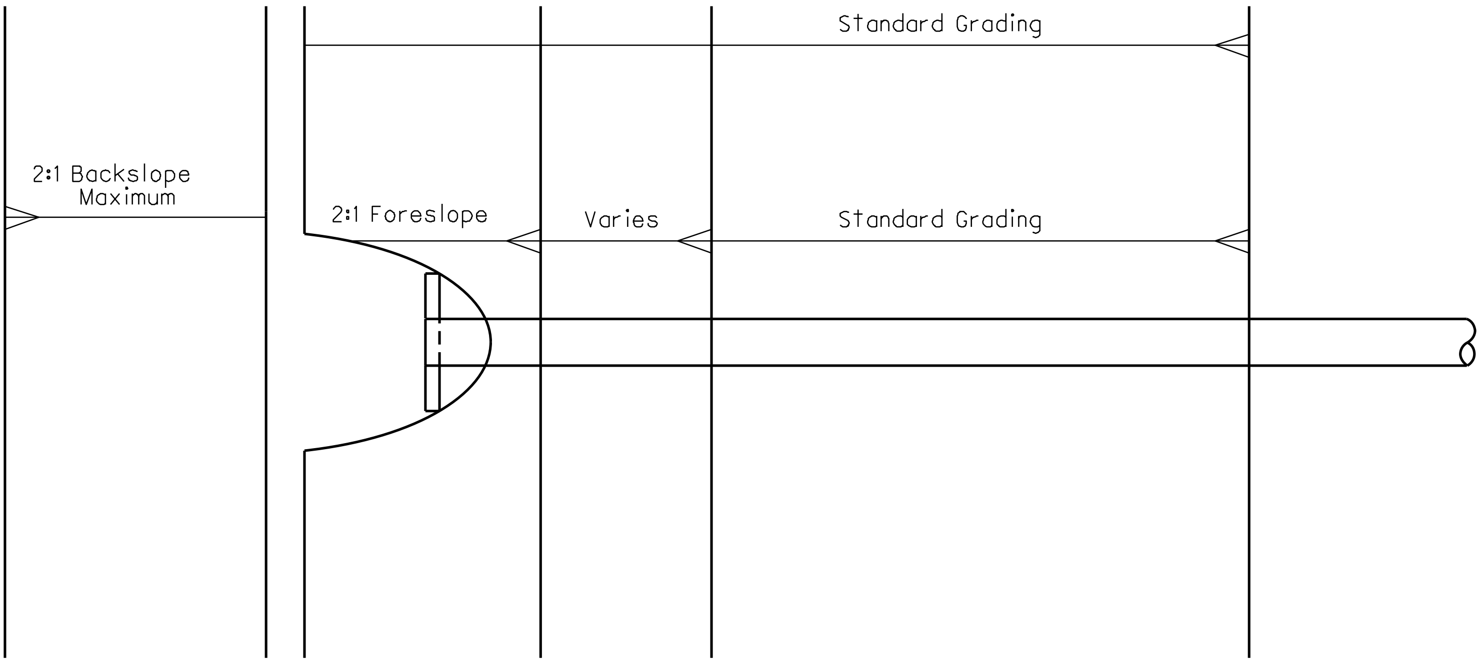
4. Ensure the design and check headwaters meet requirements of L&D, Section 1105.

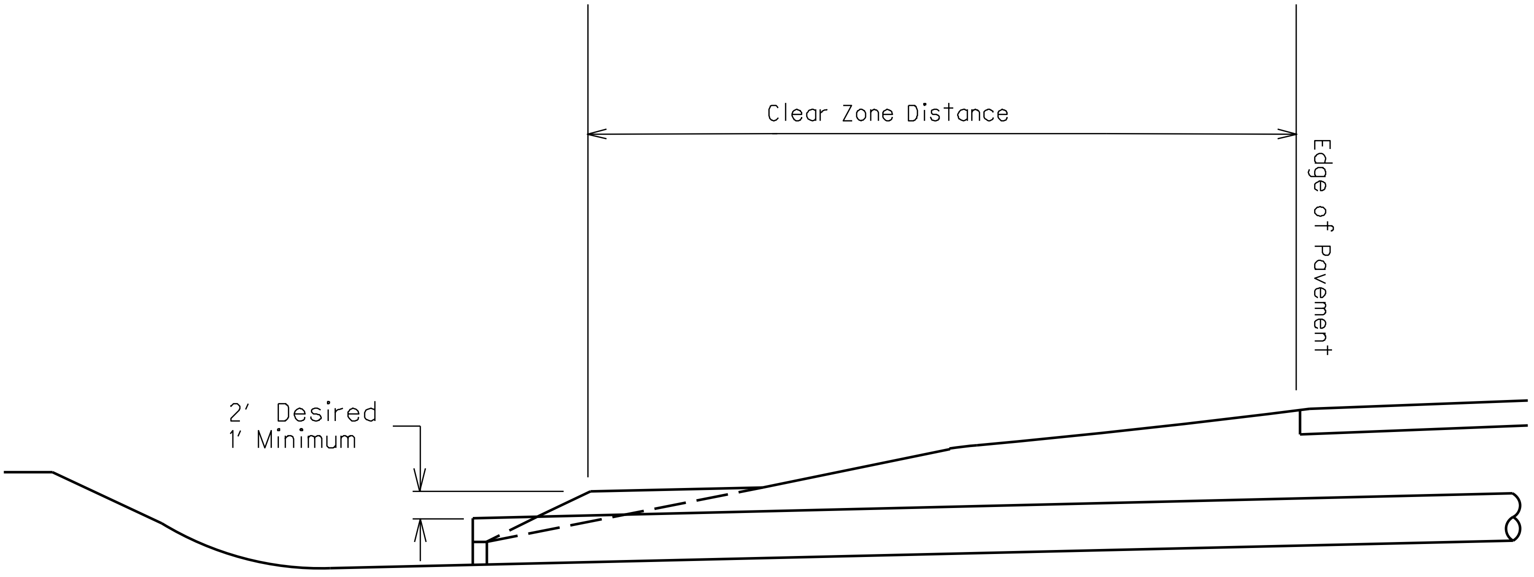
END TREATMENT GRADING DETAIL

1106-1

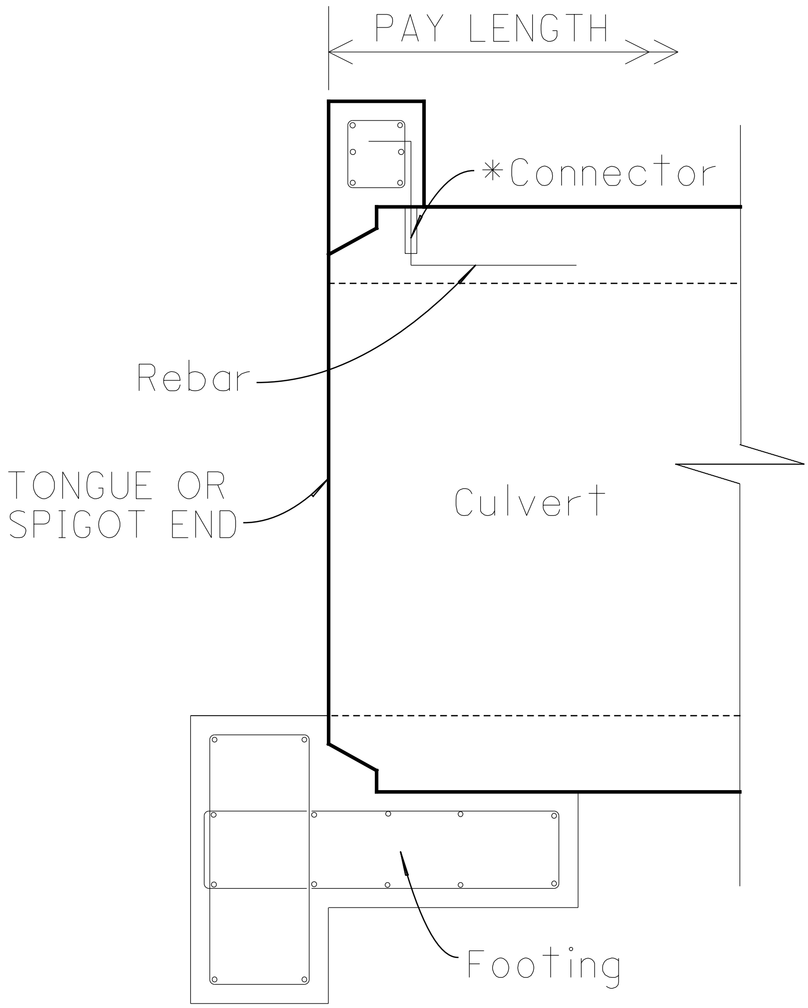
REFERENCE SECTION

1106.1





BOX CULVERT OUTLET DETAIL	1106-2
	REFERENCE SECTION 1106



OUTLET DETAIL (NTS)

* Anchoring Method

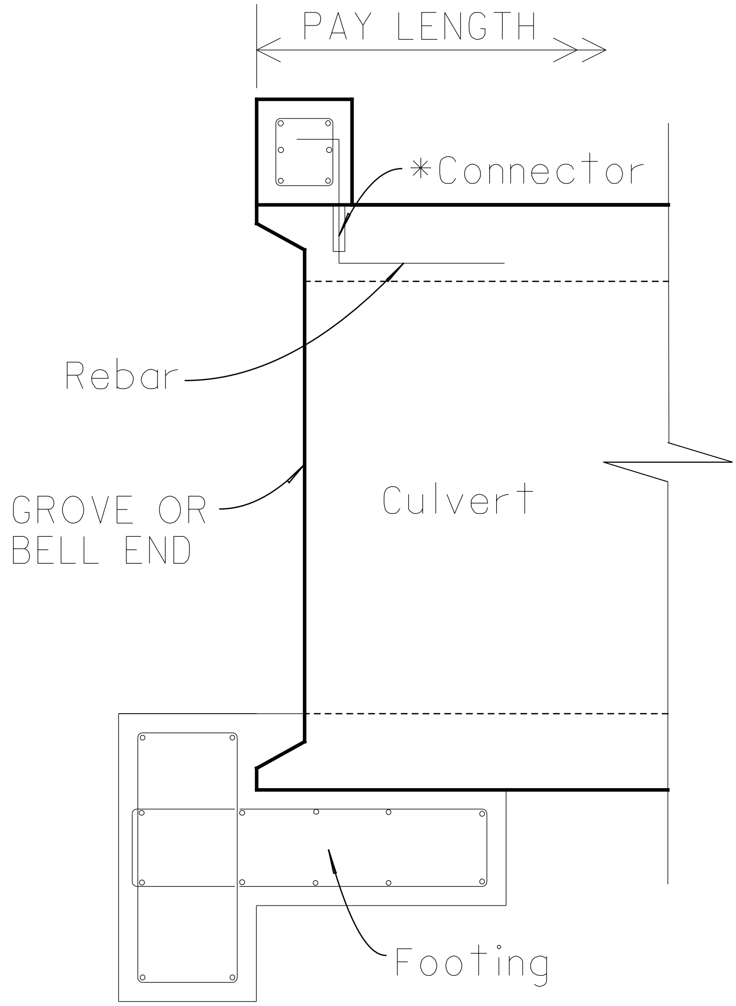
Mechanical connector embedded into precast box culvert.

Notes:

Specify required rebar size and connector diameter needed.

JULY 2021

BOX CULVERT INLET DETAIL	1106-3
	REFERENCE SECTION 1106



INLET DETAIL (NTS)

*** Anchoring Method**

Mechanical connector embedded into precast box culvert.

Notes:

Specify required rebar size and connector diameter needed.

NOTICE OF INTENT (NOI) ACREAGE CALCULATION FORM	1109-1
	REFERENCE SECTION 1109

	Area (acres)
Project Earth Disturbing Activities	
If the project is a Routine Maintenance Project, an NOI is not required. (See Section 1109)	
Contractor Earth Disturbing Activities	
Field Office per C&MS Item 619:	
Enter 0.125 for Type A; 0.25 for Type B; or 1.00 for Type C	
Batch Plant: Yes = 2.0; No = 0	
Off-Project Waste / Borrow Pit:	
Add 1.0 acre per 15,000 CY of waste or borrow	
Miscellaneous Other Off-Project Areas:	
Off-Project staging areas, stock yards, etc.	
Contractor Earth Disturbing Activities **Subtotal**	
Total Earth Disturbing Activities (add Project EDA and Contractor EDA) **TOTAL**	
NOI Earth Disturbing Activities (see below to determine value) **TOTAL**	

Project Earth Disturbing Activities - Enter the area of earth disturbing activities directly related to project activities. Earth disturbing activity is defined as any activity that exposes bare ground or an erodible material to storm water as well as anywhere Item 659 Seeding, or Item 660 Sodding is being furnished.

Contractor Earth Disturbing Activities:

Field Office - These sizes were determined with regard to size of the trailer, parking, and some stock area for equipment and materials based on Item 619 Field Office.

Batch Plant - It is assumed that a typical batch plant would occupy 2 acres of ground. The designer should investigate the location of the project relative to existing plants, facilities, etc. to estimate whether a batch plant might be used by the Contractor. This is not needed for existing plants, it is only for plants set up for the specific project.

Off-Project Waste / Borrow - The specified estimation is based on approximately 10 feet of depth or fill over 1 acre. The designer may choose a different value based on knowledge of the project area, bedrock elevations, previous projects, etc. Consideration should be given for grindings, as well. (10ft. x 43560 s.f. / 27 = 16,133 c.y. ~ 15,000 c.y.)

NOI Earth Disturbing Activities - This is the combined Project and Contractor Earth Disturbed Area. Based on project conditions and activities, some flexibility in the area calculation should be provided to avoid the possibility of the estimated work being less than the actual work. This scenario would require submittal of an NOI for projects originally calculated to be less than one acre during construction.

For projects with Total EDA less than one acre: No NOI is required.

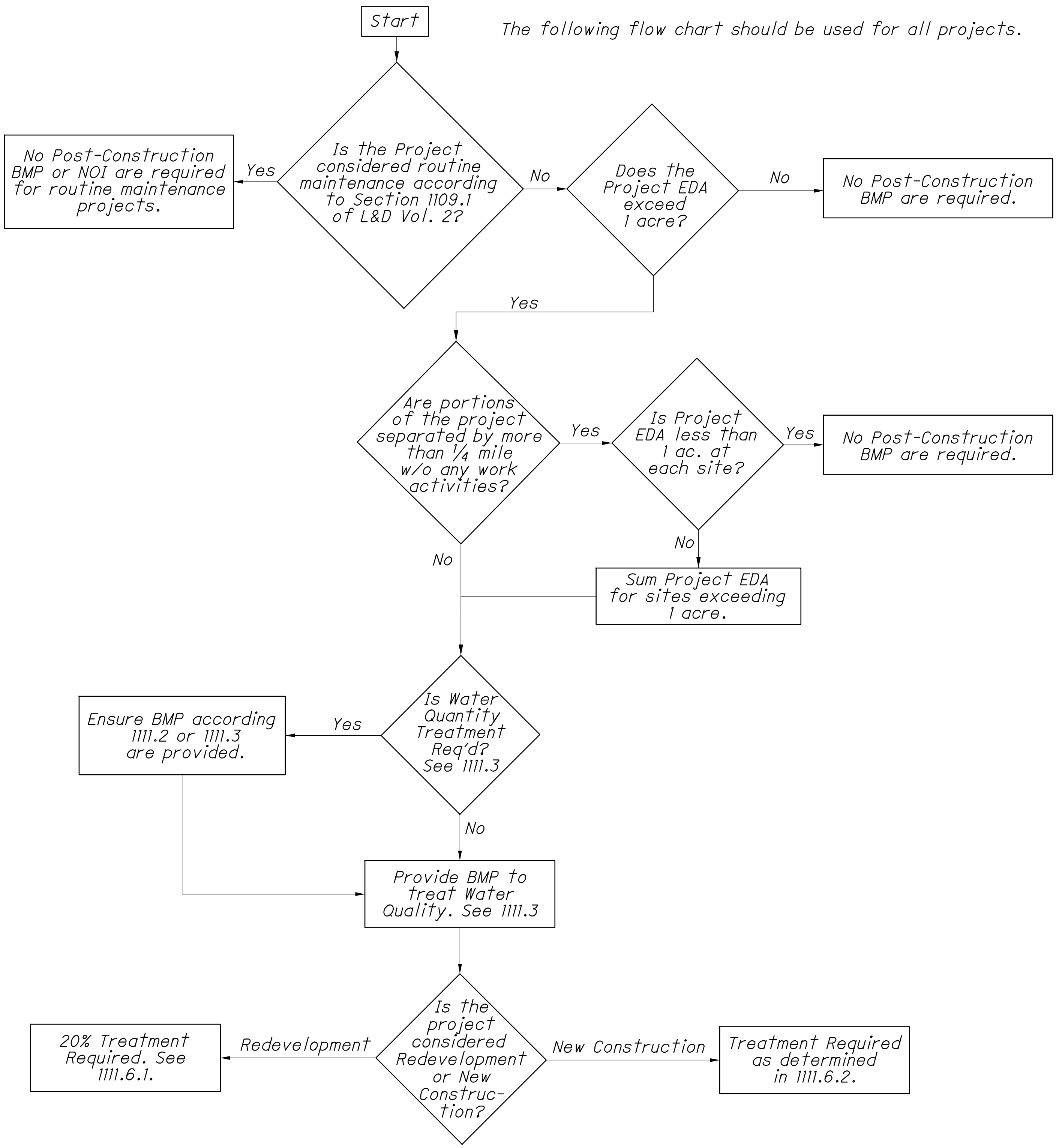
A Routine Maintenance Project consists of activities that do not change the line, grade, or hydraulic capacity of the existing condition and has less than 5 acres of earth disturbing activities (see section 1109.2).

POST-CONSTRUCTION BMP TREATMENT

1111-1

REFERENCE SECTION
1111

The following flow chart should be used for all projects.



# Duration vs. Intensity Table	1111-2
	REFERENCE SECTION 1111.5

For Water Quality Flow (WQ_F) Calculation for Manufactured Systems

DURATION t_c (minutes)	INTENSITY (i) (inches/hour)	DURATION t_c (minutes)	INTENSITY (i) (inches/hour)
10	1.85	36	0.90
11	1.76	37	0.88
12	1.68	38	0.86
13	1.62	39	0.85
14	1.56	40	0.83
15	1.51	41	0.82
16	1.46	42	0.80
17	1.41	43	0.78
18	1.37	44	0.77
19	1.33	45	0.76
20	1.29	46	0.75
21	1.26	47	0.74
22	1.22	48	0.73
23	1.19	49	0.72
24	1.16	50	0.71
25	1.13	51	0.69
26	1.10	52	0.68
27	1.07	53	0.67
28	1.05	54	0.66
29	1.03	55	0.66
30	1.01	56	0.65
31	0.99	57	0.64
32	0.97	58	0.64
33	0.95	59	0.63
34	0.93	60	0.62
35	0.92		

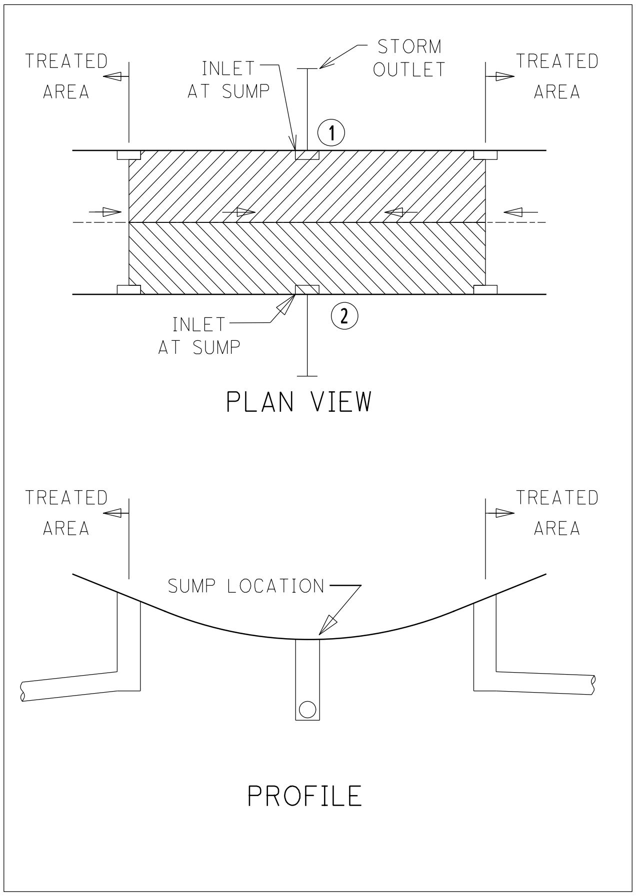
Notes:

1. The minimum time of concentration allowed is 10 minutes.
2. For a time of concentration calculated over 60 minutes, use i = 0.62 in/hr to determine the water quality flow (WQ_F) for manufactured system sizing.
3. Use an intensity equal to 0.65 in/hr for calculation of the water quality flow (WQ_F) for design of vegetated biofilters

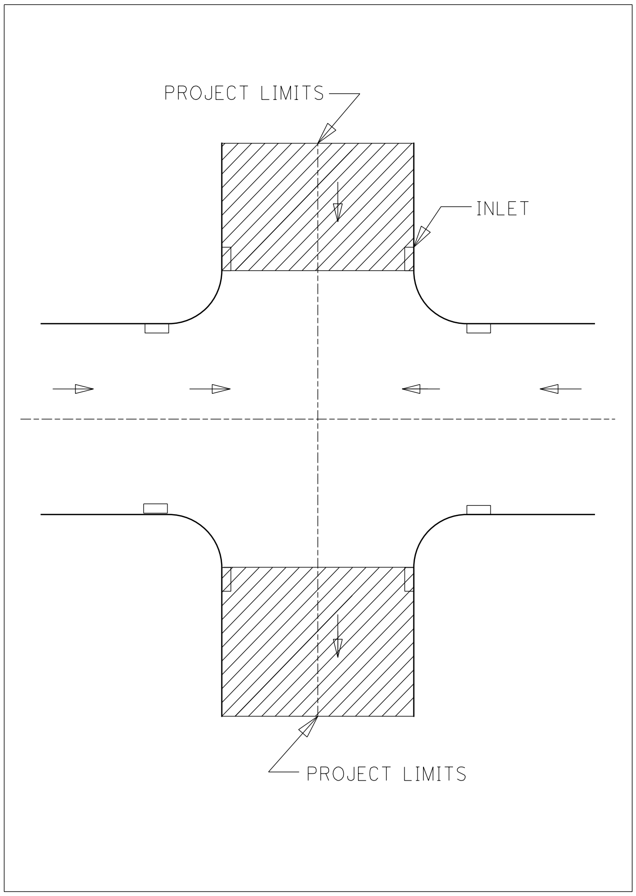
EXEMPT OUTFALLS

1112-1

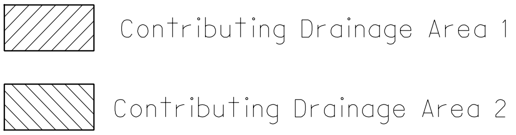
REFERENCE SECTION
1112



INLETS OR SCUPPERS IN SUMPS



INLETS AT INTERSECTIONS



If the contributing drainage areas to drainage structures #1 or #2 are less than 0.25 acres, Water Quality Treatment is not required.

The above example shows areas that are each less than 0.25 acres.

Treatment is required for the drainage areas tributary to the flanking inlets.

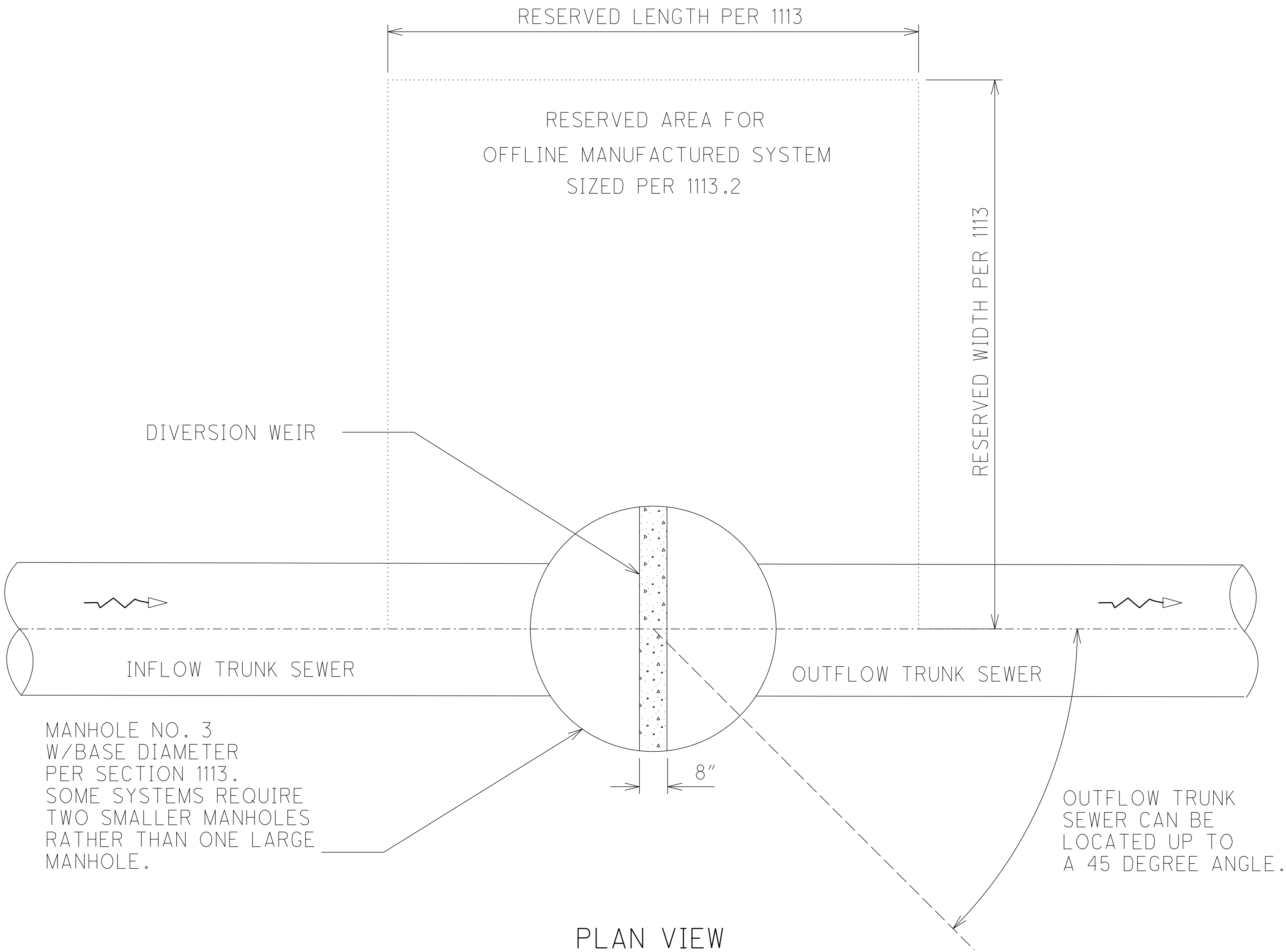
If the drainage area within the project limits is less than 0.25 acres, then no Water Quality Treatment is required.

The hatched areas above indicate that treatment is not required.

Treatment is required on the through street.

JULY 2021

MANUFACTURED SYSTEM DETAIL	1113-1
	REFERENCE SECTION 1113



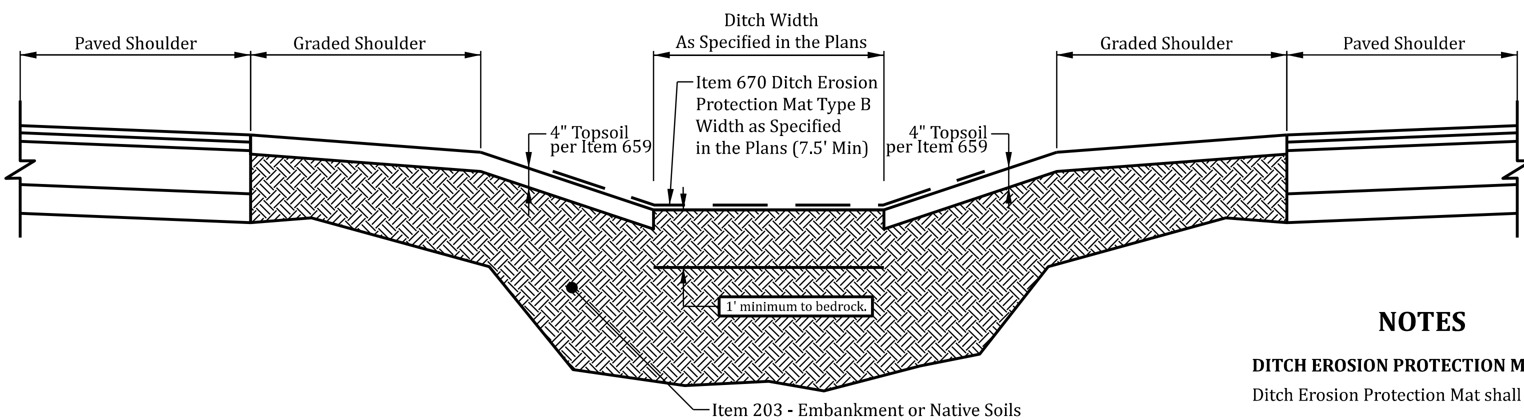
PLAN VIEW

NOT TO SCALE

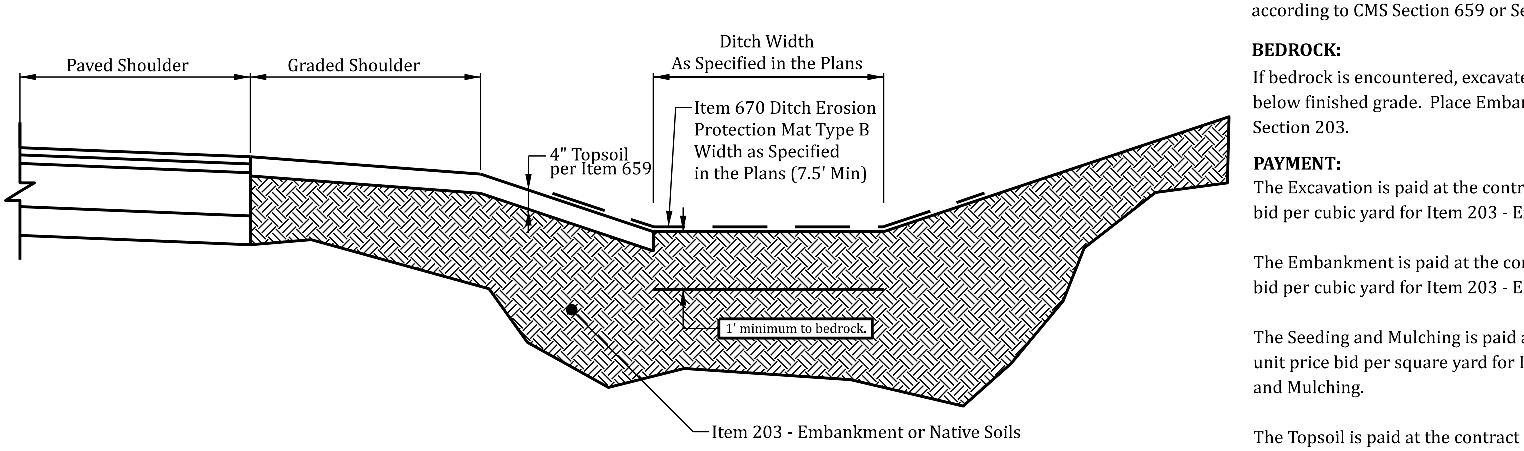
VEGETATED BIOFILTER DETAIL

1113-2

REFERENCE SECTION
1113



CROSS-SECTIONAL VIEW
VEGETATED BIOFILTER - PAVEMENT ON BOTH SIDES



CROSS-SECTIONAL VIEW
VEGETATED BIOFILTER - PAVEMENT ON ONE SIDE

NOTES

DITCH EROSION PROTECTION MAT:

Ditch Erosion Protection Mat shall be Type B.

Install Ditch Erosion Protection Mat according to the manufacturers instructions.

SEEDING AND MULCHING:

Place Seeding and Mulching or Sodding on all Topsoil according to CMS Section 659 or Section 660.

BEDROCK:

If bedrock is encountered, excavate rock to one foot below finished grade. Place Embankment per CMS Section 203.

PAYMENT:

The Excavation is paid at the contract unit price bid per cubic yard for Item 203 - Excavation.

The Embankment is paid at the contract unit price bid per cubic yard for Item 203 - Embankment.

The Seeding and Mulching is paid at the contract unit price bid per square yard for Item 659 - Seeding and Mulching.

The Topsoil is paid at the contract unit price bid per cubic yard for Item 659 - Topsoil.

The Sodding is paid at the contract unit price per square yard for Item 660 - Sodding.

The Ditch Erosion Protection Mat is paid at the unit price bid per square yard for Item 670 - Ditch Erosion Protection Mat, Type B.

EXTENDED DETENTION BASIN EXAMPLE	1113-3
	REFERENCE SECTION 1113

Given:

- Total Tributary Area = 7.5 ac
  - Tributary Area within Existing R/W = 5.8 ac
  - Tributary Area, Impervious, Outside of R/W = 0.0 ac
  - Tributary Area, Pervious, Outside of R/W = 1.7 ac
  - Tributary Area, Pavement and Paved Shoulders = 1.5 ac
  - Tributary Area, Berms and Slopes 4:1 or Flatter = 6.0 ac
- Rainfall Area B
- Time of Concentration, t_c = 25 min (calculation shown in this example)

Calculate the water quality volume WQ_v:

- WQ_v= (R_V * P * A) / 12
- P = 0.90 in
- A = 7.5 ac
- RV = 0.05 + 0.9 * i
  - i = impervious area divided by the total area (within the BMP drainage area)
  - The area within existing ODOT right-of-way is considered impervious area for the purpose of post-construction BMP design considerations. (L&D Vol 2, Sec. 1111.6.1)
  - i = $\frac{5.8\ ac + 0.0\ ac}{7.5\ ac}$ = 0.773
- R_V = 0.05 + 0.9 * 0.773 = 0.746
- WQ_V = (0.746 * 0.90 in * 7.5 ac) / 12
- WQ_V = <u>0.42 ac-ft</u>

Calculate the minimum detention basin volume, forebay volume, and micropool volume:

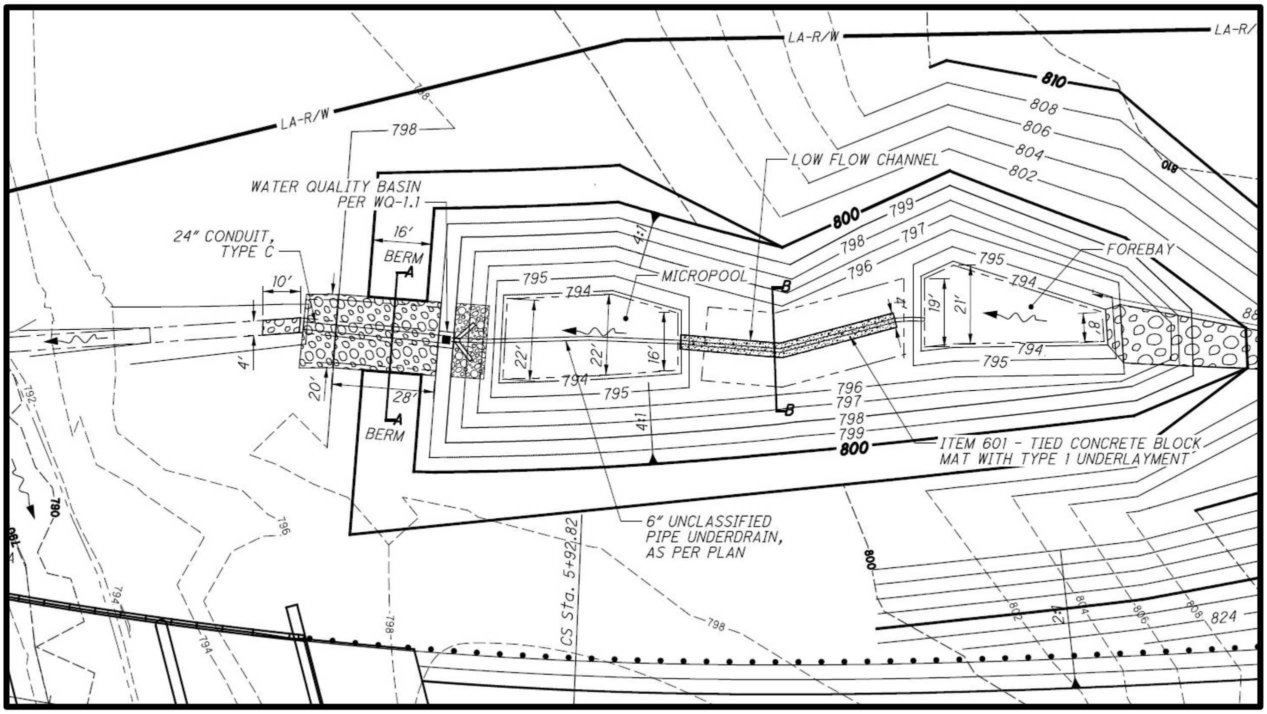
- Minimum basin volume = WQ_V * 1.2 (due to 20% increase)
    - WQ_V* 1.2 = 0.42 ac-ft *1.2 = 0.504 ac-ft
- 10% WQ_V for forebay volume, 10% * 0.042 ac-ft = <u>0.042 ac-ft</u>
- 10% WQ_V for micropool volume, 10% * 0.42 ac-ft = <u>0.042 ac-ft</u>

Layout a detention basin configuration that meets the following requirements:

- Forebay volume below the lowest outlet elevation at upstream end of the basin
- Micropool volume below the lowest water quality outlet invert elevation at the downstream end of the basin
- Maximum 4:1 side slopes
- Include provisions for vehicle access

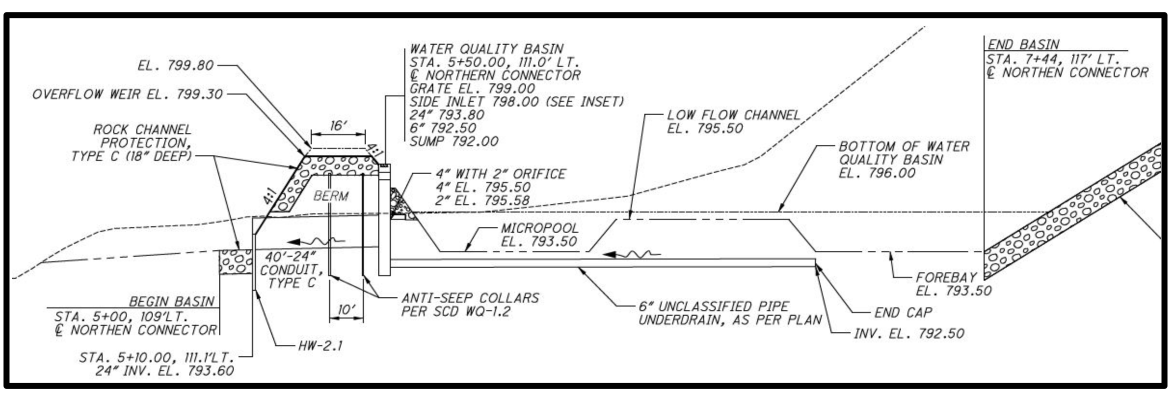
EXTENDED DETENTION BASIN EXAMPLE

Detention Basin Plan View:



Note: Section AA and BB not shown in this example.

Detention Basin Profile View:



Forebay:

- The forebay volume is the volume stored upstream of the low flow channel. The volume in the forebay is held in a permanent pool and is unable to flow downstream towards the outlet. The purpose of the forebay is to allow runoff to slow sufficiently for coarse sediment to settle out. This improves performance and reduces the maintenance burden by concentrating sediment buildup in one location designed for maintenance access.
- Forebay volume must be greater than or equal to 0.042 ac-ft.
- Forebay volume as calculated in CAD for this example = 0.042 ac-ft.
- 0.042 ac-ft is equal to the 0.042 ac-ft requirement: Acceptable

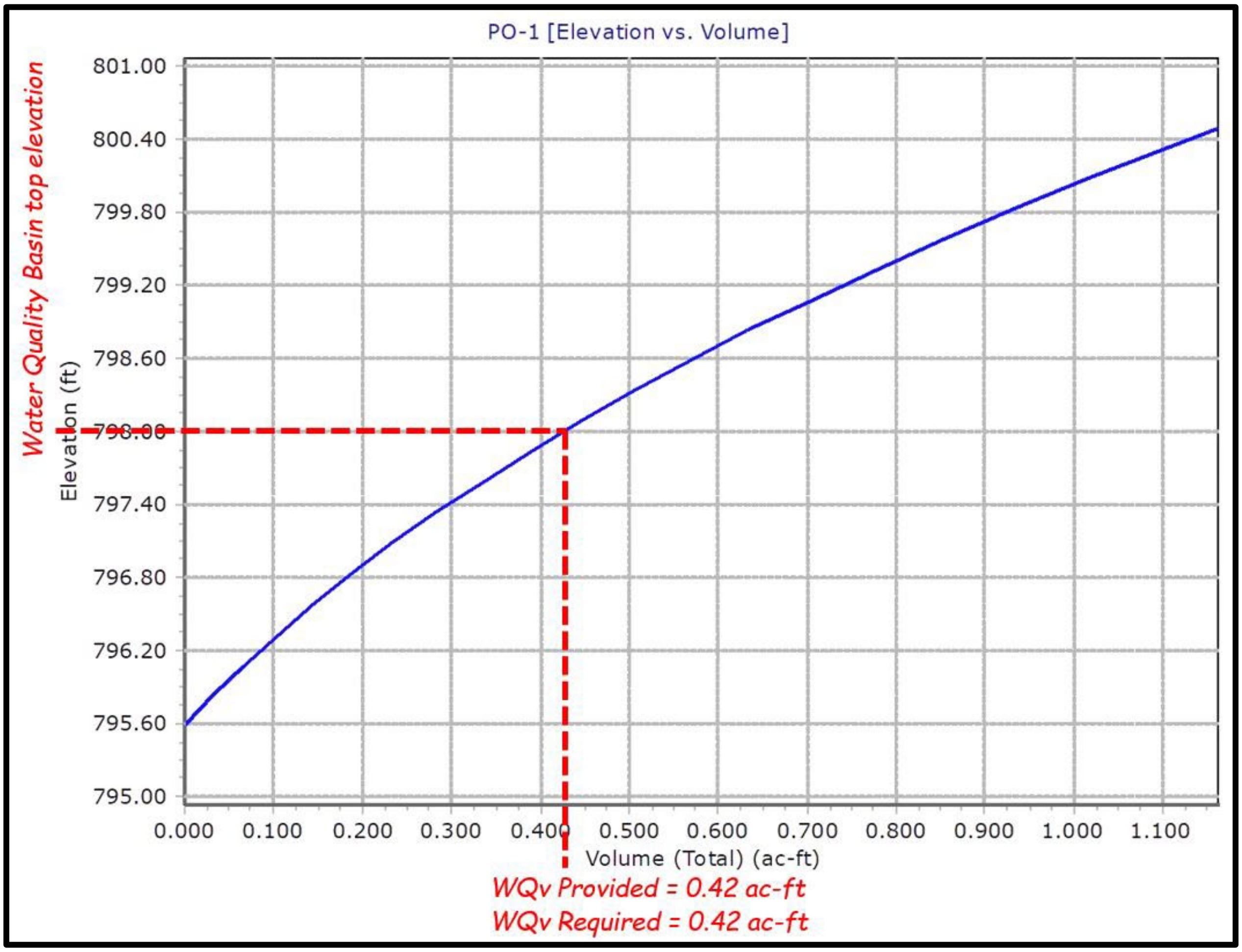
Micropool:

- The micropool volume is the volume that is stored below the lowest invert elevation of the lowest water quality outlet. The purpose of the micropool is to slow runoff draining towards the outlet structure, promote sediment settling below the outlet structure, and allow use of a non-clogging outlet. This improves performance and reduces clogging and maintenance.
- Micropool volume must be greater than or equal to 0.042 ac-ft.
- Micropool volume as calculated in CAD for this example = 0.047 ac-ft.
- 0.047 ac-ft is greater than 0.042 ac-ft requirement: Acceptable

Water Quality Volume (WQ_V) Storage:

- The WQ_V must be fully stored above the lowest water quality outlet elevation.
- The lowest water quality outlet is at an elevation of 795.58 ft.
- The WQ_V (0.42 ac-ft) must be stored between 795.58 ft and side inlet bottom elevation.

Stage (Elevation) vs. Volume Curve:

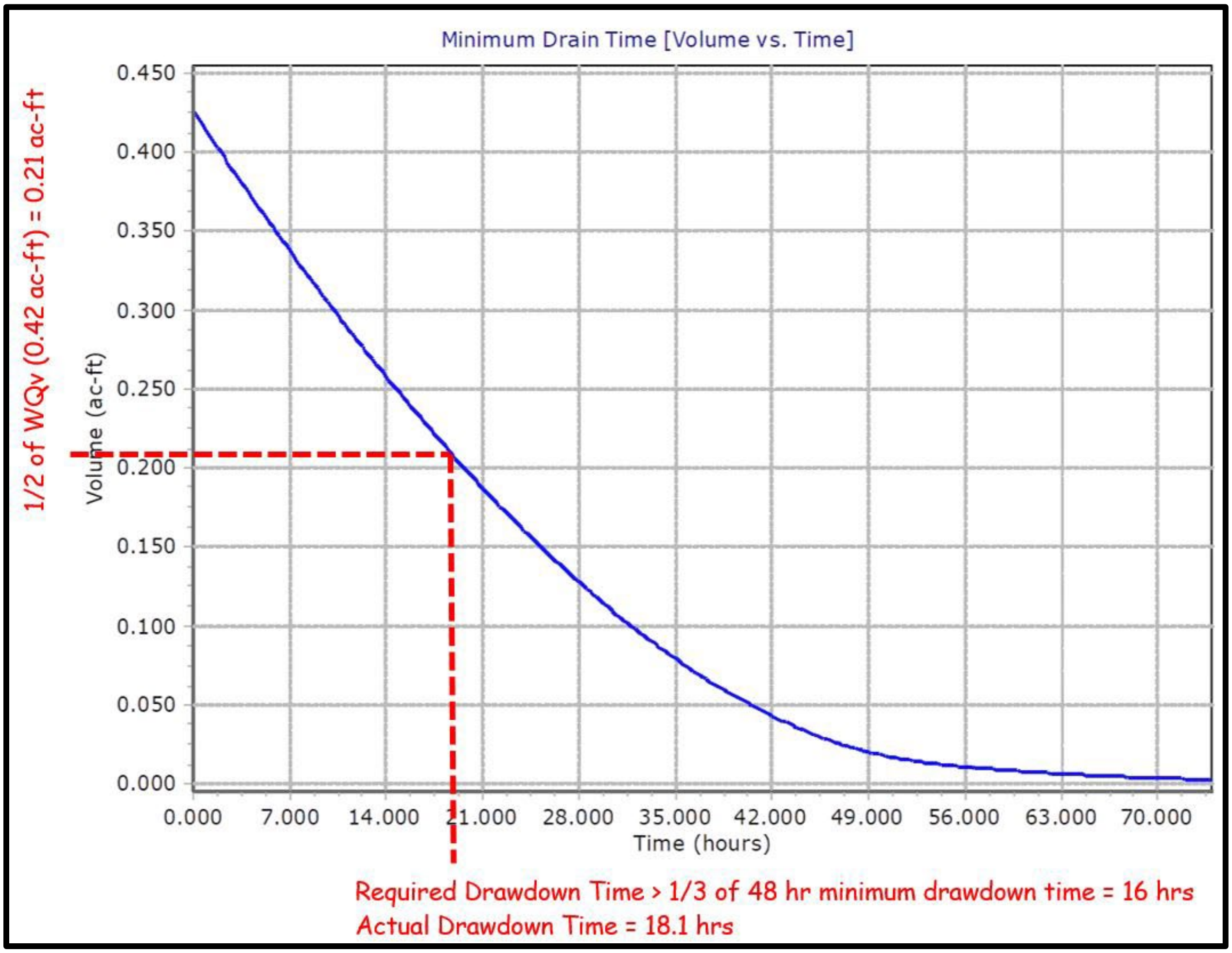


The graph shows that the full WQ_V is stored between 795.58 ft and 798.0 ft in the detention basin. The forebay and micropool have been excluded from this stage vs. volume graph since the volume associated with the forebay and micropool is assumed to be constantly standing in water.

Design the Detention Basin Water Quality Outlet:

- The minimum discharge time of the WQ_V is 48 hours with no more than 50% of the WQ_V being released from the detention basin in the first one-third of the 48 hour drain time.
- WQ_V = 0.42 ac-ft; must take 48 hours or longer to drain
- 50% or less of the WQ_V (i.e. 0.21 ac-ft) must be drained in 16 hours.
- Choose a 2 in diameter circular orifice 795.58 ft
- Calculate the drawdown curve.
    - This calculation can be done by hand by creating a stage vs. discharge table and interpolating between values, but it is generally easier to use a model to simulate runoff through a detention basin such as PondPack or HydroCAD.
- Do not route a design storm hydrograph through a detention basin to determine the drawdown curve. Start the simulation with the water surface at a level equivalent to the WQ_V storage (for this example, at an elevation of 798.00). Then allow the pooled water filling the WQ_V to drain by gravity out of the water quality outlet structure. Include all detention basin outlets that would affect this drawdown curve. Include any downstream constraints such as tailwater or limiting conveyance downstream. For this example, there is no tailwater and there is a free discharge from the detention basin.

Modeled Drawdown Curve using Pond Pack:



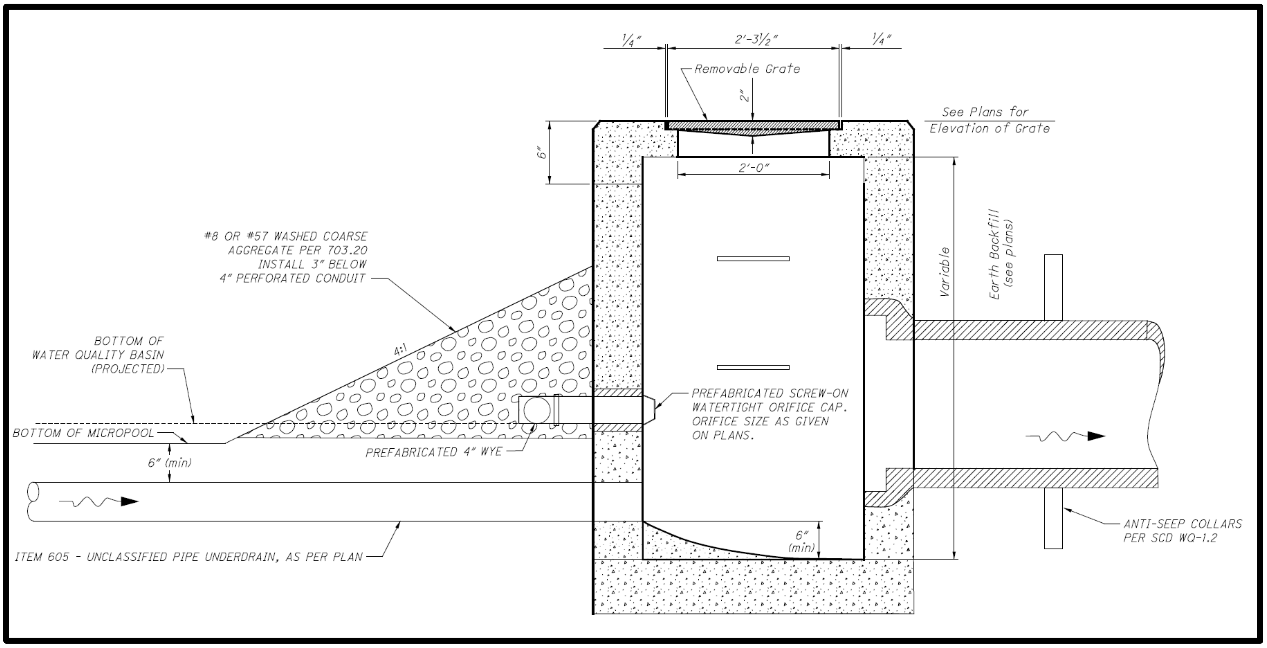
- The graph shows that it takes longer than 48 hours to drain the WQ_v (0.42 ac-ft); therefore, it is acceptable.
- The graph shows that it takes at least 16 hours ($^1/_3$ of the minimum drawdown time) to drain one-half of the WQ Basin WQ_V (0.21 ac-ft); therefore, it is acceptable.

Size the Primary Detention Basin Outlet:

- There are three main parts of a typical extended detention basin discharge structure:
  - Water quality outlet(s)
  - Primary outlet
  - Overflow weir

- The primary detention basin outlet normally consists of a catch basin grate, catch basin side inlets, and the conduit that conveys discharges from the detention basin during all but the least frequent precipitation events.
- The primary outlet should be sized to convey the 10% AEP design storm.

ODOT Water Quality Catch Basin Detail (WQ-1.1):



Determine the 10% AEP design flow rate:

- For the purposes of post-construction BMP calculations, all existing right-of-way is to be considered impervious. For the purpose of general conveyance sizing, runoff coefficients should be calculated using Table 1101-2 in ODOT's L&D Vol. 2.
- Q = CiA

Calculate the weighted C value:

1.5 acres of tributary area are pavement and paved shoulders: C = 0.9

6.0 acres of tributary area are berms and slopes 4:1 or flatter: C = 0.5

$$C_{weighted} = \frac{1.5\ ac*0.9+6.0\ ac*0.5}{7.5\ ac} = 0.58$$

Time of Concentration (t_c) Calculations:

- t_c = Time of overland flow (t_O) + Time of shallow concentrated flow (t_S) + Time of channel flow (t_C)
- Overland Flow (t_O)
  - $\frac{1.8(1.1-C)(L)^{1/2}}{s^{1/3}}$
  - C = Runoff Coefficient (0.58 for this example)
  - L = Distance to most remote location in drainage in feet (max. 300 ft) (200 ft in this example)
  - s = Overland slope (percent) (0.33% in this example)
  - $\frac{1.8(1.1-0.58)(200)^{1/2}}{0.33^{1/3}}$= **19.16 minutes**
- Shallow Concentrated Flow (t_s)
  - V_S = Velocity of shallow concentrated flow (ft/sec) = $3.281ks^{0.5}$
  - k = Intercept Coefficient (L&D Table 1101-1) = (0.457 in this example)
  - s = Overland slope (percent) (0.33% in this example)
  - $V_S = 3.281 * 0.457 * 0.33^{0.5}$= 0.86 ft/sec
  - Length of shallow concentrated flow = 200 ft.
  - t_S = 200 ft / 0.86 ft/sec = 233 sec = **3.88 minutes**
- Channel Flow (t_C)
  - Manning's Equation: V = $\frac{1.49r^{2/3}\, s^{1/2}}{n}$
  - V = velocity in the channel (ft/sec)
  - r = hydraulic radius (0.69 ft in this example)
  - s = channel slope (0.01 ft/ft in this example)
  - n = Manning's Roughness Coefficient (L&D Vol. 2, Table 1102-3) (0.03 in this example)
  - V = $\frac{1.49*0.69^{2/3}*0.01^{1/2}}{0.03}$= 3.88 ft/sec
  - Channel length = 500 ft (for this example)
  - t_c = 500 ft / 3.88 ft/sec = 129 sec. = **2.15 minutes**
- $t_c = t_O + t_S + t_C$ = 19.16 + 3.88 + 2.15 = 25.19 minutes. Use t_c = **25 minutes**

Determine the precipitation intensity:

Rainfall Area B

t_c = 25 min

(The time of concentration is given in this example as 25 minutes because there is significant overland flow over grassed area. The time of concentration for each site should be based on the site-specific flow path. 25 minutes would likely be too high of a value if the detention basin were receiving flow from a piped system. See the time of concentration calculations above.)

L&D Vol. 2, Figure 1101-2: Area B, 10% AEP frequency, 25 min t_c: i = 3.4 in/hr

- 10% AEP design flow rate: Q = 0.58 * 3.4 in/hr * 7.5 ac = <u>14.79 cfs</u>

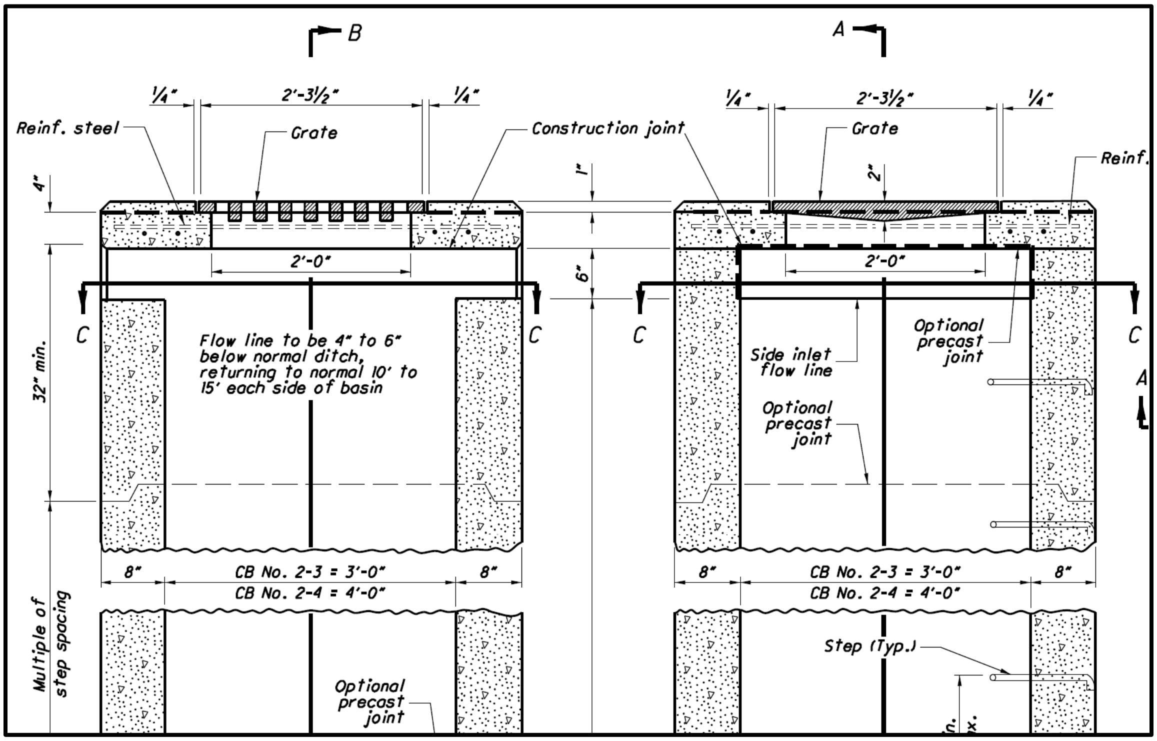
Size the primary detention basin discharge conduit:

- The discharge conduit must be large enough to convey the 10% AEP design storm, keeping the maximum hydraulic grade line within the crown of the pipe.
- This example has the following conduit characteristics:
  - Conduit slope = 0.005 ft/ft
  - No Tailwater; free discharge
  - Pipe Roughness Coefficient = 0.015 (L&D Vol. 2, Section 1104.4.5)
- The minimum conduit size that conveys the 10% AEP design flow (14.79 cfs) with the given characteristics is a <u>24-inch diameter pipe.</u>

Set the catch basin grate elevation:

- The WQ_V fills the detention basin to an elevation of 798.0 ft at water surface elevations of 798.0 ft and below, all discharge should pass through the water quality outlet. (In this example, the water quality outlet is the 2 in orifice cap at 795.58 located at the outlet of the 4 in conduit at 795.5 ft)
- The ODOT standard water quality catch basin detail (SCD WQ-1.1) calls for either Catch Basin No. 2-3 or 2-4 depending on the outlet pipe size. Both catch basins have a 6-inch high side inlet that is either, 3, or 4 feet wide depending on the catch basin. See the Standard Construction Drawing for details.

ODOT Catch Basin No. 2-3 and No. 2-4:



- The side inlets are set at 1 ft below the grate elevation in accordance with the subject Standard Construction Drawing. The elevation of the bottom of the side inlet should be set at the WQ_V elevation. Therefore, any runoff volume above the WQ_V will discharge into the catch basin through the side inlet and subsequently the grate.
  - Side inlets bottom elevation = 798.0 ft (Top of WQ_V)
  - Catch basin grate elevation = 799.0 ft

Set the catch basin invert elevation:

- Set the catch basin invert elevation to the lowest of:
  - 6 in below the orifice invert
    - 793.58 – 0.5 = 793.08
  - 6 in below the 6 in underdrain invert
    - 792.50 – 0.5 = 792.00
  - Invert of the discharge conduit
    - 793.8
  - Catch basin invert elevation = 792.00 ft

Set the Overflow Weir Invert Elevation:

- The 10% AEP design flow rate (14.79 cfs) should pass fully through the primary discharge. Therefore, no flow should discharge from the overflow weir until the 10% AEP design flow rate has been exceeded.
- Set the overflow weir invert elevation just high enough above the catch basin grate such that the full 10% AEP design flow rate is conveyed through the primary discharge.
- For this example, the primary discharge pipe is sized at 24 inches in diameter; therefore, Water Quality Basin using a Catch Basin No. 2-3 is appropriate.
- Catch Basin No. 2-3 has the same grate as Catch Basin No. 2-2B.
- The Water Quality Basin has three openings, in addition to the water quality outlet, to discharge runoff: 2- Side Inlets and the No. 2-2-B Grate.
- The composite stage-discharge relationship of these two openings can be hand calculated using appropriate weir and orifice equations. Alternatively, most commercial software programs can also perform the required calculations.
- Using a common commercial software program, the water surface elevation required to pass a flow rate of 14.79 cfs is 799.3.
- <u>Set the overflow weir elevation at 799.3.</u>

Size the Emergency Overflow Weir and Set the Top of Basin Elevation:

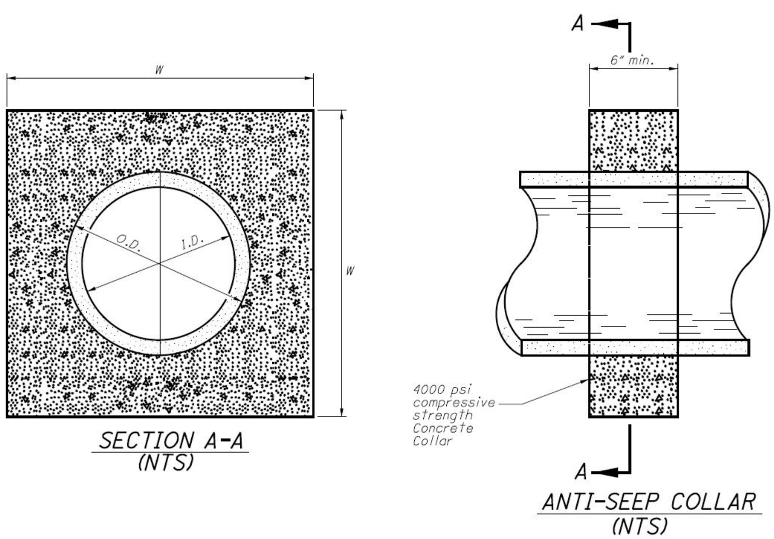
- L&D Vol. 2, Section 1104.3.2 states that the hydraulic grade line should be checked for the 4% AEP storm.
- The 4% AEP design flow rate should pass fully through the overflow weir.
- Calculate the design flow rate:
  - 4% AEP intensity @ t_C = 25 min and Rainfall Area B: 3.8 in/hr
  - 4% AEP design flow rate: Q = CiA = 0.58 * 3.8 in/hr * 7.5 ac = 16.53 cfs
- Calculate the required weir length for each design storm flow:
  - Overflow weir elevation = 799.30 ft
  - Assume a top of detention basin elevation of 799.80 ft.
  - Maximum height at overflow weir = 799.30 ft – 799.80 ft = 0.50 ft
  - Weir equation: $Q = C*L*H^{1.5}$
    - C = 3
    - H = 0.7
    - L = ?
  - Length of a weir: $L = \frac{Q}{C*H^{1.5}}$

   - 4% AEP: $L = \frac{16.53}{3*0.5^{1.5}} = 15.6$ ft
- Provide a 16 ft wide overflow weir.
- The top of basin elevation is 799.80 ft.
- The overflow weir length could be reduced by increasing the top of basin elevation. Or the top of basin elevation can be lowered by increasing the overflow weir length. The 4% AEP design flow rate must fully pass through the overflow weir without overtopping the detention basin.
- Flow rates greater than the 4% AEP design flow rate may overtop the detention basin uncontrolled.
- Provide erosion protection at the overflow weir, to the bottom of the berm, and continuing downstream if there is erosion potential.

Design Anti-Seep Collars:

- Anti-seep collars reduce the conveyance of flow along pipe bedding, outside of a conduit and increase the flow path for the seepage of water. This helps protect the berm above the discharge conduit from a detention basin from internal erosion.

ODOT Standard Drawing WQ-1.2:



DIAMETER (I.D.) (FT.)	CONCRETE (C.Y.) DIMENSION OF COLLAR W X W (FT.)		
	3X3	4X4	5X5
1	0.15	0.28	0.45
2	N/A	0.24	0.40
3	N/A	N/A	0.33

- Calculate the saturated zone length along the conduit (Ls)
  - Ls = Y(Z+4)[1+S/(0.25-S)]
  - Y = depth of water during the 10% AEP storm
  - Z = slope of embankment
  - S = slope of conduit
- Maximum elevation at 10% AEP storm = 799.30 ft
- Conduit elevation = 793.80 ft
- Y = 799.30 ft – 793.80 ft = 5.50 ft
- Z = 4
- S = 0.005
- Ls = 5.50 (4+4)[1+0.005/(0.25-0.005)] = 44.90 ft
- ΔLs = 0.15*Ls = 0.15 * 44.90 ft = 6.7 ft
- Total Projection: P = W – D
  - W = 2ft + 2 ft diameter + 2 ft = 6 ft
  - P = 6 ft – 2 ft = 4 ft
- Number of collars = ΔLs / P = 6.7 ft / 4 ft = 1.7
  - Minimum of 2 collars per outlet conduit
  - <u>Use 2 anti-seep collars</u>
- Place both anti-seep collars in a saturation zone (within 44.90 ft of front edge of berm).
- Spacing between collars: between 10 and 25 feet

Additional Considerations:

- Vegetate the sides of the detention basin with Item 670 Slope Erosion Protection per L&D Vol. 2, Section 1113.3.1.
- Connect the forebay to the micropool in the bottom of the detention basin with a low flow channel lined with tied concrete block or rock channel protection.
- For all open water carriers at each inlet and discharge from the detention basin, check the shear stress and ensure appropriate lining per L&D Vol. 2, Section 1102.3.2.
- For all discharges into or out of a detention basin, ensure that appropriate rock channel protection is included per L&D Vol. 2, Section 1105.2.5.
- Place a 6" thick layer of Item 601.10 Detention Basin Filter to all parts of the detention basin that are expected to be continually inundated with water, such as the forebay and micropool.
- Provide a 6" diameter underdrain (as per plan) located with a minimum of 6 inches of separation between the bottom elevation of the micropool and the crown of the underdrain. Extend the underdrain from the location of the low flow channel, under the micropool, and connecting into the Water Quality Basin. If the invert of the outlet conduit from the Water Quality Basin is not lower than the orifice elevation, then do not include the 6" diameter underdrain. The underdrain is as per plan because the trenching and backfilling requirements are waived to reduce the potential for short circuiting of water in the detention basin.
- Include calculated detention basin ponding elevations in the calculation of the hydraulic grade line for the upstream conveyance system per L&D Vol. 2, Section 1104.3.2.
- Attempt to locate structures outside of designated flood plains. If a detention basin encroaches on a flood plain, follow the flood assessment requirements in L&D Vol. 2 Section 1005.
- Ensure that safety criteria are met in the clear zone per L&D Vol. 1, Section 600.2.
- Ensure that no more than one foot of permanent standing water is located within the clear zone without barrier protection, per L&D Vol. 1, Section 601.1.1.
- Engage local project stakeholders in potential public safety considerations associated with detention basins.
- Develop a plan for how regular maintenance will be performed.
    - Vehicle access
    - Mowing
    - Removal of woody vegetation
    - Regular unclogging of the water quality outlet

RETENTION BASIN EXAMPLE	1113-4
	REFERENCE SECTION 1113

Given:

- Total Tributary Area = 7.5 ac
  - Tributary Area within Existing R/W = 5.8 ac
  - Tributary Area, Impervious, Outside of R/W = 0.0 ac
  - Tributary Area, Pervious, Outside of R/W = 1.7 ac
  - Tributary Area, Pavement and Paved Shoulders = 1.5 ac
  - Tributary Area, Berms and Slopes 4:1 or Flatter = 6.0 ac
- Rainfall Area B
- Time of Concentration, t_C = 25 min (calculation shown in this example)

Calculate the water quality volume WQ_V:

- $WQ_V = (R_V * P * A) / 12$
- P = 0.90 in
- A = 7.5 ac
- $R_V = 0.05 + 0.9 * i$
  - i = impervious area divided by the total area (within the BMP drainage area)
  - The area within existing ODOT right-of-way is considered impervious area for the purpose of post-construction BMP design considerations. (L&D Vol 2, Sec. 1111.6.1)
  - $i = \frac{5.8\ ac + 0.0\ ac}{7.5\ ac} = 0.773$
- $R_V = 0.05 + 0.9 * 0.773 = 0.746$
- $WQ_V = (0.746 * 0.90\ in * 7.5\ ac) / 12$
- WQ_V = <u>0.42 ac-ft</u>

Determine the minimum volume of the detention pool and the permanent pool:

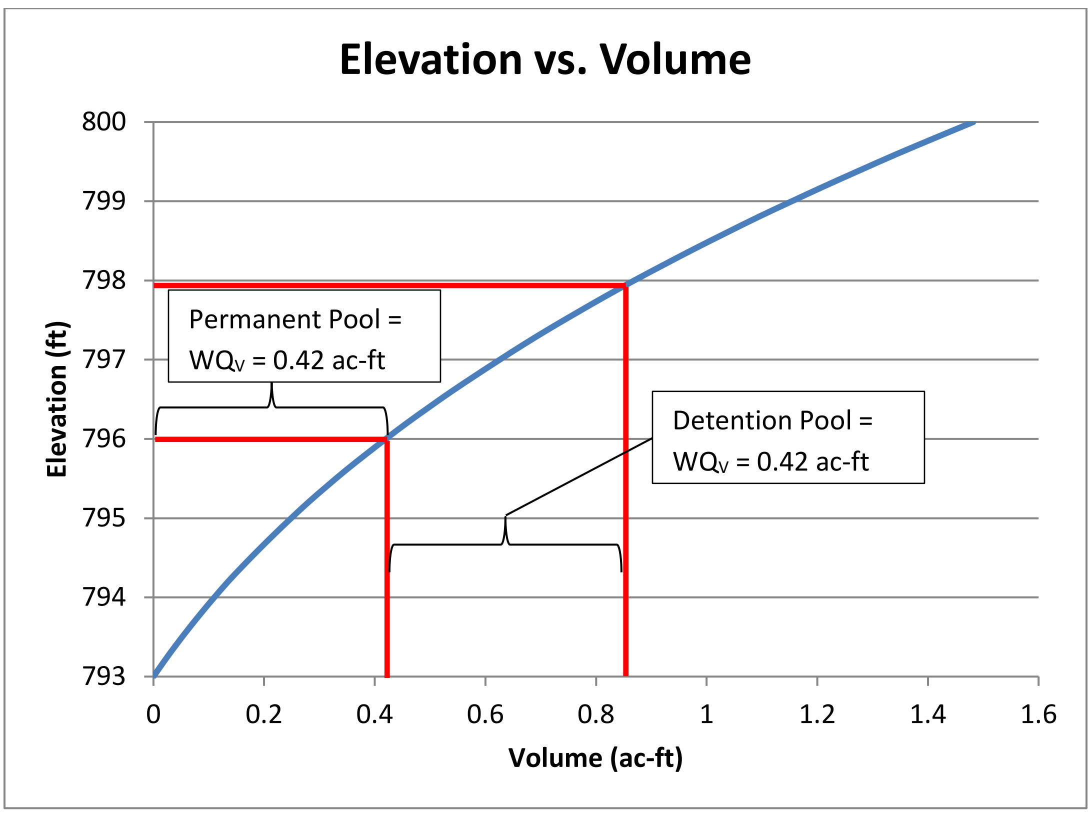
- Retention Basins have an upper storage volume (detention pool) that is above the water quality discharge and is designed to drain in 24 hours or more. The minimum detention pool volume is equal to the WQ_V.
- Detention pool volume = 0.42 ac-ft
- Retention Basins have a lower storage volume (permanent pool) that is permanently full of water, below the water quality discharge point. The minimum permanent pool volume is equal to the WQ_V.
- Permanent pool volume = 0.42 ac-ft
- If there were a forebay, sized at 10% of the WQ_V, that would be included 0.42 ac-ft of the permanent pool.

Layout a retention basin configuration that meets the following requirements:

- Maximum 4:1 side slopes
- Include provisions for vehicle access
- Length to width ration of at least 3:1

Elevation vs. Volume Table:

Elevation (feet)	**Storage** (acre-feet)	**Elevation** (feet)	**Storage** (acre-feet)	**Elevation** (feet)	**Storage** (acre-feet)
793	0	795.4	0.313	797.8	0.817
793.2	0.02	795.6	0.347	798	0.869
793.4	0.041	795.8	0.383	798.2	0.923
793.6	0.063	796	0.42	798.4	0.978
793.8	0.086	796.2	0.458	798.6	1.035
794	0.11	796.4	0.498	798.8	1.093
794.2	0.135	796.6	0.539	799	1.154
794.4	0.162	796.8	0.582	799.2	1.216
794.6	0.19	797	0.626	799.4	1.28
794.8	0.219	797.2	0.671	799.6	1.345
795	0.249	797.4	0.718	799.8	1.413
795.2	0.28	797.6	0.767	800	1.482



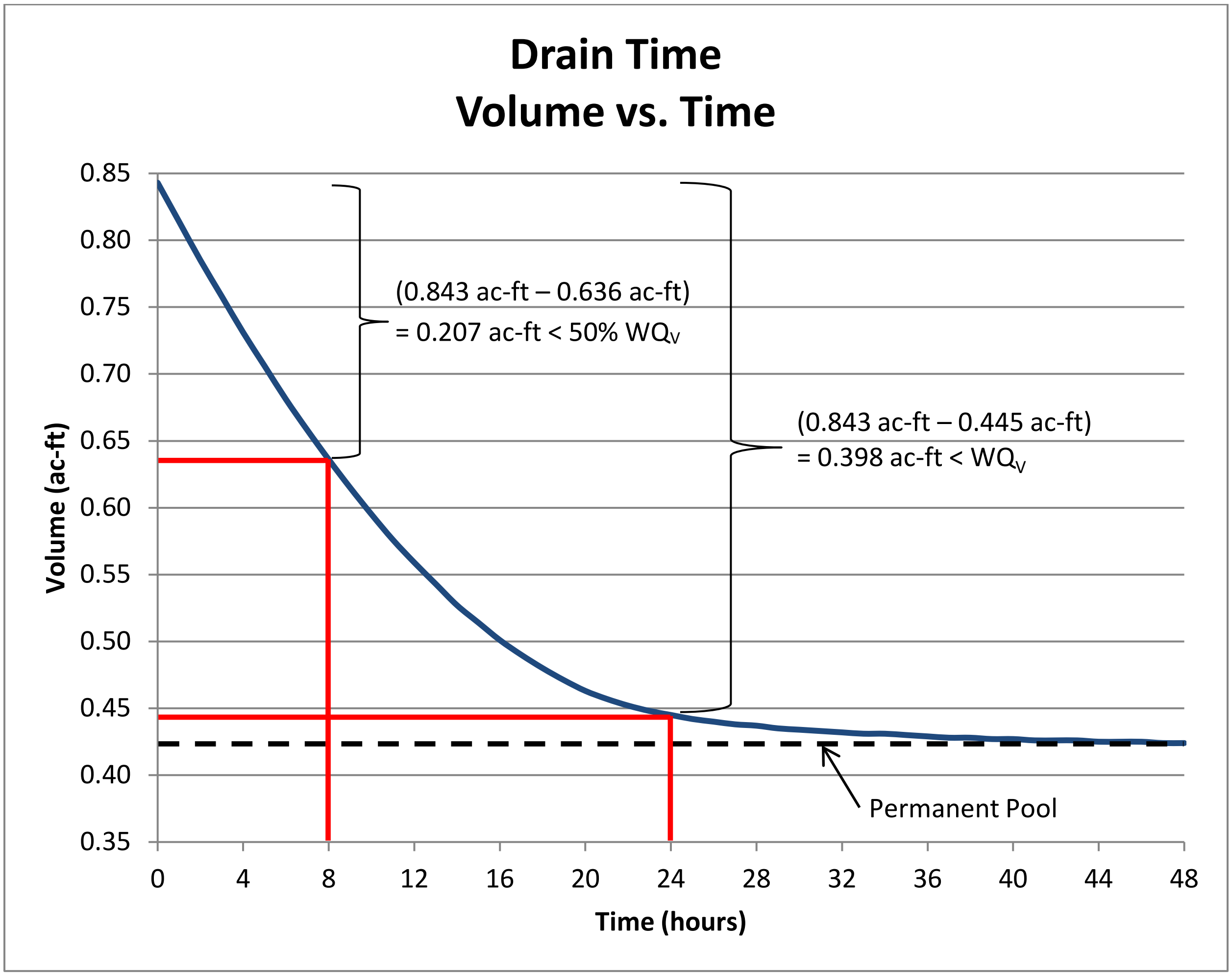
- The permanent pool elevation is set at 796.0 ft.
  - 0.42 ac-ft of storage is permanently ponded.
  - 0.42 ac-ft is equal to or greater than the WQ_V (0.42 ac-ft); therefore, it is <u>acceptable</u>.
- The detention pool volume is between 797.9 ft and 796.0 ft.
  - 0.84 ac-ft – 0.42 ac-ft = 0.42 ac-ft
  - 0.42 ac-ft is equal to or greater than the WQ_V (0.42 ac-ft); therefore, it is <u>acceptable</u>.

Design the Retention Basin Water Quality Outlet:

- The minimum discharge time of the WQ_V (in the detention pool) is 24 hours with no more than 50% of the WQ_V being released from the retention basin in the first one-third of the 24 hour drain time.
- WQ_V = 0.42 ac-ft; must take 24 hours or longer to drain
- 50% or less of the WQ_V (i.e. 0.21 ac-ft) must be drained in 8 hours or more.
- Choose one 3.2 inch diameter circular orifice at an elevation of 796.0 ft.
- Calculate the drawdown curve.
  - This calculation can be done by hand by creating a stage vs. discharge table and interpolating between values, but it is generally easier to use a model to simulate runoff through a retention basin such as PondPack or HydroCAD.
- Do not route a design storm hydrograph through a retention basin to determine the drawdown curve. Start the simulation with the water surface at a level equivalent to the WQ_V storage (for this example, at an elevation of 797.90). Then allow the pooled water filling the detention pool to drain by gravity out of the water quality outlet structure. Include all retention basin outlets that would affect this drawdown curve. Include any downstream constraints such as tailwater or limiting conveyance downstream. For this example, there is no tailwater and there is a free discharge from the retention basin.

Retention Basin Drawdown Hydrograph:

Time (hours)	**Storage** (acre-feet)	**Elevation** (feet)	**Discharge** (cfs)	**Time** (hours)	**Storage** (acre-feet)	**Elevation** (feet)	**Discharge** (cfs)
0	0.843	797.9	0.36	19	0.471	796.26	0.1
1	0.814	797.79	0.35	20	0.463	796.23	0.08
2	0.785	797.67	0.34	21	0.457	796.19	0.07
3	0.758	797.56	0.33	22	0.452	796.17	0.05
4	0.731	797.45	0.31	23	0.448	796.15	0.04
5	0.706	797.35	0.3	24	0.445	796.13	0.04
6	0.681	797.24	0.29	25	0.442	796.12	0.03
7	0.658	797.14	0.27	26	0.44	796.11	0.02
8	0.636	797.05	0.26	27	0.438	796.1	0.02
9	0.615	796.95	0.25	28	0.437	796.09	0.02
10	0.595	796.86	0.23	29	0.435	796.08	0.01
11	0.576	796.78	0.22	30	0.434	796.08	0.01
12	0.559	796.69	0.2	31	0.433	796.07	0.01
13	0.543	796.62	0.19	32	0.432	796.07	0.01
14	0.527	796.54	0.18	33	0.431	796.06	0.01
15	0.514	796.48	0.16	34	0.431	796.06	0.01
16	0.501	796.42	0.15	35	0.43	796.05	0.01
17	0.49	796.36	0.13	36	0.429	796.05	0.01
18	0.48	796.31	0.11				

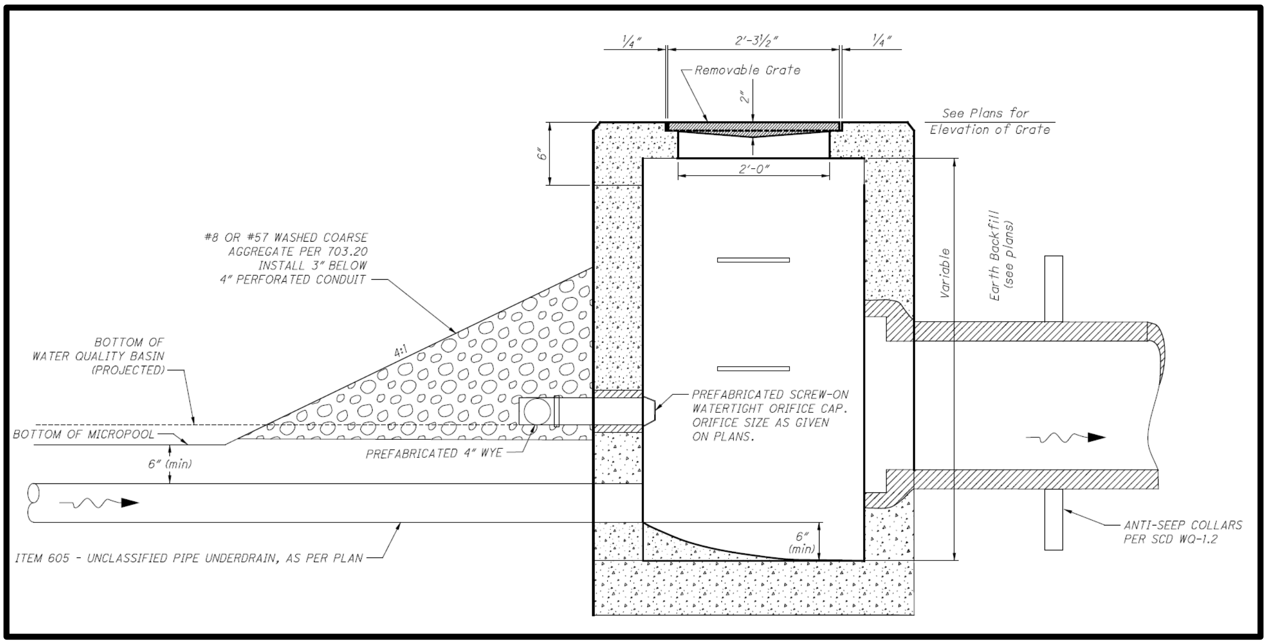


- In 24 hours, the volume goes from 0.843 ac-ft to 0.445 ac-ft.
    - 0.843 ac-ft – 0.445 ac-ft = 0.398 ac-ft
- WQ_V = 0.42 ac-ft
    - 0.42 ac-ft $\geq$ 0.398 ac-ft. It takes longer than 24 hours to drain the WQ_V; therefore, it is acceptable.
- In 8 hours, the volume goes from 0.843 ac-ft to 0.636 ac-ft.
    - 0.843 ac-ft – 0.636 ac-ft = 0.207 ac-ft
- 50% WQ_V = 0.21 ac-ft
    - 0.21 ac-ft $\geq$ 0.207 ac-ft. It takes longer than 8 hours to drain 50% of the WQ_V; therefore, it is acceptable.

Size the Primary Retention Basin Outlet:

- There are three main parts of a typical retention basin discharge structure:
  - Water quality outlet(s)
  - Primary outlet
  - Overflow weir
- The primary retention basin outlet normally consists of a catch basin grate, catch basin side inlets, and the conduit that conveys discharges from the retention basin during all but the least frequent precipitation events.
- The primary outlet should be sized to convey the 10% AEP design storm.

ODOT Water Quality Catch Basin Detail (WQ-1.1):



Determine the 10% AEP design flow rate:

- For the purposes of post-construction BMP calculations, all existing right-of-way is to be considered impervious. For the purpose of general conveyance sizing, runoff coefficients should be calculated using Table 1101-2 in ODOT's L&D Vol. 2.
- Q = CiA

  Calculate the weighted C value:

  1.5 acres of tributary area are pavement and paved shoulders: C = 0.9

  6.0 acres of tributary area are berms and slopes 4:1 or flatter: C = 0.5

  $C_{weighted} = \frac{1.5\ ac*0.9+6.0\ ac*0.5}{7.5\ ac} = 0.58$

  Determine the precipitation intensity:

  Rainfall Area B

  t_C = 25 min

  (The time of concentration is given in this example as 25 minutes because there is significant overland flow over grassed area. The time of concentration should be calculated for each site based on the site-specific flow path. 25 minutes would likely be too high of a value if the detention basin were receiving flow from a piped system. See the time of concentration calculations below.)

  L&D Vol. 2, Figure 1101-2: Area B, 10% AEP storm, 25 min t_C: i = 3.4 in/hr

- Q = 0.58 * 3.4 in/hr * 7.5 ac = <u>14.79 cfs</u>

  Time of Concentration (t_C) Calculations:

  - t_C = Time of overland flow (t_O) + Time of shallow concentrated flow (t_S) + Time of channel flow (t_C)
  - Overland Flow (t_O)
    - $t_O = \frac{1.8(1.1-C)(L)^{1/2}}{s^{1/3}}$
    - C = Runoff Coefficient (0.58 for this example)
    - L = Distance to most remote location in drainage in feet (max. 300 ft.) (200 ft. in this example)
    - s = Overland slope (percent) (0.33% in this example)
    - $t_O = \frac{1.8(1.1-0.58)(200)^{1/2}}{0.33^{1/3}}$ = **19.16 minutes**
  - Shallow Concentrated Flow (t_S)
    - V_S = Velocity of shallow concentrated flow (ft/sec) = $3.281ks^{0.5}$
    - k = Intercept Coefficient (L&D Table 1101-1) = (0.457 in this example)
    - s = Overland slope (percent) (0.33% in this example)
    - $V_S = 3.281 * 0.457 * 0.33^{0.5}$ = 0.86 ft/sec
    - Length of shallow concentrated flow = 200 ft.
    - t_S = 200 ft. / 0.86 ft/sec = 233 sec = **3.88 minutes**

- Channel Flow (t_C)
  - Manning's Equation: V = $\frac{1.49r^{2/3}s^{1/2}}{n}$
  - V = velocity in the channel (ft/sec)
  - r = hydraulic radius (0.69 ft. in this example)
  - s = channel slope (0.01 ft/ft in this example)
  - n = Manning's Roughness Coefficient (L&D Vol. 2, Table 1102-3) (0.03 in this example)
  - V = $\frac{1.49*0.69^{2/3}*0.01^{1/2}}{0.03}$ = 3.88 ft/sec
  - Channel length = 500 ft. (for this example)
  - t_C = 500 ft. / 3.88 ft/sec = 129 sec. = **2.15 minutes**
- $t_C = t_O + t_S + t_C$ = 19.16 + 3.88 + 2.15 = 25.19 minutes. Use t_C = **25 minutes**

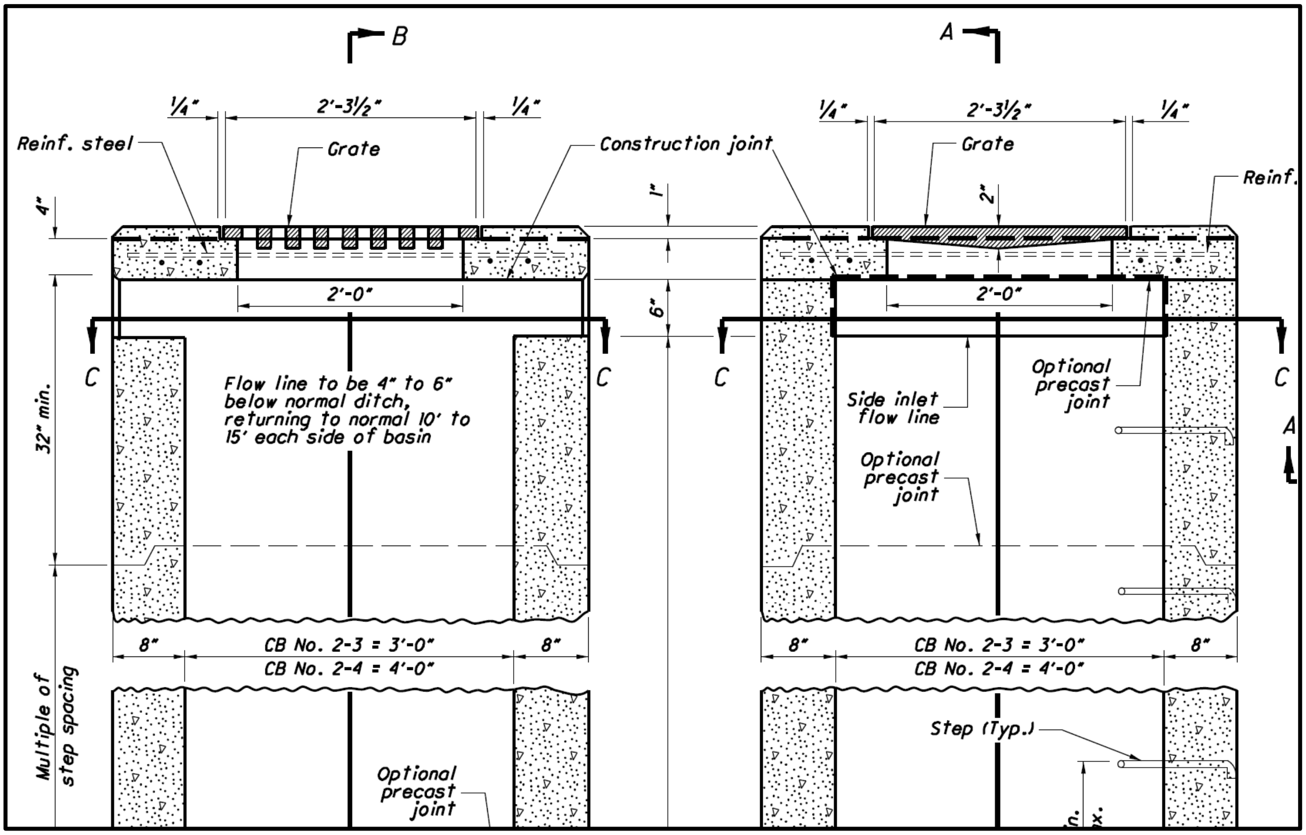
Size the primary retention basin discharge conduit:

- The discharge conduit must be large enough to convey the 10% AEP design storm, keeping the maximum hydraulic grade line within the crown of the pipe.
- This example has the following conduit characteristics:
  - Conduit slope = 0.005 ft/ft
  - No Tailwater; free discharge
  - Pipe Roughness Coefficient = 0.015 (L&D Vol. 2, Section 1104.4.5)
- The minimum conduit size that conveys the 10% AEP design flow (14.79 cfs) with the given characteristics is a 24-inch diameter pipe.

Set the catch basin grate elevation:

- The WQ_V fills the retention basin to an elevation of 797.9 ft. At water surface elevations of 797.9 ft and below, all discharge should pass through the water quality outlet. (In this example, the water quality outlet is one 3.2 inch diameter orifice at 796.0 ft.)
- The ODOT standard water quality catch basin detail (SCD WQ-1.1) calls for either Catch Basin No. 2-3 or 2-4 depending on the outlet pipe size. Both catch basins have a 6-inch high side inlet that is either 3 or 4 feet wide depending on the catch basin. See the detail:

ODOT Catch Basin No. 2-3 and No. 2-4:



- The elevation of the invert of the side inlets should be set at the WQ_V elevation (the top of the detention pool). Therefore, any volume above the WQ_V may discharge into the catch basin through the side inlets or grate.
- The elevation of the top of the grate is 1 foot above the elevation of the side inlets.
  - <u>Side inlets bottom elevation = 797.9 ft</u> (Top of WQ_V)
  - <u>Catch basin grate elevation = 798.9 ft</u>

Set the catch basin invert Elevation:

- Set the catch basin invert elevation to the lower of:
  - 6 in below the orifice invert
    - 796.0 – 0.5 = 795.5
  - Invert of the discharge conduit
    - 795.0
  - <u>Catch basin invert elevation = 795.0 ft</u>

Set the Overflow Weir Invert Elevation:

- The 10% AEP design flow rate (14.79 cfs) should pass fully through the primary discharge. Therefore, no flow should discharge from the overflow weir until the 10% AEP design flow rate has been exceeded.
- Set the overflow weir invert elevation just high enough above the catch basin grate such that the full 10% AEP design flow rate is conveyed through the primary discharge.
- For this example, the primary discharge pipe is sized at 24 inches in diameter; therefore, Catch Basin No. 2-3 is appropriate.
- Catch Basin No. 2-3 has the same grate as Catch Basin No. 2-2B.
- The water quality catch basin has three openings to allow runoff inside: two side inlets and a Grate No. 2-2-B.
- Use the orifice equation with 6" X 36" openings for the two side inlets.
- Use L&D Vol. 2, Figure 1102-1 to determine the flow rate through a No. 2-2-B grate.
- According to the orifice equations and the grate flow figure, at an elevation of 799.0, the three outlets combined should convey approximately 15.2 cfs, which is just above the required flow rate of 14.79 cfs.
- Set the overflow weir elevation at 799.0 ft.

Size the Emergency Overflow Weir and Set the Top of Basin Elevation:

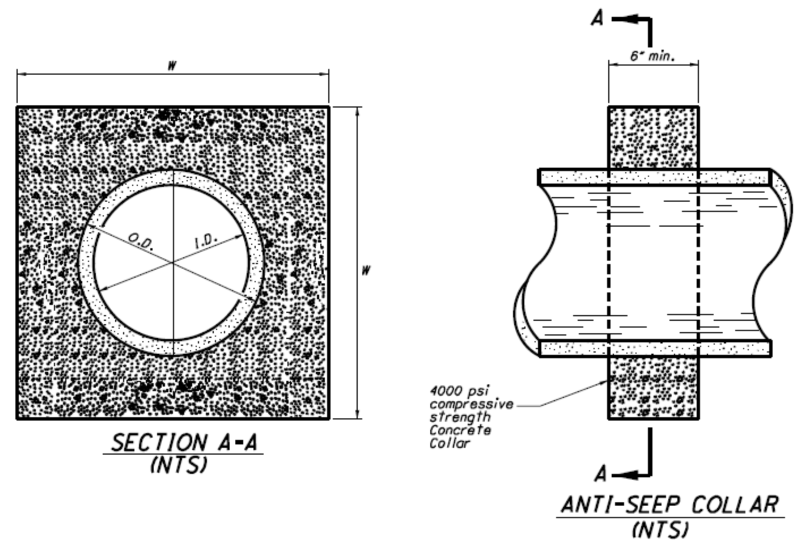
- L&D Vol. 2, Section 1104.3.2 states that the hydraulic grade line should be checked for the 4% AEP storm.
- Calculate the design flow rate for each design storm:
  - 4% AEP intensity @ t_C = 25 min and Rainfall Area B: 3.8 in/hr
  - 4% AEP design flow rate: Q = CiA = 0.58 * 3.8 in/hr * 7.5 ac = 16.53 cfs
- Calculate the required weir length for each design storm flow:
  - Emergency overflow weir elevation = 799.0 ft
  - Assume a top of retention basin elevation = 799. 5 ft
  - Maximum height overflow weir = 799. 5 ft – 799.0 ft = 0.5 ft
  - Weir equation: $Q = C*L*H^{1.5}$
    - C = 3
    - H = 0.5
    - L = ?
  - Length of a weir: $L = \frac{Q}{C*H^{1.5}}$
  - 4% AEP: $L = \frac{16.53}{3*0.5^{1.5}}$ = 15.6 ft
- Provide a 16 ft wide overflow weir.
- The top of basin elevation is 799.5 ft.

- The overflow weir length could be reduced by increasing the top of basin elevation. Or the top of basin elevation can be lowered by increasing the overflow weir length. The 4% AEP design flow rate must fully pass through the overflow weir without overtopping the detention basin.
- Flow rates greater than the 4% AEP design flow rate may overtop the detention basin uncontrolled.
- Provide erosion protection at the overflow weir, to the bottom of the berm, and continuing downstream if there is erosion potential.

Design Anti-Seep Collars:

- Anti-seep collars reduce the conveyance of flow along pipe bedding, outside of a conduit and increase the flow path for the seepage of water. This helps protect the berm above the discharge conduit from a retention basin from internal erosion.

ODOT Standard Drawing WQ-1.2



DIAMETER (I.D.) (FT.)	CONCRETE (C.Y.) DIMENSION OF COLLAR W X W (FT.)		
	3X3	4X4	5X5
1	0.15	0.28	0.45
2	N/A	0.24	0.40
3	N/A	N/A	0.33

- Calculate the saturated zone length along the conduit (Ls)
  - Ls = Y(Z+4)[1+S/(0.25-S)]
  - Y = depth of water during the 10% AEP storm
  - Z = slope of embankment
  - S = slope of conduit
- Maximum elevation at 10% AEP storm = 799.0 ft
- Conduit elevation = 795.0 ft
- Y = 799.0 ft – 795.0 ft = 4.0
- Z = 4
- S = 0.005
- Ls = 4.0(4+4)[1+0.005/(0.25-0.005)] = 32.65 ft
- ΔLs = 0.15*Ls = 0.15 * 32.65 ft = 4.9 ft

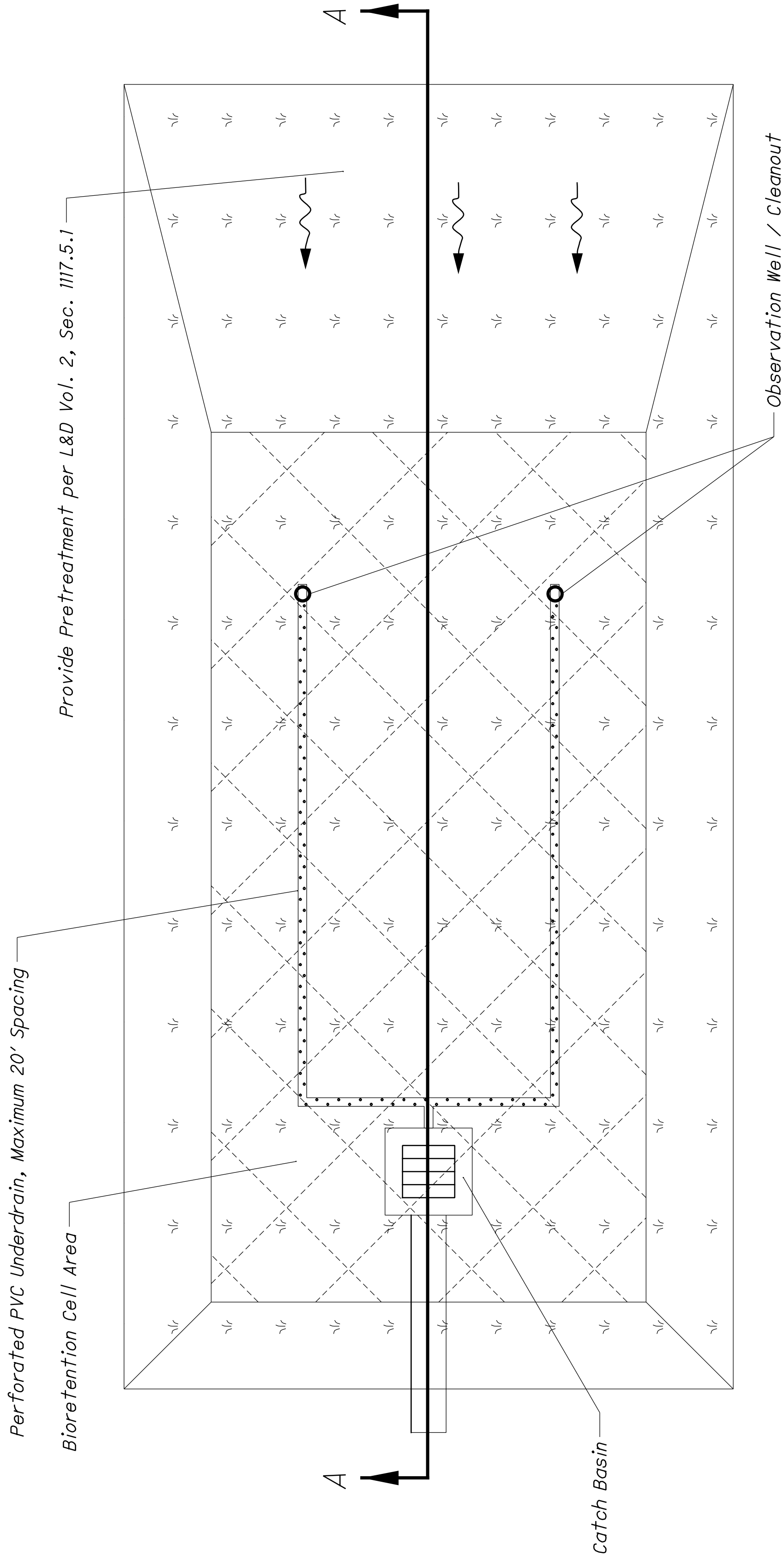
- Total Projection: P = W – D
  - W = 2ft + 2 ft diameter + 2 ft = 6 ft
  - P = 6 ft – 2 ft = 4 ft
- Number of collars = ΔLs / P = 4.9 ft / 4 ft = 1.23
  - Minimum of 2 collars per outlet conduit
  - <u>Use 2 anti-seep collars</u>
- Place both anti-seep collars in the saturation zone (within 32.65 feet of front edge of berm).
- Spacing between collars: between 10 and 25 feet

Additional Considerations:

- Vegetate the sides of the retention basin that are above the permanent pool with Item 670 Slope Erosion Protection per L&D Vol. 2, Section 1113.4.
- The 6" diameter underdrain (as per plan) called out in SCD WQ-1.1 should not be included in retention basins.
- For all open water carriers at each inlet and discharge from a retention basin, check the shear stress and ensure appropriate lining per L&D Vol. 2, Section 1102.3.2.
- For all discharges into or out of a retention basin, ensure that appropriate rock channel protection is included per L&D Vol. 2, Section 1105.2.5.
- Include calculated retention basin ponding elevations in the calculation of the hydraulic grade line for the upstream conveyance system per L&D Vol. 2, Section 1104.3.2.
- Attempt to locate structures outside of designated flood plains. If a retention basin encroaches on a flood plain, follow the flood assessment requirements in L&D Vol. 2 Section 1005.
- Ensure that safety criteria are met in the clear zone per L&D Vol. 1, Section 600.2.
- Ensure that no more than one foot of permanent standing water is located within the clear zone without barrier protection, per L&D Vol. 1, Section 601.1.1.
- Engage local project stakeholders in potential public safety considerations associated with retention basins.
- Develop a plan for how regular maintenance will be performed.
  - Vehicle access
  - Mowing
  - Removal of woody vegetation
  - Regular unclogging of the water quality outlet

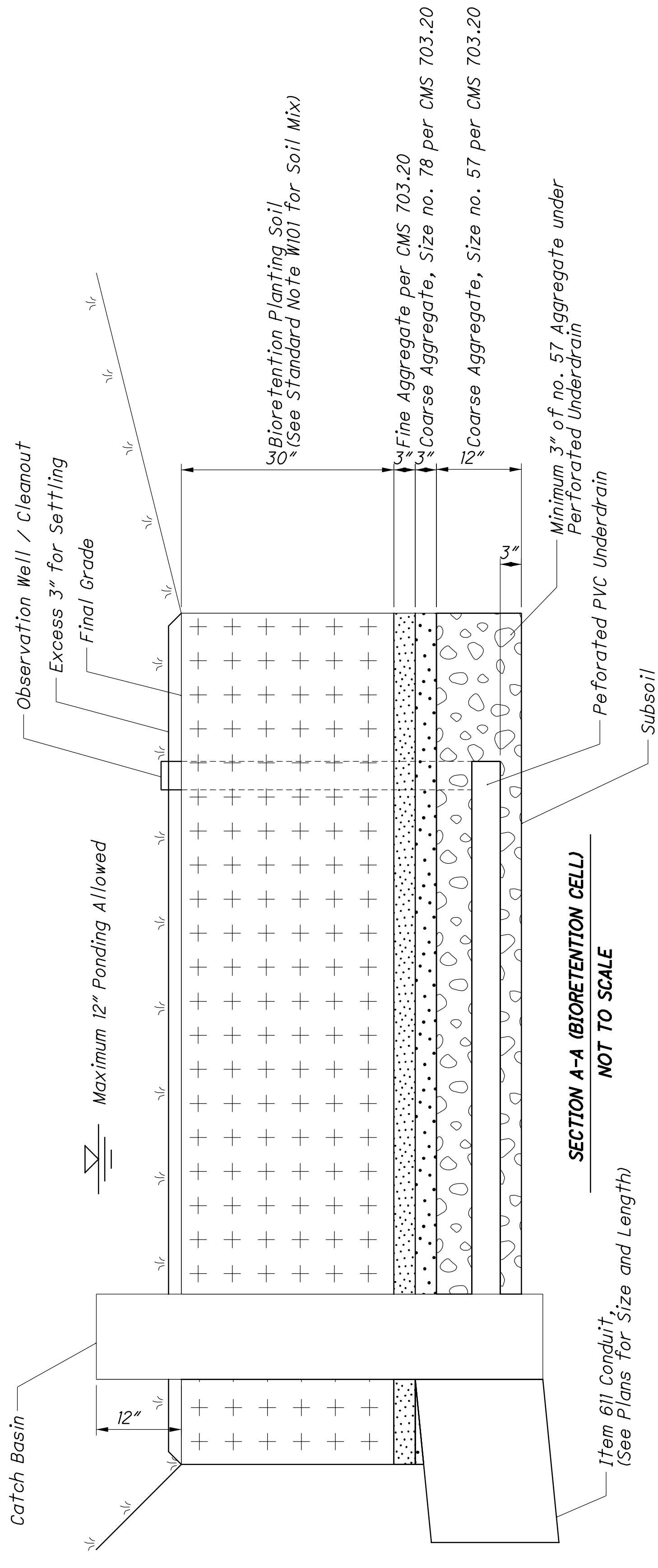
BIORETENTION CELL

1113-5
REFERENCE SECTION 1113.5



PLAN VIEW BIORETENTION CELL IN OPEN AREA WITH LEVEL SURFACE
NOT TO SCALE

BIORETENTION CELL (CONT.)	1113-5
	REFERENCE SECTION 1113.5

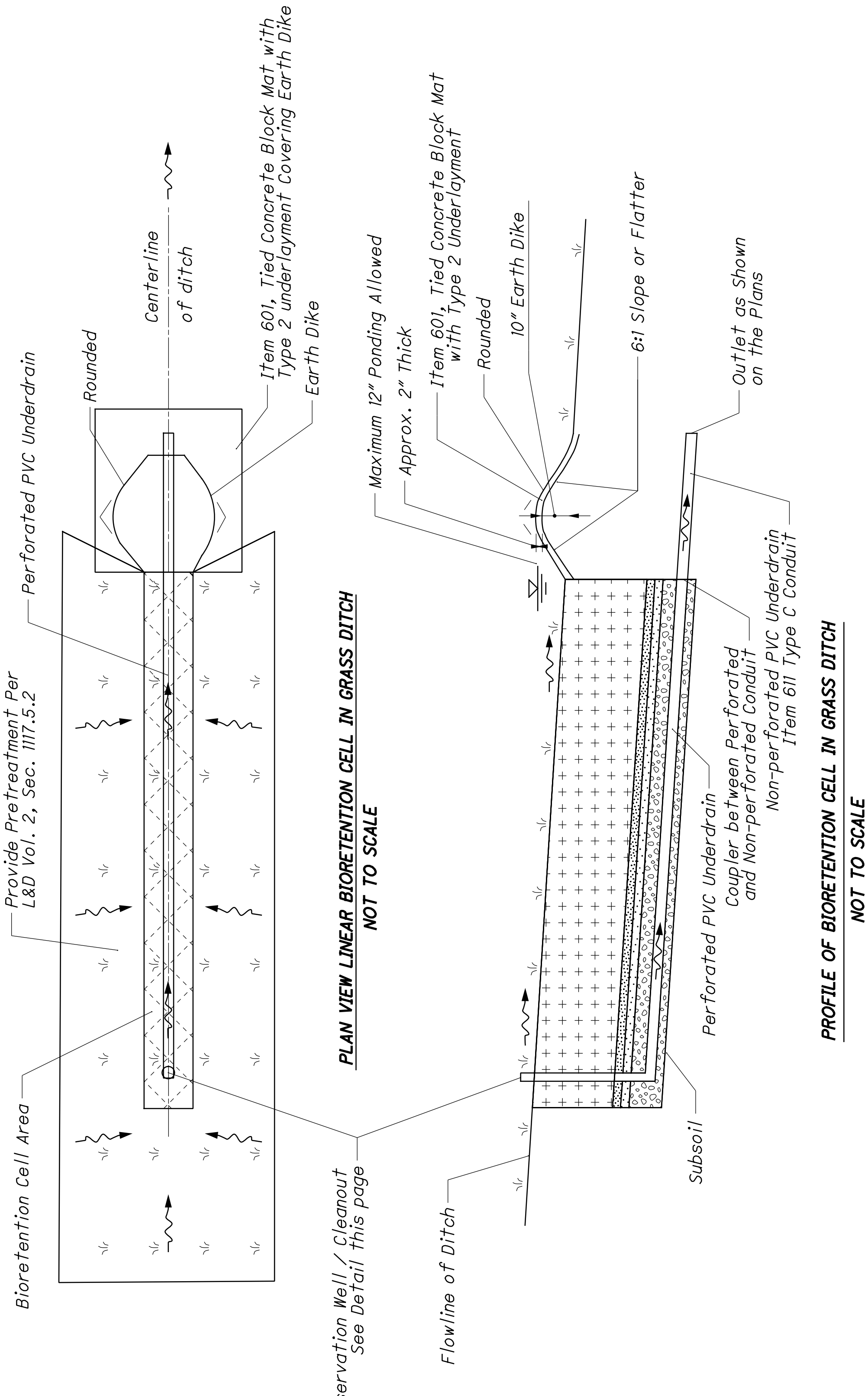


SECTION A-A (BIORETENTION CELL)

NOT TO SCALE

BIORETENTION CELL (CONT.)

1113-5
REFERENCE SECTION 1113.5



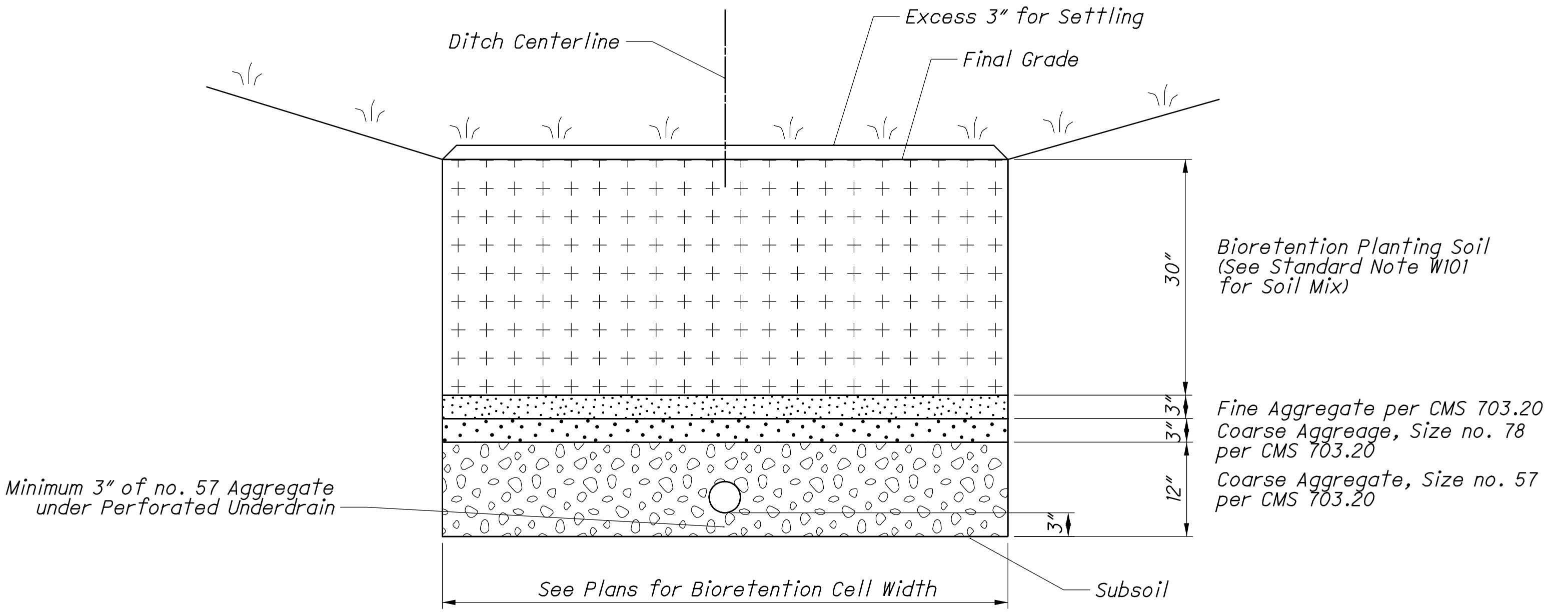
PLAN VIEW LINEAR BIORETENTION CELL IN GRASS DITCH
NOT TO SCALE

PROFILE OF BIORETENTION CELL IN GRASS DITCH
NOT TO SCALE

BIORETENTION CELL (CONT.)

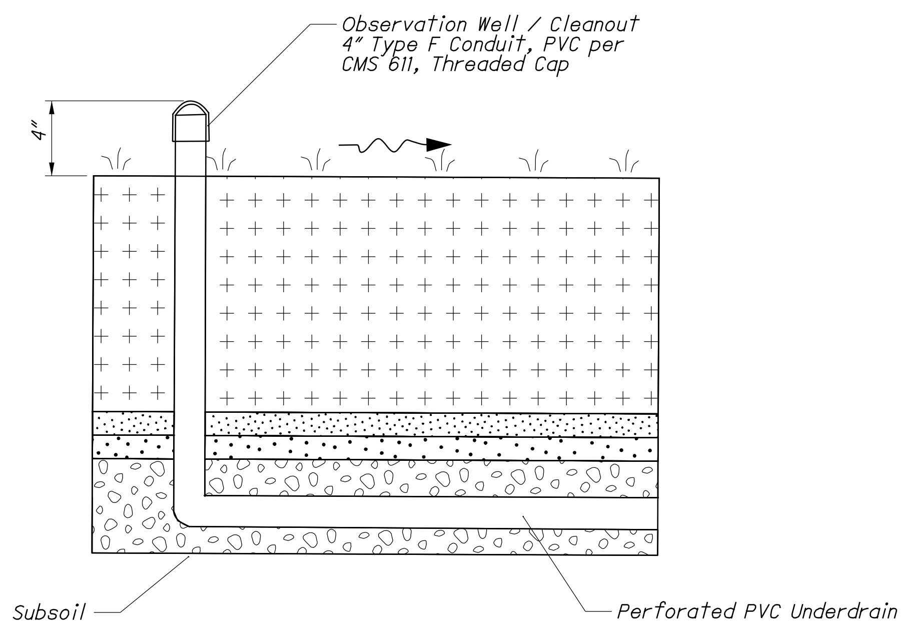
1113-5

REFERENCE SECTION 1113.5



SECTION OF BIORETENTION CELL IN GRASS DITCH

NOT TO SCALE



OBSERVATION WELL / CLEANOUT

NOT TO SCALE

BIORETENTION CELL (CONT.)	1113-5
	REFERENCE SECTION 1113.5

NOTES

BASIN MATERIALS: *Provide basin dimensions, materials, and grate as specified. Do not use side inlet windows.*

EROSION CONTROL: *For grassed bioretention, include temporary erosion control mat Type A, B, C, or E per CMS 671 over the surface of all bioretention planting soil.*

BIORETENTION PLANTING SOIL: *See Plan Note W101 (Bioretention Cells) for approved bioretention planting soil characteristics.*

PLANTINGS: *If not specified on the plans, seed the bioretention cell area per CMS 659. Do not apply fertilizer or lime to the bioretention cell area.*

SUBSOIL: *Scarify the subsoil 3" minimum before installation of aggregate into bioretention cell.*

BIORETENTION SIDES *Construct bioretention cells with vertical sides unless otherwise specified.*

PAYMENT: *Bioretention cell will be paid for as Item 601, Bioretention Cell cu yd and Item 601 Tied Concrete Mat sq yd. Excavation will be paid for as Item 203, Excavation as per plan cu yd. Perforated underdrains, observation wells, and associated fittings and couplers will be paid for as Item 605, Underdrain as per plan. Non perforated underdrains will be paid for as Item 611, Outlet Pipe. Seeding and mulching for the bioretention cell will be paid for as Item 659, Seeding and Mulching sq yd. Erosion control mats will be paid for as item 671, Erosion Control Mats sq yd.*

INFILTRATION BASIN EXAMPLE

1113-6

REFERENCE SECTION
1113

GIVEN:

Sandy Loam Soil (infiltration rate (k) = 1.0 in/hr)

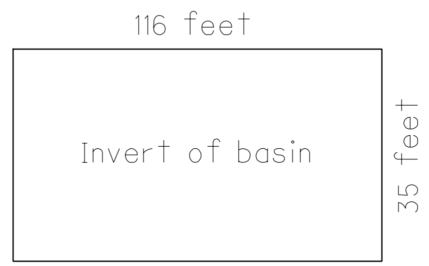
WQv = 0.25 Ac-ft

Surrounding Soil Permeability (K) = 0.000065 ft/sec

Drain time = 48 hours

- Calculate the required surface area of the basin invert:

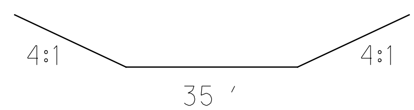
$$A = \frac{0.25 \text{ Ac-ft} \times 1.5 \times 12}{1.0 \text{ in/hr} \times 48 \text{ hours}} = 0.093 \text{ Ac} = 4{,}084 \text{ sf}$$



Plan

- Will try a 35 foot wide basin:

$$\text{Length} = \frac{4{,}084 \text{ sf}}{35 \text{ ft}} = 116 \text{ feet}$$



Cross Section

- Calculate the depth of the basin:

Will assume that only basin invert infiltrates storm water

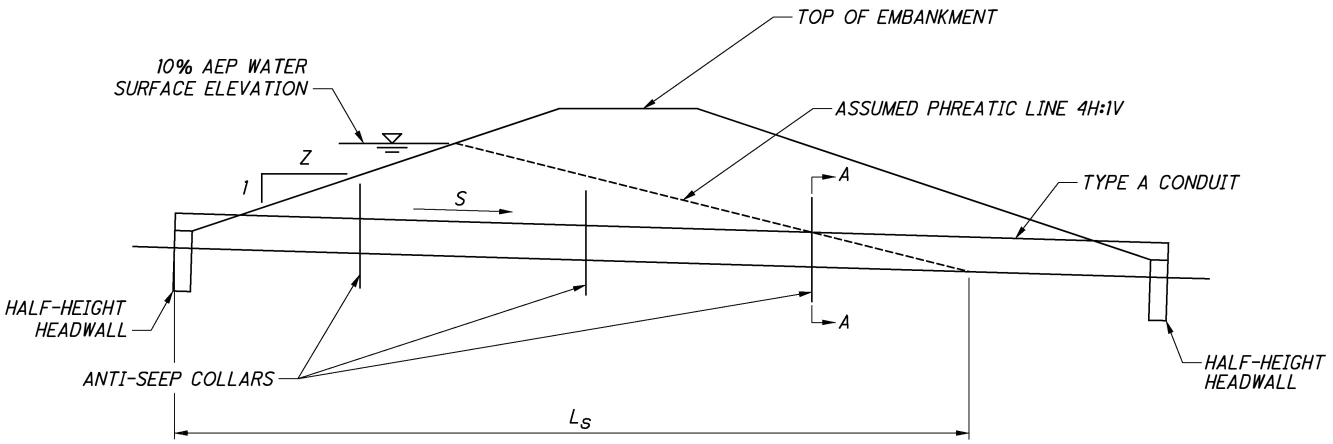
Therefore, depth = WQv/Invert Area = 0.25 Ac-ft/0.093 Ac = 2.68 feet

Add one foot for freeboard requirement => Depth = 3.68 feet

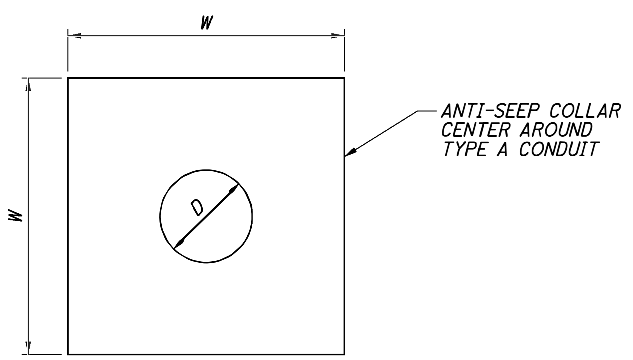
- Therefore, dimensions of the basin are:

116 feet x 35 feet x 3.68 feet with 4:1 slopes

ANTI-SEEP COLLARS	1113-7
	REFERENCE SECTION 1113



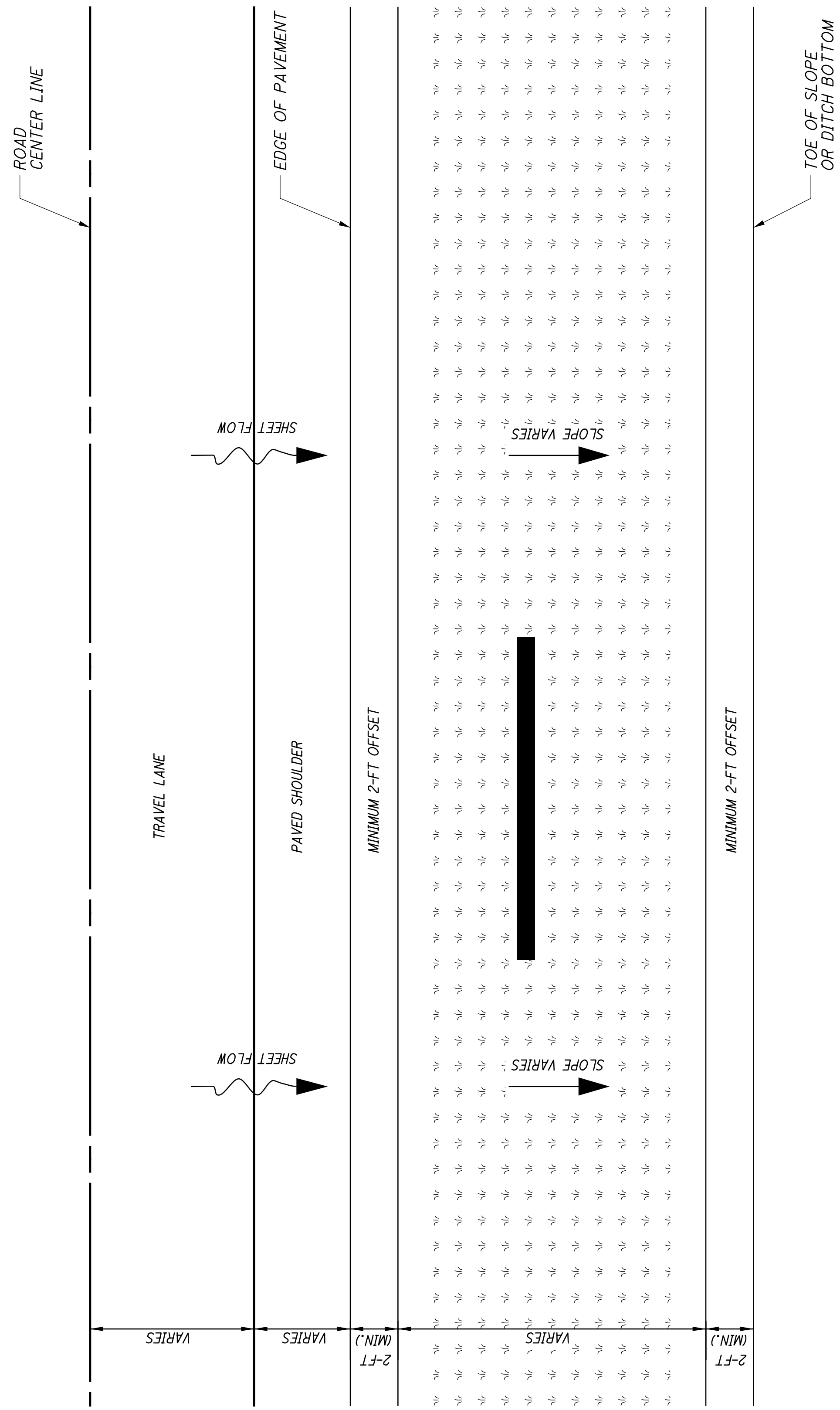
OUTLET PROFILE



SECTION A-A

AMENDED VEGETATED FILTER STRIP

1113-8	REFERENCE SECTION 1113

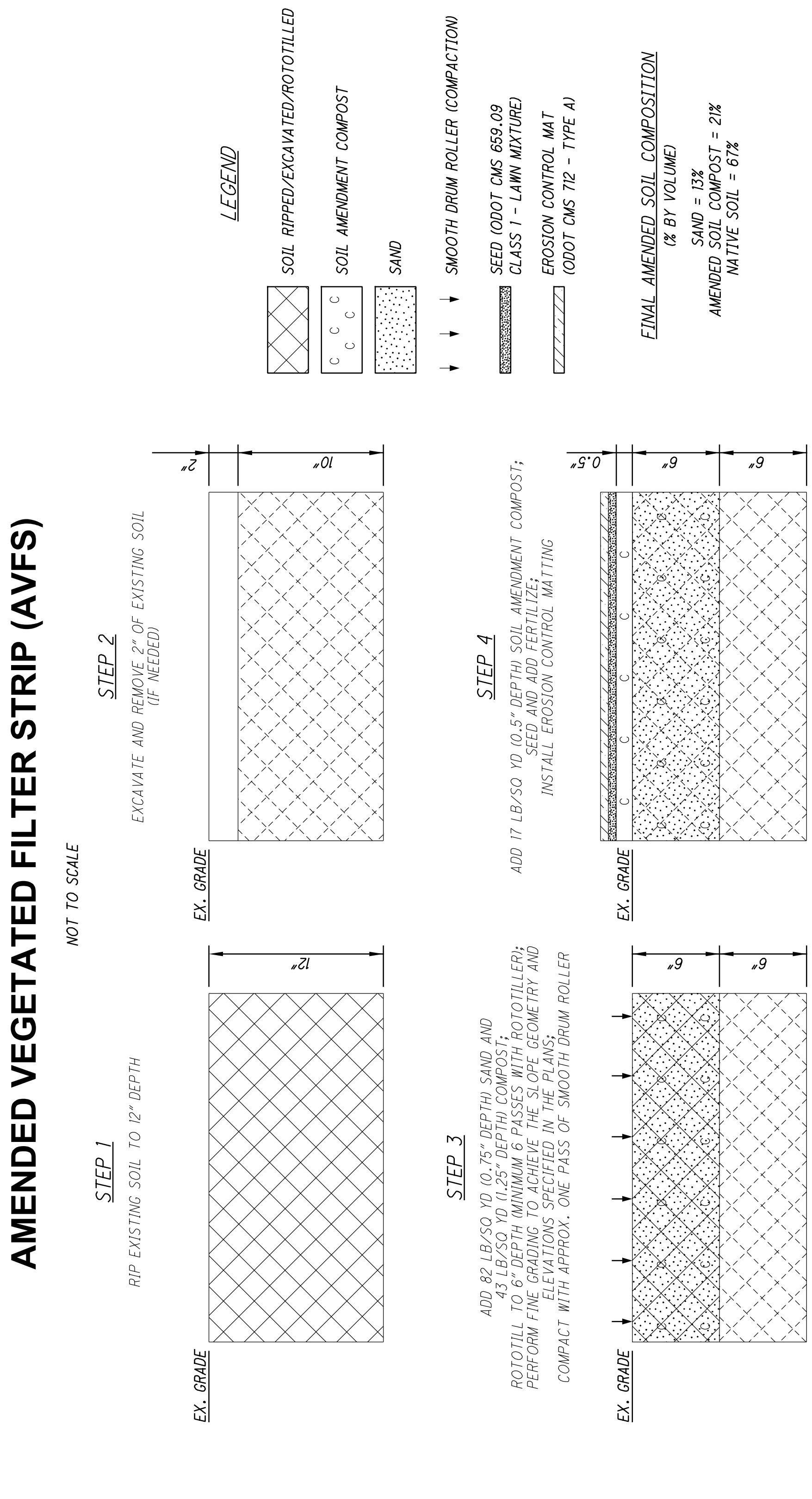


AMENDED VEGETATED FILTER STRIP (AVFS)

NOT TO SCALE

AMENDED VEGETATED FILTER STRIP (CONT.)

AMENDED VEGETATED FILTER STRIP (CONT.)	1113-8
	REFERENCE SECTION 1113



AMENDED VEGETATED FILTER STRIP NOTES

AMENDED VEGETATED FILTER STRIP (AVFS)

THE AMENDED VEGETATED FILTER STRIP (AVFS) CONSISTS OF THE GRASSED PORTION OF THE GRADED SHOULDER AND GRASSED FORESLOPE, WHERE THE UNDERLYING SOILS HAVE BEEN AMENDED WITH COMPOST AND SAND. THE AVFS SHOULD BE IMPLEMENTED IN A STRIP, PARALLEL WITH THE ROADWAY, SO THAT IT CAN RECEIVE SHEET FLOW DIRECTLY FROM THE ROADWAY.

MATERIAL SPECIFICATIONS

SAND

1. MEET ODOT CMS 703.02 - FINE AGGREGATE

SOIL AMENDMENT COMPOST

1. SOIL AMENDMENT COMPOST SHALL ORIGINATE FROM AN OHIO EPA CLASS IV COMPOSTING FACILITY.
2. 100% OF MATERIAL MUST PASS THE 1/2-INCH SCREEN, WITH 75% PASSING THE 1/4-INCH SCREEN.
3. 5.5 < PH < 8.5
4. INERT MATERIAL < 1%
5. 35% < ORGANIC CONTENT < 65% (DRY WEIGHT BASIS DETERMINED BY LOSS OF IGNITION)
6. 20% < C:N RATIO < 25%
7. MATURITY > 80% (SOLVITA INDEX VALUE BETWEEN 7 AND 8). PARENT MATERIAL IS NO LONGER VISIBLE. COMPOST SHOULD BE STABLE WITH REGARD TO OXYGEN CONSUMPTION AND CARBON DIOXIDE GENERATION.
8. < 1,000 MPN/GTS FECAL COLIFORM AND < 3 MPN/GTS SALMONELLA SPP.
9. 30% < MOISTURE CONTENT < 60% WET BASIS
10. SOIL AMENDMENT COMPOST SAMPLES SHOULD BE TAKEN FROM THE MATERIAL STOCKPILED BY THE SUPPLIER WITHIN 15 CALENDAR DAYS PRIOR TO INITIAL APPLICATION. SUBMIT LABORATORY RESULTS TO THE ENGINEER FOR APPROVAL. SOIL AMENDMENT COMPOST THAT DOES NOT MEET THE SPECIFICATION SHALL NOT BE USED.

SEED

1. MEET ODOT CMS 659.09 - CLASS 1 - LAWN MIXTURE

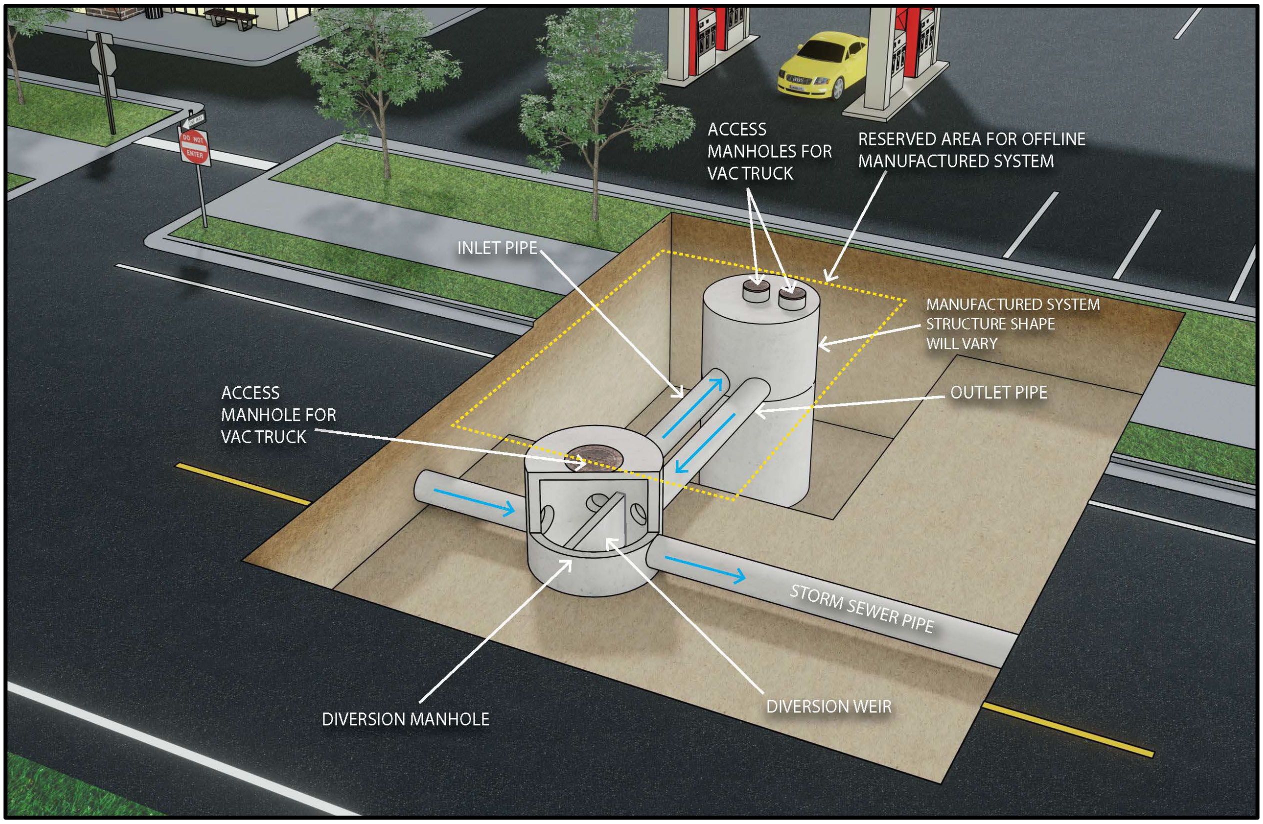
EROSION CONTROL MAT

1. MEET ODOT CMS 712 - TYPE A - TEMPORARY EROSION CONTROL MAT

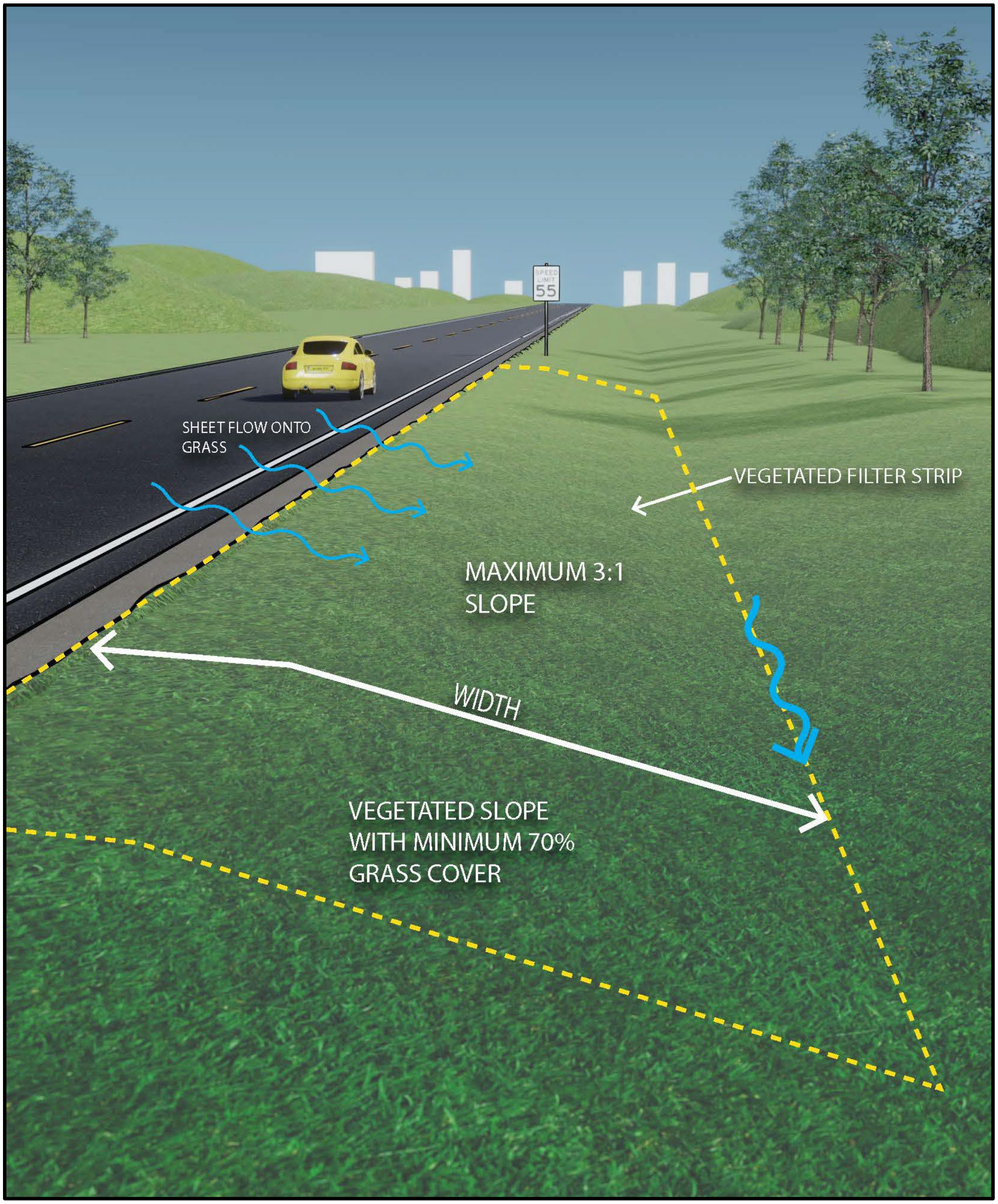
CONSTRUCTION PROCEDURE

1. SOIL RIPPING: USE A SOLID-SHANK RIPPER WITH TEETH, TRAVERSING THE AREA WITH 2 PASSES IN EACH DIRECTION TO A DEPTH OF 12 INCHES. EACH PASS IS CONSIDERED THE WIDTH OF THE RIPPER, WITH TEETH SPACED NO MORE THAN 12 INCHES APART. THIS MAY BE ACCOMPLISHED WITH IMPLEMENTS MOUNTED TO A TRACTOR OR DOZER OR USE OF A GRADER WITH APPROPRIATE IMPLEMENTS (SCARIFIER TEETH), BUT MUST MEET THE 12-INCH DEPTH. IF TEETH ARE SPACED GREATER THAN 12 INCHES, ADDITIONAL PASSES ARE REQUIRED TO MEET A FURROW SPACING OF 6 INCHES. ONLY PERFORM RIPPING DURING DRY CONDITIONS WHEN SOILS ARE FRIABLE.
2. EXCAVATION: REMOVE EXCESS SOIL, SO THAT AFTER THE AMENDMENTS HAVE BEEN INCORPORATED INTO THE EXISTING SOIL, THE EXISTING GROUND SURFACE PROFILE WILL NOT APPRECIABLY CHANGE.
3. AMENDMENT PLACEMENT AND INCORPORATION: SPREAD AMENDMENTS OVER THE GROUND SURFACE IN A UNIFORM THICKNESS TO THE SPECIFIED AMENDMENT DEPTH. INCORPORATE AMENDMENTS WITH A ROTOTILLER OR SIMILAR EQUIPMENT INTO THE SOIL TO A DEPTH OF 6 INCHES. CONTINUE TILLING UNTIL ALL SOIL CLODS ARE REDUCED TO A MAXIMUM SIZE OF 1-INCH (25 MM) AND THE MIXTURE IS UNIFORM. INCORPORATION SHOULD ONLY BE PERFORMED DURING DRY CONDITIONS WHEN SOILS ARE FRIABLE. SIX PASSES (PASS IS THE WIDTH OF THE MACHINE) WITH A ROTOTILLER OR SIMILAR IS ANTICIPATED TO MEET THE UNIFORMITY REQUIREMENT.
4. FINE GRADING AND LIMITED COMPACTION: PERFORM FINE GRADING TO ACHIEVE THE SLOPE GEOMETRY AND ELEVATIONS SPECIFIED IN THE PLANS. TO ACHIEVE AN APPROXIMATE COMPACTION OF 85 TO 90% MAXIMUM DENSITY, ONE PASS WITH A RUBBER-TIRED OR SMOOTH DRUM ROLLER IS ANTICIPATED.
5. COMPOST BLANKET: EVENLY SPREAD A 0.5-INCH THICK LAYER OF SOIL AMENDMENT COMPOST OVER THE GROUND SURFACE.
6. SEEDING AND WATERING: ODOT CLASS I LAWN MIXTURE (ODOT ITEM 659.09) INSTALLED PER ITEM 659. RAKE SEED INTO SOIL AMENDMENT COMPOST. CONTRACTOR IS RESPONSIBLE FOR ESTABLISHING A MINIMUM OF 70% PERMANENT VEGETATION COVERAGE WITHIN THE PROJECT SCHEDULE. WATERING MAY BE NECESSARY.
7. FERTILIZER: APPLY THE FOLLOWING FERTILIZER AND RATES. FOLLOW ODOT ITEM 659.04 SPECIFICATION FOR APPLICATION OF FERTILIZER.
   1.0 LB./1,000 FT^2 POTASSIUM
   2.5 LB./1,000 FT^2 POTASH
   1.0 LB./1,000 FT^2 MAGNESIUM
8. EROSION CONTROL MATTING: ODOT CMS ITEM 712 TYPE A TEMPORARY EROSION CONTROL MAT. INSTALL PER ODOT ITEM 671. DO NOT RUN MACHINERY/EQUIPMENT OVER THE AMENDED SOILS DURING INSTALLATION OF THE EROSION CONTROL MAT.

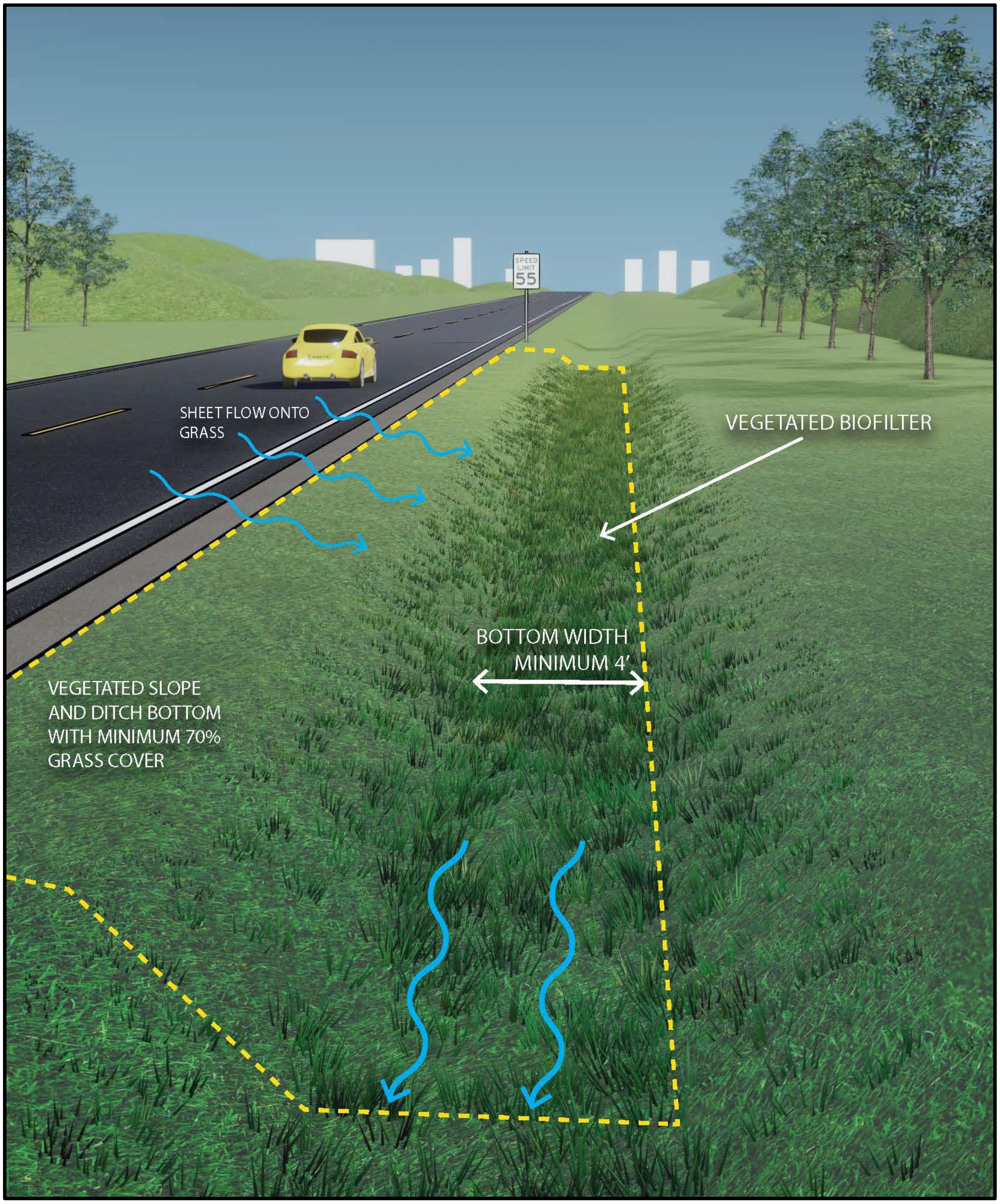
MANUFACTURED SYSTEM	1113-9
	REFERENCE SECTION 1113.1



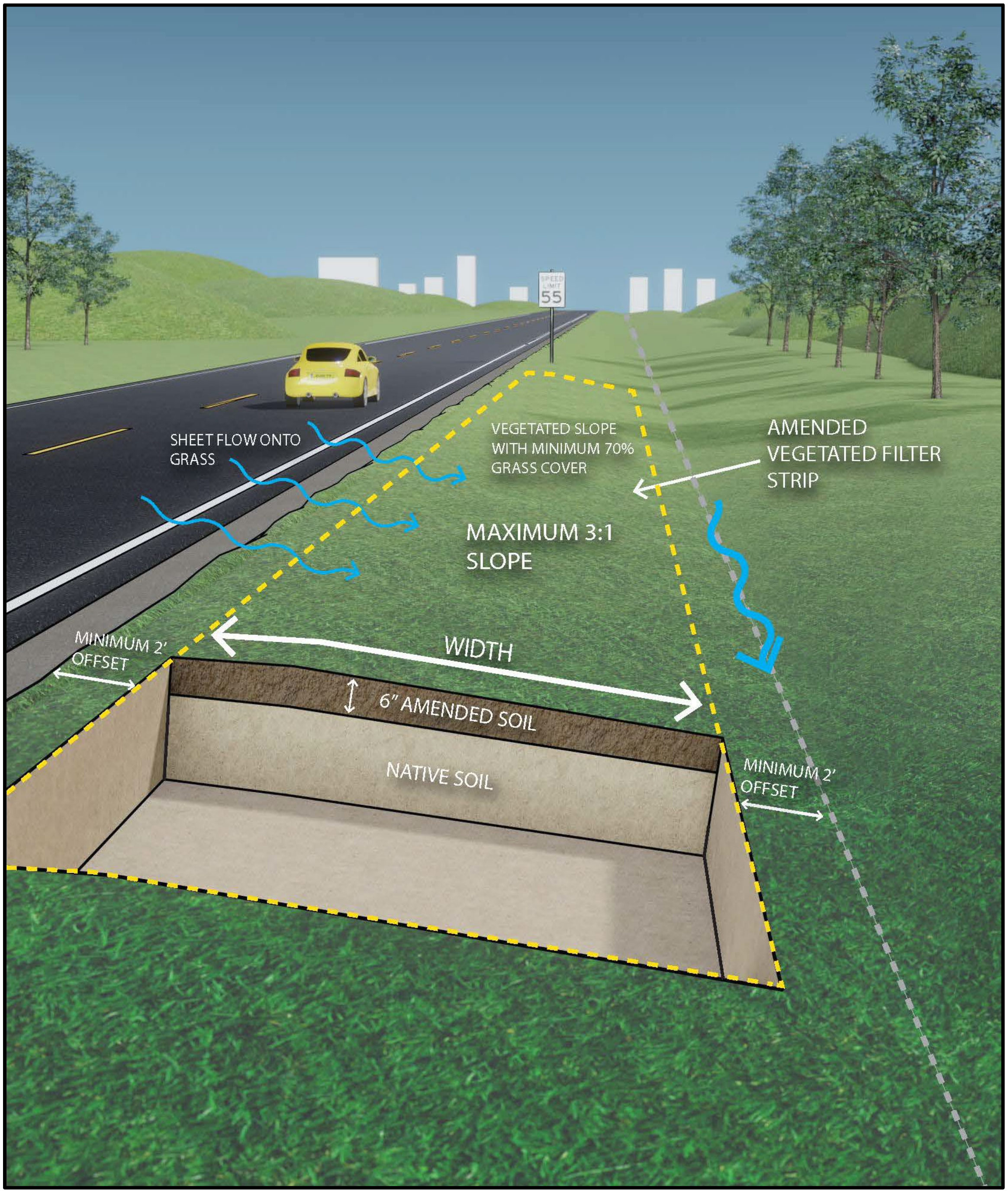
VEGETATED FILTER STRIP	1113-10
	REFERENCE SECTION 1113.2.1



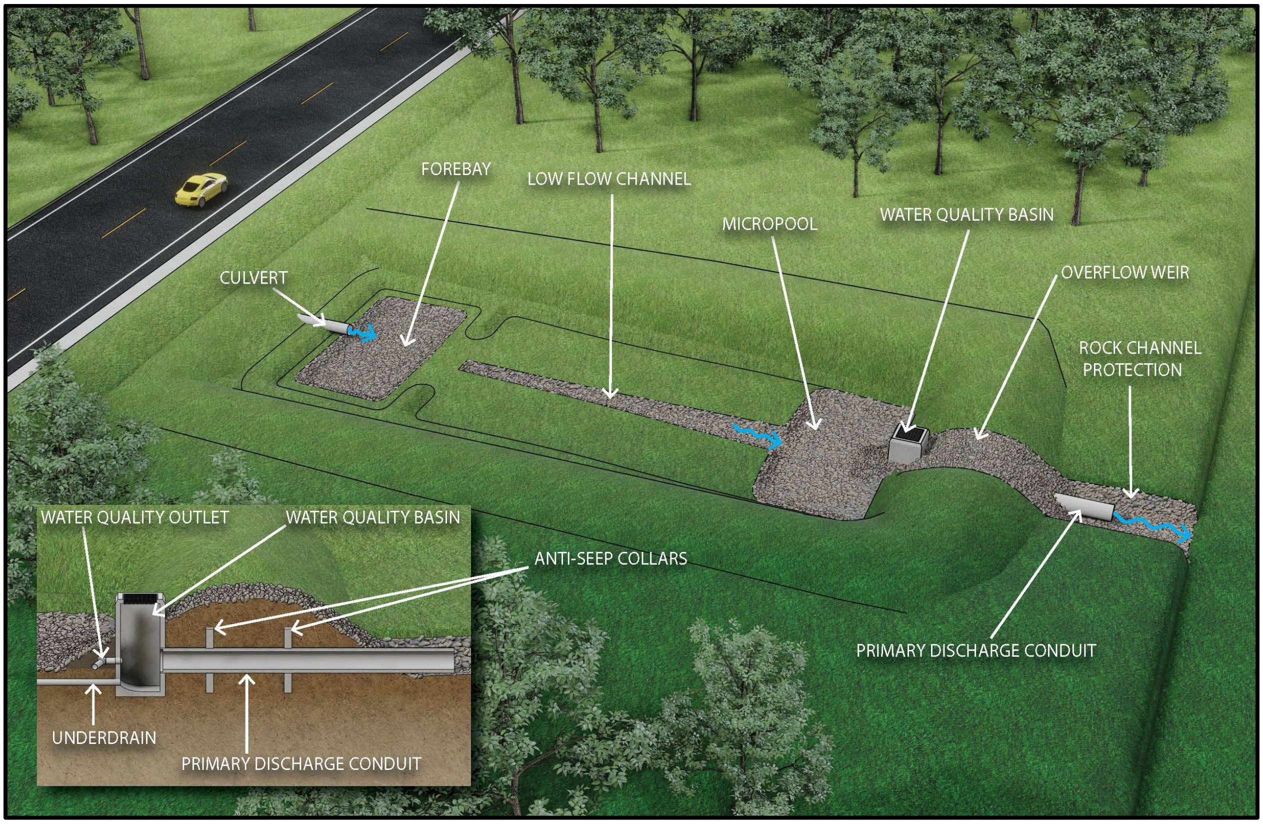
VEGETATED BIOFILTER	1113-11
	REFERENCE SECTION 1113.2.2



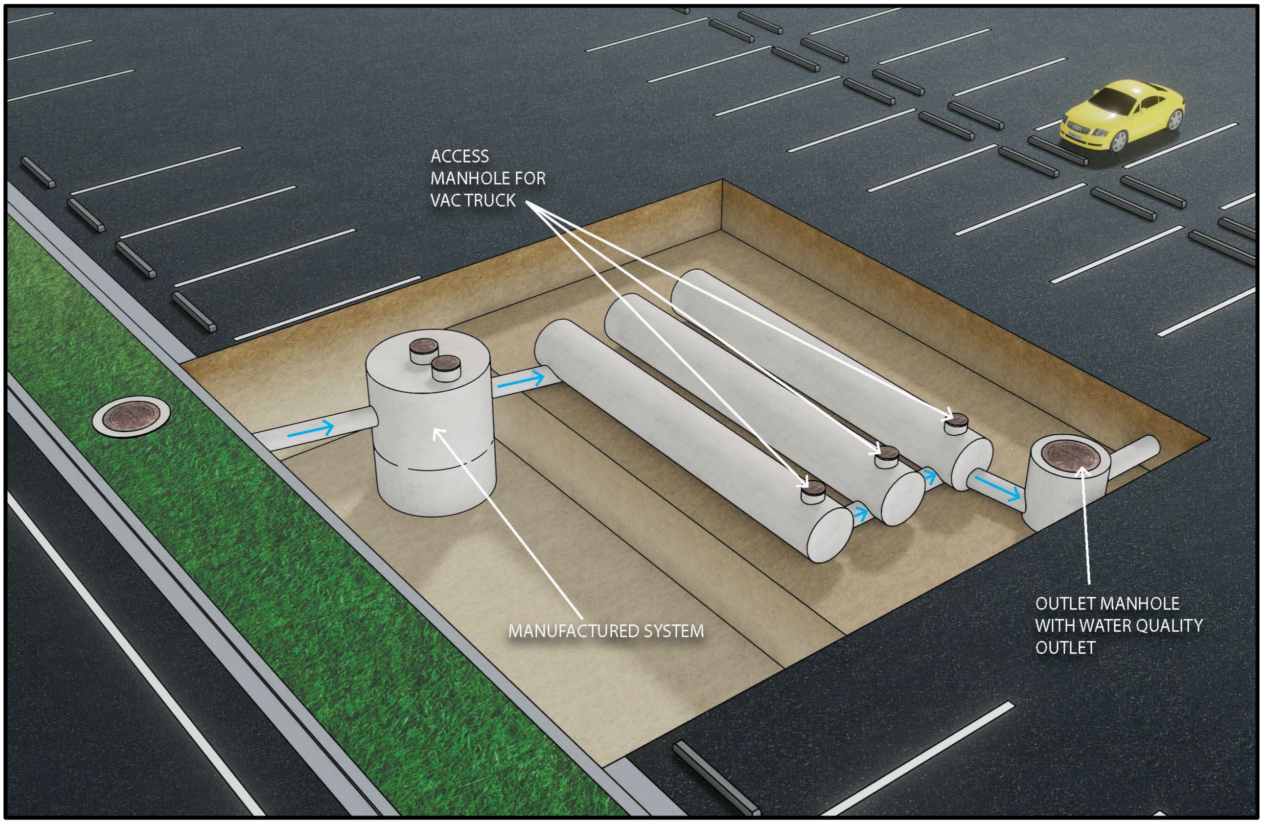
AMENDED VEGETATED FILTER STRIP	1113-12
	REFERENCE SECTION 1113.2.3



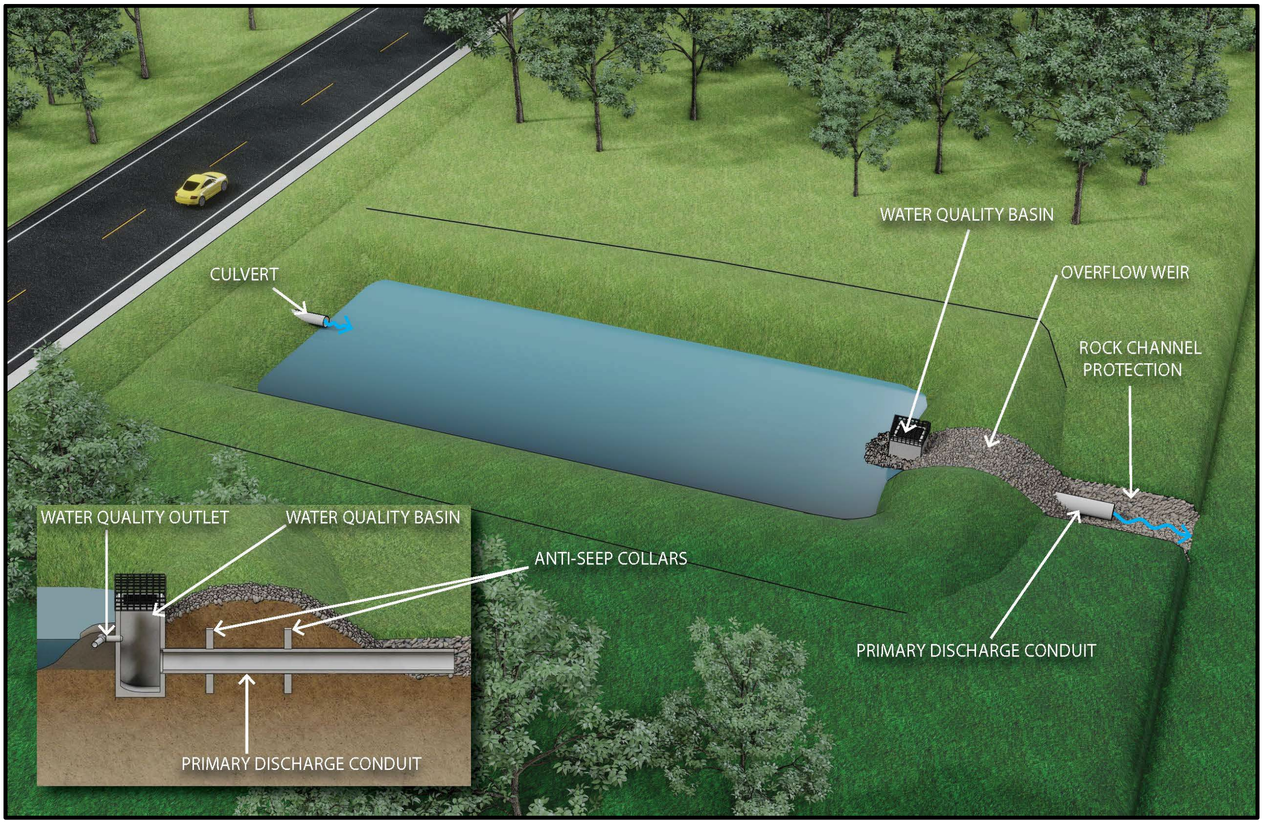
DETENTION BASIN	1113-13
	REFERENCE SECTION 1113.3.1



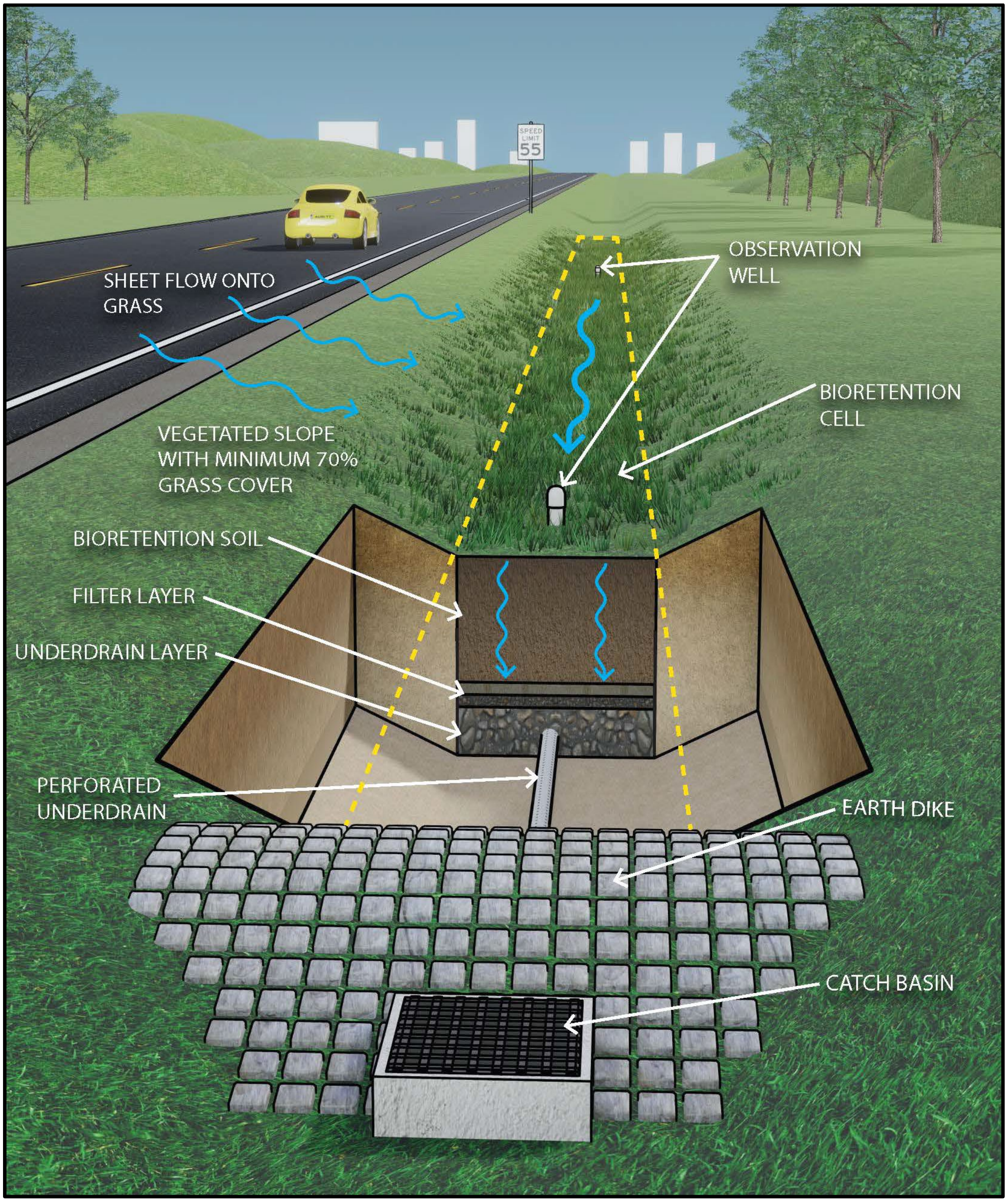
UNDERGROUND DETENTION	1113-14 REFERENCE SECTION 1113.3.2



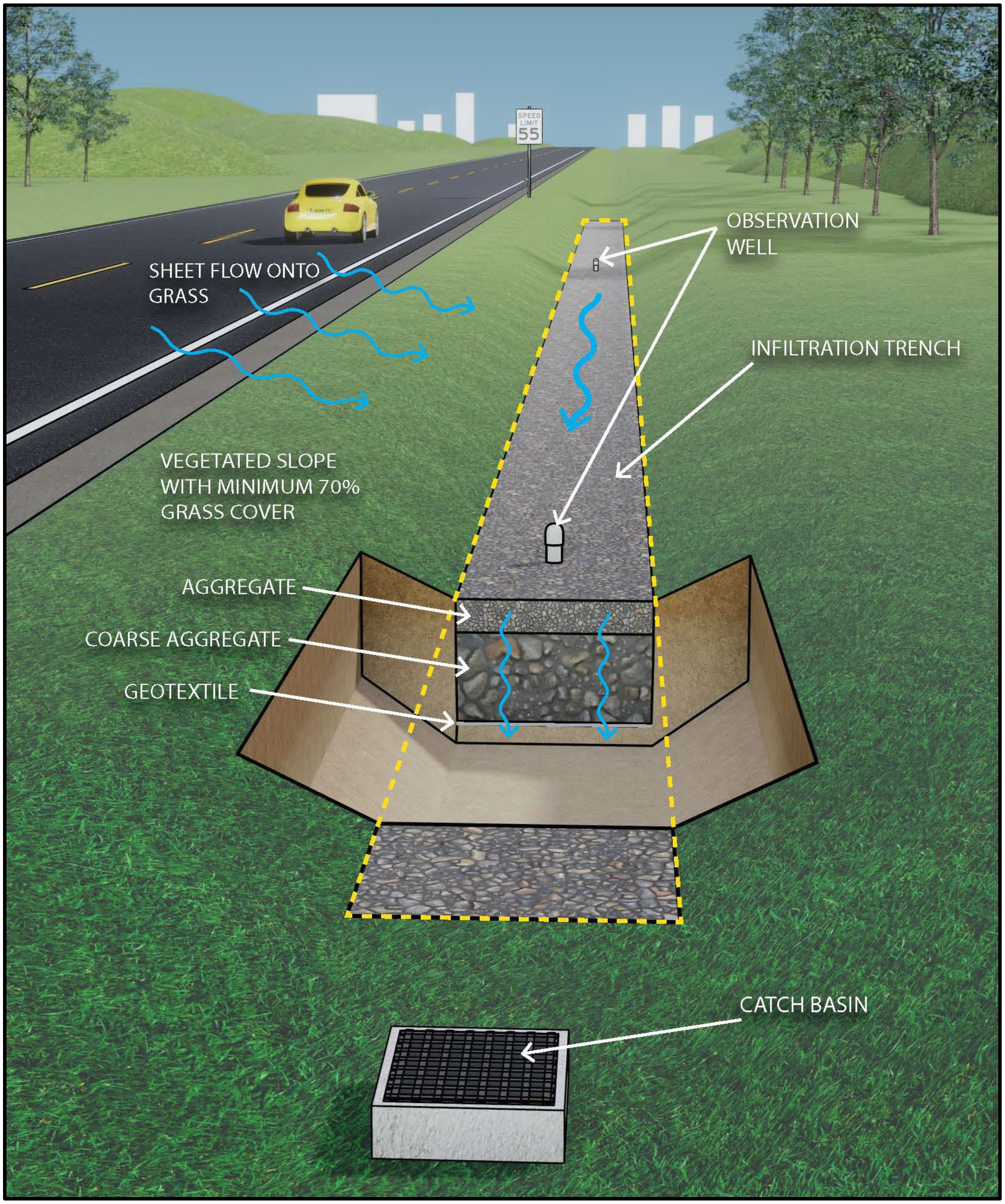
RETENTION BASIN	1113-15
	REFERENCE SECTION 1113.4



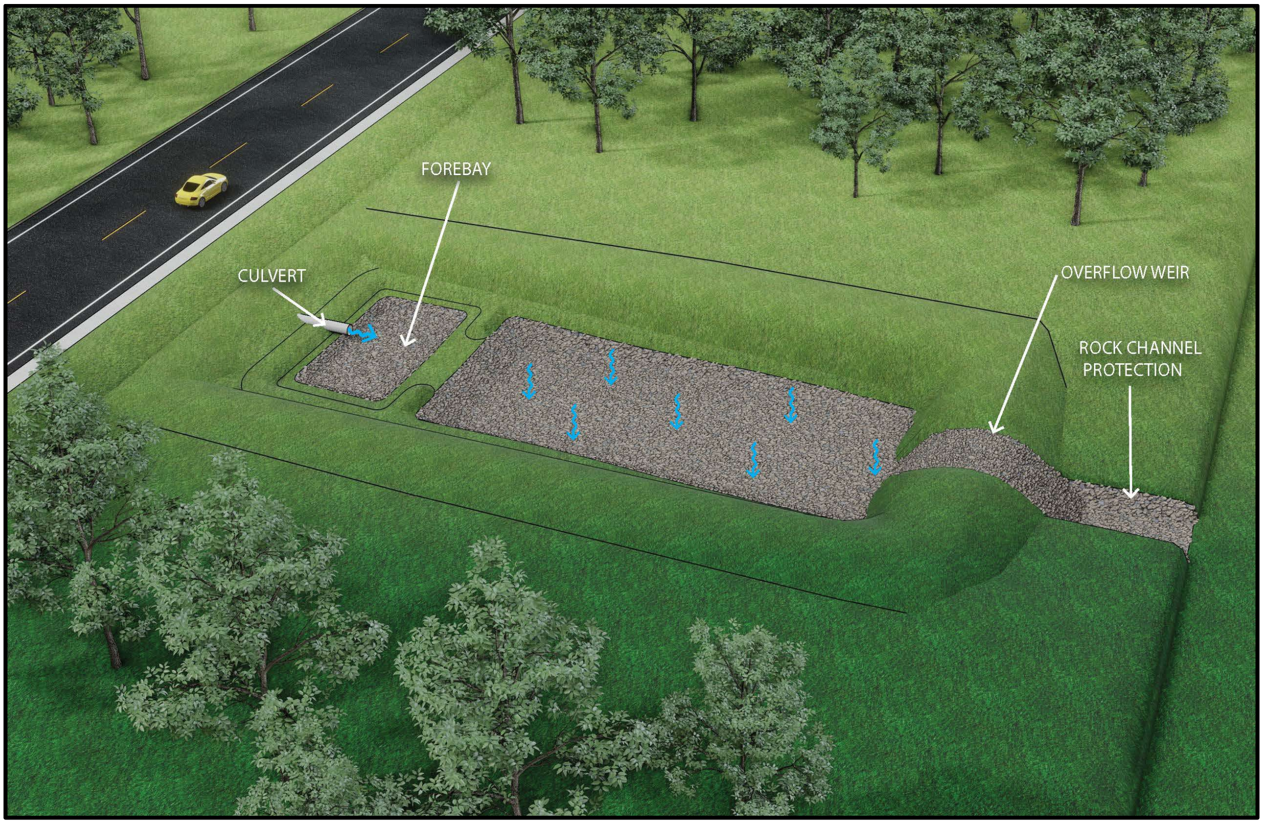
BIORETENTION CELL	1113-16
	REFERENCE SECTION 1113.5



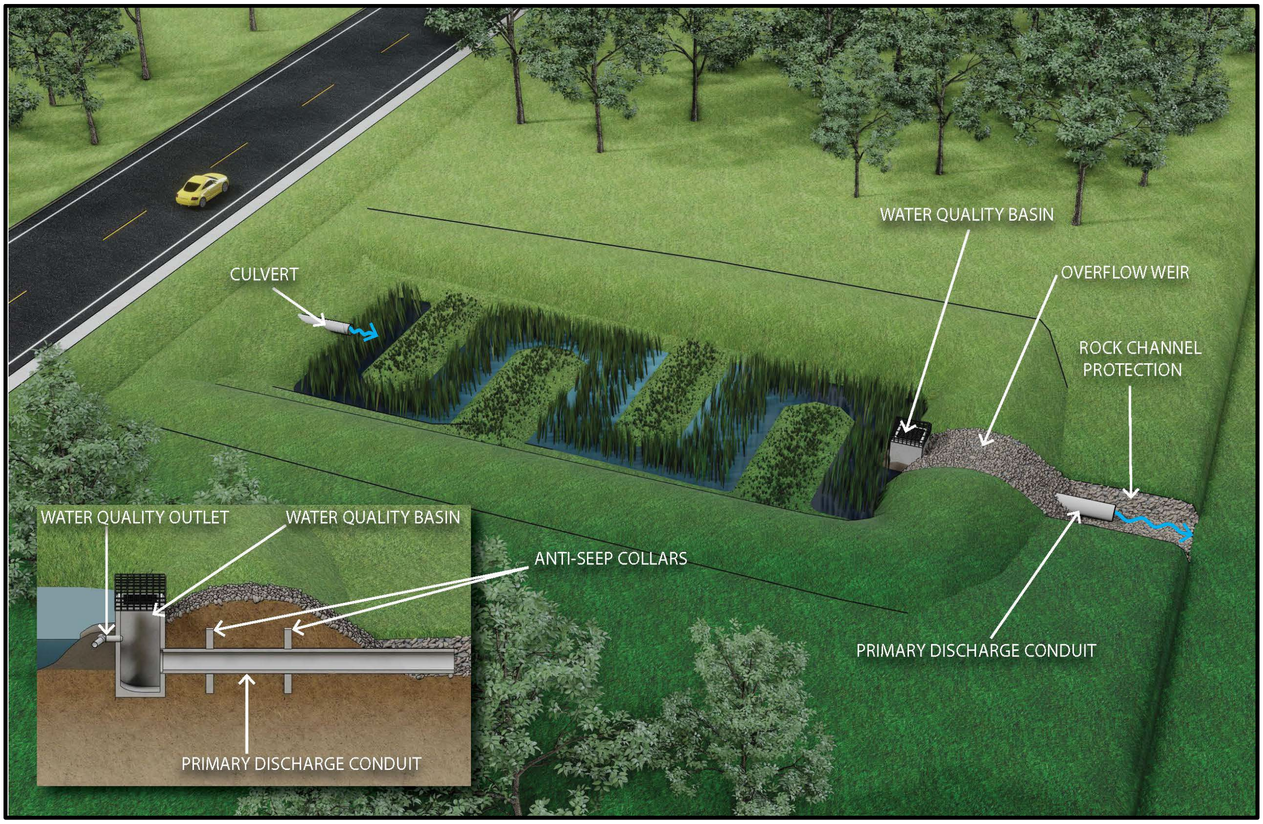
INFILTRATION TRENCH	1113-17
	REFERENCE SECTION 1113.6.1



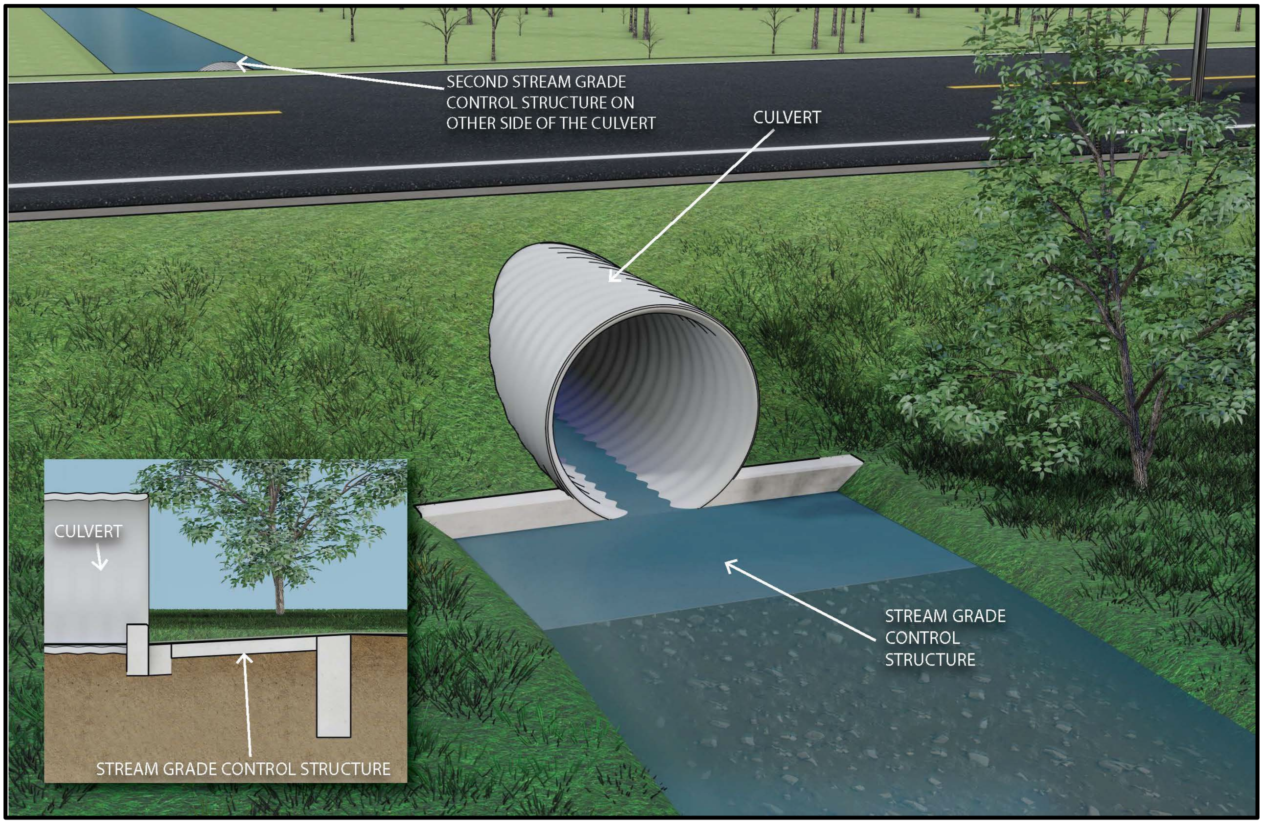
INFILTRATION BASIN	1113-18
	REFERENCE SECTION 1113.6.2



CONSTRUCTED WETLAND	1113-19 REFERENCE SECTION 1113.7



STREAM GRADE CONTROL	1113-20
	REFERENCE SECTION 1113.8



Appendix B – Reproducible Forms

<u>FORM</u>	<u>SUBJECT</u>
LD-33	**County Engineer Approval Form**
LD-35	**Ohio Drainage Design Criteria Form**
LD-50	**No-Rise Certificate**
LD-51	**Floodplain Letter of Compliance Template**
LD-52	**Floodplain Letter of Notification Template**
LD-53	**Letter of Notification of SFHA Exemption**

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Form LD-33
Revised July 2022

Ohio Department of Transportation
County Engineer Approval Form

Date Submitted to District: ______________________

Date Submitted to County Engineer: ______________________

County - Route - Section: ______________________

PID: ______________________

Station	Size & Type	Culvert Invert Elevation		Ex. Channel Elevation		Skew
		Inlet	Outlet	Inlet	Outlet	

I have reviewed and hereby approve the drainage proposed for the highway designated hereon in accordance with the provisions of the Ohio Revised Code, Section 6131.631.

____
County

______________________ ______________________
County Engineer's Signature Date

Comments: ______________________

____

____

Form LD-35
Revised January 2015

PROJECT INFORMATION:

COUNTY	ROUTE	SECTION	PID

PIPE POLICY:

The Pipe Policy of __________________ will be used for this project.

____

____

____

(Attach a copy of the written pipe policy or furnish a link to the policy. In lieu of a written policy, documentation of locally funded construction practices may be provided)

POST CONSTRUCTION BMP POLICY:

The Post Construction BMP Policy of ______________________ will be used for this project.

If a policy other than ODOT's is being used, the following BMP's are permitted:

____

____

____

DRAINAGE WATERSHED(S):

____

____

____

PROJECT SPECIFIC INFORMATION AFFECTING DRAINAGE:

____

____

____

Form LD-50
Revised July 2024

No-Rise Certification Form

This is to certify that I am a qualified licensed professional engineer in the State of Ohio.

It is to further certify that the attached technical data supports the fact that the proposed roadway project: ____ will not create any increase to
(Name of Project)

the 1-percent-annual-chance flood elevations on the ____________________________________
(Name of Stream)

at published cross-sections in the Flood Insurance Study (FIS) for

____, dated ____________________
(Name of Community/FIS)

and will not create any increase to the 1-percent-annual-chance flood elevations at unpublished cross-sections in the vicinity of the proposed roadway project.

Engineer's Name:____

Signature:____ **Date:**______________________

Phone Number:___________________ **E-MAIL:**_________________________________

Agency/Firm: ____

Address:____

City:_____________________________ **State:**____________ **Zip Code:**_____________

ENGINEERS SEAL:

Date

Name of Floodplain Coordinator
Title
County or Municipality Name
Address Line 1
Address Line 2

Re: County-Route-Section (PID)
Letter of Compliance

Dear Name of Floodplain Coordinator:

Enclosed please find the floodplain analysis for Ohio Department of Transportation project County-Route-Section (PID). The subject roadway project encroaches upon a Special Flood Hazard Area Zone A or AE within your community at the location identified in the attached report. The hydraulic calculations and No-Rise Certification Form (if Zone AE) provide the necessary documentation of compliance to all federal, state, and local floodplain standards as required.

If you need additional information please contact contact information as needed.

Respectfully,

Name of Registered Engineer, P.E.
Title

Date

Name of Floodplain Coordinator
Title
County or Municipality Name
Address Line 1
Address Line 2

Re: County-Route-Section (PID)
Letter of Notification

Dear Name of Floodplain Coordinator:

The Ohio Department of Transportation project County-Route-Section (PID) encroaches upon a Special Flood Hazard Area Zone A or AE within your community.

The proposed project list the intent and work.

Please provide your community's flood zone regulations if they differ from FEMA requirements and forward any questions you may have about the project. Future correspondence will include hydraulic calculations and required documentation for compliance. We will move forward with this project if no concerns are brought to our attention.

If you need additional information please contact contact information as needed.

Respectfully,

Name of Registered Engineer, P.E.
Title

Company Letter Head or ODOT Letter Head

Date

Name of Floodplain Coordinator
Title
County or Municipality Name
Address Line 1
Address Line 2

Re: County-Route-Section (PID)
Letter of Notification of SFHA Exemption

Dear Name of Floodplain Coordinator:

The Ohio Department of Transportation project County-Route-Section (PID) is located within a Special Flood Hazard Area Zone A or AE in your community.

The proposed project list the intent and work.

As a courtesy, we are informing you of this project. The above described work is considered maintenance that does not change the alignment, grade, or hydraulic capacity of the existing structure. Because of this, the project is exempt from the normal permit process required for work encroaching on a SFHA. No further correspondence will be forthcoming.

If you need additional information please contact contact information as needed.

Respectfully,

Name of Registered Engineer, P.E.
Title

Appendix C – Sample Plan Notes

The Sample plan notes included in this Appendix are the most frequently used. Each note is accompanied by a Designer Note to provide guidance on when to use the note and how to estimate quantities for some of the items where the methods for quantity calculations are not obvious.

The following note categories are included:

Category	Letter Prefix
Drainage Notes	**D**
Erosion Control Notes	**E**
Water Quality Notes	**W**

NOTE	NAME
D101	**Item 611 – Catch Basin Grate**
D102	**Item 611 – Conduit Misc.: Internal Joint Seal**
D103	**Item Special – Fill and Plug Existing Conduit**
D104	**Crossings and Connections to Existing Pipes and Utilities**
D105	**Pipe Connections to Corrugated Metal Structures**
D106	**Item 611 – Tunnel Liner Plate Structure**
D107	**Farm Drains**
D108	**Drainage Misc: Expand-In-Place Glass-Fiber Liner Pipe**
D109	**Spring Drains**
D110	**Drainage Discharge Continuance**
D111	**Unpermitted Drainage Discharge Removal**
D112	**Item 611 – Conduit Bored or Jacked**
D113	**Item 611 – Conduit Under Railroad**
D114	**Review of Drainage Facilities**
D117	**Manholes, Catch Basins and Inlets Removed or Abandoned**
D119	**Item Special – Miscellaneous Metal**
D120	**Item 611 – Slotted Drain**
D121	**Item Special – Pipe Cleanout**
D123	**Existing Underdrains**
D124	**Temporary Drainage Items**

D101 **ITEM 611 - CATCH BASIN GRATE**

MODIFY EXISTING CATCH BASINS BY REPLACING THE EXISTING GRATES WITH BICYCLE SAFE GRATES. QUANTITIES AND LOCATIONS ARE SHOWN IN THE PLANS AND ARE PAID FOR AT THE CONTRACT PRICE FOR ITEM 611, CATCH BASIN GRATE, TYPE ______, EACH.

Designer Note: Use the above note on projects where existing catch basin grates are not bicycle safe. The size and type of grate to be supplied must be indicated. There may be more than one type and size on a project.

If specific locations are not shown in the plan, or additional grates are to be included on a contingency basis, use the following to either replace the second sentence in the note or add to the note:

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY FOR USE AS DIRECTED BY THE ENGINEER FOR REPLACEMENT OF EXISTING CATCH BASIN GRATES WITH BICYCLE SAFE GRATES:

ITEM 611, CATCH BASIN GRATE, TYPE _______
_______EACH

D102 **ITEM 611 - CONDUIT MISC.: INTERNAL JOINT SEAL**

PROVIDE AN INTERNAL JOINT SEAL AT THE LOCATIONS INDICATED IN THE PLANS. COMPRESS THE INTERNAL JOINT SEAL AGAINST THE INTERNAL DIAMETER OF THE PIPE COVERING THE JOINT. EXTEND THE INTERNAL JOINT SEAL A MINIMUM OF 4 INCHES FROM EITHER SIDE OF THE JOINT. FURNISH AN INTERNAL JOINT SEAL COMPOSED OF EITHER MECHANICAL EXPANSION BANDS WITH LOCKING ASSEMBLY, A FIBERGLASS BASED RESIN POINT REPAIR, OR AN APPROVED EQUAL. PERFORM THE REPAIRS ON THE FOLLOWING CONDUITS:

STA. _+__, ___” CONDUIT
STA. _+__, ___” CONDUIT

CLEAN AND REMOVE ALL DIRT AND DEBRIS PRIOR TO INSTALLATION OF THE INTERNAL JOINT SEAL. FILL THE VOIDS WITH GROUT. SEALS CAN BE SUPPLIED WITHOUT TEST VALVES.

INSTALL THE INTERNAL JOINT SEAL PER THE REQUIREMENTS OF THE MANUFACTURER. THE INTERNAL JOINT SEAL, LABOR, EQUIPMENT AND ANY OTHER INCIDENTALS NECESSARY TO COMPLETE THE WORK ARE INCLUDED IN:

ITEM 611, CONDUIT MISC.: INTERNAL JOINT SEAL _______
EACH

Designer Note: Use the above note to repair failing joints and prevent soil infiltration on structurally sound culverts and storm sewers. Verify the size, material and shape availability to perform the repair with the manufacturer or the OHE.

D103 ITEM SPECIAL - FILL AND PLUG EXISTING CONDUIT

THIS ITEM CONSISTS OF THE CONSTRUCTION OF BULKHEADS IN AN EXISTING ____ INCH DIAMETER CONDUIT AND FILLING THE AREA SEALED OFF WITH ITEM 613, SAND OR OTHER MATERIAL APPROVED BY THE ENGINEER.

LOCATE THE BULKHEADS AT THE LIMITS OF THE AREA TO BE FILLED, AS INDICATED ON THE PLANS. THE BULKHEADS CONSIST OF BRICK OR CONCRETE MASONRY WITH A MINIMUM THICKNESS OF 12 INCHES.

PUMP THE FILL MATERIAL INTO PLACE OR BY OTHER MEANS APPROVED BY THE ENGINEER, SO THAT AFTER SETTLEMENT, AT LEAST 90 PERCENT OF THE CROSS-SECTIONAL AREA OF THE CONDUIT, FOR ITS ENTIRE LENGTH IS FILLED. THE LENGTH OF FILLED AND PLUGGED CONDUIT TO BE PAID FOR IS THE ACTUAL NUMBER OF FEET (MEASURED ALONG THE CENTERLINE OF EACH CONDUIT FROM OUTER FACE TO OUTER FACE OF BULKHEADS) FILLED AND PLUGGED AS DESCRIBED ABOVE.

IN LIEU OF FILLING AND PLUGGING THE EXISTING CONDUIT, THE PIPE MAY BE CRUSHED AND BACKFILLED PER 203, OR IT MAY BE REMOVED. THE LENGTH, MEASURED AS PROVIDED ABOVE, WILL BE PAID FOR AT THE CONTRACT PRICE PER FOOT FOR, ITEM SPECIAL, FILL AND PLUG EXISTING CONDUIT.

Designer Note: Use the above note when it is desired to abandon an existing conduit by filling and plugging rather than more conventional methods. If the conduit is in shallow fill, the designer may delete the crush and backfill option specified in the fourth paragraph. Add pay item 202E70000 “202, Special – Fill and plug existing conduit, ___ft” to the plans.

D104 CROSSINGS AND CONNECTIONS TO EXISTING PIPES AND UTILITIES

WHERE PLANS PROVIDE FOR A PROPOSED CONDUIT TO BE CONNECTED TO, OR CROSS OVER OR UNDER AN EXISTING SEWER OR UNDERGROUND UTILITY, LOCATE THE EXISTING PIPES OR UTILITIES BOTH AS TO LINE AND GRADE BEFORE STARTING TO LAY THE PROPOSED CONDUIT.

IF IT IS DETERMINED THAT THE ELEVATION OF THE EXISTING CONDUIT, OR EXISTING APPURTENANCE TO BE CONNECTED, DIFFERS FROM THE PLAN ELEVATION OR RESULTS IN A CHANGE IN THE PLAN CONDUIT SLOPE, NOTIFY THE ENGINEER BEFORE STARTING CONSTRUCTION OF ANY PORTION OF THE PROPOSED CONDUIT WHICH WILL BE AFFECTED BY THE VARIANCE IN THE EXISTING ELEVATIONS.

IF IT IS DETERMINED THAT THE PROPOSED CONDUIT WILL INTERSECT AN EXISTING SEWER OR UNDERGROUND UTILITY IF CONSTRUCTED AS SHOWN ON THE PLAN, NOTIFY THE ENGINEER BEFORE STARTING CONSTRUCTION OF ANY PORTION OF THE PROPOSED CONDUIT WHICH WOULD BE AFFECTED BY THE INTERFERENCE WITH AN EXISTING FACILITY.

PAYMENT FOR ALL THE OPERATIONS DESCRIBED ABOVE IS INCLUDED IN THE CONTRACT PRICE FOR THE PERTINENT 611 CONDUIT ITEM.

Designer Note: Use the above note when the designer is unsure of the exact location of a conduit that will require an extension or where the potential for interference between proposed and existing conduits exists.

D105 **PIPE CONNECTIONS TO CORRUGATED METAL STRUCTURES**

PROVIDE CONNECTIONS OF PROPOSED LONGITUDINAL DRAINAGE TO CORRUGATED METAL STRUCTURES BY MEANS OF A SHOP FABRICATED OR FIELD WELDED STUB ON THE STRUCTURE. FURNISH A STUB MEETING THE REQUIREMENTS OF 707 WITH A MINIMUM LENGTH OF 2 FEET AND A MINIMUM WALL THICKNESS OF 0.064 INCHES.

THE LOCATION AND ELEVATION OF THE STUB ARE TO BE CONSIDERED APPROXIMATE AND MAY BE ADJUSTED BY THE ENGINEER TO AVOID CUTTING THROUGH JOINTS IN THE STRUCTURE.

THOROUGHLY CLEAN AND REGALVANIZE OR OTHERWISE SUITABLY REPAIR THE FIELD WELDED JOINT, IF USED. MEET WELDING REQUIREMENTS OF 513.21.

PROVIDE A MASONRY COLLAR PER STANDARD CONSTRUCTION DRAWING DM-1.1, TO CONNECT THE LONGITUDINAL DRAINAGE TO THE STUB, WHEN PIPE OTHER THAN CORRUGATED METAL IS USED FOR THE LONGITUDINAL DRAINAGE.

PAYMENT FOR CUTTING INTO THE STRUCTURE AND PROVIDING THE CONNECTION DESCRIBED, IS INCLUDED IN THE CONTRACT PRICE FOR ITEM 611 OR 522.

Designer Note: Use the above note on all projects where connections to existing corrugated metal conduits are proposed.

D106 **ITEM 611 - TUNNEL LINER PLATE STRUCTURE**

PROVIDE GALVANIZED STEEL OR ALUMINUM TUNNEL LINER PLATE MANUFACTURED BY: DSI TUNNELING, LLC; CONTECH ENGINEERED SOLUTIONS, LLC.; OR AN APPROVED EQUAL. THE MINIMUM THICKNESS SHOWN IN THE PLANS IS PROVIDED FOR THE DURABILITY DESIGN. INCLUDE THE PLATE THICKNESS IN THE INSTALLATION PLANS PER CMS 611 FOR THE STRUCTURAL REQUIREMENTS.

PROVIDE MATERIAL FOR GALVANIZED STEEL TUNNEL LINER PLATE PER 707.03. PROVIDE MATERIAL FOR ALUMINUM TUNNEL LINER PLATE PER 707.23. PROVIDE CONCRETE FIELD PAVING PER 611.11. FILL THE ANNULAR SPACE BETWEEN THE TUNNEL EXCAVATION AND THE TUNNEL LINER PLATE PER THE REQUIREMENTS OF 837.03 C AND D. FOR ALUMINUM TUNNEL LINER PLATE, PROVIDE AN OUTSIDE COATING PER 837.02 B PRIOR TO GROUTING OPERATIONS.

Designer Note: Perform conduit durability design per L&D Vol. 2 – 1002.2.2 to determine minimum plate thickness and/or level of protection. Perform durability using 707.03 Structural Plate Corrugated Steel for Steel Tunnel Liner Plate and 707.23 Aluminum Alloy Structural Plate for Aluminum Tunnel Liner Plate.

D107 FARM DRAINS

PROVIDE UNOBSTRUCTED OUTLETS TO ALL FARM DRAINS ENCOUNTERED DURING CONSTRUCTION. REPLACE EXISTING COLLECTORS WHICH ARE LOCATED BELOW THE ROADWAY DITCH ELEVATIONS, AND WHICH CROSS THE ROADWAY WITHIN THE (RIGHT OF WAY)(CONSTRUCTION) LIMITS WITH ITEM 611, CONDUIT, TYPE B, ONE COMMERCIAL SIZE LARGER THAN THE EXISTING CONDUIT.

OUTLET EXISTING COLLECTORS AND ISOLATED FARM DRAINS, WHICH ARE ENCOUNTERED ABOVE THE ELEVATION OF ROADWAY DITCHES INTO THE ROADWAY DITCH USING ITEM 611, TYPE F CONDUIT. THE OPTIMUM OUTLET ELEVATION IS ONE FOOT ABOVE THE FLOWLINE ELEVATION OF THE DITCH. INTERCEPT LATERAL FIELD TILES WHICH CROSS THE ROADWAY WITH ITEM 611, TYPE E CONDUIT, AND CARRY IN A LONGITUDINAL DIRECTION TO AN ADEQUATE OUTLET OR ROADWAY CROSSING.

THE LOCATION, TYPE, SIZE AND GRADE OF REPLACEMENTS IS DETERMINED BY THE ENGINEER AND PAYMENT MADE ON FINAL MEASUREMENTS.

PROVIDE EROSION CONTROL PADS AT THE OUTLET END OF ALL FARM DRAINS PER STANDARD CONSTRUCTION DRAWING DM-1.1, EXCEPT WHEN THEY OUTLET INTO A DRAINAGE STRUCTURE.

PAYMENT FOR THE EROSION CONTROL PADS AND ANY NECESSARY BENDS OR BRANCHES IS INCLUDED FOR PAYMENT IN THE PERTINENT CONDUIT ITEMS.

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY FOR THE WORK NOTED ABOVE:

ITEM 611, _____" CONDUIT, TYPE B	______ FT
ITEM 611, _____" CONDUIT, TYPE E	______ FT
ITEM 611, _____" CONDUIT, TYPE F	______ FT
ITEM 601, ROCK CHANNEL PROTECTION TYPE C WITH FILTER	______ CY

Designer Note: Use the above note where excavation may conflict with existing farm drains. Use of a lateral field interceptor tile located on a temporary easement outside the limited access right of way may be appropriate on limited access facilities.

D108 ITEM 611 – CONDUIT MISC.: EXPAND-IN-PLACE GLASS-FIBER LINER PIPE

INSTALL AN EXPAND-IN-PLACE GLASS-FIBER LINER PIPE THAT IS BONDED TO THE INTERIOR SURFACE OF THE CONCRETE HOST PIPE TO BE REHABILITATED. ENSURE THE LINER PIPE FITS TIGHTLY AND CONFORMS TO THE SHAPE OF THE EXISTING PIPE WHEN THE EXPANSION IS COMPLETE. GLASS ALL SEAMS AND JOINTS A MINIMUM THICKNESS EQUAL TO THE DESIGN THICKNESS TO PRODUCE A CONTINUOUS JOINT-LESS LINER THAT IS IMPERVIOUS TO INFILTRATION AND EXFILTRATION.

PROVIDE CALCULATIONS PERFORMED AND STAMPED BY A REGISTERED PROFESSIONAL ENGINEER. DESIGN THE PIPE AS A STATE III LINER THAT INDEPENDENTLY SUPPORTS THE DEAD LOAD, LIVE LOAD, AND HYDRAULIC LOAD PER ASCE MOP 145, DESIGN OF CLOSE-FIT LINERS. USE A DESIGN SERVICE LIFE OF 50 YEARS. INCLUDE A LOAD RATING ANALYSIS, IF REQUIRED, PER THE BRIDGE DESIGN MANUAL SECTION 900 TO THE DISTRICT BRIDGE ENGINEER.

PROVIDE LINER PIPE CONFORMING TO 707.75.

PROVIDE A 2-PART BONDING SYSTEM CONSISTING OF A PRIMER AND BONDING AGENT, BOTH SOURCED FROM THE SAME PRODUCER, DESIGNED TO WORK IN CONJUCTION TO BOND THE LINER PIPE TO THE CONCRETE HOST PIPE. FILL VOIDS WITH GROUT COMPATIBLE WITH THE 2-PART BONDING SYSTEM WHERE THEY EXIST BETWEEN THE LINER AND HOST PIPE DUE TO DETERIORATION OF THE HOST PIPE (SPALLING, JOINT SEPARATION / MISALIGNMENT) AND FULL CONTACT CANNOT BE ACHIEVED.

CURED BONDING AGENT PROPERTIES	
TENSILE STRENGTH	1700 PSI (MINIMUM)
ELONGATION	480% (MAXIMUM)
MODULUS (100%)	430PSI (MINIMUM)

INSTALL LINER PIPE AND BONDING SYSTEM AS PER THE DIRECTION OF THE MANUFACTURER USING ONLY MANUFACTURER CERTIFIED PERSONNEL.

CLEAN AND REMOVE DEBRIS FROM THE HOST PIPE PRIOR TO INSTALLING THE LINER PIPE. DEWATER PIPE AND BYPASS FLOW DURING INSTALLATION. RESTORE ACTIVE SERVICE CONNECTIONS AFTER INSTALLATION OF THE LINER PIPE. PERFORM A POST-INSTALLATION VIDEO SURVEY OF THE PIPE AND PROVIDE A COPY OF THE VIDEO TO THE ENGINEER AS DESCRIBED IN SS902 SECTION 902.01 C.

PAYMENT FOR THE ABOVE WORK IS INCLUDED IN THE CONTRACT PRICE FOR ITEM

611, CONDUIT MISC.: EXPAND-IN-PLACE GLASS-FIBER LINER PIPE ______ FT

Designer Note: Use only to line RCP pipes 30” or greater in diameter.

This Item can be used to line the host pipe fully, or partially for spot repairs.

Contact OHE before specifying this lining method.

D109 **SPRING DRAINS**

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN CARRIED TO THE GENERAL SUMMARY FOR USE AS DIRECTED BY THE ENGINEER FOR DRAINING ANY SPRINGS SHOWN IN THE PLAN OR ENCOUNTERED DURING CONSTRUCTION. THE FOLLOWING PIPE MATERIALS ARE PERMITTED: 707.33, 707.41, 707.42 or 707.45 PERFORATED PER 707.31.

CONSTRUCT SPRING DRAINS PER STANDARD CONSTRUCTION DRAWING DM-1.1 AND PAID FOR AT THE CONTRACT PRICE FOR:

ITEM 605, 6" UNCLASSIFIED PIPE UNDERDRAINS FOR SPRINGS ______ FT
ITEM 605, AGGREGATE DRAINS FOR SPRINGS ______ FT
ITEM 611, PRECAST REINFORCED CONCRETE OUTLET ______ EACH

Designer Note: Use this only where springs are present in the project area and/or the project area is known to have spring activity. In addition to quantities required to drain springs located by field work, include estimated contingency quantities for draining springs encountered during construction.

D110 DRAINAGE DISCHARGE CONTINUANCE

FURNISH A DRAINAGE DISCHARGE CONTINUANCE FOR ANY DRAINAGE DISCHARGE DISTURBED BY THE WORK AND NOT SHOWN IN THE PLANS. THE LOCATION, TYPE (CONDUIT OR SWALE), SIZE AND GRADE OF THE DRAINAGE DISCHARGE CONTINUANCE WILL BE AGREED TO BY THE ENGINEER.

FURNISH AN INSPECTION WELL AT THE RIGHT OF WAY LINE IN PER STANDARD CONSTRUCTION DRAWING DM-3.1 FOR EACH DRAINAGE DISCHARGE THAT OUTLETS THROUGH A CURB OPENING OR INTO A STORM SEWER OR DRAINAGE STRUCTURE. THE COST IS INCLUDED IN ITEM 611, INSPECTION WELL.

FURNISH A WELL GRADED TRANSITION BETWEEN THE DITCH AND THE SWALE WHEN OUTLETTING A SWALE TO A DITCH. THE COST FOR THE GRADED TRANSITION IS INCLUDED IN ITEM 203, EMBANKMENT, AS PER PLAN.

FURNISH AN EROSION CONTROL PAD AS SHOWN IN STANDARD CONSTRUCTION DRAWING DM-1.1 WHEN OUTLETTING A CONDUIT TO A DITCH. THE COST FOR THE EROSION CONTROL PAD IS INCLUDED IN ITEM 611, CONDUIT, MISC TYPE _ FOR DRAINAGE DISCHARGE CONTINUANCE.

FURNISH A DRILLED HOLE OR A CURB SECTION WHEN OUTLETTING A CONDUIT THROUGH A CURB OPENING. THE COST OF DRILLING OR FURNISHING THE CURB SECTION WITH HOLE IS INCLUDED IN ITEM 611, CONDUIT, MISC TYPE _ FOR DRAINAGE DISCHARGE CONTINUANCE.

FURNISH A DRILLED CORE HOLE WHEN OUTLETTING INTO A STORM SEWER OR DRAINAGE STRUCTURE. THE COST OF THE DRILLED CORE HOLE IS INCLUDED IN ITEM 611, CONDUIT, MISC TYPE _ FOR DRAINAGE DISCHARGE CONTINUANCE.

DOCUMENTATION
PROVIDE WRITTEN DOCUMENTATION TO THE ENGINEER AND TO THE DISTRICT R/W PERMIT OFFICE. THE DOCUMENTATION INCLUDES THE CONSTRUCTION PROJECT NUMBER, PID, COUNTY, ROUTE, SECTION, LATITUDE AND LONGITUDE OF THE DRAINAGE DISCHARGE AT THE R/W, THE NAME OF PROPERTY OWNER WITH ADDRESS, THE DATE THE DRAINAGE DISCHARGE WAS LOCATED, THE DATE THE DRAINAGE DISCHARGE CONTINUANCE WAS FURNISHED, A DETAILED DESCRIPTION OF THE WORK AND PICTURES OF THE DRAINAGE DISCHARGE CONTINUANCE (IN PDF OR JPEG FORMAT). THE DOCUMENTATION IS INCLUDED IN ITEM 611, CONDUIT, MISC TYPE _ FOR DRAINAGE DISCHARGE CONTINUANCE OR ITEM 203, EMBANKMENT, AS PER PLAN

DRAINAGE DISCHARGE CONTINUANCE REMOVAL
THE ENGINEER MAY REQUIRE THE NEWLY INSTALLED DRAINAGE DISCHARGE CONTINUANCE TO BE REMOVED.

REMOVE THE NEWLY INSTALLED CONDUIT AND ANY EXISTING CONDUIT TO THE RIGHT OF WAY LINE. FOR CONDUIT THAT OUTLETS THROUGH THE CURB, RESTORE THE CURB BY FILLING THE HOLE WITH CLASS QC 1 CONCRETE OR REPLACE THE CURB SECTION. FOR CONDUIT THAT OUTLETS TO A STORM SEWER OR DRAINAGE STRUCTURE LEAVE 6 INCHES PROTRUDING OUTSIDE OF THE CONDUIT. PLUG THE PROTRUDING CONDUIT WITH EITHER A MANUFACTURED CAP OR CLASS QC 1 CONCRETE. FOR CONDUIT THAT OUTLETS TO THE DITCH REMOVE THE EROSION CONTROL PAD. RESTORE ALL AREAS AS REQUIRED. PLUG THE EXISTING CONDUIT REGARDLESS OF SIZE AT THE RIGHT OF WAY LINE WITH CLASS QC 1 CONCRETE AND RESTORE ALL AREAS AS REQUIRED. ALL COSTS ARE INCLUDED IN ITEM 202,

REMOVAL MISC.: CONDUIT.

DAM THE SWALE THAT OUTLETS TO THE DITCH AT THE R/W AS DIRECTED BY THE ENGINEER. ALL COSTS ARE INCLUDED IN ITEM 203, EMBANKMENT AS PER PLAN

REMOVE THE INSPECTION WELL AND RESTORE ALL AREAS AS REQUIRED. THE COST IS INCLUDED IN ITEM 202, REMOVAL MISC.: INSPECTION WELL.

CONDUIT MATERIAL TYPES
THE FOLLOWING CONDUIT MATERIAL TYPES ARE PERMITTED: 707.33, 707.41 NON-PERFORATED, 707.42, 707.43, 707.45, 707.46, 707.47, AND 707.51.

PAY ITEMS
EACH OF THE PAY ITEMS LISTED BELOW FOR CONDUIT MISCELLANEOUS TYPES B, C, E AND F FOR DRAINAGE DISCHARGE CONTINUANCE INCLUDE CONDUIT SIZES 2 INCH TO 10 INCH. THERE IS NO COST DIFFERENTIATION FOR SIZE IN THESE PAY ITEMS.

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY FOR USE AS DIRECTED BY THE ENGINEER IN MAKING THE ABOVE DRAINAGE DISCHARGE CONTINUANCE:

ITEM 611, INSPECTION WELL
______ EACH
ITEM 611, CONDUIT, MISC.: TYPE C FOR DRAINAGE DISCHARGE CONTINUANCE
______ FT
ITEM 611, CONDUIT, MISC.: TYPE E FOR DRAINAG DISCHARGE CONTINUANCE
______ FT
ITEM 611, CONDUIT, MISC.: TYPE F FOR DRAINAGE DISCHARGE CONTINUANCE
______ FT
ITEM 202, REMOVAL MISC.: CONDUIT
______ FT
ITEM 202, REMOVAL MISC.: INSPECTION WELL
______ EACH
ITEM 203, EMBANKMENT, AS PER PLAN
______ CY

Designer Note: Make a complete investigation within the project limits for the presence of any drainage discharge of:

- Treated septic, treated wastewater, treated curtain/gradient drains, treated foundation floor drains
- Sanitary wastewater, Sanitary curtain/gradient drains, or Sanitary foundation floor drains
- Roof drains, footer drains, or yard drains

Send written documentation to the District R/W Permit Office for all drainage discharge discovered by the investigation. Include the PID, county, route, section, latitude and longitude of the drainage discharge location at the R/W, the name and address of the property owner, and a detailed description of the inspection including date and pictures of the drainage discharge in pdf or jpeg format.

The District R/W Permit Office will direct the designer as to the continuance or removal and plugging of each drainage discharge discovered by the investigation. If the District R/W Permit

Office requires the drainage discharge be removed and plugged, include plan note D111.

Add note D110 **only** if any drainage discharge locations are discovered during the investigation and if the investigation yields any possibility that additional drainage discharge locations could be discovered during construction.

Furnish a minimum of 5 feet for each lane mile of project length rounded up to the next 5 foot increment for each listed type of conduit above.

Furnish a minimum of 1 inspection well for each 20 feet of conduit estimated above.

Furnish a minimum of 25% of the conduit estimated above rounded up to the next 5 foot increment to determine the length of Item 202, Removal Misc.: Conduit.

Furnish a minimum of 10% of the above estimated Item 611, Inspection Well for Item 202, Removal Misc.: Inspection Well, rounded up to the next whole number.

Furnish 50 cubic yard for Item 203, Embankment, As Per Plan.

D111 UNPERMITTED DRAINAGE DISCHARGE REMOVAL

AT THE LOCATIONS SHOWN IN THE PLANS, REMOVE THE CONDUIT REGARDLESS OF SIZE TO THE RIGHT OF WAY LINE AND PLUG THE CONDUIT WITH CLASS QC 1 CONCRETE. FOR CONDUIT THAT OUTLETS THROUGH THE CURB, RESTORE THE CURB BY FILLING THE HOLE WITH CLASS QC 1 CONCRETE OR REPLACE THE CURB SECTION. FOR CONDUIT THAT OUTLETS TO A STORM SEWER OR DRAINAGE STRUCTURE, LEAVE 6 INCHES OF THE CONDUIT PROTRUDING. PLUG THE PROTRUDING CONDUIT WITH EITHER A MANUFACTURED CAP OR CLASS QC 1 CONCRETE. FOR CONDUIT THAT OUTLETS TO THE DITCH, REMOVE THE EROSION CONTROL PAD. RESTORE ALL AREAS AS REQUIRED. PLUG THE EXISTING CONDUIT REGARDLESS OF SIZE AT THE RIGHT OF WAY LINE WITH CLASS QC 1 CONCRETE. ALL COSTS ARE INCLUDED IN ITEM 202, REMOVAL MISC. CONDUIT.

AT THE LOCATIONS SHOWN IN THE PLANS, DAM THE SWALE THAT OUTLETS TO THE DITCH AT THE R/W AS DIRECTED BY THE ENGINEER. ALL COSTS ARE INCLUDED IN ITEM 203, EMBANKMENT, AS PER PLAN.

AT THE LOCATIONS SHOWN IN THE PLANS, REMOVE THE INSPECTION WELL AND RESTORE ALL AREAS AS REQUIRED. THE COST IS INCLUDED IN ITEM 202, REMOVAL MISC. INSPECTION WELL.

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY:

ITEM 202, REMOVAL MISC.: CONDUIT
______ FT
ITEM 202, REMOVAL MISC.: INSPECTION WELL
______ EACH
ITEM 203, EMBANKMENT, AS PER PLAN
______ CY

Designer Note: Use this note when the District R/W Permit Office has identified specific locations for the removal of unpermitted drainage discharges.

Furnish the total length of conduit for the length of Item 202 Removal Misc. Conduit.

If a conduit size greater than 10 inch is known furnish that size removal item in the plans.

Furnish 50 cubic yard for Item 203, Embankment, As Per Plan.

Furnish the total number of Inspection Wells required for removal for Item 202, Removal Misc.: Inspection Well.

D112 **ITEM 611 - CONDUIT BORED OR JACKED**

WHERE IT IS SPECIFIED THAT A CONDUIT BE INSTALLED BY THE METHOD OF BORING OR JACKING, NO TRENCH EXCAVATION IS PERMITTED WITHIN ______ FEET OF THE (EDGE OF PAVEMENT) (NEAREST RAIL). PROVIDE A STEEL CASING PIPE CONFORMING TO 748.06. JOINTS WITH A CIRCUMFERENCIAL FULLY PENETRATING B-U4b WELD THAT IS PERFORMED BY A CERTIFIED WELDER FOR WELDING CODE AMERICAN WELDING SOCIETY (AWS) D1. 1 OR MACHINED INTERLOCKING JOINTS ARE PERMITTED. THE INSTALLED CASING PIPE IS THE STORM WATER CONVEYANCE CARRIER UNLESS OTHERWISE SPECIFIED IN THE PLANS. HYDROSTATIC TESTING IS NOT REQUIRED FOR THE CASING PIPE.

Designer Note: provide the following pay item 611, Conduit Bored or Jacked, _____“, Type _____ , _____ Ft. in the General Summary. Where a conduit is installed by this method under a railroad, coordinate with the Rail Company to determine the allowable distance from the nearest rail and add note D113 to the plans. Extend the casing pipe past the edge of pavement or where access will be limited to the joint. Specify a concrete masonry collar per DM-1.1 between the casing pipe and adjacent conduit material if the casing pipe is used as the final carrier pipe. Follow SGE guidance for exploratory soil borings when considering this method of installation.

D113 **ITEM 611 – CONDUIT UNDER RAILROAD**

THE DEPARTMENT WILL PAY TO THE RAIL COMPANY ALL COSTS FOR WATCHMEN OR FLAGGERS DEEMED NECESSARY BY THE RAIL COMPANY DURING THE INSTALLATION OF CONDUIT UNDER THE RAILROAD. ANY COSTS FOR WATCHMEN OR FLAGGERS REQUIRED BY AN ALTERNATE METHOD OF INSTALLATION ARE THE RESPONSIBILITY OF THE CONTRACTOR. THE COSTS FOR WATCHMEN OR FLAGGERS DUE TO THE NEGLIGENCE OF THE CONTRACTOR, OR ANY SUB-CONTRACTOR, IN CONNECTION WITH THE INSTALLATION OF THE CONDUIT MUST BE PAID BY THE CONTRACTOR.

TRACK SUPPORTS REQUIRED BY THE RAIL COMPANY IN CONNECTION WITH THE INSTALLATION OF THE CONDUIT ARE INCLUDED IN THE COMPANY FORCE ACCOUNT WORK AND PAID BY THE DEPARTMENT. THE COST OF ANY TRACK SUPPORTS REQUIRED BY AN ALTERNATE METHOD OF INSTALLATION OF CONDUIT ARE THE RESPONSIBILITY OF THE CONTRACTOR.

THE CONTRACTOR IS RESPOSIBLE TO SECURE APPROVAL OF OPERATIONS FROM THE DEPARTMENT AND THE RAIL COMPANY. THE RAIL COMPANY WILL PERFORM AN ENGINEERING REVIEW OF METHODS OF OPERATIONS AND ENGINEERING SUPERVISION OF CONSTRUCITON WITHOUT COST TO THE CONTRACTOR.

PRIOR TO BIDDING, COORDINATE WITH THE RAIL COMPANY TO AGREE UPON THE REQUIREMENTS OF WATCHMEN AND FLAGGERS TO PROTECT RAILROAD TRAFFIC DURING THE CONTRACTOR’S OPERATIONS. EXECUTE A BOND IN FAVOR OF BOTH THE STATE AND THE COMPANY AS REQUIRED BY SECTION 5525.16 OF THE REVISED

CODE OF OHIO.

COORDINATE WITH THE RAIL COMPANY CONCERNING WORK ADJACENT TO RAILROAD TRACKS, IN ORDER TO AVOID DELAY TO, OR INTERFERENCE WITH RAILROAD TRAFFIC, AND NOTIFY THE RAIL COMPANY ____ HOURS IN ADVANCE OF CONSTRUCTION OPERATIONS.

Designer Note: Provide this note when placing pipe culverts, sewers, or water lines under railroads. Coordinate with the rail company to determine the number of hours required for pre-construction notification.

D114 **REVIEW OF DRAINAGE FACILITIES**

PRIOR TO THE START OF WORK AND AGAIN BEFORE FINAL ACCEPTANCE, PERFORM AN INSPECTION WITH REPRESENTATIVES OF THE DEPARTMENT, CONTRACTOR AND LOCALS OF ALL EXISTING DRAINAGE FACILITIES THAT ARE TO REMAIN IN SERVICE WHICH MAY BE AFFECTED BY THE WORK. THE CONDITION OF THE EXISTING CONDUITS AND THEIR APPURTENANCES IS DETERMINED FROM FIELD OBSERVATIONS. RECORDS OF THE INSPECTION ARE MAINTAINED BY THE DEPARTMENT.

CONFIRM ALL EXISTING SEWERS INSPECTED INITIALLY BY THE ABOVE-MENTIONED PARTIES ARE MAINTAINED AND LEFT IN A CONDITION COMPARABLE TO THAT DETERMINED BY THE ORIGINAL INSPECTION. THE CONTRACTOR IS RESPONSIBLE TO CORRECT ANY CHANGE IN THE CONDITION RESULTING FROM THEIR OPERATIONS AS DIRECTED AND APPROVED BY THE ENGINEER.

PAYMENT FOR ALL OPERATIONS DESCRIBED ABOVE IS INCLUDED IN THE CONTRACT PRICE FOR THE PERTINENT 611 CONDUIT ITEMS.

Designer Note: Provide this note on projects where existing drainage facilities are to remain in service.

D117 **MANHOLES, CATCH BASINS AND INLETS REMOVED OR ABANDONED**

CAREFULLY REMOVE AND STORE ALL CASTINGS WITHIN THE RIGHT OF WAY FOR SALVAGE BY (DEPARTMENT) (CITY) (VILLAGE) (COUNTY) FORCES.

PAYMENT FOR ALL OF THE ABOVE IS INCLUDED IN THE CONTRACT PRICE FOR THE PERTINENT 202 ITEM.

Designer Note: Only use this note when the owner desires to retain the existing castings.

D119 **ITEM SPECIAL- MISCELLANEOUS METAL**

EXISTING CASTINGS MAY PROVE TO BE UNSUITABLE FOR REUSE, AS DETERMINED BY THE ENGINEER. THE CONTRACTOR IS RESPONSIBILE TO PROVIDE THE CASTINGS OF THE REQUIRED TYPE, SIZE AND STRENGTH (HEAVY OR LIGHT DUTY) FOR THE PARTICULAR STRUCTURE IN QUESTION. FURNISH MATERIALS PER 611 WITH PRIOR APPROVAL OF THE ENGINEER.

THE FOLLOWING ESTIMATED QUANTITY HAS BEEN CARRIED TO THE GENERAL

SUMMARY FOR USE AS DIRECTED BY THE ENGINEER.

ITEM SPECIAL, MISCELLANEOUS METAL ______ LB

REPLACE EXISTING CASTINGS DAMAGED BY CONTRACTOR NEGLIGENCE, AS DETERMINED BY THE ENGINEER, AT THE EXPENSE OF THE CONTRACTOR.

Designer Note: Use this note if existing castings are to be reused and which may be unsuitable.

D120 **ITEM 611 - ( )", SLOTTED DRAIN, TYPE ( )**

THIS ITEM CONSISTS OF ____ INCH DIAMETER SLOTTED DRAIN ALUMINUM COATED STEEL CONDUIT 707.01 WITH 6 INCH TRAPEZOIDAL GALVANIZED SOLID BAR GRATE AS APPROVED BY THE ENGINEER. ALL COSTS FOR LABOR AND MATERIALS, INCLUDING TYPE 2 BEDDING, AND BACKFILLING AS DETAILED ON STANDARD CONSTRUCTION DRAWING DM-1.3 IS INCLUDED IN THE PRICE BID PER FT FOR ITEM 611, ____ " SLOTTED DRAIN,TYPE ____ .

Designer Note: Use this note in conjunction with Standard Construction Drawing DM-1.3. Outlet slotted drain pipe into a catch basin.

D121 **ITEM SPECIAL - PIPE CLEANOUT**

THIS WORK CONSISTS OF REMOVING SEDIMENT AND DEBRIS FROM THE EXISTING DRAINAGE CONDUITS SPECIFIED IN THE PLANS. DISPOSE OF ALL MATERIAL PER 105.16 AND 105.17. CLEAN OUT TO THE APPROVAL OF THE ENGINEER.

CLEANOUT OF THE PIPE IS PAID FOR AT THE UNIT PRICE BID FOR ITEM SPECIAL, PIPE CLEANOUT. THIS PRICE INCLUDES THE COST FOR MATERIAL, EQUIPMENT, LABOR, AND ALL INCIDENTALS REQUIRED TO COMPLETE THE CLEANOUT.

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY FOR THE WORK NOTED ABOVE:

ITEM SPECIAL, PIPE CLEANOUT, 24" AND UNDER ______ FT
ITEM SPECIAL, PIPE CLEANOUT, 27" TO 48" ______ FT
ITEM SPECIAL, PIPE CLEANOUT, OVER 48" ______ FT

Designer Note: This item may not be eligible for federal participation.

D123 **EXISTING SUBSURFACE DRAINAGE**

PROVIDE UNOBSTRUCTED OUTLETS FOR ALL EXISTING UNDERDRAINS OR AGGREGATE DRAINS ENCOUNTERED DURING CONSTRUCTION.

PROVIDE AN OUTLET PER STANDARD CONSTRUCTION DRAWING DM-1.1 FOR ALL UNDERDRAINS THAT OUTLET TO A SLOPE. UNDERDRAINS THAT CAN BE CONNECTED TO THE NEW OR EXISTING UNDERDRAINS AT THE END OF THE PROJECT LIMITS AS WELL AS ALL NECESSARY BENDS OR BRANCHES REQUIRED FOR CONNECTION ARE INCLUDED IN THE BASIS OF PAYMENT FOR UNCLASSIFIED PIPE UNDERDRAINS.

THE FOLLOWING ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE GENERAL SUMMARY FOR THE WORK NOTED ABOVE:

ITEM 601, TIED CONCRETE BLOCK MAT, TYPE 1
_______ SY
ITEM 605, AGGREGATE DRAINS
_______ FT
ITEM 611, ____" CONDUIT, TYPE F
_______ FT
ITEM 611, PRECAST REINFORCED CONCRETE OUTLET
_______ EACH
ITEM 605, ____" UNCLASSIFIED PIPE UNDERDRAINS
_______ FT

Designer Note: Use the note on projects if there are existing underdrains or aggregate drains within the project limits that are to remain. Perform an investigation for the presence of existing underdrain outlet locations or potential conflict areas within the project limits and show them on the plan view sheets.

D124 TEMPORARY DRAINAGE ITEMS

TEMPORARY DRAINAGE ITEMS LABELED ON THE MAINTENANCE OF TRAFFIC PLAN ARE ITEMIZED ON THE MOT PLANS AND CARRIED TO THE GENERAL SUMMARY.

Designer Note: Provide this note when temporary drainage items are required per section 1009 of this manual. Furnish drainage items for each phase of the maintenance of traffic operations. Removal items may be required between individual phases. Utilize drainage structures furnished for final drainage design where feasible.

E101 SEEDING AND MULCHING

THE FOLLOWING QUANTITIES ARE PROVIDED TO PROMOTE GROWTH AND CARE OF PERMANENT SEEDED AREAS:

ITEM 659, SOIL ANALYSIS TEST	_______ EACH
ITEM 659, TOPSOIL	_______ CY
ITEM 659, SEEDING AND MULCHING	_______ SY
ITEM 659, REPAIR SEEDING AND MULCHING	_______ SY
ITEM 659, INTER-SEEDING	_______ SY
ITEM 659, COMMERCIAL FERTILIZER	_______ TON
ITEM 659, LIME	_______ ACRES
ITEM 659, WATER	_______ MGAL
ITEM 659, MOWING	_______ MSF

APPLY SEEDING AND MULCHING S TO ALL AREAS OF EXPOSED SOIL BETWEEN THE RIGHT-OF-WAY LINES AND WITHIN THE CONSTRUCTION LIMITS FOR AREAS OUTSIDE THE RIGHT-OF-WAY LINES COVERED BY WORK AGREEMENT OR SLOPE EASEMENT. QUANTITY CALCULATIONS FOR SEEDING AND MULCHING ARE BASED ON THESE LIMITS.

Designer Note: Use the above quantities on all projects that require grading work. The following is a basic guideline for estimating quantities for the above items. These quantities may be omitted from the note if they are itemized elsewhere in the plans. Show calculations for all items in the plans.

659, Soil Analysis Test (EACH) - Soil Analysis Tests are used to field adjust the rate of Lime based on soil conditions.

A. Soil Analysis Test is not specified.

Use the standard rate for Lime without adjustment.

B. Soil Analysis Test is specified. If specified, minimum of two tests.

If no Topsoil to be placed - One test per 10 Acres (one test per 48400 Sq. Yd.) of permanent seeded area and sodded area.

If placing Topsoil - One test per 10000 Cu. Yds. of Topsoil.

659, Topsoil (CY) - 111 Cu. Yds. per 1000 Sq. Yd. of permanent seeded area. Topsoil is optional. However, it is recommended, especially for projects involving A4 silty materials, granular embankment or granular materials due to severe erosion problems.

659, Seeding and Mulching (SY) - This quantity is usually calculated by the end width method using the cross sections. On short projects, seeding quantities may be determined by other methods. For example, the area for seeding may be estimated by calculating an area per Plan & Profile sheet determined by multiplying an average width (based on construction limits or right-of -way lines) by the distance on each sheet, and then deducting for paved surface areas. A deduction should be taken for 660 and 670 items.

659, Repair Seeding and Mulching (SY) - 5 % of the permanent seeding and mulching area.

659, Inter-seeding (SY) - 5% of the permanent seeding and mulching area.

659, Commercial Fertilizer (TON) - 30 pounds per 1000 Sq. Ft. (one Ton per 7410 Sq. Yd.) of permanent seeded area.

This rate includes 20 pounds per 1000 Sq. Ft. for the first application and 10 pounds per 1000 Sq. Ft. for the second application. If Inter-seeding is provided, use an additional 20 pounds per 1000 Sq. Ft. of commercial fertilizer for the Inter-seeding area.

659 Lime (ACRE) - Apply over permanent seeded area.

659, Water (MGAL) - Two applications each at 300 Gallons per 1000 Sq. Ft. (0.0027 M Gallons per Sq. Yd.) of permanent seeded area. The above rate is for a single application. If Inter-seeding is provided, use an additional 300 Gallons per 1000 Sq. Ft. of water for the Inter-seeded area.

659, Mowing (MSF) - 25 % of the permanent seeded area for projects expected to last more than one construction season.

E102 SODDING

THE FOLLOWING QUANTITIES ARE PROVIDED TO PROMOTE GROWTH AND CARE OF PERMANENT SODDED AREAS.

ITEM 659, SOIL ANALYSIS TEST	_______ EACH
ITEM 659, TOPSOIL	_______ CY
ITEM 659, COMMERCIAL FERTILIZER	_______ TON

ITEM 659, LIME	_______	ACRE
ITEM 659, WATER	_______	MGAL
ITEM 660, SODDING, UNSTAKED, STAKED, REINFORCED	_______	SY

Designer Note: Provide the above quantities on all projects that have pay item(s) for permanent sodding. The following is a basic guideline for estimating quantities for the above items. These quantities may be omitted from the note if they are itemized elsewhere in the plans. Show calculations for all items in the plans.

659, Soil Analysis Test (EACH) - Soil Analysis Tests are used to field adjust the rate of Lime based on soil conditions.

A. Soil Analysis Test is not specified.

Use the standard rate for Lime without adjustment.

B. Soil Analysis Test is specified. If specified, minimum of two tests.

If no Topsoil to be placed - One test per 10 Acres (one test per 48400 Sq. Yd.) of permanent seeded area and sodded area.

If placing Topsoil - One test per 10000 Cu. Yds. of Topsoil.

659, Topsoil (CY) - 111 Cu. Yds. per 1000 Sq. Yd. of permanent seeded area. Topsoil is optional. However, it is recommended, especially for projects involving A4 silty materials, granular embankment or granular materials due to severe erosion problems.

659, Commercial Fertilizer (TON) - 30 pounds per 1000 Sq. Ft. (one Ton per 7410 Sq. Yd.) of permanent seeded area.

This rate includes 20 pounds per 1000 Sq. Ft. for the first application and 10 pounds per 1000 Sq. Ft. for the second application. If Inter-seeding is provided, use an additional 20 pounds per 1000 Sq. Ft. of commercial fertilizer for the Inter-seeding area.

659 Lime (ACRE) - Apply over permanent seeded area.

659, Water (MGAL) - Two applications each at 300 Gallons per 1000 Sq. Ft. (0.0027 M Gallons per Sq. Yd.) of permanent seeded area. The above rate is for a single application. If Inter-seeding is provided, use an additional 300 Gallons per 1000 Sq. Ft. of water for the Inter-seeded area.

660, Sodding (SY) - This is the actual number of Sq. Yds. of permanent sodded area.

W100 POST CONSTRUCTION STORM WATER TREATMENT

THIS PLAN UTILIZES STRUCTURAL BEST MANAGEMENT PRACTICES (BMP'S) FOR POST CONSTRUCTION STORM WATER TREATMENT.

Designer Note: Use this note on all projects that have post construction storm water management BMP's. Follow this note by the notes below if applicable.

W101 BIORETENTION CELL(S)

CONSTRUCT THE BIORETENTION CELL(S) AFTER ALL CONTRIBUTING DRAINAGE AREAS ARE STABILIZED AS SHOWN ON THE CONTRACT PLANS. DO NOT OPERATE HEAVY EQUIPMENT WITHIN THE PERIMETER OF A BIORETENTION CELL. USE ALL

SUITABLE EXCAVATED MATERIAL IN THE WORK. ALTERNATIVELY, LEGALLY USE, RECYCLE, OR DISPOSE OF ALL EXCAVATED MATERIALS ACCORDING TO 105.16 AND 105.17.

EXCAVATE THE BIORETENTION CELL TO THE DIMENSIONS, WITH VERTICAL SIDES, TO THE ELEVATIONS SPECIFITIED. MINIMIZE THE COMPACTION OF THE BOTTOM OF THE BIORETENTION CELL. EXCAVATION WILL BE MEASURED AND PAID AS ITEM 203, EXCAVATION, AS PER PLAN.

THE BIORETENTION CELL CONSISTS OF FOUR DISCRETE LAYERS: BIORETENTION PLANTING SOIL LAYER, FINE AGGREGATE LAYER, COARSE AGGREAGE NO. 78 LAYER, AND COARSE AGGREGATE NO. 57 LAYER AND AN UNDERDRAIN SYSTEM. THE MATERIALS AND VOLUMES FOR EACH LAYER ARE AS SHOWN:

BIORETENTION CELL		**PROJECT QUANTITY (CY)**
BIORETENTION PLANTING SOIL LAYER PLUS 3 INCH COVER		
	COMPOSITION BY VOLUME	
5	PARTS SAND – CMS FINE AGGREGATE PER 703.20	
1	PART TOPSOIL – CMS 659.05	
2	PARTS COMPOST – CMS 659.06	
FINE AGGREGATE PER CMS 703.20		
COARSE AGGREAGE SIZE NO. 78 PER 703.20		
COARSE AGGREAGE SIZE NO. 57 PER 703.20		
TOTAL CUBIC YARDS		

CONSTRUCT THE UNDERDRAIN SYSTEM AS SPECIFIED.

PLACE THE BIORETENTION PLANTING SOIL IN 12 INCH LIFTS. THE BIORETENTION PLANTING SOIL LAYER PLUS 3 INCH COVER IS 3 INCHES GREATER THAN THE DEPTH SPECIFIED TO ACCOUNT FOR EXPECTED SETTLING OF THE UNCOMPACTED SOIL.

THE BIORETENTION PLANTING SOIL MUST BE A UNIFORM MIX THAT IS FREE OF STONES, STUMPS, ROOTS, OR ANY OTHER OBJECT LARGER THAN TWO INCHES. THE SOIL MAY CONSIST OF EXISTING SOIL, FURNISHED SOIL, OR A COMBINATION OF BOTH PROVIDED THAT THE PH IS BETWEEN 5.2 – 8.0 AND MEETS THE COMPOSITION REQUIREMENTS LISTED ABOVE. PHOSPHORUS CONCENTRATIONS OF THE PLANTING SOIL MUST FALL BETWEEN 15 AND 60 MG/KG (PPM) AND DETERMINED BY THE MEHLICH III TEST.

THOROUGHLY MIX THE BIORETENTION PLANTING SOIL PRIOR TO PLACEMENT.

PLACE OBSERVATION WELL AND CLEANOUT WHERE SPECIFIED. CONNECT THE OBSERVATION WELL AND CLEANOUT TO THE PERFORATED UNDERDRAIN WITH THE APPROPRIATE MANUFACTURED CONNECTIONS. EXTEND THE OBSERVATION WELL AND CLEANOUT 4 INCHES ABOVE THE SURFACE ELEVATION. CAP THE OBSERVATION WELL AND CLEANOUT WITH A THREADED SCREW CAP. CAP THE ENDS OF PERFORATED UNDERDRAIN PIPES NOT TERMINATING IN AN OBSERVATION WELL AND CLEANOUT OR CONNECTED TO OTHER CONDUITS.

PLACE SEED, TURF, TREES, SHRUBS, OR OTHER PLANT MATERIALS FOR BIORETENTION FACILITIES AS SPECIFIED. PLANT MATERIALS WILL BE MEASURED AND PAID FOR PER CMS ITEM(S) 659, 660, OR 661 DEPENDING ON THE PLANT

MATERIALS SPECIFIED. APPLY NO PESTICIDES, HERBICIDES, LIME, AND FERTILIZERS. INSTALL ITEM 611 AS SPECIFIED. INSTALL TEMPORARY EROSION CONTROL MAT TYPE A, B, C, OR E PER CMS 671 WITH EITHER STRAW MULCH OR COMPOST OR AS SPECIFIED IN THE PLANS.

BIORETENTION CELLS ARE PAID FOR AS ITEM 601, BIORETENTION CELL, CY AND ITEM 601, TIED CONCRETE MAT, SY. EXCAVATION FOR BIORETENTION CELLS IS FOR VERTICAL SIDES ONLY, AS SPECIFIED AND PAID FOR AS ITEM 203, EXCAVATION, AS PER PLAN, CY. PERFORATED UNDERDRAINS, OBSERVATION WELLS, AND ASSOCIATED FITTINGS AND COUPLERS ARE PAID FOR AS ITEM 605, UNDERDRAIN, AS PER PLAN. NON PEFORATED OUTLET PIPES FOR ARE PAID FOR AS ITEM 611. SEEDING AND MULCHING FOR THE BIORETENTION CELL ARE PAID FOR AS ITEM 659 SEEDING AND MULCHING, SY EROSION CONTROL MATS ARE PAID FOR AS ITEM 671, EROSION CONTROL MATS, SY.

Designer Note: Use this note on all projects that have bioretention cell(s) identified in the plan.

Add a note that states: "ITEM 203, EXCAVATION, AS PER PLAN, VERTICAL SIDES ONLY" on plan sheets showing bioretention cell cross sections.

W102 INFILTRATION TRENCH (OR BASIN)

THIS PLAN UTILIZES INFILTRATION FOR POST CONSTRUCTION STORM WATER TREATMENT. CONSTRUCT THE COMPLETED INFILTRATION TRENCH(ES) (AND OR BASIN(S)) AFTER ALL CONTRIBUTING DRAINAGE AREAS ARE STABILIZED AS SHOWN IN THE CONTRACT PLANS AND TO THE SATISFACTION OF THE ENGINEER. DO NOT USE INFILTRATION DEVICES AS TEMPORARY SEDIMENT CONTROL FACILITIES DURING CONSTRUCTION. DO NOT OPERATE HEAVY EQUIPMENT WITHIN THE PERIMETER OF AN INFILTRATION DEVICE DURING EXCAVATION OR BACKFILLING OF THE FACILITY.

Designer Note: Use this note on all projects that have infiltration trenches and or basins identified in the plan. Embankment work to create the impoundment will be constructed and paid for as Item 203 Embankment, using natural soils, 703.16.A.

W103 MANUFACTURED WATER QUALITY STRUCTURE

THIS PLAN UTILIZES MANUFACTURED WATER QUALITY STRUCTURES FOR WATER QUALITY TREATMENT. AREAS ARE SHOWN IN THE PLANS FOR PLACEMENT OF AN OFF-LINE SYSTEM. PAYMENT FOR THESE DEVICES IS MADE AT THE CONTRACT UNIT PRICE FOR ITEM 895, MANUFACTURED WATER QUALITY STRUCTURE, TYPE ____.

Designer Note: Use this note on all projects that have manufactured water quality structures identified in the plan. If more than one manufactured water quality structure is provided in the plans, provide a table to indicate the location and type of each structure used. Supplemental specification 895 outlines the different types of structures (1-4). **Manufactured systems may not be installed under the roadway or downstream of a connecting pipe more than ten feet deep without approval OHE.**

W104 **VEGETATED FILTER STRIP**

THIS PLAN UTILIZES VEGETATED FILTER STRIP(S) FOR POST CONSTRUCTION STORM WATER TREATMENT. PLACE EITHER ITEM 660 SODDING OR ITEM 659 SEEDING AND MULCHING WITH A 4-INCH LIFT OF TOPSOIL AND ITEM 670, SLOPE EROSION PROTECTION TO ALL DISTURBED AREAS DESIGNATED AS VEGETATED FILTER STRIPS, THE EDGE OF SHOULDER, AND THE FORESLOPE AS SPECIFIED IN THE PLANS.

Designer Note: Use this note on all projects that have vegetated filter strips identified in the plan. Pay for grass planting and topsoil as Item 659 or Item 660 and include with quantities for the rest of the project. Pay for erosion control mat as Item 670, slope erosion protection and include with quantities for the rest of the project.

W105 **VEGETATED BIOFILTER**

THIS PLAN UTILIZES VEGETATED BIOFILTER(S) FOR POST CONSTRUCTION STORM WATER TREATMENT. PLACE EITHER ITEM 660 SODDING OR ITEM 659 SEEDING AND MULCHING WITH A 4-INCH LIFT OF TOPSOIL AS SHOWN IN THE PLANS TO ANY DISTURBED AREA ON THE SHOULDER AND FORESLOPE DRAINING TO A VEGETATED BIOFILTER. THE DITCH FOR EACH VEGETATED BIOFILTER IS TRAPEZOIDAL, AS SHOWN IN THE PLAN CROSS SECTIONS. PROVIDE ITEM 670 AS SPECIFIED IN THE PLANS.

Designer Note: Use this note on all projects that have vegetated biofilters identified in the plan. Pay for grass planting and topsoil as Item 659 or Item 660 and include with quantities for the rest of the project. Pay for erosion control mat as Item 670, ditch erosion protection and include with quantities for the rest of the project.

W106 **EXTENDED DETENTION BASIN**

THIS PLAN UTILIZES EXTENDED DETENTION BASIN(S) FOR POST CONSTRUCTION STORM WATER TREATMENT. DETENTION BASINS MAY BE USED AS SEDIMENT CONTROL DEVICES DURING CONSTRUCTION. FOLLOWING STABILIZATION OF THE TRIBUTARY AREA, CONFIRM THE FINAL GRADING OF THE DETENTION BASIN MATCHES THE PLANS. REMOVE THE DETENTION BASIN OUTLET STRUCTURE FOR CONSTRUCTION SEDIMENT CONTROL AND CONFIRM THE OUTLET STRUCTURE MATCHES THE DESIGN SHOWN IN THE PLANS.

Designer Note: Use this note on all projects that have extended detention basins identified in the plan. This note may be modified for retention basins or constructed wetlands, if those are included in the plans.